Forecasting feels-like temperatures as a strategy to reduce heat illnesses during sport events

Milan Klöwer ,[1,2] Pascal Edouard ,[3,4] Andreas M Niess ,[5] Sebastien Racinais ,[6] Yannis P Pitsiladis ,[7] Florian Pappenberger ,[8] Karsten Hollander [9]

Many athletes, amateur and professional alike, compete in and train for outdoor running events every year, and even more participate in outdoor sports in general. Many major sport events such as the Summer Olympic and Paralympic Games and World Championships take place in summer and mostly in the Northern Hemisphere. Therefore, athletes are often at risk of sustaining heat illnesses during heat extremes, which are exacerbated by climate change.[1]

Heat illnesses describe a group of pathologies ranging from relatively minor to very severe symptoms such as potentially fatal exertional heat stroke.[2 3] The risk for heat illnesses increases with high air temperature, high solar radiation, high humidity, low wind speed and strenuous exercise requiring continuous muscle work.[4] There are different strategies to prepare athletes for exercising in the heat, and thus reduce the risk for heat illnesses including acclimatisation, acclimation, hydration and cooling strategies.[5] However, to properly implement those strategies, the forecasting of the environmental conditions prior to the event is paramount, but the timing of the forecasting depends on the strategy to be implemented.

Anticipation of the expected temperature can be done by the consultation of a location's climate data from recent decades.[6] The latest International Olympic Committee consensus statement on sport events in the heat recommends that bidding cities provide retrospective weather data for the 10 previous years and proactively measure environmental conditions at the respective competition venues.[5] However, the variability of weather superimposed on a location's climate is often too large for adequate anticipation and preparation weeks in advance. Most weather forecasts for a general audience quantify air temperature and include cloud cover, precipitation or strong winds qualitatively. But air temperature must be combined with solar radiation, humidity and wind to quantify more accurately the heat stress a human body is physiologically exposed to. This helps to interpret a forecast, for example, 'It will feel 3°C warmer because of high humidity, but a breeze will cool it down by 5°C in the afternoon.'

Different indices are used to quantify what temperatures physiologically feel like which we describe together as feels-like temperatures. These include the windchill index which lowers the effective temperature due to high winds; the heat index which is increased due to high humidity; the Wet-Bulb Globe Temperature which combines wind, humidity and solar radiation and is typically measured directly with a device; and the Universal Thermal Climate Index (UTCI) that has been applied to past data from weather forecast models to quantify a feels-like temperature at about 25 km resolution globally.[7]

For the Olympic and Paralympic Games in Tokyo in 2021, we ran an experimental forecast of a feels-like temperature, quantified as UTCI (figure 1). The Twitter bot @HeatForecast was set up to illustrate and test how heat illness-relevant weather information can be communicated directly to end-users like athletes and their teams. In collaboration with the European Centre for Medium-Range Weather Forecasts, we analysed their operational forecast once a day within hours of its release: The UTCI and its contributions from wind, radiation and humidity were predicted up to 10 days ahead, published as a meteogram for Tokyo and Sapporo. The forecast was later verified with direct measurements from the race walking and Marathon events in Sapporo (figure 1).

A forecast of a feels-like temperature can provide vital information to athletes, coaches, physicians and organisers, as it can allow them to adjust strategies in the final preparation of the event. Going forward, weather forecast centres and sport medicine professionals have to work closely together in order to determine the most appropriate indices and presentation formats. While weather forecasts are operationally produced at ~9 km global resolution, several times a day up to 15 days ahead, a feels-like temperature is typically not analysed or provided. A meteogram, as presented here, can be implemented into the operational weather forecast chain, providing a heat forecast for specific sport events, but also continuously for any location in general. Forecast uncertainties should be communicated and for an easily understandable presentation, transparency or categories like 'best-case' and 'worst-case rain' can be used (figure 1).

