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Effect of Temperature on the Heart and Ventilation Rates in the Agamid Lizard *Uromastyx microlipes* (the Dhubb) in the Central Region of Saudi Arabia

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Abstract. The effect of body warming and cooling on the heart and breathing rates has been studied in the agamid lizard *Uromastyx microlipes*. Electrocardiograph (ECG) of *Uromastyx microlipes* consists of P, QRS, and T components similar to those in mammals. Heart rate increases with body temperature. During warming the heart rate ranged from 7-134 beat/min, while during cooling ranged from 2-73 beat/min. The mean of heart rate during warming and cooling was not significantly different except at body temperatures of 20ºC and 35ºC. In two lizards heart rate was higher during warming than cooling for all temperatures. Both breathing types (thoracic and buccal) increased in frequency with body temperature. The range of thoracic breathing rates during both warming and cooling was 0-20 breath/min. Buccal breathing rate was 0-24 breath/min during warming, and 0-26 breath/min during cooling.

Introduction

Animals can be classified into two types according to the stability of body temperature: hometherms and poikilotherms. Other classification based on the source of body heat; *i.e.* endothermic and ectothermic animals. Reptiles are considered poikilotherms animals but often able to maintain their body temperatures at a remarkably high and constant level throughout much of the day, by varying their exposure to the available sources of heat. They bask in the sun or rest on warm rocks when they get cold while if they get too hot they shelter under vegetation or in holes. Consequently, reptiles are sometimes termed 'ectothermic or hometherms' because of their ability to use external sources of heat to maintain body temperature.

In reptiles heart rate is related to different factors such as temperature, size, metabolism, respiratory state, and level of excitement[1]. Those various factors are connected together and it is difficult to separate their effects. In general, ambient temperature plays a major role in controlling metabolism in reptiles. Cooling and warming the animal directly affects the heart rate[1,2-6]. Presumably, the increase in heart rate with temperature supports an elevated cardiac output which augments O_2 transport[1]. Reptiles can move between thermal exchange with the environment to maintain their body temperature, whereas birds and mammals control their temperature by shifts of their metabolic rates. In some lizards[2-5] and crocodilians[1] heart rate was higher during warming than cooling in the same temperatures. The heart rate is inversely related to temperature in most reptiles (increased heart rate as a result of body temperature increase)[7-10].

Three factors determined lung ventilation in most reptiles; the frequency of breathing, tidal volume and the duration of the pause period which interrupts the ventilatory[11]. In some lizards and snakes O_2 uptake can increase twenty-fold above resting values with almost no increase in ventilation frequency[12-14], due to an increase in tidal volume.

The effect of temperature on the ventilatory frequency has been studied in several species of reptiles[15-21]. The ventilation frequency increased as body temperature was raised. Consequently, the pause period was reduced[22].

In the lizard *Pogona vitticeps* the minute ventilation decreased at lower temperature as a result of a decrease in average frequency, and the tidal volume was temperature independent[23].

There is another factor behind the dependency of ventilation on changing of body temperature which is common to most reptiles; that is they maintain their blood pH in certain body temperature by controlling their ventilation, since blood pH shows a nearly linear inverse relationship with body temperature[23]. In *Uromastyx microlipes,* we attempted to determine the effect of body temperature on heart and ventilation rates and to compare it with other reptiles.

Materials and Methods

Seven lizards (*Uromastyx microlipes*) of either sex (350-1033 g) were used in this study. All lizards were collected from Riyadh. They were kept in large cage size 1.8 meters square × 1.2 meters high with its floor filled with fine coarse silver sand. In each cage there were two basking areas heated by 240 watt pig rearing lamps and two long tube light; one is a 40 watt (U.V.), and the other tube is 40 watt (U.V.B./U.V.A.). Both lights were run simultaneously to ensure the correct quantities of U.V./U.V.B./U.V.A. The power coming on at 8 am and off at 8 p.m., therefore, the lighting was on for 12 hours and the temperature in the cage was maintained in the range of 18-20ºC during the night and 30-32ºC during the day time and by mid-afternoon they can bask at between 45-47ºC. Humidity was kept between 54%-65%. Food (vegetables and fruits) was provided daily with live adult locusts 2 or 3 times weekly. Details of the animal husbandry involved in the maintenance of wild caught *Uromastyx* has been reported[25]. Dhubbs were acclimated to this environment for at least 5 weeks before any experiment. Each animal was lightly anaesthetized with sodium pentobarbitone (Sagatal May & Baker Ltd) 20 mg kg^{-1} i.p.

