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# CARDIAC RESPONSES TO TEMPERATURE IN THE LIZARD *GALLOTIA GALLOTI*

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**Abstract**—1. Electrocardiograms of *Gallotia galloti* have been processed by a computerized system, to investigate the quantitative relationship between cardiac physiological processes assessed by the ECG intervals and body temperature changes.

2. Electrocardiographic event (RR, PR, RT, QRS and TP) durations decrease exponentially with body temperature. Thus, the influence of body temperature changes on the cardiac cycle (RR interval), atrioventricular conduction time (PR interval), ventricular depolarization (QRS complex) and cardiac rest time (TP period) have been studied in terms of regression coefficients.

3. The cardiac events most affected by body temperature changes were the cardiac rest period and the atrioventricular conduction time and the least affected were the RT interval and ventricular depolarization.

4. The decrease of relative cardiac rest time together with the increase of relative RT interval appear to be the main factors that contribute to the increase of heart rate as body temperature increases.

## INTRODUCTION

Most electrocardiographic studies on reptiles have been orientated to the study of the heart rate and its relationship to body temperature (Bartholomew and Lasiewski, 1965; Spray and Belkin, 1972; Lucey, 1974; Voight, 1975; Smith *et al.*, 1981; González and Vera, 1985), body size (Licht, 1965; Hudson and Bertram, 1966; Templeton, 1970), metabolism (Templeton, 1970; Kinney *et al.*, 1977), respiratory state (White and Ross, 1966; Huggins *et al.*, 1970) and effects of anaesthesia (Kaplan and Schwartz, 1963; Valentinuzzi *et al.*, 1969b). Nevertheless, only a few papers have been dedicated to the vectorial analysis of reptilian ECG and to measurements of electrocardiographic events other than heart rate at different body temperatures (Mullen, 1967; Valentinuzzi *et al.*, 1969a,b; Huggins *et al.*, 1969; McDonald and Heath, 1971; Akers and Damm, 1963; Johansen, 1959; Jacob and McDonald, 1975).

Although some of these papers report the ECG interval duration magnitudes at several body temperatures, allowing the comparison of interval values at a given body temperature among several reptilian species, difficulties arise when one tries to determine how and how much cardiac intervals vary within a broad range of body temperatures, in order to see how the cardiac processes affect heart rate and to compare the general behaviour of electric events of the cardiac muscle and the corresponding underlying physiological processes among different reptiles. We therefore require the corresponding regression equations fitted to experimental data, which have been reported for the cardiac cycle or heart rate and other cardiac events only in a few cases.

The main objective of this study has been to investigate the quantitative relationship between the atrioventricular conduction time and that of the ventricular depolarization of the lizard *Gallotia galloti* cardiac muscle, with body temperatures over the range 5–35°C. Thus, as in humans, the atrioventricular conduction time was estimated from the duration of PR electrocardiographic interval and the ventricular depolarization from the duration of the QRS complex. The RR electrocardiographic interval, as an estimate of cardiac cycle, and the RT electrocardiographic interval—used by some authors to approximate the duration of ventricular depolarization—were also computed for comparative purposes. Finally, the contribution of different electrocardiographic intervals to increasing heart rate with body temperature was studied and equations relating cardiac events to body temperature are presented.

## MATERIALS AND METHODS

The experimental animals used in this work were 10 *Gallotia galloti* lizards weighing from 43 to 47 g and of undefined sex. The lizards were captured in Tenerife (Canary Islands, Spain). The animals were kept in terraria whose ambient temperature ranged from 22 to 25°C during the day and from 19 to 22°C at night. The relative humidity ranged from 50 to 60%. Water and food were provided *ad libitum*.

The experimental set up comprised surgical implantation of electrodes, recording of the lizard ECG at seven monitored temperature stations in the range 5–35°C and computerized acquisition of electrocardiographic intervals.

The bipolar electrocardiogram was recorded by two 5 × 6 mm stainless steel plate electrodes inserted subcutaneously to the right and left of the lizard dorsal region, one of them anterior to the heart and the other posterior to the heart. A third electrode situated at the caudal region near the tail served as earth electrode.

