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Effect of Swimming and Treadmill Exercise on Plasma Enzyme Levels in Rats[1] (38307)

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Several investigators have reported an increase in plasma enzyme levels after exercise in human subjects, dogs, and rats (1–13). These studies have shown that the magnitude of the increase in plasma enzyme levels is related to the intensity and duration of the exercise (1–4), and that physical training may reduce or eliminate the plasma enzyme response to a bout of exercise (3–8).

Although the plasma enzyme changes with exercise have been well characterized, the cause of the increased enzyme release to the blood during exercise is not known. Some investigators have reported muscle cell damage with prolonged exercise (2, 9), while others have suggested that muscle cell changes are not necessarily associated with plasma enzyme changes after exercise (6, 10, 11). Several factors such as relative hypoxia in active muscles (14, 15), catecholamine release (16), increased arterial blood pressure and heart rate (17, 18) have been studied as possible contributors to the response; however, considered individually, none of these have been shown to be responsible for the plasma enzyme changes seen during exercise. It is more likely that the combined effects of these factors are responsible for the plasma enzyme changes seen during exercise (12).

Some studies on the plasma enzyme response to exercise have been carried out using rats subjected to swimming exercise (1, 5, 8, 9). A question often arises concerning the similarity of the plasma enzyme response to swimming and running exercise because the stress of forcing rats to exercise by swimming may increase the plasma enzyme changes. The present study was carried out to compare the effects of swimming and treadmill exercise on plasma enzyme changes in rats.

Methods. Male Sprague–Dawley rats weighing between 220 and 290 g were used. Animals were housed in air-conditioned quarters and allowed feed and water *ad libitum* up to the time of the experiments.

Three groups of animals were exercised on a treadmill (Quinton, model 14-40) set at a 7° grade: (a) 30 min at 15 m/min (0.6 mph), (b) 30 min at 10 m/min (0.4 mph), (c) 60 min at 10 m/min. Animals were placed in leucite chambers (30 × 6 × 13 cm high) suspended 0.7 cm above the running surface and were prodded to continue exercising by pinching the tip of the tail. A total of four animals were rejected because of failure to complete the exercise episode; all of these animals were in the 15 m/min group.

Swimming exercise was carried out in plastic cylinderical tanks (35 cm diam and 60 cm high) with a water depth of 40 cm. The water temperature was maintained between 35 and 37°. Three groups of animals were exercised by swimming: (a) 60 min with one animal per tank, (b) 30 min with two animals per tank, (c) 60 min with two animals per tank. Animals swimming two per tank showed a much higher level of activity than those swimming one per tank. All animals completed the swimming exercise.

Immediately after the exercise the animals were anesthetized with ether and blood samples were withdrawn by cardiac puncture. The blood was heparinized and centrifuged for 5 min at 800*g* and the plasma separated. The plasma was then centrifuged for 10 min at 10,000*g* (4°) to remove leukocytes because under the assay con-

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ditions used the presence of leukocytes substantially increases lactate dehydrogenase (LDH) activity (unpublished observations). Serum was not used because coagulation results in an increase in LDH activity (19).

The plasma levels of aspartate aminotransferase (AAT), creatine phosphokinase (CPK), and lactate dehydrogenase (LDH) were determined. All enzyme analyses were carried out within 6 hr after the blood samples were taken. Plasma AAT and CPK activity were determined according to the spectrophotometric methods of Karmen (20) and Rosalki (21), respectively. Commercial reagents for both determinations were utilized (Calbiochem, San Diego, CA). The plasma LDH activity was determined by the colorimetric method of Babson and Phillips (22) using commercially available reagents (General Diagnostics Division, Warner-Chilcott Laboratories).

Results. Treadmill exercise resulted in an increase in the plasma levels of AAT, CPK, and LDH in each group of exercise animals (Table I). Increasing the intensity of the exercise from 10 to 15 m/min was associated with greater changes in each of the enzymes while increasing the duration of the exercise from 30 to 60 min resulted in a greater increase in LDH only. Plasma levels of AAT showed the smallest changes and plasma levels of LDH demonstrated the largest increases with treadmill exercise.

Swimming exercise also resulted in an increase in plasma AAT, CPK, and LDH in each group of exercised animals (Table II). Sixty minutes of swimming (two animals per tank) caused greater changes in CPK and AAT than 30 min of swimming. The animals swimming two per tank showed more physical activity than those swimming one per tank, and this is reflected in larger increases in the plasma levels of each of the enzymes in the animals swimming two per tank. The relative magnitude of changes in AAT were less than the changes in LDH or CPK with swimming exercise.

