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How to Cope with High Temperature and Humidity – The Guidelines for Marathon Organizers

Guo Xinwei
Bangkokthonburi University, Thailand
E-mail: cpu119@163.com, ORCID ID: https://orcid.org/0009-0007-6133-6869

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Abstract

Background and Aim: With the rapid development of marathon sports, the host cities of marathon events have expanded from major cities in developed countries to various regions around the world, including many tropical towns and areas that hold marathon races during hot seasons. High temperatures and humidity pose significant threats to athletes' performance and health, increasing the risk of Exertional heat-related illness (EHRI). Therefore, event organizers face the great challenge of safely conducting marathon races under such conditions. Global sports organizations have proposed detailed plans and suggestions for medical services during marathon competitions, but these experiences are scattered across different categories of research, and there are no specific articles to guide organizers on how to deal with such an environment. This study aims to construct a set of guidelines for managing marathon competitions under high temperatures and humidity.

Materials and Methods: This study was summarized into a draft guideline through a literature review, including sports industry guidelines and other relevant research. More than 20 experts from China participated in two rounds of the Delphi method. These experts include athletes with more than 50 marathon race experience, coaches with more than 10 years of experience, medical personnel with more than 10 years of service experience, and organizers with more than 20 marathon race organization experience.

Results: The guidelines describe in detail, from 4 major aspects and six stages, a total of 37 points, what marathon organizers should do when dealing with high temperature and high humidity environments.

Conclusion: The contribution of this study lies in providing a systematic approach to help event organizers better manage marathon competitions under high temperatures and humidity, ensuring the health and safety of athletes. Through the Delphi method and expert reviews, the study ensures the scientific and practical nature of the guidelines, offering valuable references for marathon event organizers worldwide.

Keywords: Marathon; High Temperatures and Humidity; Event Management; Delphi Method; Athlete Health; WBGT; PESTLE; TQM

Introduction

The marathon has developed very quickly in the past 20 years. It has gradually developed from a niche/extreme sport to a mass fitness sport with a very wide range of enthusiasts. According to World Athletics, as of May 2024, marathon events with a distance of more than half a marathon were or will be held in 1060 cities across 134 countries and regions (World Athletics, 2024). The rate of arranging running events continues to rise by 24.54% per year (Ussahgij et al., 2021). Nowadays, the marathon has become one of the most popular sports events in the world.

As we all know, for long-distance endurance events, temperature and humidity are the important factors that affect athletes' performance. High temperature and humidity levels not only potentially compromised performance but also placed the athletes' health at risk (Zeiler & Shipway, 2020). Hot and humid ambient conditions limit heat dissipation capacity during exercise, thus impairing endurance performance and increasing the risk of exertional heat illness such as heat cramps, heat exhaustion, and heat stroke (World Athletics, 2020).

Even for the world's top athletes, overcoming the impact of extreme weather is a great challenge. In the women's marathon event at the Doha 2019 World Athletics Championships, 28 of the 68 starters withdrew in grueling conditions (World Athletics, 2019). Even though the beginning time was historically changed to midnight, the weather conditions still reached temperatures of 32 °C, with humidity reaching over 70% (Saj, 2019).

Global sports organizations, such as World Athletics, IOC, NCAA, UKA, and the Thailand Ministry of Tourism and Sports, have proposed detailed plans and suggestions for medical services during marathon

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competitions. They all emphasize that cooling and hydration are essential methods for reducing the risk of Exertional heat-related illness (EHRI).

However, these experiences are scattered across different categories of research, and there is no complete set of guidelines provided to marathon organizers on how to deal with high temperatures and humidity.

Objectives

The objective of the study is to construct the guidelines for managing a marathon competition under high temperatures and humidity. This set of guidelines can provide marathon competition organizers with guidance on what methods and experiences they can learn from when facing hot and humid weather. They choose those that suit their competition and avoid measures that consume manpower, material, and financial resources, but may not have much effect.

Literature review

This research mainly focuses on the management of marathon events and the impact of weather on competitions, especially the temperature and humidity. The following literature and research were studied:

1. Theoretical research

1.1 PESTLE analysis

PESTLE (**Political, Economic**, **Social**, **Technology**, **Legal, Environmental**) analysis is a tool for understanding external factors that can influence your business strategy and decisions.

For sports event organizations, especially in outdoor sports competitions, weather factors are the most direct factor. Weather & environmental conditions – temperature, humidity, precipitation (rain, snow, etc.), wind, exposure, ground conditions, and altitude. Particularly when weather and/or environmental conditions anticipated on the day will be significantly different from those the competitors will be acclimatized to in the training period in the months & weeks /months before the event are the critical factors required at any particular road race (UKA, 2013).

