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MARATHON RUNNING IN AN ERA OF RISING TEMPERATURES: ASSESSING THE HEAT-RELATED ILLNESS RISK IN A SIMULATED STUDY

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ABSTRACT

Background: Running a marathon is considered one of the most arduous tests of physical endurance for the human body. Climate change has heightened the risk of heat-related illnesses among marathon runners as global temperatures rise. **Aim:** This study aimed to investigate gender-specific percentages of runners at risk for heat-related conditions under varying Wet-Bulb Globe Temperature (WBGT) scenarios when the skin and core body temperature rise, offering vital insights into the impacts of climate change on athletes. **Methods:** A simulated cohort of male and female runners was designed based on demographic data available online from competitive marathoners. We used website (https://www.meteor.run/running-event/summary/Marathon) to access the data. Physiological parameters—resting and maximum heart rates, skin temperatures, and estimated core body temperatures—were integrated to calculate the Physiological Strain Score. Distribution plots were employed to visualize the proportion of runners vulnerable to heat-related illnesses at different WBGT levels. **Results:** Results indicate that 29.5% of female runners are at risk at WBGT when scapula skin temperature is 34°C, escalating to 38.4% at 35°C, 48.0% at 36°C, and 57.6% at 37°C. Male percentages are lower, yet significant, with 17.8% at risk at 34°C, increasing to 29.2% at 35°C, 40.5% at 36°C, and 50.7% at 37°C. Physiological strain scores exhibit a normal distribution among female runners at various skin temperatures, while the distribution among male runners remains more uniform. **Conclusion:** At WBGT with scapula skin temperature of 34°C or higher markedly amplify the risk of physiological strain in both genders, with females facing comparatively greater vulnerability. As climate change continues to intensify heat, humidity, and radiation, future marathon events will likely pose greater health risks to participants.

KEYWORDS: WBGT, core temperature, Physiological strain.

INTRODUCTION

Over the past couple decades; there has been a noticeable increase in heat-related injuries at marathon races correlating to the increase in temperatures.[1] The ability to thermoregulate and adapt to the extreme hot and humid conditions depends on individual age, gender, morphology, hydration, clothing, muscle mass, and fitness level. Runners can experience hyperthermia when core body exceeds 39°C.[2] When the body is overheated, blood flows to the capillaries close to the surface of the skin in an effort to cool the body down by dissipating heat into the environment.[3] The human body also responds to overheating with evaporative cooling via sweating.[4] There is a range of heat-related illnesses that marathoners can experience, from mild symptoms to life-threatening organ failure. The most commonly seen heat-related illness in marathoners includes heat edema, heat rash, heat syncope, heat cramps, heat exhaustion, and heat stroke.[5]

Heat edema and heat rash are both on the milder side of the heat-related illness spectrum. Heat edema can happen when the body tries to dissipate heat by vasodilation, which attempts to send blood flow closer to the surface of the skin with the fluid creating inflammation.[5,6] Runners who experience this usually see it occur in their

lower extremities.[5] Heat rash is a red-colored rash that develops when the skin in certain spots of the body rubs against sweaty, damp, and usually warm clothing causing sweat ducts to become clogged thereby creating the rash. Runners tend to experience this around the torso or groin area.[5]

Slightly increasing in severity on the heat illness spectrum is heat syncope. When the body is exposed to heat, the blood is being shunted to the skin surface and extremities, but quick changes in body positioning can cause a sudden drop in blood pressure resulting in fainting.[5] Many runners tend to experience this if they bend over or crouch down to tie their shoes and then stand back up to continue running. Although lying down usually regulates the flow of blood fairly quickly, people may fall due to fainting which could lead to more serious issues like concussions or fractures.

Further along the spectrum of heat-related illness severity is heat cramps, which are muscle spasms associated with dehydration, electrolyte imbalance like hyponatremia, and/or muscle fatigue.[5] Although a mild form of hyponatremia can regulate fairly quickly, more severe cases (<120 mmol/L) could hinder the body's central nervous system and consequently cause cerebral edema, respiratory failure, and even lead to death if plasma sodium concentration falls too low (<110-115 mmol/L).[7] Even though heat cramps may be caused by dehydration, over-hydrating can also cause this issue because of electrolyte imbalances, so it is extremely important for runners to be cognizant of appropriate fluid intake before, during, and after their runs during the months of training leading up to the marathon race and especially on race day.[8]

