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The Role of the Tail in the Thermoregulation of the Mongolian Gerbil, *Meriones unguiculatus*

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Abstract

Metabolic rates were measured for fifteen Mongolian gerbils (*Meriones unguiculatus*) at three different ambient temperatures. Metabolic rates for ten of the gerbils (five males and five females) were also measured after removing tail hair. This procedure did not significantly affect metabolic rates, however ambient temperature did affect metabolic rates. The average metabolic rate for animals housed at 5°C was significantly higher than when animals were maintained at either 20°C or 35°C. Also, the average metabolic rate for animals housed at 20°C was significantly higher than when they were maintained at 35°C.

Introduction

The Mongolian gerbil is a small, burrowing desert rodent distributed throughout Mongolia and adjacent parts of southern Siberia and northern China (Nowak and Paradiso, 1983). There are two reasons why this species is suited for this study: they are small domesticated rodents and have a sufficiently furred tail. Body length is from 10 to 12 cm and the tail length is similar. The mean weight for females is approximately 65 grams and approximately 60 grams for males. When subjected to extreme thermal conditions in the natural habitat, gerbils likely can time their activity to correspond to preferred ambient temperatures (T_a), allowing a shift from nocturnal activity in a hot season to diurnal activity in a cold season or mixed activity during moderate T_a (Kirmiz, 1962). These gerbils can adapt to a wide range of temperature and humidity. During harsh subzero winters they are found to be active on the surface as well as summer days of more than 38°C in their natural habitats (Gulotta, 1971). Small fur-bearing animals must have relatively short light fur or it could not move about (Schmidt-Neilsen, 1984). Because of their relatively poor insulation and large surface-to-volume ratio, they must take advantage of microclimates (i.e., by living in burrows) (Hill, 1976).

Endothermic animals are able to maintain a high body temperature (T_b) by internal metabolic heat production. To maintain a constant temperature, the heat gained and the heat lost from the animal must be equal. A small animal has a much larger surface relative to its volume in comparison to an animal larger in size. In a physiological sense, small size has clear disadvantages in dealing with extreme thermal conditions of both hot and cold. Because the rate of heat exchange with the environment by conduction, convection, and radiation is mostly dependant on surface area. This allows smaller animals to lose or gain heat at a higher rate per unit of body mass than that of larger animals (Hill, 1976).

Within a temperature range referred to as the thermoneutral zone (TNZ), the resting metabolic rate is unaffected by a temperature change. Below a certain ambient temperature, called the lower critical temperature, the metabolic rate increases linearly with decreasing temperature. Above a certain ambient temperature, called the upper critical temperature, the metabolic rate increases linearly with increasing T_a.

In a cold environment as the T_a falls below the TNZ, a high body temperature can be maintained by reducing the heat loss and increasing the heat gain (metabolic heat production). This can take place through muscular activity, involuntary muscle contractions (shivering), and nonshivering thermogenesis (NST). As the T_a decreases, hairs become raised, trapping a thicker layer of stagnant air around the animal. Also, vasomotor responses constrict vessels of peripheral or superficial blood flow. Behaviorally, a small animal can curl up in a crouched position or return to its burrow for further protection from thermal stresses. In the opposing conditions of a hot environment where the T_a rises above the TNZ, the conditions for heat loss by conduction, convection, and radiation (surface area related processes) become increasingly unfavorable for small mammals. Evaporation of water becomes the key mechanism for heat loss. As the temperature increases, so does the metabolic heat production. To maintain a constant T_b, metabolic heat must be lost at the same rate that it is produced. Unfortunately, gerbils can neither sweat or pant, so other physiological functions are required such as an increase in respiratory evaporation and blood circulation (vasodilation of vessels) for heat dissipation. Behaviorally, changing postural positions by laying flat and extending appendages, licking of the fur, and returning to a cooler burrow or seeking shade are possible solutions in maintaining a constant T_b.

Elizabeth Kirksey and her associates (1975) found the tail of the cotton rat is important in temperature regulation. The metabolic rate of normal rats was significantly higher than that of rats without tails between the ambient temperatures of 4°C and 20°C. Although John Klir and his associates (1990)

