Difference in Diabetic and Nondiabetic Fat Distribution Patterns by Skinfold Measurements

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SUMMARY

Fat distribution was assessed by a series of ten skinfold measurements in 7,717 persons voluntarily undergoing a multiphasic health screening examination. From this total, in 360 diabetic and 934 nondiabetic control subjects matched for race, sex, age, height, and weight, fat distribution patterns were compared by direct skinfold measurements, and by triceps ratios and subscapular ratios: thickness of each of the individual's skinfolds relative to his triceps or his subscapular skinfold respectively. Diabetic subjects, especially women, showed a significant shift toward centripetal distribution of fat. The data indicated that centripetal fat distribution is a masculine characteristic. It is suggested that in diabetes there is a disturbance of male/female hormonal balance, responsible for centripetal fat distribution in women, and for exaggeration of centripetal fat distribution in men. Furthermore, the data suggested that persons with diabetes have more total fat than their nondiabetic counterparts. DIABETES *18*:478-86, July, 1969.

It is not known whether the obesity commonly associated with diabetes[1] is due to the diabetic genotype and the deranged metabolism of diabetes, or simply to excessive caloric intake. The hypothesis that is related to the basic metabolic defect has been given support by observations of the lipogenic effect of insulin, by reports of insulin antagonists such as synalbumin in diabetic plasma protein,[2] and of abnormal bound and free insulin complexes[3] in diabetic blood, which permit lipogenesis but interfere with the action of insulin on muscle. In addition, hyperinsulinism is characteristic of the obese state.[4] It has yet to be established that the adipose tissue of persons with diabetes differs in morphologic, histologic, biochemical, or physiologic characteristics from that of the general population. The present study was undertaken to determine whether the distribution of subcutaneous fat in diabetic patients, as measured by skinfold calipers, differs from that of nondiabetic subjects.

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SUBJECTS AND METHODS

Subjects: From persons voluntarily undergoing a multiphasic health screening examination at Kaiser Foundation Hospital, Oakland[5] during a nine-month period in 1967, 7,717 subjects were randomly selected for study. Randomization was based on availability of the technicians in relation to patient load, which fluctuated from day to day according to factors not related to this study, and did not appear to bias the selection of subjects. In each individual examined, the ten direct skinfold measurements listed under Methods (below) were made. Phases of the screening program that relate to the detection of diabetes include a section of the questionnaire, and measurement of the serum glucose one hour after an oral dose of 75 gm. of glucose. On the basis of responses to these phases, and review of the medical record for confirmation of the diagnosis, 295 Caucasian and 84 Negro subjects were identified as diabetic (table 1). Further review of the results of glucose tolerance tests in these diabetic individuals indicated that the criteria of Fajans and Conn[6] for the laboratory diagnosis of diabetes were satisfied in 83 per cent: blood glucose values $\geqq$ 160 mg./100 ml. at one hour, $\geqq$ 140 mg./100 ml. at one and one-half hours, $\geqq$ 120 mg./100 ml. at two hours (these values were increased 15 per cent if serum was analyzed). In the remaining 17 per cent, the diagnosis of diabetes had been made by the physician on the basis of abnormalities of glucose tolerance as well as positive family history, obstetrical history, or other pertinent information.

Since factors such as sex, age at onset of diabetes, and at time of study, duration of the disease, and treatment are likely to affect the observations made in any clinical appraisal of this disorder, these characteristics of the 379 diabetic subjects are shown in table 2. As expected, the mean age of the diabetic group was greater than that of the nondiabetic group, the diabetic Negroes being younger on the average than the diabetic Caucasians. The mean duration of disease from diagnosis to date of admission to this study was 4.3 years. Forty-eight per cent of the diabetic patients (53 per cent

TABLE 1

Total diabetic and nondiabetic subjects by sex, age, and race

Sex and age yrs.	Caucasian Diabetic No.	Caucasian Diabetic Per cent	Caucasian Nondiabetic No.	Caucasian Nondiabetic Per cent	Negro Diabetic No.	Negro Diabetic Per cent	Negro Nondiabetic No.	Negro Nondiabetic Per cent
Male:								
<45	28	18.3	1,302	46.7	13	28.2	299	53.5
45-54	36	23.5	770	27.6	17	37.0	173	30.9
55-64	49	32.0	460	16.5	11	23.9	80	14.3
≧65	40	26.2	258	9.2	5	10.9	7	1.3
Totals	153	100.0	2,790	100.0	46	100.0	559	100.0
Mean ages	56.5		45.9		51.6		43.2	
Female:								
<45	18	12.7	1,596	49.4	10	26.3	433	57.4
45-54	37	26.0	828	25.6	18	47.4	235	31.1
55-64	45	31.7	528	16.3	8	21.0	73	9.7
≧65	42	29.6	282	8.7	2	5.3	14	1.8
Totals	142	100.0	3,234	100.0	38	100.0	755	100.0
Mean ages	56.9		44.9		49.7		41.9	

