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Zoological Research

EFFECTS OF BODY TEMPERATURE ON ELECTROCARDIOGRAMS OF LIZARD *Eremias multiocellata**

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Abstract Electrocardiograms (ECG) of *Eremias multiocellata* were studied at 5-35℃ in body temperature. Electrocardiogram wave intervals (R-R, P-R, QRS, T-P, and R-T) shortened while heart rate increased with the increasing of body temperature. The average heart rate was 14.6／min at 5℃, whereas it was 201／min at 35℃. The duration of wave intervals of ECG and the heart rate were related significantly to the body temperature ($P<0.001$). Among the components of a cardiac cycle the cardiac rest period (TP intervals) and the atria-ventricular conduction time (PR interval) were affected mostly by body temperature. In the other hand the ventricular depolarization and repolarization (QRS and R-T intervals) were relatively less affected by the body temperature. The increasing of heart rate with body temperature was mainly caused by the shortening of ECG wave intervals, and the T-P interval (the cardiac rest period) was shortened more noticeably than other intervals.

Key words *Eremias multiocellata*, Electrocardiogram, Body temperature

The heart activity of lizards and the relation between heart activity and body temperature have been studied since 1960s (Baytholomew, 1962, 1963, 1964; Dawson, 1958, 1960, 1963; Furman, 1960; Licht, 1965; Maynard, 1960; Mullen, 1967). However, most early works were focused on the relation between heart rate and body／environment temperature. Porcell (1986) studied the electrocardiogram of lizard *Gallotia galloti* (body weight 43-47 g) and reported the pattern that the wave intervals of ECG varied with body temperature and the characteristic of excitation conduction in cardiac cycle and discussed the mechanism that the heart activity varies with body temperature. His work is of important theoretical significance to the mechanism of the variation of electrocardiac activities. However, there is only one species on which his studies were carried. Thus, further investigations and comparative studies on different species in different place and different ecological environment are needed.

In this paper, we report our work conducted on the small ovoviviparous lizard

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Eremias multiocellata (body weight 5.8–10.2 g) distributed in the desert and semi-desert area in the northwest of China using the methods adapted from Porcell (1986). The electrocardiogram was recorded at different body temperature. The pattern of heart activity variation with body temperature and its adaptation feature to temperature were studied.

1 Materials and Methods

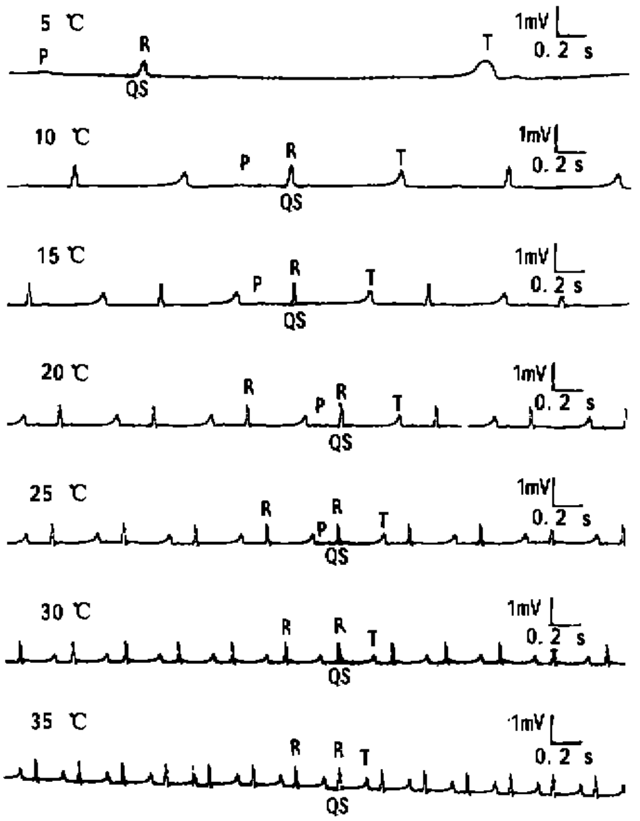

Fig. 1 ECG of *Eremias multiocellata* at body temperature of 5–35℃

Standard voltage: 2 mV / cm, rate of paper movement: 400 ms / cm.

