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Acquisition of Homeothermy in the Black-eared Kite, *Milvus migrans lineatus**

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The development of homeothermy was investigated in a hand-reared black-eared kite, *Milvus migrans lineatus*. The 20-day-old nestling was capable of thermoregulating at about 95% of the adult ability at the ambient temperature of 20°C. In effect, the kite which is one of large altricial birds acquires the homeothermy in an earlier growth stage than do small altricial ones, Such precocious development of homeothermy in the kite appears to be caused by the large body mass resulting in decreased surface to volume ratio and in increased heat production, and it allows the parents to increase the foraging time early in the nestling period. In other words, the precocious development of homeothermy plays an important part in the growth and survival of the kite nestling which requires more food and energy than do the nestlings of small altricial birds.

INTRODUCTION

Most of the young birds, regardless of precocial or altricial modes, are unable fully to regulate their body temperature for a few days or a considerably long period after hatching; therefore, they need to be brooded by the parent(s). Precocial young demand only intermittent brooding until they obtain their thermoregulatory ability, whereas altricial young require relatively continuous brooding. In the altricial birds, the length of the brooding time is influenced by the age of nestling, the time of day, the weather factors and the microhabitat conditions around the nest (Heagy and Best, 1983 ; Newton, 1978 ; Koga and Shiraishi, 1987). The female parent of the black-eared kite (*Milvus migrans lineatus*), which builds the nest at least partially exposed to sunlight during daytime, ceases to brood her still downy nestlings 17-23 days after hatching except for night or rainy days, but nocturnal brooding continues until 37-43 days after hatching, when the nestlings are fully feathered. Consequently, it has been assumed that the nestlings of the kite are capable of producing enough heat for thermoregulation at about 20 days of age and they attain the adult level of the insulative capacity at approximately 40 days of age (Koga and Shiraishi, 1987).

However, there has been no study on thermoregulation in the black-eared kite. The purpose of this study is to clarify the relationship between the cessation of diurnal brooding and the acquisition of homeothermy, and to discuss the ecological advantage to the nestling in relation to the development of homeothermy in the kite.

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MATERIALS AND METHODS

1. Hand-rearing

A hand-reared young was used in this study on the development of homeothermy. An egg taken from a wild nest on 27 March 1987 was incubated at a temperature of 37.2°C with a RH of about 90%, and turned 4 times per day. The hatchling was maintained for 12 hr in the incubator, and then placed in a brooder with a temperature of 36°C and a RH of about 60%. The temperature in the brooder was gradually reduced to 30°C by the second week. The nestling at 14 days after hatching was transferred to a cage (90 x 150 x **90** cm high) in the room kept at a temperature of about 25°C. The floor surface directly below a 125-W infrared lamp suspended from the ceiling of the cage was provided with 33°C, and the lamp was removed on 40 days of age. The 60-day-old young, which is usually capable of fledging in the wild, was moved to an aviary (2 x 4 x 2 m high).

The young was given food 3 to 5 times per day, and allowed to feed until satiated. The main foods were small pieces of chicken liver, heart, and/or chopped fishes to which one drop of a vitamin complex preparation and about 0.5 g calcium powder were added. The young was weighed every morning before feeding. The calculation of the fitting equation to the growth curve was based on the method of Ricklefs (1967).

2. Measurement of the body temperature

The thermoregulatory ability of the nestling was indicated by the body temperature at an ambient temperature of 20°C. Considering that the low ambient temperature of 20°C might exert the harmful influence on the nestling at an earlier age, the trials were started from Day 12. However, the body temperature of the 4-day-old nestling which was exposed to an ambient temperature of 25°C for 1 hr was measured in order to estimate the thermoregulatory ability at such an early age. First, the young was maintained for 1 hr in a cage placed in a cabinet which was regulated at an ambient temperature of 30°C (55% RH), and then exposed to the ambient temperature of 20°C (55% RH) for 1 hr. The body temperature was measured by inserting a Takara thermistor probe, accurate to 0.1°C, approximately 2.0-2.5 cm into the cloaca. The ambient temperature in the cage was measured with another thermistor (accurate to 0.1°C), and kept within about ±0.5°C of the desired level. Both the body temperature and the ambient temperature were continuously monitored on a 6 channel multipoint recorder (Watanabe P. 0. C. Multicorder MC 6622). All measurements were made from 09 : 00-13 **: 00** hr. The nestling was without food for about 12 hr before the above experiment.

