EFFECT OF CLIPPING THE COAT OF THE JAPANESE MACAQUE (MACACA FUSCATA) ON THE THERMOREGULATORY RESPONSES

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Abstract  Effect of clipping the coat of the Japanese macaque on thermoregulatory responses was studied. Heat production was significantly increased in clipped animals in comparison without clipped coats at ambient temperatures ranging from 5 to 25°C. At ambient temperatures of 5, 15, and 25°C tissue thermal conductance and cooling constant were significantly higher in clipped animals. Clipped animals could maintain thermal equilibrium at an ambient temperature of 5°C, compensating for the increase of heat loss by elevating heat production markedly.

It is generally recognized that the coat of an animal has insulative value, decreasing heat dissipation through the body surface to the environment. The Japanese macaque, the most northerly species among nonhuman primates, has some of the physical features which are considered to be adapted to a cold climate—very short tail, comparative large body and wide shoulders and hip (Iwamoto, 1971). At an ambient temperature of 5°C constancy of deep body temperature is well maintained by increasing metabolic rate to more than twice the rate at thermoneutral zones (Nakayama et al., 1971; Tokura et al., 1975). It is of interest from ecological as well as thermophysiological viewpoints to evaluate the insulative effect of the pelage in the Japanese macaque which can tolerate severe coldness in its natural habitat. In the present study, attempts were made to measure thermal and metabolic responses in clipped animals during exposure to cold.

MATERIALS AND METHODS

Four male adult Japanese macaque (Macaca fuscata) weighing 6–12 kg were used. They had been caged for at least one year in our Institute at a temperature of 25±3°C and were well accustomed to sitting quietly in monkey restraining chairs.
Their thermal and metabolic responses at low ambient temperatures were investigated within several hours after their coats were clipped. The experiments were made during January 1973. The length of their long hairs was 65–95 mm on the back, 65–75 mm on the side and 30–40 mm on the abdomen; that of their finer fibers was 35–45 mm, 40–45 mm, and 35–40 mm. Hairs were clipped from all over the body surface, leaving 3–4 mm from the base.

The measurements of physiological reactions were started about 2 hr after an animal was transferred to a microclimate chamber controlled at 25±1.5°C with 40 to 60% relative humidity. The ambient temperature (T°) in the chamber was lowered from 25 to 20, 15, 10, and 5°C, successively, being maintained constant at each level for 1–2 hr. The animals were fasted 24 hr before the experiments. The method for measuring thermal and metabolic responses is similar to those reported by Hori et al. (1970). Oxygen uptake and carbon dioxide output were determined by an open-flow draw system. Metabolic heat production (M) was calculated from oxygen uptake and carbon dioxide output. A plexiglass hood (250 mm high, 300 mm wide, and 300 mm long) placed over the monkey's head was continuously ventilated at a rate of 18–21 liter/min by an air-pump pulling the air through the hood and the connecting hose. The mixed ventilating and expired air was collected through a dry gas meter monitoring the flow rate into a Douglas bag for 5 min every 15 min. The mixed gas sample was analyzed for oxygen concentration with a Beckman oxygen analyzer (model E2) and for carbon dioxide concentration with a Beckman infrared carbon dioxide gas analyzer (model LB–1). Water vapor from the respiratory tract was measured using two pairs of wet and bulb thermocouples. The water content of inspired air was recorded by the first pair placed at the entrance of the hood, while that of expired air by the second pair at the exit of the hood. Since the flow rate of the air through the hood was known, respiratory water loss (Eex) was obtained by subtracting the first value from the second. Rectal (Tre) and skin temperatures at 3 points of the chest, legs, and feet were measured every minute using copper-constantan thermocouples. Using the formula for the Japanese macaque previously reported by Hori et al. (1972), the body surface area (A) and the mean skin temperature (Ts) were estimated. Tissue thermal conductance and cooling constant at a steady state condition, at which mean body temperature does not change so that change in heat storage can be regarded as zero, were calculated by the following equation:

Tissue thermal conductance (W/m²·°C)

\[
= \frac{\text{rate of heat loss through the skin surface}}{A(T_{re} - T_s)}
= M - E_{ex}/A(T_{re} - T_s)
\]

Cooling constant (W/m²·°C)

\[
= M - E_{ex}/A(\bar{T}_s - T_s)
\]

By subtracting the insulation, reciprocal of tissue thermal conductance in
clipped animals from that in unclipped ones, the net insulation due to the fur was estimated, being converted at the same time into clo units by the formula 1 clo = 0.155°C·m²/W.

