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Eating Frequency and Health

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INTRODUCTION

The day-to-day diet is increasingly dictated by work conditions,
if only because more and more meals are provided by school canteens and work restaurants.
Social meals are now only taken in leisure time and have taken on new meanings,
representing a veritable cultural form of consumption.
Eating is completely moulded to fit the division of time: in the last analysis,
it has been reduced to a mere physiological necessity,
conveniently catered for by modern restaurant practices and industrial products,
or to no more than a leisure time activity.
Time is not tailored around eating but rather eating is tailored around time.

in: "Le rôle de l'Education dans l'Alimentation" (The role of Education in Eating Habits),
by Mrs Michèle Ologoudou,
Opinions & Reports of the Social and Economic Council,
Republic of France, 2004.

"What is the relationship between eating frequency and health?"

The history of research in the field was characterised by intense activity and promising results in the 1960's. However, insufficient emphasis was placed on the practical aspects of eating frequency. The consequent lack of empirical benefit resulted in a waning of interest in the subject until the late 1980's. Now this topic regains all the more interest as it coincides with a shift in eating habits.

Danone Vitapole, the Research and Development Centre of Groupe DANONE, and LU, Biscuits and Cereal Products, a Division of Groupe DANONE, have been researching on feeding frequency and on the fourth meal impact and benefits since 1996 in close partnership with external nutritional experts. This research resulted in several scientific publications and also in two major scientific events.

In **August 2001**, within the frame of the 17th International Congress of Nutrition in Vienna, Danone Vitapole and LU jointly organized a **workshop** chaired by Prof. Jeanine Louis-Sylvestre and co-chaired by Prof. John Blundell. This workshop, entitled "About feeding frequency: the fourth meal", brought together seven different scientific teams from five countries, to discuss the definitions of meals and other eating episodes at the semantic and physiological levels; and to highlight the impact of feeding frequency on metabolism and body weight management. The exchanges that took place in Vienna resulted in a publication in the proceedings of the Congress [1].

In **January 2003**, Danone Vitapole invited fifteen experts, coming from different countries and with different areas of expertise, to participate in an **Expert Meeting** held in Mougins (France). This meeting aimed at reviewing the relevant scientific data with the remit of formulating—if justified—objective, practical recommendations.

In his keynote presentation, the Chairman John Blundell laid out some of the key questions in the field:

- What factors—physiological, biochemical, social and cultural—determine habitual eating frequency (EF)?
- How important is EF in relation to other dietary variables (*e.g.* the macronutrient composition of the food)?
- Where does EF fit in the complex interplay between the central and peripheral systems which control appetite and energy intake (EI)?
- Can a range of EFs be defined to confer optimal health, notably with respect to preventing weight gain or even promoting weight loss?
- Would this range be identical in all people, at all stages of life, and in all cultures?
- How easy is it to change EF?
- Will an imposed "healthy" EF have the same beneficial effect as a habitual "healthy" EF?
- Are benefits observed in research laboratory conditions (with tightly controlled EI and diet composition) relevant to the real world?
- If a recommendation is made to increase EF, will this necessarily lead to increased EI?

The participants reviewed current knowledge and presented data based on their own work. This booklet presents a summary of the proceedings and conclusions of the Mougins expert meeting.

CHAPTER 1

EPIDEMIOLOGICAL DATA

EATING FREQUENCY AND BODY WEIGHT

A number of epidemiological studies have set out to investigate the relationship between eating frequency (EF) and body weight. The majority of these studies have been cross-sectional by nature. Some of these studies have detected a positive correlation (*i.e.* higher EF is associated with higher weight) [2, 3], some have failed to detect any significant relationship [4, 5], and others have detected an overall inverse relationship (*i.e.* higher EF is associated with lower weight) [6-9]. Any kind of cross-sectional study which addresses dietary intake is fraught with problems, and those which set out to investigate eating frequency particularly so (as discussed in the paragraph on Methodology below). Unless such problems are effectively controlled for, epidemiological patterns may be difficult to interpret—and it has to be said that the problems are actually rather difficult to overcome.

Sandra Drummond presented her own work on a sample of 79 men and women [10]. Her team found significant inverse correlations between EF and both body weight and Body Mass Index (BMI) in the men; this was not associated with total energy intake. In contrast, in the women, no correlation—neither negative nor positive—was observed between EF and body weight, and this was associated with a significant positive correlation between EF and total energy intake, with the women who ate most frequently having the highest overall energy intakes. This suggests that **the men were compensating for energy taken in during "extra" eating episodes more effectively than the women**. The higher energy intake was not associated with increased BMI among these women, and analysis revealed a positive correlation between physical activity and EF, *i.e.* **the women that ate more frequently were expending more energy in leisure activities**. Similarly, in the men, the observation that the more frequent eaters weighed less than the less frequent eaters despite the same energy intake suggests that the former may be more physically active although no actual correlation was detected between EF and reported physical activity level. In both groups, there was a significantly positive correlation between EF and the percentage of energy derived from carbohydrate, *i.e.* **the more frequent eaters appeared to be eating more carbohydrate** at the expense of protein and fat so that a significant meal pattern-related difference emerged in the overall carbohydrate to fat ratio, a pattern similar to that observed in other studies [11]. The preponderance of carbohydrate in the diet of the more frequent eaters may well be because "snack" foods tend to be richer in carbohydrate and lower in fat than "meals" [3, 12].

Another cross-sectional study detected an inverse correlation between EF and body weight in women [13]. In this large cohort study they saw that, despite the frequent eaters eating almost twice as frequently as the infrequent eaters, they did not have a higher BMI. In fact BMI, weight and hip measurements were significantly greater in the infrequent eaters.

The results of a recent Polish study presented by Jadwiga Charzewska found a similar inverse correlation in adolescents of both sexes but, in contrast, failed to detect any correlation at all in adults and revealed a significantly positive relationship in older people. An inverse correlation was observed in adolescents in another study [14] but, in this case, no correlation was observed in any of the other groups (neither in the elderly, those of working age nor the middle-aged).

In France, data from the INCA study show fewer obese subjects among those accustomed to take a fourth meal in the afternoon [15].

Thus, despite methodological problems (discussed later), **cross-sectional epidemiological studies suggest that increased eating frequency may be associated with lower weight, at least in certain sub-populations**. However, results from prospective studies are needed to draw robust conclusions.

EATING FREQUENCY, BLOOD LIPID LEVELS AND CARDIOVASCULAR RISK

The question of eating frequency and blood lipid levels has been specifically addressed in three large-scale, cross-sectional epidemiological surveys, one carried out on a population of 379 men in Czechoslovakia [6], another on a population of 2,034 men and women in the United States [5] and the third on 14,666 men and women in Britain [16]. Certain similar patterns were observed in all of these studies with, in the largest-scale survey**, mean concentrations of total cholesterol and low density lipoprotein** (LDL) **cholesterol decreasing in a continuous relation with increasing daily eating frequency in both men and women**. In contrast, no consistent relationships were observed for a variety of other lipid parameters and other markers implicated in CVD, including high density lipoprotein (HDL) cholesterol concentration, waist to hip ratio, and blood pressure.

Thus, in the British study, frequent eating was associated with greater energy expenditure: this could be due to altered metabolic processes or, more probably, a simple undocumented difference in physical activity levels. If the latter is the case, this could be a methodological bias since physical activity is known to induce small but significant decreases in the levels of total and LDL cholesterol in the blood.

In another cross-sectional epidemiological study, in this case conducted on a free-living population of smokers, those that "ate between meals" were found (after adjustment for age, sex, pack-years of smoking, diabetes, hypertension and BMI) not only to have a lower plasma cholesterol concentration but also **less peripheral arteriosclerosis** [17], a more direct cardiovascular risk factor.

Thus, there is **epidemiological evidence that increased eating frequency may be associated with lower levels of cholesterol in the blood**. This is consistent with animal data and also with the results obtained in some of the small-scale, prospective human studies that have been performed (which will be discussed in Chapter 2).

METHODOLOGICAL OBSTACLES

In nutrition studies, the collection of data is difficult and can be imprecise. Berit Heitmann presented two specific problems to which cross-sectional investigations of eating frequency are particularly susceptible - problems which together seriously undermine the validity of any results unless they are strictly controlled.

