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Metabolic Heat Production in the Chukar Partridge

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The Barbary dove (*Streptopelia risoria*) prefers environmental temperatures within its physiological thermoneutral zone (Budgell 1971). The Chukar (*Alectoris graeca*) demonstrates a preferred environmental temperature of 26–31°C (Laudenslager and Hammel 1977). The present study describes metabolic measurements in the Chukar which indicate that the physiological thermoneutral zone of this species also corresponds closely to its preferred temperature range.

Three adult male Chukars, weighing 632–662 g at the beginning of the study, were obtained from a local game bird breeder. Each bird was housed individually in an environmental chamber maintained at 23 ± 1°C. Testing took place at the same time each day during the light phase of a LD 8:16 light cycle. Birds were deprived of food for 18 h prior to all metabolic measurements; otherwise Purina layena game bird chow and water were available *ad libitum*. The birds were tested individually in a sealed 8-l desiccator jar through which dried (relative humidity <1%) outside air was drawn at 1.8–2.2 l/min. The jar was placed in a lighted environmental chamber, maintained within ±0.5°C of test temperatures. Oxygen consumption was measured in an open flow system with a Beckman F-3 paramagnetic oxygen analyzer, calibrated by a partial pressure method (Hammel and Hardy 1963). Heat production was determined from the average rate of oxygen consumption assuming a RQ of 0.80 and 10 ml of oxygen consumed/min as equivalent to 3.38 W. The output of the oxygen analyzer was either recorded on a potentiometric recorder (Leeds and Northrup) for later analysis or entered on-line into an A to D converter for immediate processing by a Data General Nova II computer. The first 20–30 min of any test were discarded as an equilibration period, and the average rate of oxygen consumption was determined over the following 90 min. Each bird was tested at least two times at each of the following ambient temperatures (T_a): −3.5, 0, 4.5, 12, 16.5, 21.5, 24.5, 31, and 35°C. Only one T_a was tested on any day, and tests were separated by at least 48 h. Cloacal temperature (T_{Cl}) was measured with a Yellow Springs Instrument Telethermometer before and after each test with the probe inserted 6 cm.

Figure 1 illustrates the average heat production of the Chukars at the T_as tested. The average T_{cl} (N = 62) prior to testing was 41.81 ± 0.21°C (±SD). Post-test T_{cl} was not different from pretest T_{cl} for any of the T_as tested (*t*-tests, $P > .05$); post-test T_{cl} (N = 62) for all T_as averaged 41.86 ± 0.30°C (±SD). The lowest rates of heat production were observed at T_as of 24.5°C and 31°C. The broken line in Fig.

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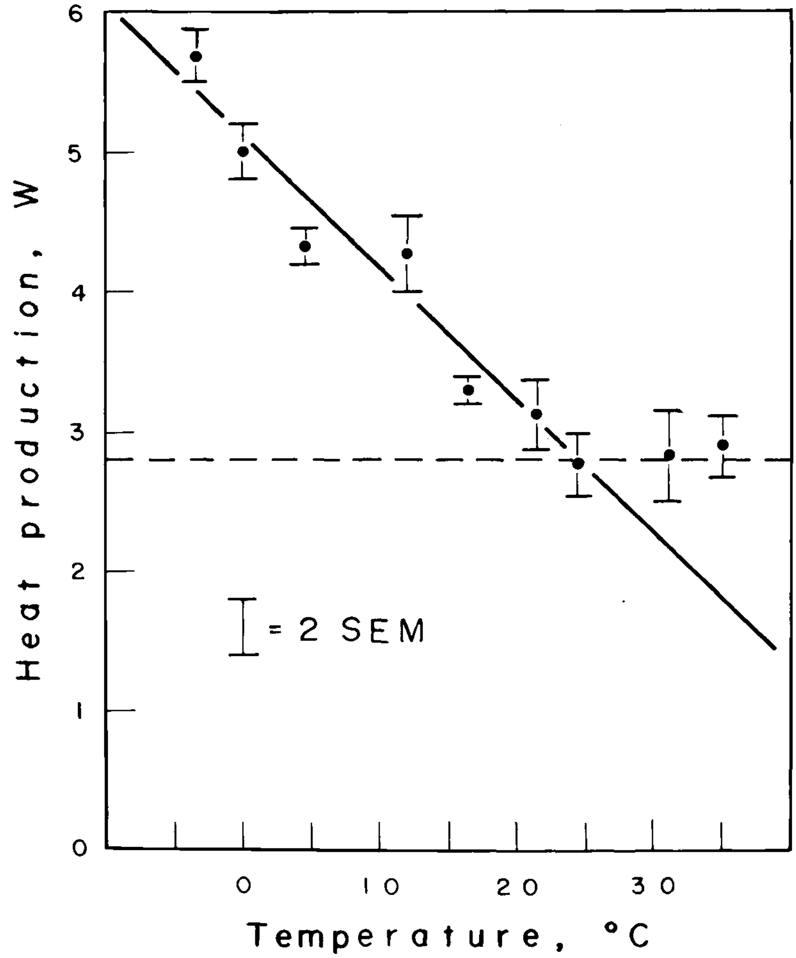

Fig. 1. Metabolic heat production of three Chukars as a function of ambient temperature. Symbols represent the average of the mean responses (bracketed by ±1 SEM) for each Chukar for tests at each ambient temperature. Note that the regression line fails to intersect 0.0W at the T_a equal to body temperature (41.8°C).

