Heat Stress Indices for Safe Archaeological Work

FAME Advice for Archaeological Practitioners

The FAME Health and Safety Guides are produced by the FAME Health and Safety Working Group to provide advice to its members to foster safe systems of work for development-led archaeological practice. They are not designed to replace existing, detailed guidance available from the Health and Safety Executive (HSE) / Health and Safety Authority (HSA) and other bodies, and must always be used in conjunction with that guidance, clearly referenced in each guide, where applicable.

FAME Health and Safety Guide 6: Heat Stress Indices

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1 Introduction

With global warming leading to increased extreme weather events and warmer average temperatures, FAME members have been considering using heat stress indices to help manage heat risks for their staff. This paper has been created to summarise the research in this area.

2 Key takeaways

- indices can provide indicators of unsafe working conditions, but should **not** be relied on solely to determine health and safety actions;
- indices can give average indications of heat stress risks, but are not accurate at an individual level;
- indices are best used with other tools and methods.

3 What is heat stress?

Heat stress occurs when the body's way of controlling its internal temperature starts to fail. A person experiencing heat stress is at risk of serious injury or even death and will show some, or all, of the following symptoms:

- tiredness;
- dizziness;
- headache;
- feeling sick or being sick;
- excessive sweating and skin becoming pale and clammy or getting a heat rash, but a change in skin colour can be harder to see on darker skin;
- cramps in the arms, legs and stomach;
- fast breathing or heartbeat;
- a high temperature;
- being very thirsty;
- weakness.

4 What are heat stress indices?

A heat stress index is a matrix of calculations that indicate the heat stress risks associated with specific temperatures. They usually take into account other relevant factors, like humidity, physical activity level, clothing, etc.

5 Why use one?

A heat index, **when used in conjunction with other techniques**, can help prevent heat stress. They give indications of when archaeologists should change their behaviour to prevent heat stress e.g. take more breaks, stop work, etc. They are also good communication tools for clients, setting out clear boundaries as to when an organisation/person will change their working patterns.

6 Can a heat stress index be used to determine 'safe' working conditions?

No, not accurately. Some individuals can experience heat stress/death before an index indicates they should.

There have been numerous studies looking at different indices and how they correlate to physiological heat stress indicators for humans, e.g. heart rate, blood pressure, body temperatures (skin surface, core, etc). There are hundreds, if not thousands, of these studies, and all the studies do find the same general trend – as temperatures rise, so does the risk of heat stress. However, the accuracy of those predictions is never 100%. As such, a heat stress index **should never be solely relied upon to make decisions about working conditions.**

7 Why are heat stress indices not accurate?

Heat stress is influenced by a multitude of factors, many of which are hard to quantify or quantify accurately outside of a controlled laboratory environment. See FAME's Health and Safety Advice guide, 'Medication Side-Effects: Heat and Sun Sensitivity', for an example of how unknowable factors (medication taken, which is usually confidential information not shared with employers) can affect a person's ability to regulate their body temperature. Without accurate data, it is not possible to create accurate predictions.

7.1 UK and Ireland climate issues

A significant factor in an individual's likelihood to experience heat stress is acclimatization. The UK and Ireland can experience significant temperature changes in a matter of days/hours; the single-day record is a change of 30.1°C. Significant changes in temperature in a short period of time will

reduce the accuracy of any heat index. For example, The Humidex (shown later), drops safe activities by 5° C for unacclimatized individuals.

8 How should heat stress indices be used?

Heat indices are meant to be used in conjunction with mitigation measures to reduce injury and fatalities. When the first heat index was created, the Wet Bulb Globe Temperature, by the US army in the 1950s, it was part of a wider change in activities to reduce fatalities at training camps, such as:

- acclimatization periods of 1 to 3 weeks for new recruits;
- special training for obese trainees;
- trial of air-conditioned barracks;
- and training programmes to be planned based on the index.

Experts recommend that heat indices be used as part of a larger mitigation plan, not as the sole aspect of such a plan.

9 Heat Index recommendations

Currently, there are no legal requirements to use a heat stress index, however, if one is to be employed, the research indicates that:

- emphasis should be placed on observing signs of heat stress in individuals to reduce or stop work for them **sooner** than what may be indicated by the heat stress index. Such an approach is not perfect, e.g. being affected by 'machoism' under-reporting of symptoms and the need to train staff to recognise the signs of heat stress in themselves and others (see above for symptoms);
- stepping down of heat index actions – that is, if an index says a person should not be working at 39 degrees Celsius and 100% humidity, then employers should plan to stop work before that point is reached to account for individual variability;
- acclimatization should be factored in; it can take several weeks for a person to acclimatize and the British Isles have significant swings in temperatures over the period of hours.
- a heat index should be incorporated within an action plan to mitigate adverse effects, e.g. increase breaks, change clothing, etc. Examples are provided later in this paper.