Core body temperature ($T$) was monitored by an electrical thermometer (Nihon Kohden MGA III-219) equipped with a small thermistor probe that was inserted into the animal's cloaca 2 cm deep.

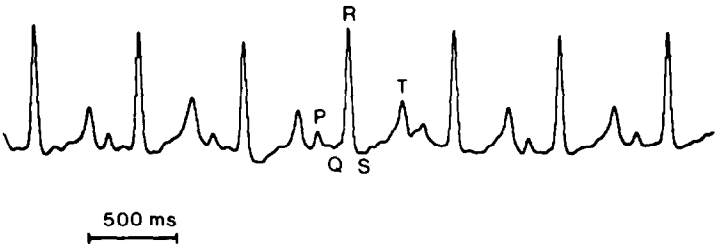


Fig. 1. Digital record of one segment of ECG from a 45 g lizard *Gallotia galloti* at 30°C of body temperature. Figures indicate ECG peaks.

The recording of the ECG was carried out in two identical chambers (40 × 40 × 30 cm) whose ambient temperature could be controlled by thermostat between 5–20 ± 0.5 and 25–35 ± 0.5°C. Relative humidity in both chambers ranged between 35 and 40%. All the experiments were carried out in still air and the animals were free to run in these chambers. Prior to all recordings, the animals were kept within the chambers for a 24-hr habituation period.

The electrocardiographic signal was led to a recording system (Nihon Kohden polygraph), whose output was connected to an automatic data acquisition and processing system for small animals based on a North Star (mod. Horizon) microcomputer (González and Vera, 1984).

Voltages from the polygraph were input to the system A/D converter and manipulated by software. A BASIC program that calls an ASSEMBLER subroutine was used for on-line sampling of the ECG; sampling rate was 250 Hz. Ten-minute segments of this signal were sampled at every body temperature investigated and stored in a file on diskette. The durations of the PR and RT electrocardiographic intervals and QRS complex were measured by means of a program that was able to display segments of the sampled ECG on the oscilloscope screen through the D/A converter; this program allowed calculation of time intervals by operating on the console of the video terminal. The period between the peaks T and P of the following ECG waveform was also measured in this way. The measurement of the consecutive RR interval of the lizard ECG was performed by a BASIC program and an ASSEMBLER subroutine for ECG peak R detection. The RR, PR, RT, TP and QRS values assigned to a given body temperature corresponded to the average of these intervals recorded at that temperature.

A statistical package of programs was used to fit the data to exponentials or straight lines using the least squares method, to compare mean values by $t$-test or by one-way analysis of variance and to compare slopes by $F$-test for slopes.

## RESULTS

Figure 1 shows a digital recording of one segment of lizard ECG at a body temperature of 30°C. Over the whole range of body temperatures investigated the P, QRS and T components on the ECG recordings appear defined. The P wave was of low relative amplitude and positive; the Q wave was of smaller relative amplitude and negative, normally appearing only at high body temperatures; the QRS complex was generally biphasic at low and middle body temperatures, because it normally only showed a high relative amplitude positive R wave and a low relative amplitude negative S wave; the T wave was positive and smaller than the R wave but bigger than the P wave. At high body temperatures a certain overlapping between the T and P waves sometimes occurred.

Over the body temperature range of 5–35°C, the RR interval ranged from 8972 to 450 ms. Heart rate values—calculated from the reciprocals of RR interval durations—varied from 6.7 to 133.2 beats/min. The duration of the RR interval decreases exponentially ($p < 0.01$) with body temperature (Fig. 2); the corresponding regression equation is:

$$\mathrm{RR\ (ms)} = 12350\, e^{-0.098 \cdot T} \quad (r = -0.99).$$

Over the body temperature range of 5–35°C, the PR interval ranged from 1725 to 118 ms; the RT interval from 2127 to 241 ms; the QRS complex from 466 to 86 ms and the Tp period from 5120 to 91 ms. Regarding the durations of ECG intervals, the RT interval was always significantly greater ($p < 0.001$) than the duration of the PR interval and the QRS complex. The duration of the PR interval was significantly greater ($p < 0.001$) than the QRS complex over the whole range of body temperatures studied.

