Prediction of WBGT for the Tokyo 2020 Olympic Marathon

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The heat during the Tokyo 2020 Summer Olympics will presumably be especially demanding for marathon runners. Therefore, the present study measured WBGT over the same three days in 2015 which correspond with the event in 2020. By using a road bike with mounted environmental thermometers, a run-through of the scheduled course from start to finish at a speed of 20 km/hr was simulated. Simulation conditions which included the speed of the marathon runners along with WBGT exposure that they could expect were examined to assess the related risk of heat stroke. The mean WBGT over the entire course on the road-bike was 30.4°C and thus higher than 30°C on July 26, and 29.6°C on August 4 and 26.9°C on August 9. The mean dry-bulb temperatures were 36.9°C on July 26, 34.5°C on August 4, and 32.4°C on August 9. The mean WBGT values obtained from concurrent stationary measurements at five locations along the course were just 0.2±0.1°C (range 0.1 to 0.3°C) higher than the mean values obtained from the moving road-bike measurements. These WBGT values indicate that athletes are exposed to a higher temperature while running than that commonly expected, which, along with the additional burden of body-temperature elevation occurring during an over 2-hour long marathon, sufficient training and acclimation under summer heat will be necessary to avoid heat stroke and permit a high level of performance. In this study, we set start time for marathon at 8:30, but think the start time to have to shift early in the morning. Furthermore, we install much mist showers in the marathon course route and think that it is necessary to make use for the physical cooling of the marathon runner.

Key words: heat stroke, runner
1. Introduction

The 2020 Summer Olympics will be centered in Tokyo and held from July 24 to August 9, with the women’s marathon on August 2 and the men’s on August 9. The marathon runners will start at the new National Olympic Stadium, progressing through the city center while flanked on both sides by many buildings, reaching the turning point in Asakusa, and then return to the stadium. As this will be the hottest time of the year in Tokyo, and not long after the end of the rainy season, the race is expected to be extremely demanding.

The Cabinet Office (2015) has established a liaison conference of ministries, agencies, and other entities relating to measures against heat exposure for athletes and spectators and initiated consideration of a broad spectrum of measures against the occurrence of heat stroke at the Tokyo 2020 Olympics. To date, however, no progress has begun on any specific programs and investigation into estimates of environmental conditions at the dates and times of the competitive events is considered essential. One such study by Kashimura et al. (2016) measured the environmental temperatures during the corresponding period in 2014 around the venues of the outdoor events to be held in the Tokyo 2020 Olympics. The results indicated a mean WBGT heat index in the range of 29.9 to 31.5°C during the 2020 Olympics. They also derived estimates based on the environmental temperatures observed by the Meteorological Agency from 1964 to 2014 and on that basis obtained a WBGT estimate of 34.65°C for the Tokyo region during the 2020 Olympics, which raises the possibility of numerous heat strokes. Marathon athletes run on roads and while running are exposed to the environmental temperature at each point on the course, in contrast to spectators who are stationary and exposed at a single point. Therefore, the environmental exposure of the athletes differs from that of the spectators; with particular differences due not only to the heat exposure and constant airflow effected by outdoor running and the resulting heat dispersion from their skin surface, but also to the higher metabolic rate induced by physical exertion and the resulting increase in body temperature.

The heat exposure of the marathon runners is presumably more demanding, and in the present study we focused on their exposure by measuring WBGT under forward movement during the period in 2015 corresponding to that of the Tokyo 2020 Olympics using a road bike equipped with environmental thermometers and travelling from the marathon starting point to its finish line at 20 km/hr to approximate the running speed in the marathon and assessed the risk of heat stroke under those conditions, with the objective of providing environmental information on the marathon course that may serve as a reference for the marathon runners and for hot-weather training programs to avoid heat stroke.

2. Method

2.1. Measurement of WBGT using a road bike

A road bike with a WBGT index meter (HD32.2, Delta Ohm S.r.L), mounted on the handlebar was ridden through the marathon course at approximately 20 km/hr as an approximation of the running speed of the marathon competitors. It was installed a WBGT index meter in the frontal steering wheel of the road-bike (Figure 1). And the distance with the observer who took a road-bike was 70 cm. The environmental temperature measurements were made at intervals of 15 sec and included dry-bulb temperature, natural wet-bulb temperature, black-globe temperature, and WBGT. The sensor of a WBGT index meter was platinum thin film resistors (Pt100); the precision a dry-bulb temperature probe (class 1/3DIN ±0.04°C), blackball temperature probe (class 1/3DIN, ±0.04°C), wet-bulb temperature probe (class A, ±0.06°C). It was conducted the proof-
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The road-bike speed was controlled by the rider using a handlebar-mounted speedometer, in covering the scheduled course of the marathon, starting and ending near the new National Olympic Stadium construction site via a turning point near Kaminari-mon in Asakusa (Figure 2). At stops for traffic lights, the time of the encounter, the time forward progress stopped, and the time forward progress resumed were voice recorded. In addition, the environmental data in the waiting at a stoplight deleted all it and analyzed it.