RESULTS

1. Changes in the body-weight

The black-eared kite nestling exhibited a typical logistic growth pattern (Fig. 1). The growth rate constant, the age at the inflection point and the asymptotic body-weight for the logistic equation were 0.191, 16.3 days and 878 g (the maximum body-weight =925 g), respectively. The logistic equation provided a best fit to the data from hatching to 40 days. The decline in the body-weight during the period from 55 to 60 days of age was simultaneous with the decrease in the food consumption (cf. Figs. 1 and 2).

2. **Changes in the body temperature**

The body temperature of the developing young is given in Fig. 3. The $-day-old nestling maintained a body temperature of 33.8°C at the ambient temperature of 25°C. The 12-day-old nestling exposed to the ambient temperature of 20°C had a low and unstable body temperature varying between 36.8 and 37.6°C during the experiment, while the nestling at 20 days and over of age could stabilize the body temperature within 20-30 minutes after exposure to the ambient temperature of 20°C. Although the latter constant body temperatures differed with days (ranging from 38.6 to 39.6°C), they generally tended to increase with age in days. The similar trend was found also in the body temperatures at the ambient temperature of 30°C, which were higher by 0.2 to 0.9°C than those at the ambient temperature of 20°C. The 95-day-old young which become independent of the parent care in the wild retained the body temperatures of

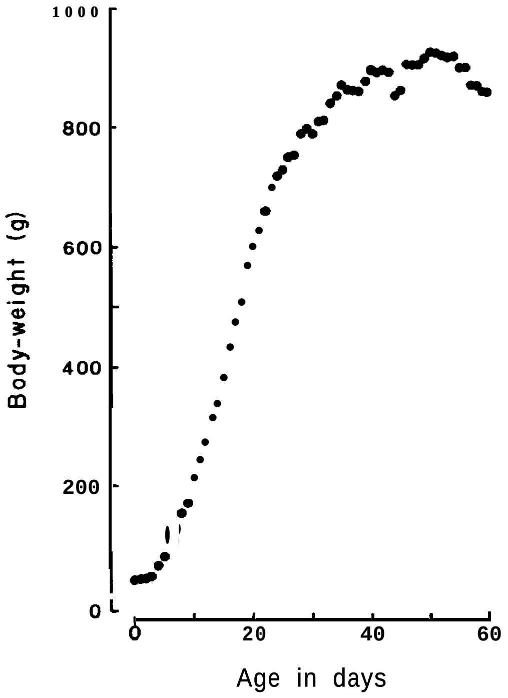

Fig. 1. Weight changes of a black-eared kite nestling. The logistic growth equation best fits the data from hatching to 40 days in accordance with the Ricklefs' (1967) method. The growth rate constant, the age at the inflection point and the asymptotic body-weight for the logistic equation are 0.191, 16.3 days and 878 g, respectively.

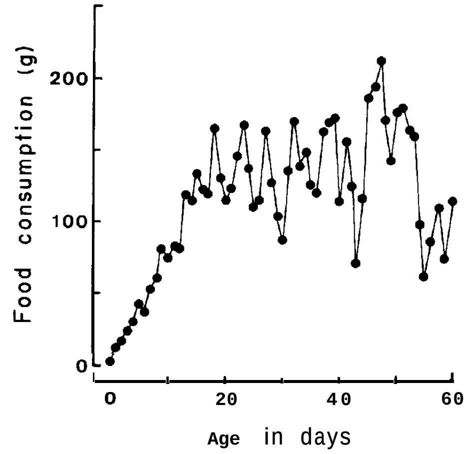

Fig. 2. Food consumption (g) of a black-eared kite nestling.

