Effect of Nibbling Versus Gorging on Serum Lipids in Man

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MANY ANIMALS ingest their daily ration in many small portions spaced throughout much of the twenty-four hour period. They are nibblers. Man, on the other hand, tends to eat his diet as large meals taken infrequently, perhaps because of convenience. He is a gorger. If the rat, who is by nature a nibbler, is trained to eat his diet in one or two short periods each day, a number of seemingly untoward consequences ensue. The rat becomes obese,[1] and hyperglycemia[2] and hypercholesterolemia develop.[3] Similarly, if the chicken is trained to gorge a diet which is high in lipid content the hypercholesterolemia and atherosclerosis which develop are much more marked than that which develops when it is permitted to nibble the same diet.[4] A number of studies indicate similar results in dogs,[5] sheep[6] and monkeys.[7,8] We have undertaken a study to determine some of the metabolic consequences of nibbling versus gorging in man, and have recently described some effects on carbohydrate metabolism.[9] The results of the present study indicate that periodicity of food intake may be an important factor affecting serum lipid levels in man.

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MATERIAL AND METHODS

Five subjects were hospitalized during the complete period of study on a metabolic research ward. Two subjects had minimal to moderate hyperlipidemia; three had normal serum lipid levels. The caloric requirement necessary to maintain body weight was estimated from a careful dietary history, and the subjects were placed on a diet containing approximately 38 per cent carbohydrate, 18 per cent protein and 44 per cent fat. The caloric content of the diet was adjusted to produce a reasonably stable body weight. This diet was given as three equal meals per day for fourteen days or longer during the first part of the study.

In the second period of study, which also consisted of fourteen days or longer, an isocaloric diet consisting of exactly the same foods was given in the form of ten identical feedings every two hours from 8:00 A.M. one day until 2:00 P.M. the next day.

In the third period of study, consisting of fourteen days or longer, exactly the same foods were eaten in a single daily meal which was taken between 4:00 and 5:00 P.M.

The order of the periods was varied as shown in the figures.

Three times each week blood was drawn from the subjects in the fasting state for lipid analysis. Total cholesterol was determined by the method of Abel et al.[10] Lipid phosphorus was determined by the method of Lowry et al.[11] and phospholipid estimated by multiplying by 25. Esterified fatty acids (EFA) were determined by the method of Stern and Shapiro.[12]

RESULTS

The results are expressed graphically in Figures 1 through 5.# In every case there was an increase of serum lipids during gorging, and a decrease during nibbling.

The normal serum lipid values in our laboratory are cholesterol, 204 mg. per cent (S. D. = 27.6 mg. per cent); phospholipids, 233 mg. per cent (S. D. = 33.3 mg. per cent); esterified fatty acids, 8.9 mEq. per L. (S. D. = 2.2 mEq. per L.).

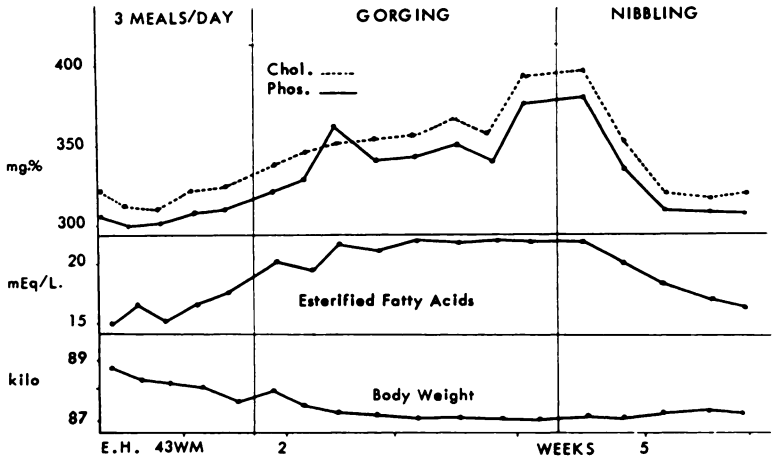

FIG. 1. Changes in cholesterol, phospholipids, esterified fatty acids and body weight with three meals daily, gorging and nibbling in subject E. H., a forty-three year old white man. Total calories, 2,492; carbohydrates, 246 gm.; protein, 107 gm.; fat, 120 gm.

