

Changes in serum triglycerides and high-density lipoprotein concentration and composition after a low-fat mixed meal. Effects of gender and insulin resistance

Adriana Branchi¹, Adriana Torri², Cristina Berra², Emanuela Colombo², Domenico Sommariva²

¹Department of Internal Medicine, University of Milan, Fondazione IRCCS, Ospedale Maggiore Policlinico, Mangiagalli and Regina Elena, Milan, ²Department of Internal Medicine 1, "G. Salvini" Hospital, Garbagnate Milanese (MI), Italy

Objective. Postprandial lipaemia is generally studied after a test meal that provides most of the calories as fat and that does not reflect the common food intake. We investigated postprandial changes in serum triglycerides (TG) and in high-density lipoprotein (HDL) concentration and composition after a regular meal poor in fat (30% of calories).

Methods. Fifty-four women and 54 men had breakfast at 8:00 a.m. (12% of daily calories) and lunch at 12:30 p.m. (53% of daily calories).

Results. With respect to fasting values, TG increased more in men (24% at 2:30 p.m. and 30% at 5:00 p.m.) than in women (19% and 23%, respectively). HDL cholesterol decreased by 4% both in men and women at 2:30 p.m., and in both genders levels returned towards baseline levels at 5:00 p.m. Apolipoprotein A-I (apo A-I) significantly decreased in men (-3% at 2:30 p.m.), but did not change in women. The apo A-I/HDL cholesterol ratio significantly increased by 3% in men at 2:30 p.m. and by 5% both in men and women at 5:00

p.m. Postprandial serum TG were higher and HDL cholesterol and apo A-I were lower in subjects of both genders with insulin resistance (high HOMA_{IR}) than in those with low HOMA_{IR}. The greatest increase in serum TG (39%) was observed in men with high HOMA_{IR}. HDL cholesterol and apo A-I significantly decreased and the apo A-I/HDL-C ratio significantly increased only in this subgroup of subjects.

Conclusions. Ingestion of low doses of fat in a mixed meal is followed by variable increases of serum TG, and the greatest response is found in insulin-resistant men. In this subset of subjects, postprandial hypertriglyceridaemia is associated with alterations in HDL that might be consistent with an increased risk of cardiovascular disease.

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Key words: apolipoprotein A-I, gender, HDL cholesterol, insulin resistance, postprandial lipaemia, triglycerides

Introduction

Elevated plasma triglycerides (TG) are associated with an increased risk of cardiovascular disease¹. However, in several studies this association does not remain statistically significant after controlling for other lipid parameters, in particular high-density lipoproteins (HDL) that are strongly associated with risk of cardiovascular disease¹. Serum concentration of TG is highly variable during the day, and the weakness of the association between serum TG and coronary heart disease might be due to the fact that serum TG levels are generally measured in the fasting state during which they reach the lowest levels². Humans are during most of

the day in a postprandial state owing to the long duration of postprandial lipaemia and to repetition of meals during the daytime³⁻⁶. Therefore, fasting TG concentrations may not provide accurate information on TG metabolic capacity and on the cardiovascular risk associated with alterations in serum TG metabolism.

Following Zilversmit⁷ who first proposed that atherosclerosis could be a postprandial phenomenon, several authors addressed their interest in the postprandial metabolism of lipoproteins. Postprandial lipid metabolism refers to the series of metabolic events that occur after the ingestion of a meal containing fat. Postprandial lipaemia is mainly characterised by an increase in plasma TG that precipitates a number of metabolic events including: the production of atherogenic chylomicron remnants, the formation of highly atherogenic, small compact low-density lipoprotein (LDL) particles, and a reduction of the concentration of the cardioprotective HDL fraction⁸. Elevation of serum TG also interacts with the process of thrombosis through the activation of the coagulation factor VII and plasminogen activator inhibitor⁹. Mechanistic studies demonstrate that

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Address for correspondence: Dr.ssa Adriana Branchi, Dipartimento di Medicina Interna, Padiglione Granelli, Università degli Studi, Ospedale Maggiore IRCCS, Via Francesco Sforza 35, 20121 Milano, Italy. E-mail: adriana.branchi@unimi.it

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TG-rich lipoprotein remnants may have adverse effects on endothelium¹⁰, and clinical data show a correlation between postprandial TG and the presence of coronary artery disease¹¹⁻¹⁶. Therefore, it might be expected that the magnitude and duration of postprandial lipaemia may be more closely related to atherogenic risk than the level of the serum concentration of TG observed in the fasting state.