of the men and 41 per cent of the women) were taking insulin or an oral hypoglycemic agent when studied. Diabetes had been first detected during routine examination in 89 per cent of the identified subjects, in most instances by the current or a previous multiphasic screening test.

The number of nondiabetic Caucasian subjects in the studied population made possible a three to one match for race, sex, age, height, and weight for each of the 138 diabetic Caucasian women and 149 diabetic Caucasian men. The smaller number of nondiabetic Negro subjects in the examined population made possible a one to one match for these factors for each of thirty-one Negro women and forty-two Negro men. The nineteen Caucasian and Negro subjects for whom no match in all five of these characteristics could be found were eliminated from the study. In table 3 are shown the mean age, height, weight, and ponderal index for the matched groups.

METHODS

The skinfolds were measured with a Lange skinfold caliper at the sites listed below, according to the criteria of the Committee on Nutritional Anthropometry, 1956.[7] The measurements were made by two trained technicians, whose results agreed well. All measurements not

TABLE 2

Clinical characteristics of total diabetic subjects

Characteristic	Total	Male	Female
Mean age (years)	50.8	50.1	51.6
Standard deviation	12.9	13.0	12.8
Range	10-79	10-79	14-76
Mean duration of diabetes (years)	4.3	4.7	3.8
Standard deviation	4.3	4.9	3.6
Range	1-36	1-36	1-20
Current therapy (number and [per cent])			
Diet	182[48.0]	88[44.3]	93[52.1]
Oral drugs	147[38.8]	85[42.9]	62[34.2]
Insulin	33[8.7]	21[10.4]	12[6.8]
None	8[2.0]	4[1.9]	4[2.1]
Unknown	9[2.4]	1[0.5]	9[4.7]
	379[100.0]	199[100.0]	180[100.0]
Method of detection of diabetes			
Routine examination	337[88.6]	172[86.4]	164[91.1]
Symptomatic	17[4.5]	9[4.5]	8[4.4]
Unknown	25[6.6]	18[9.1]	8[4.4]
Total diabetics	379[100.0]	199[100.0]	180[100.0]

TABLE 3

Comparison of matched diabetic and nondiabetic subjects by race, sex, age, height, weight, ponderal index, and per cent of subjects obese*

	Female				Male			
	Diabetic		Nondiabetic		Diabetic		Nondiabetic	
	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.
Caucasian:								
Number of subjects	138		414		149		447	
Age (years)	56.0	12.9	55.7	12.9	55.5	12.5	55.6	12.3
Height (inches)	62.6	2.3	62.9	2.2	67.9	2.6	68.0	2.5
Weight (pounds)	132.4	22.8	132.9	21.0	165.0	22.4	165.6	21.9
Ponderal index	12.27	0.70	12.30	0.64	12.35	0.52	12.35	0.52
Obese	14.5%		12.8%		11.5%		9.7%	
Negro:								
Number of subjects	31		31		42		42	
Age	47.7	8.5	47.1	7.9	49.1	8.7	49.8	7.6
Height	64.2	2.4	64.1	2.2	68.1	1.9	68.0	2.0
Weight	166.6	26.5	167.2	25.9	180.6	23.1	180.1	22.4
Ponderal index	11.65	0.67	11.61	0.64	12.01	0.53	11.99	0.48
Obese	51.6%		35.5%		16.7%		4.8%	

*Obesity, as determined from triceps skinfold, values of Seltzer and Mayer.[9]

in the midline were made on the right side of the body, in the natural line of the planes of the skin, with the subject standing, and were recorded to the nearest whole millimeter.

Chin: At neck crease, head held in Frankfurt plane, caudad application of calipers.

Triceps: Half the measured distance from the distal end of the acromion to the proximal end of the olecranon, along the posterior aspect of the upper arm. The measurement was taken with the subject's arm hanging freely by his side.