10 How much stepping should occur?

FAME cannot advise on that because the research is not clear on this point. Moreover, there are no laws or guidance setting temperatures that could be used in the UK or Ireland. FAME can only advise, based on the current research, that it is likely some individuals will experience heat stress earlier than would be indicated by an index and that employers should take that into account when developing any procedures or policies that incorporate a heat index.

11 Heat Indices Examples

Estimates in 2014/15, put the number of heat stress indices at 45+ and there are likely more now. Most use some combinations of variables such as temperature, average radiation temperature, humidity, air velocity, physical activity level, age/health and clothing. They are either developed as the result of experimental and laboratory-based studies or derived from thermal calculations and equations.

Choosing one will be based on an employer's needs. We have provided two examples of heat stress indices, a simpler version and one to an ISO standard, to demonstrate how they work and could be incorporated into archaeological work. These are not endorsements and only presented as illustrative examples.

11.1 The Heat Index

A Heat Index, also known as the "apparent temperature," is a heat stress index that considers air temperature and relative humidity only. These are the most basic of the indices.

An example, modified from the Barcelona Institute for Global Health website[1]:

[1] https://www.isglobal.org/en/heat-index-calculator

Warning	Heat Index	Health Impact
Safe	<26	No adverse effects expected
Caution	27-32	Fatigue is possible with prolonged exposure and/or physical activity
Extreme Caution	33-40	Heat stroke, heat cramps or heat exhaustion are possible with prolonged exposure and/or physical activity
Danger	41-51	Heat cramps or heat exhaustion are likely and heat stroke is possible with prolonged exposure and/or physical activity
Extreme Danger	52-95	Heat stroke is highly likely
Death	93>	Death is highly likely

	Relative humidity (%)												
Temp ° C	40	45	50	55	60	65	70	75	80	85	90	95	100
23°	22	22	22	22	23	23	24	24	24	24	24	24	25
24°	23	23	24	24	24	24	25	25	25	25	25	26	26
25°	24	25	25	25	25	25	26	26	26	27	27	27	28
26°	25	26	26	26	26	27	27	27	28	28	29	29	30
27°	27	27	27	27	28	28	29	29	30	30	31	31	32
28°	28	28	28	29	29	30	30	31	32	32	33	34	36
29°	29	29	30	30	31	31	32	33	34	35	36	39	48
30°	30	31	31	32	32	33	34	35	38	38	43	53	60
31°	31	32	33	33	34	35	35	38	39	47	57	61	63
32°	33	33	34	35	36	38	39	41	50	59	62	64	67
33°	34	35	36	37	39	40	42	53	60	63	65	68	71
34°	36	37	38	40	41	43	54	61	63	66	69	72	74
35°	37	39	40	42	44	55	61	64	67	70	73	76	78
36°	39	41	43	45	55	61	64	68	70	73	77	80	83
37°	41	43	45	54	61	64	68	71	74	77	80	84	87
38°	43	46	51	61	64	68	71	75	78	81	85	88	91
39°	46	49	60	64	67	71	75	78	82	85	89	92	95
40°	48	59	63	67	71	74	78	82	86	89	93	96	100
41°	54	62	66	70	74	78	82	86	90	93	97	101	105
42°	60	65	69	73	78	82	86	90	94	98	102	105	109
43°	63	68	72	77	81	85	89	94	98	102	106	110	114
44°	66	71	76	80	85	89	94	98	102	107	111	115	119
45°	69	74	79	84	89	93	98	102	107	111	116	120	124
46°	72	77	82	87	92	97	102	107	111	116	120	125	129
47°	75	81	86	91	96	101	106	111	116	121	125	130	134
48°	78	84	90	93	100	105	111	116	121	126	130	135	140
49°	82	87	93	99	104	110	116	120	125	131	135	140	145
50°	85	91	97	103	109	114	121	125	130	136	141	146	151
51°	88	95	101	107	113	119	124	130	135	141	146	151	156
52°	92	98	105	111	117	123	129	135	140	146	151	157	162

Advantages:

- easy to use – only two variables;
- simple tools for measurement – thermometer and humidimeter. Combination tools are available, some can be as cheap as £/€ 15, though probably more expensive models would be needed;
- online calculators –
    - https://www.alpinetrek.co.uk/heat-index-calculator/
    - https://www.isglobal.org/en/heat-index-calculator
- paper/image-based guides to risks.

Disadvantages:

- does not take into account other factors that affect heat stress, such as activities, clothing, acclimatization , etc., which tends to make such indices less accurate;
- does not include an action plan to mitigate heat stress off the shelf.

