Kona IRONMAN: Swim, run, bike

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The Kailua-Kona ultimate IRONMAN World Championships consists of 3 stages in the order of a 2.4-mile swim, a 112-mile bike ride, and finally a 26.2-mile run. The swim-bike-run order was established for overall course/event and athlete/public safety. However, putting safety concerns aside and only considering variables that factor into overall best performance (i.e. fastest total completion time), an optimized stage-order might be swim-run-bike.

Introduction and Current Race Logistics

The Hawaiian IRONMAN Triathlon started in 1977 as a "dare" and challenge to answer the question, "Who is fittest--runners, swimmers, or bicyclists?" (Ironman Triathlon, n.d.). Commander John Collins pointed out that Sports Illustrated had named the Belgian cyclist Eddy Merckx as having the highest recorded oxygen uptake of any athlete measured (Ironman Triathlon, n.d.). This sparked a debate until CDR Collins and his wife proposed combining the most challenging race events in Hawaii (2.4 mile Waikiki Roughwater Swim, 112 mile Around-O'ahu Bike Race, and 26.2 mile Honolulu Marathon) into one event--the IRONMAN (World Championship Corporation, n.d.a.). Today, the race has moved from Waikiki to Kona on the big island, Hawai'i, to become the prestigous 140.6 mile Kailua-Kona ultimate IRONMAN World Championships (Swim, Bike, Run Advisor, n.d.).

The day starts at the east side of Kailua Pier at Kailua Bay swimming clockwise a 2.4 mile elongated rectangular course extending 1.2 miles south, 100 yards wide, then returning to the pier ("Ironman: The race course," 2010). The start line is 60 yards in the water from shore ("Ironman: The race course," 2010). The water is usually 79 degrees Fahrenheit; typically no surf although small swells may be present; weak currents; and wind chop is minimized for the morning ("Ironman: The race course," 2010). Wetsuits less than 5mm thick may be worn if the water temperatures are 76.1 degrees Fahrenheit or colder. Wetsuits are forbidden if the water temperatures are 83.8 degrees Fahrenheit or warmer (World Triathlon Corporation, n.d.c.). Fabrics must not be "buoyant". Drafting is allowed in swimming.

As athletes exit the water and transition area, the 112 mile bike course starts at Kailua Pier, heading up to Palani Road and onto the Kuakini Highway head southeast towards a junction at Queen Kaahumanu Highway ("Ironman: The race course," 2010). The route then heads north to Hawi, an official course checkpoint. Along the way the terrain is intermittently "hilly" with quarter to one-mile hill spans reaching a grade of 6% ("Ironman: The race course," 2010). Reaching Hawi, the athletes head south back to the Kailua Pier transition center. No bike-drafting is allowed. There may be strong trade winds that blow through the western and northern coast of the Big Island (World Triathlon Corporation, n.d.b.).

The 26.2 mile run starts at Kailua Pier, and heads south to the first run checkpoint/turnaround at St. Peter's Church near Kahaluu Beach ("Ironman: The race course," 2010). The course then heads north on Queen Kaahumanu Highway to the Natural Energy Lab of Hawaii Authority (NELHA), the second run checkpoint/turnaround ("Ironman: The race course," 2010). From there, it is the final leg of the run back to Kailua Pier at Kailua Bay. One may expect high heat and humidity to factor in the last leg of the race (World Triathlon Corporation, n.d.b.).

General Physiological Factors to Consider

Oxygen consumption. The Kona IRONMAN Triathlon is an "ultra-endurance" triathlon (UET) as compared to shorter triathlons such as the half-triathlons or Olympic-style triathlons. UET's duration typically range from 8 to 17 hours, sometimes having an event "cut-off" time at 17 hours (Laursen & Rhodes, 2001; Wu, Peiffer, Brisswalter, Nosaka, & Abbiss, 2014). Laursen and Rhodes (2001) noted that the successful UET athlete would be able to perform each stage at an optimal pace and intensity such that the next stage would not be negatively affected--that is, being able to work consistently at a lower percentage of maximal oxygen consumption, $VO_{2max.}$

Elite athletes' VO_{2max} range for tethered swimming was between 39-49 ml/kg/min; 57-61 ml/kg/min for cycle ergometry; and 61-85 ml/kg/min for treadmill running (Laursen & Rhodes, 2001). Compared to single endurance events, these ranges were found to be lower (Laursen & Rhodes, 2001).

