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Changes in thyroxine, triiodothyronine and metabolic rate in the dik-dik antelope (*Rhynchotragus kirkii*): effects of temperature and dehydration

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Summary. 1. Changes in plasma total thyroxine, triiodothyronine (T_3) and metabolic rate were investigated in both hydrated and dehydrated dik-diks after prolonged exposure to ambient temperatures (T_a) of 25 °C, 35 °C and 15 °C.

2. At T_a of 25 °C, metabolic rate, T_3 and T_4 were 2.58 $W \cdot kg^{-1}$, 56.3 ng ml^{-1} and 0.93 ng ml^{-1} for the hydrated group, and 1.95 $W \cdot kg^{-1}$, 70.0 ng ml^{-1} and 0.85 ng ml^{-1} for the dehydrated group, respectively.

3. Exposure to 15 °C increased metabolic rate and total hormonal concentrations in both groups.

4. Following dehydration and exposure to T_a of 35 °C a significant decrease in metabolic rate occurred in the presence of a significant increase in both T_3 and T_4 concentrations.

5. Levels of total plasma T_3 and T_4 alone are unlikely to be responsible for the decrease in metabolic rate observed in the dehydrated dik-dik antelopes.

Introduction

Dik-diks inhabit arid and semi-arid areas of Eastern, Central and South West Africa (Dorst and Dandelot 1970). They are selective feeders specialising in succulent leaves and seeds with high energy content (Hofmann 1973). They are reported to be independent of drinking water (Tinley 1969) but in captivity they will drink water when offered (Hoppe 1977; Kamau and Maloiy, unpublished observation).

Perhaps the greatest constraint to the effort being made to utilize marginal land for meat and milk production is lack of adequate quantities of drinking water. The physiological responses of both wild and domestic ungulates to lack of drinking water are, however, not well understood. Those animals that do not depend so much on drinking water thrive well in semi-arid habitats. Some of these, when dehydrated, will decrease their metabolic rate, the changes ranging from none in the water buck to 9% in the eland and 35% in the oryx (Taylor 1969; Taylor et al. 1969). The hormonal changes underlying the reduction in metabolic rate are not well understood. There are indications that plasma thyroid hormone levels are depressed during dehydration in the camel (Yagil et al. 1978). The metabolic rate was, however, not measured in this case.

The purpose of this study was an attempt to answer several questions: (a) How are the levels of plasma T_3 and T_4 affected by changes in ambient temperatures in hydrated and dehydrated dik-dik antelopes? (b) How are the plasma levels of T_3 and T_4 related to metabolic rate?

Materials and methods

Animals. Nine adult dik-diks (two non-pregnant females and seven males) were used in this investigation. Their weights ranged from 3.8 to 4.5 kg. The animals were assigned to two groups – one was given food and water ad libitum – (the hydrated group), the other was allowed free access to food but water was restricted to minimum quantities that maintained the weight of the animals at 80–85% of their initial weights at the beginning of the experiments (the dehydrated group). Both groups were fed on leaves from a local bush, *Grewia similis*, lucerne leaves (*Medicago sativa*) and early calfweaning pellets.

Procedure. During the experiment the animals were housed in a temperature-controlled room in two groups of 4 and 5 animals. The light was on between 7 a.m. and 7 p.m. The temperature was set at 25 °C, 15 °C and 35 °C for periods of ten days each (in that order). Food and water were available to the normally hydrated group ad libitum. The dehydrated group was given no water for the first 36 h. The animals subsequently lost an average of 15% of their original body weights. These

