Fat Depot Removal, Food Intake, Body Fat, and Fat Depot Weights in Obese Rats[1] (35473)

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Although there are few reports in the literature, portions of the abdominal fat depots have been surgically removed to reduce body fat and weight, especially for women (1). Successful surgical manipulation of the mammary and fatty tissue surrounding the mammary gland has been reported (2, 3). However, Bankoff (1) indicates that surgical procedures cannot be used effectively for removal of other subcutaneous fat depots since such operations may result in disfiguration.

Little is known about the long-range effect of lipectomy on fat depot growth, food intake, or total body weight and fat. Liebelt *et al.* (4) induced obesity by injecting adult mice with gold thioglucose to impair hypothalamic function and then removed gonadal fat organs. In these mice the inguinal depot had a higher lipid content when the gonadal fat depot was removed, but the total body lipid content was similar to that of sham-operated mice. The author also observed that the operated mice ate more food (4). That the fat depot might be able to control food intake is suggested by investigations (5–8) which showed that when obese mice with impaired hypothalamic function were starved until there was loss of fat depot reserves, they ate more food until they achieved their prestarvation weight.

A factor which suggests that operative intervention may reduce body fat content as a result of lipectomy is the rich neurovascular supply (9–12) which is essential to fat metabolism (13). Interruption of this neurovascular (14) supply will impair or completely suppress growth of that particular depot.

The purpose of this research is to evaluate the effects of unilateral or bilateral removal of a fat depot on food intake and on certain growth parameters such as (i) body weight; (ii) percentage of carcass fat; (iii) weight of the regenerated fat depot, provided regeneration occurs; (iv) weight of the bilateral depot where only one depot was removed; (v) weight of the adjacent depots; and (vi) collective weight of all the fat depots.

Osborne Mendel rats susceptible to dietary obesity when fed a high fat diet were used. This facilitated the study of fat depot growth and interpretation of the results. The high fat diet used has been shown to produce obesity (15, 16) and excessive fat depot weights (17).

Materials and Methods. Littermate 24–28-day-old Osborne Mendel rats were paired by weight. At this time, one rat of the pair was subjected to removal of (i) the right inguinal, (ii) right and left inguinal, (iii) right testicular, or (iv) right and left testicular fat depots. The depot removal was as surgically complete as possible. Sham-operated rats merely had the depot exposed and handled to the same extent as the operated rats without damage to the neurovascular supply. Both groups were anesthesized with Metofane[2] and aseptic conditions prevailed throughout surgery.

Postoperatively, the rats were housed in individual wire bottom cages in a temperature controlled room. They were allowed free access to water and the high fat diet which contained: Crisco, 60%; casein, 25%; mineral mix, 5.0%; vitamin mix, 2.2%; nonnutri-

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[2] Methoxyflurane. Pittman-Moore, Indianapolis, Ind.

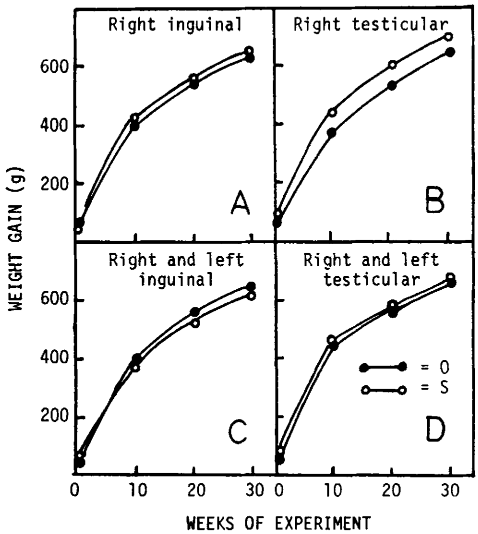

FIG. 1. Weight gain of operated (O) and sham-operated (S) Osborne Mendel male rats: (A) right inguinal depot removed; (B) right testicular depot removed; (C) right and left inguinal depots removed; and (D) right and left testicular depots removed. All operations were performed when rats were weaned.

