Lower critical temperature of competition horses

K. Morgan, L. Aspång and S. Holmgren

Swedish Equestrian Educational Centre, Strömsholm, Sweden.
Corresponding e-mail: karin.morgan@stromsholm.com

Abstract

The common theory, contradictory to horse practice, is that the active competition horse is considerable more resistant to ambient climate than the horse on maintenance, since the active competition horse get more feed and therefore has a higher energy intake. The aim of the study was to investigate if there was any difference in lower critical temperature, LCT, between the active competition horse and the horse on maintenance. The practical aim was to improve management of competition horses in relation to climate. The hypothesis was that there is a difference in LCT, which is due to the difference in feed intake. In the study we used a computer model for estimation of LCT in three different types of individuals used for equitation; Pony, Warmblood and Thoroughbred. We studied horses in winter coat and clipped horses. The intensity of feeding were both maintenance and competition. A relative part of heat production of the metabolisable feed intake energy was estimated. Input data were all based on previous research. The result showed a variation in LCT; for the pony from 1,4˚C to10,8 °C, the thoroughbred from –2,1˚C to 7,9 °C and the warmblood from –3,4˚C to 7,4°C. The competition horse had a higher energy intake in total, that gave a lower LCT in absolute value. The span between LCT was more narrow with this new model compared to previous model with a constant part of heat production. In conclusion, the climate resistance of the competition horse has been overestimated in the earlier model.

Introduction

The horse is a homeotherm animal with a relative constant body temperature normally between 37.2-38.2°C (Reece, 1991). Horses have coped in a wide range of ambient climate from 58°C in northern Australia to -40°C in western Canada and have been able to maintain their internal body temperature (McConaghy, 1994). To maintain an almost constant body core temperature there has to be a thermal balance. The simplest form of thermal balance is expressed as "heat production = heat loss ± heat storage" (Bianca, 1968). Heat is continually produced by metabolism; directly from the feed or indirectly from energy stored in the body. The heat has to be physiological transferred to the periphery of the horse, where it is dissipated to the environment as non-evaporative (radiation, convection and conduction) and evaporative heat loss. The rate of heat loss is governed by physical parameters as wind speed, difference in temperature and vapour pressure (Morgan *et al*, 1997). The non-evaporative heat loss also depends on the insulation of the horse (Morgan, 1997). The total insulation between an animal´s body core temperature and its environment is provided by three thermal insulating layers acting in series; the peripheral body tissue, the coat and the boundary layer of the air (McArthur, 1981, 1991).

The horse is a large animal, relatively small body surface in relation to body mass, and it has therefore a wide thermoneutral zone. McBride *et al* (1985) measured a thermoneutral zone for mature Quarter horse geldings between -15°C and 10°C. Within the thermoneutral zone (Mount, 1973) the rate of heat loss is controlled by the thermoregulatory system, so that the heat loss equals the thermoneutral heat production. The lower limit of the thermoneutral zone is called the lower critical temperature (LCT). Mount (1973) defines LCT as "below this limit the metabolic rate must rise if the deep body temperature is to be maintained". LCT is estimated from the following parameters; deep body temperature, total heat production, evaporative heat loss and the thermal resistance of the three thermal insulating layers (Ehrlemark, 1991).

There are alternative ways to estimate the total heat production. It can be practically predicted from indirect calorimetry by measuring oxygen uptake (Wooden *et al*, 1970). In the Swedish Standardisation, the total heat production calculated based on the body weight (SIS, 1992). The heat production is a part of the metabolisable energy (ME) and can therefore be estimated hereby(Pagan & Hintz, 1986; Wooden *et al*, 1970). In previous estimations of LCT, the heat production has been estimated as 80% of ME by a praxis. These estimations have shown that that the active competition horse is considerable more resistant to ambient climate than the horse on maintenance, since the active competition horse get more feed and therefore has a higher energy intake. This is contradictory to horse practice in the stables, where the competition horses normally are covered with one or several blankets in the winter time.

The aim of the study was use a relative model to estimate heat production from metabolisable energy from this model investigate if there was any difference in lower critical temperature, LCT, between the active competition horse and the horse on maintenance. The practical aim was to improve management of competition horses in relation to climate. The hypothesis was that there is a difference in LCT, which is due to the difference in feed intake.