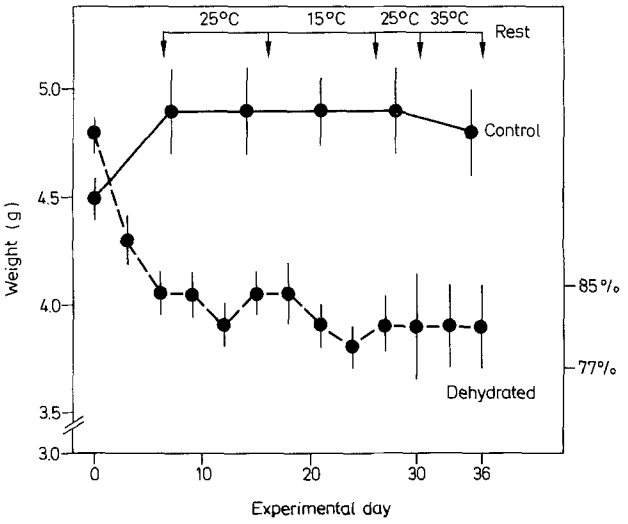

Fig. 1. State of weight loss and order of exposure to different ambient temperatures in hydrated and dehydrated dik-diks. Means ± standard deviations. *Arrows* indicate beginning of experiments at the specified temperature

weights were subsequently maintained at 15–19% below the original body weight for the rest of the experiment by giving 20–50 ml of water per animal per day. The state of dehydration and order of temperature exposure are shown in Fig. 1.

Blood sampling. Blood was withdrawn from the jugular vein at days 6 and 10 during each temperature exposure. The sampling was done between 9.30 and 11.00 a.m. on each of these days. Coagulation was prevented by ethylenediamine tetraacetic acid (EDTA); the blood was centrifuged and the plasma stored at −20 °C.

Rate of oxygen consumption ($\dot{V}_{O_2}$). During the last five days of acclimation period the $\dot{V}_{O_2}$ was determined at least twice from each animal for a 3–4 h period between 8 a.m. and 1 p.m. $\dot{V}_{O_2}$ was determined within the climatic room using an open-flow system as previously described (Kamau and Maloiy 1982).

Determination of hormone concentration. Total T_4 and T_3 concentrations were determined in plasma by radioimmunoassay using $^{125}I-T_4$ and T_3 as tracers. In both cases polyethylene glycol was used to precipitate the antibody-antigen complexes. T_4 and T_3 kits were supplied by Hypolab, Switzerland. Radioactivity was counted using a 400 CGD automatic gamma scintillation counter (Packard Instruments).

Packed cell volume, osmolality and total protein. Packed cell volume (PCV), osmolality and total plasma protein were determined the same day the blood was withdrawn. PCV was determined by a microhematocrit method, centrifuging microcapillary tubes for 5 min at 8,000 *g* (Adams Autocrit). Plasma osmolality was determined using an Advanced Instruments wide-range laboratory osmometer. Total plasma protein was determined by the Goldberg refractometer.

Significance of difference was found by one-way analysis of variance (Campbell 1974) using a Hewlett-Packard HP-97 computer.

Table 1. Total plasma T_3 and T_4 and metabolic rate of hydrated and dehydrated dik-dik antelopes at three ambient temperatures. Values are means ± SEM; number of samples in brackets

Temperature	State	Hormone level		Metabolic rate $W \cdot kg^{-1}$
		T_3 (ng/ml)	T_4 (ng/ml)	
15 °C	Hydrated	2.45 ± 0.12 (8)	119.3 ± 13 (8)	3.20 ± 0.01 (17)
	Dehydrated	1.85 ± 0.04 (8)	136.0 ± 15 (8)	2.94 ± 0.09 (21)
25 °C	Hydrated	0.93 ± 0.01 (12)	56.3 ± 4.7 (9)	2.58 ± 0.01 (10)
	Dehydrated	0.85 ± 0.01 (15)	70.0 ± 9.8 (8)	1.95 ± 0.10 (9)
35 °C	Hydrated	0.49 ± 0.06 (6)	23.0 ± 6.3 (8)	2.41 ± 0.10 (11)
	Dehydrated	0.94 ± 0.02 (6)	30.3 ± 5.6 (8)	1.87 ± 0.05 (12)