Discussion. The levels of exercise selected for study were such that nearly all of the animals were able to complete the exercise without prior training. Both swimming and treadmill exercise resulted in elevations of the plasma levels of AAT, CPK, and LDH. Increasing the intensity of both forms of exercise resulted in larger changes in the plasma enzyme levels while increasing the duration of the exercise did not cause consistently greater changes.

The relative magnitude of changes in the plasma levels of AAT, CPK, and LDH with exercise appears to be species specific. In the present study, the changes in plasma AAT were much less than the changes in CPK and LDH with swimming and treadmill exercise. In dogs, treadmill exercise results in a qualitatively similar pattern as seen in rats but the increase in AAT was nearly as great as the increase in CPK (13). In human subjects LDH showed the smallest changes and AAT showed the largest changes with swimming, bicycle and running exercise (4, 12).

The intensity of the two forms of exercise may be assessed from the changes in the oxygen consumption and cardiac output associated with the

TABLE I. The Effect of Treadmill Exercise on Plasma Enzyme Levels.[a]

	Control	30 min 10 m/min	60 min 10 m/min	30 min 15 m/min
n	9	8	8	8
CPK	49 ± 4.1[b]	84 ± 8.0[c]	90 ± 8.7[c]	150 ± 19.4[c,d]
		(71)[f]	(84)	(206)
AAT	51 ± 1.5	58 ± 2.1[c]	61 ± 1.7[c]	65 ± 2.5[c,d]
		(14)	(20)	(27)
LDH	15 ± 0.9	23 ± 1.0[c,e]	49 ± 7.8[c]	68 ± 9.3[c,d]
		(53)	(227)	(353)

[a] Enzyme activity is expressed as IU/liter of plasma.
[b] Mean ± standard error of the mean.
[c] $P < 0.05$ compared with control.
[d] $P < 0.05$ compared with 30 min, 10 m/min.
[e] $P < 0.05$ compared with 60 min, 10 m/min.
[f] % change.

TABLE II. The Effect of Swimming Exercise on Plasma Enzyme Levels.[a]

	Control	60 min 1 animal/tank	30 min 2 animals/tank	60 min 2 animals/tank
n	10	8	8	8
CPK	50 ± 5.4[b]	84 ± 6.6[c] (68)[f]	134 ± 7.2[c,e] (168)	183 ± 14.4[c,d] (266)
AAT	53 ± 1.7	60 ± 1.5[c] (13)	59 ± 0.9[c,e] (11)	67 ± 1.4[c,d] (26)
LDH	13 ± 0.8	18 ± 1.5[c] (38)	29 ± 2.6[c,e] (123)	34 ± 2.9[c,d] (162)

[a] Enzyme activity is expressed as IU/liter of plasma.
[b] Mean ± standard error of the mean.
[c] $P < 0.05$ compared with control.
[d] $P < 0.05$ compared with 60 min. one animal/tank.
[e] $P < 0.05$ compared with 60 min. two animals/tank.
[f] % change.

exercise. Resting oxygen consumption in the rat is about 15–20 ml/kg per min (23, 24), and it has been shown that rats swimming one animal per tank have an oxygen consumption of 54 or 62.6 ml/kg per min (25, 26). Popovic *et al.* have shown that rats exercising on a treadmill at 10 m/min have an oxygen consumption of 35 ml/kg per min and at 20 m/min the oxygen consumption was 40 ml/kg per min (27). Cardiac output in swimming rats increased about 50% (28) while treadmill exercise at 10 and 20 m/min increased cardiac output 22 and 44%, respectively (27). From these data it appears that swimming represents a greater exercise load for the rat than treadmill exercise at 10 or 20 m/min.

In the present study, the plasma enzyme changes associated with swimming and treadmill exercise were generally similar. However, it appears that, for a given increment in oxygen consumption, treadmill exercise results in a greater increase in plasma enzyme levels. This is consistent with the work of Beaton on changes in plasma malate dehydrogenase in rats after swimming or treadmill exercise (7, 8). It is apparent, therefore, that the stress of forcing rats to exercise under unnatural conditions, *i.e.*, swimming, does not result in greater plasma enzyme changes than are seen with treadmill exercise.

Summary. Swimming or treadmill exercise in the rat resulted in elevations of the plasma levels of AAT, CPK, and LDH. With both forms of exercise the magnitude of the plasma enzyme response appears to be more importantly related to the intensity of the exercise than to the duration of the exercise. The relative magnitude of the increase in AAT was much less than the increase in CPK or LDH. The plasma enzyme changes were generally similar with the two forms of exercise even though the swimming exercise may have been more strenuous than the treadmill exercise.

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