The effect of thermal environmental conditions on the health and performance of horses

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Horses are adaptable to a wide range of environmental conditions and are found in climates where temperatures may fall as low as -40°C or rise as high as +40°C.

Being a large mammal and thus having a low surface area to body mass ratio (~1:100; m^2:kg), the horse has a greater capacity to retain than dissipate heat. Whilst this is an advantage in cold climates, in hot or hot and humid climates this may render the horse at a disadvantage. For a large mammal, the horse also has a tremendous capacity to utilise oxygen for ATP regeneration. During exercise the predominant sites of ATP turnover and thus heat production are the locomotory muscles.

If different compartmental temperatures are measured during exercise, the hierarchy is usually muscle (up to 46°C), blood (up to 45°C for pulmonary artery temperature), rectal (~42°C) and skin temperature (~40°C). As the rate of heat production is related to the rate of oxygen consumption, a high maximal oxygen uptake indicates that on a per kg basis the rate of heat production will also be high. For horses exercising at trot, the rate of heat storage, assuming no heat dissipation, would equate to an increase in body temperature of around 0.25°C/minute of exercise. Thus for an hour of endurance exercise, without dissipation of any of the heat produced, the horse's body temperature would increase by around 15°C. This implies significant heat dissipation. However, during racing exercise the rate of heat production is around 1°C/minute. As in a 2-3 min Thoroughbred flat-race it is not unusual for rectal temperature to increase by 2-3°C, the implication is that during high intensity exercise such as racing very little heat dissipation takes place and almost all the heat produced is stored within the body.

The mechanisms by which a horse exchanges heat with its environment (net loss of heat or gain of heat) are radiation, conduction, convection (including forced convection) and evaporation see [1]. The predominant route of heat dissipation for the horse is by sweating. Under severely thermally stressful hot or hot humid conditions, around 80-90% of the heat produced would be dissipated by sweating. The second most important mechanism under these conditions would be respiratory heat loss by either primary (high rate, low tidal volume) or second phase panting (lower rate, high tidal volume). The horse's disadvantages in a hot climate in relation to its capacity for heat production and high surface area to body ass ratio have been partially compensated for by the evolution of the most prodigious sweating rate in the animal kingdom. The horse is able to sweat at rates of 15 litres/hour during exercise in hot or hot humid conditions with regional sweating rates as high as 50 ml/m^2/min. This gives the horse a high capacity to dissipate heat but also the potential to succumb to marked dehydration due to its willingness to exercise. However, the GI tract of the horse represents around 12% of its bodyweight (considerably more than in man) and the horse is able to redistribute water from the GI tract during exercise and can commonly tolerate up to around 5% reduction in body mass without medical consequence. This is much greater than the degree of dehydration that can be tolerated in man.

The horse is not only able to attain higher rectal temperatures (42-43°C) than it's human counterpart, the rider, it is also able to tolerate such body temperatures for short periods of time. Thus, when organising and managing equestrian competitions in thermally stressful conditions, the effect on both horse and rider must be considered.

Thermal stress can be brought about by exercise in cold, hot or hot/humid environmental conditions. The effects of environmental conditions may be manifested through:

Cold

- Increases in circulating catecholamines and greater glycogen utilisation, resulting in the earlier onset of fatigue [2]
- Respiratory tract inflammation [3]
- Decreased fluid intake and dehydration [4]
- Concussion due to hard ground
- Long term weight loss associated with increased heat generation

These deleterious effects can be minimised by accurate assessment of the environmental thermal stress and by implementing appropriate management measures. For exercise in the cold, warm-up times should be increased and the amount of walking prior to trotting should be increased to elevate muscle temperatures. In addition, dehydration may be reduced if water is warmed to 15-20°C. It has been estimated that for each degree that the average air temperature falls below 0°C, the energy intake should be increased by 1%, otherwise bodyweight will slowly decline due to the increased energy used for generation of heat at rest.