When asked, **people in general tend to underestimate the amount of food they eat**: this is known as **under-reporting**. The only known method of gathering information on habitual diet intake is to ask subjects to supply this information themselves. Every self-report modality is prone to the problem of under-reporting, the degree being dependent on the specific type of instrument (*e.g.* diet record data are less reliable than diet recall or diet history data). In addition, **certain sub-populations are more likely to under-report their food intake than others**, in particular the obese, the post-obese, the overweight and the diet-restrained subjects [18].

Snacks tend to be under-reported to a greater extent than meals, with the consequence that the overweight are more likely to report a misleadingly low number of eating episodes than those of normal weight. The consequence of this can be an apparent correlation between lower eating frequency and greater weight.

The tendency to under-report energy intake seems to be dependent on the stigma associated with certain foodstuffs, notably those rich in fat and sugar, and with eating between meals. The intensification of health campaigns to reduce fat and sugar intakes may explain why **under-reporting seems on the increase even in people of normal body weight** [19].

The extent of under-reporting is already apparent in published epidemiological surveys and can be appreciated by retrospectively comparing reported energy intake figures with calculated minimum energy requirements (based on the basal metabolic rate [BMR] multiplied by a conservative coefficient, *e.g.* 1.05). **In under-reporters, the reported dietary intake is below that necessary to guarantee the minimum energy requirement**, and the discrepancy increases with increasing body weight.

In more recent surveys [10, 11], suspected under-reporters were identified using this method, and excluded from the analysis. Of course, after the exclusion of a certain number of extreme cases, the sample may still include under-reporters with a "plausible" dietary intake.

In large-scale epidemiological surveys of free-living populations where objective measurements of dietary intake are not feasible, this problem can be insurmountable.

Compounding the problem of the under-reporting of dietary intake is that of **the over-reporting of physical activity**, and those subjects who under-report their dietary intake to the greatest extent are probably also the most likely to over-report their physical activity, as Stephan Rössner underlined on the basis of his own experiments.
The lack of accurate methods may explain the fact that very few studies take physical activity into account.
Another danger in the analysis of results is the "**reverse causality**" phenomenon. In a general manner, cross-sectional epidemiological studies are observational studies, from which no cause-effect relationship can be inferred. For instance, many overweight subjects reduce eating frequency in an attempt to reduce intake—they "skip" meals. One can thus observe at time "t" a correlation between reduced eating frequency and excess weight; but it would be an error to conclude that a higher eating frequency *leads to* reduced body weight. To draw such conclusions, prospective epidemiological studies are needed, from where information on eating frequency among normal weight individuals is available prior to the studied weight changes, so that the temporal relationship can be assessed.
We must also keep in mind that **results acquired in one context cannot be extrapolated to another**: this is pertinent because so many of the results in this field come from the United States where eating behaviour is certainly quite different from in Europe.

Key facts

- Epidemiological data show that higher eating frequency may be associated with
  - lower body weight, at least in certain sub-populations;
  - a reduction in total cholesterol and LDL-cholesterol.
- Cross-sectional epidemiological studies yield associations and not causal relationships. However, prospective epidemiological data is generally lacking.
- The validity of these results can be compromised by methodological biases (under-reporting, physical activity not accounted for).

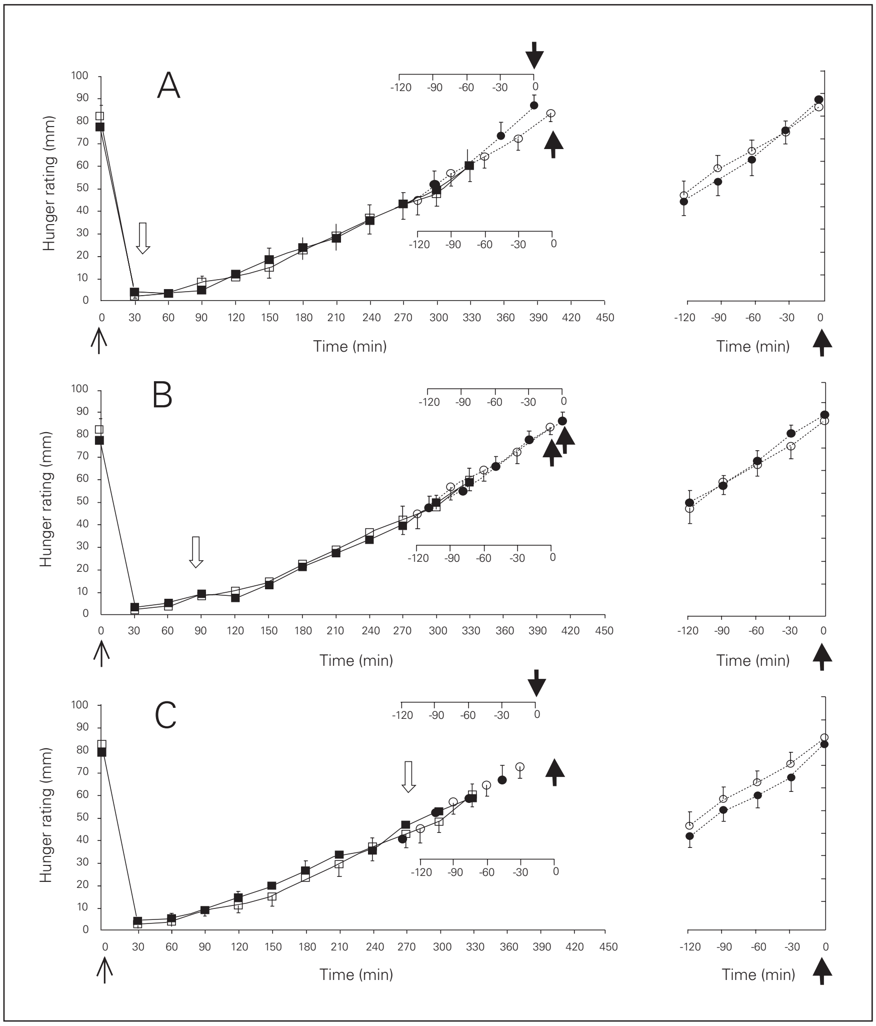
CHAPTER 2

EATING FREQUENCY AND METABOLISM

Before dealing with intervention studies, Jeanine Louis-Sylvestre provided a **definition for meal and snack** upon which the analysis was based. A "meal" occurs when a food is consumed by a person in a state of hunger, whilst the term "snack" can be used for consumption in the absence of hunger, *i.e.* the pre-prandial biochemical profile is a key parameter [20]. This definition is used by these particular researchers, and would not be agreed by all participants.

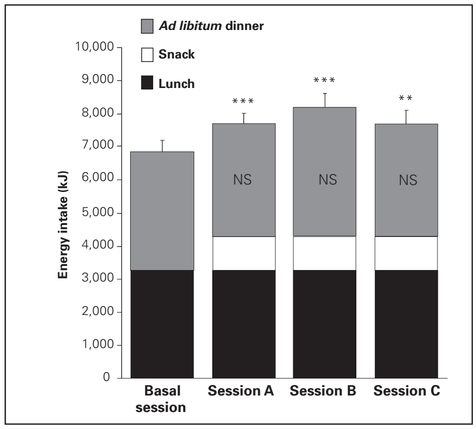
A food intake triggered by hunger sensations is preceded by not surprisingly high hunger scores but also by a linear decline in plasma glucose and insulin concentrations. These profiles are not observed before an eating episode triggered under conditions of satiety. Thus it is likely that postprandial metabolic responses are different between these eating episodes. **Different postprandial metabolic consequences of a snack consumed at various times during the intermeal interval (*i.e.* when subjects were in a satiety state)** have been well characterised [21]: given early in the intermeal interval, the snack elicited a greater insulin response but no change in the glucose excursion and also no change in the fatty acid profile whereas when the snack was given later, the rise of the fatty acids levels, normally 30 minutes before the request of the subsequent meal, was inhibited. In conclusion **substrate and hormone profiles were indicatives of carbohydrate storage when the snack was consumed early in the intermeal interval, and of fat storage when the snack was ingested later**.

