5-11-2013

The Effects of Hydration Status on Pacing and Performance During an Ironman Triathlon

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Recommended Citation

Hicks, Tracy L., "The Effects of Hydration Status on Pacing and Performance During an Ironman Triathlon" (2013). Master's Theses. 395.

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The Effects of Hydration Status on Pacing and Performance During an Ironman Triathlon

Tracy Lynn Hicks

B.S. State University of New York: College at Brockport, 2011

A Thesis
Submitted in Partial Fulfillment of the Requirements for the Degree of
Masters of Science
At the
University of Connecticut
2013
Masters of Science Thesis

The Effects of Hydration Status on Pacing and Performance During an Ironman Triathlon

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2013
ACKNOWLEDGEMENTS

Dr. Casa – The past two years with you have helped me grow more than you will ever know. Your devotion to the field of athletic training, and to the education of the students here at the University of Connecticut is truly inspiring. Thank you for everything you have done to help me be successful in the classroom, the field, and my everyday life.

Dr. Armstrong – Thank you for taking time out of your busy schedule to be a part of my thesis committee. It is an honor to have such an outstanding member of the University of Connecticut faculty on my committee and I appreciate your support.

Dr. Maresh – Thank you for your help with planning this entire study. Your dedication and commitment to this program is invaluable. I am extremely appreciative towards you for taking time to be on my thesis committee. Thank you for all you do for the University of Connecticut and the Kinesiology Department.

Rebecca Stearns – There are not enough words to even begin to say how much I appreciate all the help you have given me throughout this process. Without you this thesis would not exist. I am truly honored to have such an intelligent mentor, and will forever be grateful for this experience.

My family, friends, classmates, and professors deserve the biggest thanks as well. Without each and every one of you, this process would have been impossible. And to Eric Bartholomew, thank you for always believing in me and pushing me to always do my best.
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ABSTRACT

The Effects of Hydration Status on Pacing and Performance During an Ironman Triathlon

Tracy L. Hicks, University of Connecticut

Context: Dehydration can negatively impact aerobic performance. Objective: To observe the effect of hydration status on Ironman Triathletes’ overall performance and their ability to maintain pace throughout the event; and to observe the effect of hydration status on pacing and performance for those athletes who monitor heart rate for pacing feedback.

Design: Observational ironman triathlon study of the Lake Placid Ironman Triathlon including two days of baseline measures and race day measures. Setting: Lake Placid Ironman racecourse (WBGT, 22.1±2.0 °C). Participants: 41 (30 males, 7 females) triathletes (age, 39±7 yrs; height, 174.0±9.9 cm; pre-race weight, 72.4±10.1 kg; body fat, 15.3±5.6%).) divided into groups based on use of heart rate (HR) as pacing feedback or no feedback (NHR) and hydrated (HY) or dehydrated (DHY) based on post race hydration levels. Those who used heart rate were also divided into hydrated (HRH) and dehydrated (HRD) groups.

Main Outcome Measures: hydration (urine specific gravity (USG), percent body mass loss (%BML)), pacing (average pace, percent deviation from average pace, percent of overall time spent in each course loop), and physiological responses (gastro-intestinal temperature (T_{gi}), average heart rate (HR)).

Results: An overall effect of time over bike loop 1 (B1), bike loop 2 (B2), run loop 1 (R1), and run loop 2 (R2) was seen for both HY and DHY groups on overall pace (p<0.001), pace by percentage of overall time (p<0.001) and percent deviation of pace (from overall average) (p<0.001); but no group by time interaction was observed (p>0.05). An overall effect of time on average heart rate was seen during the bike (p=0.002) and run (p=0.014) sections for the
HY and DHY groups, but no group by time interaction occurred ($p>0.05$). An overall effect of time was observed on overall pace ($p<0.001$), pace by percentage ($p<0.001$), and percent deviation of pace ($p=0.013$). The HRH and HRD groups differed in $\%BML$ by 0.8% and post-race USG by 0.012. The HY and DHY groups differed in $\%BML$ by 1.52%, and post-race USG by 0.015. No group by time interaction was observed for these measures between the HRH and HRD groups ($p>0.05$). An overall effect of time on average heart rate was observed for the HRH and HRD groups ($p=0.014$), but no group by time interaction was present ($p>0.05$). Conclusion: The observed levels of dehydration did not cause significant differences in overall performance and pacing when compared to hydrated subjects. The 0.8% and 1.52% differences in body mass loss observed between HRH and HRD groups did not elicit measureable differences in performance or pacing. Although there were no differences observed between groups and the main outcome variables, consideration should be given to potential improvements that may occur with improved hydration practices of those in the dehydrated group, which could only be elucidated in a controlled cross-over design study.

Keywords: dehydration, pacing, performance, Ironman triathlon
Review of the Literature

To most elite endurance runners, performance is everything. Several factors play a key role in how well an athlete can perform a certain task. Hydration levels and pacing strategies are just two of many aspects that influence optimal performance. In addition, research shows that after roughly 10 minutes of exercise a phenomenon known as cardiovascular drift, in which stroke volume decreases and heart rate increases simultaneously, occurs.\(^1\) Dehydration and other conditions affect the degree of cardiovascular drift that an athlete experiences. This phenomenon also hinders performance, and may also be exaggerated in ultra-endurance events, such as Ironman triathlons, due to the sheer duration of the event. Many of these relationships will be discussed throughout this review of the literature.

Pacing Strategies

Most racing sports (running, skating, cycling, etc.) involve a “closed-loop design” which requires participants to cover a set distance in the fastest time possible.\(^2\) An athlete’s performance can be greatly affected by their pacing strategy. The strategy an athlete employs may depend on many factors. It has been suggested that different kinds of activities require different pacing strategies. A sprinter and an ultramarathon runner would not go about completing their races in the same manner. Research shows that an event lasting less than 30 seconds, such as a sprint, benefits from an “all out” strategy.\(^2\) Athletes who perform more than 2 minutes of a race might benefit more from an even paced run. It has been suggested that middle distance (1.5 – 2 minutes) and ultraendurance event (lasting more than four hours) athletes are more likely to use an even pacing strategy to be successful in these events.\(^2\)
Negative pacing refers to a strategy in which the athlete continuously increases speed throughout the duration of the event. It is thought to slow the rate of carbohydrate use for energy among other physiological processes. This strategy is common in middle distance runners because they tend to increase speed when they realize that the end of the race is near.

Shorter distances and sprint performances (such as those less than 400m) may result in better finishing time with an “all-out” pacing strategy. This is when the athlete begins the race and continually increases until they reach their peak, at which point speeds often tend to decline. For this reason, some people consider this to not be an optimal pacing strategy.

A positive pacing strategy occurs when athletes start at a fast pace and continuously decrease their speed throughout the performance. Athletes who use this pacing strategy may inaccurately estimate their ability to perform the event and may become fatigued early on after starting too fast. The slowed down pace associated with the fatigue could be detrimental to finishing time.

Even pacing describes a pacing strategy in which the athlete tries to maintain the same speed throughout the entire race. This strategy is supported by the fact that a greater percentage of power generated by the body is used to accelerate through the air or water than it is to maintain a constant speed.

Advances in technology, monitoring speed and distance covered, have allowed researchers to determine that a majority of athletes use a combination of the previous pacing strategies to be successful. These data show that athletes may decrease their speed
from the start of an endurance event, but will at some point in the later stages of the race
begin to accelerate towards the finish. This is called parabolic shape pacing.\textsuperscript{2}

A final type of pacing strategy is variable pacing. This is when a runner varies
their pace dependent on external factors (i.e., unidirectional strong wind, challenging an
opponent).\textsuperscript{2} The variation is usually seen in the power output parameter, and is an
attempt for the person to maintain a constant velocity with changing external factors.

\textit{Common Pacing Strategies in Triathlons}

Triathletes provide an interesting challenge when it comes to pacing because they
involve three separate events. An Ironman triathlon consists of a swimming section (3.8
km), a cycling portion (180 km), and concludes with a run of 42.2 km. Abbiss \textit{et al.}\textsuperscript{3}
studied pacing strategies of cyclists in the 2004 Western Australia Ironman triathlon.
They examined 6 well-trained triathletes during the cycling phase. This specific cycling
course had three equidistant laps to make up the 180 km bike ride. This made it
congenient for researchers to compare lap times over the course of the race. Power
output, cadence, and heart rate were collected from devices placed on the bike and on the
athlete throughout the race. After analyzing the data, investigators concluded that most of
the participants utilized a positive pacing strategy throughout the cycling section.
Environmental conditions such as changing wind speed may have affected lap times, but
the increase in time observed was correlated with decreased power output and cadence;
suggesting the decrease in performance was not only due to external factors but perhaps
an increase in psychological and physiological strain. Athletes most likely began to suffer
fatigue, increased perceptual pain, and decreased motor recruitment causing their pace to
slow throughout the race.\textsuperscript{3} The researchers also noted participants’ torque and speed
varied in portions of the cycle section, with headwinds more so than portions with tailwinds. Lastly, they noted that power output fluctuated randomly throughout the cycling section. This study was the first to discover that Ironman triathlon cyclists often use self-selected pacing, which resulted in starting out at a higher initial velocity and decreasing throughout the race (positive pacing). The authors also added their assumption that these results support the notion that pacing in ultra endurance cycling is a dynamic process rather than a predetermined strategy. It was concluded that participants’ strategy in this race were considered suboptimal due to the decease in speed and power output throughout the event. However, it is important to note that this study observed elite triathletes, and these findings may not be present with other level athletes.

In another study, by Atkinson et al. in 2000, the effects of varying cycling pace with headwinds and tailwinds were observed. Rather than trying to maintain a constant pace, researchers concluded that a 5% increase of power output above the mean when cycling into headwinds, and 5% decrease in power output when riding with a tailwind, would result in optimal performance. They suggested that this strategy was successful because a greater amount of time was spent in headwinds than tailwinds.

Some experts speculate that athletes may use a different pacing strategy for the running portion of the triathlon than they would for the cycling portion. However, there is a general lack of research involving triathlete pacing. For marathons, it is known that keeping a constant pace, or “even pacing” during the run is related to better performance times. Maughan et al. studied marathon runners’ pacing strategies and discovered faster runners were using a constant pace, whereas those who were slower generally used a
positive pace. This is most likely due to faster runners being able to maintain a faster pace throughout the race, whereas slower runners struggle to do the same.

Factors Influencing Pace

Stearns et al. studied 17 well-trained distance runners who were previously acclimatized to heat stress to determine the effects of hydration status on pacing during trail running. Participants ran two separate 12-km simulated races. For one of the races, participants began euhydrated and were given water throughout the race to remain hydrated, and for the second they began the race dehydrated and did not consume water throughout the trial. The course consisted of three- 4 km loops, which allowed the researchers to compare loops 1-3 for analysis. The main findings of this study include: 1.) Hydrated trials were performed significantly faster than dehydrated trials, and 2.) Significant differences existed between hydrated trials and dehydrated trials for pace during loop 3 and overall race pace. This suggests the hydrated trials resulted in more even pacing.

Figure 1 displays the data comparing the dehydrated and hydrated groups for each loop and the total lap time. This study also compared the fastest and slowest loop times for the hydrated and dehydrated trials. The dehydrated pace continued to slow throughout the
run which is more evidence that euhydration helps runners keep pace. This study demonstrates the importance hydration has on both performance and accurate pacing. Athletes should maintain a euhydrated state in order to perform optimally.