Table 2. Packed cell volumes (PCV), plasma osmolality and total plasma protein in hydrated and dehydrated dik-dik antelopes at three ambient temperatures, mean ± SEM. The first number in brackets represents the number of animals used. The second number represents the number of samples analysed for each group

Temperature	State	PCV %	Osmolality mOsm/l	Total protein g/dl
15 °C	Hydrated	45.75 ± 1.33 (5,8)	331.9 ± 9 (5,8)	8.50 ± 0.3 (5,8)
	Dehydrated	44.13 ± 1.9 (5,6)	338.3 ± 3.3 (5,6)	8.84 ± 0.13 (5,6)
25 °C	Hydrated	44.63 ± 1.6 (5,12)	324.0 ± 6.8 (5,12)	8.19 ± 0.3 (5,12)
	Dehydrated	45.15 ± 1.8 (5,6)	337.0 ± 3.4 (5,6)	9.16 ± 0.4 (5,6)
35 °C	Hydrated	46.8 ± 2.0 (4,8)	316.9 ± 3.9 (4,8)	8.68 ± 0.3 (4,8)
	Dehydrated	46.50 ± 1.4 (4,8)	327 ± 2.7 (4,8)	8.54 ± 0.3 (4,8)

Results

Total plasma thyroxine (T_4)

Data for T_4 are shown in Table 1. At 25 °C, plasma T_4 in the hydrated group was 56.3 ng/ml. The corresponding value for the dehydrated animals was 70.0 ng/ml. Exposure to 35 °C led to a decrease in T_4 in both hydrated and dehydrated groups, with plasma values of 23.0 ng/ml and 30.3 ng/ml, respectively. Acclimation to $T_a = 15$ °C led to an increase in plasma T_4 in both groups, the values being 119.3 ng/ml for the hydrated and 136 ng/ml for the dehydrated group.

Total triiodothyronine (T_3)

Table 1 shows T_3 in the hydrated and dehydrated groups. At $T_a = 25$ °C, plasma T_3 for the hydrated group was 0.93 ng/ml compared to 0.85 ng/ml for the dehydrated group. Exposure to $T_a = 35$ °C decreased T_3 for the hydrated group, but there was very little change in the dehydrated group, the corresponding values being 0.49 ng/ml and 0.94 ng/ml, respecitively. Exposure to $T_a = 15$ °C doubled these T_3 levels for the dehydrated group, but tripled that for the hydrated group.

Metabolic rate

At 25 °C metabolic rate for the hydrated group was 2.58 $W \cdot kg^{-1}$ compared with 1.95 $W \cdot kg^{-1}$ for the dehydrated group (Table 1). Exposure to 35 °C increased metabolic rate insignificantly for the hydrated group, but a slight decline occurred in the dehydrated group, the values being 2.41 and 1.87 $W \cdot kg^{-1}$ respectively. Exposure to 15 °C increased metabolic rate for both groups, the dehydrated group having a metabolic rate of 2.94 compared to 3.20 $W \cdot kg^{-1}$ for the hydrated group.

PCV, osmolality and total protein concentration

These results are summarised in Table 2. No significant differences were seen in most of these parameters between hydrated and dehydrated animals at the three ambient temperatures. There was, however, a slight but consistent elevation of mean plasma osmolality in the dehydrated group.