Finally, it has been shown that a snack eaten in the non-hungry state neither delays the subject's request for the next meal nor reduces the amount of food consumed thereafter (*Figure 1*). In other words, **food consumed in the non-hungry state is not subsequently compensated, so this type of consumption leads to increased net energy intake and potentially, weight gain.**



Mean (±SEM) postlunch (solid lines) and predinner (dashed lines) temporal profiles for hunger ratings in the basal session (open symbols) compared with session A (filled symbols; A), the basal session (open symbols) compared with session B (filled symbols; B), and the basal session (open symbols) compared with session C (filled symbols; C). The thin arrow at 0 min on the x axis indicates lunchtime; the open arrows above the curve indicate the snack intake time in session A (*ie*, 5 min before the peak of postprandial hyperglycemia as determined in the basal session), session B (*ie*, 40 min after the peak), and session C (*ie*, 120 min before the time of the dinner request in the basal session); and the thick arrows above and below the curves indicate the time of the dinner request. *n* = 11. There were no significant differences between sessions.

Figure 1A. Effect of a snack eaten in a non-hungry state, on the request of the next meal [21].



Mean (±SEM) total intake in the basal session and in sessions A, B, and C. $n = 11$.
NS, not significantly different from the basal session.
, * Significantly different from the basal session: $**P < 0.01$, $***P < 0.001$.

Figure 1B. Effect of a snack eaten in a non-hungry state, on the intake at the next meal [21].

Thus, in discussions of metabolism, the **"meal or snack" question** is associated with meaningful differences in certain key physiological and behavioural parameters. In all the experimental studies cited in this discussion of the effects of eating frequency on metabolic parameters, total intake was either fixed on the basis of the subjects' usual intake or was calculated from resting metabolic rate measurements. Therefore, it can be assumed that the results pertain to food consumption in the hungry state whatever the number of meals being consumed; in these circumstances, the term meal frequency might be more pertinent than that of eating frequency.

The snack *versus* meal question

What constitutes a "snack" and what constitutes a "meal"? This question is always raised whenever eating frequency is under discussion, especially in the context of epidemiological investigations.
The criteria used to make the distinction are many and various:
(i) timing, *e.g.* breakfast, lunch and dinner are meals, anything else is a snack;
(ii) the interval between adjacent episodes;
(iii) ceremonial considerations, *e.g.* whether the food is consumed in the company of others or alone (a criterion commonly used by sociologists);
(iv) nutrient composition, *e.g.* energy content or food type;
(v) whether the food is consumed in the hungry state or a non-hungry state.
Because the last is associated with important physiological differences (the "pre-prandial biochemical profile"), it is most relevant when it comes to assessing metabolic parameters in controlled laboratory-based investigations, although it is less suitable for the collection of epidemiological data.

CARBOHYDRATE METABOLISM

The short-term effects of different meal frequencies on carbohydrate metabolism have been studied in various populations, including normal [22-27], obese [28], hypercholesterolaemic [29] and diabetic [30-33] subjects. The basic strategy adopted is to split the subjects into two or more different groups and, after giving each the same type and quantity of food in different numbers of eating episodes, measure and compare certain informative physiological parameters, notably the levels of glucose and insulin in the blood.

Short term (some hours to some days)

Jenkins *et al.* compared in a simple protocol [26] the intake of 50 grams of glucose either by "gorging", or by prolonged sipping (*Figure 2*). Gorgers experience a sharp glucose excursion that is absent in sippers, but on the whole, the area under the curve (AUC) for glucose is independent of how the sugar was ingested, indicating that absorption is of the order of 100% however it is administered. In contrast, the insulin curve differs greatly between the two groups, with a greater AUC for the gorgers, which means that an acute blood glucose excursion triggers disproportionate insulin production. In other words, the amount of insulin secreted into the bloodstream depends not only on the amount of energy ingested but also on the time frame over which ingestion occurs, and a "sipping" regimen is associated with insulin economy.

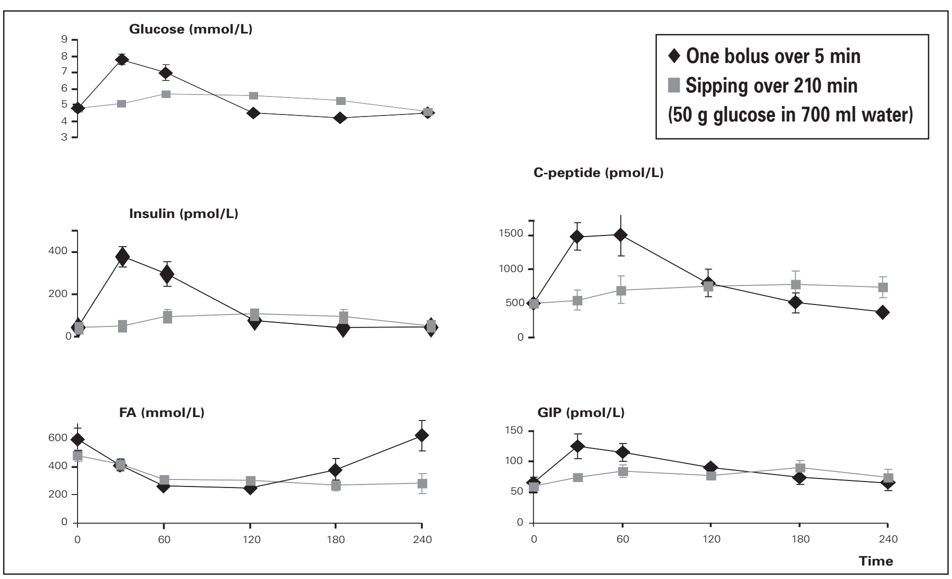


Figure 2. Compared effect of gorging and continuous sipping on blood parameters [26].

Most of the studies cited in the Introduction address longer time frames and, to a greater or lesser extent, attempt to mimic more "normal" eating patterns. Details differ from protocol to protocol but the same difference between more and less frequent eaters emerges in all such studies, as exemplified by *Figure 3*.

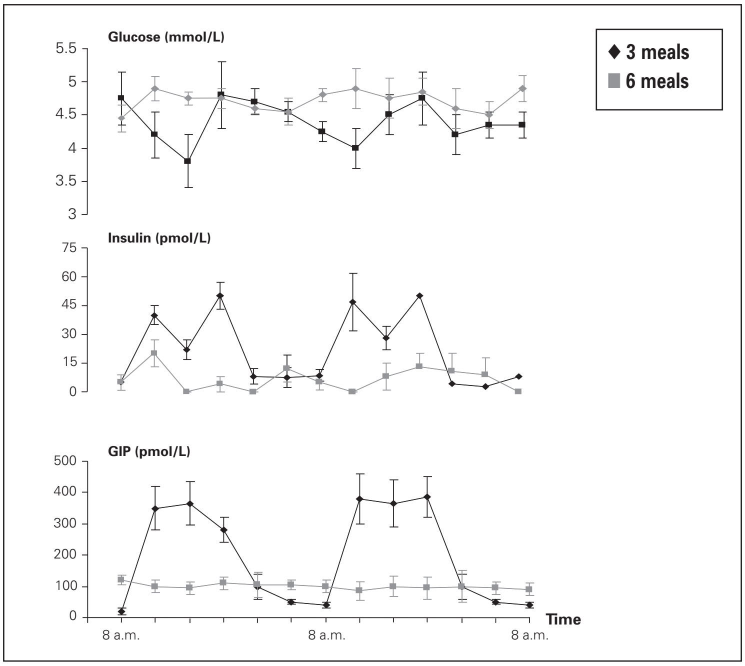


Figure 3. Effect of eating frequency on carbohydrate metabolism [56].

In the long term, glucose excursions are attenuated in the more frequent eaters although the **mean blood glucose level over the measurement period** (*i.e.* the area under the curve) **is similar for both groups**. Insulin profiles follow the blood glucose profiles but **the area under the insulin *versus* time curve is smaller for the frequent eaters**, *i.e.* in response to the same energy intake over the period, less insulin is produced by the more frequent eaters than by the less frequent eaters. The reduction in overall insulin production by the more frequent eaters ranges from 20% to 32%, **the more "extreme" the difference in meal frequency, the more marked the observed reduction in insulin level**.

The same trend was observed in **all subject types**, including diabetics [31-32] apart from one case [30] in which the diet included higher levels of fat than in any of the other tightly controlled studies discussed.

With respect to other informative parameters such as blood levels of fatty acids and triacylglycerols, the results obtained in the above-mentioned experiments were less concordant suggesting that these parameters may be more sensitive to differences between the protocols (*e.g.* in the composition of the diet, the total amount of energy provided, the characteristics of the subjects under investigation, or the specific meal frequencies being compared).