Forearm: One third the measured distance from the olecranon process to the ulnar styloid; measurement taken over the posterior aspect of the ulna while the elbow was bent ninety degrees.

Subscapular: At the inferior angle of the scapula.

Chest: One third the measured distance from the apex of the axilla to the iliac crest, in the midaxillary line.

Waist: Half the measured distance from the apex of the axilla to the iliac crest, in the midaxillary line.

Abdomen: Two measured inches to the right of the umbilicus.

Suprailiac: Immediately above the iliac crest.

Suprapatellar: Immediately above the right patella, while the right knee and hip were slightly flexed and the subject's weight was borne on his left leg.

Calf: Medial aspect of the calf at its largest diameter (by visual inspection).

Height, weight: Measured with subject's outer clothing and shoes removed.

In addition to the absolute skinfold measurements, the distribution of the subcutaneous fat was studied in each subject by relating his individual skinfold measurements at each of the nine other sites to (a) his triceps skinfold and (b) his subscapular skinfold. These two sites were chosen as standards for the ratios because they appear to be the most generally representative indicators of body fat,[8] and because one represents an extremity, the other the trunk. Furthermore, the study of ratios permitted comparison of fat distribution in males with that in females, where absolute measurements are known to differ.

RESULTS

Female Caucasian diabetics: It is generally accepted that obesity is more prevalent among diabetic than among nondiabetic persons. It was therefore contrary to expectation to observe (table 3) that obesity, as judged by the triceps skinfold criterion of Seltzer and Mayer,[9] ($>$ 23 mm. for males; $>$ 30 mm. for females) proved on statistical analysis not to be significantly more common in the diabetic than in the nondiabetic subjects of either sex or race. This was true even though gross inspection of the data revealed a trend to greater frequency of obesity in diabetic than in nondiabetic

TABLE 4
Skinfold measurements of Caucasian subjects

	Female				Male			
	Diabetic N = 138		Nondiabetic N = 414		Diabetic N = 149		Nondiabetic N = 447	
	Mean (mm.)	S.D.M.	Mean (mm.)	S.D.M.	Mean (mm.)	S.D.M.	Mean (mm.)	S.D.M.
Chin	13.8	5.4	12.8	4.7	10.7*	4.5	9.9*	3.9
Triceps	23.5	8.5	23.0	6.8	14.8	6.8	14.3	6.3
Forearm	9.5	4.3	8.8	3.9	6.6	2.6	6.5	2.7
Subscapular	21.0*	12.4	18.2*	9.4	17.8	8.0	16.9	7.2
Chest	21.5*	10.5	19.5*	9.4	19.9	9.9	18.5	8.9
Waist	19.7*	11.2	17.1*	9.4	18.8	9.9	17.2	8.6
Abdomen	38.1*	17.4	34.5*	15.4	30.0	13.8	30.1	13.2
Suprailiac	23.7	13.4	21.7	11.7	23.7	13.0	22.0	11.7
Suprapatellar	16.6	8.4	16.2	7.3	9.7	4.0	9.4	3.8
Calf	18.0	7.6	18.6	6.7	8.2*	3.7	9.0*	4.4

$^*p \leqq .05$.

Negroes. Skinfold measurements of Caucasian female diabetics were significantly larger, however, than those of the matched controls at the subscapular, chest, waist, and abdominal sites (table 4). The triceps ratios for each of these sites were greater in the diabetic white women than in their controls (table 5). The subscapular ratios (table 6) were smaller at the extremity sites, reaching significance at triceps and calf.

From these observations, a centripetal pattern of fat distribution in the Caucasian diabetic woman emerged: the fat tended to be proportionately greater in her truncal region and less in her extremities.

Male Causasian diabetics: The mean weight of Caucasian diabetic men did not exceed that of controls (table 3), and as noted previously the per cent obese did not differ significantly (11.5 per cent: 9.7 per cent). These unexpected findings in both male and female Caucasians may be explained by the greater mean height and lower mean age of the nondiabetic controls.

In the Caucasian diabetic men, skinfold measurements (table 4) were significantly larger at the chin and smaller at the calf than in controls. The other skinfolds tended to be larger in diabetic than in nondiabetic subjects. In both triceps (table 5) and subscapular (table 6) ratios, the only significant difference between diabetic and nondiabetic subjects was at the calf, where each of these two ratios was smaller in the diabetic group.

