The Effect of Fasting Lipid Levels on Alimentary Lipemia

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THE FACTORS determining the increase of fat content in the serum following a meal are poorly understood. The amount of fat contained in the meal ingested, as well as the presence of carbohydrate and protein, play a role. Ingestion of 3.5 to 4 gm. of fat per kg. of body weight will consistently produce an elevation in serum triglycerides at two hours after completion of the meal.[1] The addition of glucose to a meal containing 60 gm. of fat will eliminate or reduce the postprandial lipemia.[2] The amount of glucose which must be added to cause this reduction in postprandial lipemia varies among individuals.[2] A similar reduction in postprandial lipemia may be induced by the injection of glucagon.[3] The concentration of free fatty acids in the serum is also decreased by the ingestion of glucose or the injection of glucagon.[4] It is generally accepted that the rising level of free fatty acids in the serum noted during a prolonged fast indicates the increased mobilization of fatty acids from the fat depots of the body. The sharp decrease in the concentration of free fatty acids in the serum following the ingestion of glucose indicates a cessation or diminution of fatty acid mobilization.[4] The action of glucose in reducing the postprandial lipemia following the ingestion of fat-containing meals may then be due, at least in part, to the reduction in endogenous fat mobilization.

It has been demonstrated that protein also will cause a decrease in concentration of free fatty acids in the serum.[5] The lipemia following ingestion of a fat meal consists primarily of an increase in triglycerides in the form of chylomicra[6,7] and is accompanied by a slight increase in the concentration of free fatty acids.[8] Following a two- to seven-day period of starvation, however, the high level of free fatty acids and serum triglycerides so produced are decreased following the ingestion of fat.[9]

Variations in lipid levels may also be due to factors which are not dependent upon the diet. Physiological mechanisms for the mobilization of fat may produce elevations in serum fat concentration in the absence of absorption.[8] Epinephrine,[10] adrenocorticotrophic hormone[11] and pituitary growth hormone[12] have the ability to mobilize fat. An increase in the free fatty acid level related to psychological stress has been demonstrated[13] and mediation through one or more of the endocrine glands is presumably responsible for this effect.

In contrast to the blood sugar level, which is relatively constant in the fasting state, the serum triglycerides show great variation among individuals and in the same individual at different times.[14] Although the physiologic processes responsible for the fasting serum triglyceride level are uncertain, it seemed possible that the fasting level or the factors determining it may be important in determining the postprandial alteration. The results of the present investigation, which was designed to study the relationship of fasting serum lipids to postprandial alterations following ingestion of standard meals, indicate that in normal people there is great variability in postprandial lipid levels, which is determined at least in part by the pre-existing level.

METHOD

Changes in serum lipid content was studied in twenty healthy male housestaff physicians and

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TABLE I
Description of Contents of Meals I and II

Food	Amount	Weight (gm.)	Calories	Protein (gm.)	Carbohydrate (gm.)	Fat (gm.)
Meal I						
Bacon	5 strips	40	243	10.0	0.5	22.0
Eggs	2	108	154	12.0	0.5	11.0
Butter	2 tbsp.	28	200	0	0	23.0
Cream, heavy	2 tbsp.	90	295	2.0	3.0	31.0
Total			892	24.0	4.0	97.0
Meal II—All Constituents of Meal I and in Addition:						
Bread, white	2 slices (1/2 inch thick)	23	63	2.0	12.0	0.7
Orange juice	8 oz.	246	108	2.0	27.0	0.3
Sugar	5 tbsp.	60	240	0	62.0	0
Total			1,303	28.0	105.0	98.0

medical students. Each ate the diet to which he was accustomed and continued his usual activity during the experiments. After an overnight fast of approximately twelve hours each subject was given as breakfast on separate days, the meals designated as I and II (see Table I). Meal I consisted of 5 strips of bacon fried crisp, 2 eggs, 2 tablespoons of butter and 2 tablespoons of 20 per cent cream. Meal II contained, in addition, 1 glass of orange juice, 1 piece of toast and 5 tablespoons of sucrose. Coffee was allowed *ad libitum*. Meal II was thus appreciably higher in glucose content and in caloric value than meal I, but the fat content was identical. Samples of blood were drawn for analysis before the meals were eaten and at three and six hours following their completion.

