EMOTIONAL HYPERGLYCEMIA AND HYPERTHERMIA IN TROPICAL MAMMALS AND REPTILES

BY

S. W. BRITTON AND R. F. KLINE

From the Physiological Laboratory of the University of Virginia Medical School

REPRINTED FROM THE AMERICAN JOURNAL OF PHYSIOLOGY
Vol. 125, No. 4, April, 1939
pp. 730-734

Reprinted from THE AMERICAN JOURNAL OF PHYSIOLOGY
Vol. 125, No. 4, April, 1939

EMOTIONAL HYPERGLYCEMIA AND HYPERTHERMIA IN TROPICAL MAMMALS AND REPTILES

S. W. BRITTON[1] AND R. F. KLINE

From the Physiological Laboratory of the University of Virginia Medical School

Received for publication January 24, 1939

Contrasting extremes in activity which are shown by different mammals and reptiles in the American tropics present a stimulating physiological challenge as well as an interesting nature study. Monkeys and sloths are remarkably opposed examples, and all degrees of activity are observed between these forms. A relentlessly uniform thermal climate the year round is nevertheless characteristic of their habitat.

A common condition, emotion, and correlated changes in blood glucose and body temperature, have recently been studied in both the above active and relatively inactive animals forms, and comparison has been made with responses in a number of other tropical species. The possible detection of an evolutionary trend in psychosomatic expressions was considered. A large number of mammals and several reptiles were studied.

METHODS. The work was carried out under fairly ideal physiological conditions in a jungle laboratory or in a nearby station in Panama.[2] Freshly collected animals were used. Most of the experiments were run in the morning after the animals had fasted approximately 12 hours over night. Normal or preëxcitement blood samples were taken with the least disturbance of the animal and as quickly as possible after withdrawing it from the cage. Blood glucose determinations were made according to the method of Folin and Malmros (1929). Deep rectal temperatures were taken.

Emotional excitement was readily elicited in nearly all specimens. Usually an animal was restricted or cornered in a cage or some part of the laboratory by one or more attendants, and simple thrusts and sallies made toward it with a straw brush or with one's heavily-gloved hand. A sham

[1] John Simon Guggenheim Memorial Fellow, 1937–38.

[2] The physiological phases of these studies were carried out at the Barro Colorado Island Laboratory, C.Z., and the Gorgas Memorial Laboratory, Rep. Panama. The thanks of the authors are gratefully extended to Mr. James Zetek and Dr. Herbert C. Clark of these laboratories respectively for their unfailing courtesies during the investigations.

TABLE 1

Blood sugar and body temperature changes on emotional excitation of various tropical animals

ANIMAL USED	NUMBER OF CASES	BLOOD SUGAR			RECTAL TEMPERATURE	
		Normal range	Normal average	Average rise after emotion	Normal average	Average rise after emotion
		mgm. per cent	*mgm. per cent*	*per cent*	*°C.*	*°C.*
White-faced monkey						
Cebus capucinus imitator	7	87–132	105	23	39.8	0.3
Marmoset monkey						
Leontocebus geoffroyi	8	112–156	128	34	38.8	0.8
Black spider monkey						
Ateles dariensis	6	78–180	114	23	39.2	0.2
Red spider monkey						
Ateles geoffroyi	5	79–105	93	26	38.3	0.5
Night Monkey						
Aotus zonalis	3	100–184	130	35	38.5	0.8
Vampire bat						
Desmodus rotundus murinus	3	152–215	192	28	38.4	0.6
Fruit bat						
Phyllostomus hastatus	7	53–65	62	10	38.9	0.6
Short-tailed bat						
Hemiderma perspicillatum	6	60–65	63	9	37.5	0.7
Brown bat						
Chilonycteris rubiginosa	5	60–66	64	7	38.7	0.5
Ocelot						
Felis pirrensis	3	75–174	114	40	38.7	0.9
Raccoon						
Procyon canerivorus	9	71–114	92	14	39.0	0.9
Kinkajou						
Cercoleptes caudivolvulus	3	67–185	117	21	37.2	1.5
Capybara						
Hydrochoerus isthmicus	6	146–273	219	16	37.9	0.9
Spiny rat						
Proechimys semispinosus	4	87–135	112	9	37.5	0.5
Mountain peccary						
Tayassu pecari	3	100–165	135	12	38.7	0.9
Collared peccary						
Pecari angulatus	8	98–190	134	18	38.5	1.3
Two-toed sloth						
Choloepus hoffmanni	11	57–120	79	34	34.6	0.5
Three-toed sloth						
Bradypus griseus	5	59–116	81	37	33.2	0.5
Armadillo						
Dasypus novemcinctus	4	54–97	72	24	31.9	1.1
Mexican opossum						
Marmosa isthmica	5	62–105	82	39	35.7	1.4
Zorro opossum						
Didelphis marsupialis	10	69–94	80	28	34.9	1.0
Water opossum						
Chironectes panamensis	3	67–91	79	26	35.2	1.1
Crocodile						
Crocodylus acutus	24	76–138	101	25	27.4	1.4
Rattlesnake						
Crotalus ruber	2	67–90	79	16		
Fer-de-lance						
Bothrops atrox	4	63–87	73	11	31.2	1.1
Boa constrictor						
Constrictor c. imperator	4	54–80	70	14	27.3	1.4
Rainbow boa						
Epicrates cenchris	2	96–90	93	14	29.8	0.7
Coral snake						
Micrurus nigrocinctus	2	105–109	107	15	29.2	1.2

attack period of three minutes was used, except in a few instances in which somewhat more prolonged tests were carried out over six or nine minutes.