1.2 TQM (Total Quality Management)

Total Quality Management (TQM) is a continuous quality improvement method that involves all members of an organization, aiming to enhance the quality of products and services to meet customer needs and expectations. The concept of TQM first appeared in Japan and promoted the development of Japan's manufacturing industry in the 1970s. In the 1980s, the United States Naval Air Systems coined TQM, whose principles were founded on the Japanese TQC (McDaniel & Doherty, 1990).

TQM emphasizes a systematic approach and continuous improvement process throughout the organization. Its core principles include **Customer Focus, Total Employee Involvement**, **Process Management, Systematic Thinking, Continuous Improvement, and Data-Driven Decision Making.**

For marathon event organizations, “Data-Driven Decision Making” is the most basic criterion. It is necessary to refer to historical climate data when selecting a competition date; the application of the WBGT index allows competition organizers to have a more intuitive and data-based judgment on weather conditions to determine whether the competition can proceed as planned or needs to be interrupted due to the deterioration of weather conditions.

2. Method research

2.1 Delphi Method

The Delphi method offers an opportunity to produce new knowledge and seek a resolution to persistent problems by documenting the views of experts and stakeholders. By collecting knowledge among a group of professionals to better understand complex problems in rapidly changing environments, the Delphi technique can support new ways of thinking about problems and potential solutions (Habibi et al., 2014). Key features of the Delphi Method:

Expert anonymity: Expert anonymity participation helps reduce the influence of the leading figure and allows for unbiased input. In the Delphi technique, the experts and people who use the survey do not

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know each other. Anonymity ensures overcoming the obstacles of groupthink. A coordinator collects the experts' opinions, and then he/she provide other members with the summarized results. Then, based on the summarized results in the previous step, individuals again adjust and express their opinions. Finally, after reaching a consensus, the results are discussed in terms of a statistical report (usually mean or median) and are used for decision-making (Habibi et al., 2014).

Iteration: This process involves multiple rounds of questionnaire surveys. The iterative process could potentially go on forever until consensus is achieved. Traditionally, there are three rounds (Connell, 2023). Experts answer a series of questionnaires, and after each round, the coordinator provides a summary of expert predictions and reasons.

Control feedback: After each round, the coordinator provides an anonymous summary of expert predictions and reasons. This feedback helps the expert reconsider their previous answers.

Statistical summary of group response: Summarize the response statistics to reach a consensus or reflect the scope of opinions.

3. Related research

3.1 Definition and measurement of high temperatures and humidity

As we know, air temperature alone is not an accurate index of climatic heat stress. Radiant energy, wind speed, and humidity also contribute to climatic heat stress. Therefore, WBGT (the Wet Bulb Globe Temperature) is widely used in outdoor sports and labor. It consists of three thermometers: a dry bulb (Tdb) for air temperature, a wet bulb (Twb) for relative humidity, and a black globe (Tg) for solar radiation.

The Wet Bulb Globe Temperature (WBGT) =

(0.7 x Twb) + (0.1 x Tdb) + (0.2 x Tg) (Outdoor or environments with sunlight radiation)

(0.7 x Twb) + (0.3 x Tdb) (Indoor or no sunlight environment)

Table 1 We can more intuitively see the relationship between the WBGT index and temperature and humidity.

Relative humidity (%) \ Temperature (°C)	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	15	16	16	17	18	18	19	19	20	20	21	22	22	23	23	24	24	25	25	26	27	27	28	28	29	29	30	31	31
5	16	16	17	18	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	27	28	29	29	30	31	31	32	33	33
10	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29	30	30	31	32	32	33	34	35	36
15	17	17	18	19	19	20	21	21	22	23	23	24	25	26	26	27	28	29	29	30	31	32	33	33	34	35	36	37	38
20	17	18	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	31	32	32	33	34	35	36	37	38	39	
25	18	18	19	20	20	21	22	23	24	24	25	26	27	28	28	29	30	31	32	33	34	35	36	37	38	39			
30	18	19	20	20	21	22	23	23	24	25	26	27	28	29	29	30	31	32	33	34	35	36	37	39					
35	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39						
40	19	20	21	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39							
45	19	20	21	22	23	24	25	26	27	27	28	29	30	32	33	34	35	36	37	38									
50	20	21	22	23	23	24	25	26	27	28	29	30	31	33	34	35	36	37	39										
55	20	21	22	23	24	25	26	27	28	29	30	31	32	34	35	36	37	38											
60	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38												
65	21	22	23	24	25	26	27	28	29	31	32	33	34	36	37	38													
70	22	23	24	25	26	27	28	29	30	31	33	34	35	36	38	39													
75	22	23	24	25	26	27	29	30	31	32	33	35	36	37	39														
80	23	24	25	26	27	28	29	30	32	33	34	36	37	38															
85	23	24	25	26	28	29	30	31	32	34	35	37	38	39															
90	24	25	26	27	28	29	31	32	33	35	36	37	39																
95	24	25	26	27	29	30	31	33	34	35	37	38																	
100	24	26	27	28	29	31	32	33	35	36	38	39																	

