THE BODY TEMPERATURE OF THE AMERICAN KESTREL, *FALCO SPARVERIUS*

BY GEORGE A. BARTHOLOMEW AND TOM J. CADE

DESPITE the number of falcons which have been trained and kept in captivity, remarkably few quantitative data are available on even the most obvious aspects of their physiology. Aside from the studies on *Falco tinnunculus* reported over half a century ago (Simpson and Galbraith, 1905) and the data compiled by Wetmore (1921), almost nothing has been published on body temperature in members of the order Falconiformes.

The genus *Falco* offers particularly attractive opportunities for the study of comparative physiology. It comprises an extremely homogeneous group morphologically, yet various of its species occur at almost all latitudes and occupy virtually every terrestrial habitat. The species *F. sparverius*, considered in the present study, ranges from the northern limit of trees in North America to Tierra del Fuego at the southern tip of South America, and occurs in a variety of habitats including deserts.

Materials and Methods

The kestrels were captured in noose traps of the "balchatri" type (see Cade, 1955, for a description). Except when being used for experimental purposes they were housed together in a cage measuring 6 × 6 × 6 feet and made of fish net with half-inch bar stretched over a framework of tubular aluminum. The data presented herein were obtained between November, 1954, and September, 1955. Ten adult birds were used. Except for one bird which was killed by an overdose of anesthesia, none died or suffered any apparent injury as a result of the experimental treatment. The captive birds maintained their weight without water on a diet of beef heart and freshly killed mice.

All temperatures were measured to the nearest tenth of a degree centigrade with silver-soldered 30-gauge copper-constantan thermocouples which were connected to a recording potentiometer.

The long term records were obtained from thermocouples implanted in the pectoral muscles. The copper and constantan wires were soldered end to end, ground smooth, and threaded through a surgical needle. The bird to be studied was anesthetized with an intramuscular injection of nembutal. A perforation was made in the skin in the pectoral region and the needle was inserted. The thermocouple was then drawn through and adjusted to lie beneath the pectoral muscle adjacent to the sternum. Leads were attached to the thermocouple and seized to a stitch sewn through a dorsal feather tract. Kinking of the leads, which were led out through the top of the cage, was prevented by sheathing them in vinyl tubing. It was possible to obtain continuous 24-hour records from birds which were rigged in this manner and were free to eat and move about in cages with a volume of about 2 cubic feet.

The short term records of deep body temperature were obtained from thermocouples sheathed with vinyl tubing and inserted through the cloaca into the large intestine to a depth of 3 or 4 cm. and secured in place by clips attached to the rectrices. Skin temperature of the legs was determined from thermocouples attached to the naked tarsometatarsus with adhesive tape. The ambient temperature was monitored with thermocouples and controlled by an insulated chamber equipped with heating and cooling units, a blower, lights controlled by a clock-driven switch, and insulated glass ports for observation.

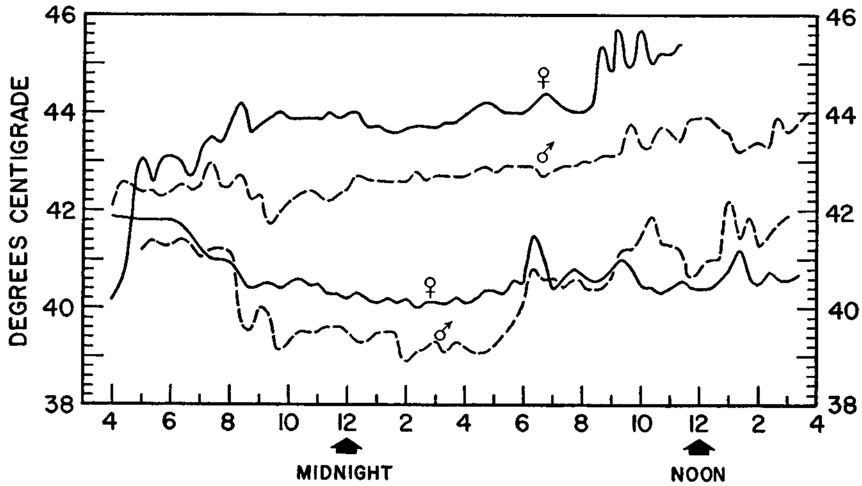

FIG. 1. Continuously recorded body temperatures in *Falco sparverius*. The two lower records are from birds held at an ambient temperature of 20° to 22° C. The two higher records are from birds held at an ambient temperature of 39° to 40° C. Photoperiod for all runs, 6:00 a.m. to 8:00 p.m.