RESULTS

In Fig. 1, mean values of physiological variables of clipped animals obtained at $T_a$ ranging from 25 to 5°C are compared with those of unclipped animals which were reported in our previous study made on the same Japanese macaque (TOKURA et al., 1975). Heat production was 1.4–2 times greater in clipped animals

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Fig. 1. Comparison of heat production, rectal and mean skin temperatures at various ambient temperatures ranging from 5 to 25°C between clipped and unclipped Japanese macaques. ●: clipped, ○: unclipped. Vertical segments denote standard error of means. The data on unclipped animals are quoted from TOKURA et al. (1975). Two values in a steady state condition are adopted from each animal at each ambient temperature.
than in unclipped animals. At $T_a$ of 25°C heat production was $95.7 \pm 13.1$ W/m² (mean ± standard error) in clipped, and $47.6 \pm 5.0$ W/m² in unclipped animals, which increased at $T_a=5$°C by about 95% and 49% to $142.3 \pm 13.0$ W/m² and $92.8 \pm 10.3$ W/m², respectively. $T_{re}$ was slightly lower at every $T_a$ in clipped animals than in unclipped animals ($p<0.05$ for $T_a=10$°C). Clipped animals showed lower $T_r$ at $T_a$ of 10, 20, and 25°C ($p<0.05$ for $T_a=20$°C) and a little higher values at $T_a$ of 5 and 15°C.

As represented in Fig. 2, cooling constant and tissue thermal conductance were significantly higher in clipped animals than in unclipped animals when compared at $T_a$ of 5, 15, and 25°C. They are estimated to increase by 35–60% and 20–40%, respectively, after clipping. Although clipped animals showed slightly lower rectal temperature at every $T_a$, they maintained thermal equilibrium well down to $T_a$ of 5°C.

![Graph showing cooling constant and tissue conductance](image)

The net insulation due to the fur which is estimated by subtracting the insulation in clipped animals from that in unclipped animals is 0.03 (0.19 clo), 0.03 (0.19 clo) and 0.01 (0.06 clo) °C·m²/W at $T_a$ of 5, 15, and 25°C, respectively.

**DISCUSSION**

According to Berman and Kibler (1959), clipped dairy heifers showed about 7% increase of the temperature gradient between the surface temperature and
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$T_a$ and probably decrease of the insulation coefficient. The clipped animals responded to heat loss by increasing heat production and maintaining thermal balance. Webster (1966) also reported that at $T_a$ of $-10^\circ C$ oxygen consumption was greater in the sheep with a fleece depth of 15–25 mm than in the one with a fleece depth of more than 40 mm. Our findings that cooling constant and tissue thermal conductance are significantly high in comparison with that seen in the unclipped animals show the reduction of the ability of insulative properties through skin surface in the clipped monkey. The animals responded to the increase of heat loss by increasing heat production and maintained thermal balance. The relation obtained in our present experiment is essentially in agreement with those found in heifers and sheep.

Scholander et al. (1950) found the insulation of the fur inclusive of the hide for tropical mammals such as shrew, squirrel, weasel and lemmlings 0.005–0.025 $^\circ C \cdot m^2/kcal/24\text{ hr}$, employing the guard hot plate method. Assuming that the insulation of the hide for the Japanese macaque is 0.015 $^\circ C \cdot m^2/kcal/24\text{ hr}$ (the middle point of the insulation for tropical mammals), the insulation of the fur inclusive of the hide for the Japanese macaque can be calculated as 0.017, 0.017, 0.016 $^\circ C \cdot m^2/kcal/24\text{ hr}$ at $T_a$ of 5, 15, and 25°C, respectively. Though our data cannot be compared exactly with those from Scholander et al. (1950), as the measurement methods are different, the insulation of the fur inclusive of the hide for the Japanese macaque used seems to be similar to that for tropical mammals which is far smaller than that for arctic mammals. However, it must be remembered that the animals studied in this experiment had been housed at a constant room temperature of 25°C and a constant artificial 12-hr light-dark change throughout the year. Therefore, there might be a possibility that wild Japanese macaques have higher insulation values of the fur especially in snowy periods.

Our findings that the differences in $\bar{T}_n$ were not conspicuous between clipped and unclipped animals might be attributed to the fact that the measurements were taken on the chest and legs, where the fur is comparatively sparse.

The present experiment shows that the Japanese macaque is able to maintain thermal balance at $T_a$ of 5°C without the major part of its pelage, compensating for the increase of heat loss by elevating heat production markedly.

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REFERENCES


