Body fat distribution and non-insulin-dependent diabetes: comparison of a fiber-rich, high-carbohydrate, low-fat (23%) diet and a 35% fat diet high in monounsaturated fat


ABSTRACT The effects of a fiber-rich, high-carbohydrate, low-fat (HCLF) diet and a modified-fat (MF) diet high in monounsaturated fat on body fat distribution were examined by dual-energy X-ray absorptiometry (DXA) in 16 subjects with non-insulin-dependent diabetes (NIDDM) during a randomized crossover study. Subjects lost similar amounts of body fat consuming the HCLF and MF diets (−0.83 ± 0.37 and −0.87 ± 0.40 kg, respectively) despite a marked difference in total fat consumption. With the MF diet, the ratio of upper- to lower-body fat (UF:LF) remained unchanged because fat was lost proportionately from the upper and lower body. In contrast, with the HCLF diet, a disproportionate loss of lower-body fat caused the UF:LF to increase. The effects of diet on regional body fat loss were significant (P < 0.05, two-factor repeated-measures ANOVA).


KEY WORDS Non-insulin-dependent diabetes, monounsaturated fat, carbohydrate, body weight, body composition, regional fat distribution, upper-body fat, lower-body fat

INTRODUCTION

Non-insulin-dependent diabetes (NIDDM) is associated with an increased risk of cardiovascular disease (CVD) (1). Well-established recommendations for dietary treatment (2, 3) are to reduce the intake of saturated fat because saturated fat has been long known to elevate total blood cholesterol (4, 5). Debate has arisen, however, over the best way to replace the energy lost to decreased consumption of saturated fat (6, 7). Early recommendations were to consume a diet high in carbohydrate and fiber and low in both saturated and total fat (2). More recently, concerns have been expressed that a high-carbohydrate, low-fat (HCLF) diet may adversely affect glycemic and lipid control (6, 7) unless the carbohydrate consumed is also rich in dietary fiber (7-9). As an alternative, the modified-fat (MF) diet has been advocated, in which saturated fat is replaced by monounsaturated fat rather than by carbohydrate (6, 10-12).

The MF diet is not a low-fat diet and although several studies indicate beneficial metabolic effects (6), less is known about its longer-term effects on body fat. Most persons with NIDDM are overweight and have a characteristically high deposition of fat in the abdominal region (13). High amounts of abdominal fat contribute to the development of metabolic aberrations, as was reported for white American women (14) and men in the Normative Aging Study (15). In NIDDM, abdominal fat is associated with an increased risk of cardiovascular disease (16).

Dual-energy X-ray absorptiometry (DXA) is a relatively new technique that not only allows fast, precise measurement of body fat tissue mass (FTM) and lean tissue mass (LTM) (17), but will also allow assessment of regional body fat (17, 18). In the present study we used DXA and anthropometry to examine the effects of HCLF and MF diets on body composition and regional fat distribution in subjects with NIDDM in a randomized crossover study in which each diet was followed for 3 mo.

SUBJECTS AND METHODS

Subjects

Sixteen subjects (6 men, 10 women) completed the dietary study, which was approved by the Ethics Committees of the Geelong Hospital and Deakin University. All gave written informed consent. The subjects were aged 61.8 ± 1.8 y and had a mean body mass index (BMI; in kg/m²) of 28.1 ± 0.7. Five subjects had NIDDM controlled by diet alone and 11 were taking low-dose oral hypoglycemic medication (glipizide, glibenclamide, metformin, or tolbutamide). All women were postmenopausal. Mean time from diagnosis of diabetes in these subjects was 7.3 ± 2.7 y.

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2 Supported by a grant from Diabetes Australia. The International Olive Oil Council and MeadowLea Foods Australia provided study foods.