Table 1 Wet bulb globe temperature based on temperature and relative humidity. (Values are derived from an approximate formula that depends on temperature and humidity, and that is valid for full sunshine and a light wind. Heat stress may be overestimated in other conditions.) (MSD MANUAL, 2023)

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Table 2 A corresponding colored flag system can be used to visually signal the thermal injury risk of current weather conditions to competitors and spectators (World Athletics, 2020).

Heat Index (WBGT)		Comment
Temperature in ℃	Temperature in °F	
Above 30℃	**Above 86F**	**Danger**
28℃ to 30℃	82,4°F to 86°F	Severe Warning
25℃ to 28℃	77°F to 82.4°F	Warning
21℃ to 25℃	69.8°F to 77°F	Caution
Below 21℃	Below 69.8°F	Almost Safe

3.2 The threats posed by high temperatures and humidity

Long-distance endurance exercise or competition in high temperatures and humidity environments often results in the following symptoms: muscle cramping, unsteadiness (unable to stand or walk without assistance), confusion, vomiting, irritability, pale or flushed skin, rapid, weak pulse, high body temperature, nausea, headache, dizziness, disturbances of vision and fainting. If not treated properly, it may even endanger life. The above symptoms are collectively referred to as **Exertional heat-related illness (EHRI).**

Table 3 The most common EHRI types: EAC (exercise-associated collapse), EAMC (exercise-associated muscle cramps, EHS (exertional heatstroke), and HE (heat exhaustion). (Nichols, 2014).

Condition	Core temperature	Associated symptoms
Heat Edema	Normal	None
Heat Rash	Normal	Pruritic rash
EAC (Exercise-Associated Collapse)	Normal	Dizziness, generalized weakness
EAMC (Exercise-Associated Muscle Cramps)	Normal to <40℃	Painful muscle contractions
HE (Heat Exhaustion)	Normal to 40℃	Dizziness, malaise, fatigue, nausea, vomiting, headache
EHS (Exertional Heatstroke)	>40℃	Possible history of HE symptoms before the onset of MS changes
ER (Exertional rhabdomyolysis)	Normal to > 40℃ (if with EHS)	Severe muscle pain, ±EHS, often associated with “novel over-exertion”
EAH (Exercise-Associated Hyponatremia)	Normal to 40℃	Peripheral edema, possible history of HE symptoms before onset of MS changes

Among various types of EHRI, the most common and harmful ones are as follows:

3.2.1 Exertional heatstroke (EHS)

The most severe form of EHRI is exertional heat stroke (EHS). It’s characterized by a core body temperature above 40.5 ℃ associated with central nervous system dysfunction (delirium, convulsions, coma) (Bouscaren et al., 2021). According to the NCAA (2014), all these signs and Symptoms are related to EHS: Muscle cramping, decreased performance, Unsteadiness, Confusion, Vomiting, Irritability, Pale or flushed skin, Rapid, weak pulse, High body temperature, Nausea, Headache, Dizziness, Unusual fatigue, Sweating has stopped, Disturbances of vision, Fainting (NCAA, 2014).

3.2.2 Heat Exhaustion (HE)

Heat exhaustion (HE) is the most common form of EHRI and is characterized by hypotension and cardiovascular insufficiency in persons who become dehydrated while exercising in conditions of environmental heat stress. Symptoms include nausea and vomiting, tachycardia, dizziness, muscle cramps, energy depletion, central fatigue, and syncope (Nichols, 2014).

3.2.3 Exercise-associated collapse (EAC)

Exercise-associated collapse (EAC) may be defined as an event in which the conscious athlete is unable to stand or walk without assistance because of lightheadedness, faintness, dizziness, or syncope.

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EAC characteristically presents after a bout of strenuous physical activity and accounts for 59 %–85 % of medical visits to marathon, ultra-marathon, and distance triathlon medical tents. The incidence of EAC increases with higher ambient temperatures, humidity levels, and levels of dehydration (Nichols, 2014).

