Organ weights in rats with activity-stress ulcers

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Rats were housed in activity cages and fed 1 h daily. When these rats died, wet and dry weights were obtained for adrenals, spleen, liver, kidney, heart, stomach rumen, and stomach body. Most activity rats, as compared to food-yoke control and home-cage control rats, had lesions in the glandular stomach. Adrenal and heart weights suggested that activity rats had been subjected to some degree of stress. Characteristic starvation effects, such as rumenal lesions and edema of stomach tissue, were not observed in activity rats.

Glandular lesions occur in rats which are housed in running wheel activity cages and fed only 1 h each day (Paré, 1974, 1975; Vincent & Paré, 1976). Rats which are exposed to this regimen will die within 3 to 10 days and reveal lesions in the glandular stomach when autopsied. Control rats which are housed in standard cages without activity wheels and are fed the same amount of food as the activity rats do not die and are ulcer free. Since starvation induces stomach lesions in the rat (Paré & Temple, 1973; Peters, 1967; Pfeiffer, 1970), the possibility existed that the lesions observed in activity rats were the result of the restricted feeding schedule. However, in a later study (Paré, 1975), control rats consumed the same amount of food as activity rats, and these control rats did not develop lesions.

Prolonged fasting in the rat has a number of characteristic effects on various organ systems. Rumenal lesions (cardiac stomach) and edema are commonly observed as a result of starvation (Pfeiffer, Dembro, & Muller, 1966). The water content of the stomach tissue increases as a function of starvation (Peters, 1967). Some organs, notably liver and spleen, lose weight at a faster rate than total body weight, whereas adrenal and stomach rumen show a relative increase in weight as fasting continues (Peters & Boyd, 1966). The weight of some organs, such as the heart and kidney, decreases at the same rate as total body weight during starvation (Peters, 1967). These studies show that in addition to rumenal lesions, starvation has typical effects on different organ systems. In the present study, rats were exposed to the activity-stress procedure and various organs were subsequently weighed to determine if the characteristic starvation effects were present in these animals. The study was performed to determine the extent to which activity-stress animals resembled starved animals and to further assess the impact of restricted feeding on the development of the activity-stress ulcer.

METHOD

Subjects

This experiment used 90 male Sprague-Dawley rats

(ARS/Sprague-Dawley, Madison, Wisconsin) weighing 187-209 g at the beginning of the study.

Apparatus

Cages were standard running wheel activity cages (Wahmann Manufacturing Co., Baltimore, Maryland). Each activity wheel was equipped with an adjoining cage measuring 25 x 15 x 13 cm. A sliding door separated the cage from its adjoining wheel. Wheel revolutions were recorded for each cage by an Esterline-Angus strip-chart event recorder and by digital counters. Room temperature was controlled at 74-75°F, and daylight conditions were artificially maintained between 6 a.m. and 6 p.m.

Procedure

Rats were equated on the basis of body weight into three groups: an activity group, a food control group, and a home-cage control group. Activity animals were individually housed in activity cages. Food control and home-cage control rats were individually housed in standard single laboratory cages. The food control animals were located in the same room with the activity animals, whereas the home cage animals were situated in one of the laboratory's animal colony rooms which had temperature and lighting conditions similar to those in the activity wheel room. During a 5-day cage-habituation phase, all rats had continuous access to food (granular Purina Rat Chow) and water. The doors in the activity cages were closed, thereby preventing entry into the wheel portion of the activity cages. On Day 6, food was withdrawn from activity rats at 9 a.m., and the doors leading to the activity wheel were opened, allowing access to the running wheel. On Day 7, food was withdrawn from food control rats. On the same day, activity rats were fed for 1 h between 9 a.m. and 10 a.m. The amount of food consumed was measured. Food control rats were individually matched with an activity rat, and the amount of food consumed by the activity rat in 1 day was subsequently fed to its food control mate on the next day. The number of wheel revolutions was recorded daily for each activity rat. All rats were weighed daily. Home-cage control rats had continuous access to food during the experiment.