Anaerobic threshold. Laursen and Rhodes (2001) found that as the length of the endurance race increased (up to the length of an UET), the anaerobic threshold (AT) was found to be a strong predictor of performance in both cycling and running stages. AT has also been found to be a good estimate of blood lactate threshold (Kenney, Wilmore, & Costill, 2012). Laursen and Rhodes (2001) noted that theoretically under the best conditions, the UET athlete would perform at the intensity for AT throughout the IRONMAN.

Nutrition and hydration. While it is beyond the scope of this paper to go in-depth into nutrition and hydration, it must be noted that fuel and hydration are very important to consider as energy expenditure for an UET level race can range from 8500 to 11500 calories with sweating rates up to 2 liters/hr in the hot weather (Laursen & Rhodes, 2001). General recommendations include making sure adequate carbohydrate (CHO) is ingested during the entirety of the race, preferably added into fluid replacement drinks (Laursen & Rhodes, 2001). Maltodextrin was found to be preferable as it reduced gastric distress and discomfort (Laursen & Rhodes, 2001). Laursen and Rhodes (2001) generally recommended 30-70g CHO/hr or 0.2-0.6g CHO/kg/hr as 5-10% CHO solution. Fat oxidation also makes a significant contribution (25-30%). The most common problem requiring medical assistance during the Kona IRONMAN was dehydration, and the second most common reason was hyponatraemia associated with fluid overload (Laursen & Rhodes, 2001).

Cardiac drift. The phenomenon of cardiac drift has been observed in long endurance bouts. Cardiac drift is when there is a slow, steady increase in heart rate over a prolonged period with relatively constant effort (Laursen & Rhodes, 2001). Cardiac drift seems to occur as a result of decreasing stroke volume which causes a need to increase heart rate to maintain the same cardiac output. The effect is exacerbated by dehydration, limited fluid replacement, and blood glucose levels. (Laursen & Rhodes, 2001). Because cardiac drift may occur for participants in the ultra-endurance events, using heart rate to approximate exercise intensity may result in over-estimation.

Pacing. Wu et al. (2014) define "pacing" as the distribution of speed, work, or energy expenditure over the duration of an exercise task so as to optimize performance. Wu et al. (2014) make the distinction between pacing and pacing strategy (which is what most people refer to when saying "pacing") where the latter means to utilize a conscious plan to manipulate exercise effort. According to Edwards and Polman's (as cited in Wu et al., 2014) "pacing awareness" model, pacing may be both conscious and subconscious (e.g. the body's ability to regulate and maintain homeostasis within small fluctuations).

The triathlon presents unique pacing issues as compared to single event performances. Wu et al. (2014) identified important factors affecting pacing as relevant to triathlons: distance/duration; race dynamics (e.g. drafting, influence of other competitors); environmental (e.g. weather, terrain); transitions from one stage to the next (e.g. swim to cycle, cycle to run); age; and sex. Of all the factors, exercise duration/distance seems the most impactful (Wu et al., 2014). Wu et al. (2014) observed that positive pacing (gradual speed reduction) was observed for both the shorter Olympic-style triathlons and also the IRONMAN. The causes behind positive pacing vary, but may likely be due to neuromuscular fatigue, lactic threshold, and depletion of glycogen stores (Wu et al., 2014).