3.2.3 Exercise-associated muscle cramps (EAMC)

Exercise-associated muscle cramps (EAMC) typically affect the larger skeletal muscles during or after exercise in the heat. Although EAMC is usually associated with excessive sweat losses, the individual is not necessarily overheated, and if so, the core temperature does not exceed 40 ℃. Muscle twitches occur initially, with progression to severe and widespread muscle spasms. Muscle fatigue, dehydration, high sweat rates, and high sodium sweat concentrations predispose to EAMC (Nichols, 2014).

3.3 What should the organizers do

When the injury caused by high temperature and humidity has already occurred, the treatment will normally include rest, protection from further heat exposure (in shaded treatment facilities), provision of fluids, and cooling (ice treatment). In hot weather conditions, adequate supplies of ice must be provided at treatment facilities. But more importantly, how to avoid harm as much as possible through early preparation:

3.3.1 Select a reasonable event date and time.

World Athletics (2020) pointed out that the medical setup for an Out-of-Stadium endurance event should consider environmental conditions (ambient temperature, humidity, WBGT, altitude, wind speed and direction, hours of sunrise and sunset, air pollution levels)

In Thailand, organizers of running events are required to consider the weather conditions in each area. (such as temperature, Relative humidity, etc.) The time of day puts participants at risk from Minimal heat (Thailand Ministry of Tourism and Sports, 2019).

3.3.2 Medical service and preparation

The medical services should include medical stations, ambulances, and team members, including a responsible doctor with a team of assistants who have been trained in emergency resuscitation courses (Sports Medicine). The implementation should be specified: ice cold water and hot water, blankets, patient beds, necessary medical supplies, an External defibrillator (AED), and other emergency medical equipment (Thailand Ministry of Tourism and Sports, 2019).

3.3.3 Information communication

Before the competition, organizers should issue announcements detailing the current weather conditions and the anticipated forecast. The race medical team, comprised of personnel stationed at aid stations and medical volunteers, should be prepared to promptly address any changes in weather conditions. Color-coded WBGT/PET index flags for heat stress should be displayed prominently at the start area and announced in the pre-race weather announcement. Color-coded flags can be placed at selected aid stations along the course to alert runners of changing conditions (World Athletics, 2020).

3.3.4 Recommended supply while running in a heat and humid environment

Marathon is a sport that involves long-distance running; therefore, preparing beverages or nutrients to reduce sweating is very important. Beverage service points provide sufficient energy alternatives for marathon participants (Thailand National Institute of Emergency Medicine, 2019).

Zeiler and Shipway (2020) highlight that cold fluid has a heat-lowering effect compared to a drink with a more neutral temperature, thus reducing the effects of thermal stress on the body and extending the time taken to reach an exercise-limiting core temperature.

Faced with high temperatures, Thai event organizers said, “We prepared more ice to make cold water, and we provided mist stations. And as we shifted from day to night run, we used a fire engine to cool down the road” (Jantori & Pongponrat 2022).

3.3.5 Treatment while a heat-related illness is coming

Treatment will normally include rest, protection from further heat exposure (in shaded treatment facilities), provision of fluids, and cooling (ice treatment). In hot weather conditions, adequate supplies of ice must be provided at treatment facilities (UKA, 2013)

For heat exhaustion (HE), Optimum medical support for elite and mass-road race events should be to ensure a continuous and adequate supply of sealed drinks (e.g., water, etc.) along the race and to ensure cold water immersion treatment is available throughout the course and at the finish line.

To reduce the severity of EHS, immediate cooling of the entire body with an ice bath. Or use a cool cloth to quickly wipe the body, arms, legs, and head, and apply ice to the neck, armpits, and groin (Meepradit & Nakmon, 2023).

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Generally, cold-water immersion via a tub or shower to rapidly cool the core body temperature and skin temperature is highly effective, but not always practical (Malcolm, 2019).

To treat EAMC (Exercise-associated muscle cramps). Single spasms respond to stretching the relevant muscle, often best achieved by assisted walking.

4. Summaries of related literature

Through the review of existing literature, it was found that more literature discusses the adaptability training of high-level athletes to such conditions, and less literature focuses on the management of the marathon event. Most of the valuable pieces come from sports organizations and sports associations, such as World Athletics, Thailand and UK Athletics, NCAA, and ITU.

Nevertheless, there are many valuable views and opinions on the management of marathon events in high temperatures and humidity from the perspectives of participating athletes and event observers, such as the importance of information communication and the implementation of cooling strategies.