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Study design and composition of the diets

Studies were conducted on an outpatient basis. After an initial baseline period of 1 mo, during which subjects followed their usual diet, test diets were prescribed in a random cross-over design for 3 mo each with a 1-mo intervening washout period. Subjects were given a set of food scales and detailed instructions from a dietitian for recording dietary intake. Subjects completed 7-d weighed food records during the initial baseline period (two records) and at monthly intervals during each diet (three records). Test diets provided the same amount of energy as the subject’s usual diet as determined in the initial baseline period. Usual alcohol intake and physical activity patterns were maintained. The HCLF diet was designed to supply 20% of its energy as fat and 59% as fiber-rich carbohydrate. The MF diet was designed to supply 40% of its energy as fat, one-half as monounsaturated fat. Thus, 13% of energy was supplied as olive oil (Bertolli Extra Light; Lucca, Italy, made available by the International Olive Oil Council) and 7% of energy as olive oil–based margarine [66.2% oleic acid (18:1) (19)] (MeadowLea Foods Ltd, Mascot, Australia). Both diets were similar in protein content (20% of energy) and were low in cholesterol (< 300 mg/d). Fiber intake was prescribed at 4.5 g/MJ for the HCLF diet but not specified for the MF diet. The 7-d dietary records were analyzed by using the computer-based System for On Line Dietary Analysis (SODA), version 5.0, based on the Australian nutrient composition database NUTTAB90 (20). Unlisted foods were coded as a listed food of very similar composition.

Body composition

Subjects were weighed without shoes and while wearing light clothing or underwear. Weight was measured on 2 d, each 4 d apart, at the beginning and end of each dietary period and an average value was then used for statistical analysis. Other anthropometric measurements were made once at each time point. Body weight was determined to the nearest 0.1 kg on a digital scale and body height was measured to the nearest 0.1 cm by using a wall-mounted stadiometer. BMI was calculated as weight (kg) divided by height (m) squared. Basal energy expenditure (BEE) was calculated from sex, age, and body weight with the Schofield equation (21).

Measurement of body circumferences and skinfold thicknesses was undertaken by the same individual, who was blinded to previous data collected but not to treatment. Waist and hip circumferences were measured directly on the skin or over light underwear by following accepted procedures (22). Briefly, the waist circumference was measured as the smallest horizontal narrowing in the area between the lower rib margin and the iliac crest. The measurement was taken at the end of gentle expiration, with the measurer facing the subject. The hip circumference was taken as the maximum extension of the buttocks with the measurer standing on one side of the subject.

Subscapular and suprailiac skinfold thicknesses were measured with calipers (Holtain Ltd, Crymych, United Kingdom) directly on the skin by following established procedures (22). Measurements were made three times at each body site at each critical time point during the study, and mean values were used for statistical analysis. The CV for measurement of the sum of subscapular and suprailiac skinfold thicknesses was 1.7%.

DXA measurements

At the beginning and end of each diet period DXA measurements were performed with a total-body scanner (DPX-L; Lunar Corporation, Madison, WI). This instrument uses a constant potential X-ray source with a K-edge cerium filter designed to produce a dual-energy beam at energies of 38 and 70 keV. The scanner was calibrated daily against the standard calibration block supplied by the manufacturer to control for possible baseline drift. Each subject was scanned at a similar time in the early morning, while fasting, to avoid diurnal change in body composition (23). Scans were completed in 15 min and gave a radiation dose of 3–5 μSv. Total-body bone mineral content (BMC), FTM and LTM were derived according to computer algorithms provided by the manufacturer (DPX-L software version 1.3 Y; Lunar Corporation). The FTM represents the sum of fatty elements in all fat tissue whereas the LTM represents the sum of all chemically fat-free soft tissue elements (24).