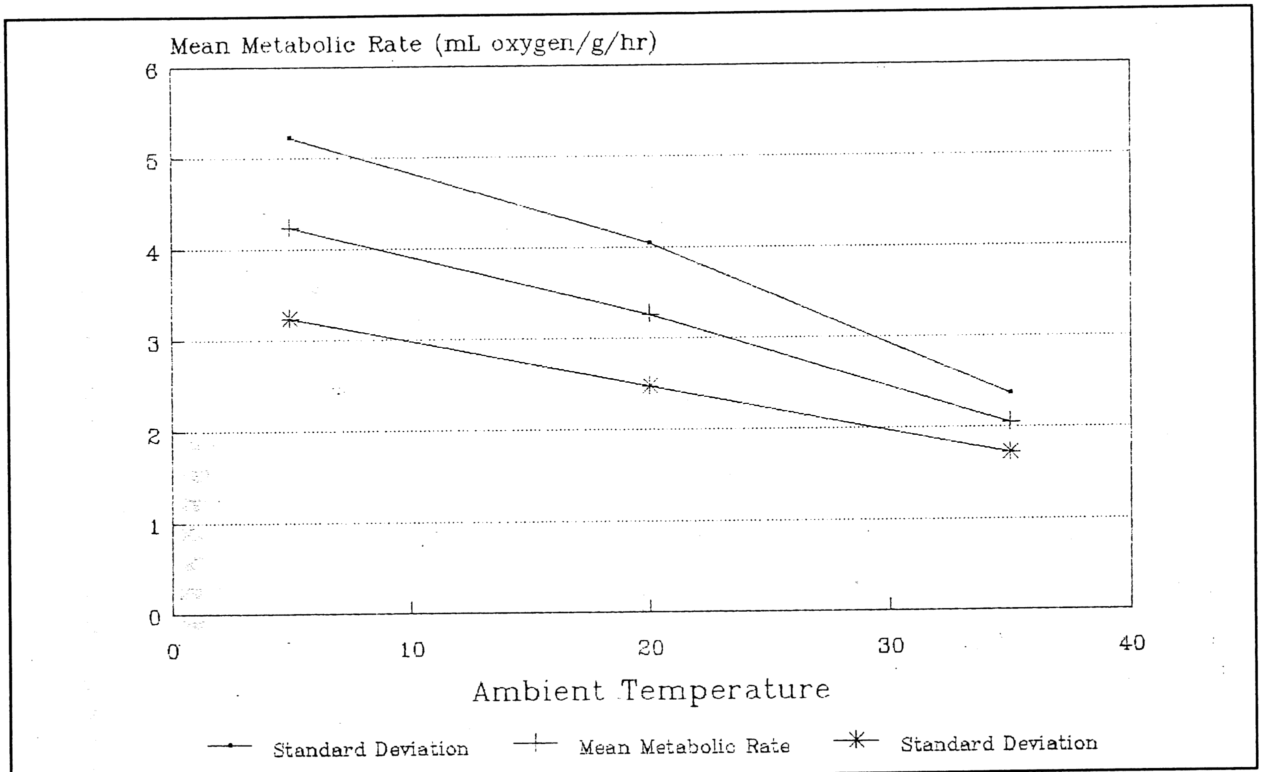

Figure 1. The mean metabolic rate of the Mongolian gerbil (*M. unguiculatus*) in relationto the ambient temperature.

developed another opinion with his surface temperature study, suggesting that the Mongolian gerbil shows little control of surface temperature and has not developed any special thermoregulatory surface areas to regulate heat exchange with its environment.

By removing the tail, it seems that many interruptions to the fully interactive physiological processes essential for the body to properly function. I feel that it would be better to shave the tail (removing insulation) and exposing the skin directly to the environment, and therefore would alter the metabolic rate. Gerbils with shaved tails should be able to respond to various T_a differently. The gerbils with tail fur should be able to regulate temperature more effectively outside the TNZ than those with shaven tails due to the loss in ability to conserve heat to where the fur had originally insulated the tail and retarded heat loss. The purpose of this study was to find if the tail (not removed, but shaven) will have a significant effect on the metabolism in order to thermoregulate temperature in ambient temperatures of 5°C, 20°C, and 35°C. If the tails do have a role in the thermoregulation, then the gerbils without tail fur (WOT) will have a narrower TNZ than gerbils with tail fur (WIT).