Material and Methods

We conducted a computer simulation for LCT of the three different types of riding horses, see Table 1 for “modelhorses”. The feed intensity was set to either maintenance or equestrian competition. The training intensity for the competition was estimated to 30 minutes of walk and 30 minutes of trot / canter per day. The metabolisable energy was calculated according to Swedish feeding recommendations (Jansson *et al*, 2004), that are a collaboration between the Nordic countries and are based on French, Dutch and US recommendations.

Table 1. Presentation of the characteristics of the ”modelhorses” in the study

Type	Body weight	Height of the withers	Estimated body surface area*)
Pony	350 kg	145 cm	4,2 m^2
Thoroughbred	500 kg	160 cm	5,1 m^2
Warmblood	600 kg	165 cm	5,6 m^2

*)Body surface area is estimated according to $A=2*h^2$ (Engström m fl, 1997).

In previous work (Morgan, 1996) when analysing data from two different studies of feeding (Pagan & Hintz, 1986; Wooden *et al*, 1970) a relation between daily metabolisable energy intake, ME, (MJ kg^{-1}) and the ratio heat production to metabolisable energy intake was found, see Fig 1. The regression line (R^2=0.93) is expressed as equation 1 (valid in the range 0.3 – 1 MJ $kg^{-0.75}$).

$$HP/ME = 1.2 – 0.649 * ME \qquad \text{(Eqn 1)}$$

where
HP is heat production,
ME is daily metabolisable energy intake, [MJ kg^{-1}].

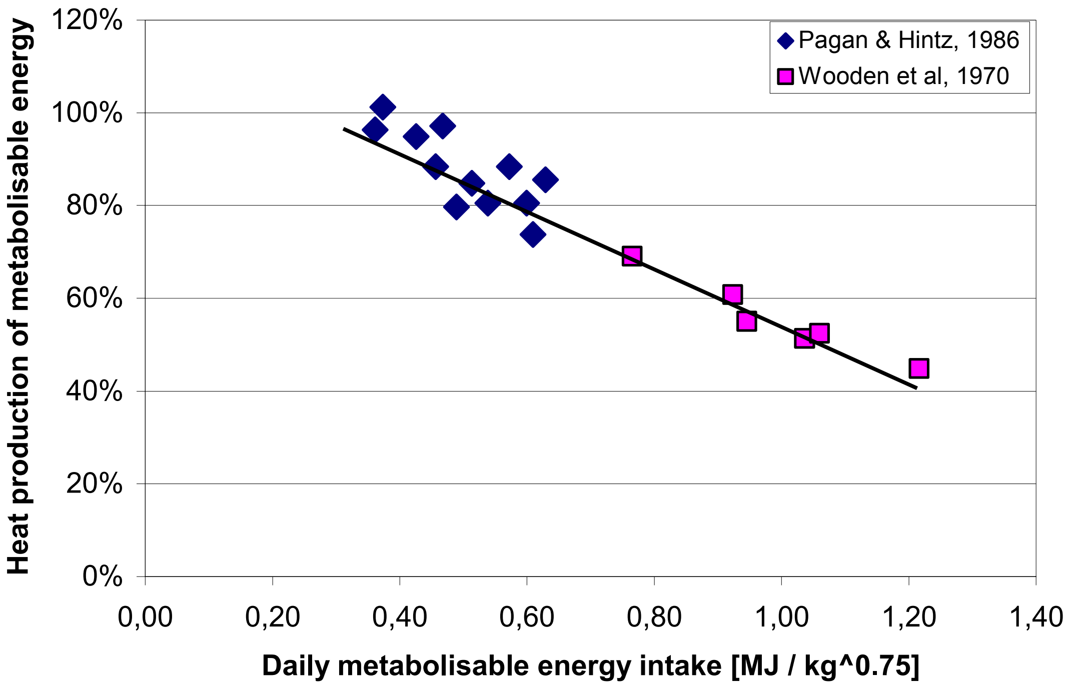

Figure 1. The diagram shows the a relation between daily metabolisable energy intake, ME, (MJ kg^{-1}) on the x-axis and the ratio heat production to metabolisable energy intake on the y-axis (Morgan, 1996). The input data is based on two different studies on feeding (Pagan & Hintz, 1986; Wooden *et al*, 1970).