Into the critically dangerous side of the heat-related illness spectrum is heat exhaustion, which presents with symptoms of fatigue, dizziness, heavy sweating, nausea, vomiting, headache, fainting, weakness, and cold clammy skin.[5] Heat exhaustion can progress into life-threatening conditions like heat stroke if not promptly addressed. Heat stroke happens when the body's core temperature climbs higher than 104°F (40°C).[9] The body's central nervous system becomes impaired at that point and the runner's mental state turns irritable, confused, and even combative before losing consciousness.[5] The runner's skin is usually both hot and dry to the touch, which indicates failure of the body's attempts to thermoregulate.[5] Heat stroke can be fatal if not immediately addressed, so recognition of these symptoms, by runners and race organizers is essential. There are two main types of heat stroke: classic and exertional. Classic heat stroke basically means that the overly warm environment around a runner is affecting the body's ability to dissipate heat.[10] Factors like higher temperatures, humidity, sun exposure, clothing choices, hydration levels, and more play into this. Exertional heat stroke basically means that a runner's own heat production is too much so the body is not able to regulate its core body temperature because the metabolic heat production is out of sync with the body's ability to dissipate heat via evaporation, radiation, convection or conduction.[11] Exertional heat stroke is particularly worrisome because unlike classic, it can occur in any type of weather conditions.[10] However, outdoor physical activity in hot and humid temperatures can compound the effects of exertional heat stroke.[12-14]

Although marathons around the world continue to host more participants every year, the medical guidelines and suggestions for training and the actual race day are not as detailed as one might expect. Since all major marathon races are held outdoors, the effects of climate change like heat related illness have become important factors to take into consideration when training for and running a marathon.[8,15-17] Currently, there are no marathons that require any minimum health qualifications to be met prior to registering for the race. Although some races have minimum qualifications in regard to previous marathon finishing times in order to be eligible for certain races (like the equally exclusive and elusive Boston Marathon), this is driven merely by the prestige and reputation of the event rather than any concern to the health of its participants. Race organizers around the world have yet to develop a universally established methodology for warning participants of heat-related illness risks that many marathoners may not realize they are susceptible to while running long distances in progressively worsening climate change conditions.

To the best of the authors' knowledge, no investigation of the climate-change projected impacts of heat stress in marathon runners has been previously published.

The study seeks to assess the escalating risk of heat-related illnesses among marathon runners due to increasingly warmer climates, as quantified by the Wet Bulb Globe Temperature (WBGT). Using the Intergovernmental Panel on Climate Change's (IPCC) Representative Concentration Pathway of 8.5 (business-as-usual scenario), the global change in WBGT that was averaged over the last decade of this century shows an increase of 2.37–4.4°C, with an ensemble average of 3.36°C.[18] There is limited data on gender-specific physiological responses under high WBGT conditions. To provide critical insights into how marathon running can be affected in an era of rising temperature, this study aims to: 1. assess the gender-specific risk percentages of marathon runners encountering heat-related illnesses under varying WBGT conditions; 2. identify trends in the distribution of physiological strain scores at different skin temperatures among male and female runners; and 3. provide strategic recommendations for race organizers to mitigate the effects of increasing heat stress on participants.

METHODS

As we wanted to assess and forecast the public health implications of climate change in marathon runners, we

used currently available scientific information to model expected core body temperatures under varying climate conditions. A group of male and female marathon runners were simulated based on the demographic profile of competitive marathon runners, simulated resting and maximum heart rate and skin temperature, estimates of core body temperature using these values, and, lastly, calculating the expected physiological strain score. Plots of the distributions were used to visualize how many marathon runners would be expected to be at risk for heat-related illnesses at varying skin temperature based on Wet-Bulb Globe Temperature Index (WBGT).

We collected and analyzed the simulated data. In separate simulations, samples of 20,000 men and 20,000 women aged 20 to 80 years of age were simulated based on the distribution of runners in marathons (https://www.meteor.run/running-event/summary/Marathon).[19] Three age groups were used for grouping men and women. In women, 56% of marathon runners are 20 to 39 years of age, 42% are 40 to 59 years of age, and only 2% are over 59 years old. In men, 45% are between 20 and 39, 48% are between 40 and 59 and 7% are over 59 years of age. The uniform distribution was used to sample the proportion of runners within each age category.