Default software readings provided lines defining body regions. These lines were adjusted as described previously by Ley et al (18) to delineate the trunk by an upper horizontal border below the chin, vertical borders lateral to the ribs, and a lower border formed from two oblique lines passing through the hip joints. The leg region was then demarcated as the area below the two lines through the hip joints. The terminology used previously by Ley et al was followed, ie, FTM of the trunk is referred to as upper-body fat (UF) whereas FTM of the leg and hips is referred to as lower-body fat (LF). FTM on the arms is referred to as arm fat, delineated by the vertical borders of the trunk. Mean precisions ± SEs as determined by five repeated measurements taken on four healthy volunteers and one subject with NIDDM over a period of 2 wk were 2.0 ± 0.4% for total-body fat, 2.6 ± 0.6% for FTM, 1.3 ± 0.4% for BMC, 2.8 ± 0.6% for UF, 3.0 ± 0.7% for LF, and 4.3 ± 1.4% for arm fat.

Plasma fatty acid analysis

Fasting blood samples taken at the beginning and end of each dietary period were collected into tubes with heparin fluoride. Lipids were extracted from plasma with chloroform-methanol and the cholesteryl ester fractions were isolated by thin-layer chromatography. Methyl esters were formed by saponification followed by transesterification in BF₃ in methanol and then analyzed by capillary gas-liquid chromatography as described previously (25).

Statistical analysis

Relations between UF and LF and other variables were established with Pearson’s correlation coefficient. Analyses of variance (ANOVA) and descriptive statistics were performed by using the statistical software package MINITAB (release 8, Macintosh version; Minitab Inc, State College, PA). Dietary consumption during the subjects’ usual diets and during the two prescribed diets was compared by a single repeated-measures ANOVA followed by a paired t test using the Bonferroni correction. Changes in cholesteryl ester percentages, total-body LTM or FTM, upper- or lower-body fat, or in anthropometric measurements during the HCLF and MF diets were compared by a two-factor repeated-measures ANOVA with diet and time as the two factors. In cases where a signif-
significant interaction was noted between diet and time, an additional repeated-measures ANOVA was performed, with time and diet as two within-subject factors and sequence (the order in which diets were consumed) as a between-subjects factor. These analyses were performed by using the statistical software package SPSS for Windows 6.0 (SPSS Inc, Chicago). Results are expressed as the mean ± SE and the level of statistical significance is taken as < 0.05 (two-tailed).

RESULTS

Dietary compliance

The mean compositions of the two study diets consumed over 3 mo, as reported by the subjects, are shown in Table 1. The study diets and the subjects’ usual diets differed significantly in protein, fat, carbohydrate, and dietary fiber contents but did not differ in energy content or in the ratio of reported energy intake to BEE (P < 0.005, one-way repeated-measures ANOVA). Subjects assigned to the HCLF diet consumed significantly less total fat than they had during their usual diets (P < 0.001, paired t test with Bonferroni correction) and had significantly lower intakes of saturated, monounsaturated, and polyunsaturated fats (P < 0.001, P < 0.017, and P < 0.017, respectively; paired t test with Bonferroni correction). Total fat intake on the HCLF diet was near prescribed amounts (23% of energy compared with 20%) although subjects on this diet reported a lower intake of carbohydrate and a higher intake of protein than had been recommended. Subjects on the MF diet consumed significantly less saturated fat and significantly more monounsaturated fat than they had during their usual diets (P < 0.01 and P < 0.001, respectively; paired t test with Bonferroni correction). Intakes of monounsaturated fat and carbohydrate were at prescribed values (20% and 40% of total energy, respectively). The HCLF and MF diets differed significantly in reported intake of total fat, monounsaturated fat, carbohydrate, and dietary fiber (P < 0.001, P < 0.001, P < 0.001, and P < 0.005, respectively, paired t test with Bonferroni correction).

As a second estimate of dietary compliance, the fatty acid composition of plasma cholesteryl esters was determined before and after each of the two diets. These data are presented in Table 2. The proportion of linoleic acid (18:2n–6) in cholesteryl esters decreased by 2.6% during the HCLF diet and by 0.4% during the MF diet. Analysis of the data showed a significant effect of time but not diet although the interaction between time and diet showed a trend toward significance (P < 0.05 and P = 0.09, two-factor repeated-measures ANOVA). At the end of the MF diet, the proportions of oleic acid and arachidonic acid (20:4n–6) tended to be higher than at the end of the HCLF diet, although these changes, like the changes seen in other fatty acids, were not statistically significant.