The 125 lizards used in this work were collected in Minqin county, Gansu Province. The average body weight was (7.03 ± 1.40) g, mean snoutvent length (SVL) was (60.6 ± 4.9) mm. The lizards were kept in the laboratory and fed with the worm, *Tenebrio molitor*. The body weight and SVL were measured before every ECG recording. They were recorded at 7 body temperature situations— 5, 10, 15, 20, 25, 30 and 35℃, some individuals were recorded at 40, 42, 44, 45 and 46℃. At each body temperature situation, 15 individuals were recorded. The recording of ECG was carried out in a thermostat controlled ambient (over room temperature) or a thermostat controlled refrigerator (below room temperature). Animals were bound to a plate with the back side down and put in the ambient or refrigerator about 30 minutes before recording. The body temperature was monitored by an electric thermometer (Instrument of Beijing Normal University) whose small thermistor probe was inserted into the animals' cloaca 2 cm deep. The recording was started 5 min after the set temperature was reached. For each individual the recording last 5–10 min. The records of rest states of animals were chosen for analysis.

The bipolar electrocardiogram was recorded by two stainless steel needle electrodes punctured subcutaneously to the right and left front limbs about 5 mm deep. A third electrode was inserted to the right hind leg served as earth electrode. The signal was led to a two channel physiograph (Chengdu Instrument Factory) and the electrocardiogram was depicted onto the record paper

The duration of the PR, TP, RT, and RR intervals and QRS complex were measured by a ruler on the record paper. The data were processed using statistical methods, and the t-test was used to check the signification.

2 Results

The intervals were mesured as: R-T interval or S-T period—from the end of QRS to the end of T wave; T-P interval—from the end of T wave to the beginning of P wave; P-R interval—from the beginning of P wave to the beginning of QRS.

The segments of electrocardiogram of number 2 lizard (w: 7.61 g, SVL: 65.5 mm) at 7 body temperature situations in the range 5-35℃ were shown in Fig. 1. The P wave was of very low relative altitude and positive. The T wave was also positive and its altitude was higher than P wave. The voltage of P was 0.027-0.053 mV and mostly appeared when body temperature ranged from 5 to 20℃. When body temperature was over 25℃ the T and P were almost overlapping in most animals' ECG, and difficult to be recognized. The Q wave was very small, and usually could not be seen. The S wave was negative and appeared at temperature over 15℃.

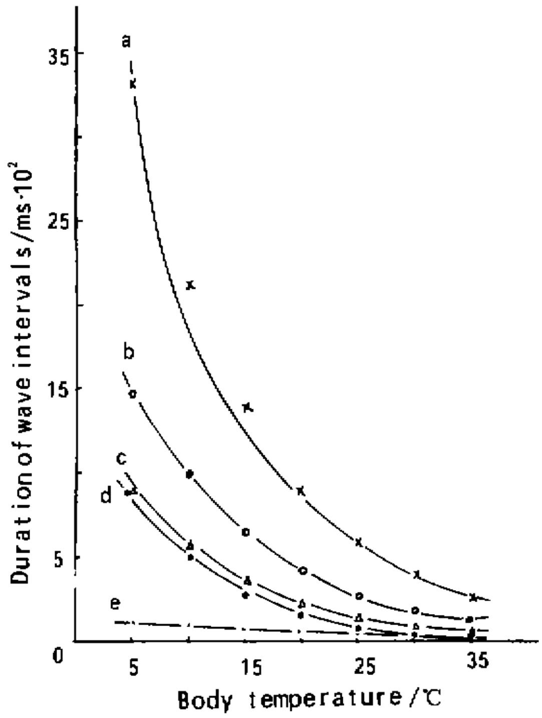

Fig. 2 The relation between ECG wave intervals and body temperature
a. RR; b. RT; c. TP; d. PR intervals
e. QRS complex.

The voltage of waves is given in Table 1.

The relationship between each interval duration and body temperature was calculated by corresponding regression. The regression equation are

$RR(ms) = 5026e^{-0.0852T}$ ($r=-0.9863$ $P<0.0001$)

$PR(ms) = 1411e^{-0.0891T}$ ($r=-0.9906$ $P<0.0001$)