Heart rate (HR) was estimated based on the National Health and Nutrition Examination Survey (NHANES) cardiovascular fitness data (CDC/NCHS, 2009),[20] as presented in published fitness reference charts (ACSM, 2017),[21] which classify values into four categories: athlete, excellent, above average, and average for each age group and separately for males and females. Men tend to have lower heart rates at every fitness level. For women, the heart rate is estimated 55 in athletes, 63 in those with excellent fitness, 70 for those in above average fitness, and 77 in those at an average level of fitness. For men, the heart rate is 50 in athletes, 57 in those with excellent fitness, 65 for those in above average fitness, and 72 in those at an average level of fitness. Resting heart rate and maximum heart rates were calculated for each simulated runner. The maximum heart rate was estimated using the revised method of Tanaka et al. (2001) and calculated as 208 – 0.7*age with a standard deviation of 10.[22]

The WBGT is a weighted average of several environmental weather-related parameters. It combines ambient air temperatures, solar radiation, humidity, and wind speed into a measure that captures the collective effects of weather.[23] The formula for calculating the WBGT is $WBGT = 0.70 * TW + 0.20 * TG + 0.1 * TA$. In this formula, TW is the wet bulb temperature, TG is the globe temperature, and TA is the ambient temperature.

Increases in any components of WBGT equation elevate the overall index, thereby raising the net heat load on the body. This heightened load tends to increase skin temperature as the body absorbs more heat from the environment or loses less to it.[24] For instance, elevated air or radiant temperatures, coupled with high humidity, reduce the efficiency of heat dissipation, leading to warmer skin.

Importantly, the relationship between WBGT and skin temperature is non-linear and highly individual.[25] Evaporative cooling and vasodilatory mechanisms have physiological limits; once sweating reaches its maximum or radiant heat predominates, even small increases in WBGT can trigger disproportionately large rises in skin temperature—or, conversely, minimal changes. Moreover, individual factors such as metabolic activity, clothing insulation, acclimatization status, hydration level, age, and overall health significantly influence how skin temperature responds to elevated WBGT.

External weather conditions are also critical to Core Body Temperature (CBT) because the ability to dissipate excess heat is a function of the components of the WBGT. When heat dissipation is restricted in higher WBGT, there will be rise in both skin temperature and CBT. CBT was calculated using the regression model developed by Eggenberger et al. (2018),[26] (CBT=0.01*HR + 0.0837 *T(insulated scapula) + 33.1735) for various scapula skin temperatures ranging from 34°C to 38°C.

We used CBT and HR measured at baseline and during exercise to estimate a Physiological Strain Index (PSI) as suggested by Cuddy et al. (2013) that can classify who was at-risk of a heat-related event and who was not. The equation used is $PSI=5*(Tcore(t) - Tcore(0)) * (39.5 - Tcore(0))^{-1} + 5*(HR(t)-HR(0))*(180-HR(0))^{-1}$. In the equation, (0) denotes the baseline (pre-exercise or resting) value and (t) denotes the value at a specific time during exercise. The distributions were plotted and the proportion of those greater than PSI 7 was determined to estimate how many would be at-risk at various scapula skin temperatures.

These methods were employed to simulate a typical marathon similar to the New York City Marathon to better understand the future risk of heat-related illness in marathon runners.

Constraints and Complexities of the Experiment

When problems are complex and data are not available to evaluate risks, simulation and modeling can be used to address public health issues.[27] Simulation is a tool that incorporates evidence-based science to ask what health risks might be expected under a wide range of scenarios. It can be used to design interventions and mitigation programs. In this report, simulation was based on publicly available data, the science of core body temperature, and the forecasting of physiological strain scores under varying environmental conditions.

Calculating the wet bulb temperature (TW) and globe temperature (TG) values is not an easy process in the

measurement of Wet-Bulb Globe Temperature (WBGT) and requires substantive weather data. Recognized limitations also include the fact that it does not take into account when sweating is restricted or the variability due to the wearing of different types of clothing or levels of exertional activity (CDC, 2019).[28] Like all estimates, measurement error is also a concern since it relies on quality, available weather data. An alternative method that has been proposed is the Universal Thermal Climate Index (UTCI), especially for athletes.[29-31] Another simple and commonly used metric is the heat index which requires only air temperature and either dew point or relative humidity.[32]

Measuring internal core body temperature cannot be done practically. Reliable measures require invasive procedures such as esophageal, rectal, and gastrointestinal thermometers.[33,34] Due to the difficulty of measuring core body temperature, mathematical models have been employed to estimate it using non-invasive measures that include skin temperature from various parts of the human body, heart rate, heat flux, and external weather conditions.[26,35-37] The regression equation used to estimate core body temperature (CBT) is: CBT=0.01*HR + 0.0837 *T (insulated scapula) + 33.1735. We used insulated skin temperature at the scapula in this study because previous research has shown it to be the second most important predictor for rectal temperature and on marathon runners, scapular temperature seems the most fitting given the circumstances of physical activity being analyzed.[26] If another area of the body were to be used in this model to determine core body temperature, resulting data may vary.