However, some organisations have built work plans around such indices that do take into account activities and mitigation triggers. The Humidex[2] is a response plan created by The Occupational Health Clinics for Ontario Workers Inc. (OHCOW), which provides recommended responses for each humidex range that includes activity levels and acclimatization:

[2] https://www.ccohs.ca/oshanswers/phys_agents/humidex.html

Humidex 1 - Moderate physical work, unacclimatized worker, OR heavy physical work, acclimatized worker	Response	Humidex 2 - Moderate physical work, acclimatized worker, OR Light physical work, unacclimatized worker
25-29	• supply water to workers on an 'as needed' basis	32-35
30-33	• post Heat Stress Alert notice • encourage workers to drink extra water • start recording hourly temperature and humidity	36-39
34-37	• post Heat Stress Warning notice • notify workers they need to drink extra water • ensure workers are trained to recognize symptoms of heat stress	40-42
38-39	• work with 15 minutes of relief per hour • provide adequately cool (10-15 C) water • at least one cup (240ml) of water every 20 minutes • workers with symptoms should seek medical attention	43-44
40-41	30 minutes of relief per hour and all previously listed conditions	45-46
42-44	45 minutes of relief per hour and all previously listed conditions	47-49
45 or over	Only medically supervised work can continue	50 and over

11.2 ISO 7243

ISO standard 7243 is based on Wet Bulb Globe Temperature (WBGT) – this is the most widely used heat-stress index. It also takes into account clothing, including PPE, and activities, which are more likely to be relevant to archaeological work. For more information, see https://doi.org/10.2486/indhealth.44.368

Advantages:

- most widely researched index;
- shown to work well in a range of conditions;

- there are dedicated tools to measure it:

A REED R6200-NIST Heat Stress Meter. This image is purely for illustrative purposes. FAME does not endorse a particular brand or type of these devices.

- accounts for activity;
- accounts for clothing;
- most research finds it to be the most accurate with heat stress indicators;

Disadvantages:

- it requires a special tool, as taking individual readings and making the calculations is not recommended for untrained individuals;
- tools cost £/€ 150+, some may be available for £/€ 50 but may be of questionable quality at that price point.

Like most indices, it does not come with an action plan, but it is easily adaptable to make a decision table. Here is one for sport from the US, the Kansas State High School Activities Association Thresholds for Wet Bulb Globe Temperature, via the National Weather Service:

Warning: this example is for young fit athletes who are acclimatised. The US army stops all activities at a wet bulb globe temperature of 88˚F, two degrees below this example. Any action plan needs to be adapted to the likely individuals using it and not taken out of context.

WBGT Level/Zones	Activity Modification
<79.9° F	• Normal activities. • Provide at least 3 separate rest breaks each hour with a minimum duration of 3 minutes each.
80-84.6° F	• MINIMUM 3 separate rest breaks each hour with a minimum duration of 4 minutes each. • Cold water immersion tub or other rapid cooling method should be prepared and ready.
84.7-87.7° F	• MINIMUM 4 separate rest breaks each hour with a minimum duration of 4 minutes each. • 2 HOUR MAXIMUM length of practice (not including rest breaks). • Cold water immersion tub or other rapid cooling method should be prepared and ready. • Consider competition alterations
87.8-89.7° F	• 1 HOUR MAXIMUM length of practice (not including rest breaks). • MINIMUM 20 minutes of rest breaks distributed throughout the 1 hour of practice. • Cold water immersion tub or other rapid cooling method should be prepared and ready. • Consider competition alterations • Consider delaying practice/competitions until a cooler WBGT is reached
>89.8° F	No outdoor practice/competitions until a cooler WBGT is reached

12 Alternatives

Heat Stress Indices attempt to predict likely heat stress outcomes, but it is possible to measure such stresses directly with biosensors. However, they can be expensive and the most accurate sensors for core body temperature are those that are swallowed, which makes retrieval an undesirable process. Wearable biosensors are not as accurate as internal ones and can become dislodged during activities. Some individuals might also not feel comfortable being tracked, even if it is for health and safety reasons.

Given these drawbacks, this is not likely to be a viable alternative for most archaeologists at present. However, the technology is constantly improving, and it may, in the future, be a tool that archaeologists use, especially if they can be combined with other Health and Safety monitoring e.g. musculoskeletal issues.

13 Further Reading

Temperature in the workplace (UK)

https://www.hse.gov.uk/temperature/employer/heat-stress.htm

Heat exhaustion and heatstroke

https://www.nhs.uk/conditions/heat-exhaustion-heatstroke/

Heat stress checklist

https://www.hse.gov.uk/temperature/assets/docs/heat-stress-checklist.pdf

Personal protective equipment and heat: risk of heat stress

https://content.govdelivery.com/attachments/UKMHRA/2022/07/15/file_attachments/2214090/HSE%20UKHSA_PPE%20and%20Heat-Risk_Public%20Health%20Message.pdf#:~:text=Heat%20stress%20can%20cause%20heat%20exhaustion%20and%20lead,stay%20cool%20and%20well%20hydrated%20should%20be%20made.

Heat at work – Guidance (EU) for workplaces

https://osha.europa.eu/en/publications/heat-work-guidance-workplaces

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Construction (Design and Management) Regulations 2015 (2020)

Safe Working Around Utilities (UK) (2021)

Near-Miss Reporting (2022)

Medication Side-Effects: Heat and Sun Sensitivity (2023)