$RT(ms) = 2239e^{-0.0820T}$ $(r = -0.9985 \quad P < 0.0001)$

$TP(ms) = 1584e^{-0.1149T}$ $(r = -0.9713 \quad P < 0.0001)$

$QRS(ms) = 122e^{-0.0412T}$ $(r = -0.9452 \quad P < 0.001)$

Table 1 Voltage (mV) of ECG waves at different body temperature

Body temperature / ℃	P wave $\bar{x} \pm SD$	T wave $\bar{x} \pm SD$	R wave $\bar{x} \pm SD$
5	0.027±0.011	0.099±0.022	0.199±0.064
10	0.041±0.016	0.120±0.053	0.240±0.062
15	0.036±0.011	0.108±0.036	0.273±0.037
20	0.035±0.013	0.144±0.077	0.327±0.098
25	0.048±0.013	0.156±0.075	0.303±0.063
30	0.053±0.005	0.194±0.089	0.3487±0.096
35	0.050±0.001	0.187±0.073	0.513±0.103

Fig. 2 is the curves derived from the regression equations above, showing the variation of interval duration to body temperature. The interval durations decreased exponentially with body temperature increasing, and the correspondence was very significant ($P < 0.001$). For searching the mechanism of the increase of heart rate with the increasing of body temperature, the variation of the relative values of every periods was shown by the regression equations below:

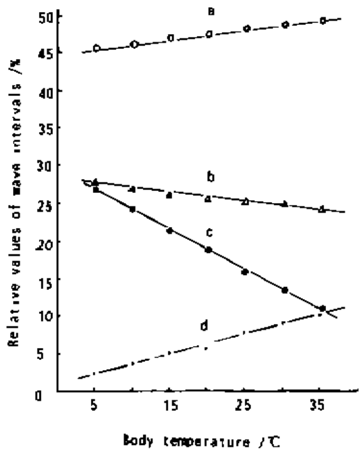

Fig. 3 The relation between the relative value of wave intervals and body temperature
a RT/RR; b. PR/RR; c. TP/RR; d. QRS/RR.

$QRS/RR(\%) = 1.037 + 0.2697T$ $(r = 0.9661 \quad P < 0.001)$

$RT/RR(\%) = 45.12 + 0.1334T$ $(r = 0.2606 \quad P < 0.25)$

$TP/RR(\%) = 29.86 - 0.5397T$ $(r = -0.7513 \quad P < 0.025)$

$PR/RR(\%) = 28.28 - 0.1099T$ $(r = -0.3422 \quad P < 0.1)$

Fig. 3 was derived from these equations. QRS / RR was significantly correlated with body temperature ($r = 9.9661$, $P < 0.001$) ranged from 2.39% to 10.48% over the body temperature range 5–35℃. The correlation between RT / RR and body temperature was also positive but not significant ($r = 0.2606$; $P < 0.25$), RT / PT ranged from 45.79% to 49.79% over the body temperature range. Yet TP / RR and PR / RR were correlated negatively to body temperature. The TP / RR correlation was significant ($r = -0.7513$; $P < 0.05$) and PR / RR correlation was not ($r = -0.3422$, $P < 0.01$). TR / RR ranged from 27.16% to 11.24%, PR / RR from 27.73% to 24.43% over the body temperature range 5–35℃.

Table 2 Comparison of heart rate of different lizard species at body temperature of 35℃

Species	Weight / g	Heart rate (beat / min)	Literature
Amphibolurum barbatus	300–500	61–86	Bartholomew,1963
Tiliqua rugosa	400	62	Licht,1965
Gallotia galloti	43–47	133	Porcell,1986
Crotaphytus collaris	25–35	120	Dawson,1963
Phrynocephalus przewalskii	4.6–9.5	244.9	Li,1992
Eremias multiocellata	5.8–10.2	201	This paper

3 Discussion

At the same body temperature 35℃, the heart rate of *Eremias multiocellata* was notably higher than that of most lizard species reported (Table 2). Licht (1965) reported the relation between the heart rate and body weight is $R = 153Wt^{-0.267}$. Generally the greater the weight, the lower the heart rate, However, the heart rate of *Gallotia galloti* was higher than *C. collaris* whose body weight was lower. The body weight of *E. multiocellata* is similar to that of *P. przewalskii*, but the heart rates were quite different. These may be attributed to the ecological environment as well as taxonomic status. The speciation is the result of evolution and the adaptation to the environment. The adaptation can affect many physical aspects of species. *G. galloti* lives in the Canary Island and *C. collaris* lives in the arid, semi–arid zone in North America. Still, *E. multiocellata* lives in bush clumps in semi–desert region, so that its home range is relatively small and it does not move a lot. however, *P. przewalskii* lives on broad sand ground, where there is less vegetation, so that its home range is much larger and it moves more than *E. multiocellata*.

