Diabetologia (1982) 22: 46–50

Diabetologia

Lipoprotein Lipase Activity and Serum Lipoproteins in Untreated Type 2 (Insulin-Independent) Diabetes Associated with Obesity

M.-R. Taskinen, E.A. Nikkilä, T. Kuusi and K. Harno

Third Department of Medicine, University of Helsinki, Helsinki, Finland

Summary. Serum lipoproteins and the heparin-releasable lipoprotein lipase (LPL) activity of adipose tissue and skeletal muscle were measured in 36 untreated obese patients with Type 2 (insulin-independent) diabetes and the values were compared with those of non-diabetic subjects of similar age, sex and relative body weight. In diabetic men, the LPL activity of adipose tissue was significantly reduced when expressed per tissue weight or per fat cell ($p < 0.01$). Diabetic females had slightly but not significantly lower LPL activity in adipose tissue than the non-diabetic females. The muscle LPL activity was similar in diabetic and non-diabetic subjects of both sexes. When the diabetic men were classified according to fasting blood glucose, the patients with high glucose levels had lower adipose tissue LPL activity than those with moderate hyperglycaemia. In both diabetic and non-diabetic subjects, there was a significant positive correlation between HDL cholesterol concentrations and adipose tissue LPL activity. It is concluded that Type 2 diabetes influences adipose tissue LPL activity and plasma lipoprotein concentrations and that this effect is superimposed on the similar changes produced by obesity alone.

Key words: Cholesterol, triglyceride, VLDL, LDL, HDL, lipoprotein lipase, adipose tissue, skeletal muscle, obesity, Type 2 (insulin-independent) diabetes.

Serum lipoprotein levels are often altered in Type 2 (insulin-independent) diabetes although the reported data are not totally consistent. Cholesterol and triglyceride concentrations in whole serum and in very low density lipoproteins (VLDL) have been shown to be either increased [1, 2] or normal [3], whereas high density lipoprotein (HDL) cholesterol values are slightly reduced [1] or unchanged [3]. The mechanisms behind these changes are not fully understood. Since simple obesity also influences serum triglyceride, VLDL and HDL levels [4, 5], it is often difficult to separate out lipoprotein alterations caused by diabetes, obesity or other factors. The VLDL production rate is enhanced in both Type 2 diabetes and obesity [5–9]. The increase of VLDL synthesis is thought to result from hyperinsulinism caused by peripheral insulin resistance and to account for the elevation of serum triglyceride [9].

The lipoprotein alterations of diabetes may also be caused by changes in the activity of lipoprotein lipase. This enzyme participates in the regulation of plasma levels of both VLDL and HDL [10]. The main sources of lipoprotein lipase activity are vascular beds of adipose tissue and skeletal muscle. It is well established that adipose tissue lipoprotein lipase activity is controlled by insulin; the enzyme activity being low in insulin deficiency [11] and during caloric restriction [12]. In untreated Type 2 diabetes the lipoprotein lipase activity of adipose tissue is reported to be reduced compared with non-diabetic subjects [13, 14]. However, in these studies, the diabetic patients were not adequately matched with non-diabetic subjects for weight [13] and sex [14] both of which are known to affect adipose tissue lipoprotein lipase activity [5, 10, 15]. Furthermore, in the study of Pykälistö et al. [13], some of the non-diabetic control subjects had definite hyperlipidaemia.

This study aims to assess the heparin-releasable lipoprotein lipase activity of adipose tissue and skeletal muscle, serum lipids and lipoproteins in untreated Type 2 obese diabetics subjects and in normolipidaemic, non-diabetic subjects carefully selected to match for age, weight and sex.

0012-186X/82/0022/0046/$01.00

Table 1. Age, relative body weight, fasting blood glucose and plasma insulin in obese non-diabetic and diabetic subjects

	No. of subjects	Age (years)	Relative body weight (%)	Blood glucose (mmol/l)	Plasma insulin (mU/l)
Males					
Non-diabetic	27	38 ± 2	156 ± 7	4.4 ± 0.1	21 ± 3
Diabetic	25	43 ± 2	157 ± 6	8.9 ± 0.7	32 ± 3[b]
Females					
Non-Diabetic	22	40 ± 2	176 ± 9	4.3 ± 0.1	18 ± 2
Diabetic	11	46 ± 3	179 ± 12	8.9 ± 1.1	32 ± 8[a]