Studies on postprandial lipaemia are mostly done after meals that provide an amount of fat that exceeds the recommended fat intake and the fraction of total food energy as fat. Recent studies show that postprandial TG response is dose-dependent^{5,17}. The rate at which serum TG levels increase after fat ingestion is a function of several factors, among them: composition of the meal, sensorial stimuli, gastric emptying and intestinal absorption¹⁸. A test meal is an artificial situation that does not reflect common food intake. Therefore, experimental results might not be applicable to *in vivo* subjects.

In the present study we evaluated serum lipoprotein pattern in subjects in the morning before breakfast and 2 and 4.5 h after lunch. The main purpose of the study was to investigate the postprandial changes in serum TG levels and in HDL concentration and composition after a regular meal relatively poor in fat. Previous studies show that oral fat load is followed by HDL changes in parallel with the increase in serum TG levels^{4,17}. Less well known are the effects of low fat meals.

Methods

The study was carried out on 108 volunteers (54 men and 54 women, range 28-70 years, mean 53.5 years, SEM 1.10 years) in good clinical and nutritional conditions selected from hospitalised patients. Clinical history of the subjects included chest discomfort of non-cardiac origin (n = 34), hypertension (n = 24), paroxysmal supraventricular dysrhythmias (n = 14), abdominal pain (n = 13), dizziness (n = 10), osteoarthritis (n = 5), urticaria (n = 4), anxiety attacks (n = 3), and transient global amnesia (n = 1). Exclusion criteria were dyslipidaemia, neoplastic

diseases, hepatic and renal dysfunction, hypothyroidism, diabetes and treatment with drugs known to affect insulin action or lipoprotein metabolism. All subjects gave their informed consent to the study protocol that was conducted according to the guidelines of the Declaration of Helsinki. The study was approved by the local ethics committee.

All meals were prepared by the hospital kitchen, and the subjects were instructed to choose among three different menus what was more similar to their usual diet. The subjects did not consume alcoholic beverages. The subjects had their breakfast (12% of daily calories: carbohydrates 71%, protein 18%, fat 11% of total energy) at 8:00 a.m. and their lunch (Table 1) at 12:30 p.m. The composition of meals was assessed by an accurate nutritional analysis that was made for each subject by two of us (CB and EC). Quantities of intake were estimated according to a table with standardised portion sizes (Atlante Ragionato di Alimentazione, Istituto Scotti Bassani, Milan, Italy). Blood samples were collected at 8:00 a.m. after an overnight fast and before breakfast, at 2:30 and 5:00 p.m. All samples were immediately centrifuged. Total cholesterol was measured by CHOD-PAP method, serum TG by GPO-PAP method, HDL cholesterol by HDL-C plus method and blood glucose by GOD-PAP method (Roche Diagnostics, Mannheim, Germany). Measurements of serum lipids, HDL cholesterol and blood glucose were done on the Hitachi 917 autoanalyser (Boehringer, Mannheim, Germany). Apolipoprotein (apo) B and A-I were determined by immunoturbidimetric method (Roche Diagnostics) and plasma insulin by radioimmunoassay (Insulin RIA, Adaltis Italia, Casalecchio sul Reno-BO, Italy). The accuracy of determinations was assessed according to the intra- and interlaboratory quality control program UNITY (Bio-Rad Laboratories, Segrate-MI, Italy). Insulin resistance (HOMA_{IR}) was calculated according to the method of Matthews et al.¹⁹.

Body mass index was calculated by dividing weight (in kg) by height² (in m). Waist circumference was measured at the level of the umbilicus, and hip circumference at the level of the greater trochanters.

Table 1. Composition of the lunch.

	Men		Women		p
	Mean	95% CI	Mean	95% CI	
Energy (cal)	1193	1148-1238	1050	1000-1099	< 0.001
Carbohydrate (%)	52	49-54	51	48-53	NS
Protein (%)	19	17-20	19	17-20	NS
Total fat (%)	31	29-32	31	30-33	NS
Saturated fat (%)	9	8-10	9	9-10	NS
Cholesterol (mg)	150	125-174	137	115-160	NS
Fibre (g)	16	15-17	13	12-14	< 0.001

CI, confidence interval.

The magnitude of postprandial changes in serum lipid and lipoprotein levels was estimated by calculating the incremental area under the curve (IAUC), according to the trapezoidal method after subtraction of fasting values.