The following analyses were carried out on each blood specimen: serum turbidity as described by Mueller,[15] free fatty acids by the method of Dole,[4] cholesterol and cholesterol esters by the method of Schoenheimer and Sperry,[16] phospholipids by Youngburg's method,[17] and serum triglycerides by the method of Bradgon[18] or of Albrink.[19]

RESULTS

The ingestion of meals I and II produced significant changes only in the serum triglycerides, the serum turbidity and the free fatty acids. Fasting triglyceride values ranged from 25 to 425 mg. per 100 ml.; some subjects showed an unpredictable variation in fasting serum triglyceride content of slightly less magnitude. A fasting serum triglyceride level less than 180 mg. per 100 ml. will be referred to as normal. Fasting free fatty acid levels ranged from 800 to 1,200 μEq. per L. Serum turbidity in the fasting state was 0.4 units optical density.

In sixteen of the twenty subjects the fasting serum triglyceride level was normal (less than 180 mg. per 100 ml.) when meal I was given. As seen in Figure 1, a mean increase in the serum triglycerides of 90 per cent of the fasting level occurred at three hours after ingestion of the meal with a decline to 20 per cent above the fasting level at six hours. A marked increase in serum turbidity, with a peak at three hours accompanied the elevation of serum triglycerides. The free fatty acids showed only a 20 per cent increase at three hours and increased further to 60 per cent above the fasting level at the end of six hours. Also shown in Figure 1 are the changes in serum lipids in the four subjects in whom the fasting serum triglyceride

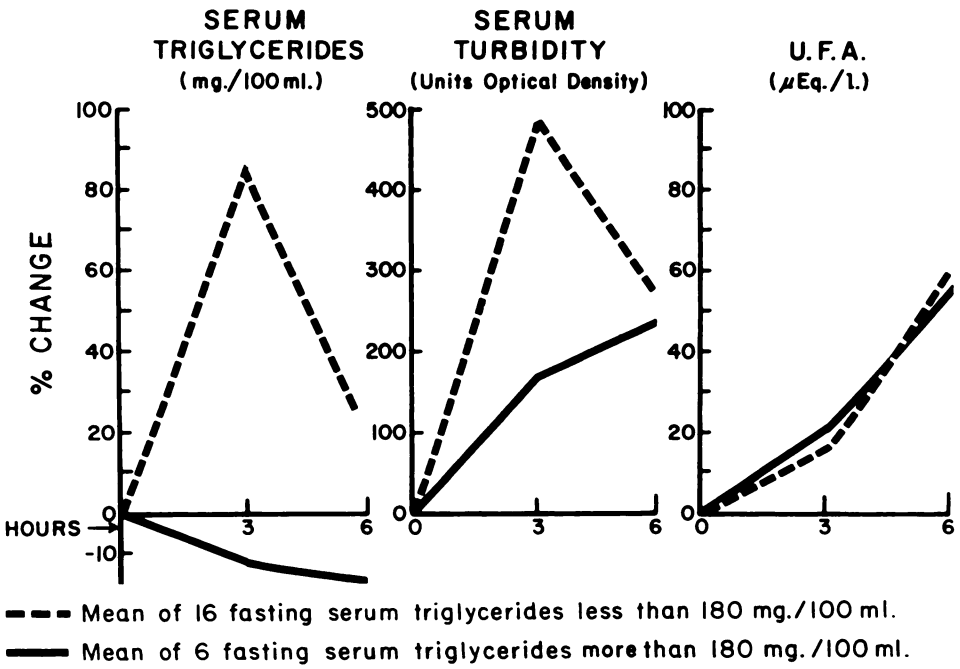

FIG. 1. Postprandial lipid levels following ingestion of meal I presented as per cent change of the fasting level.

level was elevated when meal I was eaten. The serum triglycerides and serum turbidity showed a different response in these four subjects. At three hours, there was a mean decrease of serum triglycerides, with a still further decrease at six hours. The increase in serum turbidity was only half as great as in the sixteen subjects with normal fasting levels and occurred at the end of six hours rather than at three hours. The postprandial changes in free fatty acid content were essentially the same in all twenty subjects following the ingestion of meal I.

Eight subjects ate meal I on two separate occasions. Figure 2 shows the fasting and three hour serum triglyceride values after the ingestion of each of these meals in these eight subjects. In subjects 1, 2, 4 and 8 the fasting levels were normal and there was an increase in the three-hour serum triglyceride level on each occasion. The three-hour level and the increase in serum triglycerides was greater with the lower fasting value in subjects 1, 2 and 8. In subject 3 the fasting serum triglyceride level was elevated and there was a decrease from the fasting level after ingestion of each meal. In subject 7 there was a decrease in the serum triglyceride level after three hours when the fasting value was elevated and an increase when the fasting value was normal. Subjects 5 and 6 showed an increase in serum triglycerides after fasting three hours, both at normal and elevated levels.