tive fiber, a cellulose type, 2.0%; Aureomycin, 0.01%; liver powder, 2.0%; DL-methionine, 0.25%; and sucrose, 3.54%. Body weights were recorded weekly. Food intakes were calculated for individual rats, by carefully collecting any spilled food, weighing, and subtracting it from the total food supplied. This was done for each of the first 4 weeks and every 4th week thereafter, until termination of the experiment at 32 weeks postoperatively. At this time, rats were weighed and euthanitized with an overdose of ether. Individual fat depots were removed and weighed as described previously (17). In addition, intermuscular depots of the inguinal area were removed and weighed. The fat depots and remaining rat carcass, exclusive of gastrointestinal contents were placed in a jar, covered, autoclaved, and homogenized (16, 18). Aliquots were taken for the determination of body fat by ether extraction. The *t* test was used for statistical comparisons of operated (O) and sham-operated (S) rats (19).

Results. Body weight. All groups of rats gained weight at similar rates and attained similar final body weights (Fig. 1). However, rats with one testicular depot removed consistently weighed around 50 g less than the sham-operated controls (Fig. 1B) but the difference was not significant ($p > 0.05$). When both testicular depots were removed there was no difference in the weight gain or final body weights when operated and sham-operated rats were compared (Fig. 1D).

Body fat. The mean percentage of carcass fat was the same for the operated and sham-operated rats in each group [$p > 0.05$ (Table I)]. Of 19 sham-operated rats, 12 had a higher percentage of body fat than their operated littermates; this was associated with a larger final body weight in 10 of these sham-operated rats (compared with their littermates whose depot(s) had been removed).

Spatial effects of fat depot removal. A depression at the site of the inguinal fat depot was visible following surgery. This defect be-

TABLE I. Body Weight and Body Fat in Carcasses of Operated (O) and Sham-Operated (S) Male Osborne Mendel Rats.

All rats were fed the high fat ration from weaning.

Expt. group	N	Body wt[a,b] (g)	Body fat[b] (g/100 g of carcass)
		Right inguinal depot[c]	
O	5	701 ± 97[d]	36.5 ± 3.1[d]
S	5	702 ± 90	37.9 ± 4.9
		Right and left inguinal depot[c]	
O	4	715 ± 23	35.7 ± 1.5
S	4	695 ± 73	37.3 ± 3.9
		Right testicular depot[c]	
O	6	699 ± 53	40.1 ± 1.8
S	6	756 ± 48	41.8 ± 3.4
		Right and left testicular depot[c]	
O	4	736 ± 51	38.6 ± 4.2
S	4	735 ± 54	38.5 ± 0.7

[a] Body weight exclusive of GI tract contents after the rats had been on experiment for 32 weeks.

[b] *t* statistics were done for body weight and body fat between operated (O) and sham-operated (S) rats; $p > 0.05$ for all.

[c] The fat depots listed were surgically removed (O) from each rat at weaning while its littermate was sham operated (S).

[d] Mean ± SD.

TABLE II. Weight of Inguinal Fat Depots of Operated (O) and Sham-Operated (S) Osborne Mendel Male Rats Sacrificed After 32 Weeks of Experiment.

Rats were fed a high fat ration.

Expt. group	Wt of inguinal fat depot (mg/100 g of body wt) Right	Left
	Right inguinal depot[a]	
O	1234 ± 332[b,c]	3850 ± 400[b]
S	3243 ± 295[c]	3768 ± 557
	Right and left inguinal depots[a]	
O	1511 ±1196[c]	1619 ± 619[c]
S	3297 ± 496[c]	3538 ± 734[c]
	Right testicular depot[a]	
O	3610 ± 453	3683 ± 347
S	3602 ± 542	3767 ± 441
	Right and left testicular depots[a]	
O	3451 ± 364	3587 ± 330
S	3560 ± 393	3637 ± 531

[a] The fat depots listed were either surgically removed (O) from the rat at weaning or the rat was sham operated (S).

[b] Mean ± SD.