Data are presented as mean (95% confidence interval) or mean \pm SEM (in figures). Differences between groups were analysed with the Student's *t*-test for unpaired data. Student's *t*-test for paired data was used to compare data within groups. Relationships among anthropometric, fasting and postprandial metabolic variables were evaluated by calculating Pearson's coefficient of correlation. Multiple backward stepwise regression analysis was used to study the independent variables able to predict the response of serum TG, HDL cholesterol, apo A-I and apo A-I/HDL cholesterol ratio to the meal. IAUC of serum TG, HDL cholesterol, apo A-I and apo A-I/HDL cholesterol ratio were considered dependent variables and age, gender (dummy variable), anthropometric measures, biochemical variables and food intake were included in the statistical model as independent variables. Covariates were introduced in the equation as z-scores. The two-tailed significance threshold was set at $p < 0.05$.

Results

Table 2 summarizes physical characteristics and fasting metabolic variables of the 108 subjects included in the study. Men had greater abdominal fat accumulation than women, though the two groups had the same body mass index. Fasting serum TG and apo B levels were significantly higher, and HDL cholesterol and apo A-I levels were significantly lower in men than in women. Anthropometric and metabolic variables showed complex interrelationships. In particular, the body mass index and waist circumference were positively correlated

with HOMA_{IR} ($r = 0.33$, $p < 0.001$ and 0.42 , $p < 0.001$, respectively), fasting insulin ($r = 0.32$, $p < 0.01$ and 0.41 , $p < 0.001$) and blood glucose ($r = 0.21$, $p < 0.05$ and 0.28 , $p < 0.01$), and inversely correlated with fasting HDL cholesterol ($r = -0.29$, $p < 0.01$ and -0.47 , $p < 0.001$) and apo A-I levels ($r = -0.31$, $p < 0.01$ and -0.48 , $p < 0.001$). HOMA_{IR} was positively correlated with fasting TG levels ($r = 0.22$, $p < 0.05$) and negatively correlated with HDL cholesterol ($r = -0.29$, $p < 0.01$) and apo A-I levels ($r = -0.31$, $p < 0.01$). Fasting TG levels were directly correlated with insulin ($r = 0.18$, $p < 0.05$) and blood glucose levels ($r = 0.25$, $p < 0.05$), and inversely correlated with HDL cholesterol ($r = -0.40$, $p < 0.001$) and apo A-I ($r = -0.24$, $p < 0.05$) levels.

The mean percent composition of the lunch is shown in Table 1 and was similar in men and women. However, men consumed more calories during the lunch than did women.

In men, the postprandial increase of serum TG level was 24% at 2:30 p.m. and 30% at 5:00 p.m., and in women was 19% and 23%, respectively. HDL cholesterol levels decreased by 4% in both men and women at 2:30 p.m., and in both genders returned towards baseline levels at 5:00 p.m. Apo A-I levels significantly decreased in men (-3% at 2:30 p.m.), but did not change significantly in women. The difference in postprandial TG, HDL cholesterol and apo A-I levels between men and women was statistically significant (Fig. 1). With respect to fasting values, the apo A-I/HDL cholesterol ratio significantly increased in the postprandial period (3% in men at 2:30 p.m. and 5% in both men and women at 5:00 p.m.). Blood glucose levels increased by 14% in men and by 21% in women at 2:30 p.m., and returned towards fasting values at 5:00 p.m. Plasma insulin levels similarly increased in men and women at 2:30 p.m., and in both genders remained 2-fold higher than baseline at 5:00 p.m. (Fig. 1). As expected, the TG IAUC areas calculated were

Table 2. Physical characteristics and fasting metabolic profile of the study subjects.

Variable	All subjects (n=108)		Men (n=54)		Women (n=54)		p
	Mean	95% CI	Mean	95% CI	Mean	95% CI	
Age (years)	53.5	51.4-55.7	52.6	49.6-55.6	54.3	51.1-57.6	NS
Body mass index (kg/m ²)	27.8	26.8-28.7	27.9	26.7-29.0	27.6	26.1-29.2	NS
Waist circumference (cm)	92.5	89.6-95.5	98.1	94.2-102.0	87.0	83.1-90.8	< 0.001
Waist/hip ratio	0.91	0.89-0.93	0.97	0.94-0.99	0.86	0.84-0.87	< 0.001
Serum triglycerides (mg/dl)	129.9	120.1-139.7	141.7	128.4-155.1	118.1	104.4-131.8	< 0.01
HDL cholesterol (mg/dl)	45.9	43.1-48.8	39.6	36.7-42.5	52.3	48.0-56.5	< 0.001
Total cholesterol (mg/dl)	198.3	191.6-204.9	201.6	192.5-210.7	194.9	185.2-204.6	NS
Apolipoprotein A-I (mg/dl)	116.6	111.4-121.9	107.7	101.6-113.7	125.6	117.8-133.5	< 0.001
Apolipoprotein B (mg/dl)	104.3	100.0-108.5	110.2	104.6-115.7	98.5	92.3-104.6	< 0.01
Glucose (mg/dl)	92.9	90.4-95.5	93.9	90.2-97.6	92.0	88.5-95.4	NS
Insulin (μ U/ml)	12.0	10.3-13.7	12.3	10.0-14.6	11.7	9.2-14.3	NS
HOMA _{IR}	2.8	2.4-3.3	2.9	2.3-3.6	2.7	2.1-3.4	NS

