corrective thermoregulatory behaviour. In view of the present result, it may be hypothesized that the signal for behaviour was the difference: $T_a - T_{spin.\ cord}$. One would then expect the dog behaviourally to reduce its ambient temperature, when its spinal temperature was maintained at a low value.

Such was the case in the previous experiment; Figure 2 summarizes the results then obtained for dogs Buf and Ami. The behavioural response was measured in terms of the number of fan coolings requested by the dogs during the 30 min trial period. When ambient temperature in the climatic chamber (T_a) was higher than spinal thermode temperature (T_{th}), the dogs' behaviour was proportional to $T_a - T_{th}$. This was true for all values of T_{th} and T_a. Here again, the dogs' behaviour may seem paradoxal, because with a cool spinal cord (20 °C), dog Buf behaved in such a way as to reduce its skin temperature. Two completely different circumstances: thermal spinal cord self-stimulation and environmental temperature adjustment seemed, therefore, to be motivated by the same signal, $T_s - T_{th}$. The dogs where working to reduce this signal, when $T_a - T_{th} > 0$ assuming that $T_s = f(T_a)$.

Role of Catecholamines in Thyroxine-Induced Changes in Metabolism and Body Temperature During Exercise in Dogs

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Summary. Blockade of beta receptors inhibited thyroxine-induced increases in T_{re}, blood FFA and LA levels during exercise in dogs.

Pretreatment with thyroid hormones markedly increases plasma free fatty acid (FFA) levels and body temperature during exercise[2–4]. A suggestion was made that this increase in the plasma FFA concentration is mostly caused by potentiation by thyroid hormones of the lipolytic action of catecholamines, which are released in increasing amounts during exercise in dogs[5].

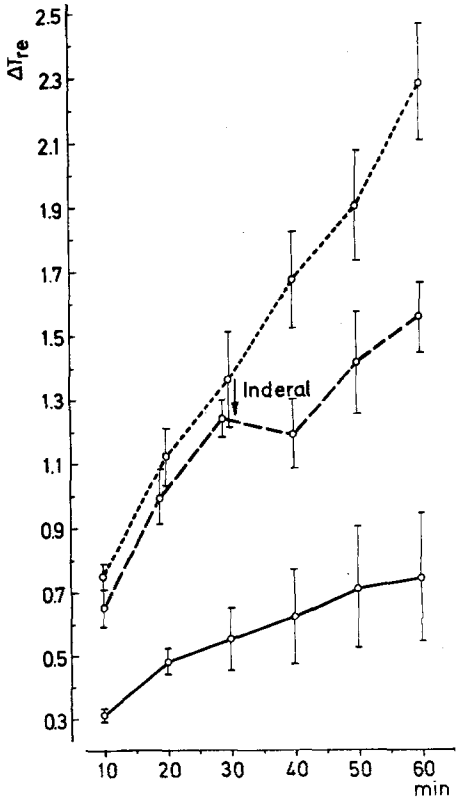

Fig. 1. Changes in rectal temperature (ΔT_{re}) during 60 min exercise. ○—○, control exercise; ○—○, exercise performed 72 h following T_4 + Inderal given at 30 min of the run; ○- - -○, exercise performed 72 h following T_4 without Inderal.

The thyroid hormone-induced exercise hyperthermia was supposed to be at least partly due to a greater heat production during exercise, since an increased FFA mobilization usually results in increased calorigenic action. An enhancement in anaerobic metabolism might also have had a part in this mechanism.

In the present study, an attempt was made to ascertain the role of catecholamines in the thyroxine-induced changes in metabolism and temperature during exercise. For this purpose propanolol, which inhibits the metabolic action of catecholamines, was administered during the exercise performed by thyroxine-treated dogs.

Material and methods. Experiments were carried out on 6 male, mongrel dogs weighing 18–25 kg. Before each experiment the dogs were deprived of food for 18–20 h, but had free access to water. At first, the dogs performed a 60 min control run on a treadmill. The slope of the treadmill was 12° and its speed ranged from 1.2–1.6 m/sec, according to the individual capacity of each animal. Then, after at least 1 week interval, the dogs were injected s.c. with L-thyroxine (Light and Co., England) in a single dose of 100 µg/kg body weight. 3 days after the injection the animals performed treadmill exercise of the same intensity and duration as in the control experiments. At 30 min of the exercise propranolol (Inderal, ICI) was given i.v. in a dose 0.25 mg/kg body weight, and after 10 min rest the run was continued for a further 30 min. In the same dogs thyroxine (T_4) injection was repeated after at least a 1-month interval, and the dogs performed an exercise run 3 days following the injection. In these additional experiments only T_{re} measurements were

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carried out to compare T_{re} changes with those found after propranolol administration.