Mechanisms underlying reduced insulin secretion

A first clue comes from experiments such as that presented in *Figure 2*, in which the investigators also measured the blood concentration of **glucose-dependent insulinotropic polypeptide** (GIP; sometimes referred to as gastric inhibitory polypeptide), a potent insulin stimulant. In all cases in which this parameter was measured, **the more frequent eaters produced less GIP. Thus, decreased GIP production may underlie insulin economy**, in which case it might be appropriate to say that the insulin profile follows that of GIP.
Furthermore, GIP inhibits gastric emptying, and gastric motility. Thus an increased eating frequency, via a reduction in GIP, could in theory accelerate gastric emptying. This is counteracted by other mechanisms: the stomach empties at an increasingly faster rate as it becomes more distended [34]. **With a small meal, gastric emptying is slowed down** [35-36]; this decreases the rate of energy delivery from the stomach into the intestine and the rate of glucose absorption; which in turn results in a decreased insulin secretion.

Consequences of reduced insulin secretion

- **Switch from glucose oxidation to lipid oxidation**

Insulin inhibits lipolysis by directly inhibiting hormone-sensitive lipase activity (which hydrolyses triglycerides inside adipocytes prior to their mobilisation), and **promotes lipogenesis** by stimulating endothelial lipoprotein lipase (which hydrolyses circulating triglycerides to generate free fatty acids for transport into adipocytes). Jeanine Louis-Sylvestre therefore inferred that **reducing net insulin levels by increasing meal frequency** will result in lipid being both less efficiently sequestered out of the circulation and more efficiently released from adipocytes: **lipid will be more available** and thus preferably utilized.

Insulin also increases blood flow through adipose [37] **and skeletal tissue**. Therefore a **decrease in the insulin level** will **reduce blood flow** through the very tissues where glucose is trapped by cells for more or less immediate consumption - skeletal tissue accounts for 80% of insulin-mediated glucose uptake [38]. With less glucose-laden blood flowing through these tissues, **glucose is less available** and less of it will be metabolised.

Another activity of insulin is to **promote blood flow through the mesenteric artery**. **Reduced insulin levels** will slow down glucose absorption from the gut, resulting in **attenuation of glucose excursions** (*i.e.* lower peak blood glucose concentrations), thereby constituting a minor positive feedback loop tending to oppose steep rises in insulin production.

Thus J.Louis-Sylvestre concludes that **lipid oxidation is favoured in people who eat more frequently, whereas glucose oxidation predominates in those who eat less frequently**.

● Better appetite control

Speechly & Buffenstein have investigated this question in normal-weight male subjects [39]. The results in *Figure 4* show that **more frequent eating tends to flatten out the hunger response**. And when offered food *ad libitum* at a subsequent meal, those whose intake had been spread out over the preceding five hours ate less—by a factor of over 25%—than those who had eaten the same amount over that period but in a single instalment five hours previously. Thus, **spreading out a given amount of food intake over a longer period would seem to promote better appetite control**, at least in the short term. A similar effect was seen in obese subjects [28].
These authors and others [40-41] attribute this phenomenon to differential effects on the rate of gastric emptying, blood glucose concentrations and the levels of certain hormones, not only insulin but also cholecystokinin (which, like GIP, inhibits gastric emptying).

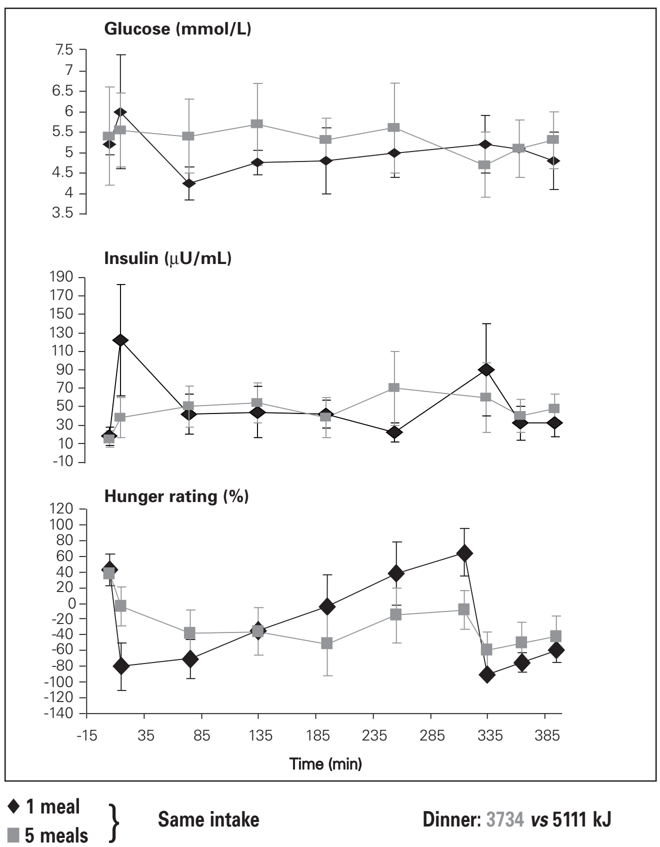
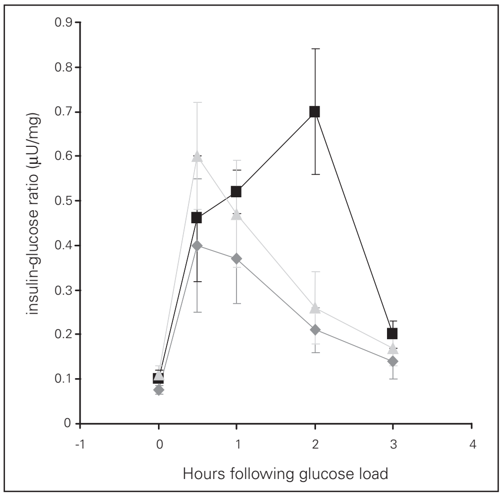


Figure 4. Influence of eating frequency on the hunger response [39].

We must keep in mind that obese subjects are in a constitutively hyperinsulinaemic state so a moderate decrease in insulin secretion may not have the same impact as in normal-weight subjects.

Long-term effects

A number of studies [6, 42-47] showed that **an increase in meal frequency prolonged over four weeks** results in **improved glucose tolerance** (*Figure 5*).



▲ **3 meals for the first week: 2/8,3/8,3/8 (usual pattern)**
■ **2 meals during 4 weeks : 1/8,7/8**
◆ **8 isocaloric meals during 4 weeks**

Figure 5. Effect of an increased eating frequency on glucose tolerance [45].

Other studies with a similar but shorter protocol (two weeks in most cases) failed to detect any such effect, no matter how extreme the differential meal frequency [22, 25-26, 48-50]. In summary, **improved glucose tolerance was observed in all of the longer-term studies** (four weeks or longer) **and in none of the shorter-term ones**, *i.e.* an adaptive response appears to become installed between two and four weeks after a change in meal frequency. What physiological mechanisms might underlie this long-term effect? The latency seems too long to concern biochemical adaptations even such as alterations in gene expression [51]. So Jeanine Louis-Sylvestre hypothesizes that increasing meal frequency leads to a favored lipid utilization. Thus, the frequency of meals could affect the adiposity of subjects and therefore their level of circulating fatty acids, and as a consequence, may impact their glucose tolerance.

Conclusion on carbohydrate metabolism

The only mean to "spontaneously" reduce passive overconsumption, is to reduce insulin secretion. Increasing meal frequency induces a decreased insulin secretion with its consequence on fuel utilization and therefore on energy and macronutrient intakes, blood lipids and particularly cholesterol synthesis, blood uric acid... all these points with their sequelea. It should be interesting to determine the minimum number of meals required for a valuable reduction of passive overconsumption and consistent with a normal social life.