The 2012 Boston marathon took place on April 16th when temperatures reached above 80°F in bright sunny weather. This was the hottest Boston marathon in ten years and it greatly exposed athletes to very strenuous conditions. The overall pace of the entire race was more than nine minutes slower than the previous year, primarily thought to be due to high temperatures. As discussed before, there are many pacing styles for marathon runners. Although many runners may have had pre-race pacing strategies, a large percentage of them were altered when this strenuous heat was present. For several years now, Kenyan runners have dominated the Boston marathon. This is largely thought to be due in part to their explosive surges and aggressive running nature. Wesley Korir, from Kenya, and also the winner of the 2012 Boston Marathon had a much different approach this year. He held a very solid and consistent pace the entire race even as fellow runners burst by him. He was able to maintain a 3:05-3:10/km for a majority of the race, which landed him in sixth at about the 30km mark. Those who chose the “surge” method began suffering from
their maximal efforts and dropped back in the race allowing Korir to continue his climb to the victory. Korir also had more in reserve than other top finishers and was able to finish the final 2.2km in 7:33 minutes; which was the fastest in the race. The problem with the Kenyan “surging” method is the physiological cost associated with them. The aggressive surges in the middle of the race likely caused body temperature to increase. With this thermoregulatory response, thermal comfort and perception levels also change. In a race with normal environmental temperatures, most athletes are able to recover from this with no problem. However, when 80°F temperatures are factored in, this adds a greater amount of physiological strain. Heat cannot be quickly removed, so when high environmental temperatures are combined with powerful surges in the race, the physiological cost is much greater and will take longer to recover from. Figure 2 displays the pacing of the 2011 winner, the 2012 winner and a top contender in 2012. Notice that Korir (green line) maintained a relatively even pace throughout the entire event whereas the others had aggressive surges and a varying pace. The red line (Matebo) shows how the “surge” method can be detrimental to performance. Matebo followed the Kenyan “surge” strategy and increased his speed at the 25km point. This came at a very large cost to him, as he was unable to maintain his pace afterwards. He continuously decreased speed over the last 10km. The important note that comes from this race is that, in hot environments, an even pacing strategy will benefit runners greatly; whereas an aggressive surge-like pace will cost great amounts of energy and possibly leave the runner without enough to finish strongly.

Another challenge that elite athletes often face is traveling to a variety of places to compete. This can be difficult for many reasons, one of which is a change in altitude. Ten
trained male cyclists and triathletes who were not acclimatized to high altitudes were studied to determine the effect of altitude on power output, gross efficiency, and pacing. The participants completed 5-5 minute bouts of submaximal exercise (at 50, 100, 150, 200, and 250 Watts) at four different altitudes (200, 1200, 2200, 3200 meters), which allowed VO$_{2\text{max}}$ and gross efficiency to be measured. Subjects then rested for 10 minutes and completed a 5-minute time trial to determine VO$_{2\text{peak}}$ and power output. Researchers did observe a considerable decrease in power output at higher altitudes, but the participants’ pacing remained the same for all trials if the 200 or 1200-meter time trial was first. Participants who completed the 2200 or 3200-meter trial first had variation in their pacing for all trials. This might suggest that gradually working up to high altitudes should not affect pacing, but immediately going to a high altitude may impair accurate pacing for cyclists.

deKoning et al. combined data sets from 9 previous studies, which looked at runners and cyclists and determined that athletes are likely to pace themselves based on how they feel and how much of the race is left. Researchers developed a “Hazard Score” which they explained as the product of momentary Ratings of Perceived Exertion (RPE) and the percent of the race remaining at the point in which the RPE was recorded. They believed that the Hazard

![Figure 3. Changes in velocity (A), Rate of Perceived Exertion (RPE) (B) and the Hazard Score (C) in 9 competitive simulations in running or cycling events that required from 4 to 60 minutes.](image)
Score would dictate when athletes needed to slow down or accelerate based on homeostatic changes. The Hazard Score is indicative of how likely the athlete is to experience a catastrophic collapse at that point. A higher score means the athlete is more at risk and should slow down. A relationship was observed between Hazard Score values and changes in pace. Lower Hazard Scores were associated with increases in velocity or faster pace; and higher Hazard Scores were linked to decelerations or slower pace. Figure 3 shows the relationships between velocity, RPE, Hazard Score and relative distances from all 9 studies. The experiments included in this study were all completed in the laboratory, thus future field research should support its validity. The authors concluded that athletes decide to distribute their effort throughout an entire event based on how they feel at that moment and how much of the race remains.

Athletes often use different types of feedback to keep a steady pace during competition. Faulkner et al. studied the effect of distance feedback during running on performance and consistent pacing in 2010.\textsuperscript{10} Participants ran on a treadmill with no feedback, inaccurate feedback, or accurate feedback given. When feedback was received, regardless of accuracy, participants maintained similar levels of perceived exertion and had similar completion times. However, when athletes were not given distance feedback they took longer to perform the task. This implies distance feedback may help athletes pace for an optimal finishing time.

In 2011, Corbett and his colleagues\textsuperscript{11} attempted to determine if competition played a role in athletes’ pacing. Fourteen cyclists completed three familiarization time trials on an ergometer followed by an additional time trial, and then a simulated competition with video projected in front of them of other racers. The participants were
not aware that the images projected were their own familiarization time trials, but it was
evident that competition influenced the participants to enhance their performance,
because their pace mirrored that of the familiarization trial and then participants sped up
in the last 1000 meters. This gives evidence of a physiological reserve in competitive
athletes, giving them the opportunity to push harder than the currently selected pace.

To extend research further, March et al.\textsuperscript{12} studied 185 male and 134 female non-
elite marathon runners to determine relationships of age, sex, and finishing time with
pacing. Participants included athletes from 2005, 2006, and 2007 marathons, which took
place in a cool environment (temperatures never rose above 5°C) on a relatively flat
racecourse in the Midwestern United States. This eliminated a number of factors that can
also influence pacing such as heat stress and course gradient change. Researchers
obtained their data from a website which posted the age, male/female, and split race times
for every mile of the marathon. There were several important findings in this study. Data
showed that faster runners were often more consistent pacers with minimal differences in
velocity between laps. When time to complete the race and age were controlled for,
women were observed to pace more consistently than men. Older runners were also seen
to have more consistent pacing. Each of these variables was evaluated individually,
which supports the thought that age, sex and finishing time all play their own significant
role on consistent pacing.

Factors such as environmental conditions, changes in altitude, available feedback
for the athlete, the presence of competition, the athlete’s age, and sex are all very difficult
if not impossible to control during competition. One key factor the athlete can control
during competition is hydration.
Hydration

One of many very important factors that affect an athlete’s performance is hydration status. Research studies have firmly established that dehydration causes aerobic performance deficits, therefore athletes should take the necessary steps to minimize dehydration during competition.

Different definitions in regard to hydration should be explained before discussing the use of hydration testing, current recommendations, common strategies, factors affecting hydration status, and the influence of hydration status on performance.

Although easy to define, euhydration, or the body possessing a normal level of water balance, is difficult to assign a concrete value. Hyperhydration results from an excess of water or “positive water balance” whereas hypohydration is a result of too little water or “negative water balance”. Dehydration is specifically the process of the body losing water, which leads to a state of hypohydration and rehydration is the process of the body gaining water, leading to a state of hyperhydration. Dehydration will impair performance and is a huge risk for athletes in warm to hot environments because it may lead to exertional heat illnesses.

Factors Influencing Fluid Loss

By participating in physical activity, people are exposed to many factors that affect their rate of fluid loss and consequently fluid intake. The heat produced by working muscles during exercise causes a rise in core body temperature. This change in temperature initiates cooling efforts by the body in which blood flow to the skin increases, aiding in sweat formation, and ultimately sweat evaporation which allows the heat to be transferred into the environment and out of the body. Sweating, which uses
the process of evaporation, is the most efficient way for the body to lose heat. The environment has one of the biggest impacts on fluid loss by influencing sweat rate. An environment with high humidity will make it difficult for the body to remove heat through evaporation. If an athlete is sweating profusely throughout prolonged exercise, it is imperative for the athlete to replace the water and electrolytes that are lost to avoid dehydration.

An individual’s sweat rate during exercise is the primary factor in the process of dehydration. Sweat rate is influenced by the duration of the activity, the intensity of the exercise, equipment worn while partaking in the exercise, an individual’s acclimatization status, overall body size, genetic conditions, and the environmental conditions in which the activity occurs. A person’s general make up will also influence their sweat rate for a specific exercise. Due to the vast inter-individual differences in sweat rates, a single recommended rate of fluid consumption is impossible to formulate. This is why fluid replacement based on individualized sweat rate calculations is the best method for athletes to ingest adequate amounts of fluids during exercise.

Table 1. Observations of sweat rates, voluntary fluid intake and levels of dehydration in various sports. Values are mean, plus (range) or [95% reference range].

<table>
<thead>
<tr>
<th>Sport</th>
<th>Condition</th>
<th>Sweat rate (l.h⁻¹)</th>
<th>Mean</th>
<th>Range</th>
<th>Voluntary fluid intake (l.h⁻¹)</th>
<th>Mean</th>
<th>Range</th>
<th>Dehydration (% BMI)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterpolo [41]</td>
<td>Training (males)</td>
<td>0.29</td>
<td>0.23–0.35</td>
<td>0.14</td>
<td>[0.09–0.20]</td>
<td>0.26</td>
<td>[0.19–0.34]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Competition (males)</td>
<td>0.79</td>
<td>[0.69–0.86]</td>
<td>0.38</td>
<td>[0.30–0.47]</td>
<td>0.35</td>
<td>[0.23–0.46]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netball [16]</td>
<td>Summer training (females)</td>
<td>0.72</td>
<td>[0.45–0.95]</td>
<td>0.44</td>
<td>[0.25–0.62]</td>
<td>0.7</td>
<td>[0.31–1.17]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer competition (females)</td>
<td>0.99</td>
<td>[0.45–1.49]</td>
<td>0.62</td>
<td>[0.33–0.71]</td>
<td>0.9</td>
<td>[0.15–1.14 kg]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swimming [41]</td>
<td>Training (males &amp; females)</td>
<td>0.37</td>
<td>[0.09–2.02]</td>
<td>0.38</td>
<td>[0.01–1.20]</td>
<td>0.7</td>
<td>[0.35–2.3]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rowing [22]</td>
<td>Summer training (males)</td>
<td>0.39</td>
<td>(0.74–2.34)</td>
<td>0.78</td>
<td>(0.09–3.50)</td>
<td>1.2</td>
<td>(0.18–2.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basketball [46]</td>
<td>Summer training (males)</td>
<td>1.37</td>
<td>(0.3–1.8)</td>
<td>0.60</td>
<td>(0.06–2.25)</td>
<td>1.0</td>
<td>(0.2–3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer competition (males)</td>
<td>1.6</td>
<td>[1.25–1.97]</td>
<td>1.08</td>
<td>[0.46–1.70]</td>
<td>0.6</td>
<td>[0.1–2.6]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soccer [139]</td>
<td>Summer training (males)</td>
<td>1.45</td>
<td>[0.38–1.95]</td>
<td>0.95</td>
<td>[0.16–1.35]</td>
<td>1.55</td>
<td>[0.4–2.8]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer competition (males)</td>
<td>1.6</td>
<td>[0.71–1.77]</td>
<td>0.28</td>
<td>[0.03–0.65]</td>
<td>1.62</td>
<td>[0.67–5.5]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American football [82]</td>
<td>Summer training (males)</td>
<td>2.14</td>
<td>[1.1–3.18]</td>
<td>1.42</td>
<td>[0.57–5.04]</td>
<td>1.7 kg (1.5%)</td>
<td>[0.1–5.9 kg]</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Summer competition (males)</td>
<td>1.6</td>
<td>[0.82–2.55]</td>
<td>1.42</td>
<td>[0.57–5.04]</td>
<td>1.3</td>
<td>(+3–14 kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer competition (females)</td>
<td>0.50</td>
<td>[0.50–1.34]</td>
<td>0.9</td>
<td>[0.06–1.0]</td>
<td>0.7</td>
<td>[0.09–0.3]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennis [15]</td>
<td>Summer competition (cramp-prone males)</td>
<td>2.60</td>
<td>[1.79–3.41]</td>
<td>1.6</td>
<td>[0.80–4.0]</td>
<td>2.12</td>
<td>[0.1–4.2]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squash [16]</td>
<td>Competition (males)</td>
<td>2.37</td>
<td>[1.49–2.55]</td>
<td>0.68</td>
<td>1.28 kg (0.1–2.4 kg)</td>
<td>1.28</td>
<td>[0.1–2.4 kg]</td>
<td></td>
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<tr>
<td>Half marathon running [21]</td>
<td>Winter competition (males)</td>
<td>1.49</td>
<td>[0.75–2.23]</td>
<td>0.75</td>
<td>[0.03–0.65]</td>
<td>2.42</td>
<td>[1.33–3.8]</td>
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<tr>
<td>Cross-country running [82]</td>
<td>Summer training (males)</td>
<td>1.77</td>
<td>[0.99–2.55]</td>
<td>0.57</td>
<td>[0.01–1.3]</td>
<td>1.8</td>
<td>[1.33–3.8]</td>
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</tr>
<tr>
<td>Ironman triathlon [132]</td>
<td>Summer training (males &amp; females)</td>
<td>2.22</td>
<td>[1.50–2.83]</td>
<td>1.72</td>
<td>[0.01–1.3]</td>
<td>2.22</td>
<td>[1.33–3.8]</td>
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<tr>
<td></td>
<td>Total race</td>
<td>1.02</td>
<td>[0.4–1.0]</td>
<td>0.63</td>
<td>[0.24–1.13]</td>
<td>2.2 kg</td>
<td>[1.5–3.5 kg]</td>
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</table>

* = gain in BMI; *not corrected for change in BMI that occurs in very prolonged events due to factors other than fluid loss (e.g. metabolic fuel losses).
Although sweat rates and fluid consumption are main components affecting hydration status, research has shown that gender may play a role in development of dehydration. Sawka et al.\textsuperscript{26,27} and Avellini et al.\textsuperscript{27} concluded that, due to having smaller body size and lower metabolism, women have lower sweat rates and lose fewer electrolytes than men, generally speaking. This may be helpful to attenuate fluid loss.