The results are expressed as mean ± SEM
[a] $p < 0.05$, [b] $p < 0.01$ diabetic versus non-diabetic obese men or women

Subjects and Methods

Subjects

The clinical material included 36 obese diabetic (11 women, 25 men) and 49 obese non-diabetic (22 women, 27 men) subjects. The characteristics of the subjects are presented in Table 1. Relative body weight was calculated using Metropolitan Life Insurance Tables [16]. Obesity was defined as relative body weight > 120%. Diabetes was diagnosed when either fasting blood glucose exceeded 6.7 mmol/l or both the 2½ h or 1 h values during an oral glucose tolerance test were > 10 mmol/l [17]. The diabetic patients were newly diagnosed and untreated. All control subjects had fasting blood glucose < 5.6 mmol/l and normal oral glucose tolerance test (1 h values and maximal value < 10.0 mmol/l and 2 h value < 6.7 mmol/l) [17] and were normolipidaemic (fasting serum triglyceride < 2.0 mmol/l and cholesterol < 7.5 mmol/l). Twenty-three of the 37 diabetic subjects had Type 4, four had Type 2b and three subjects Type 5 hyperlipoproteinaemia [18]. All subjects had normal liver, thyroid and renal function according to laboratory tests and none was known to use regularly alcohol or any drug affecting lipid metabolism.

The subjects were studied as out-patients on two consecutive mornings. They abstained from all alcoholic beverages for 3 days before the study. On the first experimental morning, venous blood was taken for the lipid analyses after a 12-h overnight fast. Thereafter, an oral glucose tolerance test (1 g glucose/kg body weight, maximal dose 100 g glucose) was performed on each subject. Tissue biopsies for the assay of heparin-releasable lipoprotein lipase were taken on the following morning, again after a 12-h fast. The purpose and possible adverse effects were explained to each subject and informed consent obtained.

Assay of Tissue Lipoprotein Lipase Activities

Heparin-releasable lipoprotein lipase activity was measured from needle biopsy specimens of adipose tissue and skeletal muscle. Samples of SC adipose tissue were taken from the gluteal region and from skeletal muscle on the lateral midpoint of the thigh. The skin at both biopsy sites was anaesthetized with 1% lignocaine. Tissue pieces were put into saline, rinsed, blotted, weighed and immediately assayed for heparin-releasable lipoprotein lipase activity [15]. The enzyme activity was expressed per weight of fresh tissue. For adipose tissue the activity is also given per fat cell and per estimated total body fat mass [19]. Total body fat mass was obtained by subtracting estimated lean body mass from actual weight [19]. The fat cell size was calculated from the average diameters of the adipocytes measured by microscopy. The number of fat cells was calculated by a Honeywell Bull 66/20 computer [20].

Chemical Analyses

Blood glucose [21] and plasma insulin [22] levels were determined from venous blood. The sensitivity of insulin assay was 2 mU/l and coefficient of variation 3%. Concentrations of cholesterol (enzymatic colorimetric method, kit 1873/3, Boehringer Mannheim, Diagnostica) and triglyceride [23] were measured from whole serum and from separated main lipoprotein fractions (chylomicrons, VLDL, LDL and HDL). If the serum showed turbidity or opalescence the chylomicrons were removed at the density of 1.006 g/ml by spinning for 30 min at 18,000 rev/min using a Type 50 Ti rotor (Beckman) in Sorvall OTD 15 preparative ultracentrifuge. Thereafter, VLDL was separated at the density of 1.006 g/ml by spinning for 18 h at 40,000 rev/min. LDL was isolated at the solvent density of 1.063 g/ml after spinning for 24 h at 42,000 rev/min [24]. The infranatant of the density 1.063 g/ml was taken to contain the HDL lipids.

Statistical Analyses

The results are expressed as mean ± SEM. Statistical analyses were carried out using computer programs for unpaired differences, unilinear regression and correlation analysis and for analysis of covariance.

Results

The average relative body weight was similar in diabetic and non-diabetic men and women, respectively (Table 1). The diabetic patients had significantly higher fasting plasma insulin levels ($p < 0.05$) than the non-diabetic controls (Table 1).