The durations of the TP period and the PR and RT intervals, as well as that of the QRS complex of the lizard ECG, decrease exponentially ($p < 0.01$) with body temperature (Figs 3–6). The regression equations are:

$$\mathrm{TP\ (ms)} = 9201\, e^{-0.133 \cdot T} \quad (r = -0.99)$$

$$\mathrm{PR\ (ms)} = 2257\, e^{-0.091\ T} \quad (r = -0.98)$$

$$\mathrm{RT\ (ms)} = 2579\, e^{-0.070\ T} \quad (r = -0.99)$$

$$\mathrm{QRS\ (m)} = 463\, e^{-0.053 \cdot T} \quad (r = -0.96).$$

Comparing the regression coefficient of the previous exponential equations by $F$-test for slopes proved that the regression coefficient from the TP period equation was significantly greater ($p < 0.01$) than that from the PR interval one, and that from the PR interval was significantly greater ($p < 0.05$) than that of the RT equation; likewise, this test showed no significant differences between those from the RT and QRS exponential equations.

On the other hand, the relative QRS complex (QRS/RR) ranged from 5.2 to 19.0%; the relative PR interval (PR/RR) ranged from 19.2 to 26.1%; the relative RT interval (RT/RR) ranged from 23.7 to 53.6% and the relative TP period (TP/RR) ranged from 57.1 to 20.3%. Over the whole range of body temperatures studied, the ratios RT/RR and QRS/RR increase linearly ($p < 0.01$) with body temperature and the ratio TP/RR decreases linearly

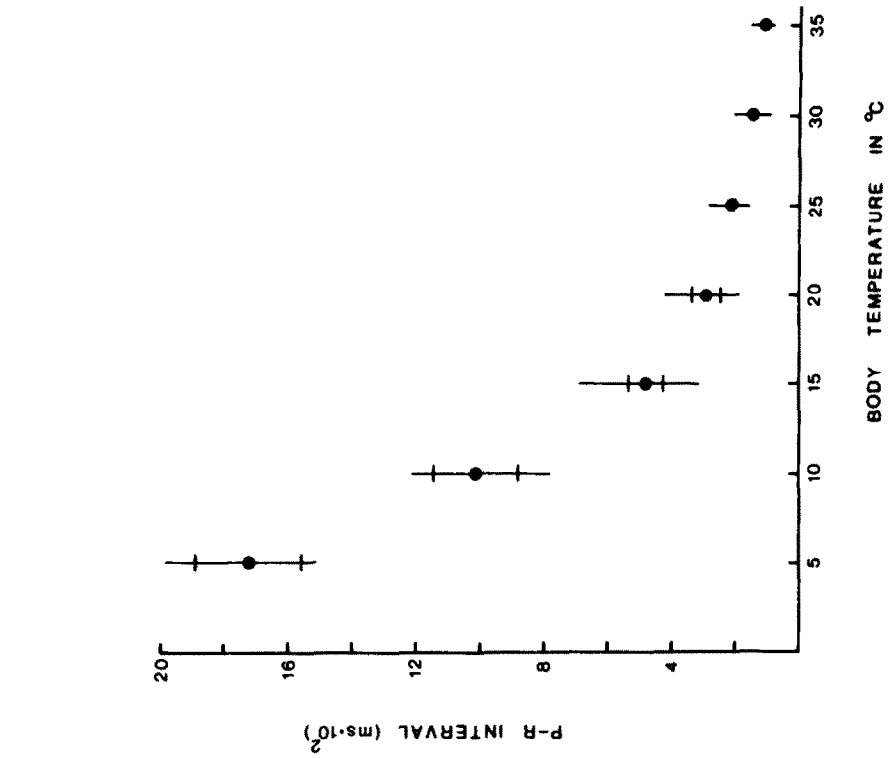


Fig. 3. Mean PR interval vs body temperature. Vertical lines indicate ranges and horizontal lines indicate means ± 2 SE.