When an activity rat died, the stomach was removed immediately and inspected for ulcers. The number of ulcers was counted and extent of ulceration was determined by measuring the length and width of each ulcer. The stomach was then separated into two parts: the body and the rumen. These were weighed on a Torbal analytical balance (Model EA-IAP). At the same time that the stomach was removed, the adrenals, spleen, liver, kidney, and heart were also removed and wet weights were obtained from these organs. Organs were then placed in a drying oven at 150°C for 16 h, and a subsequent dry weight was obtained. When an activity rat died, its food-yoke control mate and home-cage control mate were killed 24 h later, and the stomachs and other organs treated as described above. The study continued for 21 days. Animals still alive at this time were killed with ether, and wet and dry organ weights were obtained. Differences in organ weights between groups were evaluated by an

analysis of variance design with a post hoc Tukey a test for group comparisons (Winer, 1962).

RESULTS

Practically all activity rats died and revealed lesions in the glandular stomach. Lesions were observed in only one food-yoke control rat, and all home-cage control animals were ulcer free. These data are summarized in Table 1.

When compared to their pre-experimental body weights, activity animals lost 37.0% of their body weights by the end of the experimental period, food-yoke control rats lost 28.9%, and home-cage control rats gained 36.8% in body weight.

The absolute dry and wet weights for the various organs are presented in Table 2. In this table, the organ weights of the activity rats and food-yoke control rats are compared to the home-cage control rats, and differences from home-cage controls are expressed as percent change. For both activity rats and food-yoke control rats, adrenals showed the least change from home-cage controls, whereas the greatest loss of both wet and dry weights was shown for spleen and liver.

Table 1
Summary of Stomach Pathology for the Three Treatment Conditions

Treatment	N	Rats With Ulcers	Mean Ulcers Per Rat	Mean Ulcer Length*
Activity	30	26	14.2	43.94
Food Yoke	30	1	3.7	9.42
Home Cage	30	0	0	0

*Millimeters

Table 3
Mean Relative Organ Weights and the Percentage of Water in All Organs for the Three Treatment Conditions

	Activity		Food Yoke		Home Cage	
Organs	% Body Weight*	% Water†	% Body Weight	% Water	% Body Weight	% Water
Adrenal	.0347	73.8	.0300	72.6	.0169	70.5
Spleen	.1129	76.3	.1549	76.7	.2782	77.8
Liver	2.7646	76.6	3.6916	75.2	5.0984	74.4
Kidney	1.0092	79.2	.9425	78.0	.8746	77.3
Heart	.4433	75.1	.4317	77.5	.3781	78.6
Stomach						
Rumen	.2254	78.3	.2150	78.3	.1551	76.5
Body	.4960	80.9	.5261	80.8	.3991	77.9

*Measured as percent of autopsy body weight
†Measured as percent wet weight

Relative organ weights for all three treatment groups are outlined in Table 3. Relative weights are expressed by percent of body weight and the water level, or percent water for each organ. There was a significant difference between groups for the adrenals ($F = 123.73$, $df = 2/86$, $p < .001$). The relative adrenal weight of activity rats was significantly greater as compared to food-yoke rats ($p < .01$), and the adrenals of food-yoke rats were significantly larger than home-cage controls ($p < .01$). Significant differences were observed for relative spleen weights ($F = 170.01$, $df = 2/87$, $p < .001$). The spleens of home-cage rats were larger than the spleens of food-yoke controls ($p < .01$) and the food-yoke control rats had larger spleens than those of the activity rats ($p < .01$). Significant differences in liver weights between groups ($F = 61.04$, $df = 2/87$, $p < .001$) reflected the pattern observed with spleen weights, with

Table 2
Mean (± SE) Absolute Dry and Wet Organ Weights for All Three Treatment Conditions

Organ	Home Cage Organ Weight (Grams)	Activity Organ Weight (Grams)	% Change*	Food Yoke Organ Weight (Grams)	% Change*
		Dry Weight			
Adrenal	.0124 ± .0006	.0109 ± .0003	−.12	.0115 ± .0003	−.07
Spleen	.1614 ± .0034	.0330 ± .0027	−.79	.0513 ± .0028	−.68
Kidney	.5210 ± .0109	.2513 ± .0048	−.52	.2865 ± .0051	−.45
Heart	.2118 ± .0047	.1192 ± .0032	−.43	.1361 ± .0035	−.35
Liver	3.79 ± .1325	.8135 ± .0757	−.78	1.3143 ± .0741	−.65
Stomach Rumen	.0942 ± .0019	.0591 ± .0028	−.37	.0658 ± .0023	−.30
Stomach Body	.2313 ± .0039	.1161 ± .0058	−.49	.1423 ± .0037	−.38
		Wet Weight			
Adrenal	.0439 ± .0011	.0417 ± .0011	−.05	.0420 ± .0003	−.04
Spleen	.7282 ± .0155	.1410 ± .0126	−.81	.2218 ± .0127	−.69
Kidney	2.293 ± .0418	1.208 ± .0208	−.47	1.321 ± .0189	−.42
Heart	.9585 ± .0298	.5354 ± .0136	−.44	.6069 ± .0159	−.36
Liver	13.39 ± .3313	3.445 ± .3103	−.74	5.275 ± .2891	−.61
Stomach Rumen	.4060 ± .0089	.2758 ± .0152	−.32	.3039 ± .0116	−.25
Stomach Body	1.047 ± .0182	.6008 ± .0194	−.43	.7402 ± .0164	−.29
Body Weight	254.3 ± 4.42	120.8 ± 2.64	−.52	140.7 ± 2.40	−.45