RESULTS

BODY TEMPERATURE IN THE ABSENCE OF STRESS

The deep body temperature of the kestrel, like that of other birds which have been studied, shows considerable lability. Because of the excitement incidental to handling, manually taken cloacal temperatures were apt to be above the resting level. A better approximation of the true resting body temperature was given by continuous records obtained from thermocouples implanted in birds, which had become adjusted to captivity. Two such records are presented in the lower part of Figure 1. There is a diurnal cycle. The body temperature at night averages about one degree lower than during the day, but it is relatively more uniform. The variations in body temperature in the daytime center about 40.5° C. and may rise almost to 42° C. under conditions of moderate excitement, such as produced by sudden illumination, or by eating. During the investigation many hours of continuously recorded temperatures were obtained from birds that we judged to be relatively unstressed. These data agree with the 24-hour records shown in Figure 1 and indicate that in the absence of conspicuous nervousness, environmental stress, or high levels of activity, deep body temperatures lie between 40.2 and 41.4° C. in alert adults of this species.

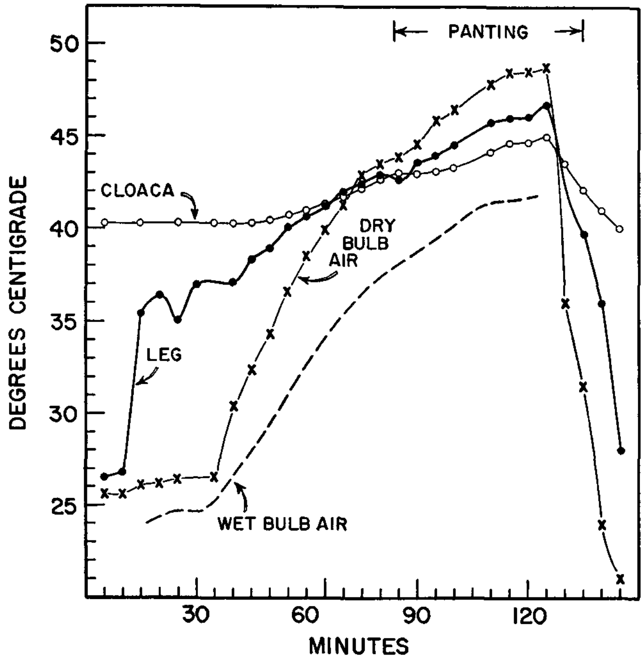

Fig. 2. Response of cloacal and tarsometatarsal temperatures to changing ambient temperature.

BODY TEMPERATURE DURING HEAT STRESS

Short term response to rising air temperatures.—After many unsuccessful attempts, continuous records of leg and cloacal temperatures were obtained from four individuals exposed to a slowly rising and then rapidly decreasing ambient temperature. All four birds showed responses of the sort shown in Figure 2. At ambient temperatures around 25° C. the cloacal temperature was between 40° and 41° and the first measurement of the temperature of the scaly part of the tarsometatarsus was between 25° and 30° C. but this almost immediately rose to 35° or more, presumably as a result of vasodilatation. As the ambient temperature started to rise, the leg temperature immediately increased but the cloacal temperature rose only slightly if at all. As the ambient temperature passed 35°, cloacal temperature began to rise more steeply, and as the ambient temperature continued to increase, cloacal and leg temperatures approximated and paralleled each other. When cloacal temperature reached 42.8° to 43.0° C., panting usually commenced; saliva was clearly visible in the open mouth, and the cere appeared to become somewhat moist. As the cloacal temperature continued to rise the panting became heavier and more rapid, and a powerful, rapid, in-and-out flutter of the tongue was initiated. As the cloacal temperature approached 45° C. the plumage became compressed, the wings drooped, and the eyes bulged.

When the cloacal temperature reached 45° C. the doors of the temperature chamber were opened and ambient temperature was allowed to fall rapidly. With all its mechanisms for heat dissipation activated, the animal's cloacal and leg temperatures fell rapidly and soon returned to the original temperatures prior to the period of stress.