LIPID METABOLISM

Blood lipid levels

As was seen in Chapter 1, epidemiological data suggest that increasing meal frequency may improve certain clinically pertinent parameters of lipid metabolism, such as LDL and total cholesterol.
As stated by Denis Lairon, **results of intervention studies are not consistent**.
In some studies, significant decreases in blood **triglycerides** were observed [27] whereas no change in this parameter was observed in others [5, 22, 25].
Some of the results showed an inverse relationship between eating frequency and **LDL cholesterol** levels [5, 16, 22, 25, 52], but no such association was observed in other studies. For instance, in two studies [22, 25], a randomised cross-over design with close dietary supervision was adopted so that the consequences of two-week regimens at different meal frequencies could be reliably compared on a subject-by-subject basis, thereby controlling for variability between different subjects (*e.g.* due to genetic differences). **Moderate reductions in LDL cholesterol** were observed in both of these (13.5% on seventeen meals *versus* just one; and 8.1% in the case of a more practical comparison, namely nine meals *versus* three).
In **diabetic patients**, similarly confusing results have been obtained with specific meal frequency-related effects on lipid metabolism detected in some studies—*e.g.* moderate decreases in the levels of **triglycerides** [32] or **non-esterified fatty acids** [31]—but not in others [49].
In contrast, results obtained in well designed experiments conducted on **hyperlipidaemic subjects** [29, 53] have been relatively consistent: a change in eating frequency has not been observed to have any effect on any indicator of blood lipid metabolism, including that of the fasting blood LDL cholesterol concentration.

Denis Lairon concludes that:
- epidemiological observations suggest that eating frequency can apparently modulate blood cholesterol levels;
- mixed evidence has been obtained in intervention studies, but certain of the better conducted of these studies support the idea;
- no detrimental effect of increased eating frequency on any aspect of lipid metabolism has ever been reported;
- the magnitude of the observed effects on blood cholesterol, although moderate, is such that significant impact on cardiovascular risk might be expected;
- data on other indicators of lipid metabolism (levels of triglycerides, free fatty acids, etc.) is inconclusive, so that no kind of "mechanistic" hypothesis can be proposed with respect to these indicators at this time.

Possible mechanisms underlying the cholesterol-lowering effect of increased eating frequency

The reduction in total cholesterol could be linked to the reduced blood insulin. Insulin is known to promote **hepatic cholesterol synthesis** by stimulating hydroxymethylglutaryl-CoA (HMGCoA) reductase [54], the rate-limiting step in this synthetic pathway [55]. Thus, reducing insulin output would tend to decrease hepatic cholesterol synthesis.
This question has been directly addressed [56] by measuring ^{2}H incorporation into plasma free cholesterol: cholesterol synthesis was reduced in the more frequent eaters against a background of decreased blood levels of insulin and GIP. Another approach to the same question involves monitoring the urinary secretion of mevalonic acid, a marker for HMGCoA reductase activity. This parameter too was found to correlate well with meal frequency-related changes in serum cholesterol levels [57].
Another hypothesis is based on **reverse cholesterol transport**: cholesterol is removed by this process essentially in the post-prandial phase, even after the ingestion of only small amounts of fat, so more frequent eating episodes might result in the ultimate removal of more cholesterol.

Gorging and nibbling: data from rabbits

The rabbit is a useful model in research into nutrition, lipid metabolism and cardiovascular risk factors, because of physiological analogies with the human system, and an important capacity to develop measurable atheroma deposition within a matter of weeks of exposure to a lipid-rich diet [58-60]. This capacity may be related to the protracted (20 to 30 hours) post-prandial hyperlipidaemic response to a fat bolus meal which is observed after adaptation to a high fat/high cholesterol diet [61]; a reduced hyperlipidaemic response to a fat load is observed in control animals which have been fed a conventional, low fat diet.

In a study by Juhel and co-workers [62], two groups of rabbits were fed the same overall **high fat/high cholesterol diet**. One group (the "nibblers") was allowed to consume all the diet over the course of the 24-hour period; the other group (the "gorgers") was allowed to nibble most of the components, but was given almost the entire fat ration in the form of an intrabuccal bolus which was ingested within 20 minutes.
The results obtained in this study show that **nibbling vs gorging** a high fat, cholesterol diet in rabbit for eight weeks lowers fasting and postprandial responses for triglycerides and triglyceride-rich lipoproteins and **reduces the extent of aorta atheroma deposition**. Authors also showed that in rabbit cultured hepatocytes, the higher the rate of triglyceride-rich lipoproteins supply, the lower the rate of hepatic lipid uptake and bile acid secretion.

Conclusion on lipid metabolism

The results of the rabbit studies suggest that, at least in this species, some of the long-term adverse effects of a diet high in fat and cholesterol are exacerbated if the fat is ingested in a small number of large doses rather than a greater number of smaller ones. This picture is consistent with epidemiological and experimental data acquired in humans that tend to suggest that eating frequency is inversely related to blood cholesterol concentration. The exact mechanisms underlying the phenomenon remain undefined.

Besides, relationships between feeding frequency and gene polymorphisms of interest need to be determined to take into account important differences in individual susceptibility.

Another key factor is the exact macronutrient composition of the diet and, not only did this parameter vary between the different studies, but furthermore dietary control and supervision were less than strict in some of them.

Key facts

- Spreading food intake out over an increased number of episodes during the day has a number of documented short-term effects. Changes occur in lipid and carbohydrate metabolism:
    - glucose excursions are blunted;
    - net insulin production is reduced;
    - LDL-cholesterol tends to be lowered.

- In the overall hypothesis which is emerging, gastric emptying is slowed down and overall insulin production is reduced when eating frequency is increased. The net result is that lipid oxidation is favoured at the expense of glucose oxidation and lipid storage, and cholesterol synthesis is reduced. This may reduce adiposity and the level of circulating fatty acids, thereby leading to systematic, adaptive changes in both lipid and carbohydrate metabolism.

- Such long-term responses to a sustained increase in meal frequency are actually observed:
    - improved glucose tolerance;
    - moderately reduced fasting plasma total and LDL cholesterol.

CHAPTER 3

EATING FREQUENCY, BODY WEIGHT AND ENERGY BALANCE

As was seen in Chapter 1, the epidemiological data indicate that a higher habitual eating frequency may be associated with lower body weight or greater energy intake for an equivalent body weight. In other words, that there exists some form of relationship between eating frequency and energy balance—the balance between energy intake and energy expenditure. Several intervention studies have been undertaken to investigate this association between eating frequency and energy balance, and the results of some of these will be presented in this Chapter.

EATING FREQUENCY AND BODYWEIGHT: INTERVENTION STUDIES

Livestock breeders are well aware that fractionating the same quantity of feed over time yields animals with a higher fat-free mass and a lower fat mass. In parallel to this selective loss of adipose tissue without any differential in body weight, when a gorging diet was imposed on animals which are natural nibblers, concentrations of serum lipids increased [63-64].

In humans, the study by Fabry *et al.* [65] was the first one to demonstrate that **a lower eating frequency is associated with increased adiposity**. This study involved children in three schools: children in one school were allowed to continue with their habitual pattern of five meals a day, while children in the second school were switched to three meals a day, and in the third school to seven meals. After one year, the children on the seven-meal regimen had put on relatively less weight than the other groups, and had a greater fat-free mass (as estimated by measuring skinfold thickness at a series of points on the body). In this study, energy intake over the year was estimated as "comparable" between the groups. In 1973, Debry *et al.* published results showing that **mean weight loss in dieting overweight individuals was significantly greater among those who fractionated their intake** between seven eating episodes than in those who were eating only three meals a day [66]. However, the success of this strategy could not be reproduced by a number of different groups despite robust protocols and wide-ranging differences in eating frequency [67-68].

Stephan Rössner speculates that **any putative metabolic benefits accruing from increased eating frequency might well be more than outweighed by the tendency of overweight patients to lose control** of the amount that they eat once they have started eating. In other words, more frequent eating episodes might lead to more frequent loss of control and even higher energy intake. Moreover, altering a subject's meal pattern risks further destabilising their already pathological eating behaviour with adverse consequences, *e.g.* triggering the so-called night-eating syndrome (characterised by morning anorexia, insomnia and concentrated eating in the evening) which is common in the obese.
No current guidelines on the treatment of obesity (*e.g.* those issued by the National Weight Control Registry in the USA) mention eating frequency as such, although introducing breakfast—if this meal is often missed—is a common recommendation.

