

SELECTED BODY TEMPERATURE, THERMAL TOLERANCE AND FOOD ASSIMILATION IN A VIVIPAROUS SKINK, *SPHENOMORPHUS INDICUS*

by

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ABSTRACT

We studied in the laboratory several aspects of the thermal biology in adult viviparous skinks, *Sphenomorphus indicus*. The selected body temperature, the critical thermal minimum and the critical thermal maximum averaged 25.7, 3.1 and 37.6°C, respectively. No significant variations in food intake, food passage time and food assimilation as a function of temperature were found within the range of 26 to 32°C, which approximately represents a range of 6°C above the selected body temperature of the skinks in our sample.

KEY WORDS: Reptilia, Scincidae, *Sphenomorphus indicus*, selected body temperature, thermal tolerance, food passage time, food assimilation.

INTRODUCTION

It is well known that extreme body temperatures are damaging and potentially lethal, whereas moderate to relatively high body temperatures usually maximize performance (HUEY & KINGSOLVER, 1989). In many reptiles, the optimal temperatures and the thermal sensitivities of various physiological and behavioural performances may differ considerably (BUSTARD, 1967; LANG, 1979; POUGH, 1980; HUEY, 1982; VAN DAMME *et al.*, 1991; JI *et al.*, 1995, 1996). Thus body temperature selected by a given species or a given group of reptiles may, in various degrees, reflect a compromise for different performances.

Measurements of the possible thermal dependence of food assimilation are routine studies of thermal biology of lizards. Data generated are helpful in determining the role of lizards in the energy dynamics of ecosystems (BALLINGER & HOLSCHER, 1983). Previous studies generally showed that the influence of temperature on some traits (e.g., food intake and food passage time) of reptilian digestive physiology was more pronounced than

on others (e.g., apparent digestive coefficient and assimilation efficiency) (WALDSCHMIDT *et al.*, 1986; JI & WANG, 1990; VAN DAMME *et al.*, 1991; JI *et al.*, 1993, 1995, 1996), although a consistent pattern among species was not found in each single trait.

Sphenomorphus indicus (Scincidae) studied here is a small viviparous skink. This skink is a widely foraging diurnal insectivore and locally very common in Hangzhou (30°16'N, 120°9'E), Zhejiang, eastern China. For this species, detailed information on activity pattern, feeding habits and habitat selection (WANG, 1964) and incidental notes on reproduction are available (WANG, 1966; GU, 1990), but little is known about its thermal biology. Compared to other common diurnal lizards in Hangzhou, *S. indicus* characteristically lives in shady places covered by dense trees and bushes. We conducted this study to determine (1) if selected body temperature (T_{sel}), critical thermal minimum (CT_{min}), and critical thermal maximum (CT_{max}), of *S. indicus* differ from other sympatric diurnal lizards that live in more open places, (2) if there are any differences in T_{sel} , CT_{min} and CT_{max} between males and females and (3) if temperature has a significant effect on food assimilation within the range of 26 to 32°C, which approximately represents a range of 6°C above the T_{sel} of the skink.

MATERIALS AND METHODS

T_{sel} , CT_{min} and CT_{max}

In late April 1994 and 1995, we collected a total of 51 adult *S. indicus* (21 in 1994 and 30 in 1995) from various localities in Hangzhou. The skinks were immediately transported to our laboratory at Hangzhou Normal College, where they were measured and weighed. Snout-vent length (SVL) of males and females ranged from 67.3 to 87.4 and from 69.9 to 91.4 mm, respectively. Various sized yolked follicles could be found in adult females, but none of them was pregnant (WANG, 1966; JI, pers. obs.).

Both sexes were housed separately 4-5 to each glass terrarium (40 × 30 × 30 cm), which was filled with soil, blocks of wood, stones and grasses. Mealworms (larvae of *Tenebrio molitor*) and water were provided ad libitum. To prevent possible interactions between the experiments, we conducted each experiment at intervals of a week. The sequence was T_{sel} , CT_{min} and CT_{max} determinations. Prior to each experiment, all skinks were maintained in a constant-temperature room at 28°C for 48 h to allow habituation to the starting temperature. The photoperiod was 12 light:12 dark; lights were switched on at 07:30 (Beijing time).