Change in soft tissue as measured by DXA after the study diets

Total body scans indicated that although the test diets differed in amount and type of dietary fat, both had very similar effects on total body fat (Table 3). Subjects lost similar amounts of FTM on both diets whereas LTM was retained. Thus, time but not diet had a significant effect (P < 0.05, two-way repeated-measures ANOVA) on FTM.

Despite similar losses of total-body FTM, the two diets differed in their effect on regional body fat distribution. This is indicated by the change in the UF:LF as presented in Table 3 and Figure 1. During the HCLF diet the UF:LF increased by 0.21 ± 0.08 whereas during the MF diet it remained unchanged. Analysis of these data indicated a significant effect of diet but not of time and a significant diet × time interaction (P < 0.05 and P < 0.01, respectively, two-factor repeated-measures ANOVA).

The study had a randomized crossover design. A carryover effect due to differing sequences of diets may have influenced the diet × time interaction. When subjects started their first diet, there was little difference in the UF:LF between those starting the HCLF diet (2.08 ± 0.17) and those starting the MF diet (2.13 ± 0.20). In contrast, at the start of the second diet, the UF:LF was higher for those who had just completed the HCLF diet (2.41 ± 0.17) than for those who had just completed the MF diet (1.93 ± 0.18).

An additional repeated-measures ANOVA was thus undertaken, with time and diet as within-subject factors and with sequence (the order in which diets were followed) as a between-subjects factor. This indicated that the UF:LF was

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**Table 1**

Dietary consumption by 16 subjects with non-insulin-dependent diabetes mellitus (NIDDM) following their usual diet; a high-carbohydrate, low-fat (HCLF) diet; or a modified-fat (MF) diet

<table>
<thead>
<tr>
<th></th>
<th>Usual diet</th>
<th>HCLF diet</th>
<th>MF diet</th>
<th>P²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (% of energy)</td>
<td>23 ± 0.8</td>
<td>25 ± 0.7</td>
<td>22 ± 0.4</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Total fat (% of energy)</td>
<td>31 ± 1.6</td>
<td>23 ± 1.2</td>
<td>35 ± 1.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Saturated fat</td>
<td>13 ± 0.6</td>
<td>9 ± 0.5</td>
<td>10 ± 0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Monounsaturated fat</td>
<td>12 ± 0.6</td>
<td>9 ± 0.6</td>
<td>20 ± 0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Polyunsaturated fat</td>
<td>6 ± 0.5</td>
<td>4 ± 0.3</td>
<td>5 ± 0.1</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Carbohydrate (% of energy)</td>
<td>44 ± 1.2</td>
<td>49 ± 1.2</td>
<td>40 ± 1.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Alcohol (% of energy)</td>
<td>1 ± 0.5</td>
<td>1 ± 0.5</td>
<td>1 ± 0.3</td>
<td>NS</td>
</tr>
<tr>
<td>Fiber (g/MJ)</td>
<td>4.0 ± 0.2</td>
<td>4.8 ± 0.2</td>
<td>4.0 ± 0.2</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Energy (MJ)</td>
<td>6.9 ± 0.6</td>
<td>6.5 ± 0.6</td>
<td>6.6 ± 0.5</td>
<td>NS</td>
</tr>
<tr>
<td>Energy (MJ)/basal energy expenditure</td>
<td>1.17 ± 0.10</td>
<td>1.03 ± 0.08</td>
<td>1.05 ± 0.07</td>
<td>NS</td>
</tr>
</tbody>
</table>

1 ± SE; n = 16.
2 One-way repeated-measures ANOVA.
3,5,6 Significantly different from usual diet (paired t test with Bonferroni correction): 3 P < 0.17, 5 P < 0.001, 6 P < 0.01.
4,7 Significantly different from HCLF diet (paired t test with Bonferroni correction): 4 P < 0.001, 7 P < 0.005.
TABLE 2
Fatty acid composition of plasma cholesteryl esters in 16 subjects who followed a high-carbohydrate, low-fat (HCLF) or a modified-fat (MF) diet for 12 wk.