CI, confidence interval; HDL, high-density lipoprotein; HOMA_{IR}, insulin resistance.

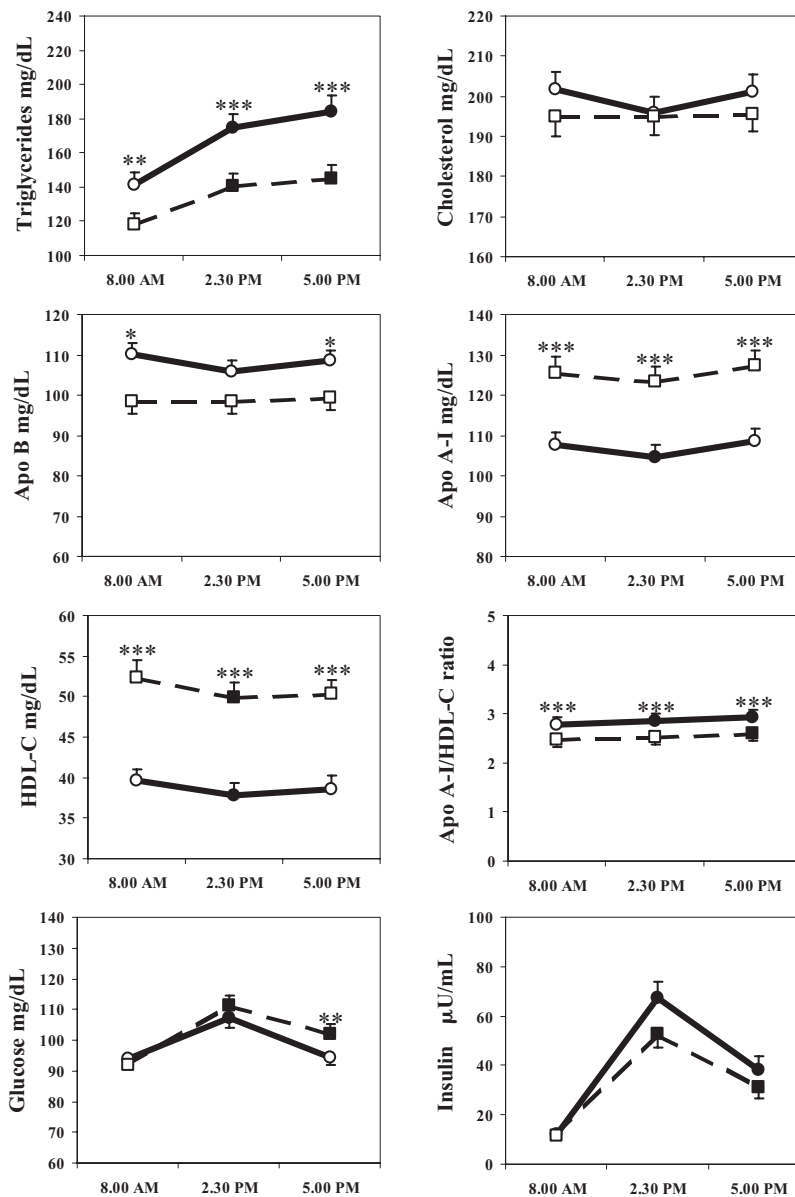


Figure 1. Line plots showing the postprandial responses of serum lipids, high-density lipoprotein cholesterol (HDL-C), apolipoprotein (Apo) B and A-I, blood glucose and insulin in men (○) and in women (□). Vertical bars represent SEM. Filled symbols (●,■), significant difference from baseline. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ between genders.

significantly greater in men than in women, while IAUC calculations of HDL cholesterol, apo A-I levels and apo A-I/HDL cholesterol ratios did not show significant differences between the two groups (Table 3). As shown in Table 4, the IAUC calculations of the serum TG levels were significantly correlated with HOMA_{IR}, fasting TG levels and IAUC calculations of both HDL cholesterol and apo A-I. The IAUC calculations of HDL cholesterol and of apo A-I levels were significantly correlated with their respective fasting value and with IAUC calculations of TG levels. The macronutrient composition of lunch did not show significant correlations with postprandial

changes of TG, HDL cholesterol, apo A-I levels and the apo A-I/HDL cholesterol ratio.