T_{sel} was determined in a 220 × 90 × 60 cm plastic terrarium. Three light bulbs (total 1000 W) suspended above one end, created a gradient of air

temperatures (2 cm above the substrate) ranging from 14 to 70°C. Skinks were moved into the terrarium at 07:30 when the lights were switched on. To avoid the possibility of diurnal variations in T_{sel} , we began all our measurements at 15:00 and completed them within 2 h. This procedure makes the data from this study comparable to those collected by us in other lizard species. Body temperatures (cloacal, T_b) of active skinks in the thermal gradient were taken using a RC-95 quick reading electronic thermometer (Shanghai Jinhua Instruments). To address the reliability of our measurements, we measured each skink twice on two consecutive days and considered the mean of the two readings as the skinks body temperature in the thermal gradient. Efforts were made to make the two measurements fall within the same period (no more than 1 h) of the two days. We used the mean of all readings of body temperature as the selected body temperature.

CT_{min} and CT_{max} were determined in a LRH-250A incubator (Guangdong Medical Instruments). Experiments were conducted between 10:00 and 15:00. Skinks were cooled or heated from 28°C at the rate of 0.25°C per min. During the experiment, we observed the behaviour of the skinks. The body temperatures associated with a transient loss of righting response at lower and upper thermal limits were used as CT_{min} (Ji *et al.*, 1995, 1996) and CT_{max} (LOWE & VANCE, 1955), respectively.

Food passage time and food assimilation

In mid-May 1994, 38 adult skinks (males : females = 1 : 1) were collected from the same sites and divided into four groups; each group was placed in 26, 28, 30 and 32°C constant-temperature rooms, respectively. The fluorescent tubes and room lighting were on a 12 light : 12 dark cycle; lights were switched on at 7:30. Each skink was housed in a 20 × 20 × 20 cm glass terrarium, fasted for 3 days at the test temperature, and then weighed and measured. The test period at each temperature was 12 days. Final body mass was recorded at the end of a 3-day fast which terminated each test period.

Prior to feeding the skinks, we marked mealworms by inserting a 3 mm red plastic thread (diameter 0.2 mm) into their abdomen, and force-fed these mealworms to skinks. Unmarked mealworms and water were then provided ad libitum. Because faeces and urates were usually ejected during the photophase, we collected them and separated faeces from urates during this phase at intervals of 15 min. All faeces were examined with a stereomicroscope until the appearance of plastic threads. The food passage time was defined as the time from swallowing to the first appearance of plastic threads in the faeces. We excluded from our analyses one skink at 30°C and two at 32°C that died following the experiment.

Faeces, urates and mealworms were dried to constant mass in an oven at 65°C and weighed. Subsamples were burned in a GR-3500 adiabatic calorimeter (Changsha Instruments) and energy densities were obtained. Titrations were performed of the residuals after calorimetry to correct for nitrogenous wastes. The assimilation efficiency (AE) was calculated as: $AE = (I - F - U)/I \times 100\%$ (KEPENIS & MCMANUS, 1974; JI & WANG, 1990), where I = total calories ingested, F = calories in faeces and U = calories in urates; apparent digestive coefficient (ADC) was calculated as: $ADC = (I - F)/I \times 100\%$ (HARWOOD, 1979; BALLINGER & HOLSCHER, 1983; WALDSCHMIDT *et al.*, 1986).

RESULTS

There were no significant differences in T_{sel} , CT_{min} and CT_{max} between males and females; data collected in the two years did not differ significantly (Mann-Whitney U -test, all $P > 0.05$). T_{sel} , CT_{min} and CT_{max} averaged 25.7, 3.1 and 37.6°C, respectively (table I).

Mealworms fed to skinks at 26, 28, 30 and 32°C had a mean energy density of 5887.4, 5887.4, 5804.8 and 5804.8 cal g⁻¹ dry mass, respectively. There were significant differences in energy density among faeces collected at different temperatures ($F_{3,31} = 30.20$, $P < 0.001$) (table II), whereas the energy densities of urates remained almost unchanged across the test temperatures, with a mean of 2551.4 cal g⁻¹ dry mass.

