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PERCENTAGE CONTRIBUTION OF INCREASED HEART RATE TO INCREASED OXYGEN TRANSPORT DURING ACTIVITY IN *PSEUDEMYS SCRIPTA*, *TERRAPENE ORNATA* AND OTHER REPTILES

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Abstract—1. A new formula which correctly expresses the percentage contribution of increased heart rate to increased oxygen transport during activity is presented.

2. The percentage contribution is reported for the turtles *Pseudemys scripta* and *Terrapene ornata* at body temperatures of 10–40°C.

3. Corrected values for this parameter in reptiles studied at 30°C by other authors are also presented.

SEVERAL recent physiological studies have included simultaneous measurements of metabolic rate and heart rate of resting and active reptiles. Bartholomew & Tucker (1963) presented an equation which they felt expressed the relative change of metabolism and heart rate during activity, a parameter which they termed the percentage contribution of increased heart rate to increased oxygen transport during activity. The equation which these authors derived from the Fick equation for this parameter is

$$\% \text{ contribution} = \left(\frac{\text{AHR} - \text{SHR}}{\text{SHR}}\right) \div \left(\frac{\text{AHR} - \text{SHR}}{\text{SHR}} + \frac{\text{AOP} - \text{SOP}}{\text{SOP}}\right) \qquad (1)$$

where AHR, SHR, AOP and SOP are active and standard heart rate and oxygen pulse, respectively. This equation, however, overestimates the percentage contribution because the denominator of the right-hand side of the equation

$$\left(\frac{\text{AHR} - \text{SHR}}{\text{SHR}} + \frac{\text{AOP} - \text{SOP}}{\text{SOP}}\right)$$

does not represent the actual fractional change in oxygen transport during activity, i.e. metabolic scope (active metabolic rate minus standard metabolic rate) divided by standard metabolic rate. Consider the hypothetical case where

$$\text{SMR} = 10, \quad \text{SHR} = 5, \quad \text{SOP} = 2,$$
$$\text{AMR} = 40, \quad \text{AHR} = 15, \quad \text{AOP} = 2{\cdot}67,$$

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in which SMR and AMR are standard and active metabolic rate, respectively. Note that metabolic rate equals heart rate times oxygen pulse at rest and during activity. According to Bartholomew & Tucker's (1963) equation

$$\% \text{ contribution} = \left(\frac{15-5}{5}\right) \div \left(\frac{15-5}{5} + \frac{2{\cdot}67-2}{2}\right)$$
$$= 0{\cdot}86$$

It should be noted that the right-hand side of Bartholomew & Tucker's equation should be multiplied by 100 to yield an actual percentage rather than a decimal fraction. A new equation is proposed here which is a true representation of the percentage contribution of increased heart rate to increased oxygen transport:

$$\% \text{ contribution} = \left[\left(\frac{\text{AHR}-\text{SHR}}{\text{SHR}}\right) \div \left(\frac{\text{AMR}-\text{SMR}}{\text{SMR}}\right)\right] \times 100. \quad (2)$$

Rearranged, this equation becomes

$$\% \text{ contribution} = \left(\frac{\text{HRI} \times \text{SMR}}{\text{SHR} \times \text{Scope}}\right) \times 100, \quad (3)$$

where

HRI (heart rate increment) = AHR − SHR and Scope = AMR − SMR.

Using the hypothetical case

$$\% \text{ contribution} = \left(\frac{10 \times 10}{5 \times 30}\right) \times 100$$
$$= 67.$$

Table 1 presents the values for this parameter based on metabolic and heart rate data for the turtles *P. scripta* and *T. ornata* (Gatten, 1974). This percentage

TABLE 1—PERCENTAGE CONTRIBUTION OF INCREASED HEART RATE TO INCREASED OXYGEN TRANSPORT DURING ACTIVITY IN *P. scripta* AND *T. ornata*

T_b (°C)	Percentage contribution	
	P. scripta	*T. ornata*
10	6	27
15	8	35
20	9	21
25	10	13
30	11	14
35	12	23
40	13	35

Values were calculated using Equation 3 and standard and active metabolic and heart rates from Gatten (1974).

is always lower in *P. scripta* than in *T. ornata*, which indicates that increased cardiac frequency contributes less and increased oxygen pulse contributes more to oxygen demand during activity in the former than the latter species. This parameter increases steadily with rising body temperature in *P. scripta*, whereas it reaches a minimum value at 25–30°C and maximum values at lower and higher body temperatures in *T. ornata*.

Table 2 summarizes information on the percentage contribution of increased heart rate to increased oxygen transport during activity in a number of reptiles at 30°C. This parameter is lower in *P. scripta* than in any other reptile studied

TABLE 2—PERCENTAGE CONTRIBUTION OF INCREASED HEART RATE TO INCREASED OXYGEN TRANSPORT DURING ACTIVITY IN REPTILES AT 30°C

Species	Percentage contribution [equation (3)]	Percentage contribution [equation (1)]	Reference
Amphibolurus barbatus	36	46	Bartholomew & Tucker (1963)
Egernia cunninghami	21	34	Wilson (1971)
Iguana iguana	14	18	Moberly (1968)
Physignathus lesueuri	20	33	Wilson (1971)
Pituophis catenifer	15	30	Greenwald (1971)
Pseudemys scripta	11	29	Present study
Sauromalus hispidus	24	51	Bennett (1972)
Spalerosophis cliffordi	19	24	Dmi'el & Borut (1972)
Sphenodon punctatum	13	11	Wilson & Lee (1970)
Terrapene ornata	14	42	Present study
Tiliqua rugosa	37	58	Wilson (1971)
Tiliqua scincoides	34	46	Bartholomew *et al.* (1965)
Varanus gouldii	12	19	Bennett (1972)
Varanus spp.	23	33	Bartholomew & Tucker (1964)

Values were calculated using Equation 3 and Equation 1 of Bartholomew & Tucker (1963).

previously at 30°C. This implies that a relatively great change in cardiac stroke volume and/or arterial–venous oxygen difference occurs with activity in this species. Equation 3 gives substantially lower values for this parameter than does Equation 1 of Bartholomew & Tucker (1963), except in the case of *Sphenodon punctatum* where the percentage contribution is lower than in any other species.

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