Case Study: Beverage Temperature at Aid Stations in Ironman Triathlon

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Purpose: The aim of this study was to measure the effect of environmental conditions and aid-station beverage-cooling practices on the temperature of competitor beverages. Methods: Environmental and beverage temperatures were measured at three cycling and two run course aid stations at the 2010 Langkawi, Malaysia (MA), and Port Macquarie, Australia (AU), Ironman triathlon events. To measure the specific effect of radiant temperature, additional fluid-filled (600 ml) drink bottles (n = 12) were cooled overnight (C) and then placed in direct sun (n = 6) or shade (n = 6) near to a cycle aid station at AU. Results: During both events, beverage temperature increased over time (p < .05) as environmental conditions, particularly radiant temperature increased (p < .05). Mean beverage temperature ranged between 14–26°C and during both events was above the palatable range (15–22°C) for extended periods. At AU, bottles placed in direct sunlight heated faster (6.9 ± 2.3 °C·h–1) than those in the shade (4.8 ± 1.1°C·h–1, p = .05). Conclusion: Simple changes to Ironman aid-station practices, including shade and chilling beverages with ice, result in the provision of cooler beverages. Future studies should investigate whether provision of cool beverages at prolonged endurance events influences heat-illness incidence, beverage-consumption patterns, and competitor performance.

Keywords: drink temperature, endurance exercise, ultradistance event

The capacity to maintain hydration and thermoregulate effectively during prolonged strenuous exercise is challenging for most participants (Laursen et al., 2006). Experimental studies demonstrate that a pleasant flavor and cooler (<22°C) beverage temperature improve both the palatability and consumption of beverages during exercise (Burdon et al., 2012; Passe et al., 2000). The American College of Sports Medicine (ACSM) recommends regular consumption of fluid during exercise and notes that beverage temperatures between 15–21°C tend to be preferred to optimize palatability (Sawka et al., 2007). Consumption of cooler beverages has also been reported to reduce the rise in core body temperature and improve endurance exercise performance (Lee & Shirreffs, 2007; Lee et al., 2008; Mundel et al., 2006). However, studies comparing the effect of a cold beverage on thermoregulation and performance have used a variety of control beverage temperatures (4–38°C).

Athletes competing in endurance events such as Ironman triathlon (4-km swim, 180-km cycle, and 42-km run) depend on aid stations for the supply of both beverages and foods to sustain performance. Research on aid-station provision at Ironman and other endurance events is limited (Kimber et al., 2002; Maruyama et al., 1994). To our knowledge, the temperature of aid-station beverages has not been investigated. The present case study aimed to measure the temperature of beverages distributed at Ironman aid stations and examine the influence of hot (WGBT >27°C) versus temperate (20–24°C) environmental conditions on beverage temperature (Armstrong et al., 2007). It also aimed to describe and evaluate the impact of aid-station beverage cooling and distribution practices on the temperature of fluids provided. We hypothesized that beverage temperature would be higher in hot compared with temperate environments.

Details of the Events

Two Ironman events (4 km swim, 180-km cycle and 42-km run) were selected for observational investigation: the Langkawi, Malaysia (MA) Ironman (27th February 2010), which is in typically conducted in hot, humid conditions; and the Port Macquarie, Australia (AU) Ironman (28th March 2010) which has historically been conducted in more temperate conditions. Race start times were 6:30 and 5:30 a.m. for MA and AU respectively, and both events had a 17-hr completion limit. An adjustment for daylight saving was made for AU data so time based temperature evolution measurements remained comparable between events. At both events, three loops were completed for both cycling and run courses. Three
Beverage Preparation and Presentation

At MA, all beverages were prebottled product provided by suppliers. On the cycle leg, beverages were delivered to the aid stations in individual bottles (600 ml) and chilled in large ice-filled tubs before being collected by competitors. Ice was delivered intermittently to aid stations to support adequate beverage cooling. At run course aid stations, beverages were stored in individual 1–2 L bottles immersed in large tubs of ice. The beverages were then dispensed into cups as required.