Subject E. H. (Fig. 1) was mildly hyperlipidemic with baseline cholesterol levels ranging between 303 and 328 mg. per cent, baseline phospholipid levels ranging between 293 and 303 mg. per cent, and baseline EFA levels ranging between 15.2 and 17.4 mEq. per L. At the end of the gorging period, the cholesterol level had risen to 387 mg. per cent, the phospholipid level to 356 mg. per cent and the EFA level to 20.5 mEq. per L. At the end of the nibbling period, the cholesterol level had dropped to 326 mg. per cent, the phospholipid level to 302 mg. per cent and the EFA level to 17.0 mEq. per L.

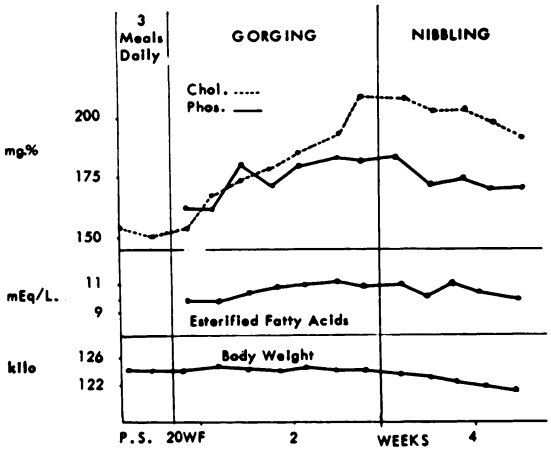

FIG. 2. Changes in cholesterol, phospholipids, esterified fatty acids and body weight with three meals daily, gorging and nibbling in subject P. S., a twenty year old white girl. Total calories, 2,506; carbohydrates, 219 gm.; protein, 106 gm.; fat, 134 gm.

Unfortunately, in the study of subject P. S. (Fig. 2), adequate baseline values were not obtained. During the period of gorging, however, serum cholesterol increased from 176 to 193 mg. per cent and EFA from 9.5 to 11.2 mEq. per L. After nibbling, the cholesterol level was 202 mg. per cent, the phospholipid level 171 mg. per cent and the EFA level 9.3 mEq. per L.

Subject A. P. (Fig. 3) was moderately hyperlipidemic with baseline serum cholesterol values ranging from 390 to 403 mg. per cent, phospholipids from 338 to 348 mg. per cent and EFA from 16.0 to 17.4 mEq. per L. This was the only subject in whom gorging was maintained for four weeks. In this instance all the serum lipids reached peak values after two weeks of gorging, but fell off slightly at the end of four weeks. After two weeks of gorging, the serum cholesterol was 491 mg. per cent, phospholipid 382 mg. per cent and EFA 17.8 mEq. per L. At the end of the nibbling period, serum cholesterol was 388 mg. per cent, phospholipid 332 mg. per cent and EFA 16.0 mEq. per L.

In subject H. A. (Fig. 4) nibbling preceded gorging. Baseline serum cholesterol levels ranged from 197 to 234 mg. per cent, phospho-

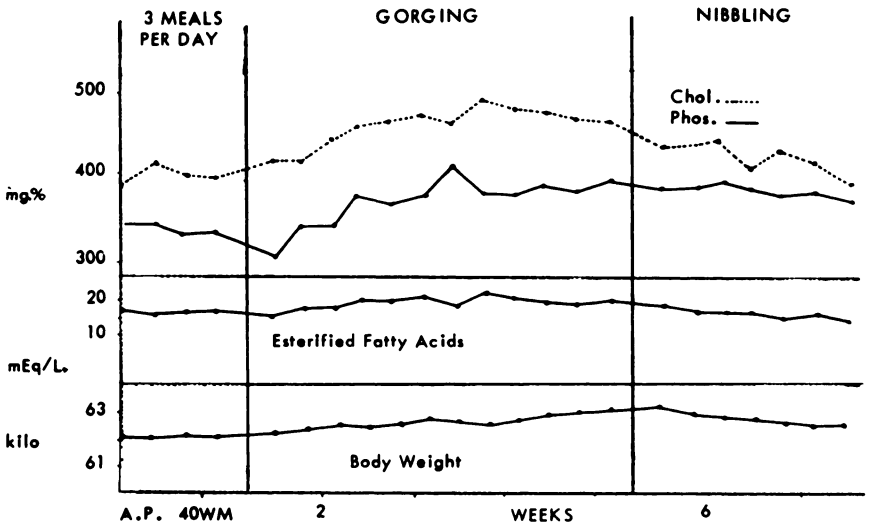

FIG. 3. Changes in cholesterol, phospholipids, esterified fatty acids and body weight with three meals daily, gorging and nibbling in subject A. P., a forty year old white man. Total calories, 2,468; carbohydrates, 234 gm.; protein, 104 gm.; fat, 124 gm.

