



Effect on body composition and other parameters in obese young men of carbohydrate level of reduction diet^{1,2}

Charlotte M. Young,³ Ph.D., Sonia S. Scanlan,⁴ M.N.S., Hae Sook Im,⁵ M.N.S., and Leo Lutwak,⁶ Ph.D., M.D.

Very limited studies have been made of changes in body composition during weight reduction on various dietary regimens, particularly over any extended period of time and with subjects engaged in their usual activities. Practical interests are concerned with reduction regimens that can be followed for extended periods as individuals pursue their normal routines.

In this laboratory considerable experience has been accumulated with the weight reduction of both young men and young women who are moderately obese, using a low carbohydrate, high protein, moderate fat type of diet originally promulgated by Ohlson (1-5). This type of diet seems to have certain advantages for long-term weight loss: *a*) it can be adequate in all nutrients except calories; *b*) it is simple to follow both at home and away from home; and *c*) it may be expanded easily to a lifetime pattern of eating when one is ready for weight maintenance. A further asset is that patients are notably free from hunger, and fatigue, though present during the reduction process, seems as limited as for any regimen used. For moderately obese young males in the usual sedentary occupations, an 1,800-kcal level has been used with 115 g protein, 104 g carbohydrate, and 103 g fat; 50% of the calories are from fat. Recently there have been vigorous advocates, especially in the popular press, for still greater restriction in carbohydrate in the reduction diet. Is there any advantage to be gained?

The present study was undertaken to com-

pare results of the low carbohydrate diet previously used extensively with the results of two isocaloric, isoprotein diets in which carbohydrate was reduced by approximately one-half to 60 g and then one-half to 30 g daily. Thus, the study compares the effect of varying levels of carbohydrate and fat in a moderate reduction regimen over an extended period on moderately obese young men engaged in their usual activities. Comparisons will be made in terms of weight loss; changes in body composition measured by density, anthropometric (envelope) measurements, skin-fold thicknesses, and balances of nitrogen, sodium, and potassium; blood lipid levels; qualitative excretion of ketone bodies in the urine; and subjective response. Of the three levels of carbohydrate used, which appeared to be the most desirable?

Experimental

The subjects were eight young college men aged 20.6 to 27.8 years (median, 22.8; mean 23.3) (Table 1). All were science majors; four were graduate students and four were upper-class undergraduates. Originally there were nine subjects but the data from one were discarded because of pos-

¹ From the Graduate School of Nutrition, Cornell University, Ithaca, New York 14850.

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³ Professor of Medical Nutrition. ⁴ Research Assistant. ⁵ Graduate Assistant. ⁶ James Jamison Professor of Clinical Nutrition.

TABLE 1
Description of subjects

	Mean	Median	Range
Age, years	23.3	22.8	20.6 - 27.8
Height, cm	176.2	179.1	163.8 - 182.4
Weight, kg	98.0	98.6	78.9 - 113.6
Density, g/cc	1.0317	1.0298	1.0179- 1.0531
Specific gravity	1.0379	1.0363	1.0237- 1.0590
Fat, % body wt	30.20	30.94	19.49 - 37.56
Skin-fold thickness, mm	305.4	306.2	266.8 - 353.2

sible irregularities in collections. Median body weight was 98.6 kg; median body density, 1.0298; and median percent body weight as fat, using the Rathbun and Pace formula, was 30.94%, roughly three times the usual percent body weight as fat for this age group.

The general experimental plan was as follows. For approximately 3 weeks subjects were on a maintenance diet for base-line observations. Then three as comparable as possible subgroups of three each were formed on the basis of maintenance caloric requirements and percent body weight as fat. Because of the discard of data for one subject originally assigned to subgroup *A* (leaving only two subjects), the resulting average initial characteristics of the subgroup are not as comparable as when they were formed (Table 2).

TABLE 2
Characteristics of diet subgroups

Mean	Diet subgroups		
	<i>A</i>	<i>B</i>	<i>C</i>
Weight, kg	98.55	95.82	102.2
Density, g/ml	1.0349	1.0319	1.0314
Fat, % body wt	28.40	30.20	31.39
Skin-fold thickness, mm	275.4	314.9	315.8
Maintenance, kcal	3,700	3,666	3,666

For 9 weeks (interrupted after 3 weeks for 1 week of spring vacation), one subgroup each was placed on isocaloric, isoprotein diets (1,800 kcal, 115 g protein) at three different levels of carbohydrate: *Diet A*, 104 g; *Diet B*, 60 g; and *Diet C*, 30 g/day. Table 3 gives the details of the diet plan.

