ENVIRONMENT AND BODY TEMPERATURES OF REPTILES IN VOLGA–URAL REGION

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INTRODUCTION

A number of studies have been dedicated to the thermoregulatory mechanisms of ectotherms (Sergeyev, 1939; Chernomordikov, 1943; Khozatsky, 1959; Pianka, 1975; Hutchison, 1976; Hutchison and Maness, 1979; Bartholomew, 1982; Huey, 1982; Cherlin, 1983; Cherlin and Muzychenko, 1988; Cherlin and Chikin, 1991; Hutchison and Dupre, 1992; Du Wei-Guo et al., 2000; Blumberg et al., 2002; Sartorius et al., 2002; Franklin and Seebacher, 2003).

The majority of ectotherms, when taken in the same temperature ranges, warm up more rapidly than cool down. This so-called thermal hysteresis is usually connected with the changes in bodily thermal conductivity, resulting in blood vessel diameter change (Bartholomew et al., 1965; Myhre and Hammel, 1969). Some amphibians and reptiles thermoregulate by evaporation. These thermoregulatory reactions, as well as the behavioral ones, are affected both by environment temperatures and brain stem and core temperature (Crawford and Barber, 1974). The rate of heat exchange with the environment is under neural control in reptiles. The rate of the reptile-environment heat exchange is neurally controlled due to cardiac output changes and blood redistribution. Thermoregulatory behavior helps reptiles to avoid overheating, though under some circumstances they may be subject to subcritical temperatures. In such cases the thermal tolerance is limited by functional capabilities of the cardiovascular system and its regulatory mechanisms.

We studied the changes of the electric cardial activity as reaction to extreme temperature influence.

MATERIAL AND METHODS

The environment, body temperatures and their ratios have been studied for 11 species of snakes and lizards (*Anguis fragilis*, *Eremias arguta*, *Lacerta agilis*, *Zootoca vivipara*, *Natrix natrix*, *N. tessellata*, *Elaphe dione*, *Coronella austriaca*, *Vipera berus*, *V. nikolskii*, *V. renardi*). The temperatures were taken with sensor thermistors at the eight body spots for lizards: the top and the bottom of a head, back and belly, the top and the bottom of a tail in the mean (external temperatures), esophagus and anus (internal temperatures). For snakes the temperatures at the top and the bottom of a head, back and belly, esophagus and anus were taken. The topography of body temperatures at different environment temperatures was studied.

Sometimes we were measuring the heat flux density (irradiance) (W/m^2) of the solar incident radiation and of that emitted from the surface, rather than the temperature. The special spiral heat flux sensor was used in the measurements. This particular sensor was selected due to its favorable operating characteristics such as high sensitivity and tiny dimensions that made it possible to carry out localized measurements. Environment temperature measurements have been correlated with the duration of daily activity. First of all, we should remark that we were terming esophagus temperature as the “body temperature.” For the vast majority of cases this temperature is somewhat higher than the anal temperature (Table 1). In this paper we are using some widely accepted terms as the body and environment temperature optima, the maximum and minimum voluntary activity temperatures and the temperature range of activity. The correlation ratio (h) has been derived in order to reveal the degree of dependence between the body and the surface temperatures, as well as for the surface air (3 – 5 cm above the surface) temperatures. These data are summarized for the snakes in Table 1.

Cardiac activity was registered with needle electrode of a single channel portable cardiograph with heat recording. The grass-snakes were cooled down before recording: *Natrix tessellata* ($n = 12$) down to 6.0°C in esophagus, *Natrix natrix* ($n = 14$) down to –1.0°C; followed by gradual warm-up to 38.0°C in esophagus.

RESULTS AND DISCUSSION

As long as reptiles actively pursue their optimal temperatures throughout the season, we found it possible to

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TABLE 1. Basic Temperature Indices of Snakes for the 1999 – 2002 Activity Season