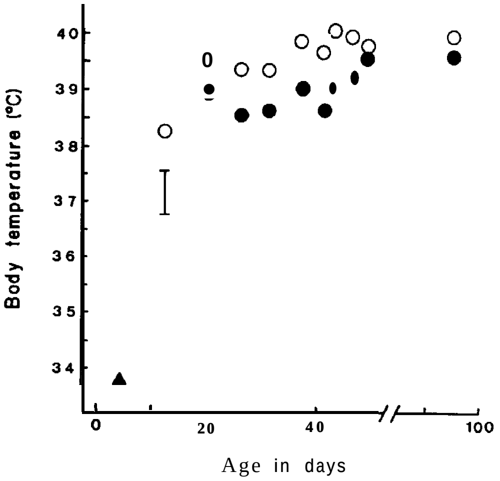

Fig. 3. Body temperatures of a young black-eared kite. A solid triangle shows the stabilized body temperature for a 1 hr period at the ambient temperature (Ta) of 25°C. ○ and ●, the stabilized body temperatures for a 1 hr period at the Ta of 30 and 20°C, respectively ; vertical bar, the range of the unstable body temperatures in a 12-day-old nestling for a 1 hr period at the Ta of 20°C.

39.6 and 40.0°C at the ambient temperatures of 20 and 30°C, respectively.

DISCUSSION

To our knowledge, there have been few studies on the development of homeothermy in the order Falconiformes, except for the reports of Jud and Kulzer (1975) for a buzzard (*Buteo buteo*) and Wink et *al.* (1980) for Eleonora's falcons (*Falco eleonorae*). Therefore, this is the first and important report on the homeothermic development in the black-eared kite nestling, although the sample size is small ($n=1$).

The body temperature is maintained within the narrow limits by adjustment of the equilibrium between thermogenesis and thermolysis. In order to regulate heat balance, sensory information which was sent from temperature sensors located throughout the body must be controlled by a thermoregulatory centre. The studies of destructive lesion and electrical stimulation in birds and mammals have revealed that the area of the preoptic and anterior hypothalamus functions as the thermoregulatory centre (Bligh, 1966 ; Hammel, 1968 ; Calder and King, 1974 ; Cabanac, 1975). The spinal cord also is an important part of the temperature regulation system in birds (Rautenberg et *al.,* 1972 ; Dawson, 1975 ; Simon et *al.,* 1976 ; Hammel *et al., 1976* ; Snapp *et al.,* 1977 ; Bech et *al.,* 1982). Accordingly, the maturation of such neural control systems is required for the effective control of the body temperature (Marsh and Wickler, 1982), not to mention the elevation in quality and the increase in quantity of tissues (muscular, circulatory and respiratory systems and plumage, etc.).

According to the equation of McNab (1966) for the relationship between the body temperature (Tb) and the body-weight (W) for adults, viz.

$$Tb = 14.3\ W^{-0.09} + 32.2,$$

the expected body temperature of an adult black-eared kite (average body-weight= 1,038 g, $n=50$, unpublished data) was 39.9°C, with which the body temperature of the 95-day-old young well corresponded. Therefore, the 20-day-old nestling (the body temperature of 39.0°C at the ambient temperature of 20°C) achieved approximately 95% of the adult thermoregulatory ability, which was calculated as a percentage of the difference between the body temperature and the ambient temperature of 20°C for the nestling to the difference maintained by the adult, and consequently it may be said that the nestling acquired homeothermy at about 20 days after hatching. This achievement of homeothermy coincided with average 20 days (ranging from 17 to 23 days) of age when diurnal brooding had almost stopped (Koga and Shiraishi, 1987).