At AU, premixed carbohydrate-electrolyte beverage was delivered to aid stations in 5-L plastic jugs and stored in ice bins. The beverages were transferred into 38-L dispensing containers for filling of individual bottles or cups. Water was directly bottled from either mains or water trucks. The same process was used at all aid stations. Drink bottles and cups were then placed on a table awaiting collection by competitors. Aid-station personnel were instructed to have no more than 20 bottles or cups available at any given time.

Environmental and Beverage Temperature Measurement

The temperature of beverages immediately available to participants was measured every 10 min with a digital thermometer (at MA: Thermolab T Model, Alla, France; at AU: TLogger, University of Sydney, Australia). At both locations (MA and AU), two beverages of each fluid type (water or carbohydrate-electrolyte) were measured at each time point to minimize error and reduce the effect of potential outliers. To gauge the temperature of beverages carried by athletes, a convenience sample of competitor discarded drink bottles (n = 250 from each location) on the cycling leg was also collected (within ~5 min of discard) and assessed for beverage type and measured for temperature (Thermistor 400 series, Cole Parmer, Illinois, USA).

Environmental conditions at the aid stations were monitored every 30 min during the event. At MA, a weather station (WBGT-103, Kyoto Electronics, Tokyo, Japan) was used to measure dry and wet bulb and black globe temperature, WBGT and relative humidity. Measurements were made at one aid station on the cycle (0700–1300) and one on the run course (1300–1800), in both shade and direct sun.

At AU, black globe temperature was measured at every aid station attended (n = 5). Wet and dry bulb temperatures were measured with a whirling hygrometer (Casella, Kempston, England) at two cycling and two run leg aid stations and WBGT was calculated. A sliding scale (D7185 Casella, Kempston, England) was used to determine relative humidity from wet and dry bulb temperatures. At the other cycling aid station, a weather station was used (Kestrel 4500, Mt Eliza, Australia) to measure dry and wet bulb temperature, WBGT relative humidity and wind speed. Wind speed was measured at two cycling and one run course aid station.

An additional experiment was conducted at AU to investigate the effect of radiant heat on beverage temperature. Bottles (n = 12) identical to those used in the event were placed in either the sun or shade. The bottles (containing 600 mL of water) were initially cooled overnight. Before race commencement, four bottles were allocated to each of three cycle aid stations where two were placed in the shade and two in the sun. Beverage temperature was measured every 10 min for 3 hr. Total heat energy transferred to the drinks was calculated using

\[ q = m \times C_g \times (T_f - T_i), \]

where \( q = \) total heat gained or lost, \( m = \) mass, \( C_g = \) specific heat of the substance (water = 4.182 J/°C/g), \( T_f = \) final temperature and \( T_i = \) initial temperature.

The study was approved by the University Human Research Ethics Committee, February 2010.

Statistical Analysis

A sampling rate of 30 min was used for measurements during the MA and AU events. Univariate analysis of variance (ANOVA) was used to compare beverage temperature at different time points and locations for the cycling and run courses. To compare beverage temperature on the different courses, a three way ANOVA was used with time, location, and course as fixed factors. A Bonferroni adjustment post hoc test was used to determine the significantly different groups. Radiant temperature was used as a covariate. All Statistical analyses were performed using SPSS version 17.0. Statistical significance was set at \( p < .05 \) and results are presented as mean ± SD.

Outcome

Measured environmental conditions at MA (31 ± 2.6°C, 63 ± 13% RH, Figure 1) approximated with those reported for that day by the Malaysian Meteorological Department. At AU, measured mean (26.3 ± 3.1) and maximum (29.7°C) temperatures (Figure 1) were higher than five year historical data (19.0 ± 0.8°C, maximum of 25.2 ± 1.0°C) but similar to Australian Bureau of Meteorology observations (mean 22.7°C, maximum of 28.4°C) from a site near to the event (20km).