Response to sustained high ambient temperatures.—We were able to obtain from implanted thermocouples two continuous 24-hour records of body temperature in birds maintained at air temperatures of 39° to 40° C., which is as high as any mean daily temperature that kestrels are apt to meet under natural conditions (Fig. 1). In both cases deep body temperature rose (in one instance 2° and in the other 4° C.) above normal and remained at this new high level. The birds panted almost continually, but ate normally. During the hours of darkness, the temperature of both birds approached an equilibrium condition, but as soon as the lights came on it started to rise. In one case, something approaching thermal homeostasis was maintained for some hours, but the bird eventually lost control and a series of oscillations ensued with the body temperature approaching 46° C. at the peaks. To prevent injury the bird was returned to room temperature and in about one-half hour its cloacal temperature had fallen to the customary level. The bird behaved normally thereafter and two days later it was released in good condition. In the second case, as soon as the lights came on, body temperature began to rise. Despite the continuous panting of the bird its increased activity apparently imposed a severe heat load and body temperature rose and oscillated between 43.5° and 44.0° C. until the experiment was terminated.

Water Economy

The American kestrel can be maintained indefinitely in captivity on a diet of fresh meat without drinking water. None of the birds used in the present study was given water and all either maintained or gained weight during the period of captivity. In the spring of 1954 a pair of kestrels was kept in captivity for two months during which time they mated and laid eggs. Although no water was available even the female, despite the water loss involved in ovulation, gained weight.

Discussion and Summary

Body temperature in *Falco sparverius* shows a clear diurnal pattern related to activity, and conspicuous short-term variations related to excitement and stress. However, the diurnal temperature cycle of *F. sparverius* and also that of *F. tinnunculus* (Simpson and Galbraith, 1905) are of smaller amplitude than those of most birds for which data are available. As in most birds, panting is the principal mechanism of heat dissipation when ambient temperature exceeds body temperature, but the possibility of slight evaporative cooling from the cere, and perhaps the cornea, exists. When ambient temperature is lower than body temperature heat loss is regulated to a considerable degree through vasomotor activity in the unfeathered parts of the tarsometatarsus. When subjected to high ambient temperatures, the kestrel's body temperature rises from the normal resting level of about 40.5° C. and maintains itself at a new level 2° to 4° C. higher.

The observations summarized above assist in understanding the ability of kestrels to occupy desert regions even during the hot weather of summer. Their capacity to exist under conditions of heat and aridity appears to be related in part to their toleration of greatly elevated body temperatures and to the fact that their carnivorous diet minimizes the importance of drinking and thus frees them of dependence on surface water. Their physiological tolerance of desert conditions is of course reinforced by their behavior. In the desert in the summer kestrels confine their hunting to early morning and early evening. They are inactive during the heat of the day and stay in the shade. In the winter they hunt throughout the hours of daylight and occupy exposed perches. Despite the tolerance of kestrels to heat and aridity, the density of their breeding population in deserts is low when compared with levels in cooler and less xeric environments.

That the remarkably extensive geographic range of this species includes deserts as well as virtually every other major terrestrial habitat south of the tree line in the New World is another instance of the success of a eurytopic bird in occupying the desert without special physiological adaptations (Bartholomew and Dawson, 1953; Bartholomew and Cade, 1956).

Acknowledgment

These studies were aided in part by a contract between the Office of Naval Research, Department of the Navy, and the University of California (NR 160–171).

LITERATURE CITED

BARTHOLOMEW, G. A. AND T. J. CADE
1956 Water consumption of house finches. *Condor*, 58:406–412.

BARTHOLOMEW, G. A. AND W. R. DAWSON
1953 Respiratory water loss in some birds of southwestern United States. *Physiol. Zool.*, 26:162–166.

CADE, T. J.
1955 Experiments on winter territoriality of the American kestrel, *Falco sparverius*. *Wilson Bull.*, 67:5–17.

SIMPSON, S. AND J. J. GALBRAITH
1905 An investigation into the diurnal variation of the body temperature of nocturnal and other birds, and a few mammals. *Jour. Physiol.*, 33:225–238.

WETMORE, A.
1921 A study of the body temperature of birds. *Smithsonian Misc. Coll.*, 72(12): 1–52.

DEPARTMENT OF ZOOLOGY, UNIVERSITY OF CALIFORNIA, LOS ANGELES, JULY 10, 1956