All food intake was weighed and consumed at our Special Diet Table Unit while students attended school and participated in their usual noneating, nondrinking activities. Physical activity was not controlled, though a retrospective questionnaire, related to these and other matters and completed at the end of the study, gave estimates of energy expenditures. Only glass-distilled water was used in

cooking, to drink, and to prepare tea and coffee, which with water were allowed ad libitum and recorded daily. Food was prepared without salt and each man had his daily supply to be used in toto in 24 hr. Sodium intake during maintenance was calculated to be an NaCl equivalent of 11 g/day; during weight reduction, of 5 g/day.

Each subject was weighed in fasting condition and without shoes or jacket, prior to any other morning activity.

Nitrogen, sodium, and potassium balances were conducted during the last 10 days of the 3-week weight maintenance period and during the first 3 and last 3 weeks of the 9-week weight reduction period. Account was not taken of cutaneous losses except in the interpretation of sodium and potassium balances. All periods were 7 days in length except the 10-day maintenance period and the third week of reduction, which was a 6-day period.

Estimates of all other parameters of body composition were made at four intervals: the last week of weight maintenance and the 3rd, 6th and 9th week of weight reduction. Urinary creatinines were measured daily and ketone bodies in the urine were estimated qualitatively daily during balances of weight reduction by means of Ketostix and of the nitroprusside test.

Body density was determined by underwater weighing with simultaneous measurement of residual air (6). For calculating body fat from density, the Rathbun and Pace formula was used (7). Some 14 skeletal and 9 envelope measurements were made using techniques described elsewhere (8). Skeletal measurements included: height; iliocristal height; sitting height; biacromial, biiliac, and bi-trochanteric diameters; chest width at xiphoid level; knee to knee, knee, ankle, and wrist widths; and knee, ankle, and wrist circumferences. Envelope measurements included shoulder, chest (xiphoid level), biceps, upper arm, forearm, calf, abdominal at hypochondriac and abdominal at umbilicus level circumferences and deltoid diameter. In addition, 12 skin-fold measurements were made as previously described (8) except that the skin fold over the biceps was added and that halfway between the umbilicus and the pubis on the midabdominal line was deleted.

Data will be viewed as comparisons between diet subgroups by carbohydrate level: *A* (104 g), *B*

TABLE 3
Diet plan

Nutrient	Maintenance		Reduction					
	Grams	% Calories	A		B		C	
			Grams	% Calories	Grams	% Calories	Grams	% Calories
Protein	115	12.8	115	25.5	115	25.6	115	25.5
Carbohydrate	425	47.2	104	23.1	60	13.3	30	6.7
Fat	160	40.0	103	51.4	122	61.1	135.5	67.8
Calories	3,600	100	1,800	100	1,800	100	1,800	100

(60 g) and C (30 g) on an average basis, though in most instances individual data are included.

Results

Weight loss

Weight maintenance caloric needs varied from 3,400 to 4,000 kcal/day. Table 4 gives the weight losses by isocaloric, isoprotein subgroups with diminishing carbohydrate intake during the 9 weeks reduction period. Losses ranged from 9.19 to 18.14 kg; the mean was 13.82; the median, 12.87 kg. *Group A* with 104 g carbohydrate daily lost an average of 11.85 kg; *group B* with 60 g carbohydrate daily lost an average of 12.78 kg; *group C* (30 g carbohydrate daily) an average of 16.18 kg. Thus, there seems to have been a slight increase in weight loss as carbohydrate in the diet decreased. However, it must be remembered that physical activity was not controlled. The retrospective reporting of activity would indicate that the average caloric expenditures of all groups were very comparable, about 3,400 kcal/day for *groups A* and *C*; 3,300 for *group B*.