Multiple backward stepwise analysis showed that the IAUC calculations of serum TG levels were significantly associated with male gender, fasting TG and HOMA_{IR} levels. The IAUC calculations of HDL cholesterol correlated with fasting HDL cholesterol levels, waist girth and the IAUC calculations of TG levels. The IAUC calculations of apo A-I levels correlated with fasting apo A-I levels, the IAUC calculations of TG levels, and the IAUC calculations of insulin levels. No significant association was found between fat or other nutrient

Table 3. Incremental area under the curve (IAUC) calculations of serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A-I (apo A-I) and apo A-I/HDL-C ratio in men and women.

	Men		Women		p
	Mean	95% CI	Mean	95% CI	
IAUC TG	203.2	156.7-249.7	134.9	87.8-181.9	< 0.05
IAUC HDL-C	-9.4	-18.2;-0.6	-13.1	-24.1;-2.1	NS
IAUC Apo A-I	-12.3	-23.3;-1.3	-7.3	-23.5-8.9	NS
IAUC Apo A-I/HDL-C ratio	0.48	0.04-0.91	0.41	0.03-0.78	NS

Values are expressed in mg*9 h/dl. CI, confidence interval.

Table 4. Coefficients of simple correlation between incremental area under the curve (IAUC) of serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A-I (apo A-I) and apo A-I/HDL-C ratio and anthropometric, metabolic and dietary variables.

Variable	IAUC TG	IAUC HDL-C	IAUC apo A-I	IAUC apo A-I/HDL-C ratio
Body mass index	0.05	-0.07	0.07	0.12
Waist circumference	0.12	-0.08	-0.02	0.11
HOMA _{IR}	0.21*	-0.05	-0.02	0.14
Fasting TG	0.22*	0.12	0.04	-0.03
IAUC TG	–	-0.20*	-0.28**	0.08
Fasting HDL-C	-0.03	-0.38§	-0.23*	0.11
IAUC HDL-C	-0.20*	–	0.50§	-0.67§
Fasting apo A-I	0.02	-0.18	-0.34§	-0.13
IAUC apo A-I	-0.28**	0.50§	–	0.17
Fasting apo A-I/HDL-C ratio	0.04	0.30**	-0.09	-0.35§
IAUC apo A-I/HDL-C ratio	0.08	-0.67§	0.17	–
IAUC insulin	0.17	-0.10	-0.16	0.15
Dietary total fat	0.11	-0.01	-0.09	-0.05
Dietary saturated fat	-0.05	-0.05	-0.04	-0.01
Dietary carbohydrates	0.10	0.09	0.11	0.05
Dietary proteins	0.13	0.01	-0.12	-0.07

HOMA_{IR}, insulin resistance. * p < 0.05; ** p < 0.01; § p < 0.001.

intake and the postprandial changes in serum TG, HDL cholesterol and apo A-I levels (Table 5).

Figure 2 shows that in both genders, postprandial serum TG levels were higher, and postprandial HDL cholesterol

and apo A-I levels were lower in subjects belonging to the third tertile (> 2.8) of the distribution of HOMA_{IR} than in subjects with HOMA_{IR} < 2.8 (first and second tertiles). With respect to fasting values, serum TG levels increased by 30%

Table 5. Results of multiple backward stepwise analysis: variables significantly associated with incremental area under the curve (IAUC) of serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A-I (apo A-I) and apo A-I/HDL-C.

	Baseline level*	Gender	HOMA _{IR}	IAUC TG	Waist circumference	IAUC insulin
IAUC TG				–	NS	NS
β	29.38	38.27	27.50			
Partial F	4.21	5.14	4.62			
IAUC HDL-C		NS	NS			NS
β	-19.31			-8.15	-10.90	
Partial F	31.22			4.54	10.13	
IAUC apo A-I		NS	NS		NS	
β	-21.14			-14.76		-13.14
Partial F	21.51			7.38		7.74
IAUC apo A-I/HDL-C ratio		NS	NS	NS	NS	
β	-0.61					0.33
Partial F	20.09					6.09

Data are presented either as β coefficient and partial F. HOMA_{IR}, insulin resistance. * fasting value of each variable.