Elite athletes use a "fast-start" strategy regardless of Olympic-style or UET triathlon (Wu et al., 2014). Fast-start allows those athletes to secure a place in the first pack which has been shown to be important not only for drafting but for overall performance times (Wu et al., 2014). For UETs, after the intial fast-start, it may be advisable to employ a more even-pacing strategy which can be challenging when faced with environmental variables such as wind and current (Wu et al., 2014). Wu et al. (2014) also noted that if the athlete's speed falls below the average speed at any time during the race, it is difficult to make it up due to the increase of power output required and energy expenditure when physiologically the athlete is already taxed.

In "mass-starts" or "wave-starts", it is important and advantageous to go out with the first-pack and maintain the first-pack position (Wu et al., 2014). The first-pack becomes even more important for draft-legal stages/events. The impact of the first-pack principle will be discussed in subsequent stage-related sections.

Swim

In the current Kona IRONMAN Triathon, swimming is the first stage. With regards to performance optimization, swimming should be the first stage as well. As mentioned in the introduction, the water temperature, water resistance (surf, swells, current), and wind resistance are optimal in Kailua Bay for the early morning race start-time. If the water were warmer (late morning to afternoon), then additional heat stress and cooling issues would plague the athletes (Dallam, Jonas, & Miller, 2005). If the water were cooler (evening, nightfall), then wetsuits might need to be employed, and time would be lost in changing into a wetsuit and the transition from land to water.

Mass-start and first-pack. Perhaps the most important reason why swimming should be the first stage is the advantage of a "mass-start" and drafting in the first-pack. Placing swimming in the second or last stage of a triathlon would reduce swimming to more of an "individual" event without the benefit of pack-swimming. Drafting can improve swimming economy by reducing the drag force by 10-26%, reducing blood lactate concentration by 31%, reducing rate of perceived exertion by 21%, oxygen consumption by 5-10%, and performance improvements of 3.2-6% which may equate to 9-12 seconds over 400m (Bentley, Millet, Vleck, & McNaughton, 2002; Wu et al., 2014). The energy expenditure required for a fast-start in the swim to maintain a first-pack position pays off by the benefits of being able to draft with the lead swimmers (Wu et al., 2014).

Landers, Blanksby, Ackland, and Monson (2008) studied the importance of placing in the first-pack of swimmers on the overall triathlon results. Landers et al. (2008) found a 4 second separation time between packs to be the most accurate measurement to "separate" packs of swimmers. Four seconds is roughly a 5m gap in swimming, a 45m gap in cycling, and a 20m gap in running (Landers et al., 2008). Twenty percent of top-10 male overall finishers were in the first-pack of swimmers; and twenty-four percent of top-10 female overall finishers were in the first-pack of swimmers (Landers et al., 2008). In the study of 10 male races, 9 of the winners were part of the first-pack of swimmers; and 7 of 10 female winners were also found to be first-pack swimmers (Landers et al., 2008). Landers et al. (2008) found that placing in the first-pack of swimmers improves the chance of winning or placing in the top-10 overall.

Swim technique. The importance of the swimming stage has been underrated. While swimming is a combination of both conditioning and technical skills, technique is more important to swimming than it is to either cycling or running. Olbrecht (2011) noted that for shorter distance bouts, stroke rate and length are the main determinants for swimming performance. A 2m stroke-length at submaximal speed should be the goal, followed by improving stroke rate (Olbrecht, 2011). For longer bouts, consistency (for endurance and efficiency) may be more important. Olbrecht (2011) summarized the factors involved in a fast swim: ability to produce high mechanical power output to generate high propulsive forces; reduce drag/friction; reducing energy lost in pushed-away water.

Mejias and Anta (2011) analyzed the importance of swimming efficiency with regards to stroke-technique. A swimmer's speed increases and decreases within the swim stroke, intra-cycle velocity (Mejias & Anta, 2011). The greater variability in the swim-stroke, the greater the energy cost. To strive for a consistent intra-cycle velocity in the crawl-stroke, the swimmer must keep both arms moving simultaneously for continuous propulsion like kayak paddles ("kayak principle") (Mejias & Anta, 2011). Chollet et al. (as cited in Mejias & Anta, 2011) defined the "index of coordination" (IdC) as the lag time between the beginning propulsion of one arm and the ending of propulsion in the opposite arm. Optimally, IdC equals zero or "opposite stroke". Olbrecht (2011) noted that as swim speeds increased, IdC also increased which implies that training and maintaining technique to cut down the "sloppiness" is crucial.