Basic temperature indices	Species and their origin								
	Natrix natrix, Ural Foothills	*N. natrix*, Mid-Volga	*N. tessellata*, Mid-Volga	*Elaphe dione*, Mid- and Lower Volga	*Coronella austriaca*, Ural Foothills and Mid-Volga	*Vipera berus* (bright morph), Ural Foothills	*V. berus* (black morph), Ural Foothills	*V. nikolskii*, Mid-Volga	*V. renardi*, Mid- and Lower Volga
Mean body temperature and sample volume	25.2 ± 0.19 *n* = 322	25.3 ± 0.66 *n* = 45	25.9 ± 0.37 *n* = 94	29.3 ± 0.09 *n* = 16	27.9 ± 2.13 *n* = 4	27.7 ± 0.57 *n* = 88	23.9 ± 1.02 *n* = 23	28.9 ± 0.45 *n* = 40	29.7 ± 0.95 *n* = 18
Mean external body temperatures, back/belly	21.8 ± 0.23	22.0 ± 0.54	23.0 ± 0.34	24.9 ± 1.36	23.8 ± 2.23	23.2 ± 0.60	20.8 ± 1.04	23.6 ± 0.84	22.2 ± 2.49
	21.0 ± 0.23	21.9 ± 0.52	23.2 ± 0.32	25.2 ± 1.51	23.1 ± 1.30	23.2 ± 0.57	20.8 ± 1.09	23.3 ± 0.89	21.1 ± 2.63
Mean environment temperatures, land surface air 5 cm/surface	21.1 ± 0.31	20.9 ± 0.59	23.3 ± 0.46	32.6 ± 2.12	21.1 ± 2.70	22.9 ± 1.31	—	22.5 ± 0.67	26.9 ± 2.96
	24.4 ± 0.28	21.5 ± 0.61	25.6 ± 0.65	33.3 ± 2.45	20.7 ± 0.67	25.2 ± 0.79	19.6 ± 1.24	22.7 ± 0.63	27.7 ± 2.18
Max and min voluntary body temperatures	13.6 – 33.2	16.0 – 32.4	14.8 – 33.2	22.1 – 32.9	24.7 – 31.1	6.2 – 34.3	12.7 – 29.7	21.9 – 34.0	21.3 – 35.8
Max and min voluntary external temperatures, back/belly	8.2 – 32.2	16.0 – 33.4	14.8 – 33.0	19.8 – 30.3	20.5 – 27.1	5.2 – 31.2	11.6 – 27.5	15.5 – 30.2	11.0 – 30.7
	9.2 – 32.9	16.0 – 32.1	15.1 – 32.2	19.3 – 30.1	21.0 – 25.2	5.4 – 31.8	12.2 – 27.3	15.1 – 32.3	10.3 – 29.4
Max and min voluntary external temperatures, land surface air 5 cm/surface	13.5 – 35.3	13.9 – 31.6	14.0 – 38.6	24.2 – 43.2	21.1 – 29.0	14.1 – 32.3	—	14.1 – 27.6	14.2 – 43.3
	14.2 – 40.0	14.2 – 34.3	15.8 – 40.7	23.6 – 45.6	20.4 – 21.0	3.7 – 39.9	6.6 – 28.7	15.1 – 31.4	14.5 – 44.8
Body temperature optimum	21.7 – 29.5	24.3 – 29.7	24.7 – 30.1	27.9 – 31.4	—	26.7 – 32.0	22.4 – 29.4	26.3 – 31.0	28.6 – 34.5
External temperatures optimum, land surface air 5 cm/surface	18.2 – 22.3	18.3 – 24.5	20.7 – 27.5	—	—	20.6 – 26.3	—	20.3 – 26.0	—
	20.0 – 28.9	17.3 – 26.0	20.8 – 28.5	30.7 – 32.9	—	22.5 – 33.2	12.9 – 26.3	20.8 – 28.9	23.9 – 39.3
Temperature range of activity by body temperature	19.6	16.4	18.4	10.8	—	28.1	17.0	12.1	14.5
Temperature range of activity by external temperatures, land surface air 5 cm/surface	21.8	17.7	24.6	19.0	—	18.2	—	13.5	29.1
	25.8	20.1	24.9	22.0	—	36.2	22.1	16.3	30.3
Degree of dependence between body and surface temperatures, η	0.48 ± 0.04	0.72 ± 0.07	0.82 ± 0.03	0.75 ± 0.13	—	0.84 ± 0.03	0.99 ± 0.004	0.62 ± 0.09	0.91 ± 0.04
Degree of dependence between body and land surface air (5 cm) temperatures, η	0.46 ± 0.08	0.93 ± 0.02	0.78 ± 0.04	0.86 ± 0.08	—	0.76 ± 0.12	—	0.71 ± 0.11	1.00

