Effect of prefeeding lipid on food intake and satiety in man

C P Sepple, N W Read

Abstract
Experiments were carried out in normal volunteers to investigate whether preingestion of lipid reduces food intake. In the first set of experiments, 300 ml beef consomme soup with or without 60 g margarine was fed to each of six volunteers, followed 20 minutes later by either a low fat solid meal or a preselected appetising meal. Subjects were allowed to eat as much of the meal as they wished. Preingestion of the high fat soup had no significant effect on the consumption of either of the solid meals and did not influence sensations of hunger or fullness. As we have previously shown that prefeeding a fatty soup delays gastric emptying of a subsequent meal, this suggests that gastric distension may play a relatively minor role in regulating food intake. In the second set of experiments, we studied the effect of ingesting either a high fat breakfast (65 g fat, 927 kcal) or a similar low fat breakfast (8.1 g fat, 418 kcal) on the consumption of a preselected appetising lunch in six healthy volunteers. The high fat breakfast significantly reduced the amount of the meal eaten at lunchtime (p<0.02), the total energy intake from the meal (p<0.05) and the rate of eating (p<0.05) compared with the low fat breakfast. When the subjects were presented with their lunchtime meal they felt significantly less hungry after the high fat breakfast (p<0.05). Only a small proportion of either meal (15% of the high fat meal and 12% of the low fat meal) remained in the stomach and plasma glucose concentrations had returned to fasting levels. Plasma triglyceride concentrations were much higher at lunchtime after ingestion of the high fat breakfast (p<0.001). The energy intake from the breakfast and lunch combined was not significantly different on the high fat breakfast day, indicating that the energy consumption at lunch compensates for the amount eaten at breakfast. These results are compatible with the concept that the interaction of nutrients with small intestinal receptors may play a part in limiting food intake.

Experiments carried out in man and experimental animals suggests that food intake can be inhibited by the presence of nutrients in the small intestine. Infusion of fat into either the jejunum or the ileum, but not into a peripheral vein of human volunteers can decrease food intake and induce early satiety. The association of this effect with a delay in gastric emptying might suggest mediation by gastric distension, although this is contradicted by the observation that the continuous feeding that occurs in animals equipped with open gastric fistulae, can be abolished by infusion of nutrients into the small intestine.

The aim of these experiments was to investigate whether preingestion of lipid rich foods would effect food intake and induce early satiety in human volunteers. Because we had previously observed that preingestion of a high fat soup delays the emptying of a solid meal eaten 20 minutes later, the first experiment investigated the effect of feeding the same high fat soup on food intake and satiety from a subsequent meal. The second experiment investigated the effect of feeding a high fat breakfast on the amount of food eaten at lunchtime.

Methods

SUBJECTS
Each set of experiments was carried out on six healthy male volunteers. All volunteers were within the normal weight range for their age, sex, and height.

EFFECT OF FEEDING A HIGH FAT SOUP ON SATIETY AND INTAKE OF A SOLID MEAL PRESENTED 20 MINUTES LATER
Two sets of experiments were carried out on six volunteers. In the first set of experiments, the meal fed to each volunteer consisted of ratatouille and pasta mixed together (2.2 g fat/100 g, 6.2 kcal/100 g) and was selected from the normal weight range for their age, sex, and height.

Protocol
Volunteers were allowed to eat breakfast if they normally did so, providing that they ate it before 8.30 am, and it was the same on both occasions. Midmorning snacks or drinks were not permitted. At 12.30 pm, the subjects ingested 300 ml beef soup (150 ml condensed beef soup, Campbell’s, Norfolk) mixed with either 150 ml water (total caloric value = 12 kcal) or homogenised with 90 ml water and 60 g margarine (Suma Wholefoods, Halifax) (total caloric value = 455 kcal). Twenty minutes after consuming the soup, subjects were offered a solid meal and allowed to eat as much as they wished. The order of the two experiments in each of the studies was randomised. The amount eaten (g) and the volume of fluid
consumed was assessed by weighing the contain-
ers before and after consumption and the caloric
value of the meal was calculated from these
values. The time taken to complete the meal was
recorded and the average rates of eating and
drinking calculated. Subjective sensations such as
hunger, fullness, and nausea were recorded by
means of visual analogue questionnaires, which
were completed by the subjects at 10 minute
intervals for a total of 70 minutes. Volunteers
completed the first questionnaire just before they
consumed the soup and the last, 50 minutes after
they were presented with their solid meal.