Hot and or Hot/Humid

- Increases in circulating catecholamines and greater glycogen utilisation, resulting in the earlier onset of fatigue [5]
- Hyperthermia
- Dehydration
- Electrolyte and acid-base disturbance
- Airway drying (hot/dry conditions)
- Effects on GI tract
- Concussion due to hard ground
- Long term weight loss with increased heat dissipation

For exercise in thermally stressful environmental conditions due to heat or heat and humidity, acclimatisation improves heat tolerance, exercise capacity and reduces dehydration compared with un-acclimatised exercise in these conditions [6-13]. However, heat acclimation can only partially compensate for thermally stressful conditions and other measures must be considered. These may include:

- Alteration of time of day or time of year at which an event is run
- Reduction in overall effort (shorter distance, less jumping efforts, etc)
- Stricter criteria for veterinary inspections (e.g. at vet gates in endurance or horse inspections e.g. in eventing)

- Criteria should be developed based on assessment of the severity of environmental thermal stress at which ride should be modified or abandoned
- Education of riders, grooms and officials
- Provision of shade
- Provision of adequate means of cooling horses

Measurement and Assessment of Thermal Environmental Conditions

Horses are generally at greater risk of injury from competing in hot, thermally stressful conditions as opposed to in cold conditions.

What factors determine environmental thermal stress?

- Air temperature (in the shade)
- Humidity
- Solar radiation
- Windspeed

The higher the air temperature, the more thermally stressful the conditions. If the air is dry (i.e. relative humidity is low, <40%) then sweat will evaporate efficiently. Under these conditions horses may not appear to be excessively covered in sweat as the rate of evaporation will be high. Nevertheless, although horses may be able to control their body temperature adequately, the potential for dehydration is very high. Under conditions of high air temperature and with increasing humidity, the rate of evaporation of sweat becomes increasingly reduced. When environmental air temperature reaches skin surface temperature and humidity reaches 100%, heat can no longer be lost from the horse to its environment.

The temperature and humidity of the environment have the predominant effect on the horses ability to lose heat but solar radiation and windspeed also have an impact. When there is no cloud and especially during the summer in regions close to the equator, the solar heat load can be very high and contributes significantly to the degree of thermal stress. Air movement over the body has a cooling effect by the process of forced convection. Thus, the absence of air movement will increase the environmental thermal stress. So in summary, shade air temperature, humidity, radiation and windspeed all need to be taken into account to accurately assess the level of environmental thermal stress at any point in time.

Where should conditions be measured?

Weather stations are often situated close to where events are being held and can provide an indication of temperature, humidity, radiation and wind. However, these may be cited at a high level or in areas which do not represent the local conditions at a ride. The information provided may also not be in a format that can easily be used to calculate an overall thermal index. Conditions close to the ground (at the level of horse and rider) are often more thermally stressful than those measured at a higher level in well ventilated areas.

How should these variables be measured?

(1) Shade air temperature

A simple dry bulb mercury or oil thermometer can be used to estimate shade temperature. This can be hung in the shade or placed inside a white, ventilated screen

(See Figure 1). Air temperature can also be measured using digital electronic thermometers of the kind made for offices and greenhouses. These generally have an accuracy of ±1°C. Air temperature can also be measured by calibrated instruments with greater accuracy produced by companies such as Vaisala (http://www.vaisala.com/) or Casella (http://www.casella.co.uk/). These often measure both temperature and humidity in one unit.