A rectal probe (Digitron instrumentation 3200K) was inserted through the cloacal opening to measure rectal temperature and a lamp was used to warm the animal. The ECG and EMG were recorded by inserting couple of bipolar wire electrodes of either copper (0.2-0.3 mm diameter) or stainless steel (0.006 inch diameter Johnson Matthey Metals Ltd.) subcutaneously; first couple were inserted in the chest close to the heart. The other was inserted to the end of thoracic cage near the lungs. This configuration invariably recorded the electrical activity of the heart and the intercostal muscles when active. The signals were fed into a preamplifier (Isleworth Electronics Type A101) and then further amplified and filtered (5-5000 Hz) (Neurolog NL 105, 106, 115, 120, 125), then led into an intelligent computer interface (1401 CED system) and displayed on a computer using data capture software (Spike2 CED). The data was sampled at 100-1000 Hz and stored on hard disk for subsequent analysis.

Each lizard was first heated over a range of temperatures beginning at 15ºC and increasing in the following steps 20ºC, 25ºC, 30ºC, 35ºC and 40ºC. Then the cooling experiment was turn over for the range of: 40ºC, 35ºC, 30ºC, 25ºC, 20ºC, 15ºC, 10ºC. The whole warming and cooling cycle took about 3 hours. 5-10 minutes was recorded at each temperature studied.

Results

The ECG of *Uromastyx microlipes* consists of P, QRS and T components (Fig. 1). The P wave is smaller relative amplitude and positive; Q is also smaller relative amplitude and negative; QRS complex is biphasic with a high relative amplitude positive R and low relative amplitude negative S wave, T wave in low temperature is similar to P wave, but in high temperature is higher than P wave (Fig. 1).

The heart rate was recorded in seven lizards in both warming and cooling experiments, at the temperatures of 10ºC, 15ºC, 20ºC, 25ºC, 30ºC, 35ºC, and 40ºC. The heart rate ranged from 7-134 beat/min during warming and 2-73 beat/min during cooling (Table 1). The results of the effect of both warming and cooling on the heart rate were illustrated in Table (1). Heart rate increases with in-

FIG. 1. The normal ECG of *Uromastyx microlipes,* at body temperature 25ºC .The P, QRS and T components were indicated:
1. One cycle of ECG.
2. Two cycles of ECG.

creasing of body temperature (Fig. 2, 3). The heart rate was significantly higher during warming than cooling at two body temperatures; 20ºC and 35ºC (P = 0.01), whereas it was similar at all other temperatures. In two lizards (L2, W. 907 g and L3, W. 1033 g) heart rate was higher during warming than cooling at all temperatures (Table 4).

TABLE 1. The warming and cooling experiments and their effect on heart rate (The mean and standard error were interacted).
A. The warming experiments.
B. The cooling experiments.

A

Temperatures	L1-w	L2-w	L3-w	L4-w	L5-w	L6-w	L7-w	Mean	S.E.
15	12	18	16	8	7	11	8	11.43	1.60
20	22	23	23	29	11	28	12	21.14	2.69
25	32	55	24	58	19	50	20	36.86	6.44
30	41	72	33	44	27	36	31	40.57	5.68
35	69	73	69	82	72	58	72	70.71	2.69
40	85	134	80	116	101	76	102	99.14	7.89

