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OXYGEN CONSUMPTION AND THYROID FUNCTION IN THE SQUIRREL MONKEY (*SAIMIRI SCIUREUS*)[1,2,3]

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SUMMARY • *Thyroidal accumulation of ^{131}I and the biological half-life of ^{131}I-thyroxine were determined in the squirrel monkey. Oxygen consumption and the respiratory quotient were also measured. A peak uptake of ^{131}I by the thyroid of 45.3% of the injected isotope occurred 4 hours after administration of the radioisotope. The biological half-life of the ^{131}I-thyroxine was 22–24 hours. Oxygen consumption was 1.02 cm^3 O_2/g/hour and the respiratory quotient was 0.82. It was concluded that the squirrel monkey is hypermetabolic when compared with other laboratory animals of the same size.*

KEY WORDS • *Metabolism—Oxygen consumption—Thyroid function—Saimiri—Squirrel monkey*

Nonhuman primates are being used with ncreasing frequency as test subjects in bionedical research. Because large primates are xpensive and require special laboratory facilities, small primates are used whenever ossible. The squirrel monkey is one of these mall primates; however, it has not been netabolically characterized. Therefore, we nade a study of several metabolic variables in his species. These data were then compared vith similar data from other laboratory aninals of about the same size.

MATERIALS AND METHODS

Adult male squirrel monkeys (*Saimiri ciureus*),[6] weighing 670–970 g were caged ndividually in a room which was artificially ighted from 0700 to 1900. The temperature

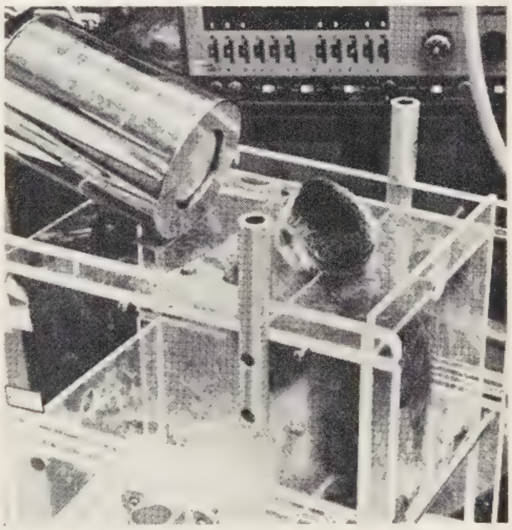

Fig 1. *Determination of thyroidal accumulation of ^{131}I in squirrel monkey using scintillation detector.*

was maintained at 23.3–25.5°C. The diet consisted of a commercial monkey diet[7] supplement with apples and oranges. Water was available *ad libitum*. To eliminate metabolic variations due to circadian rhythms, oxygen consumption and respiratory quotient measurements were made between 0900 and 1300, after fasting the monkeys for 15–18 hours.

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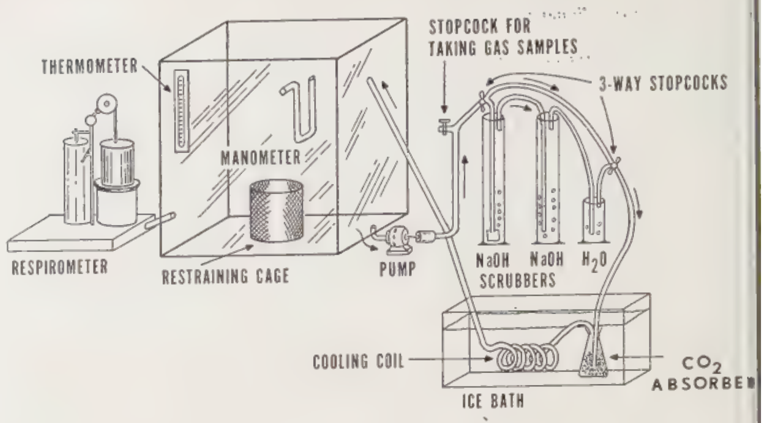

Fig 2. *Diagram of apparatus used to measure oxygen consumption in squirrel monkey.*

Thyroidal accumulation of ^{131}I was used as a test for thyroid function. Two microcuries of carrier-free ^{131}I in a volume of 0.25 ml were injected intraperitoneally. The monkey was then placed in a restraining chair as shown in Figure 1, and external neck counts were started within 20 minutes. A scintillation detector[8] with a 5 x 5-cm (2 x 2-inch) NaI crystal shielded with a 2.5-cm-thick straight bore lead collimator 12.5 cm from the monkey's neck was used for external neck counts.