Global sports organizations have proposed detailed plans and suggestions for medical services during marathon competitions, emphasizing that cooling and hydration are essential methods for reducing the risk of Exertional heat-related illness (EHRI).

However, these experiences are scattered across different categories of research, and there is no complete set of guidelines provided to marathon organizers on how to deal with heat and humidity.

Conceptual Framework

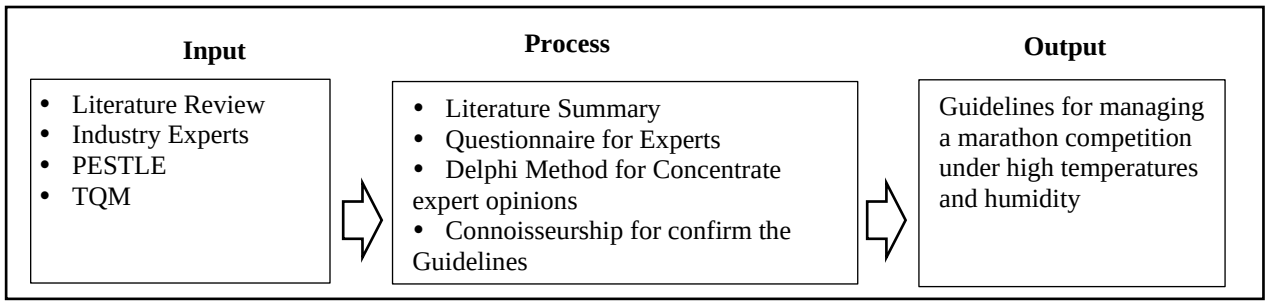
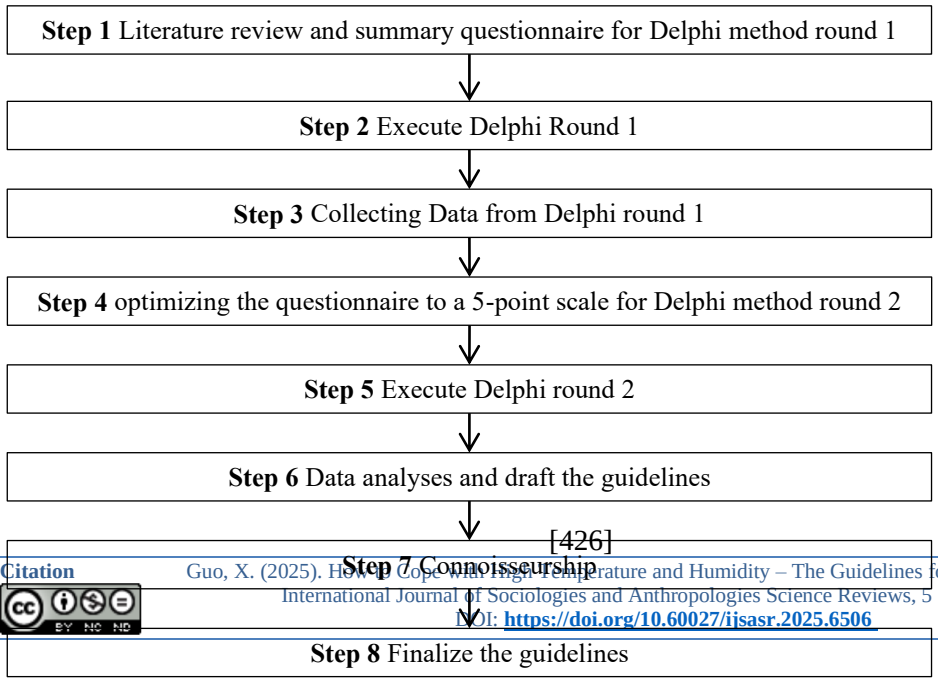


Figure 1 Conceptual Framework

Methodology

Because of the lack of systematic research on how event organizers cope with high temperatures and humidity, this study involved the Delphi method to collect and refine the opinions of experts in related fields to achieve the ultimate goal of this research: to construct guidelines for managing a marathon competition under high temperatures and humidity.

1. Research process



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2. Population and sample

2.1 Population

In 2023, more than 85 sports companies were operating full or half-marathon running events with a scale of 1000 people or more, involving more than 385 events. The most experienced marathon organizers and medical personnel work in these 85 companies, and the number of core personnel shall not exceed 500 people (Running Zero Distance, 2023). The organizers and medical personnel will be sampled from this field.