TABLE 4
Weight losses in kilograms, during reduction period

Subjects	Group and carbohydrate level		
	A (104 g/day)	B (60 g/day)	C (30 g/day)
1	9.19	13.04	12.25
2	14.52	12.59	18.14
3		12.70	18.14
Mean	11.85	12.78	16.18
Median	11.85	12.70	18.14
Range	9.19-14.52	12.59-13.04	12.25-18.14

Ketone excretion

An additional factor that may contribute somewhat to the differences in weight losses on the isocaloric diets is the variation in loss of energy through the excretion of ketone bodies in the urine (Table 5). Unfortunately the ketone measurements were only qualitative tests, but the two tests used agreed very well in their relative estimations. In general, it can be said that the daily tests of the urine showed increasing ketone bodies with decreasing carbohydrate intake and that ketone bodies continued to increase and for a longer time as the carbohydrate level in the diet decreased. For *group A*, during the first 2 weeks, a low to moderate level of ketone bodies appeared in the urine but this was much diminished by the 3rd week; by the 7th through 9th week, they had disappeared entirely. For *group B* the picture was much the same as *group A* in the first 3 weeks, but in the last 3 weeks, ketones were absent for one subject, questionable for another, and at the lowest detectable level for the third. In contrast, all of *group C* had the heaviest load of ketones in the urine of any of the subjects and the level remained high throughout the first 3 weeks. By the last 3 weeks, the level was somewhat lighter but still high in all three subjects. Continued heavy loss of ketone bodies in the urine on the very restricted carbohydrate intake ultimately would result in a loss of base from the body and possible acidosis, as well as some loss of energy.

Changes in body fatness

In Table 6 are presented changes in body weight, and in fatness or lean body mass, or both, based on differences between the first set

TABLE 5
Qualitative ketone losses in urine by diet group

Week of reduction	Diet group		
	A	B	C
1	++	++	++
2	++	+	+++
3	+	+	+++
7	0	⊕	++
8	0	+	+++
9	0	⊕	++

of tests (approximately the last week of the maintenance period) and the fourth set of tests (the last week of the reduction period). Calculations are based on changes in nude weight, density, total of skin-fold thicknesses, total of envelope or circumference measurements, and average creatinine excretion. The total number of days between tests is not exactly equal, being slightly greater on the average for group A than groups B and C, which are essentially equal.

Note that body fat losses on the average increased progressively with less carbohydrate. The same is true for the percent of weight loss that is fat. Over the 9-week reduction period close to 100% of the weight lost by group C, the lowest carbohydrate

group, was fat. The decreases in total of skin-fold thicknesses and of body circumferences, whether expressed in absolute amounts or percentage of maintenance values, again showed the greatest losses in the lowest carbohydrate group, C, and least in the highest group, A, with the intermediate carbohydrate level group in the intermediate position. Curiously, the groups fell in the same relative positions with regard to increases in average creatinine excretions between the two test periods.

Nitrogen balances

Table 7 gives the average nitrogen retentions per day and the balance status of subjects by period and by diet groups. During weight maintenance all the subjects were retaining nitrogen except one in group B who was in balance. In the first week of weight reduction all but one subject in group B were losing nitrogen regardless of diet group. Thereafter, all subjects retained nitrogen or were in balance except one in group B who lost nitrogen throughout the reduction period. (In the 3rd week of reduction the loss was not quite great enough to be classified "L.") The highest carbohydrate group, A, initially retained more nitrogen early in reduction, i.e., 2nd and 3rd week. However, by the 7th

TABLE 6
Changes in body fatness

Subject by group	Weight loss, kg	Fat loss		Weight lost as fat, %	Density of tissue lost, g/ml	Skin-fold loss		Circumference loss		Changes in creatinine excretion, g/24 hr
		% body weight	kg			mm	%	cm	%	
A1	8.50	5.71	6.56	77.2	0.9424	118.5	44.4	45.6	7.9	+0.371
2	13.88	6.67	10.2	73.5	0.9572	142.7	50.2	52.8	8.1	-0.025
Mean	11.19	6.19	8.38	75.3	0.9498	130.6	47.3	49.2	8.0	+0.173
B1	13.38	8.42	9.89	73.9	0.9544	155.6	59.7	57.4	9.1	+0.043
2	11.56	7.11	9.94	86.0	0.9353	164.7	49.8	56.4	9.1	+0.863
3	11.80	8.12	10.9	92.4	0.9240	155.6	44.1	51.9	8.3	-0.012
Mean	12.25	7.88	10.2	84.1	0.9379	158.6	51.2	55.2	8.8	+0.298
C1	10.77	a	a	a	a	137.2	46.7	56.3	9.1	+0.232
2	15.25	11.3	14.7	96.4	0.9181	199.8	62.7	61.6	9.6	+0.360
3	15.99	10.1	15.0	93.8	0.9206	173.5	51.8	63.3	9.4	+0.553
Mean	14.00	10.7	14.85	95.1	0.9193	170.2	53.7	60.4	9.4	+0.382

^a Experimental error in density measurement at 9th week of weight reduction for subject C1. Averages for C subgroup based on only C2 and C3.