In Figure 3 the changes in serum turbidity, free fatty acids and triglyceride content following the ingestion of meal I are compared to those following meal II, when the fasting serum triglycerides were less than 180 mg. per 100 ml. The postprandial increase in serum triglycerides was less at three hours after ingestion of the meal with the greater carbohydrate content (meal II) and there was little increase in optical density. Similar changes in the free fatty acid level occurred after each meal.

Figure 4 compares the effect of meal II in subjects with normal fasting serum triglycerides with that in subjects with elevated fasting levels. When the fasting levels were normal, meal II produced an elevation of the serum lipids which was much less than that of meal I at three hours and which continued

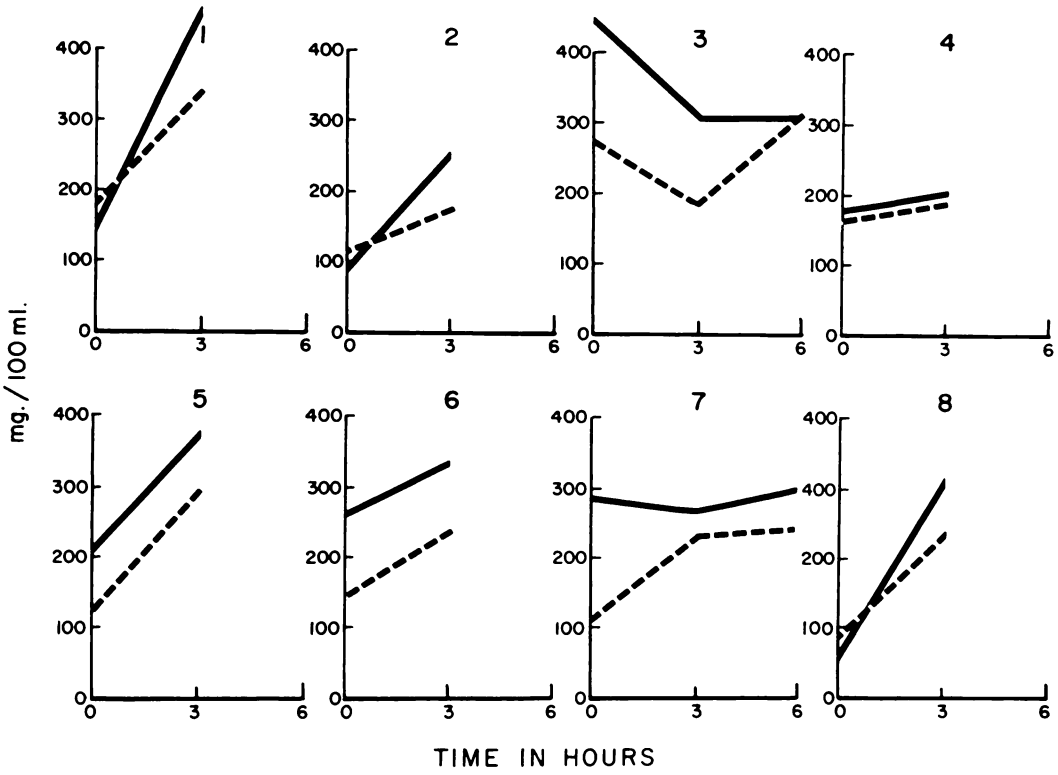

FIG. 2. Comparison of postprandial serum triglyceride levels following first (broken line) and second (solid line) ingestion of meal I.

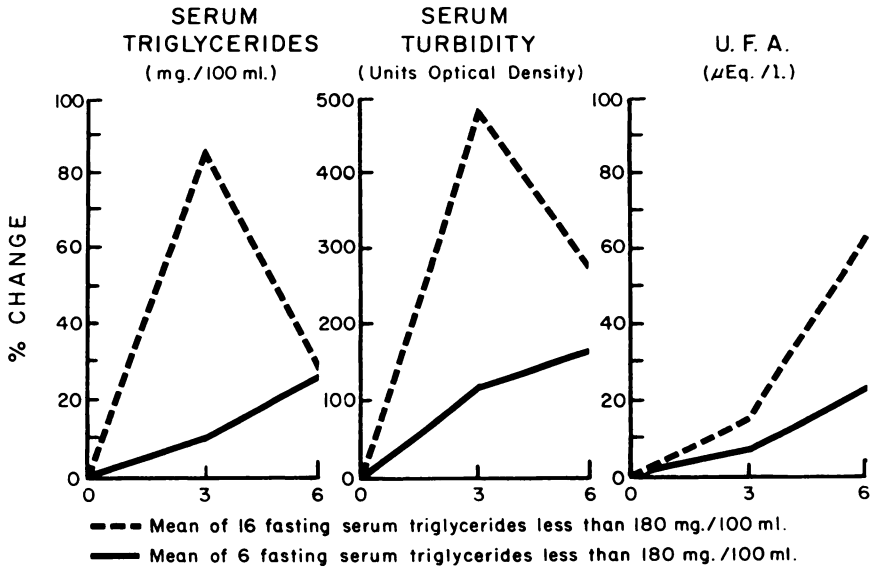

FIG. 3. Comparison of lipemia following ingestion of meal I with that following meal II at similar fasting triglyceride levels.