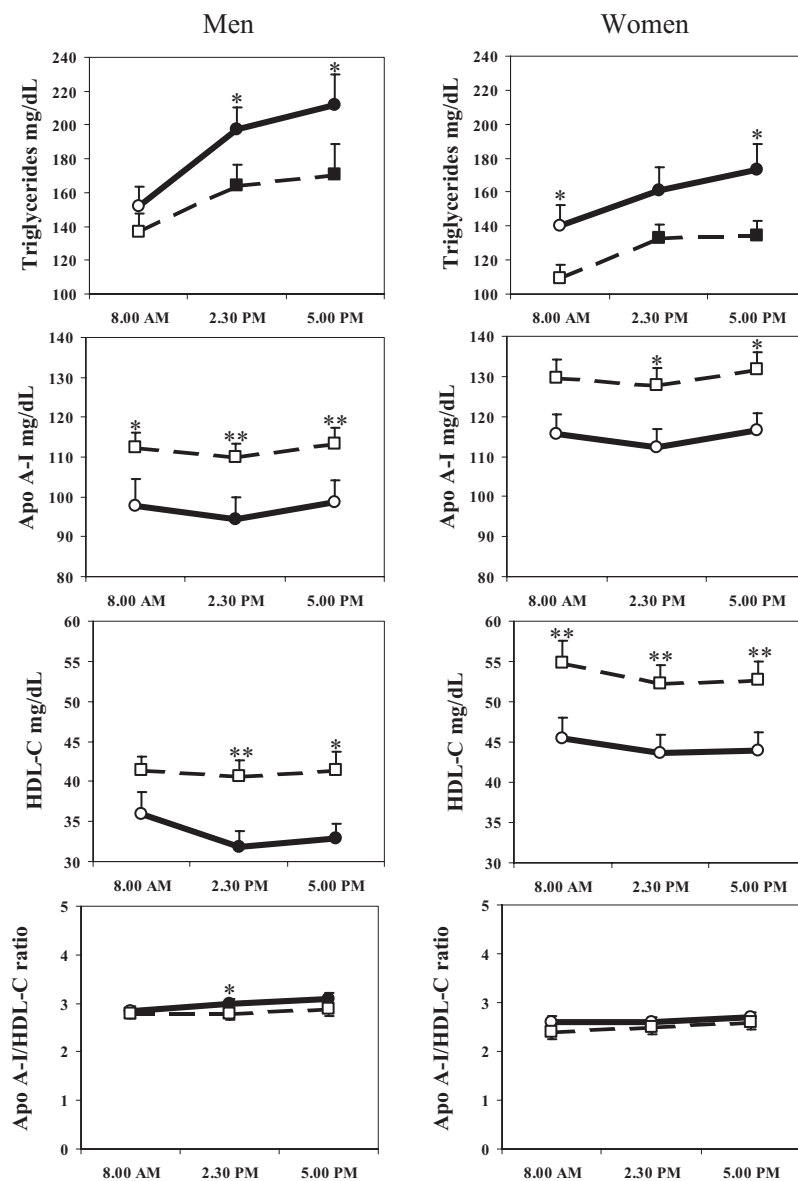


Figure 2. Line plots showing the postprandial responses of serum triglycerides, apolipoprotein (Apo) A-I, high-density lipoprotein cholesterol (HDL-C) levels and the Apo A-I/HDL-C ratio in men and in women of the third tertile (●) and of the first two tertiles (□) of HOMA_{IR}. Vertical bars represent SEM. Filled symbols (●, ■), significant difference from baseline. * $p < 0.05$, ** $p < 0.01$ vs the other group.

at 2:30 p.m. and by 39% at 5:00 p.m. in men with levels of HOMA_{IR} > 2.8 and by 20% and 25% in men with levels of HOMA_{IR} < 2.8. In women postprandial changes of serum TG levels were 15% and 23% at 2:30 and 5:00 p.m., in those with levels of HOMA_{IR} > 2.8 and 21% and 23% in those with levels of HOMA_{IR} < 2.8, respectively. A significant decrease in HDL cholesterol (-11% at 2:30 p.m. and -8% at 5:00 p.m.) and apo A-I (-4% at 2:30 p.m.) levels and a significant increase in the apo A-I/HDL cholesterol ratio (6% at 2:30 p.m. and 9% at 5:00 p.m.) was observed only in men with levels of HOMA_{IR} > 2.8 (Fig. 2). The IAUC calculations of TG levels and of the apo A-I/HDL cholesterol ratio were significantly greater in men with levels of HOMA_{IR} > 2.8

than in men with levels of HOMA_{IR} < 2.8. No significant difference in the IAUC calculations of serum TG, HDL cholesterol, apo A-I levels and apo A-I/HDL cholesterol ratio was found in women with levels of HOMA_{IR} > 2.8 with respect to women with levels of HOMA_{IR} < 2.8 (Table 6). As reported in Table 7, the lunch composition was similar in subjects with high and low levels of HOMA_{IR}.