Materials and Methods

There were 15 gerbils used in this study, 5 males and 10 females. They were placed individually into separate plastic cages with water and rodent chow supplied. Metabolic rates were determined by measuring the carbon dioxide production per unit time by a CO_2 analyzer, and subsequent conversion to oxygen consumption per unit time (mL O_2/g/hr). The animal testing chamber was a large glass jar that had a volume of 19,875 mL. Between trials, the air had to be flushed out with virtually CO_2 free air due to the sensitivity of the CO_2 analyzer. A pressurized air bottle containing a 21% oxygen and 79% nitrogen mixture was used for the first portion of the experiment. Due to expense, a method using an oxygen respirator forcing air through 1 L of 10 mol KOH solution and 1 L of drierite ($CaSO_4$) crystal proved to be just as effective for the remainder of the experiment. After each testing chamber was flushed out, it was sealed with a stopper and placed into the environmental chamber to acclimate the inner air temperature of the testing chamber to the proper testing temperature. Data for each gerbil was obtained every 30 seconds for a period of approximately 10 minutes or until the upper limits of the CO_2 concentration reached the sensitivity limits of the analyzer. Tails were shaved with a razor using soap as a lubricant. An anesthetic was used for this procedure. There was a four hour period before the metabolic measurements resumed. The metabolic rates were measured for both WIT and WOT gerbils at ambient temperatures of 5°C, 20°C, and 35°C. Average metabolic rates measured under different conditions were compared using the paired Student's t-Test.

Results

Presence or absence of tail-fur had no effect upon metabolic rates of gerbils. Ambient temperature did, however, have a significant effect upon metabolic rates. The average rate for animals housed at 5°C was 4.23 mL O_2/g/h (s.d. = 0.99), at 20°C was 3.25 mL O_2/g/h (s.d. = 0.78), and at 35°C was 2,04 mL O_2/g/h (Figure 1). These values were significantly different from each other at the $p < 0.05$ level.

Discussion

According to the results of this study, the presence of tail fur had no effect on metabolic rates in gerbils. An apparent effect may have been observed if the measurements of the metabolic rate were taken a 3°C intervals within the range of ambient temperatures instead of 15°C intervals used in this study which only gave us a very vague understanding of the relationship between the gerbil's metabolism and ambient temperature. A more definite pattern of metabolic rates being plotted, could have shown a fairly close approximation of TNZs as well as the width of the ranges in comparison to the fur content upon the tail. Although the results reported by Kirksey et al. (1975) indicated that removing the tail affects thermoregulation by narrowing the thermoneutral zone of cotton rats, the tail may not have been a special thermoregulating surface. By removing the tail, complete circulation of body fluids throughout the body would not be possible, reducing the overall convective heat exchange. The metabolic heat production must rely on other mechanisms to compensate for the tails role in heat exchange with the environment. The same effect may have been observed in the amputation of a limb.

An infrared thermographic study done by Klir et al. (1990) of the surface temperature in relation to external thermal stress in the Mongolian gerbil, demonstrated little control of surface temperature, therefore indicating a lack of physiological thermoregulatory mechanisms. Instead, it was suggested that the gerbil uses mainly behavioral and ecological adaptive strategies to compensate for the stressful effects of its habitat. When the temperature inside the burrow falls below the TNZ during the winter, the gerbil uses nonshivering thermogenesis to increase metabolic heat production in a crouched up (ball-like) posture to reduce exposed surface area to maximize insulation and respiration and decrease circulation as mechanisms of heat conservation (Schmidt-Neilsen, 1984). During the summer in high ambient temperatures, it comfortably uses microclimates produced by burrowing 6 to 18 inches below the ground surface to minimize the probability of hyperthermia as well as the need for evaporative and convective cooling (Schmidt-Neilsen, 1984) . Also, it was observed to lay on the cooler spots along the floor with limbs in extended positions at higher temperatures.

Since an oxygen analyzer was not available for this study, a carbon dioxide analyzer was used to measure the metabolic rate. The CO_2 production used to measure the metabolic rate is considered less practical and far less accurate for two main reasons: one is that within the body, a pool of carbon dioxide is present in the reserve tidal volume of the lungs; the other relates to the caloric equivalent of 1 liter of carbon dioxide. The latter is referring that different food sources give rather varied amounts of energy for each liter of CO_2 produced. The food source provided for this study is an approved rodent chow that contains a high amount of usable substances that is easily oxidized and digested (93.7%) and a very low fat content (6.3%) which within itself is the major contributor to altering the metabolic rate and producing error among measurements taken. This diet minimized any adverse effects to the results obtained. The pool of CO_2 in the gerbil is relatively small which would lead to a less notable effect on the metabolic rates recorded. Furthermore, the possibility was minimized by flushing out the testing chambers between trials as well as the gerbil remaining fairly inactive during the testing. More precise measurements could have been made if the need for handling the animals prior to testing was removed, but this would have required the altering of the experimental design by connecting the holding cages directly to the testing chamber. This would be impractical and unnecessary in considering the space and equipment available for this study.

In closing, the tail of the Mongolian gerbil according to this study, did not appear to have any significant function in the thermoregulatory mechanisms in maintaining a constant body temperature at various ambient temperatures. The only contributing factor that had an affect in altering the metabolic rate was temperature.

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