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Diel variation in thermoregulatory set points of the lizard *Podarcis muralis*

Gianluca Tosini¹, Roger Avery

School of Biological Sciences, Bristol University, Bristol BS8 1UG, UK

¹ present address: Biology Department, University of Virginia, Charlottesville, VA 22901, USA

Diel cycles of temperature preference in lizards have been reported by several workers (e.g. Rismiller and Heldmaier, 1987; Sievert and Hutchison, 1989), and may be endogenous (Cowgell and Underwood, 1979; Innocenti et al., 1993). The experiments have usually been performed in the artificial conditions of laboratory gradients. The development of a system using a pyroelectric vidicon infra-red camera as a radiation thermometer to measure body temperatures (T_b s) non-invasively (Jones and Avery, 1989) has made it possible to determine values for both lower and upper set point temperatures (Firth and Turner, 1982) in unrestrained lizards which can move freely about an arena. Under these conditions the animals can utilise a normal range of thermoregulatory

behaviours; shuttling heliotherms can alternate basking beneath a tungsten bulb with foraging and other movements within the arena (Avery, 1985; Tosini and Avery, 1993). The purpose of the study reported here was to investigate whether there are diel changes in set point temperatures in the wall lizard *Podarcis muralis* under these conditions.

Two male and four female wall lizards, captured near Florence (Italy), were housed singly in enclosures measuring $130 \times 90 \times 40$ cm with an 8 hour photophase from 0800 to 1600 h. Heat was supplied from a 60 W tungsten reflector bulb held 20 cm above the floor of the arena, and shone through a metal funnel so that a pool of heat and light only 10 cm in diameter was produced at floor level. Temperatures of basking lizards were determined by thermography as described by Tosini and Avery (1993). Body temperatures during the photophase were measured during ten basks each lizard immediately after 1000 and 1500 h. During the scotophase the tungsten bulbs were switched on at either 2200 h or 0300 h and T_b s measured during the second to eleventh basks. The bulb was then switched off. The T_b recorded when a lizard appeared at the basking spot was termed T_{bask} , that when it moved off T_{move} (see Jones and Avery, 1989, for a rationale for this terminology). T_{bask} and T_{move} are equivalent to the upper and lower set points. The durations of individual basks and forages were recorded, and heating rates were then determined using the simple relationship $T_{move} - T_{bask} / t_2 - t_1$ (see Tosini and Avery, 1993). Room temperature was within the range 20.0 to 21.5°C throughout. Most statistical tests were carried out in both parametric and non-parametric form.

There were no differences between individuals at any time of day for any of the variables measured (one-way ANOVA, $F_{5,54} = 1.12-1.85$, $p > 0.1$ in all cases) and so data for the six lizards have been combined in analyses.. Neither mean T_{bask} nor mean T_{move} varied significantly within any ten consecutive basks at any time of day (one-way ANOVA and Kruskal-Wallis tests, $F_{9,50} = 0.56-1.98$; $H_9 = 0.55-1.01$; $p > 0.05$ in all cases). Mean values for both set points showed significant reductions during the scotophase (table 1) compared with photophase values, which did not differ significantly from one another (T-method tests, $p > 0.1$). The mean values for both set point temperatures were significantly lower at 0300 h than at 2200 h (T-method and multiple comparison tests, $MSD = 0.32$ and 0.29 for T_{bask} and T_{move} respectively, $p < 0.05$).

Table 1. Mean and median values (°C) for T_{bask} and T_{move} in relation to time of day.

	mean	T_{bask} s.d.	median	mean	T_{move} s.d.	median
1000 h	33.72	0.65	33.88	38.82	0.57	39.00
1500 h	33.87	0.59	33.95	38.85	0.55	38.95
2200 h	33.11	0.68	33.15	37.97	0.65	37.90
0300 h	32.59	0.78	32.70	36.54	0.64	37.60
$F_{3,236}$	44.63***			66.04***		
H_3				94.67***		
				115.12***		

*** $p < 0.001$

Table 2. Mean values for bask duration (min), forage duration (min) and heating rate ($K\ min^{-1}$) in relation to time of day.

	Bask duration		Forage duration		Heating rate	
	mean	s.d.	mean	s.d.	mean	s.d.
1000 h	1.57	0.51	3.64	2.34	3.93	0.70
1500 h	1.56	0.49	3.68	2.25	3.78	0.89
2200 h	1.91	0.49	3.82	2.41	2.45	0.98
1300 h	2.18	0.72	4.03	2.11	2.06	0.94
$F_{3,236}$	16.89***		0.36		30.04***	

*** $p < 0.001$

Mean bask duration did not differ between times during the photophase, but increased during the scotophase (table 2); the mean for 2200 h was higher than the mean for 0300 h (T-method test, $MSD = 0.27$, $p < 0.05$). Heating rates showed a reversed pattern (table 2; T-method test, $MSD = 0.61$, $p < 0.05$). Mean foraging duration did not show any difference with respect to time of day (table 2).

These data show conclusively that both lower and upper set point temperatures have diel cycles of approximately the same amplitude in *P. muralis*. The changes in set points are probably related to circadian changes in levels of plasma melatonin (Janik and Menaker, 1990; Foà et al., 1992), but this remains to be demonstrated experimentally. More speculatively, changes in melatonin levels may also affect thermoregulatory behaviour; the reductions in heating rates observed during the scotophase (table 2) occurred because the lizards tended to bask more peripherally in the pool of heat and light from the tungsten bulb, although this was not investigated systematically.

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