Direct skinfold measurements and ratios showed fewer significant differences between diabetic and nondiabetic men than between diabetic and nondiabetic women among Caucasians; but the same pattern of exaggerated centripetal fat distribution was suggested in the male diabetic.

In Negroes, as in Caucasians, the difference between diabetic and nondiabetic subjects was greater in women than in men.

Female Negro diabetics: The mean weight for the unmatched diabetic Negro females (not shown in the tables) was 168.4 pounds, twenty pounds greater than that of the total unmatched nondiabetic Negro female group (148.4 pounds). It is of interest that the mean

TABLE 5
Ratio, skinfold/triceps skinfold, in Caucasian subjects

	Female				Male			
	Diabetic N = 138		Nondiabetic N = 414		Diabetic N = 149		Nondiabetic N = 447	
	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.
Chin	0.61	0.20	0.57	0.20	0.80	0.35	0.77	0.32
Forearm	0.41	0.13	0.39	0.14	0.48	0.16	0.49	0.16
Subscapular	0.86*	0.32	0.78*	0.30	1.27	0.43	1.26	0.44
Chest	0.90†	0.30	0.84†	0.31	1.38	0.54	1.35	0.53
Waist	0.81†	0.30	0.74†	0.32	1.29	0.47	1.25	0.51
Abdomen	1.64†	0.55	1.51†	0.56	2.13	0.76	2.26	0.96
Suprailiac	0.98	0.39	0.92	0.39	1.65	0.75	1.61	0.77
Suprapatellar	0.74	0.35	0.73	0.31	0.72	0.33	0.72	0.27
Calf	0.80	0.34	0.84	0.32	0.59*	0.23	0.67*	0.28

$^*p \leqq .01$.
$^†p < .05$.

TABLE 6

Ratio, skinfold/subscapular skinfold, in Caucasian subjects

	Female				Male			
	Diabetic N = 138		Nondiabetic N = 414		Diabetic N = 149		Nondiabetic N = 447	
	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.
Chin	0.77	0.31	0.80	0.31	0.64	0.23	0.63	0.24
Triceps	1.33*	0.54	1.46*	0.54	0.87	0.28	0.88	0.29
Forearm	0.52	0.21	0.54	0.22	0.39	0.12	0.41	0.15
Chest	1.12	0.40	1.14	0.40	1.12	0.35	1.10	0.35
Waist	0.98	0.34	0.98	0.39	1.05	0.33	1.02	0.31
Abdomen	2.08	0.81	2.05	0.74	1.77	0.65	1.83	0.60
Suprailiac	1.20	0.48	1.24	0.49	1.34	0.54	1.31	0.56
Suprapatellar	0.98	0.56	1.07	0.59	0.59	0.23	0.62	0.28
Calf	1.08*	0.65	1.23*	0.63	0.50†	0.21	0.58†	0.31

* $\leqq .05$.
†p $\leqq .01$.

weight of Negro diabetic women (167 pounds) in the matched group far exceeded that of Caucasian women (132 pounds) (table 3); and that 52 per cent of the Negro diabetic women were classified as obese, in contrast to the 15 per cent of Caucasian diabetic women. The nondiabetic Negro female was also heavier than the nondiabetic Caucasian female, and obesity was more common in the Negro than in the Caucasian nondiabetic women (35.5 per cent: 12.8 per cent).

Although the only significant discrepancy between the skinfold measurements of the thirty-one matched diabetic and nondiabetic Negro women (table 7) was the 6.9 mm. excess at the diabetic abdominal skinfold, all other means were also considerably larger for the diabetic except at suprapatella and calf, where they were smaller in the diabetic.

On triceps (table 8) and subscapular (table 9) ratio analysis, no significant differences between diabetic and nondiabetic Negro females emerged. However, all triceps ratios in diabetics were larger except at the suprapatella and calf, where they were smaller than for nondiabetics. The subscapular ratios (except for chin and suprailiac) were smaller in the diabetic than in the nondiabetic Negro women. Thus, although the mean triceps and subscapular skinfolds were larger in the diabetic than in the nondiabetic Negro women, triceps ratio analysis demonstrated that in the individual diabetic the subcutaneous fat concentration is greater in the trunk and less in the leg; while subscapular ratio analysis showed that at all other body sites the diabetic Negro female has less fat in proportion to her subscapular fat than has her nondiabetic counterpart. The differences between diabetic and nondiabetic Negro women with respect to absolute skinfold measurements and ratios were not statistically significant by the method employed; but the same pattern emerged as in the Caucasians, and presumably with analysis of a larger sample, significant levels would have been achieved.