Discussion

Several conditions have been demonstrated to influence postprandial lipoprotein metabolism; among them

Table 6. Incremental area under the curve (IAUC) of serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A-I (apo A-I) and apo A-I/HDL-C ratio in men and women divided according to the tertile of distribution of insulin resistance (HOMA_{IR}) (first and second tertiles < 2.8, third tertile > 2.8).

	Men				p	Women				p
	HOMA _{IR} > 2.8		HOMA _{IR} < 2.8			HOMA _{IR} > 2.8		HOMA _{IR} < 2.8		
	Mean	95% CI	Mean	95% CI		Mean	95% CI	Mean	95% CI	
IAUC TG	277.8	173.8-381.8	166.0	123.4-208.5	< 0.05	133.4	76.3-190.6	135.4	73.6-197.2	NS
IAUC HDL-C	-21.9	-40.1;-3.8	-3.1	-12.1-5.9	NS	-10.3	-26.7-6.1	-14.2	-28.1;-0.2	NS
IAUC Apo A-I	-14.9	-31.4-1.7	-11.1	-25.5-3.3	NS	-14.1	-41.8-13.7	-4.7	-24.6-15.2	NS
IAUC Apo A-I/HDL-C ratio	1.16	0.29-2.04	0.13	-0.31-0.58	< 0.05	0.20	-0.63-1.04	0.49	0.07-0.90	NS

Values are expressed in mg*9 h/dl. CI, confidence interval.

Table 7. Composition of the lunch in men and women divided according to the tertile of distribution of insulin resistance (HOMA_{IR}) (first and second tertiles < 2.8, third tertile > 2.8).

	Men				p	Women				p
	HOMA _{IR} > 2.8		HOMA _{IR} < 2.8			HOMA _{IR} > 2.8		HOMA _{IR} < 2.8		
	Mean	95% CI	Mean	95% CI		Mean	95% CI	Mean	95% CI	
Energy (cal)	1207	1111-1303	1185	1137-1234	NS	1025	933-1116	1059	1000-1119	NS
Carbohydrate (%)	50	47-54	52	49-55	NS	52	48-55	50	48-53	NS
Protein (%)	19	16-21	19	17-20	NS	19	16-23	19	17-20	NS
Total fat (%)	31	27-34	31	28-33	NS	30	26-33	32	30-34	NS
Saturated fat (%)	9	7-10	9	8-10	NS	9	7-11	10	9-11	NS
Cholesterol (mg)	154	112-198	147	117-177	NS	119	80-158	144	117-172	NS
Fibre (g)	16	14-19	16	14-18	NS	12	11-14	13	12-15	NS

CI, confidence interval.

age^{4,20}, gender^{4,21-25}, physical exercise^{23,26,27}, diet^{24,28-31}, insulin resistance^{25,29,32-34}, diabetes^{25,31}, obesity^{22,24,29,31,32,34-36} and fasting TG levels^{4,22,24,29,34,35,37}. With few exceptions, postprandial lipaemia has been studied after challenge meals rich in fat, which overload absorptive and clearance processes. In this study we have shown that gender, fasting TG level and insulin resistance were the main determinants of the postprandial elevation of serum TG levels and of changes in HDL concentration and composition after a meal relatively low in fat content, and closely mimicking the recommended fat intake³⁸.

Greater elevation of TG levels in men than in women was already observed in a study on diurnal capillary TG profiles in free living subjects eating regular meals²⁵ and after oral fat loading tests^{4,22}. One study ascribes this to the greater visceral adipose tissue in men²². In our series as well, men had greater abdominal fat accumulation than women, as suggested by the difference in waist circumference, which is believed to be a good indicator of visceral adiposity³⁹. Visceral adiposity is associated with metabolic abnormalities such as fasting hypertriglyceridaemia, low HDL cholesterol levels and hyperinsulinaemia, which are common features of the insulin resistance syndrome³⁸. In our subjects, waist circumference positively correlated with levels of HOMA_{IR}, which is a reliable index of insulin resistance¹⁹.