Serum Lipids and Lipoproteins

The diabetic subjects of both sexes had higher triglyceride, VLDL and LDL concentrations in serum than the respective non-diabetic subjects (Table 2). Total cholesterol and VLDL cholesterol levels were also elevated in the diabetic patients. In contrast, the HDL cholesterol level was decreased by 14% ($p < 0.01$) in diabetic men and by 25% ($p < 0.01$) in diabetic women compared with the respective control subjects (Table 2). When the diabetic men were grouped

Table 2. Triglyceride and cholesterol concentrations in whole serum and in lipoprotein fractions

	Males		Females	
	Non-diabetic	Diabetic	Non-diabetic	Diabetic
Triglyceride (mmol/l)				
Total	1.39 ± 0.06	3.87 ± 0.61[c]	1.09 ± 0.10	3.79 ± 0.94[c]
VLDL	0.88 ± 0.06	3.12 ± 0.48[c]	0.64 ± 0.09	3.03 ± 0.59[c]
LDL	0.34 ± 0.02	0.56 ± 0.03[c]	0.31 ± 0.02	0.54 ± 0.06[c]
HDL	0.17 ± 0.01	0.18 ± 0.07	0.15 ± 0.01	0.22 ± 0.03[a]
Cholesterol (mmol/l)				
Total	5.64 ± 0.18	6.54 ± 0.20[c]	5.56 ± 0.19	6.55 ± 0.80[a]
VLDL	0.55 ± 0.04	1.53 ± 0.19[c]	0.36 ± 0.04	1.76 ± 0.44[c]
LDL	3.95 ± 0.16	4.02 ± 0.26	3.94 ± 0.18	3.84 ± 0.44
HDL	1.14 ± 0.04	0.99 ± 0. 04[b]	1.26 ± 0.08	0.95 ± 0.07[b]

Results are expressed as mean ± SEM.
[a] $p < 0.05$, [b] $p < 0.01$, [c] $p < 0.001$ compared with non-diabetic men and women

Table 3. Heparin-releasable lipoprotein lipase activities of adipose tissue and skeletal muscle in obese non-diabetic and diabetic subjects

	Adipose tissue LPL activity			Skeletal muscle LPL activity
	per weight (μmol NEFA $g^{-1} h^{-1}$	per cell (pmol NEFA h^{-1} $cell^{-1}$)	per total body fat (mmol NEFA/h)	per weight (μmol NEFA $g^{-1} h^{-1}$)
Males				
Non-diabetic	2.16 ± 0.26	1.93 ± 0.26	84 ± 10	0.85 ± 0.10
Diabetic	1.36 ± 0.15[a]	1.08 ± 0.14[a]	63 ± 10	0.60 ± 0.10
Females				
Non-diabetic	4.86 ± 0.69	4.73 ± 0.59	203 ± 27	0.65 ± 0.08
Diabetic	3.39 ± 0.63	3.70 ± 0.73	160 ± 42	0.52 ± 0.12

Results are expressed as mean ± SEM.
[a] $p < 0.01$ compared with obese non-diabetic men

on the basis of fasting blood glucose, patients with blood glucose above 7.0 mmol/l (mean value 11.2 ± 0.7 mmol/l) had significantly higher VLDL triglyceride levels than those with lower fasting blood glucose values (mean 5.7 ± 0.2 mmol/l). Diabetic subjects with a fasting blood glucose > 7.0 mmol/l had significantly lower average HDL cholesterol levels than those with a fasting blood glucose < 7 mmol/l (0.92 ± 0.08 versus 1.08 ± 0.06 mmol/l, $p < 0.05$).

Tissue Lipoprotein Lipase Activities

The mean values of heparin-releasable adipose tissue lipoprotein lipase (AT-LPL) activity in diabetic patients and controls are shown in Table 3. Most diabetic men had AT-LPL activity below the mean value of non-diabetic men. The average AT-LPL activity of diabetic men was decreased by 37% ($p < 0.01$) per tissue weight and by 44% ($p < 0.01$) per fat cell. In diabetic women on the other hand, the range of individual AT-LPL values was similar to that of non-diabetic women. The mean AT-LPL activity of diabetic women was reduced by 30%/tissue weight and by 22%/fat cell, but these changes did not reach statistical significance (Table 3). The muscle LPL activity of diabetic patients of both sexes was similar to that of non-diabetic subjects (Table 3). When the diabetic patients were grouped by their fasting blood glucose using 7.0 mmol/l as the dividing point, AT-LPL activity of subjects with blood glucose > 7.0 mmol/l was 38% ($p < 0.05$) and skeletal muscle enzyme activity 34% (NS) lower than corresponding values in the less hyperglycaemic group, despite similar plasma insulin values (33 ± 5 versus 32 ± 4 mU/l).