Although there are heart rate monitors that wrap securely around the sternum, there are other wearable technology options that have recently been developed to estimate and monitor core body temperature.[38,39] These are useful in various occupational settings from first responders to elite athletes, but the prices tend to be quite expensive. In addition to providing a reliable estimate of core body temperature, the wearable device measures heart rate, exertion, fall detection, GPS location, and distance traveled, all of which are useful to long-distance runners.

RESULTS

According to model projections, skin temperature at 33°C in both female and male does not show any runners registering a CBT reading greater than 38 or experiencing physiological strain (Table 1). However, when the skin temperature increases to 34°C in females, 5,891 runners experience strain and 1,915 runners register a CBT greater than 38 and a physiological strain score of 7.18. When the skin temperature increases to 35°C in females, 7,677 runners experience strain and 5,295 runners register a CBT greater than 38 and a physiological strain score of 7.32. When the skin temperature increases to 36°C in females, 9,597 runners experience strain and 9,873 runners register a CBT greater than 38 and a physiological strain score of 7.47. When the skin temperature increases to 37°C in females, 11,521 runners experience strain and 14,532 runners register a CBT greater than 38 and a physiological strain score of 7.61.

Table 1: Model Projections of Increased Temperatures and Strain in Females and Males.

Skin temp.	Female			Male		
	No. of runners with core body temp. > 38	PSI mean	No. of runners experiencing strain (%)	No. of runners with core body temp. > 38	PSI mean	No. of runners experiencing strain (%)
33°C	0	N/A	N/A	0	N/A	N/A
34°C	1,915 (9.5%)	7.18	5,891 (29.5%)	45	7.08	3,551 (17.8%)
35°C	5,295 (26.5%)	7.32	7,677 (38.4%)	2,877	7.22	5,830 (29.2%)
36°C	9,873 (49.5%)	7.47	9,597 (48.0%)	8,412	7.36	8,092 (40.5%)
37°C	14,532 (72.5%)	7.61	11,521 (57.6%)	14,174	7.51	10,133 (50.7%)

Note: Skin temperature is the mean resting scapula skin temperature. PSI: Physiological Strain Index

Similar, yet slightly fewer instances of strain are seen in male runners (Table 1). When the skin temperature increases to 34°C in males, 3,551 runners experience strain and 45 runners register a CBT greater than 38 and a physiological strain score of 7.08. When the skin temperature increases to 35°C in males, 5,830 runners experience strain and 2,877 runners register a CBT greater than 38 and a physiological strain score of 7.22. When the skin temperature increases to 36°C in males, 8,092 runners experience strain and 8,412 runners register a CBT greater than 38 and a physiological strain score of 7.36. When the skin temperature increases to 37°C in males, 10,133 runners experience strain and 14,174 runners register a CBT greater than 38 and a physiological strain score of 7.51.

Distributions for physiological strain scores between females and males are notably different. For females,

seen in Figure 1, the distribution appears normally-distributed. However in males, seen in Figure 2, the distribution is more uniform. To obtain this data for both genders, the same formula was used. Consistent female responses (most PSI values concentrated near the mean with fewer extreme values) may reflect more homogeneous factors among the sampled women as body composition, hormonal influences, fitness level, hydration, acclimatization, clothing and other probable variables were held constant in simulated environment that narrow variability at different skin temperatures. Heterogeneous male responses (PSI values spread more evenly across the range) compared to females seems to be attributable to the differing heart rate data, at rest and exertional, between females and males. With all levels of fitness showing consistently lower resting heart rate levels in males compared to females, this could make males less at risk than females. More importantly this gender variation is also suggestive of more individualized preventive approach may be required for the male marathon runners to protect from heat stress problems.

