Thermoregulatory Control in Cattle Exposed to the Natural Climate

Abstract

In the diurnally cyclic natural climate thermoregulative changes in vasomotor functions were related to a cycle in skin and tympanic membrane temperature. In summer vasomotor responses were correlated with tympanic membrane temperature whereas in winter responses were correlated with skin temperature. No seasonal change was found in the tympanic membrane temperature.

Introduction

Most studies on thermoregulation in cattle have been in climatic chambers. Complete response of animals to a given ambient temperature is attained after at least 7 weeks of continuous exposure (9, 11). This is considerably longer than exposures in most climatic chamber studies. Natural climate is characterized by a slow change in mean temperature. Animals exposed to natural climate would, thus, approach complete acclimatization to conditions at a given time. However, only limited information is available on thermoregulatory reactions of dairy cattle in natural climate. Knowledge of diurnal patterns of these reactions and of factors activating them is required for proper alleviation of heat stress.

Temperature homeostasis is maintained by the thermoregulatory system in which deviations from the set point temperature activate compensatory reactions; the degree of activation of compensatory reactions is proportional to the deviation from the regulated set point temperature (5). The thermal strain imposed upon the body by ambient temperature is usually expressed in body temperature. This does not account, however, for changes in body temperature during acclimation (9). Assessment of heat strain in terms of compensatory reactions is likely to be more appropriate, as it reflects the heat strain as sensed by the thermoregulatory system (10). In transient thermal situations, such as those prevailing in the natural climate, tympanic membrane temperature is a better index of regulated temperature than rectal temperature (13, 14); it also responds faster to changes in ambient temperature (3).

Methods

This study was performed on 3 Israeli-Holstein heifer calves in midsummer and repeated in midwinter on the same animals. Their body weights ranged within 330 to 390 kg in the summer and 430 to 500 kg in the winter. The respective ages were 14 to 16 and 19 to 21 months. It was believed that the advance in age would not materially alter reactions of the animals as thermoregulative responses stabilize at about 10 to 12 months of age (7). Animals were stanchioned for experimental periods in an open shelter, in which they were protected from direct sun radiation.

Thermoregulatory reactions were measured over 10 consecutive days in each season. Measurements were performed at two hour intervals from 05 to 19 hr and in winter also at midnight. For all temperature measurements 38 swg enamelled polythene-coated thermocouples were used. Reference junctions were set into a 10 by 15 cm perspex cylinder immersed in a circulated 14–1 water bath. Stability of the reference temperature was better than .005 C. Tympanic membrane temperature was taken to .01 C by a probe ending in a double loop permanently set on the ear drum for the entire experimental period. Rectal temperatures were measured to .01 C by 15-cm long insemination tubes at the end of which thermocouples were fixed. Skin temperatures were measured to .1 C on 9 cm² shaved patches on the rump, lower flank, and thoracic back. and recorded on a multipoint potentiometric recorder. Nonevaporative heat loss was determined on the same body surface sites with Hatfield type heat flow discs. Outputs of heat flow discs, rectal, and tympanic thermocouples were amplified by a chopper amplifier.

Skin and respiratory evaporative heat losses were calculated from Missouri data (8). Changes in body heat content were derived from the Hardy and DuBois equation (6). Heat production was calculated from the nonevaporative heat loss and the aforementioned data. Dividing the mean rate of heat loss by the rectal-to-mean skin temperature gradient yielded the rectal-to-skin heat conductance, krs. This measure is a thermal index of vasomotor function which plays an important role in body temperature regulation through adjustments in peripheral blood flow.

Results and Discussion

In the summer experimental period the diurnal range of air temperatures was 21 to
30.5 °C; the respective figures for the winter were 11.7 to 20.7 °C. In both seasons black globe temperatures were practically identical with air temperatures.

The diurnal cycles in \( k_{rs} \) in the two seasons are in Figure 1. A distinct cycle in main body \( k_{rs} \) was similar to the rectal-to-ear conductance data. The mean standard deviation within a measurement period was 2.3 conductance units; the cycling in vasomotor function within the diurnal cycle was statistically significant (P < .01). The pattern of the cycle was essentially the same in the two seasons in spite of the 10 °C difference in mean daily temperature. This similarity of summer and winter diurnal cycles was also in other studies on respiratory vaporization and respiratory activity in dairy heifer calves (1) and sweating and vasomotor activity in dairy cows (Berman and Morag, in preparation).

The diurnal cycle in \( k_{rs} \) occurred concomitantly with fluctuations in skin temperature and tympanic membrane temperature. Figure 2 points to a strong apparent dependence of \( k_{rs} \) upon skin temperature. These data seem to indicate a critical skin temperature beyond which \( k_{rs} \) increases, similar to responses in the rhesus and dog (4). However, tympanic membrane temperature also fluctuated concurrent with skin temperature. A partial regression analysis partitioned effects of skin temperature and tympanic membrane temperature on \( k_{rs} \). This analysis indicated that in the summer the effect of tympanic membrane temperature was predominant (P < .01) while the effect of skin temperature was small and nonsignificant statistically. The reversed situation was in the winter. The discrepancy between the apparent relationship of \( k_{rs} \) to skin temperature in the summer and the results of the partial regression analysis is due to the correlation in this season between skin and tympanic membrane temperature.

Decrease in mean ambient temperature from summer to winter was associated with the following changes: mean skin temperature decreased from 34.8 ± 1.2 to 30.4 ± 1.3 °C (P < .05), and mean rectal temperature decreased from 39.12 ± .1 to 39.76 ± .1 °C (P < .05). The mean tympanic membrane temperature remained, however, the same in the two seasons (38.58 versus 38.56 °C). An important seasonal change occurred in the mean daily heat production; it rose by 20% from a summer level of 161 ± 18 kcal/m²-h to 201 ± 20 kcal/m²-h in winter; this increment was significant at 5% probability. This seasonal change is close to that earlier found in
similar animals, in which heat production was derived from oxygen consumption (2).

The seasonal change in mode of control of vasomotor function was, therefore, not associated with a change in mean tympanic temperature. It is also unlikely that this seasonal change is due to the relatively small decrease in the mean skin temperature, more so since diurnal fluctuations in skin temperatures were of same magnitude as seasonal change in mean skin temperature. A seasonal shift in the effect of skin thermoreceptors on hypothalamic set-point temperature is possibly involved in this alteration of the mode of control of vasomotor thermoregulative function.

Dependence, in the summer, of vasomotor function on body core temperature suggests that peripheral cooling of animals by short showers is not likely to diminish vasomotor heat-dissipating response as long as body temperature is not reduced. Such short showers reduce midday increase in skin temperature; this is effective in maintaining a greater rectal-to-skin temperature gradient, coupled with larger rectal-to-skin heat conductance. Contrasting with this, prolonged showers would cause deep body cooling, resulting in depression of the rectal-to-skin heat conductance.

Seasonal change in heat production does not seem to be associated with tympanic membrane or skin temperature for the mentioned reasons. Similar results for heat production, tympanic and skin temperatures were obtained in a later experiment on high-yielding dairy cows (Berman and Morag, in preparation). This change in heat production is possibly associated with seasonal variation in thyroid activity, evidence for which was reported in cattle (12). It is likely that the similarity of the summer and winter diurnal cycles in vasomotor function resulted from the higher winter heat production.

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References