However, the levels of HOMA_{IR} were similar in men and in women suggesting that abdominal fat accumulation and the associated insulin resistance do not entirely explain the greater postprandial lipaemia in men than in women. On the other hand, a greater TG response to a fat load was also observed in healthy non-obese men as compared with women²³.

Various factors control postprandial serum concentration of TG, in particular the breakdown of TG-rich lipoproteins by lipoprotein lipase. In women, lipoprotein lipase activity is greater than in men⁴⁰, and indeed enzyme activity is found to be a good predictor of the concentration of TG-rich lipoproteins after a test meal during different experimental conditions^{20,33,36}. A reduced lipoprotein lipase activity may then delay the removal from the circulation of TG-rich lipoproteins accounting for an exaggerated postprandial lipaemia in men as compared with women.

Insulin sensitivity plays a key role in the overall metabolism of TG-rich lipoproteins⁴¹. In our subjects, both men and women with high levels of HOMA_{IR} had higher postprandial levels of TG than subjects belonging to the two lower tertiles of HOMA_{IR}. The IAUC calculations of TG was however significantly greater only in men with high than in men with low levels of HOMA_{IR}. Women with high levels of HOMA_{IR} showed TG IAUC calculations similar to that of men and women

with low levels of HOMA_{IR}, and significantly lower than that of men with high levels of HOMA_{IR}, emphasising the role of gender in determining postprandial lipaemia. The increase in serum TG levels was associated with changes in HDL particles. It is well known that HDL composition and concentration depend on metabolism of TG-rich lipoproteins¹². In our study, multiple regression analysis showed a significant inverse association of the IAUC calculations of both HDL cholesterol and apo A-I with the IAUC calculations of TG. A significant postprandial decrease in apo A-I and HDL cholesterol levels was seen only in insulin-resistant men who experienced the greatest elevation of serum TG level. The reduction in both apo A-I and HDL cholesterol levels in insulin-resistant men suggests that in these particular subjects circulating HDL particles decreased. The decrease was transient and at the last control at 5:00 p.m., apo A-I concentration returned to fasting values, while HDL cholesterol was still significantly lower than in the fasted state. Though short-lived, the decrease of HDL in our male insulin-resistant subjects may be of interest since HDL particles are believed to have antiatherogenic properties. Postprandial HDL cholesterol levels decreased more than apo A-I levels, and the resultant increase in the apo A-I/HDL cholesterol ratio suggests a remodelling of HDL particles characterised by a loss of cholesterol as demonstrated by Dubois et al.¹⁷ after different amounts of fat in the usual range of ingestion. Insulin resistance was then associated in men with a worse postprandial lipid and lipoprotein profile. Insulin-resistant women too had higher postprandial levels of TG and lower levels of HDL cholesterol and apo A-I than non-insulin-resistant women. However, insulin-resistant women did not show significant alterations of HDL composition and concentration after the meal providing further evidence that changes in HDL after the meal were accounted for by the magnitude of hypertriglyceridaemia.

It may be argued that three sample points do not allow an efficient analysis of postprandial lipemia. Guerci et al.⁴² and Carstensen et al.³⁷ find good correspondence between calculations of postprandial lipaemia by three-point sample analysis and 5-7 lipid determinations conventionally used in studies on postprandial lipaemia. In our study, the last sampling of serum lipoprotein pattern was obtained only 4.5 h after the beginning of the lunch. Maximal TG response occurs 2-3 h after fat loads, and the elevation of serum TG levels lasts for several hours⁵. In a previous study on circadian triglyceridaemia², we find that in healthy subjects, TG levels in whole serum and in the density fraction < 1006 remain significantly higher than in the fasted state from noon until the dinner at 7:30 p.m., and then increase again until midnight. In the present study, we have missed late values of postprandial serum TG levels. Therefore, it is possible we have

underestimated duration, but not the magnitude of postprandial hypertriglyceridaemia and the associated changes in HDL concentration and composition. At the last control of 5:00 p.m., HDL cholesterol and apo A-I levels returned towards the fasting values in all the four groups of subjects.

The nutrient intake of our study group was similar to that recommended by the National Cholesterol Education Program ATP III as a first dietary approach in the prevention of ischaemic heart disease³⁸. Results of the present study show that ingestion of low doses of fat in a mixed meal is followed by variable increases in serum TG levels, and the greatest response is found in insulin-resistant men. In this subgroup of subjects, postprandial hypertriglyceridaemia is associated with alterations in HDL that might be consistent with an increased risk of cardiovascular disease.

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