**EFFECT OF EATING A HIGH FAT BREAKFAST ON SATIETY AND INTAKE OF A MEAL CONSUMED AT LUNCHTIME**

Paired studies were carried out on each of six
volunteers, which were separated by a week. On
the nights before the studies, volunteers con-
sumed a similar light dinner; food was pro-
hibited after 9:30 pm. At 8:30 am on the morning
of the experiment, volunteers ate either a high fat
breakfast (caloric value = 927 kcal, fat content =
65 g, total weight = 287 g), or a low fat breakfast
(caloric value = 418 kcal, fat content = 8.1 g, total
weight = 283 g). The two breakfasts were similar
in appearance and virtually identical in carbo-
hydrate and protein content. The low fat breakfast
consisted of very lean bacon, scrambled egg, white,
toast and a drink of skimmed milk, whereas the
high fat breakfast was composed of streaky bacon,
scrambled whole egg, toast spread with 30 g butter
and a drink of full cream milk. From 8:50 am until
12:30 pm, subjects were free to leave the depart-
ment, but care was taken to ensure that they had no further food or
drink and their activities were similar on both
study days. At 12:30 pm, they were presented with
an appetising meal, which they had pre-
selected from a menu. They were invited to
consume as much food and non-alcoholic fruit
juice as they wished. The amount of food and
drink consumed, the energy intake, the rates of
eating and drinking and the time taken to
complete the meal were measured. Subjective
sensations were recorded on visual analogue
scales, completed at five minute intervals from
8:30 am until 8:50 am and then at half hourly
intervals until 12:30 and at 10 minute intervals
until 13:20 pm.

**EFFECT OF A HIGH FAT BREAKFAST ON GASTRIC EMPTING, PLASMA GLUCOSE CONCENTRATIONS AND SERUM TRIGLYCERIDE LEVELS**

Paired studies were carried out in six volunteers.
On one occasion, subjects consumed the high fat
breakfast and on the other occasion, they ate the
low fat breakfast.

At 8:30 am, subjects were given their breakfast
which was labelled with 1.85 MBq of technetium
sulphur colloid (99m-Tc). Subjects were then
positioned under a scintigraphic gamma camera
in a semisupine position. Gastric emptying of the
breakfast was monitored for four hours by
scintigraphy. Blood samples were taken at
regular intervals via an indwelling venous catheter. Plasma glucose concentrations were
measured at 15 minute intervals and serum
triglyceride concentrations were measured at
hourly intervals throughout the study.

**STATISTICAL ANALYSIS**

The statistical significance of the difference in
the results obtained during the test and control
studies was assessed by the paired t test.

**Results**

**EFFECT OF PREFEEDING A HIGH FAT SOUP ON FOOD INTAKE AND SATIETY OF A SOLID MEAL PRESENTED 20 MINUTES LATER**

Preigestion of either the high fat soup or the low
fat soup did not influence the amount of either
the standard low calorie meal or the appetising
meal ingested, the time taken to complete either
meal and the rate of ingestion (Table 1). Subjects
drank more fluid after ingestion of the high fat
soup with preselected appetising meal (p<0.01),
but not with the standard meal.

If the soup is included in the sum of total
energy intake, then the calorie intake from the
standard meal during the high fat study was
significantly larger than during the correspond-
ing control study (p<0.01). Irrespective of the
nature of the soup, the energy intake from the
preselected appetising meal was greater than the
energy intake from the standard meal (p<0.01).
Preigestion of either high fat or low fat soup
did not influence scores of fullness or any other
sensations in either experiment.

**EFFECT OF FEEDING A HIGH FAT BREAKFAST ON FOOD INTAKE AND SATIETY OF AN APPETISING MEAL FED AT LUNCHE TIME**

Ingestion of the high fat breakfast significantly
reduced the amount eaten at lunchtime (p<0.02),
the energy intake from that meal (food and
drink, p<0.05) and slowed the rate of consump-
tion of lunch (p<0.05), but did not influence the
time taken for subjects to complete the meal
(Table II, Fig 1).

The overall energy intake from breakfast and

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**Table I** Effect of high fat soup on food intake and satiety of a standard low calorie meal and an appetising meal

<table>
<thead>
<tr>
<th></th>
<th>Ratatouille meal</th>
<th>Preselected appetising meal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Test</td>
</tr>
<tr>
<td>Meal completion time (min)</td>
<td>15 (2)</td>
<td>11 (2)</td>
</tr>
<tr>
<td>Total amount eaten (g)</td>
<td>549 (72)</td>
<td>440 (70)</td>
</tr>
<tr>
<td>Rate of eating (g/min)</td>
<td>45 (3)</td>
<td>42 (4)</td>
</tr>
<tr>
<td>Energy value of food (kcal)</td>
<td>357 (56)</td>
<td>305 (48)</td>
</tr>
<tr>
<td>Total energy intake (kcal) (meal + soup)</td>
<td>378 (55)</td>
<td>770 (48)</td>
</tr>
</tbody>
</table>