The three measurement dates and times of July 26 and August 4 and 9 starting at 08:30 in 2015 correspond to the period of the Tokyo Olympics. Continuous video recording (HERO4, GoPro) of the road-bike movement was performed to provide confirmation of the riding times and locations.

2.2. Calculation of WBGT in the Tokyo region

From the Meteorological Agency’s website (Meteorological Agency, 2016), we obtained the maximum temperature and mean relative humidity observed by the Meteorological Agency at the times of the road bike travel on July 26 and August 4 and 9 starting at 08:30 in 2015 in the Tokyo region. From these values, we calculated the WBGT using the following equations (Shinya et al., 2003; Nakai et al., 1992).

\[
\text{Wet-bulb temp.} = (\text{max. temp.} + 10) \times (\text{mean RH} / 250 + 0.615) - 10
\]

\[
\text{WBGT} = 1.925 + 1.298 \times (0.7 \times \text{wet-bulb temp.} + 0.1 \times \text{max. temp.})
\]

2.3. Measurement of WBGT at time of stationary measurement on marathon course

WBGT measurements at stationary points were made near the new National Olympic Stadium, Suidobashi, Zojoji Temple, Sudacho, and Asakusa Kaminari-mon (Figure 2).

At each location, the measurements were performed at 15-sec intervals with a WBGT index meter (HD32.2, Delta Ohm) at a height of 1.5 m as in the road-bike measurement, but mounted on a tripod. We compared the environmental temperature values obtained by the road-bike and stationary measurements in a period extending 1 min before and after road-bike passage by that point. The place of the fixed-point observation was carried all out on the sidewalk of 1 m from a road. All places were exposed to sunlight during the measurement period.

2.4. Statistical analysis

The stationary and road-bike WBGT were compared using analysis of variance.

3. Results and discussion

The Tokyo Olympics marathons were conducted at intense heat environment in 2020, but was performed by the Los Angeles Olympics in environment similar in August, 1984. By Los Angeles Olympics, air temperature before and after competition of one week was 35°C. As for the Tokyo Olympics, dry-bulb temperature may exceed 35°C in 2020, and, in intense heat Los Angeles Olympics or more, it is expected that a marathon competition is held.

Days with clear weather and sunshine throughout or nearly throughout were chosen for the measurements. Measurements were performed July 26, August 4, and August 9 in 2015, corresponding to the following time points in the 2020 Olympic calendar: just after the opening ceremony, the midpoint, and the
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In regard to the marathon, the following measures are also being considered: water-retentive and heat-barrier pavings to the course roads to reduce the rise in their surface temperature; preservation of existing greenery and roof and wall greening in the Olympic environs to reduce heat-island formation; provision of air temperature, humidity, and other heat-related meteorological data to athletes and spectators via organizational-committee official websites and other means; and other methods of countering heat along the marathon course. As the marathon in particular is presumably the Olympic event that is most affected by high heat exposure, reliable prediction of the heat exposure that may actually be encountered by the athletes in the race is essential.

Figure 3 shows the WBGT patterns found in this study by the road bike traveling at approximately 20 km/hr on July 26, August 4, and August 9 in 2015. All the environmental data of the waiting at a stoplight deleted it and then handled these data. The WBGT values on July 26 were the highest among these three days, often exceeding 30°C. Those on August 4 were lower than on July 26, but were all above 28°C throughout the measurement period. Those on August 9 were lower than on the other two days, and did not exceed 30°C at any time.