The LCT was estimated from equation 2 (Ehrlemark, 1991). The evaporative heat loss was estimated to 25% of the total heat loss based on experience from previous work (Morgan, 1996). The simulation was conducted for intact wintercoat as well as clipped coat. Thermal insulance for tissue 0,12°C m^2 W^{-1}, wintercoat 0,10°C m^2 W^{-1}, clipped coat 0,05°C m^2 W^{-1}, boundary layer of the air 0,14°C m^2 W^{-1}(Morgan, 1997). The input data for the "modelhorses" based on the set prerequisites are presented in Table 2.

$$LCT = T_{body} - q_{total} (M_{tissue} + M_{coat} + M_{air}) + q_{evap} (M_{coat} + M_{air}) \qquad \text{(Eqn 2)}$$

where,

LCT	is lower critical temperature [˚C],
T_{body}	is body core temperature [˚C],
q_{total}	is heat flow from total heat production [W/m²],
q fukt	is evaporative heat loss [W/m²],
M_{index}	is thermal insulance in tissue, coat, air [m²˚C/W].

Table 2. The input data of according to the set prerequisites for metabolisable energy intake (ME), the ratio HP/ME and the heat production (HP)

Type	Feeding	ME MJ/day	Relative HP/ME	HP (Rel.) W/m²	Previous HP/ME	HP (Prev.) W/m²
Pony	Maintenance	42	0,86	100	0,8	92
	Competition	58	0,74	117	0,8	128
Thoroughbred	Maintenance	58	0,84	111	0,8	105
	Competition	80,5	0,71	129	0,8	146
Warmblood	Maintenance	64	0,86	112	0,8	105
	Competition	91	0,71	133	0,8	149

Result and Discussion

The results of the estimated LCT are presented in Table 3. In general, a competition horse with intact wintercoat was the most cold resistant and the clipped horse on maintenance was the least cold resistant. The LCT of the pony ranged from 1,4˚C to 10,8 °C. The thoroughbred's LCT varied from –2,1˚C to 7,9 °C and the Warmblood from -3,4˚C to 7,4°C. A previous study (Morgan, 1998) in a climatic chamber of four Standardbred trotters and one Shetland pony on maintenance found a LCT of approximately 5˚C. These results agree with the present results of the simulation model. Young & Coote (1973) also found LCT of 0˚C - 5˚C in young horses and indoor horses. McBride *et al* (1985) established LCT from their experimental horses to -15˚C, however these horses had approximately 1,5 times feed energy intake compared to horses in Morgan's study (1998). In Finland, results from loose housed weanling horses indicated LCT between -9˚C and -16˚C (Autio *et al*, 2007). A study on foals have found a LCT range from 13˚C to 26˚C with an average of 20˚C (Ousey *et al*, 1992). Further, sick foals aged less than one week had on average a LCT of 24˚C and the metabolic rate was about 25% below that of healthy foals of similar age (Ousey *et al* 1997). In a literature review, Cymbaluk & Christison (1990) reported LCT ranging from -15˚C to 10˚C and noted that most values in literature were unsupported by experimental studies. The differences in LCT can be explained by the fact that there are many parameters that affect LCT; such as physiological state, metabolic rate, feed intensity, feed quality, age, size, ratio surface area to body mass, housing system, activity, acclimatisation, season, multiple climatic factors. Consequently estimation of LCT is a multifactorial challenge, where a simulation model can be a helpful tool but in true horsemanship never replace the horseman's eye.

Table 3. The results of the lower critical temperatures (LCT) for the three different types of horses. The relative model is based on a ratio of heat production due to level of metabolisable energy intake. The previous model estimates LCT with a fixed level of heat production (80%) of metabolisable energy

Type	Feeding	Coat	LCT Relative HP/ME °C	LCT Previous °C	Difference Relative - Previous °C
Pony	Maintenance	Clipped	10,8	12,8	-2,0
		Intact	6,9	9,1	-2,3
	Competition	Clipped	6,1	3,3	2,8
		Intact	1,4	-1,8	3,2
Thoroughbred	Maintenance	Clipped	7,9	9,5	-1,6
		Intact	3,4	5,3	-1,8
	Competition	Clipped	3,0	-1,6	4,6
		Intact	-2,1	-7,4	5,3
Warmblood	Maintenance	Clipped	7,4	9,4	-2,0
		Intact	2,9	5,2	-2,3
	Competition	Clipped	1,9	-2,6	4,5
		Intact	-3,4	-8,6	5,1