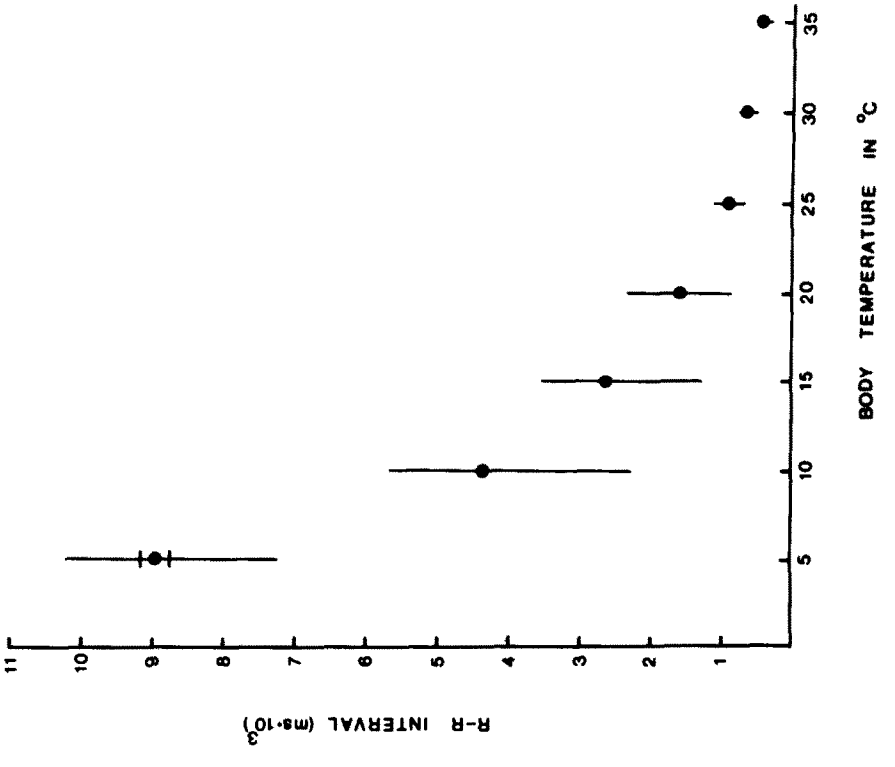


Fig. 2. Mean RR interval vs body temperature. Vertical lines indicate ranges and horizontal lines indicate means ± 2 SE.

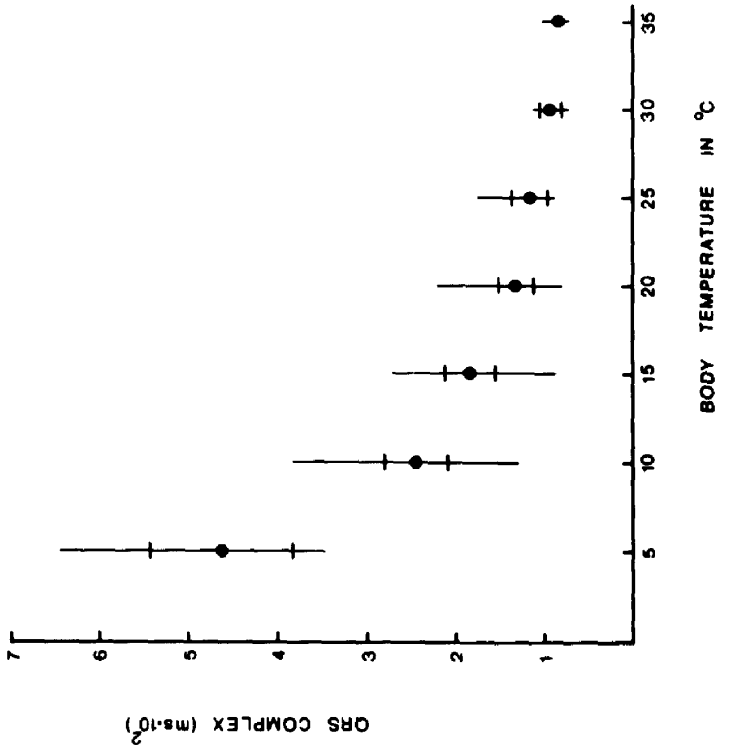


Fig. 5. Mean QRS complex vs body temperature. Vertical lines indicate ranges and horizontal lines indicate means ± 2 SE.