We did not find significant differences in food passage time, food intake, AE and ADC between males and females across the test temperatures (Mann-Whitney U -test, all $P > 0.05$), so we pooled data for both sexes. Within the range of 26 to 32°C, temperature had no significant influence on food passage time ($F_{3,31} = 1.97$, $P > 0.05$), food intake ($F_{3,31} = 2.07$, $P > 0.05$), AE (arc-sine transformation; $F_{3,31} = 1.11$, $P > 0.05$) and ADC (arc-sine transformation; $F_{3,31} = 0.98$, $P > 0.05$) (table III).

DISCUSSION

Body temperature is believed to play an important role in determining many physiological and behavioural performances of reptiles, and is selected by animals so that various performances could be at or near their optimal temperatures (HUEY, 1982; STEVENSON *et al.*, 1985; HUEY & KINGSOLVER, 1989; PETERSON *et al.*, 1993). The selected body temperature (or the preferred body temperature) of reptiles is measured in the laboratory, indicating the range of body temperatures that reptiles try to maintain in the absence

TABLE I

The selected body temperature, the critical thermal minimum and the critical thermal maximum ($^{\circ}\text{C}$) of adult *Sphenomorphus indicus*.

	T_{sel}	CT_{min}	CT_{max}
Mean	25.7	3.1	37.6
N	51	25	8
1SE	0.2	0.2	0.3
Range	22.3-29.6	1.7-4.1	36.5-38.5

TABLE II

Faecal calories (cal g^{-1} dry mass) of *Sphenomorphus indicus* maintained in constant-temperature rooms.

$T (^{\circ}\text{C})$	Mean	N	1SE	Range
26	4181.2	10	23.4	4112.1-4269.9
28	4594.7	10	39.5	4418.6-4788.4
30	4464.1	9	13.3	4423.3-4511.7
32	4297.2	6	64.5	4153.0-4441.4

TABLE III

Initial body mass, food passage time, food intake, ADC and AE of *Sphenomorphus indicus* at different temperatures. Data are expressed as Mean \pm SE and range.

$T (^{\circ}\text{C})$	N	Initial body mass (g)	Food intake ($\text{cal g}^{-1} \text{day}^{-1}$)	Food passage time (h)	ADC (%)	AE (%)
26	10	9.8 ± 0.7 7.8-15.4	144.1 ± 15.3 43.9-231.6	36.7 ± 2.9 26.0-49.0	90.2 ± 0.7 87.2-93.7	81.9 ± 0.9 75.3-89.0
28	10	8.6 ± 0.4 7.6-10.6	186.4 ± 13.1 139.3-256.8	40.9 ± 2.1 34.0-57.0	91.3 ± 0.8 85.9-94.5	84.3 ± 1.3 75.3-89.0
30	9	10.1 ± 0.8 8.3-15.8	147.6 ± 12.3 82.9-181.5	33.8 ± 2.8 22.0-46.0	91.7 ± 0.7 89.1-94.0	84.0 ± 1.6 78.8-92.1
32	6	9.1 ± 0.7 7.3-12.0	164.0 ± 15.5 116.7-214.7	32.0 ± 2.8 22.0-37.0	91.7 ± 0.5 89.9-93.2	85.1 ± 1.2 80.5-88.3

of abiotic restrictions. Based on previous studies, T_{sel} cannot be considered as a fixed characteristic of a given species, because it is influenced by many external and internal factors (see HUTCHISON, 1976). CT_{min} and CT_{max} are likewise influenced by many factors (also see HUTCHISON, 1976). However, it is not impossible to compare data of T_{sel} , CT_{min} and CT_{max} among or within species that differ in geographical distribution, activity pattern, habitat utilization, etc. To do so, it is very important to standardize experimental methods. Data collected in the same way described here show

obvious differences in T_{sel} , CT_{min} and CT_{max} among the three most common diurnal lizards in Hangzhou: *S. indicus*, the Chinese skink *Eumeces chinensis* (T_{sel} 31.2°C, CT_{min} 6.3°C, CT_{max} 42.7°C; Ji *et al.*, 1995) and the grass lizard *Takydromus septentrionalis* (T_{sel} 30.0°C, CT_{min} 3.9°C in males and 5.9°C in females, CT_{max} 42.3°C; Ji *et al.*, 1996). These lizards are sympatric species in Hangzhou but differ considerably in habitat utilization and activity pattern (WANG, 1964), and hence exhibit obvious differences in T_{sel} , CT_{min} and CT_{max} . The lower T_{sel} , CT_{min} and CT_{max} in *S. indicus* primarily mirror their habit of living in shady places where both air and substrate temperatures are generally lower.