Immediately before exercise, at 30 min of exercise, and after its termination, both in the control and T_4-treated dogs, venous blood samples were taken for determinations of plasma free fatty acid[6], blood lactate[7], and glucose levels. Blood glucose was measured using an enzymatic method.

During the runs rectal temperature was measured continuously with a calibrated thermocouple thermometer (Ellab, Copenhagen). Statistical significance was tested by means of Student's t-test for paired samples and the level of significance was $p < 0.05$.

Results. Following a single injection of T_4, rectal temperature (T_{re}) increases during exercise were higher ($p < 0.01$) than during the control runs, although the temperatures at rest did not differ. Inderal injected after 30 min of the exercise reduced the further rise in T_{re} (Figure 1).

Changes in blood free fatty acid (FFA) and lactate (LA) concentrations during exercise following T_4 administration are presented in Figure 2. In comparison with control values, there was a marked increase ($p < 0.01$) in the plasma FFA level at 30 min of the exercise performed after T_4 administration, and propranolol abolished this effect.

After 30 min of exercise, performed 3 days following T_4 administration, blood LA was markedly elevated ($p < 0.05$) above the level found in the control run, and at the end of the exercise it was still higher ($p < 0.05$) than the control value.

In the thyroxine-pretreated dogs, the mean $\pm$ SE pre-exercise blood glucose concentrations 3.9 $\pm$ 0.08 mM/l were higher ($p < 0.01$) than in the control expriments 3.2 $\pm$ 0.08 mM/l. At the end of the exercise performed by thyroxine-pretreated dogs injected with Inderal blood glucose level decreased to 2.4 $\pm$ 0.2 mM/l, whereas in the control experiments it was reduced to 2.6 $\pm$ 0.1 mM/l.

Discussion. In agreement with previous findings[3,4], the data presented showed that T_4-pretreatment markedly increases plasma FFA concentration and T_{re} during exercise in dogs. Moreover, it was found that exercise-induced increases in blood LA concentrations after T_4 injection were markedly higher than in the control experiments and much higher than those reported by TIPTON et al.[8] at the end of more intensive exercise. The high levels of blood LA during exercise with T_4-pretreatment indicate marked stimulation of anaerobic metabolism, and suggest that the latter may be at least partly responsible for the greater increases in T_{re}. More rapid decrease in blood glucose concentration in the propranolol – injected dogs confirms the results obtained by BRZEZIŃSKA and NAZAR[9], and NAZAR et al.[10], and indicates that the blockade of β-adrenergic receptors increases carbohydrate consumption during exercise.

Administration of propranolol at 30 min of the exercise performed 3 days following T_4 administration abolished the exercise-induced increase in the plasma FFA level, and inhibited to a certain extent the increase in body temperature, so that T_{re} at the end of the exercise never achieved such high values as in the runs performed at the same time after T_4 injection, but without propranolol.

The fact that propranolol, a potent β-adrenergic blocking agent, reduced the metabolic changes induced by thyroxine indicates that during exercise thyroid hormones potentiate the action of catecholamines by influencing β-receptors.

It should be mentioned that propranolol has been employed with satisfactory results in the treatment of the many clinical manifestations of hyperthyroidism[11,12], although as reported by AZIZI et al.[13] the drug has no influence on the thyroid gland function or the peripheral metabolism of thyroxine.

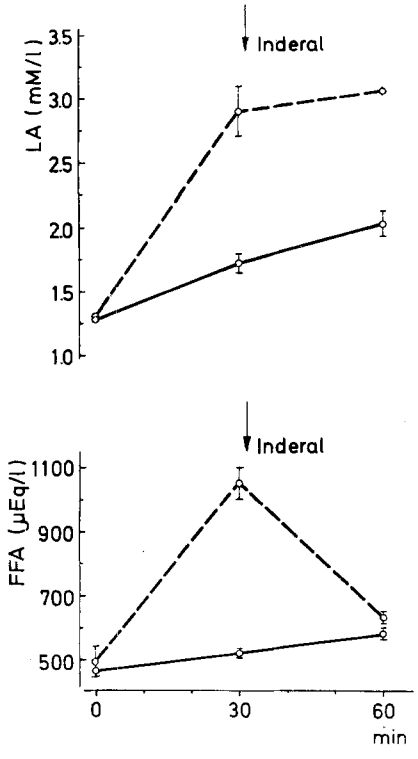

Fig. 2. Changes in blood FFA and LA concentration during 60 min exercise. ○—○, control exercise; ○- -○, exercise performed 72 h following T_4 + Inderal at 30 min of the run. Values are means $\pm$ SE of 6 experiments.

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