Male Negro diabetics: Direct skinfold measurements in the matched series of forty-two diabetic Negro men showed the same trend toward larger skinfolds at all sites than in the nondiabetic males, as was seen in the

TABLE 7

Skinfold measurements of Negro subjects

	Female				Male			
	Diabetic N = 31		Nondiabetic N = 31		Diabetic N = 42		Nondiabetic N = 42	
	Mean (mm.)	S.D.M.	Mean (mm.)	S.D.M.	Mean (mm.)	S.D.M.	Mean (mm.)	S.D.M.
Chin	11.2	4.2	9.7	4.3	7.7	3.5	7.7	3.6
Triceps	31.0	9.7	28.8	6.7	15.6	7.3	14.1	5.2
Forearm	11.4	4.7	10.3	4.1	7.0*	3.1	5.8*	1.9
Subscapular	35.3	13.0	30.2	12.3	24.0	10.3	20.7	7.9
Chest	30.3	11.5	26.7	10.0	23.3	11.6	21.5	9.8
Waist	29.4	11.9	26.3	8.9	22.5	12.3	19.4	8.6
Abdomen	52.8*	13.5	45.9*	13.6	37.1	17.9	35.4	11.9
Suprailiac	39.0	14.2	32.8	12.2	28.2	14.4	26.2	12.5
Suprapatellar	18.1	7.5	18.6	7.8	9.6	3.5	10.6	4.9
Calf	19.2	7.2	20.4	6.6	8.6	4.1	8.1	3.2

*$p < .05$.

TABLE 8

Ratio, skinfold/triceps skinfold, in Negro subjects

	Female				Male			
	Diabetic N = 31		Nondiabetic N = 31		Diabetic N = 42		Nondiabetic N = 42	
	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.
Chin	0.39	0.20	0.33	0.14	0.56	0.24	0.59	0.25
Forearm	0.38	0.12	0.36	0.11	0.48	0.14	0.44	0.13
Subscapular	1.14	0.32	1.03	0.36	1.61	0.46	1.54	0.50
Chest	0.98	0.25	0.91	0.25	1.54	0.64	1.56	0.61
Waist	0.95	0.25	0.91	0.27	1.46	0.53	1.41	0.54
Abdomen	1.76	0.46	1.63	0.49	2.54	1.01	2.67	1.07
Suprailiac	1.25	0.32	1.12	0.30	1.92	0.86	1.92	0.72
Suprapatellar	0.60	0.23	0.65	0.26	0.68*	0.21	0.81*	0.32
Calf	0.64	0.22	0.71	0.21	0.61	0.34	0.62	0.23

*$p < .05$.

women. The exceptions were at suprapatella and chin in the men, instead of at suprapatella and calf as in the Negro women (tables 7-9).

DISCUSSION

Both direct skinfold measurements and comparisons of triceps and subscapular ratios indicate that the pattern of subcutaneous fat distribution in patients with diabetes mellitus differs from that characteristic of nondiabetic persons of comparable race, sex, age, height, and weight. According to these findings, diabetes is associated with a centripetal distribution of subcutaneous fat, more pronounced in female than in male patients. Since the diabetic subjects studied encompassed a broad range of body weight, the conclusions are applicable to both lean and obese patients. It would appear, furthermore, that persons with diabetes have more total subcutaneous fat and presumably more total body fat than persons without this disease: nine of ten skinfold measurements in diabetic women, and eight of ten in diabetic men were larger than those in sex-matched nondiabetic subjects of comparable age, height, weight, and ponderal index.

The important question, whether obesity as defined by triceps skinfold relates to "male" or "female" fat distribution patterns, was dealt with by us in an analysis of the entire group of 7,717 subjects. No consistent or clear differences emerged. In the final analysis of matched groups described here, it was felt that the number of obese subjects in the diabetic groups, and particularly among the Negroes, was too small to permit valid statistical comparison.

Centripetal fat distribution is frequently associated with hyperadrenocorticism. Some reports have suggested an increase of urinary 17-ketosteroids in diabetic females, but measurements of adrenal cortical function in patients with uncomplicated diabetes have demonstrated no consistent deviations from the normal in regard to cortisol production.[10-12] It is therefore unlikely that increased adrenal function accounts for the fat distribution reported here.