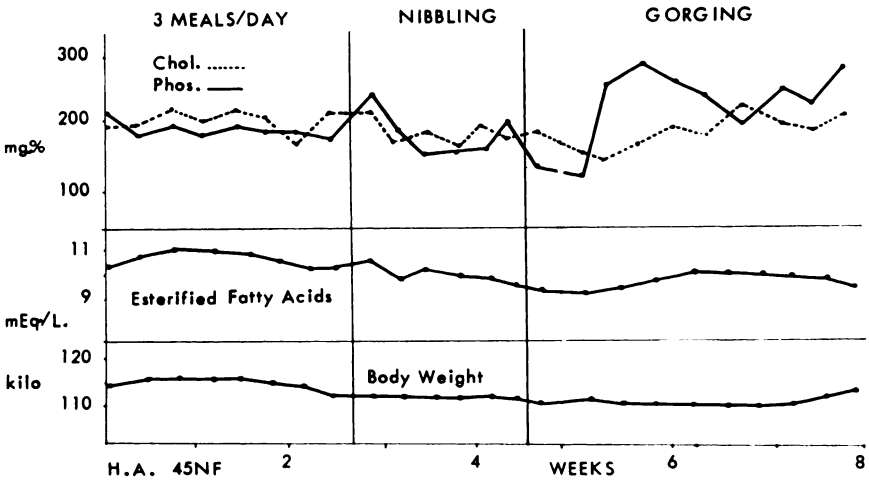

FIG. 4. Changes in cholesterol, phospholipids, esterified fatty acids and body weight with three meals daily, gorging and nibbling in subject H. A., a forty-five year old Negro woman. Total calories, 996; carbohydrates, 96 gm.; protein, 45 gm.; fat, 48 gm.

lipid levels from 199 to 234 mg. per cent and EFA levels from 10.5 to 12.3 mEq. per L. After nibbling, serum cholesterol was 203 mg. per cent, phospholipids 212 mg. per cent and EFA 8.5 mEq. per L. At the end of the gorging period, serum cholesterol was 210 mg. per cent, phospholipids 243 mg. per cent and EFA 8.5 mEq. per L.

The study of subject L. D. (Fig. 5) was the most complete in that baseline values were obtained before nibbling and again before gorging. During the first baseline period, serum cholesterol ranged from 140 to 164 mg. per cent, phospholipids from 159 to 184 mg. per cent and EFA from 7.7 to 8.9 mEq. per L. After nibbling serum cholesterol was 130 mg. per cent, phospholipids 144 mg. per cent and EFA 7.4 mEq. per L. During the second baseline period, the cholesterol level rose slightly to 135 mg. per cent, the phospholipid level to 155 mg. per cent and the EFA level to 8.1 mEq. per L. At the end of the gorging