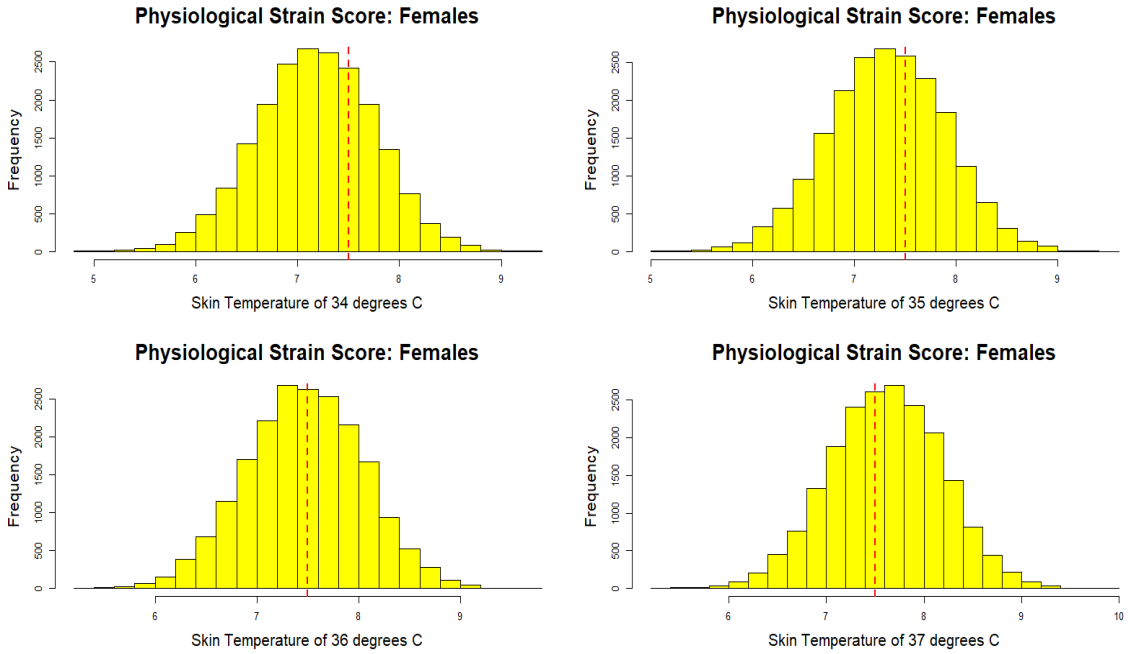

Figure 1: Simulated distributions of calculated physiological strain score at various skin temperature in 20,000 female marathon runners.