The previously mentioned factors are all important for athletes to consider when attempting to maintain good hydration practices. Athletes who begin prolonged exercise euhydrated will gradually dehydrate while performing the activity, if no attempt to ingest fluids is made. Dehydration is known to cause physiological strain that is observed through increasing core body temperature, heart rate and perceived exertion.\textsuperscript{13} Researchers have shown dehydration >2% decreases aerobic performance.\textsuperscript{28} Larger deficits of dehydration have demonstrated further decreases in aerobic performance.\textsuperscript{14,16} Studies have also gathered that the impact of dehydration on performance is greater in warm environments than it is in cool environments.\textsuperscript{29,30} These decreases in performance result from several physiological factors such as higher core body temperature, increased cardiovascular strain, increased use of glycogen stores, changes in metabolic function and possibly changes in central nervous system function.\textsuperscript{13,19} These factors do not act in isolation but rather are cumulative and exaggerate each other.\textsuperscript{31}

**Hydration Status Effect on Physiological Aerobic Performance**

A few key studies demonstrate that dehydration negatively affects performance. Pitts et al.\textsuperscript{32} conducted a study in 1944 in which heat-acclimatized males were asked to walk at a set intensity for six different trials. Subjects walked during 2 trials without consuming any drinks, two trials drinking according to their thirst sensation, and two
trials where they drank water every fifteen minutes. The trials in which subjects were not allowed to drink anything showed increasing rectal temperatures with no sign of leveling off. The trial in which participants drank to thirst showed a consistent rectal temperature for 13 miles on average and then core temperature began to rise. When forced to consume water every fifteen minutes to replace sweat losses, participants’ rectal temperature and perceive exertion remained low. The key point of this article was that performance is best when dehydration is minimal.32

Below et al33 studied cyclists during 50 minutes of cycling at 85% VO₂ max. Trials included one in which approximately 80% of sweat losses were replaced, and one in which only 13% of sweat losses were replaced. Performance in the dehydrated (13% replaced) trial decreased by 6.5% when compared to the hydrated trial (80% replaced).
The main conclusions of this study were that lower esophageal temperatures, lower heart rates, and lower ratings of perceived exertion were related to the participants being better hydrated. Figures 4 and 5 display the data for these findings.

Ebert et al\textsuperscript{17} conducted a study in 2007 to examine the effect of hydration on performance in trained cyclists. The study evaluated whether cyclists gained a benefit from dehydrating (and therefore having less body mass and carrying a lighter load). Each participant completed a trial with a low level of fluid intake (dehydrated) and a trial with a high level of fluid intake (hydrated). They were asked to complete a 2-hour submaximal exercise bout and then complete a performance task, which would be timed. Every participant performed worse in the dehydrated trial. On average, the dehydrated trial was performed 5.6 minutes slower than the hydrated trial, which resulted in a relevant decrease in performance of 28.6\%. Ebert and colleagues concluded that the potential benefit from decreasing body mass was irrelevant due to the overriding decreases in performance that resulted from dehydration.

In 2010, Casa et al\textsuperscript{15} performed a field study in which participants completed four 12km runs in the heat (a hydrated and dehydrated race trial and a hydrated and dehydrated submaximal run).
temperatures were recorded in the dehydrated submaximal trials than the hydrated submaximal trials. Interestingly, they also found that for each additional 1% of body mass lost during exercise due to dehydration intestinal temperature increased 0.22°C and heart rate increased by 6 b·min⁻¹. This study was important because it demonstrated that dehydration causes a decrease in performance, while running in the heat, and an increase in physiological strain.

**Cardiovascular Drift**

One of the ways exercise increases physiological strain is through the phenomenon called cardiovascular drift. This phenomenon occurs when stroke volume decreases and heart rate increases gradually, during prolonged exercise.⁴⁴,⁴⁵ There are two opposing themes that explain what causes this drift in cardiovascular responses.

**Cardiovascular Drift: Definitions and Concepts**

A traditional hypothesis⁴⁶ offered the idea that the body increases blood flow to the skin when exercising in the heat for thermoregulatory purposes. This progressive increase in skin blood flow results in decreased pressure in the central veins. To make up for the decreased blood volume, a reflex in the heart initiates a corresponding increase in heart rate. The increase in heart rate is critical to ensure enough blood supplying oxygen to working muscles during exercise.

In 2001, Coyle et al⁴¹ refuted the traditional hypothesis by arguing the previous hypothesis lacked evidence because it did not obtain measurements of central blood volume. The arguments against the traditional hypothesis state that exercise causes the increase in heart rate, which doesn’t allow the heart enough time to fill completely, and therefore stroke volume progressively decreases.⁴⁴
Other Factors Influencing Cardiovascular Drift

Cardiovascular drift may be influenced by many factors. Research has shown that hyperthermia, which is often caused by exercising in the heat, triggers cardiovascular drift to be greater than it would be in a cooler environment. The healthy body responds to an increase in core temperature by increasing heart rate and peripheral blood flow to dissipate heat effectively. Cardiac Output (Q) is a main variable in oxygen delivery; and is dependent upon stroke volume and heart rate. (Q = SV x HR) Therefore, an increased heart rate and an increase in skin blood flow are both mechanisms that will result in a decreased stroke volume, which further exacerbates the cardiovascular drift that occurs with exercise.

Studies also have shown that dehydration is related to cardiovascular drift. Montain and Coyle studied trained cyclists who each completed 4 different hydration protocols. The key finding in their study was the degree of hyperthermia and the degree of cardiovascular drift during exercise were directly related to the athletes’ degree of dehydration. They also concluded that athletes should strive to consume volumes of fluid equivalent to what was lost during exercise, to decrease the effects of hyperthermia and cardiovascular drift.

After reviewing the literature, it is still challenging to identify one distinct cause of cardiovascular drift. It is more likely that both the traditional and contemporary models of thought have a role in this phenomenon. There are also many other factors that may influence a change in peripheral/central blood flow or a change in heart rate. There remains a great need for more research in this area.
Implications and Effects of Cardiovascular Drift

A review of the literature shows that cardiovascular drift negatively impacts performance through a number of various factors. A majority of the research focuses on cardiovascular drift and how it affects VO$_{2\text{max}}$.

While studying cyclists, Wingo et al. found that a 12% increase in heart rate in combination with a 16% decrease in stroke volume was associated with a 19% decrease in VO$_{2\text{max}}$. There were no changes in skin temperature, but there was an average increase of 1°C in rectal temperatures throughout the trials. This supports that as rectal temperature increases cardiovascular drift increases and results in the decrease of VO$_{2\text{max}}$.

A second study was performed to determine if exercise intensity played a role in cardiovascular drift. The researchers lowered exercise intensity to keep heart rate constant. Stroke volume still declined by 21%, but researchers concluded it was most likely due to a decrease in workload that resulted in less metabolic demand and not cardiovascular drift. Wingo et al. only controlled heart rate in this study, but offered the idea of controlling heart rate and stroke volume to determine a relationship for cardiovascular drift with VO$_{2\text{max}}$ measures.

In 2006, a study was developed in which heart rate and stroke volume were controlled. The researchers controlled stroke volume by cooling the participants with airflow from fans, as soon as cardiovascular drift was present. The results of this study suggested when cardiovascular drift is alleviated, the decrease in VO$_{2\text{max}}$ is also reduced.

Ganio et al. looked at dehydration and its effect on cardiovascular drift and VO$_{2\text{max}}$. The increase in heart rate and decrease in stroke volume were both 14% and the decrease in VO$_{2\text{max}}$ was only 9%. The researchers concluded that the cardiovascular drift
associated with a rise in core temperature from performing in a hot environment has a larger degree of influence on VO\textsubscript{2max} than cardiovascular drift associated with dehydration.

The final study in this group\textsuperscript{34} aimed to see if cardiovascular drift also occurred in cooler climates where athletes were euhydrated. Variables were similar to all previous studies, whereas those in the experimental group (22\textdegree C) were much smaller. In this study, heart rate and stroke volume decreased by 2\%, which resulted in a decrease of VO\textsubscript{2max} by 5\%. This minimal decrease in VO\textsubscript{2max} was not considered significant. The data collected shows a decreased environmental temperature allowed for less cardiovascular drift, which caused minimal VO\textsubscript{2max} deficits.

Table 2 displays the findings of these studies and the relationships between cardiovascular drift and VO\textsubscript{2max}. In summary, the series of studies from Wingo and his colleagues formed the following conclusions. 1.) An increase in cardiovascular drift due to hyperthermia decreases VO\textsubscript{2max}. 2.) By controlling heart rate and stroke volume researchers were able to minimize cardiovascular drift which also minimized the concurrent decrease in VO\textsubscript{2max}. 3.) Increasing core temperatures have a larger effect on cardiovascular drift associated reductions in VO\textsubscript{2max} than dehydration does. 4.) Exercising in cool environments mitigates cardiovascular drift and therefore limits deficits in VO\textsubscript{2max}. Throughout the research discussed here and elsewhere, it is evident that the degree of cardiovascular drift directly relates to the degree of VO\textsubscript{2max} reduction.
Influence of Cardiovascular Drift on performance

Performance output measures were also recorded for all of the previously mention studies involving cardiovascular drift and its effect on VO$_{2\text{max}}$. The researchers obtained peak power outputs and length of time to complete the exercise test. In the studies that looked at 15 and 45 minutes post exercise, the decrease in power output associated with cardiovascular drift ranged from 12-17%. The mean duration of the graded exercise test decreased across a range of 28-37%. The other study in this group had similar...
findings, with a 13% decrease in peak power output and a 27% decrease in the duration of the graded exercise test.

These results do not encompass all the possible measurements that relate to all types of exercise performance, but they support the concept that cardiovascular drift can lead to decreased performance in endurance athletes.

The importance of this research on cardiovascular drift for athletes pertains to decreasing the physiological strain associated with participating in exercise. Cardiovascular drift can be mitigated by several factors. Monitoring ambient and core body temperatures, keeping athletes well hydrated, minimizing exercise duration in strenuous environments, and trying to attenuate core body temperature rises (via body cooling) in a warm environment are all valuable advice for keeping athletes safe. Although many of these factors are difficult for the athlete to control, hydration is something athletes can easily learn to control themselves.

**Special Considerations for Triathletes**

Triathletes have a very unique obstacle to overcome, for staying hydrated during their competition, due to the extreme duration of the event. Marathon and triathlon participants lose very high amounts of sweat due to the long race distances. The current recommendation to athletes is to drink enough to minimize body weight loss to less than 2%.\textsuperscript{13,16,43} Runners should never drink so much that hydrating actually results in gaining weight.\textsuperscript{16} This may lead to excess fluid retention, which can cause hyponatremia.