Discussion

Water restriction in dik-dik antelopes leads to a reduction in body weight, due to the continuous and inevitable loss of water by evaporation and through urine and faeces. The amount of water available from metabolism and the food ingested, decreases as a consequence of a decrease in food consumption and metabolism (Kamau and Maloiy, submitted for publication). At first, as depicted in Fig. 1, the reduction in body weight was rapid, but after six days a stable state was reached. The percentage loss in body weight has been used as a measure of degree of dehydration and thus as a basis of fluid therapy in veterinary practice (Blood et al. 1979) and during physiological studies in both wild and domesticated ungulates (Taylor 1970; Maloiy 1973; Schoen 1971; Schmidt-Nielsen et al. 1967; El-Nouty et al. 1978). However, in many of these studies hematological data such as plasma osmolality, sodium ion concentration, and packed cell volume, or measurements of total body water as possible indicators of intravascular changes, are not reported. Table 2 shows the recorded changes in packed cell volume, osmolality, and total protein under different T_a's. No striking differences were found between the hydrated and dehydrated animals. This indicates that the observed changes in body weight probably involved both interstitial and intracellular fluid losses, with shifts to maintain normal plasma volume and osmolality. In this study, therefore, the term dehydration is used to indicate the so-called dehydration as shown by a reduction in body weight.

In the normally hydrated dik-diks total plasma T_3 and T_4 concentration decreased with increasing ambient temperatures. This is in agreement with other studies where acute cold stress or some degree of cold acclimation have been reported to increase both plasma T_3 and T_4 concentrations and their secretion rates, as in the mouse deer (Kamis 1980), camel (Yagil et al. 1978), llama and burro (El-Nouty et al. 1978) and also in the rat (Dempsey and Astwood 1943). Exposure to high ambient temperature, on the other hand, has been shown to decrease thyroxine secretion rates, e.g. in the ram (Brooks et al. 1962).

The levels of plasma T_4 in the dehydrated dik-diks were higher than in the normally hydrated dik-diks at each of the three ambient temperatures. These values increased with decreasing ambient temperature. This was not, however, the case with T_3 where the levels were similar at a T_a of 25 and 35 °C. In the cold, T_3 levels were about twice those at 25 and 35 °C but lower than in the hydrated animals. A closer examination of our results indicates that, on average, the percentage change in the plasma levels of the two hormones from hydrated to the dehydrated state was not consistent. The higher hormonal concentrations in the dehydrated antelopes are therefore probably not due to loss of plasma water with a subsequent relative increase in thyroid hormones binding proteins.

In both hydrated and dehydrated dik-diks the metabolic rate increased as the temperature decreased from 25 °C to 15 °C. There was, however, no significant change in metabolism as the temperature rose from 25 °C to 35 °C. When the two groups were compared, metabolic rate decreased significantly ($P < 0.001$) in the dehydrated group at 25 °C and also at 35 °C, but no significant difference was noted at 15 °C.

There are very few studies in which plasma T_4 and T_3 concentrations and metabolic rate have been measured in both hydrated and dehydrated animals concurrently. In their study, El-Nouty

et al. (1978) dehydrated two llamas and two burros by exposing them to 40 °C for 72 h. Plasma T_4 and T_3 concentrations decreased as dehydration continued. There was a concurrent decrease in the rate of oxygen consumption. In our study, however, water restriction at 35 °C continued for a week compared with 2 h in the aforementioned study. It is important, nevertheless, to note the significant rise in hormone levels and a fall in metabolic rate. We observed substantial reductions in food consumption in the dehydrated dik-diks (Kamau and Maloiy, submitted for publication) which may in part explain the reduction in metabolic rate and render support to earlier findings which suggest that food consumption may be an important factor in determining metabolic rate (Macfarlane 1976; Graham et al. 1959). On the other hand, involvement of other hormones, e.g. rT_3 (Marina et al. 1980) or changes in the levels of the 'free' forms of these hormones cannot be ruled out at the moment.

In conclusion, the response of the thyroid gland to temperature changes, as measured by plasma T_3 and T_4 concentrations, are the ones expected after exposure of the animals to continuous temperature stress. This was the case whether the dik-dik antelopes were hydrated or dehydrated. Dehydrated dik-diks had a reduced metabolic rate compared with normally hydrated animals at the three ambient temperatures. Despite the observed reduction in metabolic rate, total T_3 and T_4 concentrations were higher in the dehydrated animals than in the normally hydrated ones. Hence, thyroid hormones are unlikely to be involved in the reduction of metabolic rate in the dehydrated dik-diks.

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