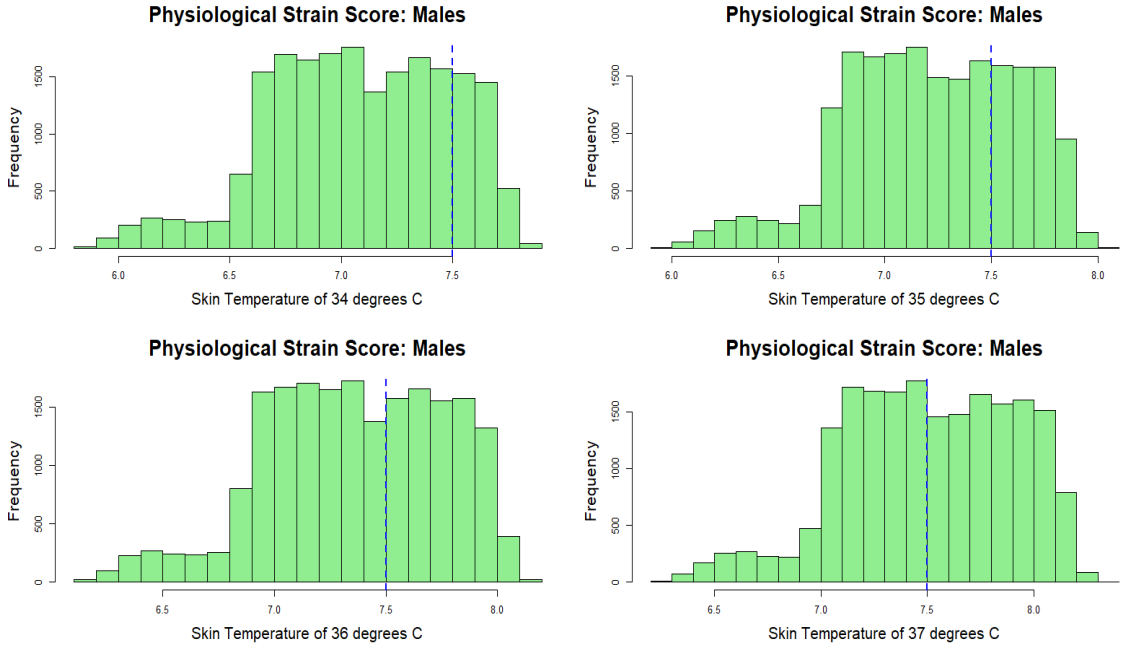

Figure 2: Simulated distributions of calculated physiological strain score at various skin temperature in 20,000 male marathon runners.

DISCUSSION

This study develops a comparison tool of sorts, by taking the potential temperature scenarios and comparing the expected WBGT values to the skin temperature figures. Heat cannot be dissipated from the body when the WBGT is greater than the skin surface temperature.[37]

By reporting the number of cases with a CBT greater than 38°C and a physiological strain score greater than 7.5, it is possible to speculate when heat stress problems would likely occur. This formula is basically comparing how much heat is being dissipated based on the WBGT reading and the skin scapula temperature, which is how the CBT is being estimated. This then factors into the physiological strain score. By raising the WBGT in the formula, even slight shifts show notable increases in the physiological strain score. This is quickly amplified by increases in humidity, and sun exposure. With humidity predicted to increase with climate change in the coming years, this will increase WBGT readings so physiological strain score will seemingly become a greater problem as time progresses.

Our results of the simulated sample of marathon runners indicate that the percentages of female runners at elevated risk of a heat-related adverse event increases to 29.5% at a WBGT of 34°C, 38.4% with a WBGT of 35°C, 48.0% at 36°C and 57.6% at 37°C. The percentage increase of men at risk of heat events was lower but was 50.7% at 37°C. At a WBGT of 34°C, 17.8% of men might experience a heat-related illness, and this percentage increased to 29.2% at 35°C, and to 40.5% at 36°C. These results indicate that running marathons in the next decades with increasing heat and humidity, as well as increased radiation, will result in more runners being at risk of heat-related illness. Previous research focusing on the various impacts of weather on marathon finishing times collectively showed progressive slowing of marathon performance as the WBGT increases between a range of 5℃ to 25℃.[40-44]

A WBGT greater than 35°C, which can be seen in traditionally hot geographical areas like deserts, can cause even fit people to overheat and die within six hours. This 35°C can be achieved at an ambient air temperature of 71°F and humidity of 50%. Conditions become dangerous when the WBGT is greater than the surface temperature of the skin because heat transfer from the body to the atmosphere does not occur. At a WBGT of 30.1°C, only fit and acclimatized individuals should be participating in rigorous outdoor physical activity.[4] When environmental conditions rise to or exceed 32.3°C WBGT, all activities, regardless of rest breaks, acclimation, or other mitigation tactics, should immediately cease to preserve human life.[4] When the WBGT is greater than a skin temperature of 35°C and the CBT is greater than 36.8°C, then the risk of heat-related illness is significantly greater. At the rate WBGT has been consistently increasing over time, it is highly likely that it will exceed the recommended temperature of 31°C in nearly all places on the planet at some point in the coming decades.

It is important to note that additional factors other than higher resting heart rate that may be influencing the difference in physiological strain distributions between females and males in our result. Regardless of the scenario, as the temperature increases, the data shows that more and more people become increasingly at risk without taking into account other factors. When including these other factors, like other environmental factors, comorbidities, clothing choices, etc., risk would only increase amongst both genders. Projecting estimates of global change in WBGT through 2100, temperatures and physiological strains are only expected to increase, presenting more challenges for anyone who endeavors to perform any physical activity outdoors like marathon runners and outdoor workers.