[c] *t* tests between O and S rats are significant ($p < 0.01$).

came more pronounced as the rats gained weight. Autopsy revealed that the central area of the inguinal fat depot was absent while there was some growth at both the cephalic and caudal ends.

When the testicular fat depot was removed, little or no fat tissue was observed at autopsy. The latter tissue lay directly in contact with the spermatic cord. If only the right testicular depot were removed, the left depot extended into the vacated right depot space, but it did not increase in weight beyond that of the sham-operated rats.

Weight of fat depots. Right inguinal depots (Table II) were heavier in the sham operated than in the rats from which the right inguinal depots were removed ($p<0.01$). The intermuscular fat depot of the inguinal area did not show any compensatory hypertrophy on the side of the removed inguinal depot ($p>0.05$).

The removed testicular depot weighed a few milligrams at autopsy and the final weight of the removed depots was always significantly less ($p<0.01$) than when the depot was not removed (Table III). Perirenal and retroperitoneal or omental and mesenteric fat depots did not become heavier when testicular depots were surgically removed ($p>0.05$).

There were no statistical differences ($p>0.05$) between the sums of all fat depots excised at autopsy when these sums included only those depots which were common to both the operated and sham-operated rats (Fig. 2). This was true whether the fat depots were removed from one or both sides.

Food intakes. Although differences were never significant ($p>0.05$), there was a tendency for operated rats to eat less than their sham-operated littermates during the first week following surgery. After this initial 7 days, there was no difference in the food in-

TABLE III. Weights of Testicular Fat Depots of Operated (O) and Sham-Operated (S) Osborne Mendel Male Rats Sacrificed After 32 Weeks of Experiment.

Rats were fed a high fat ration.

Expt. group	Wt of testicular fat depot (mg/100 g of body wt) Right	Left
	Right inguinal depot[a]	
O	1073 ± 371[b]	1064 ± 318[b]
S	1063 ± 269	1174 ± 263
	Right and left inguinal depots[a]	
O	1335 ± 406	1226 ± 412
S	1492 ± 482	1344 ± 447
	Right testicular depot[a]	
O	44 ± 45[c]	1389 ± 307
S	1120 ± 299[c]	1178 ± 289
	Right and left testicular depots[a]	
O	110 ± 29[c]	46 ± 27[c]
S	1065 ± 577[c]	1077 ± 879[c]

[a] The fat depots listed were either surgically removed (O) from the rat at weaning or rats were sham operated (S).

[b] Mean ± SD.

[c] *t* tests between O and S rats are significant ($p < 0.01$).

take of sham-operated and operated rats (Table IV).

Discussion. Based upon these data, the long-range benefits of surgical removal of fat depots as a means of reducing total-body fat or body weight are doubtful. The removal of a single fat depot or even a pair of fat depots did not produce a change which was of sufficient magnitude to cause any great reduction in final body weight, body fat, or food intake. The removal of the testicular depot caused a shift in the location of the other testicular depot thus maintaining the symmetrical appearance in the animal. Removal of this intra-abdominal fat depot caused no visible disfiguration as contrasted with the removal of the inguinal fat depot.

Fat depot growth is impossible without a neurovascular supply (20). However, intact adipose tissue may be transferred to other body sites and grow effectively (20–24). Wherever fat depots with their neurovascular supplies were surgically removed there was no regeneration of the fat depots. The growth of fat tissue at either end of the inguinal