Beverage Temperature

Radiant temperature (all day average: MA 35.2 ± 3.8°C; AU 38.6 ± 7.0°C, \( p = .89 \)) increased over time (\( p < .001 \)) and had a significant effect on water (\( p = .038 \)) and carbohydrate-electrolyte beverage (\( p = .022 \)) temperature at MA and AU. The results of the experiment which mea-
Burdon et al. measured the influence of placing bottles either in the sun or shade revealed that radiant heat from the sun tended to increase the rate of beverage temperature rise (sun: 6.9 ± 2.3°C·h⁻¹ vs. shade: 4.8 ± 1.1°C·h⁻¹, \( p = .056 \), Table 1). While not significant \((p > .05)\), the effect size is large and likely beneficial (ES: 1.16, 95% confidence interval: -0.14–2.29). In both events, beverage temperatures were significantly warmer at run (MA: 24.1 ± 4.2, AU: 25.4 ± 3.4) versus cycling course (MA: 19.3 ± 8.8, AU: 22.3 ± 8.3) aid stations \((p < .001, \text{Figures 2 and 3})\).

**Cycling Aid Stations**

Over the duration of both events, beverage temperatures were variable at cycling aid stations (Figure 2) but significantly increased as the day progressed (water: \( p < .001 \), carbohydrate-electrolyte: \( p = .037 \)). The average water temperature was 21.0 ± 6.8°C at MA and 22.1 ± 4.3°C at AU and was not significantly different between event locations \((p = .151)\). The average carbohydrate-electrolyte beverage temperature was significantly warmer at AU (22.5 ± 4.1°C) than MA (17.8 ± 10.1°C, \( p < .001 \)). Water temperature had a greater rate of rise at AU compared with MA \((p = .003)\) where water temperatures were variable across the event duration (Figure 2A). The rate of rise in carbohydrate-electrolyte beverage temperature was not different between events \((p = .254, \text{Figure 2B})\).

The average temperature of discarded bottles was 26.5 ± 5.6°C at AU and 28.0 ± 3.2°C at MA.

**Run Course Aid Stations**

The average water (MA: 14.2 ± 5.4°C, AU: 26.2 ± 2.6°C) and carbohydrate-electrolyte beverage temperatures (MA: 22.1 ± 8.1°C, AU: 25.5 ± 4.1°C) were significantly warmer at AU than MA \((p < .001 \text{ all, Figure 3})\). Water temperature decreased significantly over time at MA \((p < .001)\) but remained stable at AU \((p = .567)\) and this difference between locations was significant \((p = .027, \text{Figure 3})\). As the event progressed over the day, the tem-

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**Figure 1** — Environmental temperatures at the Langkawi (MA, unfilled) and Port Macquarie (AU, filled) Ironman triathlons.
Table 1  Beverage Temperature ($T_{bev}$) Evolution Over 3 h in a Warm Environment With and Without Radiant Heat (Sun Exposure)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Baseline ($^\circ$C)</th>
<th>1 h ($^\circ$C)</th>
<th>2 h ($^\circ$C)</th>
<th>3 h ($^\circ$C)</th>
<th>$\Delta T_{bev}$ ($^\circ$C)</th>
<th>Heat transfer (kJ)</th>
<th>Palatable time (min)$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU-sun$^b$</td>
<td>11.0 ± 1.9</td>
<td>23.2 ± 3.5</td>
<td>29.7 ± 5.3</td>
<td>33.9 ± 6.0</td>
<td>22.9 ± 6.9</td>
<td>57.4 ± 10.2</td>
<td>55 ± 45</td>
</tr>
<tr>
<td>AU-shade</td>
<td>11.0 ± 3.6</td>
<td>20.3 ± 2.0</td>
<td>23.2 ± 2.4</td>
<td>25.5 ± 2.1$^c$</td>
<td>14.5 ± 3.4$^c$</td>
<td>36.6 ± 8.5$^c$</td>
<td>102 ± 50</td>
</tr>
</tbody>
</table>

$^a$Palatable time defined as the time point when beverage temperature ($T_b$) ≤ 22 °C.