TABLE 7
Average nitrogen retentions and balance status by period and diet group

Period	Diet group					
	A		B		C	
	N, g/day	Balance	N, g/day	Balance	N, g/day	Balance
Maintenance	0.61	2 R ^a	1.93	2R B ^b	2.69	3R
Reduction 1	-1.58	2 L ^c	-1.74	1B 2L	-1.55	3L
2	1.59	2 R	0.00	R B L	0.00	3B
3	3.22	2 R	1.19	2R 1B	1.48	1R 2B
7	1.48	2 R	0.89	2R 1L	1.77	3R
8	0.96	R B	0.61	2R 1L	2.51	2R 1B
9	0.63	R B	0.25	2R 1L	1.37	2R 1B

^a R = Retention >5% intake. ^b B = Balance, within $\pm 5\%$ intake. ^c L = Loss >5% intake.

through the 9th week the lowest carbohydrate group, C, had the highest average nitrogen retentions. The individual who had the lowest percent weight loss as fat (Table 6) and who also reached the lowest percent body weight as fat, had the greatest nitrogen losses throughout. *Group C*, with the highest percent weight loss as fat, also had the highest average nitrogen retentions as weight loss progressed.

Thus, there was no marked difference in diet groups with regard to nitrogen balance, and one cannot say that any one level of carbohydrate was better than any other insofar as nitrogen retention is concerned.

Sodium balance

On the weight maintenance diet with a calculated sodium intake equivalent to 11 g NaCl/day, urinary sodium excretions ranged from 2.7 to 3.27 g/day (mean, 3.10; median, 3.17). On the isocaloric reduction diets with a calculated sodium intake equivalency of 5 g NaCl/day, average daily sodium urinary excretions ranged from 1.2 to 2.0 g in all 3 diet subgroups. The averages kept falling in the first 3 weeks so gradually that a slightly more positive balance was obtained. However, in some cases in the 7th through 9th week, the sodium excretion was slightly higher and sodium balances lower.

There were no marked group differences in sodium balances. The subject known to exercise most vigorously had consistently lower urinary sodium excretions and ap-

parently higher balances, undoubtedly due to more sodium lost in sweat. Overall sodium balances were only slightly positive except for this one individual, but the slight positive balances (range 0 to 47 mEq on a daily basis; mean, 18.69 mEq; median 17.0 mEq) were easily accountable by loss in insensible perspiration. Least sodium retention was found in the 1st week of reduction (after the change in sodium intake), with the greatest urinary sodium excretion then for all subjects, particularly in *group C*, the lowest carbohydrate group.

Potassium balances

During weight maintenance the urinary losses of potassium ranged from 3.06 to 4.04 g/day; mean, 3.29; median, 3.26. During weight reduction urinary losses ranged from 1.7 to 3.29 g/day; mean, 2.24; median, 2.11, except for one subject.

All subjects except one were in slightly negative potassium balance throughout weight reduction. Potassium loss in the 1st week of reduction was markedly higher in almost all instances; after the 1st week it was reasonably constant except in one subject in the last 2 weeks when he was nearing normal body fatness and was probably breaking down lean tissue. He was the only subject in negative nitrogen balance during these weeks. One subject who exercised most appeared to be retaining small amounts of potassium in the last 3 weeks of reduction while he was also retaining a fair amount of nitrogen. Po-

tassium losses appeared to approximately parallel weight losses in subjects, period by period.