Recommendation

For marathoners and outdoor workers alike, awareness is vital. One of the simplest recommended strategies for mitigating heat stress during mass participation running events like marathons is to schedule races for the coolest time of day and during cooler seasons of the year.[45] Training and working during cooler hours of the day, like early morning or late evening is necessary for proper acclimation. By avoiding warmer hours of the day, heat-related illness can be more easily avoided. In the northern hemisphere, early start times for marathons in conjunction with meteorological spring or autumn race seasons reduce the likelihood of high air temperatures and high solar loads and the same is true for winter races held in the southern hemisphere.[45]

Wearing proper attire according to the temperature forecast is also essential in order to avoid heat-related illness; runners need to wear sweat-wicking athletic wear. Runners need to prioritize hydration because as soon as the human body experiences dehydration, heat-related illnesses are much more likely to occur. Taking breaks and utilizing fans, mist, or air conditioning should be readily available options to cool the human body. Furthermore, runners as well as race event staff should all receive educational materials on the symptoms of heat-related illnesses so that detection may be swift, cooling tools may be used sooner rather than later, and significant bodily injury may be avoided while also saving lives. It is important to note that interventions for women may be designed around a common threshold or group level strategy as we found normally distributed PSI at various skin temperature while interventions for men should be more individualized as responses were widely distributed.

Many of the major marathon races involve large portions of participants to travel on long-haul flights that are often accompanied by jet lag in order to reach the race destination. Many of these traveling runners often arrive shortly before the race, which often inhibits preliminary

recovery and acclimatization to the local conditions.[46] Ideally, the heat acclimatization period should last two weeks in order to maximize adaptations by allowing time for certain processes like decreasing heart rate, skin and rectal temperature, increasing sweat rate, and work capacity.[47,48] In general, acclimatization to heat would involve short periods (approximately one to two hours) of heat-exposed exertion each day over a period of 10 to 14 days. This form of heat acclimatization has been shown to increase the body's ability to tolerate and dissipate heat in a healthy, non-dangerous way.[49] Furthermore, extensive flights can induce mild dehydration due to consumption of diuretic beverages, and low ambient humidity.[50] The process of heat acclimatization may vary depending on where runners reside and/or train compared to where the actual marathon race takes place, but making all participants informed would not only reduce liability, but likely prevent avoidable injuries and even save lives.

Although marathon races have been around for considerable time, there are still a portion of races that may not have recorded certain information like temperature, humidity, number of injuries, number of deaths, etc., since keeping detailed records of these factors is more of a modern trend. Data on the past history of adverse runner events at marathons is unavailable. Emergency room admissions or hospital discharge data would need to be collected and it may not contain information on the cause of the health emergency. Marathon race organizers are supposed to keep all these records including runner injuries and deaths each year. This study implores marathon race organizers to publicly publish every year's statistics and figures, especially documented heat-related injuries or hospitalizations runners experience at each race. The public health consideration behind this suggestion is to encourage information accessibility and transparency which would serve to inform others about this important data. This in turn would provide an opportunity for marathon races to uphold the public health ideals for everyone involved in these races by not only serving the marathon participants running the race, but also the course volunteers, staff, spectators, and emergency personnel who try to ensure a safe race for everyone involved. Publicly publishing this information would be extremely helpful to researchers because that the recorded data could be used to validate and compare to this model, which could yield concrete results based on the actual temperatures of prior races and the number of heat-related injuries seen at those marathons. Making this data readily accessible would also allow runners to realistically evaluate the risks they may experience, which could provide runners with a more informed pathway when deciding whether to commit to participating in a marathon race given the historical data combined with other factors, such as their training location and environment, especially if it differs from where the marathon race is actually held. Furthermore, this useful information could also help runners decide how to safely and effectively train for race day in the pivotal months leading up to the marathon.

CONCLUSION

The data from this model is clear that at WBGT when skin temperature is 33°C, both females and males do not show any runners registering a CBT reading greater than 38°C or experiencing physiological strain. However, when rise in WBGT increases skin temperature to ≥34°C, there is increasing risk CBT exceeding 38°C and experiencing physiological strain (PSI >7) in both gender but greater percentage of female runners are at risk. Lower resting heart rates in males compared to females across all levels of age and fitness possibly put them at lower risk when other variables are held constant. While physiological strain scores among female appears normally-distributed at various simulated skin temperatures, this distribution pattern is more uniform in male suggesting while group level preventive strategies may work for female, individualized approach may be necessary for males. To mitigate the heat related illness risks, implementing specific areas of a course with cooling fans, air conditioning, misting, or implementing temporary shade infrastructures could be very beneficial for runner safety. Race organizers and athletes alike should all receive recommendations for heat acclimatization - not just for race day, but in the training months leading up to the marathon race. Being as informed as possible is a key in order to prevent injury among marathon runners in adverse conditions. It is imperative to maintain exemplary record keeping of data for each marathon race in order to understand how environmental factors have been influencing human health during endurance activities and how the trends will continue into the future.

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