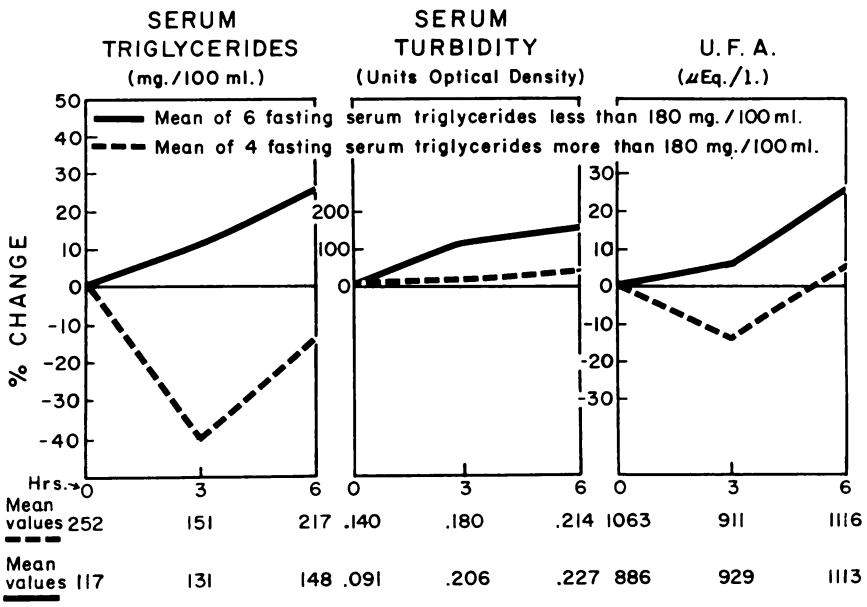

FIG. 4. Alteration in serum lipid values following ingestion of meal II expressed as per cent change and illustrating the contrast in serum triglyceride changes dependent on fasting levels.

to rise to the six-hour level although the total increase was comparatively small. If there was elevation of fasting serum triglycerides when meal II was eaten, a sharp decrease occurred in both triglyceride and free fatty acid values at three hours and the serum turbidity increased only minimally.

In two subjects comparison of alimentary lipemia following the ingestion of meal II at widely varying fasting triglyceride levels was possible. As shown in Figure 5, when subject A had a low fasting serum triglyceride content, meal II was followed by a peak at three hours and a decline at six hours although remaining above the fasting level. The serum turbidity rose at three hours and dropped toward normal at six hours. When subject A had an elevated fasting serum triglyceride, the ingestion of meal II produced no change in triglyceride level at three hours, but a definite increase at six hours. The serum turbidity in this instance was much less at three hours, but continued to rise to the six-hour level. In each instance meal II produced a sharp drop in the free fatty acid concentration after three hours and a subsequent rise in the next three hours. Subject B, when studied with elevated fasting serum triglycerides, showed a drop in the serum turbidity at the end of three hours. The serum triglycerides level followed a similar pattern at three hours, but was close to the fasting level again by six hours. In subject B the free fatty acid changes after ingestion of meal I resembled those after meal II.

COMMENTS

The postprandial lipemia noted in this study was effected not only by the composition of the meals, but also by the level of serum lipids when the meal was eaten.

Subjects with fasting serum triglycerides less than 180 mg. per 100 ml. showed an elevation in serum triglycerides, serum turbidity and free fatty acid concentration three hours after ingestion of meal I, which contained 97 gm. of fat and 4.0 gm. of carbohydrate. After six hours the serum triglycerides and serum turbidity were approaching the fasting level. The free fatty acid level continued to rise and at a slightly more rapid rate during the three- to six-hour period.