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>HCLF diet</th>
<th>MF diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before %</td>
<td>After %</td>
</tr>
<tr>
<td>14:0</td>
<td>0.7 ± 0.04</td>
<td>0.7 ± 0.03</td>
</tr>
<tr>
<td>16:0</td>
<td>13.1 ± 0.3</td>
<td>14.1 ± 0.6</td>
</tr>
<tr>
<td>18:1</td>
<td>2.9 ± 0.3</td>
<td>3.0 ± 0.3</td>
</tr>
<tr>
<td>18:0</td>
<td>1.0 ± 0.05</td>
<td>1.0 ± 0.08</td>
</tr>
<tr>
<td>18:1</td>
<td>18.7 ± 0.5</td>
<td>18.1 ± 0.6</td>
</tr>
<tr>
<td>18:2n-6</td>
<td>47.2 ± 1.0²</td>
<td>44.6 ± 1.3</td>
</tr>
<tr>
<td>18:3n-3</td>
<td>0.5 ± 0.04</td>
<td>0.6 ± 0.08</td>
</tr>
<tr>
<td>20:3n-6</td>
<td>0.7 ± 0.06</td>
<td>0.7 ± 0.06</td>
</tr>
<tr>
<td>20:4n-6</td>
<td>5.8 ± 0.3</td>
<td>5.9 ± 0.3</td>
</tr>
<tr>
<td>20:5n-3</td>
<td>0.7 ± 0.05</td>
<td>0.8 ± 0.09</td>
</tr>
<tr>
<td>22:6n-3</td>
<td>0.3 ± 0.01</td>
<td>0.4 ± 0.03</td>
</tr>
</tbody>
</table>

¹ ± SE.
² Significantly affected by time (P < 0.05) but not by diet (two-way repeated-measures ANOVA).

Evident between diet and sequence (P < 0.005, two-way repeated-measures ANOVA).

Data for the diets were combined to allow an examination for relations between the UF:LF and the proportion of fatty acids in serum. As seen in Figure 2, the proportion of oleic acid in plasma cholesteryl esters correlated negatively and significantly (r = −0.361, P < 0.01) with the UF:LF as measured by DXA. Similar relations were not seen with saturated fatty acids (14:0, 16:0, or 18:0) or with other unsaturated fatty acids (16:1, 18:2n-6, 18:3n-3, 20:3n-6, 20:4n-6, 20:5n-6, or 22:6n-3).

Change in anthropometric measurements after the study diets
Changes in anthropometric measurements after the study diets are given in Table 4. Subjects experienced similar losses in body weight and decrease in BMI for both the HCLF and MF diets. Analysis by ANOVA showed a significant effect of time but not of diet in each case (P < 0.005, two-way repeated-measures ANOVA). In addition, both diets were associated with a decrease in waist circumference and in the sum of the suprailiac and subscapular skinfold thicknesses. Again, analysis showed a significant effect of time but not of diet (P < 0.01 in each case, two-way repeated-measures ANOVA). Note, however, that during the MF diet the change in the sum of subscapular and suprailiac skinfold thicknesses was found to be positively correlated with change in UF by DXA (r = 0.59, P < 0.05; data not shown) whereas during the HCLF diet this change related very weakly to change in UF as measured by DXA (r = 0.19, NS; data not shown).

DISCUSSION
The major finding that we report in this study is that although effects on total-body fat loss were similar, the HCLF and MF diets had different effects on the regional loss of body fat in subjects with NIDDM, (ie, fat loss occurred disproportionately, with a greater loss from the lower body with the HCLF diet).