Although there are recommendations for runners in these endurance events, it is not clear whether they follow them. Williams \textit{et al.}\textsuperscript{44} studied 217 participants with a mean age of 40 years old in the London Marathon to examine hydration strategies.
Williams found 91.7% of the runners had a plan for hydrating on race day morning. The average volume the participants planned to consume pre-race was 0.75L. 95.8% of the runners had a plan for hydrating during the race. Of these participants, 21.6% planned to stop at all 24 water stations (positioned every mile from mile 3-25) along the route. However, the average number of planned water station stops of all runners was only 10. 86.5% of runners with a plan to hydrate during the race planned on stopping at 1 of the 5 sports drink stations along the route and 26.5% planned to drink from all five sports drink stations. 20.3% of these runners planned to carry their own water bottles with a mean volume of 0.5L. Figure 9 shows the volume of fluid runners planned to consume during the marathon. Williams noticed a trend in runners who planned to consume more than 3.5L and having slower finishing times, but did not differ in age or sex. 88% of participants had a plan for rehydrating post race. 57% indicated the volume they planned on drinking after the race, which was an average of 1.2 L. Three of the 217 runners had planned to drink five or more liters when the race was over. The average volumes planned to be consumed were near the values recommended by the National Athletic Trainers’ Association (NATA), but some individuals were beyond these recommendations, which may put them at risk for dilutional hyponatremia. Considering the current knowledge regarding dehydration, pacing and cardiovascular
drift, it is very important for triathletes to maintain proper hydration in order to be successful during competition.

**Conclusion**

Overall, dehydration has been shown to be detrimental to aerobic performance\(^{14,16,17,32,33}\) by increasing physiological strain.\(^{13,15}\) Dehydration also leads to an increase in the phenomenon known as cardiovascular drift\(^ {38}\) which will further impact performance.\(^ {34,39-41}\)

Dehydration-induced cardiovascular drift will cause excess physiological strain on the body (i.e. increased heart rate and decreased stroke volume). With increases in heart rate, athletes who monitor their heart rate to keep a steady pace during triathlons may actually be less consistent in pacing when they are dehydrated. Therefore, the athlete may slow their pace to stay within targeted heart rate zones for a certain section of the race, resulting in inconsistent pacing, which could lead to a decrease in overall performance.

**Gaps in the Literature**

While it is known that choosing an efficient pacing strategy will produce better performance\(^2\), and that using heart rate as feedback can be useful to endurance runners and triathletes\(^ {45}\), we do not know how effective heart rate feedback is for the purposes of pacing triathletes competing in an Ironman triathlon.

In hot environments which cause the body great thermal stress, athletes are at more of a risk for dehydration\(^ {13}\), which has been shown to impair performance,\(^ {6,13-19}\) by increasing physiological strain. This has been known to include a continuous rise in heart rate, core body temperature, and ratings of perceived exertion throughout the event.\(^ {46}\) To
the knowledge of the researchers, the effects of dehydration and the inherent physiological strain, which may impair performance, has not been studied in the Ironman triathlete population. Gaining knowledge in this area will be beneficial to triathlete health and performance in these events.

**Purpose**

The purpose of this study is to examine the pacing and performance of Ironman triathletes. A main objective is to examine hydration’s impact on pacing and performance during the event and, more specifically, this study aims to correlate the impact of hydration on pacing and performance for those athletes who pace themselves using heart rate as feedback.
INTRODUCTION

To most elite endurance athletes, maximizing performance means everything. Although many factors play a role in optimal performance, two of the most important are hydration status and pacing strategy. Dehydration is also linked to an increase in a phenomenon known as cardiovascular drift during exercise, that may also hinder performance. Knowing proper pacing strategies and how hydration affects pacing can be extremely beneficial to endurance athletes. A majority of research focusing on the relationship of hydration and pacing to performance are studies of one-event endurance athletes, such as marathons.

It has been suggested that athletes often use different pacing strategies based upon the type of event they are competing in. Research has shown “all out” strategies are useful for events lasting 30 seconds or less, such as a sprint, whereas an even paced run may be more successful in events lasting longer than 2 minutes.

There are 5 pacing strategies that summarize how most runners will pace. “Negative pacing” refers to a strategy in which the athlete continuously increases speed throughout the duration of the event, and is commonly used by middle-distance runners. A “positive pacing” strategy occurs when the athlete starts at a fast pace and continuously decreases his/her speed throughout the race. “Even pacing” describes an athlete who tries to maintain the same speed throughout the entire event. Researchers also have observed a type of pacing called “parabolic shape pacing”. In this strategy, athletes begin at a high speed and continuously decrease until a certain point in the event, and begin to increase speed at a pace that depends on how much of the race remains. A last strategy is “variable
pacing”, in which the athlete is continuously changing pace depending on external factors.²

Ironman triathletes experience the difficulty of completing three different activities over a very long duration of time. An Ironman Triathlon consists of swimming for 3.8km, cycling for 180km, and running for 42.2km. Research in the area of triathlete pacing is marginal; however, one study showed that Ironman triathletes utilize a positive pacing strategy during the bike section.³

There are many factors that affect athletes’ pacing. Extreme environmental conditions⁷, altitude changes⁹, the presence of feedback¹⁰ or competition¹¹, and even participants’ age and sex¹² have been linked to event pacing.

Dehydration has been shown to decrease pacing consistency as well as overall performance times in trail running, during the heat.⁶ An individual’s age⁴⁷, sweat rate, the intensity and duration of the activity, amount of fluid intake, and environmental conditions all play a role in hydration status.¹³ Athletes must maintain adequate hydration levels to avoid excessive physiological strain during exercise. Dehydration can cause increases in core body temperature, heart rate and levels of perceived exertion.¹³ A dehydration level greater than 2% causes deficits in aerobic performance, and more severe dehydration will result in even further performance deficits.¹⁴,¹⁶ Factors that influence hydration do not act in isolation, but rather are additive.³¹ Knowing this, it is crucial for triathletes to strive for adequate fluid replacement during events.

Exercise also results in a phenomenon known as cardiovascular drift. This causes physiological strain by increasing heart rate, as stroke volume decreases simultaneously.³⁴,³⁵ Hyperthermia³⁷, duration of exercise or activity, and dehydration³⁸
all negatively affect cardiovascular drift, which results in a decreased VO$_2$ max, and which is associated with decreases in performance.\textsuperscript{39}

Athletes who become dehydrated throughout exercise may experience a decrease in performance due to the occurrence of cardiovascular drift. This poses an interesting thought for athletes who choose to monitor heart rate for pacing feedback. Dehydrated individuals might experience higher levels of cardiovascular drift, and therefore higher heart rates, which may be a sign to slow pace to stay within targeted heart rate zones.

Monitoring environmental conditions and core body temperatures, maintaining adequate hydration levels, and minimizing exercise in strenuous environments may all help to attenuate increases in cardiovascular drift, and therefore decrease the risk associated with endurance competition.

The unique challenge faced by Ironman Triathletes may make it difficult to maintain adequate hydration levels. Limited research exists on triathlete pacing strategies and the effects of hydration on pacing during an Ironman Triathlon.

The purpose of the present study was to examine the unique pacing strategies of Ironman Triathletes. The main objectives were to observe hydration’s impact on performance and pacing during this event, as well as to specifically look at how hydration status impacted those who utilized feedback from a heart rate monitor to pace themselves.

**METHODS**

**Participants**

Forty-one elite triathletes competing in the 2012 Lake Placid Ironman Triathlon volunteered to participate in this study. Participants were split into two groups based on
those who planned to monitor their heart rate for feedback during the event (HR), and those who would not be monitoring heart rate (NHR). Recruitment of participants included the use of a recruitment flyer on social media outlets that were commonly viewed by triathletes and by verbal communication. Subjects were males and females between the ages of 18 and 60, and completed a medical history questionnaire (Appendix A) prior to involvement with the study. This was used to exclude participants for any of the following reasons: chronic health problems; a previous episode of exertional heat stroke in the last 3 years; history of cardiovascular, metabolic, or respiratory disease; contraindications for the use of the gastrointestinal pill; a current musculoskeletal injury which limits physical activity. Participants were also excluded from the study if they did not plan on completing the triathlon in roughly 12-13 hours. After recruitment, participants were contacted for a briefing session over the phone. After this screening process the remaining participants received written consent forms, which were read, signed, and returned before or on race day. The Institutional Review Board of the University of Connecticut approved this study.

**Procedures**

This was an observational study following subjects throughout the duration of the Ironman Lake Placid Triathlon. Prior to arrival in Lake Placid all participants completed a Training History Questionnaire (Appendix B), Medical History Questionnaire (Appendix A), and consent form.

**Baseline Measures**

1-2 days prior to the race, participants’ baseline measurements were recorded. Subjects were asked to record their resting heart rate using a heart rate monitor watch.
Subjects were instructed to record their heart rate for five minutes just prior to going to sleep and upon waking (before they left their bed). During this time they were instructed to lie quietly and relax as much as possible, without falling asleep. Body composition was measured in duplicate on the right side of the body with the use of hand held Lange Skinfold Calipers. A two-day baseline weight was established for each participant by recording weight prior to race day and the morning of the race. A urine and salivary sample were also collected from each participant one of these days. For the salivary sample, subjects were asked to avoid any food intake, consumption of hot fluids and brushing their teeth within 30 minutes of the assessment. Subjects were asked to place a cotton swab under their tongue to passively collect saliva. They were asked to not chew, talk or move their head. Salivary samples were removed from the Subjects’ mouths, placed in a vial, and immediately frozen (to be analyzed at a later date). Subjects were also asked to provide a urine sample, which was analyzed for urine specific gravity (USG) via refractometry (A300CL-E01, Atago, Tokyo Japan). Urine color was assessed via the urine color chart.48

Lastly participants completed a number of perceptual and questionnaires including: a sleep record (Appendix C), Thermal Sensation Scale49 (Appendix D), Thirst Sensation Scale50 (Appendix E), Profile of Mood States (POMS)51 (Appendix F), Delayed Onset Muscle Soreness (DOMS)52 (Appendix G), and Environmental Symptoms Questionnaire (ESQ)53 (Appendix H).

Participants were provided with an ingestible thermistor (CorTemp® Ingestible Core Body Temperature Sensor, HQInc., Palmetto, FL) the night before the race and
were asked to ingest the pill directly before going to bed or immediately once they woke up on race day.

**Race Day**

On the morning of the race, prior to getting out of bed, participants were asked to record their resting heart rate again using a heart rate monitor (Timex Ironman Race Trainer, Timex®, Middlebury, CT). Upon arrival, presence of the ingestible thermistor was confirmed. If a subject had already passed the pill, a new pill was provided. Subjects’ body weight was recorded to the nearest 0.1kg (Professional 349KLX, Health O Meter, Beford Heights, OH) and urine and salivary samples were taken. Gastrointestinal temperature ($T_{gi}$) was recorded for each participant prior to the start of the race. Participants were asked to complete the sleep record (Appendix C), Thermal Sensation Scale$^{49}$ (Appendix D), Thirst Sensation Scale$^{50}$ (Appendix E), POMS$^{51}$ (Appendix F), DOMS$^{52}$ (Appendix G) and ESQ$^{53}$ (Appendix H).

The participants’ heart rate, pace, time and performance data was recorded throughout the duration of the race by wearing a heart rate monitor strap and the GPS watch. (Timex Ironman Run Trainer GPS, Timex®, Middlebury CT). Power and work output values were also recorded during the cycling portion of the race through the use of the participants’ personal portable monitors mounted on their bikes. Researchers recorded Wet Bulb Globe Temperatures (WBGT) (Kestrel 4400 Heat Stress Tracker, Kestrel®, Boothwyn, PA.) and wind speeds periodically throughout the race day to monitor for changes in environmental conditions.

Immediately upon completion of the race, the participants’ body weight and $T_{gi}$ were recorded. Final urine and salivary samples were also taken. Participants were then
asked to record any fluid and food consumed during the race along with the Thermal Sensation Scale\(^4\) (Appendix D), Thirst Sensation Scale\(^5\) (Appendix E), POMS\(^6\) (Appendix F), DOMS\(^7\) (Appendix G), and ESQ\(^8\) (Appendix H). A Ratings of Perceived Exertion Questionnaire\(^9\) (Appendix I), Gastrointestinal Symptoms Questionnaire (Appendix J) and a Post Race Questionnaire (Appendix K) were also completed by each participant to conclude the data collection.