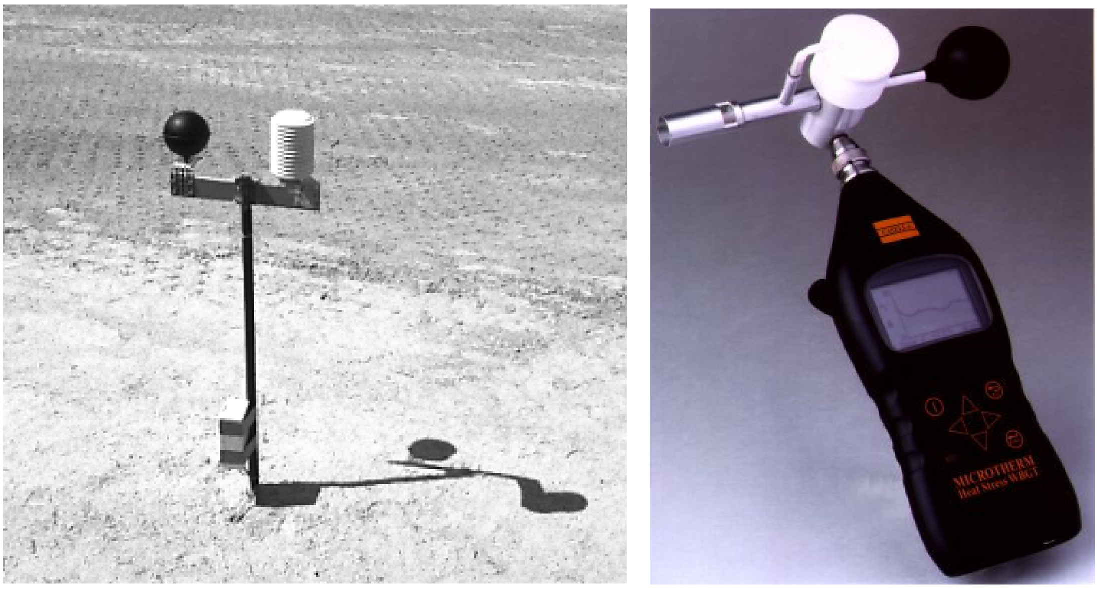


Figure 1. Left panel: Equipment for determining the wet bulb globe temperature (WBGT) index. Shade air temperature and relatively humidity or wet bulb temperature are measured inside the white ventilated screen on the right. The globe temperature is measured inside the black globe on the left. The system shown is an electronic version with the data transmitted by the electronics at the base of the pole to a remote monitoring station for display and recording. Right Panel: Microtherm hand-held WBGT meter produced by Casella.

(2) Humidity

Humidity should also be measured in the shade or in under a screen. The simplest approach is to use a mercury or oil wet bulb thermometer (also referred to as a hygrometer). The wet bulb temperature is usually paired with a dry bulb thermometer. When the humidity is very low, evaporation of water around the bulb causes the temperature of the bulb to fall. Thus, the drier the air (less humid) the greater the difference between the dry and wet bulbs. The higher the humidity the less difference between the dry and wet bulb temperatures. When the humidity is 100%, the wet and dry bulbs will read the same. Another option is to use a whirling hygrometer. This also incorporates dry and wet bulb thermometers. Digital desk style hygrometers are also relatively inexpensive and provide a direct readout in %RH (relative humidity). However, accuracy is generally ±5 or ±10%RH.

(3) Solar Radiation

Can be measured directly using devices known as pyranometers or radiometers. However, this equipment is relatively expensive. Values for solar radiation are often measured and may be available from weather information centres. An index of total radiant heat load can also be measured based on the temperature inside a black globe of approximately 15cm in diameter placed around 1metre from the ground. The temperature inside the globe increases with increasing ambient total radiation. Air movement has the effect of lowering the globe temperature by the process of forced convection. Thus, the temperature inside the globe represents a balance between radiant heat load and air movement.

(4) Windspeed

Windspeed can be measured using hot wire, rotating cup, rotating vane or ultrasonic anemometers. These devices are more expensive than temperature and humidity sensors.

Interpretation

At any point in time it is difficult to evaluate all the individual components that contribute to environmental thermal stress. For this reason a number of heat indices have been devised that produce a single number that relates to a weighting of different components.

Comfort Index

The comfort index is perhaps the simplest index that has been used in equestrian sport. Its attraction is its simplicity. It is calculated from the sum of the air (shade) temperature in °F and the relative humidity in %. However, it takes no account of radiant heat load or the presence or absence of air movement. Also, because of the simple addition of two components which are related but also on different scales (°F and %RH), this index can lead to marked underestimation of the severity of conditions and should not be used (See Figure 2).