Recently, an intervention study was performed by Didier Chapelot and his team in 24 French normal weight, young, male adults, allocated in two groups [69-70]. Members of the first group habitually took a fourth meal in the afternoon (the 'goûter') and were asked to skip it during 28 days. Members of the second group were non-goûter eaters and were asked to eat a 'goûter' in addition to their usual 3 meals for 28 days. **Suppressing the goûter led to a moderate but significant weight gain** (640 grams), **most of which was accounted for by fat mass** (350 grams) (*Figure 6*). This change is especially significant given the fact that the experimental period was just one month. At the end of the experimental period, no significant changes were observed in nocturnal levels of glucose, triglycerides, free fatty acids or insulin, compared to the baseline. In contrast, the level of **circulating leptin** rose significantly in response to suppression of the goûter.
In the other group, **introducing the goûter had no effect on weight or fat mass**, despite a small increase in net energy intake (of about 200 calories per day).
Since there is no reason to imagine that eating four meals as opposed to three meals a day has any effect on macronutrient absorption, the results of this experiment suggest that energy expenditure increased as a more or less direct consequence of the introduction of an extra fourth meal, although no direct attempt to estimate energy expenditure was undertaken.

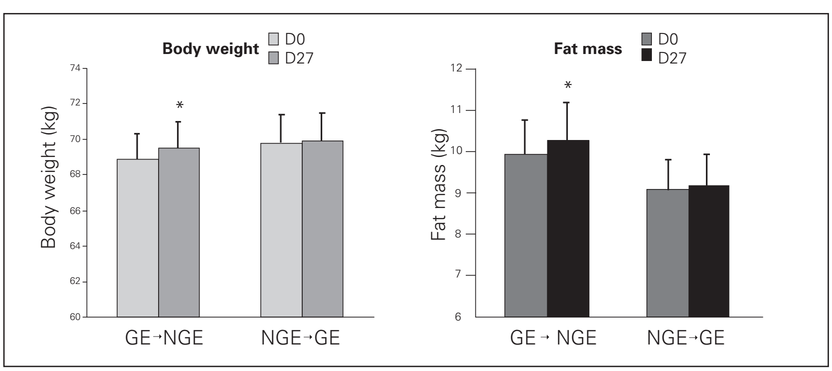


Figure 6. Body weight and fat mass before and after the change of meal frequency [70].

EATING FREQUENCY AND ENERGY EXPENDITURE

Total energy expenditure (TEE) can be broken down into three major components: diet-induced thermogenesis (DIT), the basal metabolic rate (BMR), and the energy used for physical activity (*i.e.* muscle contraction). Any eating frequency-related effect on TEE must be exerted through one or a combination of these components.

Diet-induced thermogenesis

Experiments designed to investigate the influence of eating frequency on DIT have yielded contradictory results, even when broadly similar protocols were used [71-72]. Moreover, the effects observed were minor and the weight of the evidence suggests that **eating frequency does not have any significant effect on DIT** [18] which is, in any case, a minor component of TEE in adult humans.

Physical activity

In a prospective study, Westerterp-Plantenga and her team [73-74] detected correlations between habitual meal frequency (HMF), BMI and EE components in men (but not women). The EE components defined were resting energy expenditure (REE) as measured by the ventilated hood method, and activity energy expenditure (AEE) as measured using an accelerometer (a technique which had been previously validated with reference to doubly-labelled water measurements).

in…	HMF correlates with…		
	REE	AEE	BMI
older men	+	–	+
younger men	–	+	–

The conclusion is that **increased meal frequency is associated with better energy intake regulation in healthy young men**.

Westerterp *et al.* attributed the differences observed between the patterns in younger men, older men and women, to differences in fat-free mass between these populations although this variable was not specifically measured.

Total energy expenditure

Five studies [68, 75-78] have been published in which rigorous measurements were made to compare subjects on 1-2 or 5-7 daily meals, including one study [78] in which laborato-

ry-based, 24-hour whole-body calorimetry results were confirmed with doubly-labelled water measurement of free-living energy expenditure. **In none of these studies was any statistically significant overall eating frequency-dependent difference in TEE detected**. Predictable diurnal differences may have metabolic consequences, but any differences were compensated (*e.g.* significantly raised night-time expenditure on the gorging regimen was associated with lower expenditure in the daytime) and there was no effect on the ultimately essential parameter, TEE.
Therefore, there is little evidence in favour of the hypothesis that eating frequency affects energy expenditure. If eating frequency affects energy balance therefore, we must look for effects on the other side of the equation, namely energy intake.

EATING FREQUENCY AND ENERGY INTAKE

Energy intake is regulated by **hunger** and **satiety** which together ensure that when we need energy, we seek food, and once sufficient energy has been consumed, we stop eating. The efficiency of this regulatory system appears to be asymmetrical with the appetite response more tightly matched to energy requirements than the satiety response.
Westerterp team suggest that the onset of hunger is associated with a progressive and significant decrease in the concentration of sugar in the blood, a phenomenon referred to as pre-prandial hypoglycaemia. The mechanism linking cause and response in this case appears to be based on the dynamics of glycogen synthesis and breakdown [79]. The interval between the last meal and the next episode of pre-prandial hypoglycaemia and hunger depends on numerous factors, notably the macronutrient composition of the food.
Appetite is controlled at different levels with short-term factors imposed on longer term ones. Among other mediators, **leptin** promotes satiety, on the one hand by potentiating anorectic pathways which tend to suppress appetite, and on the other hand by inhibiting orexigenic pathways which stimulate appetite**. Leptin is produced in adipose tissue at a rate which is directly proportional to adiposity** so the circulating levels of this peptide hormone rise with increasing body weight.
In the study already mentioned, Didier Chapelot [70] **demonstrated a significant increase in fat mass after removal of the goûter**, and this was accompanied by a significant increase in nocturnal leptin levels.

Chapelot also demonstrated that **removing the goûter led to an anticipatory increase of the energy intake at lunch, and to a compensatory increase of the energy intake at dinner**. On the opposite, creating a goûter led to a decrease of the energy intake at dinner.

Melanson *et al.* made a cross-over experiment in which subjects were given an isoenergetic pre-load high in either fat (96%) or carbohydrate (100%), presented in the form of a lemon drink divested of any organoleptic distinguisher [79]. When comparing the 24-hour energy intake in both study days, a significant inverse correlation can be detected between the differential in the amount of energy consumed on the two test days (*i.e.* the amount consumed on the day of the high-fat pre-load minus the amount consumed on the day of the high-carbohydrate pre-load) and the subjects' habitual meal frequency, although the causality of this relationship was not addressed.

EATING FREQUENCY AND APPETITE

In a classic experiment, Birch *et al.* [80] showed **that flavour preference in small children is conditioned by energy density**: the children express a preference for the flavour corresponding to the higher energy density (*Figure 7*). Similar experiments reveal that the same conditioning does not occur in adults [81].
However**, other forms of response can be acquired in adulthood, notably responses to environmental cues**. This is shown by the acute mid-morning rise in appetite in subjects who have been habituated to a snack at that time, compared with the flat appetite rating in unconditioned control subjects [82]. This is not a learned process but a physiological need confirmed by the glucose and insulin preprandial declines observed in the Chapelot experiments [20].

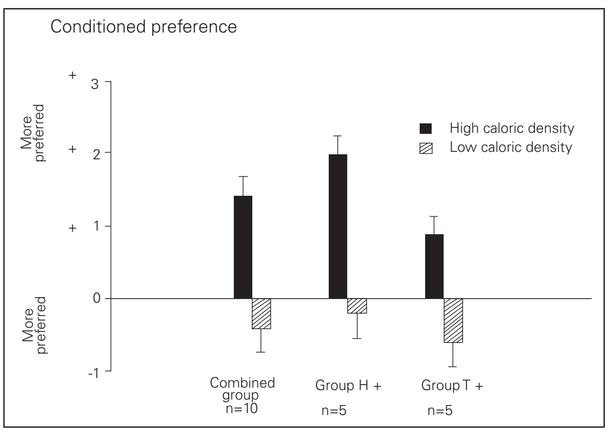


Figure 7. Conditioned preference in children, towards the flavour corresponding to the higher energy density [80].

Just as cues can be learned, in the absence of reinforcement, they tend to be "unlearned" and this can occur over a relatively short time frame too. For instance [83] at the beginning of Ramadan (the Muslim month-long period of fasting during daylight hours), appetite rises sharply around lunch time (*Figure 8*) but as the month proceeds (during which time, the lunch-time cue is systematically ignored) this response flattens out, an evolution which is associated with a gradual attenuation of the overall hunger response.