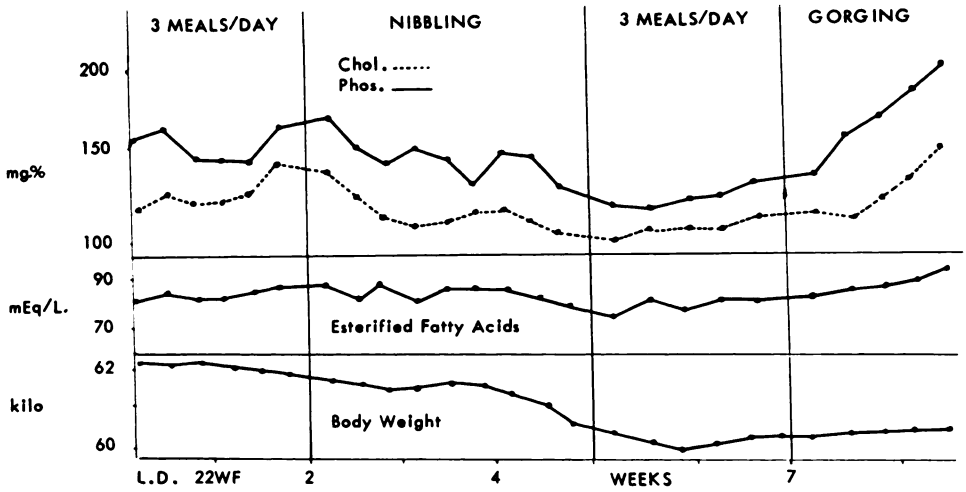

FIG. 5. Changes in cholesterol, phospholipids, esterified fatty acids and body weight with three meals daily, gorging, and nibbling in subject L. D., a twenty-two year old white woman. Total calories, 1,964; carbohydrates, 168 gm.; protein, 80 gm.; fat, 108 gm..

period, serum cholesterol was 160 mg. per cent, phospholipids 204 mg. per cent and EFA 8.9 mEq. per L.

Changes in body weight were slight and of doubtful significance. In four subjects there was a suggestion that weight loss tended to occur with nibbling and weight gain with gorging. However, in subject E. H., weight changes tended to occur in the opposite direction.

COMMENTS

The results of the present study indicate that when the meal pattern in man is changed from three meals a day to nibbling (subjects H. A. and L. D.), there is a prompt decrease in serum lipid levels; when it is changed from three meals a day to gorging (subjects E. H., P. S., A. P. and L. D.), there is a prompt increase in serum lipid levels. Although the magnitude of these changes is not great, it is consistent. Changes produced by nibbling were rapidly reversed by gorging and vice versa. In man, the changes occur in both male and female subjects; whereas in the rat, only the female is affected.[3] These changes occur in subjects with hyperlipidemia and in subjects with normal serum lipid levels.

It should be pointed out that the changes observed in this study are relatively acute ones. It remains to be shown whether prolonged maintenance on either the gorging or nibbling regimens is accompanied by persistent alteration in blood lipids. It has been observed that serum cholesterol changes produced by nibbling and gorging in monkeys persisted during eight week periods when these two feeding patterns were maintained.[8]

Although the results of this study do not define the mechanism of the observed effects, we may be permitted to speculate on the basis of biochemical studies which have been reported on animals subjected to altered periodicity of food intake. Two major metabolic adaptations occur when the rat is shifted from his natural nibbling pattern to one in which he is trained to ingest his entire twenty-four hour requirement during a single two hour feeding period.

(1) There is a markedly increased capacity for lipogenesis which is referable, at least in part, to increased glucose-6-phosphate dehydrogenase and 6-phosphogluconate dehydrogenase activity in liver and adipose tissue.[13] Such an adaptation is understandable in view of the limited capacity of animals to store calories in forms other than fat.

(2) During the long periods of fasting between meals, adaptations must occur which permit the production of a continual supply of blood glucose for metabolic processes for which carbohydrate is indispensable. It has been

demonstrated that although liver glycogen is depleted by a twenty-four hour fast in a rat that has nibbled, it is not decreased after a similar fast in a rat that has gorged.[13] It has also been shown that many enzymes involved in hepatic gluconeogenesis, such as glucose-6-phosphatase,[14] fructose-1,6-diphosphatase,[15] threonine dehydrase[16] and transaminases,[17] are increased during fasting.

It appears, therefore, that adaptations occur during the fasting phase of the gorging regimen which lead to increased gluconeogenesis from amino acids transported from the protein stores of the body to the liver. These may account for the abnormal glucose tolerance curves which we have observed in human subjects who have been gorging.[9] It is also likely that the net flux of free fatty acids from the fat depots (simply as a reflection of the prolonged periods of fasting) is increased in those who gorge in contrast to those who nibble. This would result in increased synthesis of serum lipids by the liver since, to a large extent, the uptake of free fatty acids by the liver is determined by availability.

Whether the high incidence of atherosclerosis which afflicts man and which has been correlated with serum lipid levels can be influenced by alteration of the frequency with which food is eaten must remain conjectural, but this question certainly deserves further consideration.

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