Heat Indices

Various heat indices are in use around the world. These are often quoted by media weather channels or in newspapers, especially in thermally stressful regions of the world. They are based on air temperature and humidity, but are more sophisticated than the simple addition used in the comfort index (See Table 1). Indices like this can be used but they have been devised simply for ordinary everyday activities and not for exercise. There is no data or experience to suggest how a heat index should be applied to equestrian sport. In addition, the heat index does not make any allowance for radiation and or wind movement. However, a heat index will be more informative than the comfort index and in the absence of any other way of estimating thermal stress, could be considered with caution.

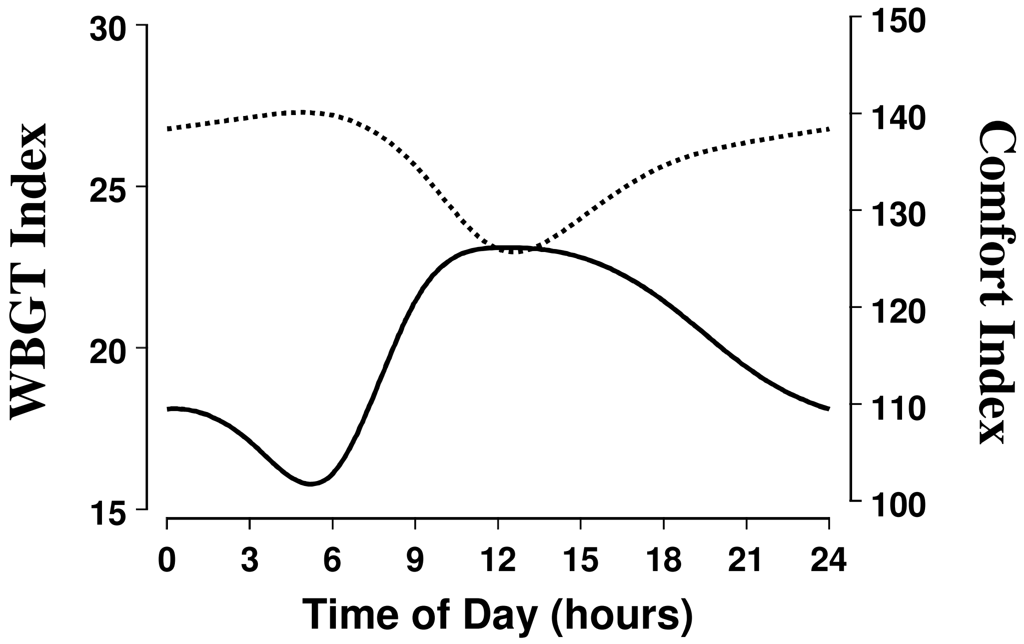


Figure 2. The same environmental data expressed as either comfort index (dotted line) or wet bulb globe temperature (WBGT) index (solid line) for a hot humid climate over a single 24h period. For both indices, higher values are supposed to represent more thermally stressful conditions. Note how the comfort index indicates that the conditions are best during the period when the WBGT index shows they are most stressful.

Wet Bulb Globe Temperature (WBGT) Index

The WBGT index takes into account all the relevant components that contribute to the environmental thermal load on the horse and rider i.e. air temperature, humidity, wind and radiation. This index has also been validated for Three-Day Eventing [1, 14]. The WBGT index is calculated as follows:

$$WBGT = 0.7\ T_{WB} + 0.3\ T_G$$

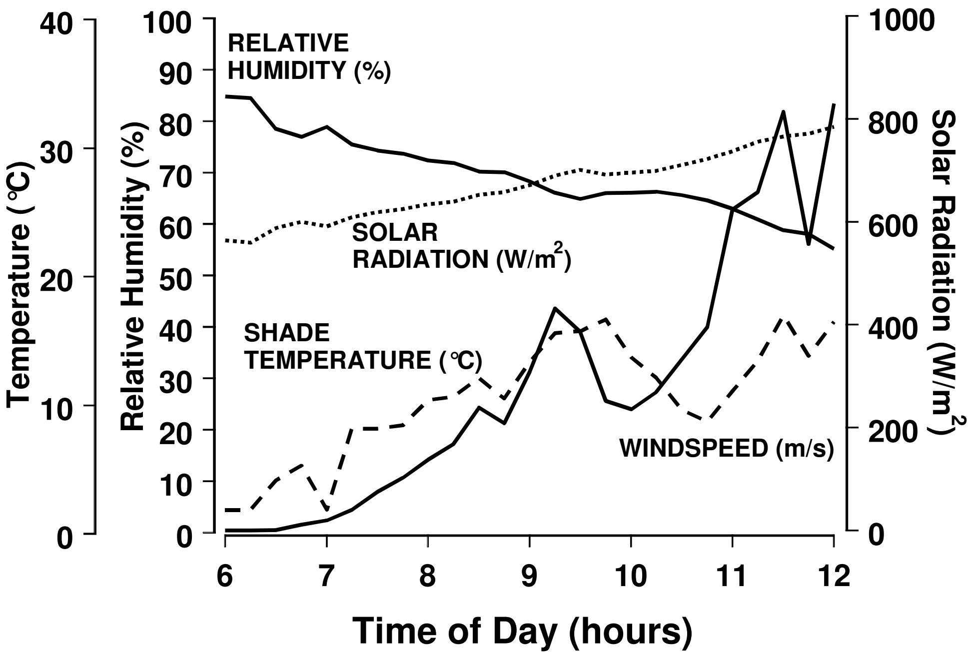
Where T_{WB} is the wet bulb temperature in °C (which takes into account the combined effect of air temperature and humidity) and T_G is the temperature inside a black globe in °C, which takes into account the effects of both radiation (heating effect) and wind movement (cooling effect).

The WBGT index can be calculated from measurements of wet bulb temperature and globe temperature using a mercury or oil wet bulb thermometers placed in a white screen and a mercury or oil thermometer with its bulb inside a black globe. The two temperatures are then read manually and the index calculated. Alternatively, the wet bulb temperature can be calculated from measurements of dry bulb temperature and relative humidity using either a psychometric chart, a lookup table or software. Measurements of air temperature and humidity and globe temperature can also be made with digital devices. Alternatively, a system that provides a continuous graphical display of the WBGT index is available (Pico Technology, Cambridge, UK, http://www.picotech.com/).

Table 1. Example of a Heat Index. The table gives the heat index for different values of air temperature and relative humidity. To determine the Heat Index, locate the actual shade air temperature along the top of the table and find the relative humidity along the left side of the chart. The value at the intersection of the column and row is the Heat Index expressed in degrees Fahrenheit.

		Shade Temperature in °F									
		70°	75°	80°	85°	90°	95°	100°	105°	110°	115°
Relative Humidity %	20%	66	72	77	82	87	93	99	105	112	120
	25%	66	72	77	83	88	94	101	109	117	127
	30%	67	73	78	84	90	96	104	113	123	135
	35%	67	73	79	85	91	98	107	118	129	143
	40%	67	74	79	86	93	101	110	123	135	
	45%	68	74	80	87	95	104	115	129	142	
	50%	68	75	81	88	96	107	120	135	149	
	55%	68	75	81	89	98	110	126	142		
	60%	70	76	82	90	100	114	132	149		
	65%	70	76	83	91	102	119	138			
	70%	70	77	85	93	106	124	144			
	75%	70	77	86	95	109	130				
	80%	71	78	86	97	113	136				
	85%	71	78	87	99	114					
	90%	71	79	88	102	122					
	95%	71	79	90	105						
	100%	72	80	91	106						

The WBGT index produces a number. It is an index so this does not have units i.e. although both the T_{WB} and T_G are in °C, the WBGT index is NOT in °C. In addition, the WBGT index is not linear. For example, a change of WBGT index from 15 to 20 is much less severe than an increase from 20 to 25. For an example of environmental data converted into the WBGT index, see Figure 3.