TABLE 3
Change in soft tissue mass as determined by dual-energy X-ray absorptiometry total body scans in 16 subjects who followed a high-carbohydrate, low-fat (HCLF) or a modified-fat (MF) diet for 12 wk.

<table>
<thead>
<tr>
<th></th>
<th>HCLF diet</th>
<th>MF diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Total FTM (kg)²</td>
<td>25.48 ± 1.61</td>
<td>24.65 ± 1.84</td>
</tr>
<tr>
<td>Total LTM (kg)</td>
<td>47.35 ± 2.31</td>
<td>47.25 ± 2.19</td>
</tr>
<tr>
<td>Upper-body fat mass (kg)</td>
<td>14.28 ± 0.91</td>
<td>14.51 ± 1.13</td>
</tr>
<tr>
<td>Lower-body fat mass (kg)³</td>
<td>7.56 ± 0.63</td>
<td>6.66 ± 0.52</td>
</tr>
<tr>
<td>Arm fat mass (kg)</td>
<td>2.26 ± 0.20</td>
<td>2.17 ± 0.22</td>
</tr>
<tr>
<td>Upper-body fat: lower-body fat ²</td>
<td>2.00 ± 0.12</td>
<td>2.21 ± 0.10</td>
</tr>
</tbody>
</table>

¹ ± SE. FTM, fat tissue mass; LTM, lean tissue mass.
² Significantly affected by time but not by diet, P < 0.05. No interaction between diet and time (two-way repeated-measures ANOVA).
³ Significantly affected by time, P < 0.05; significant interaction between time and diet, P < 0.005, and between diet and sequence, P < 0.005 (two-way repeated-measures ANOVA).
⁴ Significantly affected by diet but not by time, P < 0.05, significant interaction between time and diet, P < 0.01, and between diet and sequence, P < 0.005 (two-way repeated-measures ANOVA).
An MF diet has been advocated in recent years for treatment of NIDDM because of its observed beneficial effects on metabolic control (6, 10–12). Concerns remain, however, that the higher fat content of this diet may exacerbate tendencies for persons with NIDDM to accumulate body fat. Recently, we reported on a randomized crossover study in which subjects followed an HCLF or MF diet for 3 mo while living at home (19). During the MF diet subjects did not gain weight but rather lost a minor amount of weight, similar to that which occurred during the HCLF diet. The present study extends these findings, reporting that subjects following MF and HCLF diets had similar losses of total body fat as measured by DXA, and similar minor weight losses, again over a 3-mo period (Tables 3 and 4). Self-reported energy intake remained similar during each diet (Table 1). This result agrees with those of metabolic ward (10) and outpatient (11, 12) studies of shorter duration, in which MF diets were also reported not to generate weight gain.

DXA now allows for safe, relatively inexpensive measurement of body fat with high accuracy (24, 26, 27) but few studies (28) have used the technique to assess changes in body fat with changes in diet. In our study, use of DXA to assess changes in body composition in subjects with NIDDM led to the unexpected and potentially significant finding that MF and HCLF diets differ in their effects on the regional loss of body fat. The MF diet was associated with a proportionate loss from both the upper and lower body, such that the UF:LF remained unchanged (Figure 1). In contrast, during the HCLF diet fat was lost disproportionately from the lower body such that the UF:LF increased. Analysis of the data by two-way repeated-measures ANOVA indicated that diet had a significant effect (P < 0.05). In addition, the UF:LF was significantly affected by an interaction between sequence (the order in which subjects followed the two diets) and diet (P < 0.005, two-way repeated-measures ANOVA). The HCLF diet thus had a carryover effect not overcome by the 1-mo break between diets.