Results. It is not within the province of this paper to describe in detail emotional reactions in different animals. Amongst the mammals, snarling and hissing, baring of the teeth, biting, clawing and aggressive charging were common characteristics. Monkeys manifested the greatest and sloths and armadillos the least emotional and general physical reactions. In the case of crocodiles, vigorous snapping of the jaws and lashing of the tail occurred, while snakes coiled and struck out frequently and made attempts to bite. In all cases, the greatest possible emotional response was drawn forth during the experimental period.

The results indicate that among mammals, the very active or vigorous forms show the highest normal blood sugar readings. Thus, the levels in monkeys, ocelots, kinkajous, peccaries and capybaras[3] generally ranged between 100 mgm. and 250 mgm. per cent. Relatively inactive forms, such as sloths, opossums and armadillos showed lower levels usually ranging between 60 mgm. and 100 mgm. per cent. Most of the snakes showed similar relatively low levels. Insectivorous and frugivorous bats showed the lowest normal blood sugar levels of all mammals (60 mgm. to 65 mgm. per cent). Carnivorous vampire (blood-eating) bats showed in contrast the highest blood sugar readings (approximately 200 mgm. per cent), with the exception of the capybara.

A consideration of the changes on excitation in various groups of animals shows that the very vigorous emotional responses of monkeys were correlated with large increments in blood glucose—from 20 to 35 per cent (average 28 per cent) in 29 cases. Blood sugar changes in opossums were nevertheless equally as great as in monkeys—average 29 per cent in 18 cases—although these animals were not nearly so active as the primates which were tested. The greatest hyperglycemic responses were observed in the case of sloths, especially those of the two-toed variety, notwithstanding the fact that these forms were very lethargic and gave little emotional display.

In most cases the affective and defensive reactions of sloths to the attack form of stimulation given above were confined, it may be observed, to gentle hissing and baring of the teeth, and occasional striking with the fore limb particularly on the part of the two-toed variety. Insectivorous and frugivorous bats were in contrast very aggressive, continually attempting to claw and bite and fly; and yet the latter animals showed the smallest alterations in blood sugar on excitation—on the average less than 9 per cent.

Analysis of the results shows that in the higher mammals (including monkeys, ocelots, vampire bats) the body temperatures ranged between

[3] This is a very vigorous although fat animal.

37° and 40°; in these there was an average blood sugar level of 104 mgm. per cent and an average rise on emotional activity of 22 per cent (range, 9–40 per cent, 68 cases). In the lower mammals (sloths, armadillos, opossums) the body temperatures ranged between 31° and 36°; and there was an average blood sugar level of 79 mgm. per cent and an increase on emotional activity of 37 per cent (range, 24–54 per cent, 38 cases).

In the emotional reactions shown above, apparently maximal changes in blood glucose and body temperature took place. It was found, at least, that doubling or tripling the excitation time (i.e., to 6 or 9 min.), in a number of cases, did not significantly affect the results.

The marked hyperglycemic reactions observed in the case of sloths are in contrast to the small amount of liver glycogen found in these animals—less than half the amount found in higher mammalian types (Britton, Kline and Silvette, 1938). However, these animals accumulate large amounts of food in the stomach (Wislocki, 1928), and even after a fasting period of three days or more the stomach usually contains considerable amounts of partly digested leaves and fruits having a high carbohydrate content (Britton). Further physiological data on some of the forms used in this study have already been published (Britton and Atkinson, 1938; Britton, Silvette and Kline, 1938).

It is recognized that blood glucose and body temperature levels may of course fluctuate rather quickly, and that the readings at any one time represent only the resultant balance from many metabolic exchanges. The results which were observed under uniformly controlled conditions in the present experiments are indicative, however, that certain responses characteristic of higher types are similarly present in many widely different as well as lower animal species.

SUMMARY

The higher mammalian tropical types, including monkeys, show a higher average blood glucose level and body temperature than lower types such as sloths and marsupials—on the average 104 mgm. per cent and 38.5° respectively, compared to 79 mgm. per cent and 34°.

Hyperglycemic reactions from emotional excitement were more marked in the lower mammalian forms, and body temperature rises also tended to be greater on excitation (except in sloths).

Sloths showed striking emotional hyperglycemic responses, but small changes in body temperature. In these animals the apparent psychic and general somatic expressions were of a low-grade character.

Blood-eating or vampire bats showed normal blood glucose levels three times as high as insectivorous and frugivorous bats—an average of 192 mgm. compared to 63 mgm. per cent. Further, emotional hyperglycemia was three times as great in the carnivorous bats.

Reptiles such as snakes and especially crocodiles showed emotional hyperglycemic and hyperthermal changes which were not greatly different from those observed in mammals.

There was no uniform correspondence apparent between general psychosomatic expressions and glycemic and thermal changes in individuals or in species.

REFERENCES

BRITTON, S. W. Unpublished observations.
BRITTON, S. W. AND W. E. ATKINSON. J. Mammalogy 19: 94, 1938.
BRITTON, S. W., R. F. KLINE AND H. SILVETTE. This Journal 123: 701, 1938.
BRITTON, S. W., H. SILVETTE AND R. F. KLINE. Ibid. 123: 705, 1938.
FOLIN, O. AND H. MALMROS. J. Biol. Chem. 83: 115, 1929.
WISLOCKI, G. B. J. Morph. and Physiol. 46: 317, 1928.