B

Temperatures	L1-c	L2-c	L3-c	L4-c	L5-c	L6-c	L7-c	Mean	S.E.
10	8	6	5	5	2	9	3	5.43	0.95
15	9	8	6	14	5	12	5	8.43	1.32
20	15	12	9	17	10	13	14	12.86	1.06
25	35	23	17	21	42	16	40	27.71	4.16
30	47	39	21	34	50	30	40	37.29	3.77
35	73	50	42	60	48	54	60	55.29	3.83

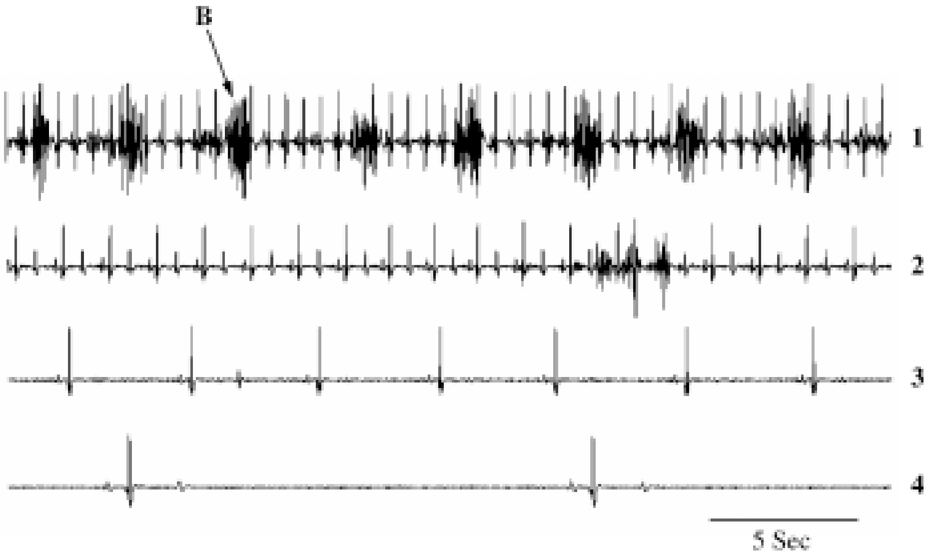

FIG. 2. The effect of warming on the heart rate and ventilation in one lizard (L 1 W. 420 g):
1. The ECG recorded during 40ºC body temperature.
2. The ECG recorded during 30ºC body temperature
3. The ECG recorded during 20ºC body temperature
4. The ECG recorded during 10ºC body temperature
B – Chest breathing