The radioactivity contained in each syringe before and after injection was determined by counting the ^{131}I in the syringe at the same distance and position from the collimator as was the monkey's thyroid; the thyroidal accumulation of ^{131}I was subsequently expressed as a percent of the injected dose of ^{131}I.

Disappearance of ^{131}I-thyroxine from the blood was used as an indicator of the metabolism of thyroxine (1). ^{131}I-thyroxine was injected intravenously into the right femoral vein. Ten minutes later a blood sample was withdrawn from the left femoral vein and counted for radioactivity. Radioactivity in subsequent samples was expressed as a percentage of the 10 minute count (2).

The 52 x 52 x 75-cm (21 x 21 x 30-inch) metabolic chamber, made of 0.5-inch clear acrylic plastic, is shown in Figure 2.

Two pumps were used to circulate a tot of 6–7 liters of air per minute. Each pum circulated air through the following scru bers: (a) two cylinders containing 2.5 N N OH for the removal of CO_2; (b) a flask water to remove alkaline solution enterin the air lines from the NaOH scrubbers; (anhydrous $CaSO_4$[9] to remove water vapo and (d) cooling coils. The anhydrous CaSC container was placed in an ice bath. A wat manometer was used to detect changes chamber pressure, and temperature was me sured with a thermometer inside the chan ber. An animal respirometer[10] was connecte to the chamber and used to measure volum changes.

The respirometer and chamber containe room air at the beginning of each test. Aft a monkey was placed in the chamber, th chamber was sealed and air was circulate through the scrubbers for 45 minutes fo equilibration. At the end of the equilibratio time, the air was diverted from the scrubbe to circulate only through the anhydrou $CaSO_4$ and cooling coils. The purpose of th procedure was to permit a direct measur ment of the expired CO_2. At this time a g sample was drawn, and the volume, ten perature, and pressure were recorded. O hour after the end of the equilibration perio a second sample was drawn. The gas sampl were analyzed for O_2 and CO_2 by the micr

[8] Tracer lab P-20-D. LFE Environmental Laboratories, Richmond, CA.
[9] Drierite. W A Hammond Drierite Co, Xenia, OH.
[10] Warren E Collins, Inc, Braintree, MA.

TABLE 1

Thyroidal accumulation of ^{131}I in squirrel monkey (n = 8)

Time after ^{131}I injection (hours)	Uptake of ^{131}I (percent of dose)
0.3	34.8 ± 4.1[a]
0.5	39.6 ± 3.6
0.6	43.5 ± 2.5
1.0	43.5 ± 2.4
1.5	44.5 ± 2.7
2.0	45.2 ± 2.4
3.0	43.5 ± 3.4
4.0	45.3 ± 4.5
5.0	43.7 ± 4.4
6.0	39.2 ± 7.5
7.0	43.7 ± 6.2
24.0	30.5 ± 4.0
30.0	27.2 ± 2.6
48.0	23.5 ± 2.7
54.0	15.2 ± 2.0
72.0	16.3 ± 2.3

[a] Mean ± SE

Scholander method (3). From these measurements, O_2 consumption and the respiratory quotient were determined.

Results

Thyroidal accumulation of ^{131}I in eight monkeys is shown in Table 1. The peak uptake of 45.3% of the injected dose occurred at 4 hours after injection. At least 50% of the peak uptake value was reached in less than 20 minutes.

The biological half-life of ^{131}I-thyroxine, determined in two monkeys, was 22 hours in one and 24 hours in the other.

Results of the oxygen consumption and the respiratory quotient determinations are shown in Table 2. The oxygen consumption of monkeys in a cage that would permit freedom of movement was 1.02 cm^3 O_2/g/hour. When the monkeys were restrained in a huddled position by a small wire cage inside the metabolic chamber, the oxygen consumption was 1.11 cm^3 O_2/g/hour. These values were not significantly different ($p < 0.05$). The respiratory quotients for restrained and unrestained monkeys were also not significantly different.

Discussion

The evidence presented in this study suggests that the squirrel monkeys maintained in our colony are hypermetabolic when compared to other laboratory animals of the same size. The peak thyroid uptake of ^{131}I after only 4 hours, with at least 50% of the peak reached within 20 minutes, indicates a rapid iodide clearance from the blood into the unblocked thyroid, and a high uptake in comparison with other small laboratory mammals (Table 3). The biological half-life of 34 hours of the ^{131}I label in the thyroid, which can be determined by plotting the data in Table 1, is indicative of a rapid release of radioactive label from the gland back into the blood. By comparison, the biological half-life thyroidal ^{131}I in the rat has been reported as 79 hours (4). Although the half-life of 22–24 hours found in this study is comparable to that for the rat (19.5 hours) (5), it is rapid compared to the half-life of 3.5 days in the rabbit (6) and 5.0 days in the guinea pig (6).