introduce the "mean body temperature." For both species of grass snakes, originating from different locations these temperatures are surprisingly close. *Vipera renardi* and *Elaphe dione* were found to have the highest mean body temperature, the fact that can be rationalized by taking into account their adaptation to relatively high surface temperatures, 33.7 and 27.7°C, respectively. *V. renardi* has the highest maximum voluntary body temperature. All the studied snakes have this maximum within 29.7 – 35.8°C. The minimum voluntary range is almost three times as wide: from 6.2°C for *Vipera berus* (bright morph) to 22.1°C for *Elaphe dione*. The bright morph of *Vipera berus* has the widest temperature range of activity, 28.1°C. The other vipers have substantially narrower values: 17.0°C for *V. berus* (black morph), 12.1° for *V. nikolskii*, and 14.5° for *V. renardi*. The dependence of body temperatures on environment temperatures (surface and surface air) is high for all the snakes, but *N. natrix* of Ural Foothills. Its relatively low correlation is not quite clear. *Eremias arguta* is the most thermophilic among the studied lizards, having its surface temperature optimum within 41.5 – 46.0°C and body temperature optimum within 31.3 – 33.0°C. *Lacerta agilis* is less thermophilic with surface temperature optimum is 28.4 – 45.3°C and body temperature optimum is 29.6 – 33.9°C. The least thermophilic are *Anguis fragilis* and *Zootoca vivipara*. The surface temperature optima are 18.1 – 22.5°C for the former and 20.6 – 28.7°C for the latter, while the body optima are 20.6 – 26.7 and 26.4 – 32.5°C, respectively. It is apparent that body temperature exceeds surface temperature until a certain point where they become equal, henceforth this ratio becomes reversed. Why? Here the body temperature regulatory mechanisms come into effect. The body temperature overcoming the optimum, the animal lowers its temperature escaping to a shady place or a shelter. It is behavioral mechanism. If there is a situation, rare (if possible) in nature, but quite possible in the experiment, when the animal cannot escape, there comes into effect physiological mechanism, evaporating moisture from the mouth mucosa. All the animals in our experiment were caught being out of their shelters. If these described regulatory mechanisms are not effective enough, then escape into a shelter follows. Thus for *Natrix tessellata* ($n = 45$) of Middle Volga this point of overheating protection lies about 27.5°C (ground temperature), for *Lacerta agilis* ($n = 67$), about 32.0°C. Diurnal activity for the lizards in summer is definitely two-peaked.

As for the aforementioned topography of temperature, the esophagus temperatures of both snakes and lizards exceed the anal temperatures. For *Natrix natrix* ($n = 227$) by 3.7°C, for *N. tessellata* by 2.0°C, for *Vipera berus* (bright morph) ($n = 86$) and *V. nikolskii* ($n = 40$) equally by 2.7°C; for *V. berus* black morph ($n = 23$) by 3.0°C; *V. renardi* ($n = 18$) by 2.8°C; *Elaphe dione* ($n = 16$) by 1.0°C; *Zootoca vivipara* ($n = 71$) by 1.6°C; and for *Lacerta agilis* ($n = 89$) by 0.6°C. The topography of body temperature has been most consistently studied for L. agilis of Middle Volga ($n = 82$): back, belly and throat region temperatures are equal, 26.4 – 26.5°C. Top-head temperature is lower by approximately 1.0°C. These temperatures have been obtained at 26.5 – 31.8°C of environment temperature, corresponding to the pinnacle of activity. An attempt to determine the difference in the mean temperatures between males ($n = 19$) and females ($n = 39$) of Ural foothills origin has shown male's back temperature (30.2°C) being significantly higher ($P < 0.01\%$), than that for the females (27.6°C) by 2.6°C during spring-summer season. Belly temperature for the males (29.8°C) is significantly higher ($P < 0.05\%$) by 2.1°C than that for the females (27.7°C). The difference between the temperatures of the other body spots is statistically insignificant for such a small sample.

At low body temperature –1.0°C the heartbeat rate reduces to 3 bpm, all cardiogram indices being incredibly extended and elongating. This points to the slow ventricular impulse conduction and its repolarizatory elongation. It may be assumed that there is an atrioventricular node impulse delay. As the internal body temperature approaches its optimum (24.7 – 30.1°C), all cardiogram indices normalize. Heartbeat rate is from 48 – 68 bpm PR interval 0.20 sec, average QRS duration 0.06 sec, QT interval 0.43 sec. At high body temperatures (38.0°C), heartbeat rate increases up to 167 bpm All intervals are shortened, indicating premature ventricular excitation.

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