Prior to statistical analysis, the thirty-seven triathletes who finished the race were ranked according to post-race USG. The top 13 and bottom 13 USG values from these participants were used to represent the hydrated (HY) and the dehydrated (DHY) groups. The 17 triathletes who used heart rate to monitor performance were also spilt into two groups, hydrated and dehydrated, (HRH and HRD) based on their post-race USG. Individuals were placed in the hydrated group if their post-race USG was \(\leq 1.025\), and were placed in the dehydrated group if their post-race USG was \(\geq 0.125\).

This Ironman course was ideal to observe pacing. The course was made up of two identical loops for each of the bike and run sections. To examine pacing as a percentage, the percent delta between bike loops and the percent delta between run loops were calculated for each participant. This was done by subtracting the participants’ time to complete the first loop of that section from the participants’ time to complete the second loop of that section, and dividing it by the overall time for the given section. This number was multiplied by 100 to obtain a percent of time for each loop.

Pace was examined in another fashion by taking each participant’s average pace for the whole bike or run section, and finding the percent from which each loop’s average
pace deviated from the overall average. This allows comparison across all four loops of the race. (Bike loop 1, (B1), bike loop 2 (B2), run loop 1 (R1), and run loop 2 (R2)).

**Statistical Analysis**

Statistical analyses were performed using PASW Statistics v. 18.0 for Mac (IBM SPSS Statistics, Chicago, IL). Data are reported as means ± SD in tables and figures. To determine differences between pre-race and post-race time points between groups an independent samples T-Test was performed. Welch-Satterthwaite corrections were made when Levene’s Test of Equality of Variances was violated. For variables with greater than two time points a linear mixed model ANOVA was utilized. Greenhouse-Geisser corrections were made when the assumption of sphericity was violated. When a significant effect of time occurred, a post-hoc paired samples T-Test was performed. Pearson’s bivariate correlation was performed to determine correlations between physiological data. Spearman Rank Order correlations were utilized for ordinal data (ie. ESQ scores). Percent delta calculations were performed on pre and post ESQ data to account for differences in pre values across subjects. An *a priori* alpha level of 0.05 was set for all tests.

**Results**

**Subject Characteristics**

Thirty-seven (30 male and 7 female) participants completed the study (mean ± SD: age, 39 ± 7 y; height, 174 ± 10 cm; pre-race weight, 72.4 ± 10.1 kg; and body fat, 15.3 ± 5.6%). See Table 4. Participants finished the race in 13.16 ± 1.35 hr, and lost an
average of 3.2 ± 1.6% of their pre-race body mass. Significant correlations between variables for all subjects can be found in Table 3.

Table 3 Correlations ($R^2$ values) between variables for all subjects

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<td></td>
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</tr>
<tr>
<td>Body Mass Loss (%)</td>
<td></td>
<td></td>
<td>1</td>
<td>0.003</td>
<td>0.285**</td>
<td>0.042</td>
<td>0.004</td>
<td>0.370</td>
<td></td>
</tr>
<tr>
<td>Body Fat</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.000</td>
<td>0.047</td>
<td>0.154*</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Post-race USG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.000</td>
<td>0.016</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Post-race $T_{gi}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.144*</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>Percent Delta Bike</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>Percent Delta Run</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 4 Selected Personal Characteristics for all subjects

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Male</th>
<th>Females</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects (n)</td>
<td>30</td>
<td>7</td>
<td>37</td>
</tr>
<tr>
<td>Age (years)</td>
<td>39 ± 8</td>
<td>40 ± 6</td>
<td>39 ± 7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177 ± 5</td>
<td>160 ± 15</td>
<td>174 ± 10</td>
</tr>
<tr>
<td>Pre-Race Weight (kg)</td>
<td>75.5 ± 8.5</td>
<td>59.7 ± 6.4</td>
<td>72.4 ± 10.1</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>14.3 ± 5.4</td>
<td>19.3 ± 4.7</td>
<td>15.3 ± 5.6</td>
</tr>
<tr>
<td>Body Mass Loss (%)</td>
<td>-3.32 ± 1.63</td>
<td>-2.57 ± 1.55</td>
<td>-3.18 ± 1.62</td>
</tr>
<tr>
<td>Finish Time (hours)</td>
<td>13.26 ± 1.41</td>
<td>12.71 ± 1.07</td>
<td>13.16 ± 1.35</td>
</tr>
</tbody>
</table>
Of the 37 participants in the study, 17 utilized heart rate pacing feedback throughout the race (HR) and 20 did not (NHR). Between-group comparisons revealed no significant differences (p>0.05) in age, height, % body fat, %BML, post-race USG, post-race GI temperature, or finish times between the HR and NHR groups. See Table 5.

Table 5 Comparative descriptive data for all groups

<table>
<thead>
<tr>
<th></th>
<th>HR Group</th>
<th>NHR Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>41 ± 7</td>
<td>37 ± 8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173 ± 13</td>
<td>175 ± 7</td>
</tr>
<tr>
<td>Pre-race weight (kg)</td>
<td>74.1 ± 9.8</td>
<td>71.0 ± 10.4</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>15.8 ± 6.4</td>
<td>15.0 ± 4.8</td>
</tr>
<tr>
<td>Finish Time (hr)</td>
<td>13.39 ± 1.57</td>
<td>12.96 ± 1.15</td>
</tr>
<tr>
<td>BML (%)</td>
<td>3.0 ± 1.58</td>
<td>3.34 ± 1.68</td>
</tr>
<tr>
<td>Post-race USG</td>
<td>1.027 ± 0.007</td>
<td>1.024 ± 0.007</td>
</tr>
<tr>
<td>Post-race Tgi (°C)</td>
<td>38.31 ± 1.00</td>
<td>38.38 ± 0.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>HRH Group</th>
<th>HRD Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>42 ± 5</td>
<td>39 ± 5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167 ± 17</td>
<td>178 ± 5</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>17.7 ± 7.0%</td>
<td>14.8 ± 6.2</td>
</tr>
<tr>
<td>Finish Time (hr)</td>
<td>13.43 ± 1.88</td>
<td>13.36 ± 1.50</td>
</tr>
<tr>
<td>BML (%)</td>
<td>2.66 ± 1.38</td>
<td>3.46 ± 1.65</td>
</tr>
<tr>
<td>Post-race USG**</td>
<td>1.020 ± 0.004</td>
<td>1.032 ± 0.003</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>HY Group</th>
<th>DHY Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>38 ± 8</td>
<td>39 ± 5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172 ± 14</td>
<td>177 ± 5</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>15.0 ± 6.3</td>
<td>16.1 ± 5.1</td>
</tr>
<tr>
<td>Finish Time (hr)</td>
<td>12.79 ± 1.48</td>
<td>13.45 ± 1.35</td>
</tr>
<tr>
<td>BML (%)*</td>
<td>2.39 ± 1.65</td>
<td>3.91 ± 1.13</td>
</tr>
<tr>
<td>Post-race USG**</td>
<td>1.017 ± 0.004</td>
<td>1.032 ± 0.003</td>
</tr>
</tbody>
</table>

* Significantly different at the 0.05 level  
**Significantly different at the 0.01 level

The 17 participants who utilized heart rate feedback were divided into a hydrated (HRH) and dehydrated (HRD) group as well. Between-group comparisons (HRH versus HRD) revealed no significant differences in age, height, % body fat, %BML, or finish...
times. Post-race USG for the HRH group (1.020 ± 0.004) was significantly different 
(p<0.001) from the HRD post-race USG (1.032 ± 0.003). See Table 5.

The top 13 hydrated participants were also placed in a group (HY) for comparison 
to the bottom 13 hydrated participants (DHY). Between-group statistical comparisons 
revealed no significant differences in age, height, % body fat, or finish times between the 
HRH and HRD groups. Post-race USG (1.017 ± 0.004) and %BML (2.39 ± 1.65%) for 
HY were significantly different (p<0.001, p=0.011 respectively) from the DHY group 
(1.032 ± 0.003; 3.91 ± 1.13%). See Table 5.

**HY and DHY Groups**

**Pace (overall)**

Participants’ average pace (in minutes per mile) across bike loop 1 (B1), bike loop 
2 (B2), run loop 1 (R1), and run loop 2 (R2) showed an overall effect of time (p<0.001), 
but no group by time interaction. Figure 10 displays the average pace throughout the race 
for the HY and DHY groups. Pace for the bike section (B1 and B2) by itself had an 
overall effect of time (p<0.05), but no group by time interaction. The run section (R1 and 
R2) pace was significantly different (p<0.001), but no group by time interaction was 
present. See Figure 10.

**Pace (expressed as a percentage)**

When time to complete B1, B2, R1 and R2 were examined as a percent of overall 
time for bike and run sections, there was an overall effect of time (p<0.001). *Post hoc* 
analysis revealed differences between B1 and B2 (p<0.001), as well as R1 and R2 
(p<0.001), but no group by time interaction was present (p>0.05). See Figure 11.
When B1, B2, R1, and R2 were compared as the percent of deviation from the average pace for their respective bike or run sections, an overall effect of time (p<0.001) was observed. Post hoc analysis revealed differences between B1 and B2 (p=0.044), B2 and R1 (p<0.001), and R1 and R2 (p<0.001). However, no group by time interaction was seen (p>0.05). See Figure 11.

Heart Rate

There was overall effect of time for average heart rate between B1 and B2 (p=0.002), as well as between R1 and R2 (p=0.014). There was no group by time effect between groups for either section of the race. See Figure 12. When examined collectively, there was a general effect of time between B1, B2, R1, and R2 (p=0.018), but no group by time interaction was observed (p>0.05). Post hoc analysis of average heart rate only revealed significant differences between B1 and B2 (p=0.018).
Figure 9 Percent of time spent on each loop of either section for the 13 most hydrated (HY) and 13 most dehydrated (DHY) individuals. Overall effects of time were observed. (***Significantly different at the \(p<0.001\)). No group by time interactions were present (\(p>0.05\))

Figure 10 Average heart rate during each loop for the 13 most hydrated (HY) and 13 most dehydrated (DHY) individuals. * Overall effect of time (\(p=0.018\)), no group by time interaction (\(p>0.05\))

**HR Groups**

**Pace (overall)**

Average pace (mean minutes per mile) across B1, B2, R1, and R2 showed an overall effect of time (\(p<0.001\)), but no group by time interaction. B1 and B2 were not
significantly different. B1 compared to R1 and R2 were significantly different \((p<0.001)\). R1 was significantly different \((p<0.001)\) from B1, B2, and R2. Pace for the bike section (B1 and B2) by itself had no overall effect of time, and no group by time interaction. R1 and R2 pace was significantly different \((p<0.001)\), but had no group by time interaction.

**Pace (expressed as a percent)**

There were no significant differences \((p>0.05)\) between the percent of time spent within each loop of the bike component as well as each loop of the run component for this group (HRH vs. HRD).

![Figure 11: Percent of time spent in each loop in either section for hydrated individuals who monitored heart rate (HRH) \((n=7)\) and dehydrated individuals who monitored heart rate (HRD) \((n=9)\). ***Effect of time \((p<0.001)\), no group by time interaction \((p>0.05)\).](image)

When B1, B2, R1, and R2 were examined, there was an overall effect of time \((p<0.001)\), but no group by time interaction \((p>0.05)\) for the percentage of time to complete each of the loops for the HRH and HRD groups \((p>0.05)\). Figure 13 shows the percent of time to complete each loop of the race for the HRH and HRD groups. *Post hoc* analysis showed differences between B1 and B2 \((p<0.001)\), as well as between R1 and R1 \((p<0.001)\).
Pace expressed as a percent of average pace

When the percent of deviation from the average pace for B1, B2, R1, and R2 from their respective bike or run sections were compared, an overall effect of time ($p=0.013$) was observed. However, no group by time interaction was seen ($p>0.05$). Post hoc analysis revealed differences between B1 and R2 ($p=0.010$), B2 and R1 ($p=0.009$), and R1 and R2 ($p<0.001$).

Heart Rate

An overall effect of time on average heart rate was seen between B1, B2, R1, and R2 for the HRH and HRD groups ($p=0.014$). However, no group by time effect was observed for these groups. Post hoc analysis revealed differences between B1 and R2 ($p=0.033$), as well as between R1 and R2 ($p=0.015$). See Figure 14.