Interrelations Between Body Weight, Blood Glucose, Serum Insulin, Lipoprotein Lipids and Tissue LPL Activities

In non-diabetic subjects, VLDL triglyceride was positively correlated with relative body weight ($r = 0.42$, $p < 0.01$) and basal plasma insulin levels ($r = 0.32$, $p < 0.05$), whereas HDL cholesterol showed an inverse correlation with relative body weight ($r = -0.48$, $p < 0.01$). In contrast, no correlation existed between these parameters in diabetic subjects. In both non-diabetic and diabetic subjects HDL cholesterol correlated inversely with VLDL triglyceride ($r =$

$-0.50, p < 0.001$ and $r = -0.53, p < 0.01$) but positively with adipose tissue LPL activity ($r = 0.44, p < 0.01$ and $r = 0.41, p < 0.05$). Furthermore, in diabetic subjects, HDL cholesterol showed a weak but significant negative correlation with blood glucose ($r = -0.38, p < 0.05$) and plasma insulin ($r = -0.34, p < 0.05$). In non-diabetic subjects, the positive correlation between HDL cholesterol and adipose tissue LPL activity was not influenced by relative body weight, blood glucose or plasma insulin. The correlation fell slightly with VLDL triglyceride as an independent variable ($r = 0.30, p < 0.05$). On the other hand, in the diabetic subjects the relationship between HDL cholesterol and adipose tissue LPL was weakened when blood glucose was taken into account ($r = 0.34$, NS). In the combined material, adipose tissue LPL activity was inversely correlated with blood glucose in men ($r = -0.35, p < 0.05$) but not in women ($r = -0.24$, NS).

Discussion

The present results show that obese men with Type 2 diabetes have lower heparin-releasable lipoprotein lipase activity in adipose tissue than non-diabetic men with similar relative body weight. Since the more severely diabetic men also had higher plasma insulin levels than the non-diabetic men, the fall of lipoprotein lipase activity cannot be attributed to insulin deficiency. It is likely that the low LPL activity represents one of the many consequences of insulin resistance. In contrast to adipose tissue, the skeletal muscle of diabetic men showed only a slight but non-significant decrease of heparin-releasable lipoprotein lipase activity. This difference between the two tissues may be due either to a lower degree of insulin resistance in muscle, or, more likely, a lower insulin sensitivity of muscle lipoprotein lipase [11, 12].

Diabetic women did not exhibit a significant reduction of adipose tissue lipoprotein lipase activity. The reasons for this sex difference are not apparent. A low adipose tissue lipoprotein lipase activity in Type 2 diabetes has been found previously [13, 14] but the diabetic subjects in these studies were not adequately matched for body weight [13] and sex [14] with the non-diabetic subjects. The present data are compatible with the observation that, in Type 2 diabetes, the clearance of both exogenous and endogenous triglyceride-rich particles is impaired [25, 26].

The prevalence of hypertriglyceridaemia in the present material was very high, exceeding the frequencies reported previously for Type 2 diabetic patients [2, 3]. Therefore it may be questioned whether the observed deficiency of LPL is in fact accounted for by clustering of patients with a primary hypertriglyceridaemia in the obese population rather than being due to diabetes itself. The diabetic patients in the present study were selected on the basis of obesity and this may explain the high prevalence of elevated triglyceride values. Since hypertriglyceridaemia and Type 2 diabetes are inherited as separate entities [27], it is likely that this hypertriglyceridaemia was secondary to diabetes and obesity. This is supported by our separate unpublished observation that the adipose tissue LPL activity of diabetic subjects is lower than that in non-diabetics with a similar degree of hypertriglyceridaemia.

The diabetic men had decreased heparin-releasable LPL activity in their subcutaneous fat when the activity was expressed per unit weight of adipose tissue. On the other hand, when the enzyme activity was calculated per estimated total body fat mass, the total LPL activity was slightly higher than previously found in normal weight non-diabetic men [28]. Therefore the overall VLDL removal efficiency and maximal capacity should be theoretically sufficient for the adequate clearance of VLDL particles from the circulation. However, the LPL activity expressed per given amount of tissue may be more important than the whole body activity as a determinant of the removal efficiency. An alternative explanation is that VLDL production is so much increased in obese diabetic subjects that the removal capacity even when above normal is unable to compensate sufficiently without elevation of the plasma concentration. This possibility is also supported by the kinetic data [8, 9]. The lack of correlation between LPL activity and VLDL concentration in diabetic subjects suggests that the rise of VLDL concentration is mainly caused by increased production of VLDL.