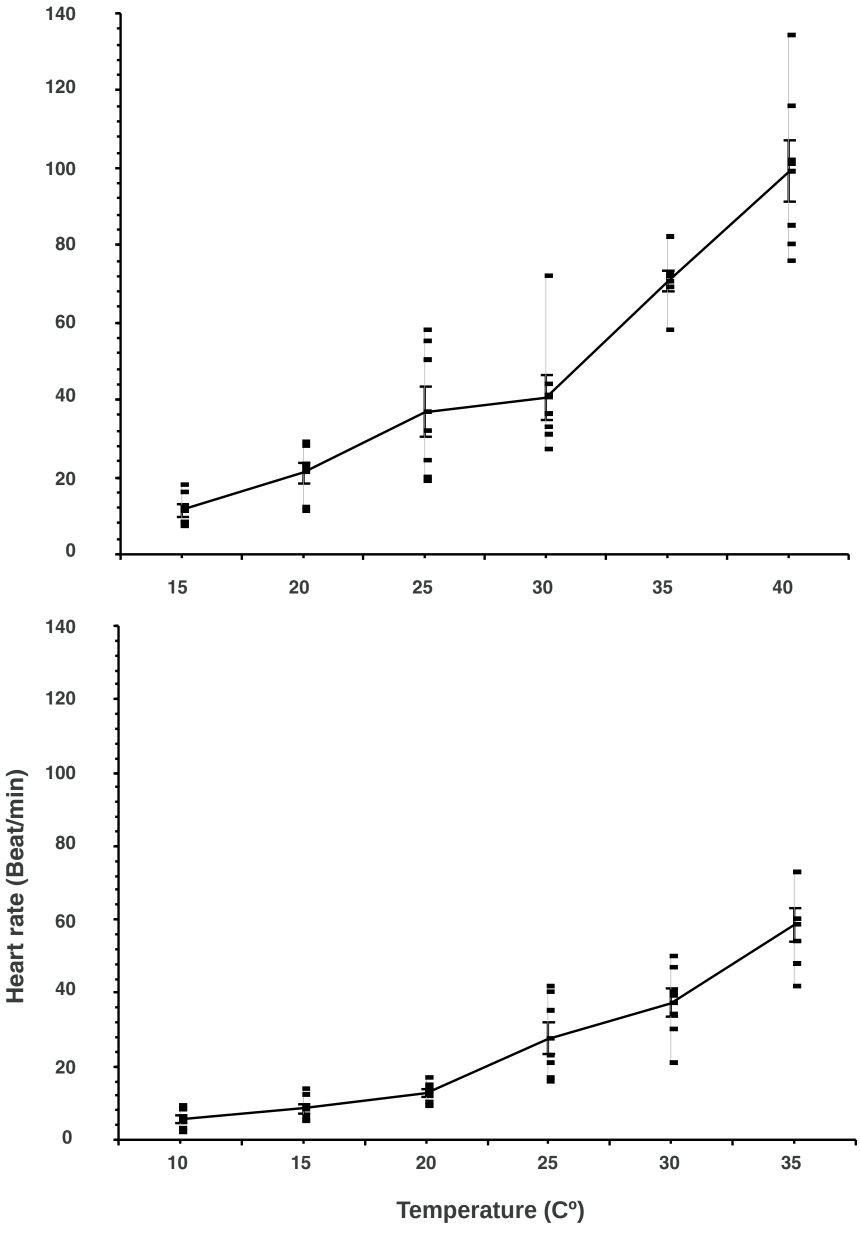

FIG. 3. The effect of body warming and cooling on the heart rate. Vertical dots indicate ranges and the carve with vertical lines indicate means ± 2 SE.
A. Warming experiments.
B. Cooling experiments.

Both thoracic and buccal breathing were recorded in the warming and cooling temperatures of 10ºC, 15ºC, 20ºC, 25ºC, 30ºC, 35ºC and 40ºC. Seven experiments were performed and the results were illustrated in Tables 2 & 3. The frequency of thoracic breathing and buccal breathing increased with increased body temperature, while the duration of the apneic periods decreased. During warming the thoracic breathing rate ranged from 0-23 breath/min, and 0-20 breath/min during cooling. Buccal breathing rate ranged from 0-24 breath/min during warming, and 0-26 breath/min during cooling.

TABLE 2. The warming and cooling experiments and their effect on chest ventilation rate (The mean and standard error were interacted).
A. The warming experiments.
B. The cooling experiments.

A

Temperatures	L1-w	L2-w	L3-w	L4-w	L5-w	L6-w	L7-w	Mean	S.E.
15	3	5	2	5	0	0	0	2.14	0.86
20	3	7	2	1	3	3	1	2.86	0.77
25	4	9	2	16	5	4	1	5.86	1.94
30	3	9	4	19	0	8	0	6.14	2.52
35	8	13	14	23	1	13	5	11.00	2.70
40	19	19	11	18	10	8	15	14.29	1.74

B

Temperatures	L1-c	L2-c	L3-c	L4-c	L5-c	L6-c	L7-c	Mean	S.E.
10	0	0	0	0	0	0	0	0.00	0.00
15	0	0	2	0	0	1	0	3.00	0.30
20	2	5	4	2	2	4	1	20.00	0.55
25	4	9	6	11	1	7	3	41.00	1.32
30	6	6	7	17	2	8	3	49.00	1.85
35	6	10	10	20	7	10	5	68.00	1.89

TABLE 3. The warming and cooling experiments and their effect on buccal ventilation rate (The mean and standard error were interacted).
A. The warming experiments.
B. The cooling experiments.