![Figure 12](image)

**Figure 12** Average heart rate during each loop for hydrated individuals who monitored heart rate (HRH (n=7) and dehydrated individuals who monitored heart rate (HRD) (n=9). *Overall effect of time ($p=0.014$), no group by time interaction ($p>0.05$).
Environmental Conditions

Average environmental measurements were taken periodically throughout the race. A summary of the day’s weather can be found in Table 6.

Table 6 Average Environmental Conditions throughout the race

<table>
<thead>
<tr>
<th></th>
<th>12:00pm-4:00pm</th>
<th>4:00pm-8:00pm</th>
<th>8:00pm-12:00am</th>
<th>Overall Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Speed (km/hr)</strong></td>
<td>1.0 ± 0.6</td>
<td>0.5 ± 0.2</td>
<td>0.3 ± 0.2</td>
<td>0.6 ± 0.5</td>
</tr>
<tr>
<td><strong>Dry Bulb Temp. (°C)</strong></td>
<td>28.1 ± 2.1</td>
<td>27.2 ± 1.7</td>
<td>22.3 ± 1.1</td>
<td>26.0 ± 3.0</td>
</tr>
<tr>
<td><strong>Wet Bulb Temp. (°C)</strong></td>
<td>18.7 ± 1.4</td>
<td>18.7 ± 1.4</td>
<td>18.4 ± 0.4</td>
<td>18.7 ± 0.9</td>
</tr>
<tr>
<td><strong>Humidity (%)</strong></td>
<td>44.6 ± 2.8</td>
<td>49.0 ± 6.7</td>
<td>69.3 ± 4.9</td>
<td>53.8 ± 11.9</td>
</tr>
<tr>
<td><strong>Heat Index (°C)</strong></td>
<td>27.7 ± 1.9</td>
<td>27.1 ± 1.9</td>
<td>22.6 ± 1.0</td>
<td>25.9 ± 2.8</td>
</tr>
<tr>
<td><strong>Globe Temp. (°C)</strong></td>
<td>38.1 ± 4.5</td>
<td>32.6 ± 4.3</td>
<td>23.0 ± 1.9</td>
<td>31.6 ± 7.4</td>
</tr>
<tr>
<td><strong>WBGT (outdoors) (°C)</strong></td>
<td>23.7 ± 1.4</td>
<td>22.5 ± 0.9</td>
<td>19.8 ± 0.8</td>
<td>22.1 ± 2.0</td>
</tr>
</tbody>
</table>

Discussion

The purpose of this study was to examine the pacing strategies of Ironman triathletes. The main objective involved observing hydration’s impact on performance and pacing in this event. A second objective of the study was to specifically evaluate ways that hydration may affect the pacing and performance of athletes who utilize heart rate for feedback throughout the event.

Pacing for Ironman Triathletes

An athlete’s performance can be greatly affected by their pacing strategy. Ironman Triathletes face quite a challenge with pacing due to the combination of three
different events and the extreme duration of the competition. Current research is lacking in the world of triathlete pacing, but many studies exist that look specifically at pacing during cycling or running individually.

The top finisher in the current study maintained a relatively even pace for each section of the race. This individual only had a 1.7% increase in time between the first and second bike loops, and had a 2.3% increase in time between the first and second run loops. This is a minimal change in pace considering some participants varied by 10-20%. These findings are similar to previous research suggests that athletes competing in ultra-endurance events (mainly marathons) will be most successful using an even pacing strategy. Maughn et al was able to demonstrate that faster runners in marathons utilized a constant pace strategy, and the slower runners used a positive pacing strategy in which they continuously slowed throughout the race. The winner of the 2012 Boston Marathon also supported this idea when he went against the typical Kenyan surge method, and held a constant pace throughout the entire race. This race took place during high temperatures, and showed that an even pacing strategy benefits runners more than varying pace, which may come as an energy cost to the athlete during late stages of the competition.

The current study found a positive pacing strategy to be common for participants during the bike section. Once again, this goes along with previous research. Abbiss et al was able to look at the pacing of cyclists in a 2004 Ironman. Researchers in that study found most of the participants used a positive pacing strategy during the cycling portion of the race. The bike portion of that race consisted of 3 identical loops; therefore researchers were able to compare power output, cadence, and heart rate for each of the
loops. The increase of time for each loop was also correlated with decreased power output and cadence, which suggests that environmental conditions did not play a role in the athletes’ slowing pace. Power output and cadence, were not measured in the current study, so environmental conditions can not fully be ruled out as a factor in the slowing of the participants’ pace throughout the bike section.

**Hydration and its affect on Pacing in Ironman Triathlons**

One of many factors that affect pacing and performance is hydration status. Many previous studies have shown that dehydration causes deficits in aerobic performance.\textsuperscript{13-18} Dehydration causes physiological strain on the body by increasing core temperature, heart rate and perceived exertion.\textsuperscript{13} Research has shown that dehydration greater than 2\% has a negative affect on aerobic performance,\textsuperscript{14, 16} and that larger deficits in performance may occur with greater dehydration levels.\textsuperscript{29, 30}

In the present study, two groups were formed to examine hydrations’ effect on pacing and performance. The HY group consisted of the top 13 hydrated individuals, according to post-race USG measures. The DHY group consisted of the bottom 13 hydrated individuals, also according to post-race USG measures. The HY and DHY groups had no significant differences between groups for age, height, % body fat, or post-race GI temperature, which allowed for comparison between the two similar groups. The groups were successfully differentiated between HY and DHY individuals as demonstrated by significant differences between groups for post-race USG and percent body mass loss. See Table 5 for the personal characteristics of subjects in these groups.
Overall Performance

The HY and DHY groups had no significant differences in finishing times, which falls in line with previous, freely paced and non-counter balanced field research studies. This finding is likely because the current study was not counter balanced, as Casa et al \(^\text{15}\) revealed that within a natural setting, hydration status will have an effect on performance when subjects performed the same race under both hydrated and dehydrated conditions.

The present study was limited by only having one race, therefore it is unknown if the subjects finishing in a dehydrated state may have performed better if they maintained a hydration status closer to euhydrated standards. Many field studies that support the relationship between dehydration and decreased performance do not employ controlled comparisons and simply evaluate a single event, such as a marathon. \(^\text{16}\) A limitation in this comparison arises from the fact that the marathon does not last as long as an Ironman triathlon, nor does it have the challenge of completing three different sections. Other studies examined hydration effects on cycling performance in the laboratory setting, to determine the impact on performance deficit, rather than in the field. \(^\text{17}\) Laboratory studies are beneficial for high control of extraneous variables, but can rarely be repeated in the real world. The previous studies mentioned above examined cyclists on a stationary ergometer and demonstrated a strong relationship between hydration status and performance. \(^\text{17}\)

Pace

The present study found an overall effect of time for pace throughout each section of the race, but found no group by time interaction. The slowed pace between loop 1 and loop 2 for each section (bike & run) was not significantly different for those who were
hydrated (HY) and those who were dehydrated (DHY). Again, previous research\(^6\) that has demonstrated pacing differences between HY and DHY subjects was performed with subjects who completed two 12 km races which is drastically shorter than that of an Ironman Triathlon. Stearns et al also used a within-subjects design, which eliminates other factors that may play a role in the outcomes when compared to a between-subjects study such as the current one.

The current study looked at pacing in a different way as well. The percent of time spent in each loop between loop 1 and 2 for each section was calculated. Both the HY and DHY groups took a larger percentage of time to complete the second loop than the first, but there were no significant differences between the groups. Therefore, within the hydration differences that were observed in this study, pacing was similar between subjects.

*Physiological Strain*

Dehydration is known to cause physiological strain on the body.\(^{13}\) One way this is evident is by an increasing core temperature. In 1944, Pitts et al completed a classic laboratory study\(^{32}\) in which they observed rectal temperatures and ratings of perceived exertion while subjects completed trials at different hydration levels. The dehydrated trials showed a continuously climbing rectal temperature with no sign of stopping, and the hydrated trial (forced drinking every 15 minutes) had constantly lower rectal temperatures and perceived exertion levels.

Another lab study by Below et al\(^{33}\), support these early results when they concluded that dehydration (“small fluid replacement” of 13%) was associated with 6.5% decrease in performance, and also that hydrated (“large fluid replacement” of 79%) trials
were associated with lower esophageal temperatures, lower heart rates, and lower ratings of perceived exertion.

In contrast to the previous two studies discussed, the present study found no significant correlations between finish time and post-race GI temperatures. However, this is similar to previous Ironman triathlon field studies, which also found no relationship between finish time and post-race temperatures.\textsuperscript{55,56} Again, these findings in the field are likely due to a lack of control over intensity, where the dehydrated individuals struggled and slowed, resulting in similar body temperatures. This idea is supported through the field study results of Casa et al\textsuperscript{15}, where significant differences in body temperature were demonstrated in a field setting where subjects were asked to complete the exercise session in a hydrated and dehydrated trial at the same intensity (same finish time).

Although a general effect of time was observed on average heart rate for each of the loops for all subjects, there were no significant differences between the HY and DHY groups for average heart rate. This also opposes the previous laboratory findings. Below et al\textsuperscript{33} observed cyclists who exercised at about 80\% of their VO\textsubscript{2 max} for 1 hour had lower heart rates in the hydrated trials as compared to the dehydrated trials. This is very different than an Ironman Triathlete who performs several different tasks over the course of many hours, but more importantly this study was done in a setting where exercise intensity was controlled.

The current study did not find an overall effect of hydration status on pacing and performance for ironman triathletes. However, this study was unable to control intensity of exercise, which may partially explain these results.
Hydration and its Affect on Heart Rate Monitoring as a Pacing Strategy

One pacing strategy often used in Ironman triathlons is heart rate monitoring. This study split participants up into two groups based on this finding. There were 16 subjects who paced themselves based on heart rate levels throughout the race. Due to the role dehydration may play on increasing heart rate\textsuperscript{13,33}, and a phenomenon called cardiovascular drift\textsuperscript{38}, researchers wanted to examine differences in pacing between hydrated and dehydrated individuals who use heart rate monitoring during an Ironman Triathlon.

Two groups were formed to observe these relationships. The HRH group consisted of the hydrated individuals using heart rate monitoring, and the HRD group consisted of the dehydrated individuals using heart rate monitoring. The HRH and HRD groups had no significant differences in age, height, % body fat, and % body mass loss. There was a significant difference between the groups for post-race USG, but this is expected due to post-race USG being the factor used to split these groups respectively. The performance, pace, and physiological strain can therefore be compared between the HRH and HRD groups due to being similar at baseline. See Table 5 for demographic data of these groups.

Overall Performance

Current research lacks evidence to describe the relationship between hydration status and performance in athletes who monitor heart rate for feedback. There was not a significant difference in finishing times between those of the HRH and HRD groups. This suggests that the performance of these two groups was either not different or, if there was a difference in performance outcomes between the two groups, it was not discernable due
to potential differences in ability of the subjects. Specifically, the faster racers may have inadvertently moved into the dehydrated group and performed sub optimally, accounting for similar finish times.

**Average Pace**

As noted before, previous research has shown that dehydration usually results in an inability to maintain an even pace during endurance events.\(^6,15\) Previous research has also demonstrated an effect of dehydration on heart rate, and cardiovascular drift, all potentially impacting pacing if an athlete is using heart rate to gauge intensity and pace. In the current study, the HRH and HRD groups slowed during both the bike and run sections, but there was no difference between the hydrated and dehydrated individuals. Therefore, the observed difference in hydration status under these conditions and between these groups did not result in differences in pace or variation of pace between loops.

**Physiological Strain**

The individuals who paced themselves using heart rate feedback had no differences in average heart rate throughout the race when the hydrated group was compared to the dehydrated group. Previous literature has demonstrated that dehydration causes an increase in physiological strain, such as core body temperature, heart rate, and perceived exertion.\(^31\) Once again, it has been evident that despite this effect being clear in laboratory studies, when intensity is controlled, in a competitive scenario the intensity is adjusted in the dehydrated group, resulting in similar heart rate responses (at the expense of intensity, which is lowered).\(^15\)

Once again, the present study did not find an effect of hydration status on the pacing and performance for athletes who pace themselves by monitoring heart rate during
an Ironman Triathlon. The inability to control for different levels of exercise intensity during the study, may partly explain the results seen here.