More research is needed to better understand which feels-like temperature is most applicable to quantify the risk of heat illnesses, in sport but also in general. For major athletics outdoor events over the last decade, the heat illness risk doubled for each 10°C increase in UTCI.[4] Sports medicine professionals, exercise physiologists and coaches should agree on and propose operational forecasts of a feels-like temperature and general heat-related information that are physiologically and clinically relevant.[5] This will help athletes and medical teams to optimally prepare and reduce the risk of heat illnesses threatening the athletes' health and performance. This forecast would be especially crucial in the days before the competition to reduce the risk of a heat illness through hydration, pacing, precooling and per-cooling strategies or even to change starting times, as was done in the Olympic women's marathon in Sapporo. In addition, if made freely available, such a forecast may also be used by recreational and leisure time athletes to reduce their risk of heat illnesses during their sports.

Weather forecasts produce large amounts of data, but often one of the main obstacles is effective communication. An operational forecast of feels-like temperatures will be a helpful tool in the anticipation of expected conditions during sport events and generally

[1]Atmospheric, Oceanic, and Planetary Physics, University of Oxford, Oxford, UK
[2]Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA
[3]Inter-university Laboratory of Human Movement Biology (EA 7424), Université Jean Monnet, Lyon 1, Université Savoie Mont-Blanc, Saint-Etienne, France
[4]Department of Clinical and Exercise Physiology, Sports Medicine Unit, University Hospital of Saint-Etienne, Faculty of Medicine, Saint-Etienne, France
[5]Department of Sports Medicine, University Hospital of Tuebingen, Tuebingen, Germany
[6]Research and Scientific Support, ASPETAR - Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar
[7]School of Sport and Health Sciences, University of Brighton, Eastbourne, UK
[8]European Centre for Medium Range Weather Forecasts, Reading, UK
[9]IInstitute of Interdisciplinary Exercise Science and Sports Medicine, MSH Medical School Hamburg, Hamburg, Germany

Correspondence to Professor Karsten Hollander, Institute of Interdisciplinary Exercise Science and Sports Medicine, MSH Medical School Hamburg, Hamburg, Germany; karsten.hollander@medicalschool-hamburg.de