According to statistics from the China Athletics Association (2023), in 2023, a total of 293200 people completed the full marathon, and 833100 people completed the half marathon. Among them, there were 80500 elite runners (the standard for elite athletes is the evaluation standard for the China Athletics Association), with an average of 1.88 comprehensive races per person. The sample will be taken from these Chinese elite athletes. And the coaches will be snowballed by these experienced athletes.

2.2 Sample

For the first round of the Delphi method, a total of 19 participants will be recruited:

Six experienced athletes will be selected by convenience sampling techniques from runners' groups with at least 50 matches.

Three coaches will be snowball-recommended by the athletes above, with at least 10 years of experience.

Seven organizers will be selected by convenience sampling techniques from professional event-management forums with at least 20 match-organizing experiences.

Three medical professionals will be snowball-recommended by the organizers above with at least 10 years of experience.

For the second round of the Delphi method, nine experts were involved. For the Connoisseurship stage, a total of 9 experts were involved.

3. Data Analysis

Median (**Mdn**) and Interquartile Range (**IQR**) will be collected and analyzed in the Delphi stage. When Mdn>3.5 and IQR<1.5, the Delphi will finish.

4. Data statistics tools

4.1 A mini program, “wenjuanxing,” will be used for data collection from the experts.

A mini program is a quick application built on a widely used software platform. It does not need to be downloaded and installed in advance. A mini program application could be launched by scanning the QR code or platform link.

The mini program “Wenjuanxing” is based on the WeChat platform, which was developed by Tencent, one of the most successful Chinese High-tech companies. It’s a professional online questionnaire survey, examination, evaluation, and voting platform. It integrates multiple data statistical models and algorithms and can provide users with a series of services such as powerful and user-friendly online questionnaire design, data collection, customized reports, and survey result analysis.

For this study, “Wenjuanxing” provides the online questionnaire and systematically provides the results.

4.2 Microsoft Excel will be used for statistics and the calculation of data results.

Results

1. Data results of the Delphi Method round 1

Through a literature review, 37 key issues in 6 aspects were summarized and written into a questionnaire for the Delphi round 1. According to the results of the experts’ questionnaire, 5 out of the 37 questions had an IQR over 1.5, and one question had an Mdn less than 3.5. Therefore, these five questions will be moved out from the questionnaires of Delphi round 3:

Table 4 Statistics of Delphi round 2, O: Opinion, √: have an additional opinion or discuss.

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No.	Mdn	IQR	O	No.	Mdn	IQR	O	No.	Mdn	IQR	O
1	5.00	0.00		**2**	5.00	0.00		**3**	5.00	1.00	
4	5.00	1.00		**5**	5.00	1.00		**6**	5.00	1.00	√
7	5.00	2.00	√	**8**	5.00	0.00		**9**	5.00	1.00	
10	5.00	1.00		**11**	5.00	1.00	√	**12**	5.00	0.00	√
13	5.00	0.00		**14**	5.00	1.00	√	**15**	4.50	1.00	
16	4.00	1.00	√	**17**	5.00	0.75		**18**	5.00	1.00	
19	5.00	1.00	√	**20**	3.00	2.00	√	**21**	5.00	1.00	√
22	5.00	1.00		**23**	5.00	0.00		**24**	5.00	1.00	√
25	5.00	1.00	√	**26**	5.00	0.00		**27**	5.00	0.00	
28	5.00	0.00	√	**29**	5.00	1.00	√	**30**	5.00	1.00	√
31	4.00	2.00	√	**32**	5.00	0.00		**33**	5.00	1.00	
34	4.00	2.00		**35**	4.00	1.75		**36**	4.00	1.00	
37	5.00	1.00	√								

2. Data results of the Delphi Method round 2

In Delphi round 3 of a questionnaire survey, all questions got "5" in the median. None of them got a score larger than 1.5 in IQR.

3. Data results of Connoisseurship

The experts did not raise objections to the existing guidelines but provided supplements and improvements to some items. Experts' opinions were added to the guidelines.

Table 5 Statistics of Connoisseurship, F frequency, P percentage.

No.	F	P	No.	F	P	No.	F	P	No.	F	P	No.	F	P	No.	F	P
1	0	0%	2	0	0%	3	0	0%	4	0	0%	5	0	0%	6	4	28.6%
7	3	21.4%	8	0	0%	9	0	0%	10	0	0%	11	0	0%	12	0	0%
13	2	14.3%	14	0	0%	15	0	0%	16	1	7.14%	17	0	0%	18	0	0%
19	0	0%	20	1	7.14%	21	0	0%	22	0	0%	23	0	0%	24	0	0%
25	0	0%	26	0	0%	27	0	0%	28	0	0%	29	0	0%	30	0	0%
31	0	0%	32	0	0%	33	2	14.3%	34	0	0%	35	0	0%	36	0	0%
37	1	7.14%															

Experts expressed strong affirmation of No.7, No.16, No.20, No.33, and No.37 and put forward suggestions for optimization of the content of No.6 and No.13. Therefore, in the final version of the guide, the contents of No.6 and No.13. have been optimized and adjusted.