Analysis of these data demonstrated a difference between male and female patterns of subcutaneous fat distribution in nondiabetic subjects of both skin colors: in the male, fat was found to be concentrated chiefly in the trunk. The preponderance of this centripetal fat distribution pattern in the male is especially apparent

TABLE 9

Ratio, skinfold/subscapular skinfold, in Negro subjects

	Female				Male			
	Diabetic N = 31		Nondiabetic N = 31		Diabetic N = 42		Nondiabetic N = 42	
	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.	Mean	S.D.M.
Chin	0.36	0.18	0.35	0.18	0.35	0.13	0.40	0.18
Triceps	0.95	0.26	1.11	0.48	0.67	0.19	0.71	0.23
Forearm	0.35	0.12	0.40	0.22	0.31	0.11	0.30	0.10
Chest	0.89	0.24	0.94	0.27	0.96	0.25	1.03	0.29
Waist	0.85	0.18	0.92	0.23	0.91	0.22	0.93	0.22
Abdomen	1.64	0.57	1.73	0.69	1.59	0.51	1.79	0.56
Suprailiac	1.16	0.38	1.17	0.43	1.19	0.40	1.27	0.40
Suprapatellar	0.60	0.36	0.78	0.58	0.45*	0.15	0.57*	0.27
Calf	0.62	0.31	0.84	0.58	0.39	0.17	0.42	0.19

*$p \leqq .05$.

in a graphic composite of the triceps and subscapular ratios in this study (shown for Caucasians only in figure 1). This graphic composite of the triceps and subscapular ratios as a method of comparison of patterns of fat distribution was suggested by the significant differences between diabetics and nondiabetics noted in tables 5, 6, 8, and 9. In similar graphic comparisons of diabetic men and women (Caucasians in figure 2; Negroes in figure 3), the female profile is shifted in the direction of the normal male pattern: the diabetic women had more fat in the trunk and less in the extremities. To a less obvious degree, the subcutaneous fat distribution profile of the diabetic male represents an exaggeration of the centripetal profile of the normal male.

A number of previous observations has supported the thesis that diabetes is associated with a disturbance in masculine-feminine features, resulting in an emphasis on the masculine components. Death rates from all causes for male and female diabetics are approximately equal;[13] whereas in the general population, death rates for males are higher than for females. In the general population, the prevalence of coronary heart disease has been estimated to be from two to four times as great in men as in women; whereas in the diabetic population, its prevalence is equal in the two sexes. Furthermore, the total prevalence of this disease among diabetics is twice that in the general population.[14] The Achard-Thiers syndrome, diabetes in bearded women,[15] is probably an extreme example of masculinization in the diabetic female.

Vague has been investigating the relationship of patterns of obesity to various disease states for the past two decades.[16] Using anthropometric measurements other than those employed by us, he has classified individuals as to degree of android or gynoid obesity, and found that 80 to 90 per cent of patients with diabetes, as well as of those with atherosclerosis or gout, have a predominantly android distribution of fat.[17] He suggested[18] that an increased production of 17-hydroxycorticoids was related to android obesity; however, the wide scatter of the data and the overlap between different types of obesity leave in doubt the importance of this aspect of adrenal function in the pathogenesis of android obesity. Further investigation of this very interesting point is indicated.

Rodríguez[19] noted that estrogens had a protective, and androgens an aggravative, effect on the onset and course of diabetes in partially pancreatectomized rats fed ad libitum. In castrated, partially pancreatectomized female rats, the forced feeding of estrogens transiently produced diabetes but then had a permanent protective action; such protection was not observed in similarly prepared rats from which estrogens were withheld. Conversely, the frequency with which diabetes follows alloxan or pancreatectomy is greater in male than in female rats; however, castration prior to induction of diabetes produces an equal diabetic response in male and female rats.