A

Temperatures	Lb1-w	Lb2-w	Lb3-w	Lb4-w	Lb5-w	Lb6-w	Mean	S.E.
15	0	0	0	0	5	0	0.83	0.8
20	0	3	0	0	15	0	3.00	2.45
25	10	5	17	0	23	0	9.17	3.82
30	12	0	20	0	3	0	5.83	3.41
35	7	2	24	1	8	0	7.00	3.65
40	13	4	21	0	19	0	9.50	3.83

B

Temperatures	Lb1-c	Lb2-c	Lb3-c	Lb4-c	Lb5-c	Lb6-c	Mean	S.E.
10	0	0	0	0	3	0	0.50	0.5
15	0	1	0	0	2	0	0.50	0.34
20	2	1	4	0	3	0	1.67	0.67
25	0	2	12	0	5	8	4.50	1.96
30	8	1	17	5	0	16	7.83	2.98
35	8	2	20	7	18	26	13.50	3.76

TABLE 4. The relation between the effect of body warming and cooling on the heart beats. Two temperatures were significantly different (*).

Temperatures	P value
15	> 0.5
20*	< 0.2
25	> 0.5
30	> 0.5
35*	< 0.2

The breathing rate increases as a result of increase in body temperature (Tables 2 & 3). There was no significant difference between the effects of warming and cooling on the breathing in *Uromastyx microlipes*.

Discussion

Temperature plays a major role in controlling activity levels in reptiles. In *Uromastyx microlipes* heart rate was increased by increasing the body temperature. This result is similar to other lizards: *Crotaphytus collaris:*[26], *Sceloporus, Dipsosaurus, Trachydosaurus* and *Uma;*[9], *Sauromalus obesus;*[27] and *Gallotia galloti;*[21]. In the lizard *Gallotia galloti* the increase of heart rate with body temperature corresponds to a linear decrease of the relative duration of cardiac rest time (TP period), in parallel to a linear increase of the relative duration of RT interval[21].

The mean of heart rate in *Uromastyx microlipes* during warming is higher than during cooling in two temperatures 20ºC and 35ºC. This compares with three species of lizards (*Amblyrhynchus, Tiliqua* and *Amphibolurus*) which show slower heart rates during cooling than during warming[4]. Bartholomew and Lasiewski suggested that the circulatory system is an important factor in the modulation of rates of temperature change in those lizards. In this study two experiments from seven revealed differences between warming and cooling, over the whole temperature range (Fig. 4). These results suggest that *Uromastyx microlipes* may show similar responses to the results obtained by Bartholomew and Lasiewski[4], but individual differences exist.

In other lizards (*e.g. Varanus*) there is no difference between heart rates during warming and cooling[4].

Ventilatory rate is temperature-dependent in many reptiles[16-21]. Oxygen consumption increased with temperature in air-breathing ectotherms[17,18], and CO_2 production similarly increases. Although ventilation also rises it is regulated to allow some accumulation of CO_2, so that blood pH is reduced as temperature rises. This enables the animal to maintain constant relative alkalinity of the blood[24].