Although appetite is to a certain extent learned, any such learned responses are superimposed on a circadian rhythm governing appetite which is related to the regular meal pattern and which is maintained during weight loss. Thus, as pointed by Kees de Graaf, **when a particular food is eaten outside of the regular meal pattern** or at an unexpected moment, **the circadian rhythm tends to drive appetite back up** towards its "normal" level at that time of day so **the subsequent compensatory decrease in energy intake is incomplete** and people end up eating more. The magnitude of this failure to adequately compensate for between-meal energy intake depends on all the various factors discussed above which have been shown to be important in determining appetite and satiety, among which the dietary composition of the eating episodes.

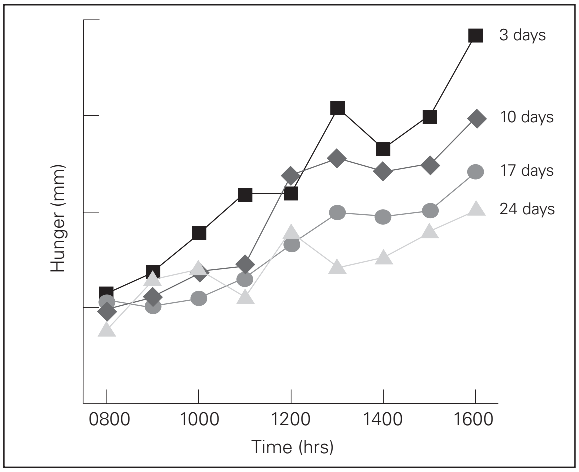


Figure 8. Hourly hunger ratings as function of days in Ramadan (3, 10, 17, 24 days) [83].

Characteristics of eating episodes that are of importance for appetite

In an obesigenic environment, one of the key issues to be addressed in any analysis of the consequences of different eating frequencies is whether or not snacking leads to increased overall energy intake and weight gain. In this respect, one must consider five major characteristics of the eating episode.

Volume and density

Bulky, dense food tends to be more satiating irrespective of its energy density. The primary mechanism here is related to stomach distension which suppresses appetite, so a diet rich in bulky, indigestible material such as fibre can suppress overall energy intake. On its own or contained in solid food, even water—the ultimate bulky, energy-poor nutrient—is an efficient if short-lived satiating agent [84]. The satiating efficiency of bulk material provides the rationale behind the strategy of using meal replacers in weight-loss programmes, a strategy which has met with considerable success [85].

Macronutrient composition

A well-documented but under-recognised (at least in the popular perception) fact, supported by extensive epidemiological evidence, is that, in general, between-meal eating episodes are richer in carbohydrate and lower in fat than regular meals (cf. next chapter).
The macronutrient composition of food consumed is particularly important, since attenuation of hunger and suppression of appetite are key factors in the energy compensation at the following meal [86].
It is generally agreed that **the satiating efficiency of protein is higher than that of carbohydrate, and the satiating efficiency of lipid is lowest of all**. Appetite being a learned response, the satiating efficiency of different types of food is not only due to their macronutrient composition *per se*, but is also related to cues associated with the food's organoleptic properties. The net result is that food that contains a large amount of energy does not necessarily lead to a higher degree of satiation than less energy-dense food.
Besides, the physiological effects of carbohydrate—including its satiating efficiency—vary greatly according to the form in which it is presented, which can be expressed by a foodstuff's Glycaemic Index (GI) (reviewed in the booklet on Glycaemic Index and Health in this series). Since a low-GI diet, as a high eating-frequency diet, flattens the glycaemic profile, many of the observed benefits of a low GI diet may be the same as those emerging in the context of increased eating frequency.

Liquid *versus* solid

Many people do not consider any kind of liquid nourishment as "food" and the underreporting of the consumption of high-energy soft drinks is a notorious problem in epidemiological surveys. This failure to register calories consumed in this way may be partly because the inducer of this type of energy consumption tends to be thirst rather than hunger.
Epidemiological data show that the massive rise in the prevalence of obesity which has occurred in the USA over the last twenty-five years has not been associated with any increase in fat intake, but rather with a 60% increase in the consumption of soft drinks [87], and this is a problem which appears to be particularly acute in the very young [88]. Some obese young men consume fully four litres of sweetened drinks every day—equivalent to the entire energy requirement of a small woman!
Intervention studies show that energy consumed in liquid form does not produce the same degree of satiation as an equivalent amount of energy with the same macronutrient composition consumed in solid form. In a cross-over study, the overall *ad libitum* daily energy intake of the subjects was significantly higher when they were being given a daily 1,880 kJ pre-load in the form of a soft drink compared with when they were being given the same sugar in solid form (*Figure 9*). Other studies show less clear results [89].

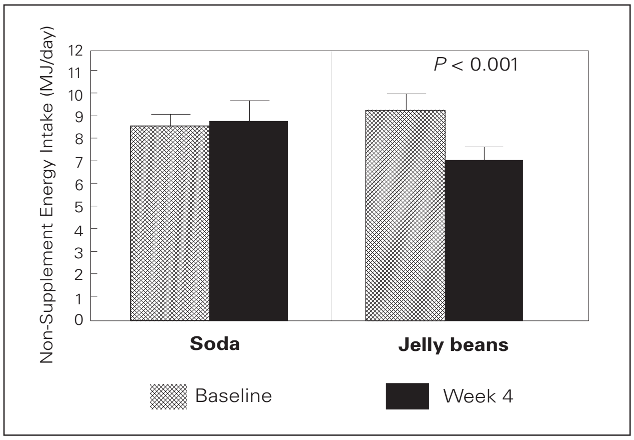


Figure 9. Satiation effect of an isoenergetic preload, ingested either in liquid (soda) or solid form (jelly beans) [87].

Moreover, we know that part of the energy taken in liquid form is taken between meals, which increases the risk of under-compensation of the calories derived from sweet drinks.

Variety

The fact that **a varied diet is associated with higher intake than is a monotonous one** is well characterised in animals [90], and this has now been demonstrated to be a significant factor in humans too. In a cross-over study, Stubbs *et al.* [91] allowed subjects to eat food of differential variety (consisting of either five, ten or fifteen different foodstuffs) *ad libitum*. While on the most varied diet, the subjects gained weight whereas on the more monotonous diets, they actually lost weight.

Snack foods tend to differ radically from meal foods in organoleptic properties so it could be expected that in the real world, snacking would tend to considerably enhance the variety of the diet: this may be a factor underlying the increased intake associated with increased eating frequency.

Timing

A final property of food intake, and one which is particularly relevant to snacking, is the time at which it occurs.

For instance, Hulshof *et al.* [92] gave groups of subjects pre-loads (*i.e.* snacks) at three different times of day. Immediately after the pre-load, the subjects' appetite for a meal decreased to subsequently rise back up with time. The fat content of the pre-load did not significantly affect either the magnitude or the kinetics of this response but the subjects' appetite returned to the pre-snack level much faster when the pre-load was taken in the mid-afternoon than when it was taken early in the morning or at lunch time. This was

reflected in subsequent energy intake in that an 800 kilocalorie pre-load taken in the mid-afternoon did not have any effect on the intake at dinner two-and-a-half hours later.
As a conclusion, we may say that these are five characteristics of eating episodes that are most relevant for appetite. For each factor, examples have been given, but for the time being there is no comprehensive review on the combination of these factors.

Key facts

- An imposed decrease in eating frequency seems to be associated with weight gain, predominantly in the form of fat.
- An imposed increase in eating frequency does not seem to lead to weight gain, despite increased food intake.
- Eating frequency does not appear to have a great effect on energy expenditure.
- Higher habitual eating frequency may be associated with better appetite control and more efficient matching of food intake to energy expenditure in certain populations.
- There are five major characteristics of a given eating episode that affect appetite:
  - volume and density;
  - macronutrient composition: there have been very few intervention studies on this subject, this could be a future avenue for investigation;
  - liquid or solid form;
  - variety (including organoleptic properties);
  - timing.

CHAPTER 4

DIFFERENT EATING PATTERNS IN EUROPE

In post-industrial Europe, there have occurred a number of major social and economic changes, notably including in the context of the present discussion: an increased number of women in the workplace and in consequence their decreased presence in the home; erosion of the traditional family structure and dissolution of traditional values in general; increased individualism (especially amongst the young); globalisation with its effects on the availability of new types of food; and the increased influence of the media—notably marketing and publicity—on people's buying habits and life styles.