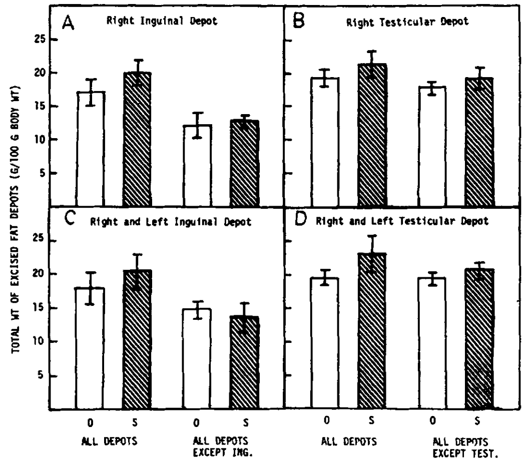

FIG. 2. Collective weights of all removed fat depots (inguinal, intermuscular of thigh, interscapular, testicular, perirenal, retroperitoneal, omental, mesenteric, xiphoid, and other fatty tissue underlying the diaphragm) compared to collective weight of all depots except those depots surgically removed (O) or exposed (S) at weaning: (A) right inguinal depot removed; (B) right testicular depot removed; (C) right and left inguinal depots removed; and (D) right and left testicular depots removed.

TABLE IV. Representative Weekly Food Intakes of Operated (O) and Sham-Operated (S) Osborne Mendel Male Rats.

All rats were fed a high fat ration from weaning.

		Feed consumed (g)[a]; week after surgery			
Expt. group	*N*	1	4	16	28
		Right inguinal depot[b]			
O	5	60.8 ± 6.2[c]	88.8 ± 9.2[c]	92.6 ± 10.1[c]	117.3 ± 21.9[c]
S	5	62.0 ± 2.8	84.8 ±14.1	98.4 ± 18.7	101.3 ± 23.4
		Right and left inguinal depot[b]			
O	4	57.8 ± 6.8	78.0 ± 8.7	98.5 ± 14.8	93.0 ± 17.1
S	4	63.3 ± 1.2	88.3 ± 3.3	89.0 ± 88.5	117.7 ± 23.1
		Right testicular depot[b]			
O	6	53.8 ± 8.0	80.5 ± 6.4	93.2 ± 12.1	108.2 ± 24.4
S	6	60.6 ± 6.2	89.5 ± 3.8	101.0 ± 10.0	108.4 ± 22.8
		Right and left testicular depot[b]			
O	4	66.0 ± 2.7	94.8 ± 2.3	98.5 ± 7.8	106.0 ± 26.7
S	4	66.3 ± 2.0	87.8 ± 5.8	91.8 ± 9.1	105.7 ± 30.9

[a] t statistics were done for weekly food intakes between operated (O) and sham-operated (S) rats; $p > 0.05$ for all.

[b] The fat depots listed were either surgically removed (O) from the rat or rats were sham operated (S) at weaning.

[c] Mean ± SD.

depot could be explained by growth of (i) adjacent adipose tissue into the area that would have been occupied by the inguinal depot, or (ii) small nests of adipose tissue which remained at the surgical site.

Despite the fact that there was no regrowth and no replacement of the excised fat depots, the percentage of body fat was not decreased as a result of the operative procedures. This suggests that other depots incorporated more fat. Although weights of the depots were not different, their content of fat could vary. That this is possible, is suggested by Liebelt and co-workers' (4) report that in hypothalamically obese mice other depots compensated for the removed gonadal depot and contained more fat.

Mice made obese by injection of gold thioglucose and in which the gonadal fat depot was removed ate more food than gold thioglucose-treated sham-operated mice (4). This suggested to Liebelt *et al.* (4) that the gonadal fat depot may influence food intake. However, in our animals, food intake was not affected by unilateral or bilateral removal of either the testicular or inguinal fat depot.

Summary. Weanling Osborne Mendel male rats had one or both inguinal fat depots, or one or both testicular fat depots removed. Another group was subjected to an identical operation but the fat pads were not excised (sham operated). Postsurgically, the rats were fed a high fat diet with progressive obesity developing during the 32 weeks of the experiment. Mean food intakes, growth rates and percentage of body fat (36 to 41%) were similar for all groups of rats. The surgically removed fat depots did not regenerate. In the group with the inguinal fat depots removed there was a visible depression at the surgical site due to the absence of the fat pad. Abdominal fat depots shifted to compensate for the removed testicular depots with no disfiguration apparent in the live rat. At autopsy, fat depots such as interscapular, axillary, perirenal and retroperitoneal, omental and mesenteric, and xiphoid weighed the same in operated and sham-operated rats.

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