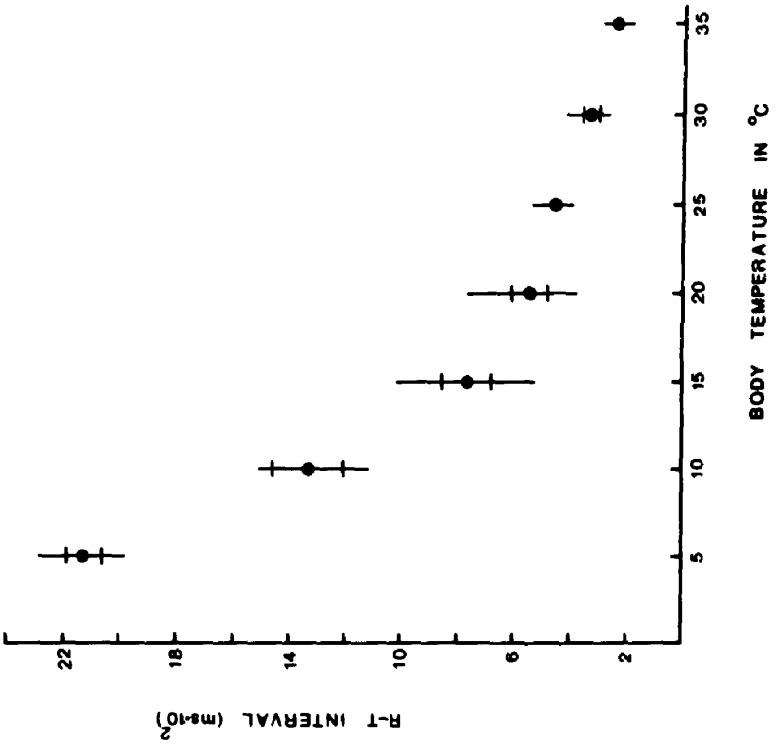


Fig. 4. Mean RT interval vs body temperature. Vertical lines indicate ranges and horizontal lines indicate mean ± 2 SE.

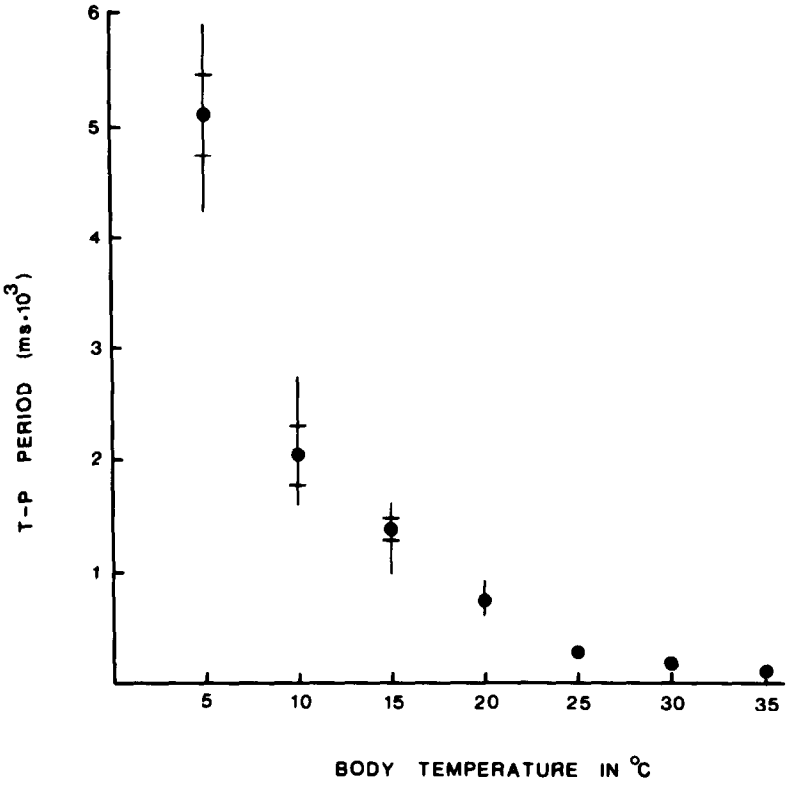


Fig. 6. Mean TP period vs body temperature. Vertical lines indicate ranges and horizontal lines indicate means ± 2 SE.