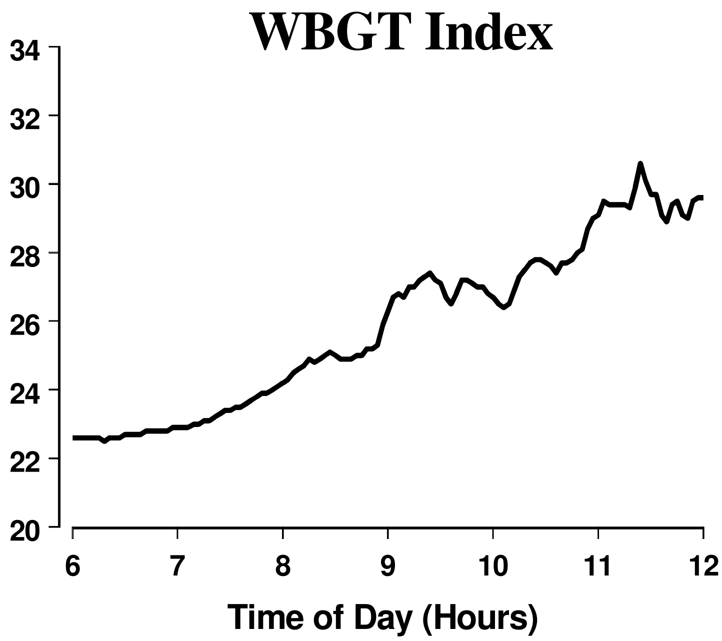


Figure 3. Upper panel shows shade air temperature, relative humidity, windspeed and solar radiation collected between 06:00 and 12:00h in a hot humid climate. The lower panel shows the same data expressed in terms of the WBGT index.

Recommendations for use of the WBGT index in Eventing have been published [14]. These are summarised in Table 2. However these guidelines only apply to acclimatised horses competing in long-format three-day event speed and endurance competitions at 3-4 star level. At present no recommendations exist for short-format or for any other disciplines. One sport in which there is an urgent need for objective assessment of thermal environmental conditions and how these impact on health and welfare is in endurance. Due to the long duration of riding, environmental conditions have a major effect on horses competing. In cooler rides the eliminations are predominantly due to lameness, but with increasing thermal stress there are increasing numbers of eliminations due to medical conditions, referred to as metabolic eliminations.

Table 2. Guide to advisable changes to the Speed and Endurance Phase of a CCI Three-Day Event at high levels of the WBGT index. From [14]

WBGT Index	Advice and Comments
<28	No changes to the FEI recommended format should be necessary
28-30	Some precautions to reduce heat load on horses are advised
30-32	Additional precautions to those for 28-30 to limit overheating of horses will be necessary
32-33	In these climatic conditions further modifications of the course will be necessary, in addition to the precautions for 28-30 and 30-32
>33	These climatic conditions may not be compatible with safe competition and further veterinary advice should be sort before continuing or undertaking a competition in these conditions

Summary

Thermal environmental conditions have the potential to affect health and welfare of sport and racehorses. The effect of heat and or heat and humidity on exercising horses increases with increasing duration of exercise. Some problems are common to both cold and hot conditions, such as hard going and concussion related injury. In very cold conditions there is increasing evidence of cold-air induced airway inflation, as is seen in human athletes (“ski asthma”). In hot conditions there is risk of earlier onset of fatigue leading to in-coordination. In horses jumping large obstacles this may result in mistakes, falls and injury. In prolonged exercise such as endurance, hot environmental conditions may lead to marked electrolyte loss and or imbalance, dehydration and gastro-intestinal disturbance. The first step in managing thermal stress is to accurately assess the risk. The WBGT index had proven useful in this respect in the sport of three-day eventing and could easily be applied to other sports.

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