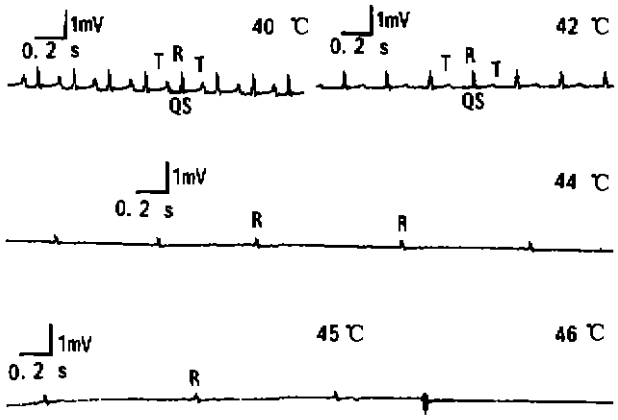

Fig. 4 ECG of *Eremias multiocellata* at high body temperature (40–45℃)
Standard voltage: 2 mV / cm,
rate of paper movement: 400 ms / cm

In the experiment, we recorded the ECG of some individuals at high temperature, and the results were shown in Fig. 4. At 40℃, the heart rate was a little slower than at

35℃, but the wave was basically normal. At 42℃ the heart rate was notably slower and the height of R and T wave were notably lower than at 35℃. When body temperature reached 44℃ ECG became abnormal—T wave disappeared, R wave was very small and RR interval became irregular. When body temperature reached 45℃ or 46℃ ECG disappeared, the heart stopped and the lizards died. This result was coincident with the reported lethal high temperature of this species (Li, 1992).

Over the body temperature range 5–35℃, the duration of every wave interval of ECG decreased with the increase of body temperature. This result agreed to the result of Porcel (1986) on *G. galloti*. The relative values QRS / RR and RT / RR correlated positively, whereas TP / RR correlated negatively with body temperature. This indicated that different part of the cardiac cycle was affected differently by body temperature. When body temperature going up, the cardiac rest period (TP interval) and the atria-ventricular conduction time (PR interval) were relatively shortened, but the duration of ventricular depolarization and repolarization (RT interval) prolonged. This meant that the increase of heart rate of *Eremias multiocellata* was caused by the shortening of rest period and acceleration of atria-ventricular conduction. The Shortening of rest period was the major factor.

Comparing the wave intervals of ECG of *G. galloti*, *P. przeovalskii* (Li Rende, 1992) with those of *E. multiocellata*, we found that for *G. galloti* the relation was TP > PR > RT > QRS, whereas for *E. multiocellata* and *P. przewalskii* it was RT > TP > PR > QRS. In other words, for *G. galloti* TP interval was the longest part of ECG, but for *P. przewalskii* and *E. multiocellata* the longest interval was RT. This meant that at same body temperature the relative value of cardiac rest period (TP) of *G. galloti* was longer but the period of ventricular electric events (RT) was shorter than that of *E. mutiocellata* and *P. przewalskii*. The heart rate of *E. multiocellata* or *P. przewalskii*, both of which have very low body weight, was higher than that of *G. galloti*. Possibly this make cardiac rest period relatively shorter in the cardiac cycle.

References

Bartholomew G A, Hudson J W, Howell T R, 1962. Body temperature, oxygen consumption, evaporative water loss, and heart rate in the poor-will. *Condor*, **64**: 117–25

Bartholomew G A, Tucker V A, 1963. Control of changes in body temperature, metabolism, and circulation by the agamid lizard, *Amphibolurus barbatus*. *Physiol. Zool.*, **36**: 199–218.

Bartholomew G A, 1964. Size, body temperature, thermal conductance, oxygen consumption, and heart rate in Australian varanid lizards *Physiol Zool*, **37**: 341–354.

Dawson W R, Bartholomew G A, 1958. Metabolic and cardiac responses to temperature in the lizard *Dipsosaurus dorsalis*. *Physiol. Zool.*, **31**: 100–111.

Dawson W R, 1960. Physiological responses to temperature in the lizard *Eumeces obsoletus*. *Physiol Zool*, **33**: 87–103.

Dawson W R, Templeton J R, 1963. Physiological responses to temperature in the lizard *Crotophytus collaris*.