Blood lipids

Limited data are available on blood lipid trends in weight reduction as compared with weight maintenance. In general, the blood lipids during weight reduction as compared with two sets of values obtained during weight maintenance showed no clear-cut pattern by diet group. Cholesterol values tended to decrease a bit with *diet A*. For *diets B* and *C*, in each case for two of the three subjects, cholesterol tended to increase and for one, to decrease. There was a little more tendency for total lipids to rise for subjects on *diet C* (lowest carbohydrate and greatest weight loss) than for those of *diet A* and to some slight extent than *diet B*. Serum phospholipids did not increase in any group. Triglycerides tended to drop in two of three cases on both *diets B* and *C*. Esterified fatty acids tended to decrease or be the same on *diets A* and *B* and were slightly up in one case on *diet C*.

Subjects' responses

Except under circumstances of unusual physical activity, after the first week hunger was not a problem to any of the subjects. Six of the eight commented on a feeling of tiredness or weakness. This was true for all three subjects on *diet C*, two on *diet B* and one on *diet A*. The subjects on *diet C* expressed a desire for more roughage, especially salads and vegetables.

Discussion

The literature with regard to the effects of the level of carbohydrate and of fat in the diet on rate of weight loss has been adequately reviewed in this journal (9). The supposed superiority of an isocaloric, low carbohydrate diet in promotion of weight loss has been explained by sodium and fluid excretion in what often have been very short-term studies. Total body water techniques do not seem to be sufficiently precise to measure the changes in fluid balance.

In the current practical study using three

levels of low carbohydrate diets of isocaloric, isoprotein content, some differences in average weight loss have been experienced over a 9-week period with decreasing levels of carbohydrate intake. No adequate explanation can be offered. These were students pursuing their normal activities. Groups were matched originally in terms of caloric requirements for weight maintenance over a three-week period and percent body weight as fat. Differences in energy expenditure might be an explanation, though retrospective comparisons via questionnaire at the conclusion of the study did not appear to indicate that this was true. There were no outstanding differences in nitrogen, sodium, or potassium balances among the diet groups. The outstanding difference between diet groups was in the daily excretion of ketone bodies in the urine, which increased with decreasing carbohydrate, and on the lowest carbohydrate level continued in abundance throughout the study. Heavy loss of ketone bodies on the most restricted carbohydrate intake may well have contributed to the greater weight losses; however, it is unlikely to be a total explanation.

In terms of practical interests, in retrospect it would appear that of the low carbohydrate diets used in this study, the one at the 104-g carbohydrate level might be the most suitable for long-term use for a number of reasons: *a*) good weight loss may be achieved; *b*) a more varied and nutritionally adequate diet might be planned; *c*) there is less loss of ketone bodies in the urine and less danger of loss of base with the potential for acidosis; *d*) there may be less likelihood of adverse effects on blood lipids; and *e*) there would be an easier transition from reduction to a normal weight maintenance diet.

From the appearance of ketone bodies in the urine over more than a transient period, it would appear that the carbohydrate level on the 1,800-kcal, 115-g protein diet probably should be slightly above 60 g.

Summary

Moderately obese young college men pursuing their usual activities were studied first during a 3-week prereduction weight main-

tenance period and subsequently were distributed into three isocaloric, isoprotein diet subgroups, which varied as to level of carbohydrate in the diet. On the 1,800-kcal reduction diet consumed over a 9-week period, *diet A* contained 104 g carbohydrate/day; *diet B*, 60 g; *diet C*, 30 g. The three-man subgroups were matched as closely as possible on the basis of maintenance caloric requirement and percent body weight as fat.

Weight loss, fat loss, and percent weight loss as fat appeared to be inversely related to the level of carbohydrate in the isocaloric, isoprotein diets. No adequate explanation can be given for weight loss differences.

There were no outstanding differences in nitrogen, sodium, or potassium balances among the diet groups. The little effect on blood lipids that was observed was probably most favorable to the highest carbohydrate diet group *A*.

The outstanding difference among diet groups was in the daily urinary excretion of ketone bodies. Although initially all subjects showed some ketone bodies in the urine, the bodies increased with decreasing carbohydrate and the urine continued to show them longer (throughout the 9-week period) and in greater abundance on the most restricted carbohydrate intake.

Any of the low carbohydrate levels in the reduction diet under study were effective in controlling hunger.

From a practical point of view, it would appear that of the low carbohydrate diets used, the one at the 104-g level would be most suitable for long-term use for the reasons cited.

From the appearance of ketone bodies in the urine over a more than transient period, it would appear that the carbohydrate level on the 1,800-kcal, 115-g protein diet should be slightly above 60 g. ☹

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