In addition to the increased VLDL concentration, the diabetic patients showed significantly lower plasma HDL concentrations than the weight-matched non-diabetic subjects. This abnormality has been previously reported in some studies on Type 2 diabetic subjects [29–31] but not in all [3, 32, 33]. The variation between the results may be due to differences between the patients studied. In some studies, the diabetic patients have been compared with non-diabetic subjects who had different relative body weights [3, 29, 32] or no information on body weight was given [30]. Other studies have included patients treated with either a weight-reducing diet and/or oral anti-diabetic drugs (both sulphonylureas and biguanides) [30, 32, 33]. The possible effects of sulphonylurea treatment on plasma HDL cholesterol have not been established. In cross-sectional studies, therapy with sulphonylureas was associated with low HDL values [29–31] whereas chlorpropamide treatment for 1 year was followed by an increase in plasma HDL [34]. The

underlying mechanism behind the fall of HDL in Type 2 diabetes is not yet established. It is possible, however, that the decrease of LPL activity partly accounts for this change.

Acknowledgements. The skillful technical assistance of Mrs. Hannele Hilden, Leena Lehikoinen, Sirkka-Liisa Runeberg and Miss Kyllikki Koskinen is greatly appreciated. This study was supported by grants from the Finnish State Medical Research Council (Academy of Finland), the Yrjö Jahnsson Foundation and Nordisk Insulinfond, Denmark.