Previous studies generally showed an influence of temperature on food passage time in lizards (HARWOOD, 1979; WALDSCHMIDT *et al.*, 1986; VAN DAMME *et al.*, 1991; BEAUPRE *et al.*, 1993; Ji *et al.*, 1995, 1996), but no consistent pattern was found. In the iguanid lizard *Uta stansburiana* and *T. septentrionalis* (WALDSCHMIDT *et al.*, 1986; Ji *et al.*, 1996), food passage time decreased with increasing body temperature; in *E. chinensis*, food passage time decreased linearly with increasing body temperature within the range of 24 to 30°C and then obviously maintained unchanged at higher temperatures (Ji *et al.*, 1995). The pattern of food passage time of *S. indicus* in our sample was somewhat similar to that reported for *E. chinensis* (T_{sel} = 31.2°C), exhibiting thermal insensitivity within the range of 6°C above T_{sel} .

The levels of ADC and AE are believed to be closely related to activities of digestive enzymes, food passage time and the type and amount of food taken by lizards. Although activities of digestive enzymes would generally increase with temperature within a certain range of temperature, lizards at lower temperatures might maintain normal ADC and AE through increasing food residency time which would prolong exposure of food to enzymatic action (HARWOOD, 1979). Due to this mechanism, weight-specific energy densities in faeces could be maintained at a relatively constant level over a certain range of temperature. Nonetheless, for insectivores, weight-specific energy densities of faeces are also determined by the amount of chitin that is not a digestible part of their food and may ultimately modify both ADC and AE. The fact that insectivorous lizards exhibit different ADC after taking different items of food may support this interpretation (see ANDREWS & ASATO, 1977). The low variation and the thermal insensitivity of ADC in *S. indicus* are similar to that reported for the rusty lizard *Sceloporus olivaceus* (DUTTON *et al.*, 1975), *U. stansburiana* (WALDSCHMIDT *et al.*, 1986), the lacertid lizard *Lacerta vivipara* (VAN DAMME *et al.*, 1991), the canyon lizard *Sceloporus merriami* (BEAUPRE *et al.*, 1993), *E. chinensis* (Ji *et al.*, 1995) and *T. septentrionalis* (Ji *et al.*, 1996). The low variation of

AE in *S. indicus* is similar to the results reported in the few studies measuring AE of lizards, including the gecko *Gekko japonicus* (JI & WANG, 1990), adult *T. septentrionalis* (JI *et al.*, 1996) and *E. chinensis* (JI *et al.*, 1995). In contrast, *S. olivaceus* (DUTTON *et al.*, 1975), *S. merriami* (BEAUPRE *et al.*, 1993) and juvenile *T. septentrionalis* (JI *et al.*, 1993), in various degrees, showed thermal dependence of AE, characteristically exhibiting decreased AEs at higher temperatures presumably due to the increase of urate production with temperature.

Extrapolation of laboratory results to field populations should be made with caution (BEAUPRE *et al.*, 1993), because lizards in captivity show loss of normal behaviour, especially when they are held in terraria with limited space. For example, we cannot explain why there was no significant increase in food intake with temperature in *S. indicus*. Generally speaking, lizards at higher temperatures should consume more food because of the increased metabolic rate. However, data generated from laboratory studies show that the increase of food intake with temperature is more evident in some species (e.g., *U. stansburiana* (WALDSCHMIDT *et al.*, 1986); *G. japonicus* (JI & WANG, 1990); juvenile *T. septentrionalis* (JI *et al.*, 1993)) than in others (e.g., *E. chinensis* (JI *et al.*, 1995); adult *T. septentrionalis* (JI *et al.*, 1996)). The thermal insensitivity of food intake seen in this study presumably resulted from large individual variation in food intake that was preserved across experimental temperatures. Whether or not such large variation can only be seen in captive lizards still remains unclear.

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