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THERMONEUTRAL ZONE AND CRITICAL TEMPERATURES OF HORSES

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Abstract—1. This short communication discusses the critical temperature and thermoneutral zone data for horses from the three earlier papers (Morgan, 1997a, 1997b; Morgan *et al.*, 1997). Some practical aspects of climatory physiology of horses are also discussed.

2. The baseline rate of total heat loss from horses, calculated by summing the rates of non-evaporative and evaporative heat loss, was 142 W m^{-2}, and remained stable in ambient temperatures ranging from 5–25°C.

3. The lower critical temperature was found to be 5°C. The upper critical temperature was proven to depend on what definition was chosen. © 1998 Elsevier Science Ltd. All rights reserved

Key Word Index: Horse; critical temperature; thermoneutral zone; thermoneutrality

CRITICAL TEMPERATURES AND THERMONEUTRAL ZONE

In Fig. 1 the obtained results (a—total heat loss; b—non-evaporative heat loss; and c—evaporative heat loss) from Morgan *et al.*, 1997 are presented and compared with the theoretical model (Mount, 1973) of an animal's heat loss and heat balance according to a thermodiagram. The results are presented with a solid line and the theoretical model, where it differs, with a dotted line.

According to theory the non-evaporative heat loss [Fig. 1(b)] starts at 0 W m^{-2} when the ambient temperature is equal to the body temperature and increases with the inverse (here 7 W m^{-2} $°C^{-1}$) of the minimal total thermal insulance as the ambient temperature decreases. The non-evaporative heat loss reaches a steady state level, which corresponds to the total heat production [plane of nutrition (Mount, 1979)] minus the minimal evaporative heat loss. Within the thermoneutral zone the animal adjusts the thermal insulance to regulate the non-evaporative heat loss. This plateau can not be seen in the the overall result of non-evaporative heat loss, but can be seen in some individual data. In ambient air temperatures at and below the lower critical temperature, the total thermal insulance is maximized and the non-evaporative heat loss increases with the inverse (here 2.78 W m^{-2} $°C^{-1}$) of the maximal total thermal insulance. Accordingly, the total heat production [Fig. 1(a)] will show an equal increase in order to maintain the body temperature. In temperatures above 25°C the results of the total heat loss are a lot higher than the theoretical model. This is due to a short-term effect with a marked increase in evaporative heat loss [Fig. 1(a) and (c)], since the horses were not acclimatized to high temperatures.

Viewing Fig. 1(a–c) one can conclude that the true nature of the pattern of heat loss and heat balance seems more complex than this theoretical model, since the solid lines differ from the dotted lines. Even so, this theoretical model can be used as a pedagogical tool for introduction to the heat balance and homeothermy of animals.

LOWER CRITICAL TEMPERATURE

According to Mount (1973) the lower critical temperature is defined as "below this limit the metabolic rate must rise if deep-body temperature is to be maintained". In Fig. 1(a) the total heat loss shows an increase below 5°C and this temperature limit will be the lower critical temperature. This agrees with Young and Coote (1973) who found the lower critical temperature in young horses and indoor horses to be 0–5°C.

UPPER CRITICAL TEMPERATURE

The upper critical temperature might be defined in three different ways, according to Mount (1973). The

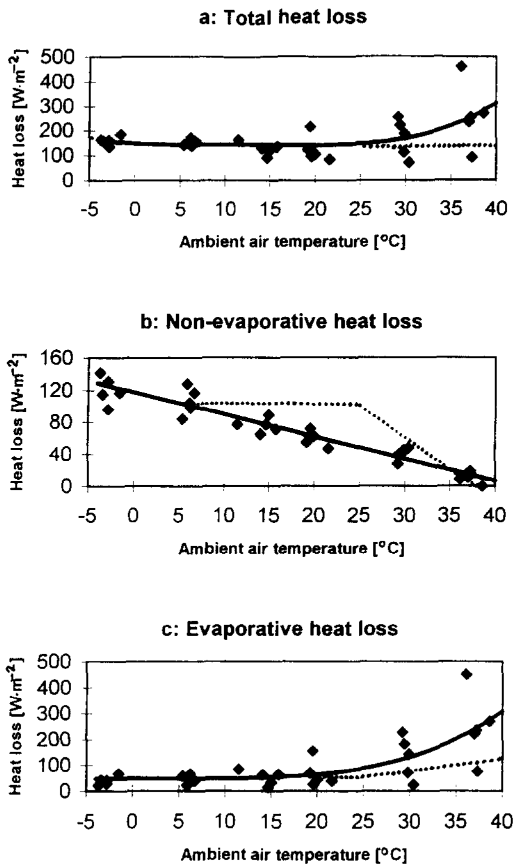

Fig. 1. The three diagrams show relationship between (a) total; (b) non-evaporative; and (c) evaporative heat loss and ambient air temperature. The dotted lines represent the theoretical model [according to a thermodiagram by Mount (1973)] and the solid lines and data points are results (Morgan *et al*., 1997).

upper critical temperature is defined as the ambient temperature when:

- the metabolic rate increases;
- the evaporative heat loss increases; or
- the tissue thermal insulance is minimal.