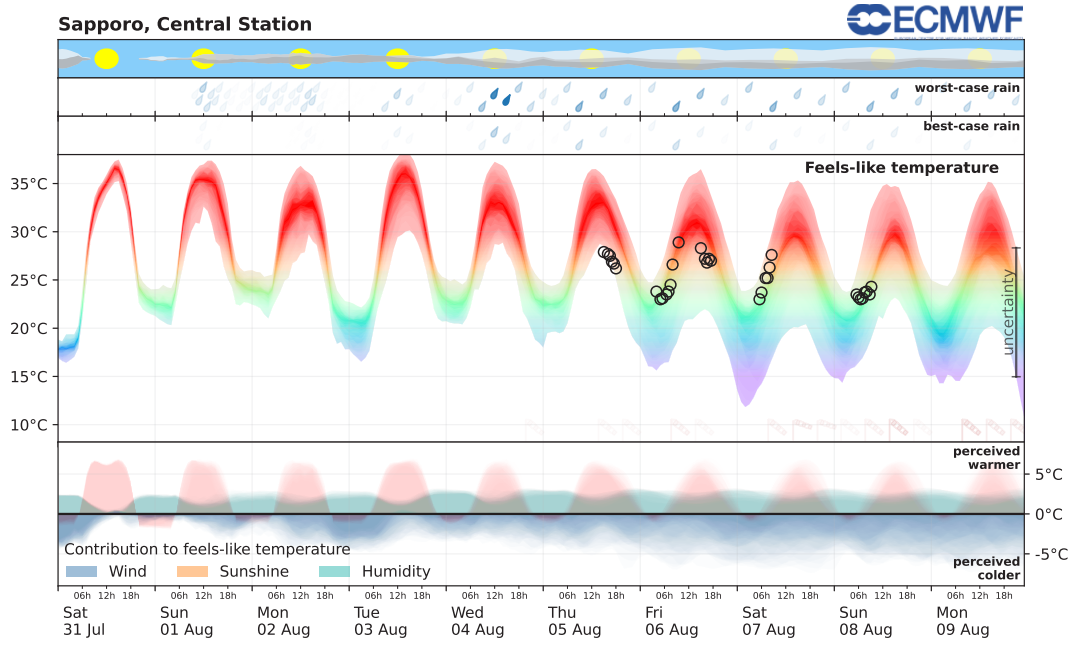

Figure 1 A heat forecast meteogram for the race walking (5–6 August) and Marathon events (7–8 August) in Sapporo, Japan, during the Tokyo Olympic Games in Summer 2021. This forecast was published by the Twitter bot @HeatForecast on 31 July for the weather of the 10 upcoming days. In the present figure, we have overlaid the measurements (Thermohygrometer TC100, Tretec, Germany) from the finish area in Sapporo during the respective events (black circles) afterwards. The panels show cloudiness, rain, the feels-like temperature UTCI, strong wind and contributions to UTCI from wind, radiation and humidity. The uncertainty of the forecast is visualised: for precipitation with the best-case and worst-case possible rain (10th and 90th percentile of the forecast ensemble); for UTCI and its contributions using transparent shading; for wind using transparent wind socks. The Twitter bot uses 'feels-like temperature', 'rain' and 'sunshine' instead of UTCI, precipitation and solar radiation to avoid confusion with a non-scientific audience. UTCI, Universal Thermal Climate Index.

any outdoor activity. In a warming climate, humans will be increasingly exposed to heat they might not anticipate nor are acclimatised for. Informing them about expected high feels-like temperatures may be of considerable benefit to their health.

Correction notice This article has been corrected since it published Online First. The acknowledgement statement has been updated.

X Milan Klöwer @milankloewer, Pascal Edouard @PascalEdouard42, Sebastien Racinais @ephysiol, Florian Pappenberger @FPappenberger and Karsten Hollander @k_hollander_

Acknowledgements We appreciate the comments of three anonymous reviewers that have considerably helped to improve the manuscript.

Contributors MK, PE and KH were responsible for the concept. MK and KH were responsible for the drafting of the manuscript. All authors had substantial contributions to the collection and interpretation of the data, revising the draft and approved the submission of this manuscript.

Funding MK gratefully acknowledge funding from the European Research Council under the European Union's Horizon 2020 research and innovation programme (ITHACA grant no. 741112).

Competing interests None declared.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

To cite Klöwer M, Edouard P, Niess AM, *et al*. *Br J Sports Med* 2023;**57**:564–565.

Accepted 13 February 2023
Published Online First 7 March 2023

Br J Sports Med 2023;**57**:564–565.
doi:10.1136/bjsports-2022-106413

ORCID iDs
Milan Klöwer http://orcid.org/0000-0002-3920-4356
Pascal Edouard http://orcid.org/0000-0003-1969-3612
Andreas M Niess http://orcid.org/0000-0002-6145-7069
Sebastien Racinais http://orcid.org/0000-0003-0348-4744
Yannis P Pitsiladis http://orcid.org/0000-0001-6210-2449
Florian Pappenberger http://orcid.org/0000-0003-1766-2898
Karsten Hollander http://orcid.org/0000-0002-5682-9665

REFERENCES

1 Seneviratne SI*et al*. Weather and climate extreme events in a changing climate. In: Masson-Delmotte V, ed. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, 2021.
2 Casa DJ, DeMartini JK, Bergeron MF, *et al*. National athletic trainers' association position statement: exertional heat illnesses. *J Athl Train* 2015;50:986–1000.
3 Hosokawa Y, Casa DJ, Racinais S. Translating evidence-based practice to clinical practice in Tokyo 2020: how to diagnose and manage exertional heat stroke. *Br J Sports Med* 2020;54:883–4.
4 Hollander K, Klöwer M, Richardson A, *et al*. Apparent temperature and heat-related illnesses during international athletic championships: a prospective cohort study. *Scand J Med Sci Sports* 2021;31:2092–102.
5 Racinais S, Hosokawa Y, Akama T, *et al*. IOC consensus statement on recommendations and regulations for sport events in the heat. *Br J Sports Med* 2023;57:8–25.
6 Bermon S, Adami PE. Meteorological risks in Doha 2019 athletics world championships: health considerations from organizers. *Front Sports Act Living* 2019;1:58.
7 Di Napoli C, Barnard C, Prudhomme C, *et al*. ERA5-HEAT: a global gridded historical dataset of human thermal comfort indices from climate reanalysis. *Geosci Data J* 2021;8:2–10. 10.1002/gdj3.102 Available: https://onlinelibrary.wiley.com/toc/20496060/8/1