*Percent difference when compared to home-cage animals.

home-cage animals having larger livers than food-yoke rats (p < .01) which, in turn, had larger livers than activity rats (p < .01). The significant differences in relative kidney weights (F = 25.30, df = 2/87, p < .001) were attributable to activity rats which had larger kidneys than food-yoke control rats (p < .01) which, in turn, had larger kidneys than home-cage control rats (p < .01). Significant differences in relative heart weights (F = 19.92, df = 2/82, p < .001) were attributable to significantly smaller weights of home-cage animals as compared to the other two groups (p < .01). The difference in heart weights between activity rats and food control rats was not significant. Activity rats and food-yoke control rats did not differ with respect to the relative weight of the stomach rumen, but both groups had rumens larger than those of the home-cage animals (p < .01). The rumen water content of all three groups was essentially the same. The weight of the glandular stomach for food-yoke control animals was greater as compared to activity rats (p < .01), and the weight of the glandular stomach of activity rats was heavier than that observed in home-cage control rats (p < .01).

DISCUSSION

Twenty-six activity rats and one food-yoke control rat had lesions in the glandular stomach. Rumenal lesions were not observed. These results are consistent with previous studies on the activity-stress ulcer (Paré, 1974, 1975; Vincent & Paré, 1976).

Adrenals were the most resistant to weight changes. Other investigators (Peters, 1967; Pfeiffer, Dembro, & Muller, 1966) have attributed the increase in relative adrenal weight change to stress. If this supposition is valid, the activity rats in the present study were subjected to more stress as compared to the other two treatment groups.

The organs which lost weight at approximately the same rate as the total body weight were kidney and heart. Jackson (1915) and Peters (1967) reported similar results for the kidney, and Beznàk (1954) and Peters (1967) reported similar results for the heart. The decrease in absolute heart weight may be due to a decrease in functional demand (Beznàk, 1954), but in the present study, activity rats had greater relative heart weights compared to the other groups. These results agree with Peters and Boyd (1968) who observed that the relative heart weight increased in rats subjected to starvation plus restraint stress.

The degree of weight loss was greater in spleen and liver as compared to total body weight loss. Peters and Boyd (1966, 1968) have reported similar results for the spleen. Other investigators (Leon, Feller, Neville, & Daligcon, 1965; Nomura, 1965) suggested that liver weight decreases less in stressed rats as compared to starved rats because stress stimulates hepatic enzyme formation. This type of relationship was not observed in this study since the relative liver weight of activity rats was less than that observed in food-yoked control rats.

In the starved rat, the degree of stomach weight loss is less than total body weight, and this lower rate of weight loss is due to an increase in water in stomach tissue. Crater-like lesions in the cardiac stomach are also characteristic of starvation. In the present study, lesions were not observed in the rumen of the stomach, and a relative enlargement of the stomach was absent in activity rats. The characteristic starvation features of the stomach were absent in activity rats in this study.

The adrenal and heart data suggest that activity rats were subjected to a certain degree of stress. The stomach lesions resemble the stress ulcers reported by other investigators (Brodie, 1971) and are not the type characteristically produced by starvation. The spleen, liver, and kidney data do resemble typical changes brought about by starvation, and it would be unreasonable to conclude that reduced feeding has no input in the development of the activity-stress ulcer. However, on the basis of previous studies (Paré, 1974, 1975; Vincent & Paré, 1976; Paré & Houser, 1973) and the present study, it is reasonable to suggest that the activity-stress ulcer is not a starvation ulcer.

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