**Limitations**

The present study has a few findings that conflict with previous laboratory literature, therefore it is important to consider the limitations faced within the field setting. This study suggests that the hydration status differences observed did not elucidate differences in overall pacing, or physiological strain on these athletes during an Ironman Triathlon. This is likely due to the lack of ability to perform a cross over design within a field setting, and therefore intensity is not controlled (a large contributor to body temperature) and comparison within subjects, for the same task is not possible.

Several limitations in design surfaced in the present study. A variety of difficulties are faced with observational field studies. Field studies are not able to isolate effects from other factors whereas laboratory studies are able to control more. Due to the nature of this event, a between-subjects design was used. It would have been impossible to perform a crossover design where each participant would complete two Ironman triathlons within a reasonable timespan of this study. A crossover design where participants are compared to themselves in another trial would have allowed for clearer conclusions to be drawn.

For optimal measurements of GI temperature, participants were asked to ingest the thermistor the night before the race. This meant that some participants might have passed the thermistor prior to race morning. There was not enough time on race morning, prior to the race, to have the participants ingest another thermistor. Because of the extreme duration of this event, other participants may have passed the thermistor during
the race as well. Therefore, those who passed the pill did not have GI temperatures for
given sections of the race.

Another limitation of this study was that the level of hydration and dehydration
was not controlled. One of the individuals who was placed in the heart rate dehydrated
category had not reached 2% dehydration, which is the level known to impact
physiological responses. In addition to not surpassing a 2% level of dehydration,
comparison between groups may have been limited due to a small difference in body
mass loss. While USG was significantly different for both the HRD and HRH groups, as
well as the HY and DHY groups, the body mass losses between these two groups differed
by 1.8% and 1.5% respectively. These differences between the groups may have simply
been too small or lacking statistical power to elucidate existing differences.

In addition to the points above, determining how to define hydrated and
dehydrated groups is difficult in an Ironman race. Due to the long duration of the event,
the ingestion of foods and fluids throughout the race may not be accurately measured,
and hydration statuses and body mass losses may not be as precise as desired.

The current study was unable to measure cadence and power output for the bike
sections, but measured average pace throughout the race. Therefore the direct connection
from decreased pace can not be linked without a decreased power output, as other studies
have shown. Consequently, we were unable to take an in-depth look at these changes and
relate power changes throughout the race to performance changes.

Lastly, it is important to remember that this study focused on a very small group
in a large population of endurance athletes. The Ironman Triathlon is extremely different
from many other kinds of exercise, and these results are strictly applicable to ultraendurance Ironman triathletes.

**Implications for performance**

Although this study did not observe differences in performance between hydrated and dehydrated individuals, it is crucial to consider the limitations of this study. First, this study was unable to utilize a crossover design; therefore, our subjects were not able to serve as their own control. In addition, lower levels of dehydration reached in this study and the inability to control intensity may explain why heart rate, pacing and $T_{gi}$ were not influenced by hydration status. It is important to remember that a more stressful environment (such as hotter temperatures), a higher intensity exercise session, and more severe levels of dehydration likely would cause decreases in performance and put athletes at risk for developing exertional heat illnesses or performance decrements. While this study did not elucidate differences between group performances, perhaps due to the small differences in hydration status, previous research still demonstrates the importance for athletes to monitor hydration status\textsuperscript{13-19, 32, 33}, core body temperatures\textsuperscript{13, 15, 19} and heart rates\textsuperscript{13-19} during intense or lengthy exercise activity. Efforts should be taken to maximize fluid replacement and to limit extreme intensity activities in strenuous environments.

**Future Research**

Based on this study’s findings, evidence of pacing and hydration practices of triathletes still remains greatly undiscovered. Future research should compare within-subject triathlon performances to better analyze the affects of hydration status on these athletes. Laboratory studies may also allow for better control over variables, and may be useful in determining these relationships.
References


50. Engell DB, Maller O, Sawka MN, Francesconi RN, Drolet L, Young AJ. Thirst and fluid intake following graded hypohydration levels in humans. Physiol Behav. 1987;40(2):229-236.


Appendix A

HUMAN PERFORMANCE LABORATORY MEDICAL HISTORY QUESTIONNAIRE

Performance and Physiological Responses in Elite Triathletes During a Competitive Race
Subject #

Name
Sex Age DOB
Street
City State Zip Phone
Email

PLEASE ANSWER ALL OF THE FOLLOWING QUESTIONS AND PROVIDE DETAILS FOR ALL "YES" ANSWERS IN THE SPACES AT THE BOTTOM OF THE FORM.

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
<td></td>
</tr>
<tr>
<td>2. Has your doctor ever denied or restricted your participation in sports or exercise for any reason?</td>
<td></td>
</tr>
<tr>
<td>3. Do you ever feel discomfort, pressure, or pain in your chest when you do physical activity?</td>
<td></td>
</tr>
<tr>
<td>4. In the past month, have you had chest pain when you were not doing physical activity?</td>
<td></td>
</tr>
<tr>
<td>5. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td></td>
</tr>
<tr>
<td>6. Does your heart race or skip beats during exercise?</td>
<td></td>
</tr>
<tr>
<td>7. Has a doctor ever ordered a test for you heart? (i.e. EKG, echocardiogram)</td>
<td></td>
</tr>
<tr>
<td>8. Has anyone in your family died for no apparent reason or died from heart problems or sudden death before the age of 50?</td>
<td></td>
</tr>
<tr>
<td>9. Have you ever had to spend the night in a hospital?</td>
<td></td>
</tr>
<tr>
<td>10. Have you ever had surgery?</td>
<td></td>
</tr>
</tbody>
</table>

11. Please check the box next to any of the following illnesses with which you have ever been diagnosed or for which you have been treated.

- [ ] High blood pressure
- [ ] Clogged or blocked arteries
- [ ] Asthma
- [ ] Epilepsy (seizures)
- [ ] Bladder problems
- [ ] Anemia
- [ ] Coronary artery disease
- [ ] Lung problems
- [ ] Diabetes
- [ ] Kidney problems
- [ ] Heart problems
- [ ] Chronic headaches

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Have you ever gotten sick because of exercising in the heat? (i.e. cramps, heat exhaustion, heat stroke)</td>
<td></td>
</tr>
<tr>
<td>13. I have no other significant illness not listed above?</td>
<td></td>
</tr>
<tr>
<td>14. Do you currently have any illness?</td>
<td></td>
</tr>
<tr>
<td>15. Do you know of any other reason why you should not do physical activity?</td>
<td></td>
</tr>
</tbody>
</table>

16. Please list all medications you are currently taking. Make sure to include over-the-counter medications and birth control pills.

<table>
<thead>
<tr>
<th>Drugs/Supplements/Vitamins</th>
<th>Dose</th>
<th>Frequency (i.e. daily, 2x/day, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

DETAILS:

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>17. Do you have suspected obstructive disease of the gastrointestinal (GI) tract? (diverticulitis or inflammatory bowel disease?)</td>
<td></td>
</tr>
<tr>
<td>18. Do you have impaired gag reflex?</td>
<td></td>
</tr>
<tr>
<td>19. Have you had previous GI surgery?</td>
<td></td>
</tr>
<tr>
<td>20. Do you believe you might undergo MRI scanning in the next 10 days?</td>
<td></td>
</tr>
<tr>
<td>21. Do you have hypomotility disorder of the GI tract?</td>
<td></td>
</tr>
<tr>
<td>22. Do you have a cardiac pacemaker or other implanted electro medical device?</td>
<td></td>
</tr>
</tbody>
</table>
Appendix A

17. Please list all allergies you have.
   Substance ___________________________________________ Reaction ___________________________________________
   ___________________________________________ ___________________________________________
   ___________________________________________ ___________________________________________

18. Have you smoked? If yes, #/day __________ Age Started __________ If you've quit, what age?
   Cigarettes ___________________________________________
   Cigars ___________________________________________
   Pipes ___________________________________________

19. Do you drink alcoholic beverages? If yes, how much? How often?

20. Do you have a family history of any of the following problems? If yes, note who in the space provided.
   YES NO
   ┌──────────────┬──────────────┐
   │ High blood pressure │ Heart disease │
   │ High cholesterol │ Kidney disease │
   │ Diabetes         │ Thyroid disease │
   └──────────────┴──────────────┘

21. Please check the box next to any of the following body parts you have injured in the past and provide details.
   YES NO
   ┌──────────────┬──────────────┐
   │ Head          │ Hip            │
   │ Neck          │ Thigh          │
   │ Upper back    │ Knee           │
   │ Lower back    │ Ankle          │
   │ Chest         │ Foot           │
   │               │ Calfhane       │
   │               │ Shoulder       │
   │               │ Upper arm      │
   │               │ Elbow          │
   │               │ Hand/fingers   │

22. Have you ever had a stress fracture?
23. Have you ever had a disc injury in your back?
24. Has a doctor ever restricted your exercise because of an injury?
25. Do you currently have any injuries that are bothering you?
26. Do you consider your occupation as?
   ┌──────────────┬──────────────┐
   │ Sedentary (no exercise) │
   │ Inactive-occasional light activity (walking) │
   │ Active-regular light activity and/or occasional vigorous activity (heavy lifting, running, etc.) │
   │ Heavy Work-regular vigorous activity │

27. List your regular physical activities
   Activity ___________________________________________ How often do you do it? __________ How long do you do it? __________ How long ago did you start? __________
   ___________________________________________ ___________________________________________
   ___________________________________________ ___________________________________________
   ___________________________________________ ___________________________________________
   ___________________________________________ ___________________________________________

ADDITIONAL DETAILS:
   ___________________________________________
   ___________________________________________
   ___________________________________________
   ___________________________________________
   ___________________________________________
Training History Questionnaire

What are you personal records for the following events?

1. Ironman Triathlon: ___________ Location: ___________ Year: ___________
2. ½ Ironman Triathlon: ___________ Location: ___________ Year: ___________
3. Olympic Triathlon: ___________ Location: ___________ Year: ___________
4. Marathon: ___________ Location: ___________ Year: ___________

What are your personal records for each of the following sections for a full Ironman?

1. Swim: ___________
2. Bike: ___________
3. Run: ___________

What are your personal records for each of the following sections for a ½ Ironman?

1. Swim: ___________
2. Bike: ___________
3. Run: ___________

What section of a triathlon do you consider your strongest & weakest:

- Strongest:
  - □ Swim
  - □ Bike
  - □ Run

- Weakest:
  - □ Swim
  - □ Bike
  - □ Run

What triathlon distance do you consider yourself to be the strongest competitor in?

- □ Full Ironman
- □ Olympic distance triathlon
- □ ½ Ironman
- □ Sprint triathlons

How many races have you completed at each of the following distances? (best estimate)

1. Ironman Triathlon: ___________ (how many of these were at Kona?) ___________
2. ½ Ironman Triathlon: ___________
3. Olympic Triathlon: ___________
4. Marathon: ___________
Appendix B

What are your goal times for this Ironman?

1. Swim: ____________
2. Bike: ____________
3. Run: ____________
4. Total Time: ____________

How many times have you raced the Lake Placid Ironman prior to this year? ____________

Specific Training History For This Race:

1. What geographic location did you perform your training for this race (circle one)

Within the United States:

New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut
Mid-Atlantic: New York, Pennsylvania, New Jersey
East North Central: Wisconsin, Michigan, Illinois, Indiana, Ohio
West North Central: Missouri, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa
South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida
East South Central: Kentucky, Tennessee, Mississippi, Alabama
West South Central: Oklahoma, Texas, Arkansas, Louisiana
Mountain: Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico
Pacific: Alaska, Washington, Oregon, California, Hawaii

Or if outside the United States:

Country: __________________ State/Province/Territory/City __________________

2. How many hours of training per week did you average? ____________ hrs/wk

3. Of these hours, what percentage of them were comprised of:
   a. Swimming ____________%
      i. What percentage of swimming was done:
         in open water ____________% vs. a pool ____________%
   b. Biking ____________%
      i. What percentage of biking was done:
         Inside ____________% vs. Outside ____________%
Subject #__________  Appendix B  Date:

c. Running__________%  
  i. What percentage of running was done:  
      Inside__________% vs. Outside__________%  

d. Strength Training_______% (any weighted resistance exercise)  

4. Please place a label next to the time of day that you normally perform the specified exercise (use S for swimming sessions, B for biking sessions, and R for running sessions)  

<table>
<thead>
<tr>
<th>Time of Day</th>
</tr>
</thead>
</table>
| Early Morning (4-7am) | Early Afternoon (1-3pm)  
| Mid Morning (7-9am)    | Mid Afternoon (3-5pm)  
| Late Morning (9-11)   | Evening (5-8pm)  
| Noon (11-1pm)        | Night (>8pm)  

5. How many weeks were you specifically training for this race?__________wks  

6. How many weeks did you taper for this race?__________wks  

7. Did you encounter any set backs during your training? (circle) YES / NO  
   a. If yes, was this due to:  
      □ Medical reasons/Injuries?  
      □ Time restraints  
      □ Other ________________________________  

8. Compared to your training and fitness in previous Ironman distance triathlons, would you say you are:  
   □ More fit  
   □ Similarly fit  
   □ Less fit  

9. Will you have another person either racing with you or pacing you? (circle) YES / NO  

10. Are you attempting to win your age group or use this as a race to qualify for the Ironman World Championships? (circle) YES / NO
11. Do you have any other concerns regarding your training or preparation leading up to this race that were not already addressed?
Modified Pittsburgh Sleep Quality Index (MPSQI)

Instructions:
Your answers should indicate the most accurate reply for the past night.
Please answer all questions.