Such observations, and the data presented here, sug-

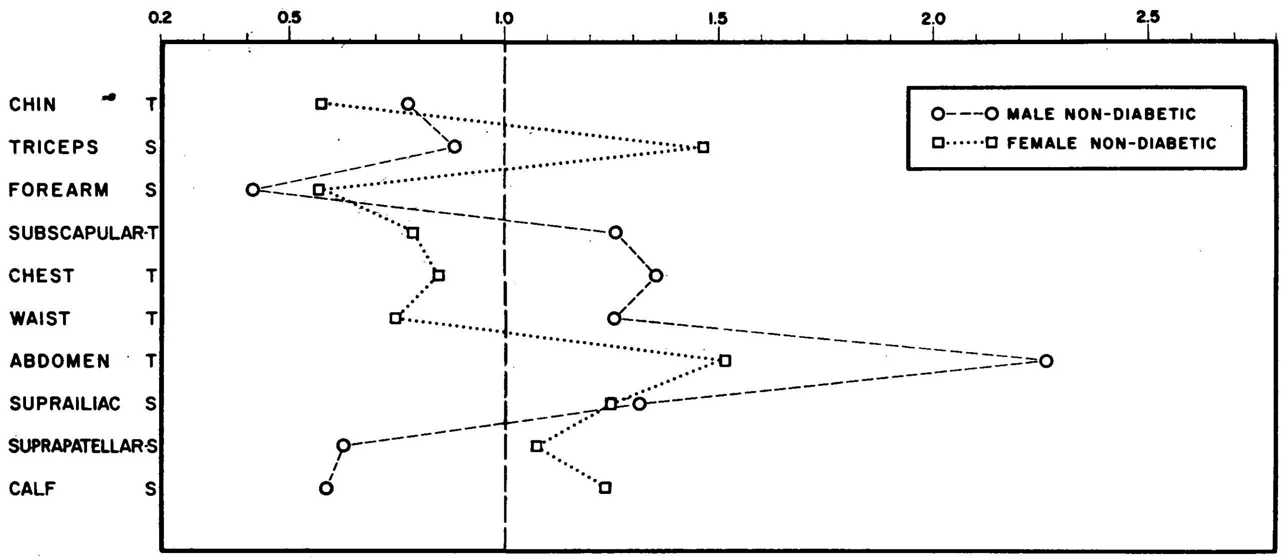

FIG. 1. Comparison of male and female fat distributions in nondiabetic Caucasian subjects, by selected mean triceps (T) and subscapular (S) ratios.

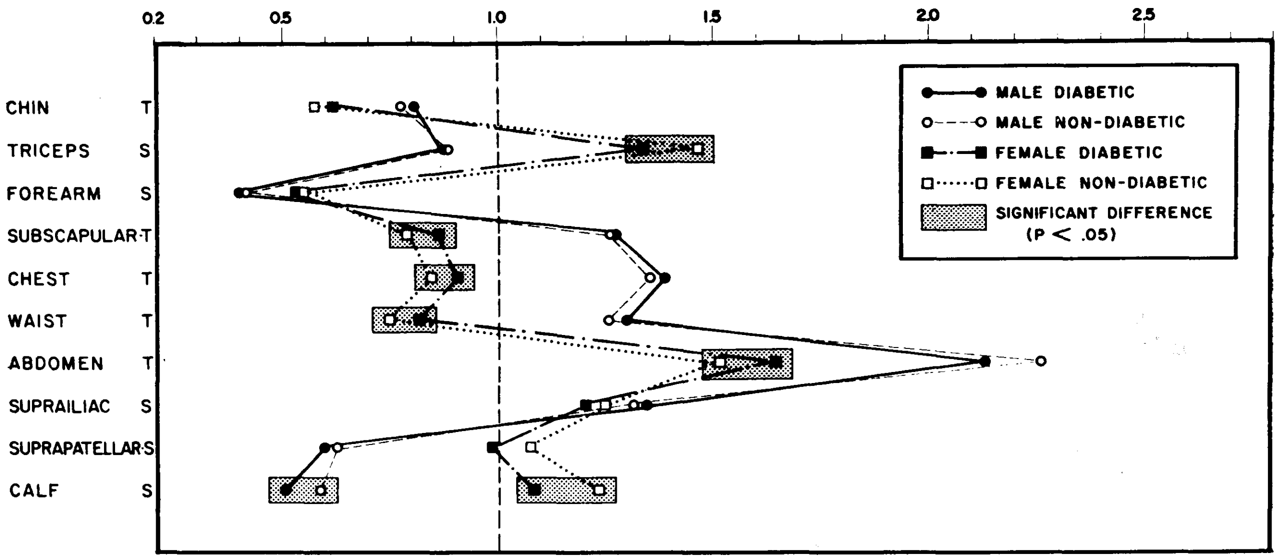

FIG. 2. Comparison of male and female fat distributions in diabetic and nondiabetic Caucasian subjects, by selected mean triceps (T) and subscapular (S) ratios.