$^b$Mean radiant heat at AU during observation 40.3 ± 4.2 °C.

$^c p < 0.01$ between conditions.

Figure 2 — Ironman cycling course aid-station beverage temperatures ($T_{bev}$) at MA and AU. Gap in data due to error in data collection. * $p < .05$ for $T_{bev}$ over time, † $p < .05$ for absolute $T_{bev}$ between event locations; # $p < .05$ for rate of $\Delta T_{bev}$ between locations.
Reflections

This research was undertaken to describe actual beverage temperature at Ironman aid stations. The study also aimed to examine the impact of the environment and aid-station cooling practices on beverage temperature at two Ironman events typically held in hot (MA) and temperate environments (AU). We hypothesized that beverage temperature would be higher at MA due to the hotter environment; however, beverage temperature was cooler at MA probably due to the beverage cooling practices employed. Beverage temperatures early in the day on the cycling course were within or close to the upper limit of the palatable range (15–22 °C). Run course aid-station beverages were warmer and outside the range considered best to optimize palatability during the middle of the day when radiant heat was higher (MA: 37.3 ± 1.9 °C, AU: 39.4 ± 1.4 °C).

Beverage temperature is a key factor in determining palatability especially during exercise (Hubbard et al., 1984) which is known to increase fluid consumption and enhance hydration (Szlyk et al., 1989). The data from the current investigation demonstrate that beverage temperatures can be outside the optimal designated palatable range (15–22 °C; Burdon et al., 2012; Sawka et al., 2007).
in warm environments and even when environmental conditions are more moderate. Cooler beverages may not only assist with hydration but also attenuate core body temperature rise and improve endurance performance in the heat (Lee et al., 2008; Mündel et al., 2006). Provision of very cold fluids (ice slushy) before and during exercise has been observed to create a substantial heat sink and represents a practical cooling method (Ross et al., 2011; Siegel & Laursen, 2012; Siegel et al., 2010; Siegel & Laursen, 2012). Dispensing slushy type beverages at races may limit fluid consumption; however the potential reduction in core temperature provides protection from the risk of heat illness. This reduction in core body temperature appears to provide an ergogenic effect (Ihsan et al., 2010; Yeo et al., 2012) despite significant dehydration (>2% body mass loss) which has previously been reported to be detrimental to endurance performance (Cheuvront et al., 2003). One field-based study has observed that provision of preexercise ice slushy reduced core body temperature and improved 10 km run performance (Yeo et al., 2012). However, the effect of cooling beverages for distribution during a prolonged endurance race on competitor thermoregulation, performance, and prevalence of heat illness is yet to be determined and warrants investigation.

At both Ironman events, beverage temperature was highest around midday, coinciding with higher radiant heat. High sun exposure experienced in Ironman and also other outdoor endurance events (e.g., marathons) translates into high radiant heat (Moehrle, 2001) which increased the temperature of beverages provided and carried by competitors. A substudy of radiant heat revealed that drink bottles placed in the sun at AU had a significantly greater heat transfer and rate of temperature change than those in the shade. Unfortunately, comparison of beverage temperature due to environmental conditions is difficult due to the different aid-station practices employed at the two locations. The lower beverage temperature at the event in hotter ambient conditions (MA) suggests that these aid-station practices have a beneficial influence on beverage temperature. Therefore, a number of simple practical strategies such as shade for beverages and cooling in ice delays the rise in beverage temperature and maintains beverages in an optimal palatability range for longer. Chilling beverages in smaller rather than larger bottle sizes may also facilitate more effective cooling. The findings of this case study also provide a guide for selecting the temperature of control beverages in future investigations employing different beverage temperatures. Future research should investigate whether the provision of cool beverages influences heat illness incidence, beverage consumption patterns or competitor performance during prolonged endurance events.

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References