Our data on oxygen consumption for squir-

TABLE 2

Oxygen consumption and respiratory quotient for squirrel monkey

Status	Body weight (g)	O_2/g/hour (cm^3)	Respiratory quotient
Unrestrained	650–970 (n = 6)	1.02 ± 0.05[a,b]	0.81 ± 0.04
Restrained	650–970 (n = 5)	1.11 ± 0.07	0.80 ± 0.04

[a] Three replicates per monkey
[b] Mean ± SE

TABLE 3

Thyroid function in different species

Species	Time after ^{131}I injection (hours)	Uptake of ^{131}I (percent of dose)	Reference
Fetal rhesus monkey	24	5.6	12
	96	14.0	
Guinea pig	24	2.4	13
	48	1.8	
Sprague Dawley rat	9	11.6	14
	24	15.8	
	96	11.6	
Hooded rat	1	2.2	15
	4	8.3	
	16	13.0	
	48	6.0	
Squirrel monkey	4	45.3	This report

rel monkeys under basal conditions are almost identical to those reported using an open system with the monkeys in a restraining chair (7), but are higher than those reported with monkeys in a huddled position (8). It has been suggested that the latter values were lower because of reduced heat loss (7), but it is more probable that the variances are due to differences in technique. The method used in the latter study (8) was an indirect measurement of oxygen consumption and required the assumption that the respiratory quotient is unity. This assumption, of course, is not correct (Table 2). Furthermore, oxygen consumption taken from animals in a huddled position in this study was not different from those in an unhuddled position (Table 2).

In general, metabolism in homeotherms is a function of body size. It is found that the total metabolism of large animals is greater than that of small animals, but the metabolic rate of the smaller exceeds that of the larger (9). However, the oxygen consumption values for the squirrel monkey reported in this study (1020–1111 cm^3 O_2/kg/hour), and those reported by others (7, 8), appear to be high for an animal of this size and do not fit the usual metabolism-body weight curve (10).

By comparison with other nonhuman primates the oxygen consumption value of 1020 cm^3 O_2/kg/hour is considerably higher tha that of the chimpanzee (*Pan troglodytes*) chackma baboon (*Papio ursinus*), and rhesu monkey (*Macaca mulatta*), which hav values of 250, 410, and 420 cm^3 O_2/kg/hou respectively (11).

REFERENCES

1. Brown-Grant K, Gibson J G: A comparison c thyroxine and triiodothyronine as inhibitors c pituitary thyrotroph hormone secretion in th rabbit. *J Physiol* 127:352–357, 1955
2. Sterling K, Chodos R B: Radiothyroxine tur over studies in myxedema, thyrotoxicosis, an hypermetabolism without endocrine disease. *Clin Invest* 35:806–813, 1956
3. Scholander P F: Analyzer for accurate estima tion of respiratory gases in one half cubic cent meter samples. *J Biol Chem* 16:235–258, 1947
4. Wolf J: Some factors that influence the releas of iodine from the thyroid gland. *Endocrinolog* 48:284–297, 1951
5. Grossie J, Hendrich C E, Turner C W: Com parative methods for determining biologica half-life of L-thyroxine in normal, thyroide tomized, and methimazoli-treated female rat *Proc Soc Exp Biol Med* 120:413–415, 1965
6. Pitt-Rivers R, Tata J R: *The Thyroid Ho mones,* Pergamon, New York, 1959
7. Stitt J T, Hardy J D, Nadel E R: Thermo regulation in the squirrel monkey. *J Appl Phy siol* 31:48–54, 1971
8. Malinow M R, Wagner R: Oxygen consumptio in squirrel monkeys. *Lab Anim Care* 16:105–10 1966
9. Prosser C L, Brown F A Jr: *Comparative An mal Physiology,* Saunders, Philadelphia, 196
10. Benedict F G: *Vital Energetics.* Publ 503, Ca negie Institute of Washington, Washingto 1938
11. Altman P L, Dittmer D S, Ed: *Biology Dat*

Book, 2nd ed, Federation of American Societies for Experimental Biology, Bethesda, 1973
12. Pickering D E, Kontaxis N E: Thyroid function in the foetus of the macaque monkey. *J Endocrinol* 23:267–275, 1961
13. Pitt-Rivers R, Cavalieri R R: Free iodothyrosine of the thyroid. *Biochem J* 86:86–92, 1963
14. Querido A, Schut K, Terpstra J: Hormone synthesis in the iodine-deficient thyroid gland. *Ciba Found Endocrinol* 10:124–134, 1957
15. Pitt-Rivers R: Iodine metabolism of the thyroid gland of the rat. *Biochem J* 82:108–110, 1962