gest that in diabetes there is a disturbance of the female:male hormonal relationships with an emphasis on the masculine, which has as one of its expressions a change in the distribution of body fat towards a masculine pattern. We have found no reports of studies of estrogen/androgen function in diabetes, particularly of investigations in which recently developed sophisticated means of sex hormone assay were employed. If such a disturbance of sex hormone balance is present, it is not possible to state on the basis of the findings in this study whether the disturbance is causally related to, or secondary to the diabetic state. It may be speculated that one cause or facet of the frequency of diabetes in both men and women in later life may be a change in sex hormonal relationships which occurs at this time. Gershberg and associates[20] have recently reported that the administration of estrogen to women with maturity-onset diabetes ameliorates their disease.

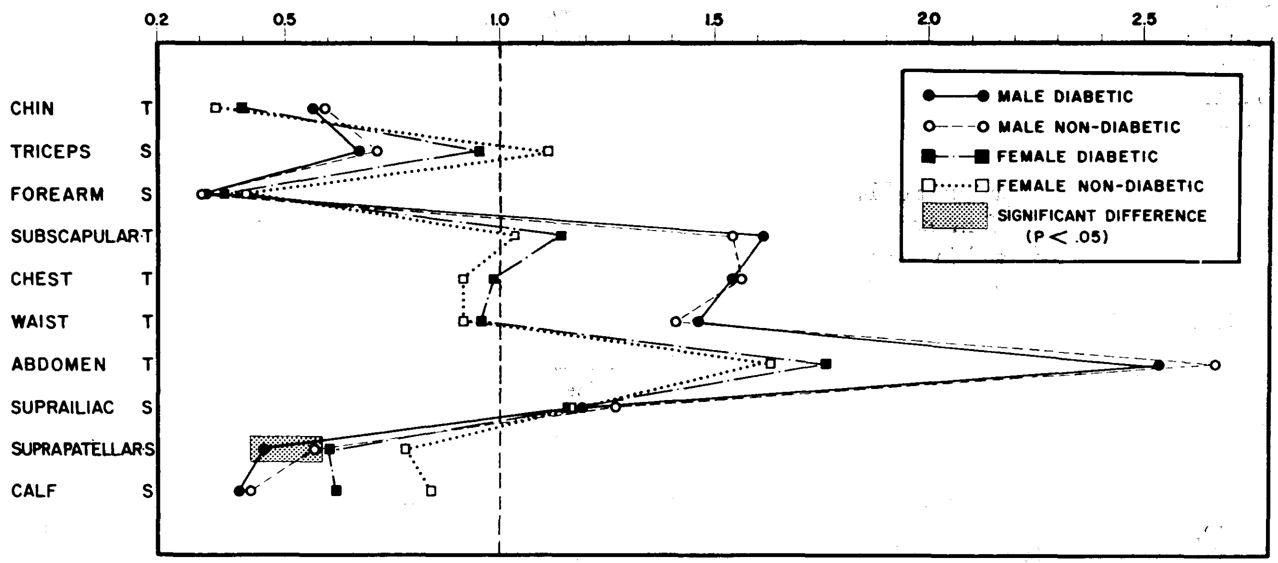

FIG. 3. Comparison of male and female fat distributions in diabetic and nondiabetic Negro subjects, by selected mean triceps (T) and subscapular (S) ratios.

Another possible interpretation is that the centripetal distribution of body fat observed in diabetics in the present study may be of genetic origin, and associated with the genetic predisposition of diabetes. Differences in fat distribution which appear to be genetic in origin have been reported between Spiny mice (with obesity and diabetes), in which the fat is primarily subcutaneous, and yellow obese mice, the New Zealand strain of obese mice, and mice made hyperphagic by injection of gold thioglucose, in which fat is mainly intra-abdominal.[21]

No data yet available lead to an understanding of factors that produce the typical masculine and feminine distributions of fat, although the distributions are presumed to be, and indeed are likely to be, secondary to male or female hormone preponderance. Why certain areas of subcutaneous fat respond selectively to these hormones is unclear.

The observation made in the study reported here, that diabetes is associated with a centripetal pattern of fat distribution, may provide further insight into the diabetic state and its management. Many questions are suggested regarding factors that determine the amount and distribution of body fat, and the effects of male/female hormonal relationships on adipose tissue and diabetes.

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