In looking toward Tokyo 2020, the Cabinet Office (2015) has established a liaison conference composed of related ministries, agencies, and other entities concerning heat-related measures for athletes and spectators. The ministries and agencies have begun to investigate a broad range of related measures, including multilingual pamphlets to raise awareness of heat strokes and their prevention, rules to ensure efficient ambulance transport for foreigners, emergency systems for heat-stroke patients and others, application of barrier films and coatings to the exterior walls and roofs of stadiums and other facilities to lower their surface temperatures, functional-fiber clothing to help maintain the physical condition of athletes and volunteer staff, and thermal environment analysis of the stadiums and their environs using the Earth Simulator supercomputer. In regard to the marathon, the following measures are also being considered: water-retentive and heat-barrier pavings to the course roads to reduce the rise in their surface temperature; preservation of existing greenery and roof and wall greening in the Olympic environs to reduce heat-island formation; provision of air temperature, humidity, and other heat-related meteorological data to athletes and spectators via organizational-committee official websites and other means; and other methods of countering heat along the marathon course. As the marathon in particular is presumably the Olympic event that is most affected by high heat exposure, reliable prediction of the heat exposure that may actually be encountered by the athletes in the race is essential.

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just one week before the Olympics opening ceremony, thus leaving insufficient time for acclimation to the intense heat of the Tokyo summer and increasing the risk of heat stroke among the athletes. Another factor is the rate of heat dispersion from the body. In the present study the environmental temperatures were measured with a WBGT index meter, but the increased perspiration of athletes induced by running may be expected to increase the rate of heat dispersion by the related airflow. Candas et al. (1979) report that airflow is a determinant of the maximum rate of sweat evaporation and plays a key role during vigorous exercise. Kashimura (1985) compares the effects of frontal airflow at 5.0 m/sec and the absence of airflow during exercise at an air temperature of 30°C and reports that the airflow sharply reduced the mean skin temperature but had no apparent effect on the rise in rectal temperature. Finally, LeBlanc et al. (1976) reports that airflow of 4.7 to 6.7 m/sec provide the maximum skin cooling effect but also infers that little or no skin-cooling effect of airflow while running can be expected in environments with air temperatures above 30°C.

In the present study, as shown in Table 1, no difference was found between the mean WBGT values estimated from the environmental temperature observations of the Meteorological Agency for the Tokyo region and those obtained from the measurements on the moving road bike. Figure 4 shows a comparison between the mean WBGT values obtained from the road bike measurements at approximately 20 km/hr and those obtained from the stationary measurements near the new National Olympic Stadium, Suidobashi, Zojoji Temple, Sudacho, and Asakusa Kaminarimon. On average, the mean WBGT values for the moving

Table 1. Predicted environmental temperatures for the planned marathon course in 2015

<table>
<thead>
<tr>
<th>Date of measurement</th>
<th>Dry-bulb temperature (°C)</th>
<th>Wet-bulb temperature (°C)</th>
<th>Globe Temperature (°C)</th>
<th>Relative humidity (%)</th>
<th>WBGT (°C)*</th>
<th>Meteorological Agency WBGT (°C)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 26</td>
<td>36.9±1.2</td>
<td>26.8±1.1</td>
<td>39.8±1.6</td>
<td>46.1±7.8</td>
<td>30.4±0.9</td>
<td>30.1±0.8</td>
</tr>
<tr>
<td>August 4</td>
<td>34.6±1.3</td>
<td>26.9±0.5</td>
<td>36.6±2.0</td>
<td>55.5±4.0</td>
<td>29.6±0.8</td>
<td>30.3±0.7</td>
</tr>
<tr>
<td>August 9</td>
<td>32.4±1.6</td>
<td>23.9±0.5</td>
<td>35.1±2.4</td>
<td>49.2±5.0</td>
<td>27.0±1.0</td>
<td>27.4±0.5</td>
</tr>
</tbody>
</table>

* WBGT; wet-bulb globe temperature
** Meteorological Agency data (calculation from dry temperature and relative humidity in Tokyo)
All the environmental data of the waiting at a stoplight deleted it and then handled these data.
road bike were only 0.2±0.1°C (0.1 to 0.3°C lower than the stationary mean values, thus showing no significant difference in environmental temperature.

These results indicate that while running the athletes will be exposed to a higher level of WBGT than might otherwise be expected. An additional factor for consideration is the burden an over 2-hour long period of body temperature elevation due to the physical exertion involved in the marathon. Advance training under high-heat conditions for sufficient acclimation is therefore deemed a necessary means of avoiding heat stroke and permitting a high level of performance.

In this study, we set start time for marathon at 8:30, but think the start time to have to shift early in the morning. Furthermore, we install much mist showers in the marathon course route and think that it is necessary to make use for the physical cooling of the marathon runner.

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Fig. 4. Comparison of WBGT measurements taken by moving road bike and stationary thermometers. Data are mean±standard deviation.