**Table II** Effect of a high fat breakfast on feeding behaviour and satiety of a lunchtime meal

<table>
<thead>
<tr>
<th></th>
<th>High fat breakfast</th>
<th>Low fat breakfast</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount eaten (g)</td>
<td>790 (82)</td>
<td>1047 (94)</td>
<td>p=0.02</td>
</tr>
<tr>
<td>Energy intake (kcal)</td>
<td>944 (94)</td>
<td>1284 (113)</td>
<td>p=0.05</td>
</tr>
<tr>
<td>Rate of eating (g/min)</td>
<td>52 (4)</td>
<td>62 (5)</td>
<td>p=0.05</td>
</tr>
<tr>
<td>Daily energy intake (kcal)</td>
<td>1871 (94)</td>
<td>1702 (113)</td>
<td>NS</td>
</tr>
</tbody>
</table>

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Figure 1: Individual results from the six volunteers showing the effect of prefeding a low fat breakfast and a high fat breakfast on the total amount eaten (left), the total energy intake (centre) and the rate of ingestion (right) of a lunchtime meal.

Lunch combined was not significantly affected by the nature of the breakfast (Table II), suggesting that the low energy intake at lunch compensated for the high energy intake at breakfast.

Subjects felt significantly more full (p<0.05) five minutes after starting the high fat breakfast than they did five minutes after the low fat breakfast (Fig 2). More important, they felt less hungry when the lunchtime meal was presented to them after eating the high fat breakfast compared with the low fat breakfast (p<0.05). There were no other statistical differences in any of the other sensations recorded.

Discussion

The effects of prefeding lipid on subsequent ingestion of food depends upon how the lipid is given in relation to the test meal. Prefeding lipid in the form of a soup before a solid meal did not significantly reduce the amount of the solid meal eaten, irrespective of whether this was a standard meal or a preselected appetising meal. The total energy intake (meal+soup) was greater when the high fat soup was consumed compared with the low fat soup and after the appetising meal compared with the standard meal, although subjects ate to similar levels of fullness. Thus the results indicate that subjects do not compensate for changes in energy density of a meal by altering the amount of food eaten, and that food intake from a single meal may be influenced more by hedonistic factors. The observation that prefeding a high fat soup delays gastric emptying, but does not influence ingestion of the subsequent meal might suggest that gastric dis- tension is a relatively unimportant factor in regulating normal eating behaviour. Alternatively, Booth and other workers have suggested that satiety is a conditioned reaction and therefore the volunteers may have consumed similar amounts as a result of past experience of the meal.

Different results were obtained if the lipid was
Effect of prefeeding lipid on food intake and satiety in man

Incorporated in a cooked breakfast; this reduced the volume and the energy intake from a lunch eaten four hours later. Also when subjects had consumed the fatty breakfast they felt less hungry immediately before lunch. This result was not related to differences in gastric emptying of the two breakfasts from the stomach. Very little of either breakfast remained in the stomach to influence food ingestion four hours later. Neither was it related to differences in plasma glucose concentrations, as they had attained fasting levels by 90 minutes after ingestion of either breakfast. Serum triglyceride concentrations, however, were still raised four hours after the high fat breakfast, suggesting continued absorption of fat at that time. Thus, the data are compatible with the limitation of energy intake by interaction of fat with small intestinal receptors. It is unlikely that the presence of plasma lipid or oxidation products are responsible for the suppression of food intake, as we have previously shown that intravenous infusion of fat emulsion failed to influence energy intake. The reason why the high fat soup failed to reduce energy intake, whereas the high fat breakfast reduced energy intake at lunch time could be explained by the possibility that after 20 minutes, insufficient amounts of the soup would have emptied from the stomach to interact with intestinal receptors regulating food intake.

The data from the breakfast experiments indicate that, at least in the short term, normal subjects possess mechanisms that attempt to normalise daily energy intake. This is in agreement with other recent data, in which subjects increased the amount eaten two hours after ingesting a low energy dense lunch compared with a high energy dense lunch. Studies carried out over longer periods of time, suggest that there is little or no compensation in the amount eaten if the fat content of a diet is changed, but the appearance and palatability remain similar. It is possible that in the long term, the subject may be able to override gastrointestinal signals and become conditioned to a higher energy intake, alternatively with continued exposure to a high energy intake, intestinal nutrient receptors or receptors sensitive to CCK released from the small intestine by exposure to fat, may become down regulated.


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**Figure 3:** Serum concentration of triglyceride (top) and plasma concentration of glucose (bottom) after consuming the high fat breakfast (dotted line) and the low fat breakfast (solid line). Results are expressed as mean (SEM) (n=6) (*p<0.01, **p<0.001).