Other considerations. Swimming is mostly an upper-body endeavor, which means that during swimming, more blood will be redirected to the upper-body where it is most needed (Bentley et al., 2002; Kenney et al., 2012). The ability to comfortably transition from a predominantly upper-body endeavor to lower-body endeavor should be part of training of the elite UET athlete (Bentley et al., 2002).

Overall effect. Laursen and Rhodes (2001) and Peeling and Landers (2009) noted that a 3000m swim did not significantly adversely affect the following cycling stage in power output, oxygen consumption, and blood lactate concentration. This may be due to the fact that UET athletes choose a more moderate pacing strategy as compared to a sprint. Adopting an 80-85% swim speed (as opposed to 90-95%) and striving to exit with the first-pack may be more beneficial (Wu et al., 2014). Hydration and nutrition are obviously impossible during the swimming stage which is a disadvantage. However, the swimming stage is relatively short, and hydration/nutrition can be "made up" as soon as exiting the water.

Because of the importance of first-pack swimming and exiting the swimming stage, and the relative non-impact of swimming on the subsequent stages, from a performance perspective swimming should remain as the first stage of the Kona IRONMAN Triathlon.

Run

Landers et al. (2008) noted that run-position/running-time was a better predictor of overall-finishing than swimming possibly because there are more opportunities to make-up time and more individual variability (e.g. endurance, speed, etc.). The advantage will go towards those athletes who have more energy reserve for the run (Landers et al., 2008). A successful run will depend more on endurance ability than run-technique (Landers et al., 2008).

Cycle

Landers et al. (2008) noted that the non-draft cycling had the least influence on overall finishing position as compared to swimming and running. Olbrecht (2011) noted that cycling relied more on conditioning than technique.

However, Wu et al. (2014) noted that cycling preceding running was notorious for increasing oxygen cost, glycogen depletion, muscle fatigue, ventilatory muscle fatigue, dehydration, decreased pulmonary compliance, increased risk of hypoxemia, and redistribution of blood flow to the legs. Athletes with less experience, especially on UETs, reported a loss of coordination transitioning from cycling to running (e.g. wobbly legs), and a delay in finding the optimal gait (Wu et al., 2014). Athletes also reported difficulty going from a non-weight bearing bout to weight-bearing--running, which feels like two to three times body mass (Wu et al., 2014). In fact, many athletes approach the cycling stage with the mindset of "cycle to run", meaning cycle conservatively and just "good enough" so that they can really complete the running stage well (Wu et al., 2014). A more conservative pacing strategy (focusing on constant effort) during the cycling significantly improved the running stage (1118 +/- 72sec).

Conclusion

From just a performance standpoint, a more advantageous UET event would be ordered swim-run-bike. Swimming should be staged first to take advantage of the legal drafting, first-pack position, and environmental variables. A fast swim and exit has statistically given the athletes a better advantage as well.

Running should be staged second, because individual variability in running is the next most impactful--being able to close or widen a "gap". With regards to energy expenditure over the duration of the entire UET, running should be stage 2 so one can make the greatest gains before detrimental fatigue sets in. Swimming is a short stage; swimming is not a full bodyweight experience. It is far better to stage running (which is a full bodyweight experience) immediately after the short swimming stage instead of having two (swimming then cycling) non-bodyweight bearing bouts consecutively before the full bodyweight experience of running. This might decrease that coordination problem of "sea-legs" that athletes complained about.

Finally, cycling should be staged last in an UET event based on how negatively cycling can impact running, and the contribution of non-draft cycling overall (which is not a deal-breaker according to the research).

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