($p < 0.01$) with body temperature. The PR/RR ratio did not show linear regression with body temperature. The regression equations for QRS/RR, RT/RR and TP/RR ratios are:

$$\text{QRS/RR}\,(\%) = 1.1 + 0.4 \cdot T \quad (r = 0.96)$$

$$\text{RT/RR}\,(\%) = 17.1 + 1.1 \cdot T \quad (r = 0.96)$$

$$\text{TP/RR}\,(\%) = 64.8 - 1.2 \cdot T \quad (r = 0.94).$$

## DISCUSSION

The range of heart rates registered for *Gallotia galloti* is smaller than that previously reported by Mullen (1967) for lizards at an equivalent body temperature range. In this sense, Jacob and McDonald (1975), working with snakes, found the same result when comparing with snake heart rates reported by Mullen (1967); they attributed this difference to the use of pentobarbital anaesthesia by Mullen (1967). On the other hand, at a body temperature range of 15–35°C, heart rate values of *Gallotia galloti* are generally comparable to rates previously reported for *Sceloporus*, *Dipsosaurus*, *Trachydosaurus* and *Uma* by Licht (1965). The exponentially increasing relationship between heart rate or RR interval and body temperature for *Gallotia galloti* is similar to that shown for the snakes *Vipera aspis*, *Natrix natrix*, *Natrix viperina* (Francaz and Aupy, 1969) and *Salvadora hexalepis* (Jacobson and Whitford, 1971) and in the turtle *Testudo mauritanica* (Francaz and Aupy, 1969), but different to that shown for the snakes *Elaphe obsoleta* (Landreth, 1972; Jacob and McDonald, 1975) and *Pituophis melanoleucus* (Landreth, 1972). This difference can be attributed to the different experimental conditions employed by these authors in their own works.

The range of PR interval values for *Gallotia galloti* is smaller than that reported for snakes by Jacob and McDonald (1975) and Mullen (1967), but slightly greater than that reported for lizards by Mullen (1967). The range of RT interval values we recorded is small than that reported for snakes by Jacob and McDonald (1975), and the range of QRS complex values is greater than reported for lizards and snakes by Mullen (1967) at equivalent body temperatures. We agree with Jacob and McDonald (1975) in that these differences, when comparing ECG intervals, can be related to acclimatization, temperature preferences, species difference and use of restraint or use of anaesthesia.

We used the QRS complex to estimate the duration of ventricular depolarization. Many authors use the QT or RT interval for the same purpose (Johansen, 1959; Mullen, 1967; Valentinuzzi *et al.*, 1969a,b; Jacob and McDonald, 1975), without taking into account that QT or RT intervals include something of the ventricular depolarization and some part of the ventricular repolarization. Still, our RT mean value corresponds closely to the mean QT interval of lizards reported by Mullen (1967) at equivalent body temperatures.

Comparing the regression coefficients of the exponential equations for the different electro-

cardiographic intervals studied, it appears that the cardiac rest time is the electrocardiographic period most affected by body temperature, followed by the atrioventricular conduction time, which is in turn more affected than ventricular depolarization and RT interval.

The results from the relative ECG intervals showed that the variations of heart rate with body temperature are mainly due to changes in the RT interval and the cardiac rest time (TP period). Indeed, the increase of heart rate with body temperature corresponds to a linear decrease of the relative duration of cardiac rest time, in parallel to a linear increase of the relative duration of RT interval. On the other hand, the relative atrioventricular conduction time remains approximately constant, while the relative ventricular depolarization increases slightly with body temperature changes.

Finally, the mean percentages of participation in the *Gallotia galloti* cardiac cycle of atrioventricular conduction time and ventricular depolarization (in this case estimated from RT interval duration), are close to those reported by Jacob and McDonald (1975) for *Elaphe obsoleta* at equivalent body temperatures. This could be attributed to the existence of morphological characteristics common to the hearts of Squamata.

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