4. The final edition of the guidelines

Table 6 final edition of the guidelines.

The final edition of the guidelines	
Section 1: The definition, measurement standards, and main risks of high temperature and high humidity	
No.1	High temperatures and high humidity threaten the athletes' health in marathon competition.
No.2	The most common EHRI types are EAC, EAMC, EHS, and HE. The real high risk is EHS.
No.3	EHS and EAC are not necessarily caused by the thermal environment. Long-distance and prolonged exercise may also cause EHS and EAC without high temperature and humidity.

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No.4	Temperature alone is not an adequate measure of thermal stress; a more comprehensive metric is needed. The **WBGT** index is the most common industry standard that meets most of the requirements of marathon organizers.
No.5	According to World Athletics, the risks that come from heat stress are divided into three levels: "**Caution**": WBGT above 21°C; "**Warning**": WBGT above 25°C; "**Danger**": WBGT above 30°C. Terminating the match becomes a possible option.
No.6	Circuit breaker mechanism for severe weather conditions should be conducted: When WBGT expects/will or has reached "dangerous" levels, competitions should be postponed\cancelled or terminated.
Section 2: Planning stage for the event: The consideration of event location, time, course, and objectives	
No.7	If the event is held in a non-tropical area, the event should be scheduled during a non-hot season. If the event is likely to encounter high temperatures, it should be scheduled during the coolest time of the day.
No.8	If the event is to be held in tropical regions, the event should be scheduled during the cooler season.
No.9	If the event is taking place in a hot environment, Organizers should inform athletes of possible weather conditions during the event registration stage.
No.10	The starting and finishing areas should be large enough to accommodate adequate medical points, drinking water points, and post-race stretching and massage areas.
No.11	The starting area should be large enough to leave enough space for athletes to stand without being too crowded.
No.12	If there may be strong sunshine at the end of the race, try to arrange the finished service and rest areas indoors with sufficient area and guaranteed electricity, air conditioning, and ventilation.
No.13	Make it clear whether the objective of the event is more for high-level competition or more for mass entertainment. If it is for high-level competition, try to avoid arranging the event in areas or seasons with high temperatures and humidity. If it is for mass entertainment, participants should be educated through various channels: 1. Lower expectations for competition results; 2. Fully understand the weather conditions for the game; 3. Carry out pre-competition adaptive training; 4. Fully understand the organizers' preparations to reduce risks, including medical treatment, supplies, cooling measures, and post-game recovery services 5. Educate athletes on the early symptoms, risks, and treatment methods of EHRI
Section 3: Preparation stage for the event: Medical service for high temperature and high humidity	
No.14	Set up medical stations at the start and finish area, and set up medical points along the race route.
No.15	According to the weather risk level, set up ambulances and medical teams that are more abundant than the recommendations and requirements of the World Athletics or local sports management agencies.
No.16	AED: Arrange enough AEDs at medical stations and points, and arrange mobile AEDs along the race route with experienced and qualified medical personnel or volunteers who can use them.
No.17	In addition to basic medical supplies, all medical stations should also be equipped with ice or ice water for body cooling, provide drinking water-electrolyte drinks, and provide medicines or sprays for treating EAMC (exercise-induced cramps). The main medical stations and finish areas are equipped with bathtubs or pools wherever possible.
No.18	Establish cooperation with capable hospitals to ensure that injured athletes receive proper treatment.
No.19	Establish cooperation with rescue agencies, such as First Aid, etc., to obtain sufficient rescue human resources.
No.20	Provide first aid training to volunteers to ensure that athletes in need of help are identified as early as possible and the fastest and most appropriate treatment methods are used.