These three temperatures will differ when viewing the results:

1. 25°C if the metabolic rate is considered to follow the total heat loss (Morgan *et al*., 1997);
2. 20°C when the evaporative heat loss increases (Morgan *et al*., 1997); and
3. 30°C when peripheral vasodilation is maximal (i.e. minimal thermal insulance of the tissue) (Morgan, 1997b).

These different upper critical temperatures show that it is hard to establish an uniform definition for the upper critical temperature. Webster (1991) argued that the upper critical temperature is not amenable to the construction of an absolute definition. Estimates of upper critical temperature vary according to whether heat stress is considered to be a problem of productivity or not and will differ depending on which physiological parameter one chooses, e.g. heat production, respiratory rate or rectal temperature (Webster, 1991). The present results show that sweating occurs before the tissue thermal insulance is minimal, which agrees with an analysis by McArthur (1987) of the data of Worstell and Brody (1953) confirming that the onset of sweating occurs before tissue resistance has reached the minimum value, so that control of heat loss by sweating and vasodilation occur together.

THERMONEUTRAL ZONE

McBride *et al*. (1983) defined the thermoneutral zone (TNZ) as related to minimal metabolic rate and concluded that the thermoneutral zone for the horses in the study was between − 15°C and 10°C in still air conditions. Christopherson and Young (1986) defined the thermoneutral zone as the range of temperatures in which an animal maintains body temperature in the short term with little or no additional energy expenditure. In the TNZ physical processes of heat transfer occur in the body to balance heat production, these responses being primarily variation of blood flow to the skin, piloerection, and postural changes. Based on the definition of Christopherson and Young (1986) a general thermoneutral zone for the horses in the present study can be estimated, from the range of steady state level of rate of total heat loss in Morgan *et al*. (1997) to range from 5–25°C. However, this will be a generalization for the horses, that will have individual deviations from this estimated thermoneutral zone. It is noticeable that the steady state level of the heart rate (Morgan, 1997a) also reflects a thermoneutral zone of 5–25°C. The span of temperature in the thermoneutral zone was 25°C in the study of McBride *et al*. (1983) and 20°C in the study. According to Cena and Clark (1979) most homeotherms have a narrow thermoneutral zone, and wider temperature ranges and lower critical temperature are associated with both greater insulation and size. The rather wide range in thermoneutral zone of horses is associated with being a fairly well insulated large homeotherm.

PRACTICAL ASPECTS

The thermoneutral zone, the non-evaporative and evaporative heat loss, together with the design and construction of the building will affect the microclimate in a stable. The ambient air temperature in the stable should be regulated to fall within the thermoneutral zone so as to be thermally neutral for the horse. During the winter season the ventilation rate is regulated to remove moisture and carbon dioxide. The non-evaporative heat loss from the horse in relation to heat loss through the building fabric and in the exhaust air is used to calculate the need for additional heating. The optimal set-point for the ambient air temperature in the stable during the cold season is just above the lower critical temperature of the horse. The evaporative heat loss will then be minimal and the non-evaporative heat loss will contribute positively to the heat balance of the stable. Ventilation rate and extra heating will be minimized, which saves money. In the warm season, the main purpose of ventilation will be to limit the temperature increase in the stable in relation to the outside ambient air temperature.

Altered insulation by shearing and covering was studied (Morgan, 1997a). In the cold season it can be of advantage to shear horses that are exercised and trained for competitions, since according to Cena and Clark (1979) hairlessness is an advantage in facilitating sweating, which can be of importance for the exercising horse. Also, the managing of the horse is facilitated and one might speculate on a faster recovery after exercise. When the ventilation rates are controlled to exhaust moisture and carbon dioxide, a decreased evaporative heat loss like in a sheared horse is an advantage, since the ventilation rates can be keep down. The increased non-evaporative heat loss in a sheared horse will be favourable for the climate, since heat from the horses will keep the indoor temperature up. It is important to point out that a sheared horse needs a rug or complementary feeding to ensure that it can maintain body core temperature.

SUMMARY

The thermoneutral zone, defined as the range of temperatures in which an animal maintains body temperature in the short term with little or no additional energy expenditure, was estimated in general for these horses to range from 5–25°C. It was shown that the upper critical temperature is hard to define and varied between 20°C, 25°C and 30°C, depending on definition. From the discussion on upper critical temperature, it was concluded that onset of sweating occurred before tissue insulance had reached the minimum value, so that control of heat loss by sweating and vasodilation occurred together.

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