References

1. Howard BV, Savage PJ, Benni on LJ, Bennett PH (1978) Lipoprotein composition in diabetes mellitus. Atherosclerosis 30: 153–162
2. Simpson RW, Mann JI, Hockaday TDR, Hockaday JM, Turner RC, Jelfs R (1979) Lipid abnormalities in untreated maturity-onset diabetics and the effect of treatment. Diabetologia 16: 101–106
3. Ballantyne D, White C, Strevens EA, Lawrie TDV, Lorimer AR, Manderson WG, Morgan HG (1977) Lipoprotein concentrations in untreated adult onset diabetes mellitus and the relationship of the fasting plasma triglyceride concentration to insulin secretion. Clin Chim Acta 78: 323–329
4. Gries FA, Koschinsky T, Berchtold P (1979) Obesity, diabetes, and hyperlipoproteinemia. Atherosclerosis Rev 4: 71–95
5. Nikkilä EA, Taskinen M-R, Harno K (1979) Plasma triglyceride metabolism in human obesity. In: Mancini M, Lewis B, Contaldo F (eds) Medical complications of obesity. Proceedings of Serono symposia, vol 26. Academic Press, London New York, pp 101–106
6. Nikkilä EA, Huttunen JK, Ehnholm C (1977) Postheparin plasma lipoprotein lipase and hepatic lipase in diabetes mellitus. Diabetes 26: 11–21
7. Nikkilä EA, Kekki M (1973) Plasma triglyceride transport kinetics in diabetes mellitus. Metabolism 22: 1–22
8. Grundy SM, Mok HYI, Zech L, Steinberg D, Berman M (1979) Transport of very low density lipoprotein triglycerides in varying degrees of obesity and hypertriglyceridemia. J Clin Invest 63: 1274–1283
9. Reaven GM (1979) Role of insulin in the development of hyperlipidemia in obesity. In: Mancini M, Lewis B, Contaldo F (eds) Medical complications of obesity. Proceedings of Serono symposia, Vol 26. Academic Press, London New York, pp 107–124
10. Nikkilä EA (1978) Metabolic and endocrine control of plasma high density lipoprotein concentration. Relation to catabolism of triglyceride-rich lipoproteins. In: Gotto AM Jr, Miller NE, Oliver MF (eds) High density lipoprotein and atherosclerosis. Elsevier/North-Holland Biomedical Press, Amsterdam, pp 177–192
11. Taskinen M-R, Nikkilä EA (1979) Lipoprotein lipase activity of adipose tissue and skeletal muscle in insulin-deficient human diabetes. Diabetologia 17: 351–356
12. Taskinen M-R, Nikkilä EA (1979) Effects of caloric restriction on lipid metabolism in man. Changes of tissue lipoprotein lipase activities and of serum lipoproteins. Atherosclerosis 32: 289–299
13. Pykälistö OJ, Smith PH, Brunzell JD (1975) Determinants of human adipose tissue lipoprotein lipase. J Clin Invest 56: 1108–1117
14. Taylor KG, Galton DJ, Holdsworth G (1979) Insulin-independent diabetes: a defect in the activity of lipoprotein lipase in adipose tissue. Diabetologia 16: 313–317
15. Taskinen M-R, Nikkilä EA, Huttunen JK, Hilden H (1980) A micromethod for assay of lipoprotein lipase activity in needle biopsy samples of human adipose tissue and skeletal muscle. Clin Chim Acta 104: 107–117
16. Documenta Geigy scientific tables, 6th edn. (1960). Geigy, Basle, p 588
17. National Diabetes Data Group (1979) Classification and diagnosis of diabetes mellitus and other categories of glucose tolerance. Diabetes 28: 1039–1057
18. Beaumont JL, Carlson LA, Cooper GR, Fejfar Z, Fredrickson DS, Strasser T (1970) Classification of hyperlipidaemias and hyperlipoproteinaemias. Bull WHO 43: 891–915
19. Hume R (1969) Prediction of lean body mass from height and weight. J Clin Pathol 19: 389–391
20. Taskinen M-R, Nikkilä EA (1977) Lipoprotein lipase activity in adipose tissue and in postheparin plasma in human obesity. Acta Med Scand 202: 399–408
21. Hyvärinen A, Nikkilä EA (1962) Specific determination of blood glucose with o-toluidine. Clin Chim Acta 7: 140–143
22. Herbert V, Lau K-S, Gottlieb CW, Bleicher SJ (1965) Coated charcoal immunoassay of insulin. J Clin Endocrinol Metab 25: 1375–1384
23. Kessler G, Lederer H (1966) Fluorometric measurement of triglycerides. In: Skeggs LT (ed) Automation in analytical chemistry. Technicon Symposium, Mediad, New York, pp 341–344
24. Havel RJ, Eder HA, Bragden JH (1955) The distribution and chemical composition of ultracentrifugally separated lipoproteins in human serum. J Clin Invest 34: 1345–1353
25. Lewis B, Mancini M, Mattock M, Chait A, Fraser TR (1972) Plasma triglyceride and fatty acid metabolism in diabetes mellitus. Eur J Clin Invest 2: 445–453
26. Brunzell JD, Porte D Jr, Bierman EL (1979) Abnormal lipoprotein-lipase-mediated plasma triglyceride removal in untreated diabetes mellitus associated with hypertriglyceridemia. Metabolism 28: 901–907
27. Brunzell JD, Hazzard WR, Motulsky AG, Bierman EJ (1975) Evidence for diabetes mellitus and genetic forms of hypertriglyceridemia as independent entities. Metabolism 24: 1115–1121
28. Nikkilä EA, Taskinen M-R, Kekki M (1978) Relation of plasma high-density lipoprotein cholesterol to lipoprotein-lipase activity in adipose tissue and skeletal muscle of man. Atherosclerosis 29: 497–501
29. Calvert GD, Graham JJ, Mannik T, Wise PH, Yeates RA (1978) Effects of therapy on plasma-high-density-lipoprotein-cholesterol concentration in diabetes mellitus. Lancet 2: 66–68
30. Kennedy AL, Lappin TRJ, Lavery TD, Hadden DR, Weaver JA, Montgomery DAD (1978) Relation of high-density lipoprotein cholesterol concentration to type of diabetes and its control. Br Med J 2: 1191–1194
31. Lisch H-J, Sailer S (1981) Lipoprotein patterns in diet, sulphonylurea, and insulin treated diabetics. Diabetologia 20: 118–122
32. Mattock MB, Fuller JH, Maude PS, Keen H (1979) Lipoprotein and plasma cholesterol esterification in normal and diabetic subjects. Atherosclerosis 34: 437–449
33. Durrington PN (1980) Serum high density lipoprotein cholesterol in diabetes mellitus: an analysis of factors which influence its concentration. Clin Chim Acta 104: 11–23
34. Paisey R, Elkeles RS, Hambley J, Magill P (1978) The effects of chlorpropamide and insulin on serum lipids, lipoproteins and fractional triglyceride removal. Diabetologia 15: 81–85

Received: 27 May 1981
and in revised form: 3 August 1981

Dr. M.-R Taskinen
Third Department of Medicine
University of Helsinki
SF-00290 Helsinki 29, Finland