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No.21	According to the prediction of the track temperature during the competition, sprinkler facilities will be deployed on the route. If necessary, ice water or water cooled by ice will be used to provide cooling assistance to athletes.
Section 4: Preparation stage: Information and Education	
No.22	If possible, it is recommended to use a WBGT-based color code or color marking system to indicate risk levels, so WBGT thermometers need to be placed along the race route to obtain weather data at any time.
No.23	Starting one week before the competition, provide detailed weather forecasts for the competition period to all staff and participants in any possible way, and keep them updated.
No.24	Organizers should brief athletes before the race on all preparations and measures taken to reduce high temperature and humidity risks, including but not limited to: 1. Lower expectations for competition results; 2. Fully understand the weather conditions for the game; 3. Carry out pre-competition adaptive training; 4. Fully understand the organizers' preparations to reduce risks, including medical treatment, supplies, cooling measures, and post-game recovery services 5. Educate athletes on the early symptoms, risks, and treatment methods of EHRI
Section 5: Event day: Medical service and communication	
No.26	If the WBGT color code or color marking system is used, make sure the system is working properly.
No.27	When necessary and by any means possible, provide all staff and competitors with detailed weather descriptions and weather change reports during the competition, especially if there are significant changes in weather conditions.
No.28	Get competition officials, medical personnel, rescue personnel, and volunteers to work early and ensure they are available for work during the competition.
No.29	Ensure that ambulances, AEDs, and other medical emergency equipment arrive or are placed in designated locations before the competition, and ensure that this equipment and facilities can be used normally.
No.30	Ensure smooth communication between event officials and medical personnel, rescue personnel, and volunteers.
No.31	Since the peak period for medical problems related to high temperature and humidity changes in time and location, medical and first aid resources should be deployed according to the time and location of the peak period, and have the ability to dynamically deploy and adjust
Section 6: Supplies should be provided to help athletes reduce the risk of high temperatures and humidity	
No.32	Provide more drinking water: Depending on the location of the water station, provide at least 150-330ml mL of drinking water for each athlete at each water station.
No.33	Provide ice for cooling the body, drinking water, and shower water.
No.34	Sponge for body cooling
No.35	Sports drinks, electrolyte drinks
No.36	Mineral salt/Salt food
No.37	Make full use of the sprinkler to cool down the athletes. The sprinkler station (including the fog cannon) should be arranged in front of the water station to reduce the consumption of drinking water. If possible, use water that has been properly cooled by ice to provide a sprinkle.

Discussion

Marathon organizers are responsible for creating safe race conditions, maintaining order, and overseeing the event. However, they cannot control athletes' actions on the course, where athletes play the leading role. Numerous studies and experts have outlined specific adaptive training methods to help athletes prepare for high-heat, high-humidity races. For professional athletes, environmental acclimatization is an essential skill for both safety and performance. However, outside of elite events like the Olympics or World

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Championships, most participants in large marathons are recreational runners with less sensitivity to weather variations, limited time, and inadequate adaptive training. Many are even unaware of basic hydration strategies. Thus, providing timely and clear information to all participants about anticipated weather conditions is the most important responsibility of the organizing committee.

This study focuses on the organization and management of marathon events, but there are many sports with similar risks, such as triathlons, cycling, trail running events, and even half-marathons or running events less than half-marathons. To be sure, if these competitions are studied, more good experiences and methods will be found. Also, the organizers can refer to the guidelines proposed in this study to provide the greatest safety guarantee to the athletes when they face high temperatures and humidity,

The scope of this research is limited to China and Thailand. Many other countries and regions in the world also face the same problem, such as other countries in Southeast Asia, the Middle East, and Central and Southern Europe. If it is possible to communicate with experts and event organizers from more countries, we can gain more experience and get more inspiration.

Conclusion

After three rounds of research, voting, suggestions, and opinions from 25 experts, and Connoisseurship from 9 experts, this study produced "the guidelines for managing a marathon competition under high temperature and humidity." The guidelines describe in detail, from 4 major aspects and six stages, a total of 37 points, what marathon organizers should do when dealing with high temperature and high humidity environments. According to the opinions of all experts participating in Connoisseurship, if this set of guidelines can be fully applied, it will effectively reduce the risks brought by high temperatures and humidity to competitions while ensuring that athletes can perform as best as possible under difficult weather conditions.

Limitations and Recommendations

The scope of this research is limited to China and Thailand. Many other countries and regions in the world also face the same problem, such as other countries in Southeast Asia, the Middle East, and Central and Southern Europe. If it is possible to communicate with experts and event organizers from more countries, we can gain more experience and get more inspiration.

For a management guide, the best way to prove its effectiveness is to put it into practice. This study adopted the method of literature research and expert interviews (Delphi method). If there is an opportunity, it will be very valuable to fully apply this set of guidelines in actual competitions and make before-and-after comparisons.

At the same time, technological progress is also an important driving force for improving management methods. If, in the future, there are effective human body cooling methods, more scientific training methods, and more effective medical treatment, research on this topic will enter a new stage.

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