1 is the mean of the individual test averages for 25.5°C and 31°C and corresponds to the standard metabolic rate, 2.804 ± 0.167 W (±SEM). The least squares regression of heat production onto T_a for 24.5°C and below is represented by the solid line ($\tilde{Y} = 5.103 - 0.095X$, $S_{y \cdot x} = .515$, $S_b = .005$, $r^2 = .772$, $N = 43$). Thus heat production in the Chukar increases 0.10 W/°C below 24.4°C where 24.4 is equivalent to the lower critical temperature or that point at which the least squares regression line intersects the standard metabolic rate.

At T_as below 24.5°C, the birds assumed a squat, compact posture. These changes from less constricted postures were also coincident with increased fluffing of the plumage. The apparent degree of ptiloerection increased as T_a decreased from 4.5°C to −3.5°C. During all these tests, the birds remained quiet. Shivering was not noticed in any of the cold temperatures tested. At T_as above 24.5°C, signs of restlessness were occasionally noted. Two birds were tested once each at a T_a of 40°C; each became quite active within 5–10 min. Gular flutter was prominent by the end of 15 min. It was necessary to remove the birds from the chamber after 45 min because of signs of severe heat stress. The birds had T_{cl} in excess of 44°C; one bird was ataxic when removed but recovered within 2 h at a T_a of 20°C. Heat production was high (4.25 W) by the end of these tests. The elevated heat production was undoubtedly attributable to the increased activity associated with attempts to escape from the test chamber noted in the birds.

Dissipation of excess heat by evaporation may be limited in experimental situations where high water vapor pressures are produced by gular flutter (Lasiewski, Acosta, and Bernstein 1966). Calder and King (1974) predict that approximately 50–60% of metabolic heat production at 40°C is lost by evaporation, which corresponds to roughly 58 mg H_2O/min in the present study. This would produce a fairly high water vapor density of 29 mg/l (relative humidity = 57%) and thus contribute to the thermal stress noted at 40°C.

The present observations indicate that when the Chukar selects environmental temperatures in the range of 26–31°C (Laudenslager and Hammel 1977), it is selecting temperatures at which heat production is minimized. When environmental temperature selection behavior is possible in nature, the organism can exhibit a minimal metabolic rate for the maintenance of a constant core temperature by selecting temperatures within this range. The Chukar has a lower preferred T_a and physiological thermoneutral zone than doves acclimated to equivalent laboratory conditions (Budgell 1971). Since core temperatures are comparable between the two species, the Chukar probably has a lower heat transfer coefficient (*HTC*) than the dove. On the basis of the allometric relationship between body weight and *HTC* (Calder and King 1974, Herreid and Kessel 1967), this is not unexpected when comparing a 150-g dove with a 650-g Chukar, but this could also be a function of alterations in vasomotor tonus. The standard metabolic rate of the Chukar falls below that predicted by the allometric equation for resting diurnal non-passerine birds tested during the day (Aschoff and Pohl 1970). This equation ($HP = 91.0\, M^{0.729}$, where *HP* equals heat production in kcal/day and *M* equals mass in kg) predicts a standard metabolic rate of 66.47 kcal/day (3.219 W) for a 650-g bird; the present study observed a lower standard metabolic rate of 57.91 kcal/day (2.804 W) for birds of comparable weight.

According to the Newtonian model of heat loss (Scholander et al. 1950), the *HTC* of a homeotherm may be estimated by the slope of the regression line relating heat production to T_a below the lower critical temperature. This relationship is considered a fair predictor of avian function within a restricted laboratory environment (Calder and King 1974). There are several requirements for this model to hold: first, the regression line must extrapolate to body temperature for zero heat production; second, insulation must remain constant below the lower critical temperature; and finally, body temperature must not change. For the Chukar, the regression line does not extrapolate to body temperature but rather to 54°C (Fig. 1). Obvious postural and plumage changes, which would alter the birds' insulation, were noted at T_as below 24.4°C. Similar observations have been made for the pigeon (*Columbia livia*) and the roadrunner (*Geococcyx californianus*) (Calder and Schmidt-Nielsen 1967). One must, therefore, be cautious when estimating the *HTC* on the basis of the slope of the regression line relating heat production to T_a.

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