The fact the pony has the highest LCTs is due to a relatively larger surface in relation to body weight. This results in a larger area for non-evaporative heat loss in relation to the total heat production, so that a fixed rate of non-evaporative heat loss (Wm^{-2}) will result in a larger total amount (W) and a larger proportion of the total heat production. When comparing the new relative model with the previous model, we found that the competition horse has previously been consider to be more cold resistant (positive differences in Tab 3) than it actually is. The competition horse in the relative model uses more energy for exercise and gets a lower heat production, which explains that it is less cold resistant. On the other hand, when viewing the horse on maintenance it is more cold resistant (negative difference in Tab 3) than previous estimations. This is due to little energy is needed for exercise and a larger proportion is used for heat.

The knowledge of LCT is of practical use for dimension of ventilation, feeding regimes in cold climate and management of the horse (housing system, blankets and clipping). During the winter in Sweden there are often problems with to high humidity in insulating buildings. The outdoor air often has a high relative humidity, that results in a decrease ability to carry moist when it passes the stable with the ventilation. Therefore, one wants to find a indoor temperature in the insulated stables where the horse have a minimal evaporative heat loss and a maximal non-evaporative heat loss. This optimal temperature is just above LCT of the horse. Below LCT, by definition, the horse needs to increase its feed intake to maintain deep body core temperature. This extra demand for feed is called climatic energy demand (CED) and can be estimated from the thermal insulance of the horse. CED has been estimated to 3 $Wm^{-2}°C^{-1}$ in cold and calm conditions, that corresponded to approximately 1.3 MJ per °C below LCT and day for a 500 kg horse (Morgan, 1995). In a study of mature Quarter Horses CED was found to be 14.2 kJ $kg^{-0.75}$ $°C^{-1}$ day^{-1} (equals 1.5 MJ per °C below LCT and day for a 500 kg horse) based on metabolic measurements of resting heat production (Christopherson & Young). Interestingly, the studies coincide in the same regime even though the methods to find CED differ; one based on maximal thermal insulance and the other on measurement of metabolic rate. Covering horses with blankets is a common management especially for competition horse, where they often wear more that one blanket. The horseowner often believes that their competition horse is very sensitive to cold. The present results show that the competition horse is less resistant to cold than previous estimation have shown. However, there is only need for one padded blanket in an insulated stable in cold conditions. If the horse is stabled in a uninsulated stable in cold conditions, one can add a woollen blanket closest to the skin and add extra feed for CED.

The previous method using 80% heat production of metabolisable energy seems with perspective rather crude. It was based from praxis within the research team and on an personal perception of an average from data of Pagan & Hintz (1986), who found the ration HP/ME to vary between 74% and 101%. The new model with a relative HP/ME gives a finer tool. It is supported by experimental data and takes in to account the fact that the working horse needs energy for its exercise. The model can serve as a useful pedagogic tool to understand how LCT varies with different parameters and also be used in estimation of LCT when calculating feeding regimes and dimension of ventilation. In the future, field studies can be conducted to validated the model. One could observe signs in the horse, e g shivering, when it reaches LCT and compare this with estimation for the actual individual by the model. For the simulation the following parameters are required [1)]heat production (estimated from feed intake), [2)]thermal insulance (calculated from measurements of temperature on the skin, coat surface and ambient temperature) [3)]body core temperature. The simulation at this point provides that the horse is dry and stands in shadow with no wind present. In a future perspective, the model can by expanded to include more parameters.

Conclusion

The competition horse had a higher energy intake in total, that gave a lower LCT in absolute value. The span between LCT was more narrow with this new model compared to previous model with a constant part of heat production. In conclusion, we found that the previous model has overrated the cold resistance of the competition horse. However, the horse on maintenance are slightly more cold resistant than earlier believed. The hypothesis “there is a difference in LCT, which is due to the difference in feed intake” can be accepted.

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