1. During last night, did you go to bed? **BED TIME**__________P.M.

2. How long (in minutes) did it take you to fall asleep? **NUMBER OF MINUTES**__________

3. What time did you get up in the morning? **TIME**__________A.M.

4. During last night, how many hours of actual sleep did you get? (This may be different than the number of hours you spent in bed.) **HOURS OF SLEEP LAST NIGHT**__________

5. Did you take any naps yesterday? (circle) **YES** / **NO**
   
   **If yes, how long?**__________

<table>
<thead>
<tr>
<th>How would you rate last nights' sleep quality overall? (circle)</th>
<th>Very bad</th>
<th>Fairly bad</th>
<th>Fairly good</th>
<th>Very good</th>
</tr>
</thead>
<tbody>
<tr>
<td>How rested do you feel overall? (circle)</td>
<td>Poorly rested</td>
<td>Fairly rested</td>
<td>Rested</td>
<td>Well rested</td>
</tr>
<tr>
<td>Other reasons for a good/bad nights sleep: (List)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D

Thermal Sensation Scale

0.0  Unbearably Cold
0.5
1.0  Very Cold
1.5
2.0  Cold
2.5
3.0  Cool
3.5
4.0  Comfortable
4.5
5.0  Warm
5.5
6.0  Hot
6.5
7.0  Very Hot
7.5
8.0  Unbearably Hot
Appendix E

**Thirst Scale**

1. Not Thirsty At ALL
2. 
3. A Little Thirsty
4. 
5. Moderately Thirsty
6. 
7. Very Thirsty
8. 
9. Very, Very Thirsty
Appendix F

Profile of Mood States

Subject: ___________________________ Date: ______________________

Below is a list of words that describe feelings people have. Please read each one carefully, then mark ONE circle under the answer to the right which best describes HOW YOU FEEL RIGHT NOW.

The numbers refer to these phrases:
0 = Not at all
1 = A little
2 = Moderately
3 = Quite a bit
4 = Extremely

<table>
<thead>
<tr>
<th>Mood State</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tense</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worn out</td>
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<tr>
<td>Irritable</td>
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<td></td>
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</tr>
<tr>
<td>Confused</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Shaky</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Poised</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On edge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Panicky</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0relaxed</td>
<td></td>
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</tr>
</tbody>
</table>

*This means you are ready to get in a physical fight.  

MAKE SURE YOU HAVE ANSWERED EVERY ITEM
Appendix G

Evaluation of Muscle Soreness

"On the horizontal line below please put a small vertical line across this horizontal line that best describes the soreness you feel. A vertical mark on the extreme LEFT side of the line would indicate that you are experiencing 'no soreness'; a vertical mark on the extreme RIGHT side of the line would indicate that you are experiencing 'unbearable soreness'.

If your degree of pain is somewhere in between these two extremes, please mark it at the place that most accurately describes your current level of soreness.

Please mark the line to indicate the pain that you are experiencing now."

Indicate your leg soreness on this scale:

No Soreness  Unbearable Soreness
### Appendix H

**How Do You Feel Questionnaire**

Place an X in the box to explain HOW YOU HAVE BEEN FEELING TODAY.

PLEASE ANSWER EVERY ITEM.

If you did not have the symptom, say NOT AT ALL.

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Not At All</th>
<th>A Little</th>
<th>Somewhat</th>
<th>Moderate</th>
<th>A Lot</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel lightheaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have a headache</td>
<td></td>
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<tr>
<td>I feel dizzy</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>I feel thirsty</td>
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<td></td>
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<tr>
<td>I feel weak</td>
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<td></td>
<td></td>
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<tr>
<td>I feel grumpy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is hard to breathe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I will playing at my best</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>I have a muscle cramp</td>
<td></td>
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<tr>
<td>I feel tired</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>I feel sick to my stomach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(nauseous)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel hot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>I have trouble concentrating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have “goose bumps” or chills</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

SOURCE: Modified from Kobrick and Sampson (1979) and Sampson and Kobrick (1980).
Appendix I

RATING OF PERCEIVED EXERTION SCALE

6
7 Very, Very Light
8
9 Very Light
10
11 Fairly Light
12
13 Somewhat Hard
14
15 Hard
16
17 Very Hard
18
19 Very, Very Hard
20
## Food and Fluid Intake Questionnaire (Ironman)

### General Information
- **Name:**
- **Date:**
- **First name:**
- **Sex:** [ ] Male  [ ] Female
- **Date of birth:**
- **Race No.:**
- **E-mail:**

### Preparation for the race
1. Have you had breakfast before the race?
   - [ ] yes  [ ] no
   - If yes, how many hours before the race did you have breakfast? 

   If you had breakfast, what did you eat exactly (please specify foods and quantities exactly, e.g. 2 table spoons cereals, 100g yoghurt, 2 thick slices white toast)

2. Did you eat anything else after breakfast (before the race)?
   - [ ] yes  [ ] no
   - Please specify when and what 

3. What (and how much exactly) did you drink in the morning before the race?
**Food and fluid intake during the race**

Please try to recall your intake as accurate as possible. It is important for us to know exactly what you consumed (type, brand and flavour of a product) and how much (e.g. 1 “GoBar” (65g, ½ Banana, 1 hand full gummy bears).

<table>
<thead>
<tr>
<th></th>
<th>Swim (just before)</th>
<th>Bike (+ Transition 1)</th>
<th>Run (+ Transition 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Bars:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Bar Performance bars (as supplied)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Energy bars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type:</td>
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<td></td>
</tr>
<tr>
<td>Type:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Energy gels:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PowerBar gels (as supplied)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other gels</td>
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<td></td>
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<tr>
<td>Type:</td>
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<td>Type:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Type:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other Food (from aid stations):</strong></td>
<td>INSERT ALL FOODS FROM AID STATIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bananas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oranges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dried fruit, please specify:</td>
<td>hand full</td>
<td>hand full</td>
<td>hand full</td>
</tr>
<tr>
<td>Other foods:</td>
<td>(please specify exactly: Type, brand…)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jelly beans/gummy bears</td>
<td>hand full</td>
<td>hand full</td>
<td>hand full</td>
</tr>
<tr>
<td>Sandwiches.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Please specify composition</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fluid intake during the race**
Post-race Questionnaire (Appendix J)

Please try to give accurate amounts of fluid ingested (ml, l, cups or bottles - but please tell us what bottle size you used). It is easiest to count how many bottles/cups you consumed on the way. But please subtract the fluid you spilt, poured over the head etc.

<table>
<thead>
<tr>
<th>Swim (just before)</th>
<th>Bike (+ Transition 1)</th>
<th>Run (+ Transition 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sportsdrink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Bar sports drink (from feed stations)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports drink (own mixture)</td>
<td>Type of Sports drink:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☐ according to instructions (on package)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☐ less concentrated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☐ more concentrated</td>
<td></td>
</tr>
<tr>
<td>Home made sports drink (please specify exact ingredients + amounts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other soft drink</td>
<td>please specify:</td>
<td></td>
</tr>
<tr>
<td>Fruit juice</td>
<td>please specify:</td>
<td></td>
</tr>
<tr>
<td>Other fluids</td>
<td>Please specify:</td>
<td></td>
</tr>
</tbody>
</table>

4. If you used the sports drink at the feed stations, how would you rate the mixture?
   ☐ according to instructions  ☐ less concentrated  ☐ more concentrated
   (on package)

5. If you used your own bottles, how big was the bottle size exactly?
   ___ ml

6. If you used drink cups from the feed stations, how much fluid did you get from 1 cup?
   ___ ml

7. Have you used any foods or drinks during the race, which you have not used before (during training or competition)?
   ☐ yes  ☐ no
   Please specify ___

Intake of other supplements

70
8. Have you consumed any of the following caffeinated products (please give amounts)?

- Caffeinated Gel
  (e.g. PowerBar Green apple, Black Currant)
- Caffeinated Bars
  (e.g. PowerBar Raspberry Cream, Coconut Crisp, Cola)
- Caffeine tablets (e.g. proplus, NoDoz)
- Other caffeinated products

9. If you took in one of the following supplements, please specify how much.

<table>
<thead>
<tr>
<th>Amount used immediately BEFORE race</th>
<th>Amount used DURING the race</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt tablets</td>
<td></td>
</tr>
<tr>
<td>Mineral Tablets</td>
<td></td>
</tr>
<tr>
<td>please specify</td>
<td></td>
</tr>
<tr>
<td>Vitamin tablets</td>
<td></td>
</tr>
<tr>
<td>please specify</td>
<td></td>
</tr>
<tr>
<td>$H_2$ blockers (e.g. Tagamet, Pepcid, Zantac)</td>
<td></td>
</tr>
<tr>
<td>Pain killer (e.g. Aspirin, Paracetamol, Ibuprofen)</td>
<td></td>
</tr>
<tr>
<td>Others:</td>
<td></td>
</tr>
<tr>
<td>please specify</td>
<td></td>
</tr>
</tbody>
</table>
10. Please rate if you experienced any of the following symptoms DURING THIS RACE:

<table>
<thead>
<tr>
<th>A Upper abdominal symptoms</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflux/Heartburn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Belching</td>
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<tr>
<td>Bloating</td>
<td></td>
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<tr>
<td>Stomach pain / cramps</td>
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<tr>
<td>Vomiting</td>
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<tr>
<td>Nausea</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>B Lower abdominal symptoms</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intestinal / lower abdominal cramps</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Side ache /stitch</td>
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<tr>
<td>Flatulence</td>
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<tr>
<td>Urge to defecate</td>
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<tr>
<td>Diarrhoea</td>
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<td></td>
<td></td>
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<tr>
<td>Intestinal Bleeding</td>
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</tbody>
</table>
### Other symptoms

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dizziness</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Headache</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Muscle cramp</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Low blood sugar</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

11. How many stops to urinate did you have?

---

**Other questions**

11. If you had a plan for your nutrient intake, did you match the intake?
   - ☐ yes
   - ☐ no
   
   Please specify, what was different

13. Did you finish the race today?
   - ☐ yes
   - ☐ no
   
   If not, can you tell us the reason why?
Subject #__________    Appendix K    Date: ________________

Post Race Questionnaire

1. Did you encounter any set backs during your race? (circle) YES / NO
   a. If yes, was this due to:
      □ Medical reasons/sickness/injuries?
      □ Equipment failure
      □ Bike crash
      □ Other __________________________

2. Would you say, in relation to your pre-race goals you:
   □ Exceeded your goals
   □ Met your goals
   □ Fell below your goals

3. Did you have another person either racing with you or pacing you? (circle) YES / NO
   If yes, did you stay together throughout the race? (circle) YES / NO
   If no, what point in the race did you separate? __________________________

4. Overall, how satisfied are you with your race performance?
   □ Extremely satisfied
   □ Very satisfied
   □ Satisfied
   □ Unsatisfied
   □ Extremely unsatisfied

5. Can you describe any other reasons or contributing factors to why you would consider this race, successful, unsuccessful or satisfactory??

________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________