Parent bird(s) can defend the nestlings against cold stress by brooding; on the other hand, they can shade their nestlings from the direct rays of the sun, but cannot protect them from the high air temperature in heat stress : therefore, nestlings must deal with heat stress for themselves ; the two main defenses available to the nestlings are evaporative cooling and hyperthermia (O'Connor, 1984). Hyperthermia, i. e. the elevation of the body temperature above normal levels, contributes to maintaining a more favourable gradient between the body temperature and the ambient temperature for the purpose of thermolysis via non-evaporative pathways, and consequently to conserving the body water (Calder and King, 1974 ; Weathers and Schoenbaechler, 1976 ; Larochelle et al., 1982 ; Mishaga and Whitford, 1983).

In order to compare the development of homeothermy with growth among different species, we discussed the relationship between the thermoregulatory ability and the percentage of the nestling weight to the asymptotic body-weight (Fig. 4). The homeothermic development in the black-eared kite, one of large altricial birds, occurred in an earlier growth stage than in small altricial ones. This is probably due to the fact that the nestling of the kite is larger in size than those of small birds ; that is, the kite nestling can gain the lower surface to volume ratio earlier in growth than can do small birds, and augment the larger bulk of the tissue which contributes to thermogenesis. Large birds require more food and energy for maintenance of their lives than do small ones, and especially raptors must expend considerable efforts in foraging for their prey. The female parent of most raptorial species entrusts the male with all foraging until the nestlings can regulate their body temperatures, because she has to spend almost all her time brooding and is not free to hunt (Newton, 1979). In addition, the amount of food consumption for nestlings increases as they grow (Olendorff, 1974 ; Newton, 1978 ; Collopy, 1984, 1986). Therefore, in order to supply the nestlings with enough food, the female parent needs to share with the male in the responsibility for both foraging and territorial defense which have been conducted by only the male until now. In short, precocious development of homeothermy in the kite allows the female to leave her nest for part of the daytime to do so from an early time of the nestling period, and contributes towards increasing the amount of food foraged by the parent(s).

In conclusion, homeothermy of the black-eared kite nestling is achieved at about 20 days of age when the female parent ceases diurnal brooding, and such precocious development of homeothermy takes an important role in hastening the independence of the kite nestlings from the thermal environment.

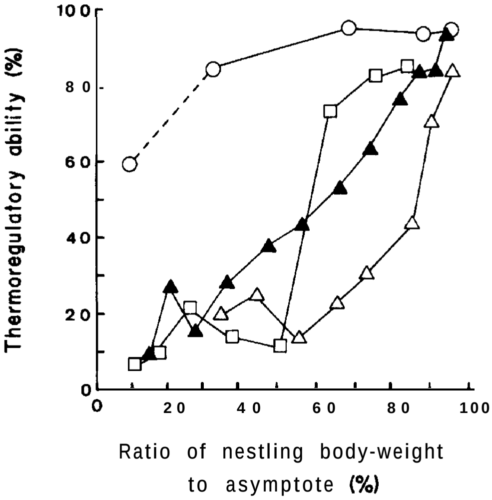

Fig. 4. Development of the thermoregulatory ability at Ta of 20±1°C in relation to growth in four species. △, cactus wren *Campylorhynchus brunneicapillus* (from Ricklefs and Hainsworth, 1968) ; ▲, starling *Sturnus vulgaris* (from Ricklefs, 1979) ; □, Lapland longspur *Calcarius lapponicus* (from Maher, 1964) ; ○, black-eared kite (a point of the ability at 8.7% of the asymptotic body-weight was calculated using the stable body temperature of 33.8°C at Ta of 25°C on Day 4 after hatching in Fig. 3, and a point of the ability at 30.5% of the asymptote was computed for the lowest body temperature of 36.8°C at Ta of 20°C on Day 12 in Fig. 3 : accordingly, these two points are joined by a broken line because of the different ambient temperatures).

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