Physiol. Zool., **36**: 219–236

Furman K I, 1960 The electrocardiogram of the South African clawed toad (*Xenopus leavis*) with special reference to temperature effects. *So Afr. J. Med. Sci*, **25**: 109–118

Li Rende, 1992 Effects of temperature on cardiac activities in the desert lizard, *Phrynocephalus przewalskii*. *Acta Zoologica Sinica*, **38**(1): 42–47. (in Chinese with English summery)

Li Rende, 1992. The influence of environmental temperature on body temperature of *Phrynocephalus przewalskii* and *Eremias multiocellata* and their selection of environmental temperature. *Zoological Research*, **13**(1): 47–52. (in Chinese with Eglish summery)

Licht P, 1965. Effects of temperature on heart rates of lizards during rest activity. *Physiol Zool.*, **38**: 129–137.

Maynard D M, 1960 Heart rate and body size in the spiny lobster. *Physiol. Zool.*, **33**: 241–251.

Mullen R K, 1967 Comparative electrocardiograph of the Squamata. *Physiol Zool*, **40**: 114–126

Porcell L D V, 1986. Cardiac responses to temperature in the lizard *Gallotia galloti*. *Comp Biochem. Physiol*, **85A**(2): 389–394.

温度对密点麻蜥心电活动的影响*

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摘 要 采用甘肃省民勤县荒漠半荒漠环境中的卵胎生蜥蜴密点麻蜥(*Eremias mutiocellata*)为材料，研究其心电活动随体温变化的规律以及对环境温度的适应特点。共记录密点麻蜥 125 只，每只蜥蜴记录 5、10、15、20、25、30、35℃ 7 个温度等级，每个等级 15～20 只；少数蜥蜴记录的温度范围扩展到 40、42、44、45 和 46℃。环境温度采用由电接点温度计和继电器控制的电冰箱和恒温箱来控制。体温测量采用 SY–2 型数字式温度计，测定时插入泄殖腔 2 cm。心电描记采用 LMS2B 型二道生理记录仪。电极为不锈钢针形电极。实验前将蜥蜴放入待测温度环境中适应 2 h。被测蜥蜴背位固定于木板上，不麻醉，将记录电极的正极插入左前肢皮下、负极插入右前肢皮下、地线插入后肢皮下、插入深度均为 5 mm。电极固定后待蜥蜴的体温达到预定温度 5 min 后再开始心电记录。在实验记录纸上测量各波的电压值及各间期的时间，其中 R～T 间期即 S～T 段，表示从 QRS 波结束到 T 波结束的时间，T～P 间期表示从 T 波结束到 P 波开始时的时间，P～R 间期表示从 P 波开始到 QRS 波开始的时间，以 t 测验检验相关系数的显著性。

体温为 5～35℃时的心电图中 P 波和 T 波是正向的，且幅度很低，R 波幅度高于 P 波和 T 波。P 波电压值为 0.027～0.0525 mV，多在 5～25℃时出现，高体温(25℃以上)时大多数蜥蜴心电图上 P 波和 T 波重叠，不易分辨。Q 波很小，大多不易辨认，S 波在 15℃以上时均可出现，且为负向波。体温由 5℃上升至 35℃时，心率由 14.6 次／min 增加为 201 次／min。P～R、R～T 和 T～P 间期的值都随之缩短。各间期值在各温度等级之间的差异都极显著($P<0.001$)。在相同体温条件下，密点麻蜥的心率范围较一些作者报道的其他蜥蜴的心率都快，且差别很大。心率和体重之间有 $R=153\ Wt^{0.207}$ 的关系(Licht, 1965)，密点麻蜥的体重小则心率快，但是密点麻蜥(*E. multiocellata*)和荒漠沙蜥(*Phrynocephalus przewalskii*)的体重相似，心率却有差异，除种属差异外，也与生态环境的差异有关。

QRS／RR 和 RT／RR 的值与体温呈正相关，而 TP／RR 和 PR／RR 的值与体温呈负相关。说明在体温升高时心动周期中各间期缩短的程度不同，即心脏的静息期(TP)和房室传导

时间(PR)相对缩短，而心室开始去极化至复极化结束的时间(QRS和RT)相对延长。这一特征说明了密点麻蜥的心率随体温升高而加快的原因是静息期缩短和房室传导速度加快，而静息期缩短是最重要的因素。

关键词 密点麻蜥，心电图，体温

中图分类号 Q959.62

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