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INTRODUCTION: The demands of hot environments during work or exercise have resulted in various attempts to quantify the thermal strain imposed on equids. Indices based on climatic factors have been used to predict the thermal load affecting exercising horses during high level competition. Use of the Comfort Index, based on the sum of environmental temperature (°C) and relative humidity (%), was criticised after the 1994 World Equestrian Games because it failed to predict the considerable heat load attributed to solar radiation (Jeffcott 1995). Subsequently, the Wet-Bulb Globe Temperature Index (WBGT), which accounts for wind speed and solar radiation as well as ambient temperature and humidity, has been used to quantify environmental conditions at many international equestrian events (Schroter et al. 1996), leading to adjustments in the course design, speed or duration to reduce the risk of heat stress in competing horses and riders. However, the WBGT has been found to be a poor predictor of rectal temperature, thermal comfort and productivity in humans (Gun and Budd 1995).

Thermoregulatory rises in heart rate (HR), respiratory rate, rectal temperature (Tre) and skin temperature (Tsk) can be measured by direct observation. These may be more representative of environmental- or exercise-induced heat load than indirect climatic measures and have been used to quantify thermal strain in humans (Meyer et al. 2001). A physiological strain index (PSI) was developed by Moran et al. (1998a) based on Tre and HR as representative of the combined strain experienced by the human thermoregulatory and cardiovascular systems during exercise or in hot environments. The PSI was scaled from 0 to 10 and could be calculated using live data collected during exercise, including rest and recovery periods, or from any pre-existing data set where measurements of HR and Tre had been taken simultaneously on more than one occasion. Its application was extended to heat stress associated with hypohydration (Moran et al. 1998b). In this study we hypothesised that the PSI could be adapted to measure thermal strain in working horses and thus potentially for those performing other types of exercise, such as competitive equestrian sports, in hot environments. We compared it with Tre and HR as single measures and with a validated behavioural assessment of heat stress (Pritchard et al. 2006). Heat stress and dehydration are physiologically inter-related in horses, so we also hypothesised that the PSI would be able to differentiate between levels of hydration in heat-stressed equids.

MATERIALS AND METHODS: Data were taken from a study of 50 horses recruited directly from draught work in Lahore, Pakistan, in environmental conditions of 30 - 44°C and 13 - 57% relative humidity. These animals were observed for five hours while resting in the shade with access to water to drink ad libitum. Behavioural assessments of heat stress (increased respiratory rate and/ or depth, flared nostrils, head nodding, apathy) and measures of HR, Tre and plasma osmolality were made on admission and at 0, 30, 60, 120, 180, 240 and 300 minutes. PSI was calculated after Moran et al. (1998a) as follows:

\[ \text{PSI} = 5 (T_{\text{ref}} - T_{\text{re0}})(T_{\text{max}} - T_{\text{re0}})^{-1} + 5(HR_{1} - HR_{0})(HR_{\text{max}} - HR_{0})^{-1} \]

where \( T_{\text{re0}} \) and \( HR_{0} \) are resting Tre and HR at 300 minutes, and \( T_{\text{ref}} \) and \( HR_{1} \) are simultaneous Tre and HR measurements taken at other time points. \( HR_{\text{max}} \) and \( T_{\text{max}} \) are the maximum HR and Tre for the species and conditions under consideration. General linear modelling for repeated measures was used to examine changes in HR and Tre, heat stress behaviour, plasma osmolality, PSI scores, environmental temperature and humidity and their interactions.

RESULTS: When modified for working horses, PSI scores fell significantly between admission and time point 0, then levelled out to a steady state (\( F_{(1,242)} = 124.71, p < 0.001 \)),
consistent with findings for its components HR and T<sub>re</sub> and suggesting that the PSI was valid for use in equids. The PSI was able to differentiate between horses with and without heat stress behaviour with a high level of significance (F<sub>(1,242) = 14.75, p < 0.001</sub>) regardless of sex, age and body condition. Physiological strain index scores were higher in animals with a higher plasma osmolality (F<sub>(1,242) = 9.23, p = 0.003</sub>), indicating suitability of the PSI for horses with differing levels of dehydration. A factor adjustment was required to achieve all positive PSI scores and as a result maximum scores for some horses were greater than 10. Table 1 compares the effects of replacing the PSI in the model by T<sub>re</sub> and then HR. Although heat stress behaviour was mainly related to a higher core body temperature, it also appeared to be linked to cardiovascular function and was best described by the combined PSI.

**Table 1: Results of general linear model examining significant associations between physiological measures of thermal strain, heat stress behaviour and plasma osmolality**

<table>
<thead>
<tr>
<th>Physiological measure of thermal strain</th>
<th>Value (mean +/- s.d)</th>
<th>Heat stress behaviour</th>
<th>Plasma osmolality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admission</td>
<td>Time 0</td>
<td>Time 300 minutes</td>
<td>F&lt;sub&gt;(0.05,94)&lt;/sub&gt;</td>
</tr>
<tr>
<td>Physiological strain index (PSI)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>6.1 +/- 2.2</td>
<td>4.9 +/- 2.0</td>
<td>—</td>
</tr>
<tr>
<td>Heart rate (beats/ min)</td>
<td>50 +/- 8</td>
<td>45 +/- 6</td>
<td>40 +/- 5</td>
</tr>
<tr>
<td>Rectal temperature (°C)</td>
<td>38.5 +/- 0.7</td>
<td>38.4 +/- 0.6</td>
<td>37.8 +/- 0.4</td>
</tr>
</tbody>
</table>

<sup>1</sup> PSI values include an adjustment factor to give all positive values. Time 300 minutes is the resting value T<sub>re</sub> against which values at other time points were compared.

**Discussion and Conclusions:** This preliminary study suggested that the physiological strain index could be useful as a quantitative indicator of thermal strain in horses, complementing the qualitative assessment of heat stress behaviour. It appeared to be valid for use in both dehydrated and euhydrated working horses. Adoption of the PSI as an alternative to assessing changes in either HR or T<sub>re</sub> overcomes some of the limitations of either as an individual measure of thermal strain, such as the potential effects of anxiety or ‘emotionality’ leading to elevated HR (Visser et al. 2002) or stress-induced hyperthermia (Bouwknecht et al. 2007). Advantages of the PSI are its relative simplicity and the fact that it provides live data during work or exercise. In theory its application could allow rolling adjustment of conditions (such as management of a horse’s speed or workload) to reduce heat production from working muscle and control the thermal strain experienced. Further research would identify the most appropriate T<sub>max</sub> and HR<sub>max</sub> values and scaling factors to produce a convenient 0 to 10 PSI scale for both working and performance horses.

**References:**


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