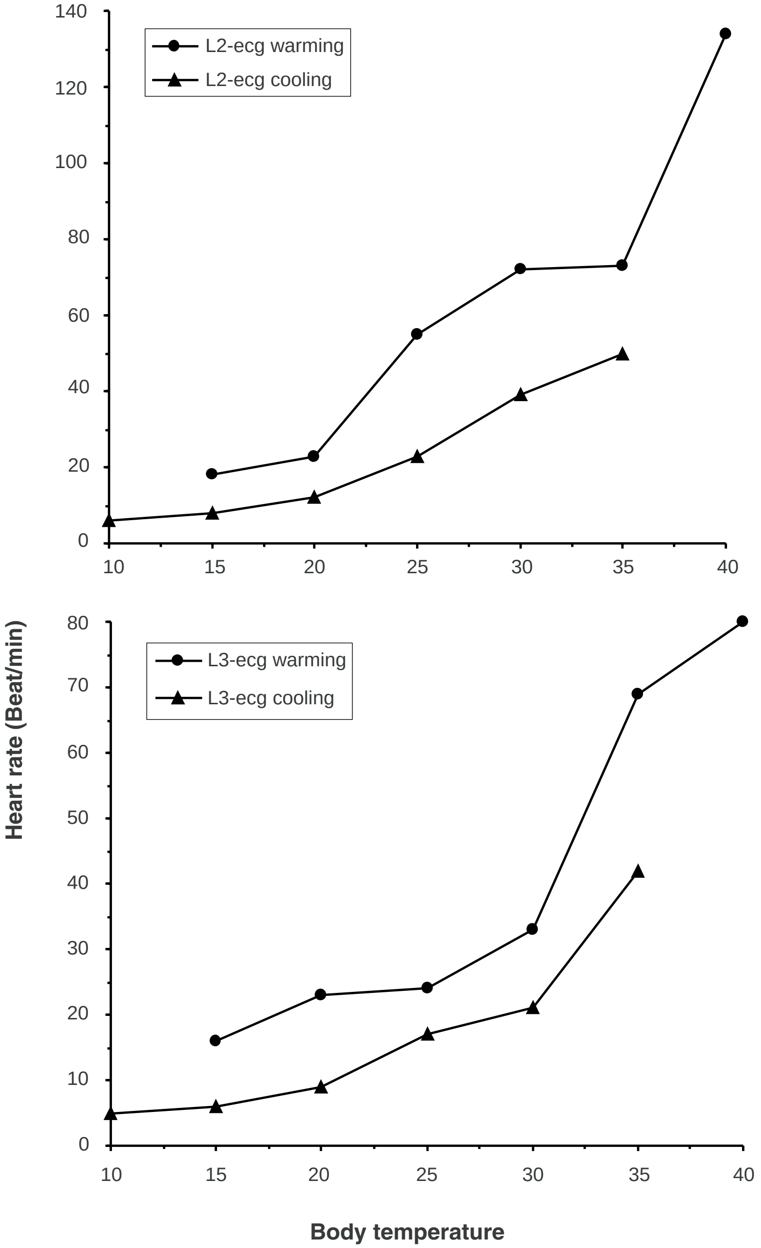

FIG. 4. The heart rate of an individual lizard shows the difference between warming and cooling in range of temperatures:

A. Lizard No. L 2 W. 907 g.

B. Lizard No. L 3 W. 1033 g.

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تأثير الحرارة على معدل نبضات القلب ومعدل التنفس في سحلية الضب *Uromastyx microlipes* في المنطقة الوسطى للمملكة العربية السعودية

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المستخلص. في هذه البحث درس تأثير التدفئة والتبريد على معدل نبضات القلب ومعدل التنفس في سحلية الضب ، وأظهر تسجيل النشاط الكهربائي القلبي محتوى مشابها لما هو في الثدييات مركب P ، QRS ، T. يزيد معدل نبضات القلب مع زيادة درجة الحرارة. معدل نبضات القلب خلال التدفئة يتراوح بين ٧-١٣٤ نبضة / دقيقة ، بينما خلال التبريد يتراوح بين ٢/ ٧٣ نبضة/ دقيقة. ليس هناك فروق معنوية بين معدل نبضات القلب خلال التدفئة والتبريد إلا عند درجة حرارة الجسم ٢٠ و٣٥ درجة مئوية. في حيوانين سجلت زيادة في معدل نبضات القلب خلال التدفئة عنه في التبريد في جميع درجات الحرارة. كلا نوعي التنفس (الصدري و الحلقي) زادا في المعدل مع زيادة درجة حرارة الجسم. تفاوت معدل التنفس الصدري خلال التدفئة والتبريد من ٠-٢٠ نفس/ دقيقة، بينما التنفس الحلقي تفاوت من ٠-٢٤ نفس/ دقيقة خلال التدفئة و٠-٢٦ نفس/ دقيقة خلال التبريد.