Meal II, which contained an additional 100 gm. of carbohydrate, also caused an increase in serum lipid content when the fasting

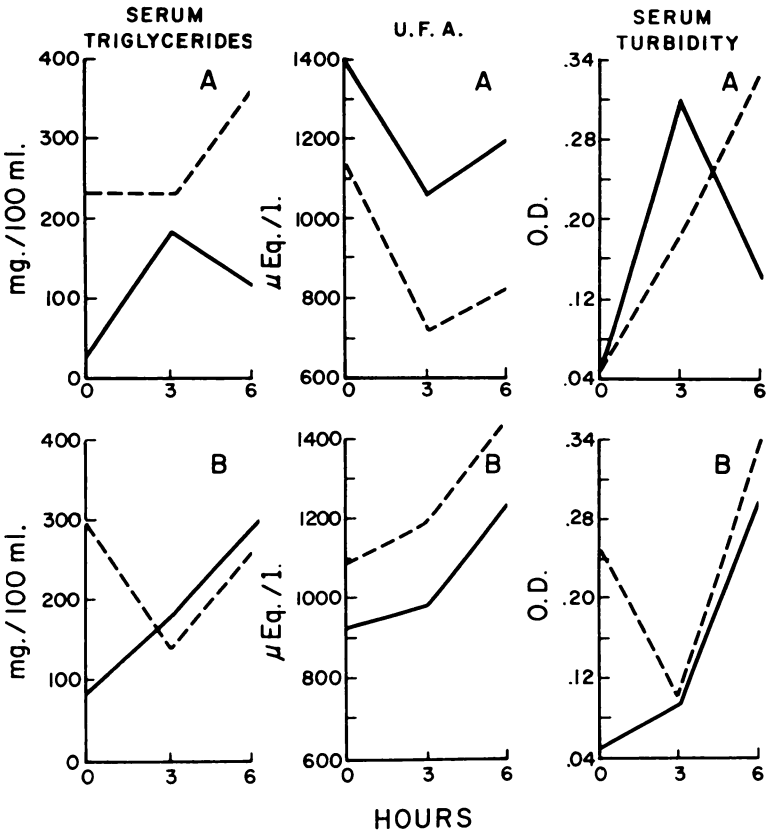

FIG. 5. Variations in postprandial lipemia occurring in subjects A and B following first (broken line) and second (solid line) ingestion of meal II.

triglyceride level was less than 180 mg. per 100 ml. The degree of increase in triglyceride, turbidity and free fatty acid content was 50 per cent less at three hours than that seen after meal I. The diminution in postprandial lipemia resulting from addition of carbohydrate to a fat meal has been described by Albrink, Fitzgerald and Man,[2] and our observations in subjects with fasting triglyceride levels less than 180 mg. per 100 ml. confirm this effect. It should be noted, however, that at six hours following meal II the triglyceride content of the serum was rising in many instances. It seems probable that a repetition of such meals might result in a fasting hypertriglyceridemia.

Following ingestion of a fat meal the triglycerides of the serum consists of those of alimentary origin plus those derived from endogenous sources. An indication of the role which endogenous fat mobilization plays in determining a serum triglyceride level may be gained by considering changes in free fatty acid concentration. A decrease in the concentration of free fatty acids is considered indicative of diminished fat mobilization. The addition of carbohydrate to a fat meal often decreases the free fatty acid concentration three hours postprandially and always results in a lesser increase than that seen after the ingestion of a fat meal alone. Thus, the diminution lipemia after meal II in comparison to meal I depends to some extent upon the inhibition of endogenous fat mobilization.

The absence of a postprandial increase in triglyceride content following ingestion of meal I when the fasting triglyceride level is high may represent an enhanced ability to utilize fat. Albrink and Neuwirth[9] have described similar changes in serum triglycerides when a fat meal was given after a prolonged fast.

The elevation of free fatty acid content after meal I was the same whether the triglyceride

level decreased or increased. This suggests that the reduction of high fasting levels of serum triglyceride following meal I may be independent of changes in glucose metabolism.

The high fasting levels of serum triglyceride noted in many of the healthy young men are unexplained. They could not be related to dietary factors. It is probable that the lipemia inhibiting effect exhibited by meal I under these circumstances will be explicable only when the factors producing the fasting elevation are known.

SUMMARY

The alimentary lipemia following the ingestion of test meals of constant fat, but varying carbohydrate content, was studied in healthy male subjects. Significant changes occurred only in the serum triglycerides, the free fatty acids and in serum turbidity. When fasting triglyceride levels were under 180 mg. per 100 ml., the degree of lipemia was 50 per cent less with the meal high in carbohydrate content. When fasting serum triglyceride levels were elevated, each meal caused a decrease in triglyceride level. It is concluded that the lipemia following a meal is influenced by the fat and carbohydrate constituents and by the fasting triglyceride level when the meal is ingested.

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