In this study, changes in regional body fat loss as detected by DXA were not mirrored by detection of any significant change attributable to diet in anthropometric measurements (waist and hip circumferences and truncal skinfold thicknesses) (Table 4). This may however, be due to the low magnitude of the total fat loss and the relative imprecision of anthropometry in detecting changes in regional body fat (29).

The finding that MF and HCLF diets differ in their effects on regional body fat distribution as determined by DXA was unexpected but is not implausible. Body fat at different sites is known to be heterogenous, differing in adipocyte size, capacity of adipocytes to replicate and differentiate, hormone responsiveness, patterns of vascularization and sympathetic innervation, as well as in lipid and carbohydrate metabolism (29). How dietary change may cause different effects on regional fat loss as observed here in subjects with NIDDM, is as yet unknown, although it may perturb complex neuroendocrine controls governing regional adipose tissue metabolism (30, 31). For example, in obese premenopausal women the percentage of UF measured by DXA was found to correlate positively, whereas the proportion of LF is correlated negatively, with concentrations of the androgen dehydroepiandrosterone (32).

The adverse change in the UF:LF seen in this study in subjects with NIDDM during the HCLF diet is of interest in relation to the well-known associations between increased amounts of abdominal fat and the development of aberrations of metabolic control (29), and is consistent with the deterioration in glycemic control, increased triacylglycerol, and lowered concentrations of high-density-lipoprotein cholesterol reported previously during HCLF diets (6, 10–12).

In our study, dietary compliance was followed by 7-d food records and also by analysis of the linoleic acid content of plasma cholesteryl esters. During the HCLF diet, subjects reported a decreased mean fat intake (from 31% to 23% of total energy) and a decrease in the intake of polyunsaturated fatty acids (from 6% to 4% of total energy) relative to their usual diets. The reported decrease in dietary intake of linoleic acid was matched by a fall from 47.2 ± 1.0% to 44.6 ± 1.1% in the proportion of linoleic acid found in the plasma cholesteryl esters of subjects on this diet. It was well established that the concentration of linoleic acid in the plasma cholesteryl ester fraction is particularly sensitive to the dietary linoleic acid intake (25, 33–36). The data on change in linoleic acid concentrations in plasma cholesteryl esters in subjects on the HCLF diet thus provide evidence that this group did indeed reduce their total fat and linoleic acid intakes.

In subjects consuming the MF diet, the reported intake of monounsaturated fatty acids increased in comparison with the
usual diet (from 12% to 20% of total energy, Table 2) but this change was mirrored by only a slight increase (0.4%) in the proportion of oleic acid in the plasma cholesteryl ester fraction. This is consistent with the data of both Sanders et al (34) and Sarkkinen et al (36). Sanders et al showed that even when two-thirds of the dietary fat was derived from olive oil, there was little change in the proportion of oleic acid in the plasma cholesteryl ester fraction over a 2-wk period. In the study by Sarkkinen et al, there was no change in the proportion of oleic acid in the plasma cholesteryl esters of subjects fed a diet enriched with monounsaturated acids for a period of 6 mo.

Examination of the proportion of oleic acid in plasma cholesteryl esters, did however, reveal a significant negative correlation ($r = -0.361, P < 0.01$) with the UF:LF (Figure 2). Similar relations were not seen with any of the other fatty acids. This finding was of interest in relation to the finding in a recent prospective Swedish study, that although development of diabetes is significantly predicted by a high proportion of 20:3n−6, 16:1, and oleic acid in plasma cholesteryl esters, a higher proportion of oleic acid in serum is associated with decreased diabetes risk (37).

The results of the present study indicate that HCLF and MF diets may differ in their effects on regional loss of body fat. Our unexpected finding was that a HCLF diet may cause a disproportionate loss of lower-body fat resulting in an increased UF:LF. Evidence from analysis of the linoleic acid content of plasma cholesteryl esters suggests that subjects did adhere to a reduced-fat diet low in linoleic acid. These findings are of potential importance and should be investigated further, particularly in circumstances in which a greater weight loss is evident.

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REFERENCES