These changes are certainly associated with many profound changes in eating habits, from an increase in the consumption of ready-made meals and homogenisation of the diet from country to country to the loss of cooking skills—a culture critically described by French sociologist Claude Fischler as one of "*gastro-anomy*" [93].

Sociologists tend to assume that epidemiological phenomena such as the current obesity epidemic and the increased incidence of eating disorders must necessarily be consequences of social changes, a view echoed in the public perception. But have European eating habits really changed for the worse as dramatically as the media would have us believe? At the Mougins meeting, the experts gave reviews of current eating patterns in their own countries. The perspective of each presenter may have been different—from that of the sociologist to that of the nutrition scientist—but each focused on recent changes and whether they could be defined as beneficial or detrimental for health.

THE NORDIC COUNTRIES

The Swedish word for the perceived change in eating behaviour is *frukostisering*, literally "breakfastisation". To investigate current eating patterns in Denmark, Finland, Norway and Sweden, a group of sociologists recently surveyed 1,200 adults in each of the four countries by means of computer-assisted telephone interviews to ascertain what the respondent had eaten the day before [94].

Interestingly, even between four countries that are culturally close, significant problems were encountered in terms of both semantics (*e.g.* the word *frokost* means breakfast in Norwegian but lunch in Danish) and definitions (*e.g.* Finns—including the qualified sociologists in the investigating team—had difficulty in classifying the intake of any amount of cold food as a meal).

As Lotte Holm stated, the analysis showed that for the majority in all countries, eating is still concentrated in **a relatively small number of episodes** (between three and five). In all four countries, certain peak periods emerge during the day when a large proportion of the population is eating something; these correspond to the conventional meals of breakfast, lunch and dinner. Eating hours are most uniform in Denmark, least so in Finland and Sweden. Smaller peaks are observed in the mid-morning, the mid-afternoon and/or the evening, but these vary considerably between the countries. Dinner is eaten a couple of hours later in Denmark and Sweden than in Finland or Norway. Eating hours were quite different and showed much more variation on Sundays, but again the most uniform pattern was found in Denmark.

At almost all times of the day, **more people eat at home than in any other place** and large proportions of each population do not often eat anywhere else. The eating system includes a mixture of events taking place alone, with other household members, with colleagues and with friends. The general pattern is one of the more "social" meals concentrated in the evening with individual eating events concentrated in the morning more evenly distributed throughout the day. Virtually all such meals are eaten at a table and although in some cases the television is on, in the majority it is not.

Thus, eating rhythms in the Nordic countries still appear relatively structured, reflecting socially shared routines that have emerged from the need for social co-ordination, particularly in relation to work and family life. One proviso may be that the telephone-based technique might tend to exclude those who are out of the house more, namely the very population who are most likely to be "grazing". At any rate, the rhythm has changed in recent years (*e.g.* in Finland the number of hot meals consumed per day is significantly lower than the average of three reported in the 1950's) and may still be changing: the rhythm is by no means experienced as compulsory (except for those living in some kind of institution) and leaves a lot of freedom for individual choice.

In conclusion, the analysis indicates that although *frukostisering* may exist, it is by no means a dominant trend. Lotte Holm speculates that the generalised but apparently overstated perception that eating behaviour is becoming seriously destructured and desocialised is due to the fact that marketing companies may be tending to over-emphasise minor trends.

FRANCE

In France, the traditional eating pattern is characterised by the consumption of three to four meals per day, eaten at fixed times. In addition to the three main meals (breakfast, lunch and dinner), many French people consume a **fourth meal**—the so-called "***goûter***"—in the middle of the afternoon.
Corinne Marmonier presented the recent INCA survey (1998-1999) aimed at evaluating individual food consumption in a representative sample of the French population (1,018 children and 1,474 adults) using 7-day dietary records [15, 95]. Most children regularly ate all three main meals, as did adults. Almost none of these meals were systematically skipped on each of the seven days.

Specific analyses were conducted on the "goûter" (self-defined by the respondents) in order to define how often it is consumed, its composition, and its contribution to the overall diet, as well as to evaluate the relationship of goûter consumption with BMI and physical activity.
Most children ate a goûter. However, the frequency of consumption of this meal drops off through adolescence and adulthood.
In both children and adults, most goûters were consumed between 4 and 5 p.m. at home, either alone or in the company of family members. They mainly comprised a combination of two products, usually a cereal-based product and a non-alcoholic drink, and tend to be high in carbohydrates.
Regular consumption of a goûter contributed significantly to the total energy intake (TEI) (16% of total energy in children and 10% of total energy in adults). Regular goûter eaters tend to have a higher TEI than non-consumers.
In neither adults nor children were any differences in physical activity levels detected between the various groups segregated on the basis of goûter consumption.
The distribution of food intake over the day was more even in children and adults with regular goûter eaters consuming less energy at lunch and dinner in both absolute terms and with respect to TEI. There were no differences in breakfast energy intake and its contribution to TEI between regular consumers and non-consumers. Although regular goûter eaters tended to derive more energy from snacks (*i.e.* all other between-meal eating episodes), the overall contribution of this type of intake to TEI was small in all groups (3-4%).
In terms of macronutrient composition, the diets of regular goûter consumers tended to be more balanced with a higher carbohydrate content.
In adults, the proportion of goûter eaters increases when BMI decreases; there were no differences in children.
In summary, this study showed a **positive association between regular goûter consumption and both nutritional status and the distribution of energy intake over the day.**

In conclusion, France is still characterised by a **highly structured eating pattern** with meals taken at regular times, mostly in a family or social context. This is very likely associated with the cultural importance of good food and the pleasure which is attached to eating in this society. However, an **alarming increase in the prevalence of obesity in children** suggests that eating behaviour and/or lifestyles (notably physical activity levels) may be changing.

BELGIUM

As underlined by Stefaan de Henauw, the data available on food and nutrition in general and on eating patterns in particular in Belgium are scanty because little research has been conducted in this area (although this situation is now being remedied by the Federal Ministry of Public Health). Moreover, making generalisations is even more fraught with problems than in many other countries, because of cultural differences between the Dutch-speaking northern part of the country and the French-speaking southern part, as reflected in the marked difference in cardiovascular mortality which is of the order of 50% higher in the south where the diet tends to be richer in fat and saturated fatty acids.
However, some limited data on eating patterns are available from the 2001 Health Interview Survey conducted by the Scientific Institute of Public Health which included questions on the frequency of consumption of the **three main meals – breakfast, lunch and dinner**. From this survey, age-standardised data on meal frequency indicate that approximately 22% of Belgians regularly skip one of the above mentioned meals (most commonly breakfast). The skipping of meals is more common in males, in 25-34 year-olds, among the less educated, and in rural areas [96]. No associations with health-related endpoints can be derived from this survey.

Perhaps the most relevant information on meal patterns in Belgium comes from a study of 341 **adolescents** (14-18 years of age) carried out in the region of Ghent in 1997. Diet was assessed on the basis of a 7-day food record [97]. The food diaries contained pre-structured sheets, with every 24-hour period subdivided into seven possible eating occasions.
One of the findings of this survey was that, **in this age group, approximately 17% systematically skip breakfast and another 25% have breakfast on an irregular basis and/or of very limited nutritional value**. Overall food and nutrient intake was poorer in those who skipped breakfast compared with those who regularly ate a nourishing breakfast. Significant differences were found in the energy-adjusted intake of a number of different vitamins and minerals and for some food groups, notably fruit, vegetables, bread, milk products and breakfast cereals.
On the whole, snacking between meals contributed an average of 22% of total daily energy intake. The macronutrient composition of snacks was quite different from that of the “main” meals, with a higher CHO content and a lower fat content. By far the most popular form of snack was a soft drink, although fruit, dairy products, biscuits, pastries and sweets were also significantly represented.

Out of a total of about 2,400 recorded days, 46% included a morning snack, 72% an afternoon snack and 66.5% an evening snack. These data were comparable for girls and boys. The mean (median) number of eating occasions was 4.6 (4.7) in both girls and boys.
In one analysis, the population was divided into two sub-groups according to eating frequency (on the basis of an individual average over seven days). Individuals with an average of five or more eating occasions per day had a significantly higher energy intake than individuals with a more "conventional" eating pattern. There was no difference however in the proportion of TEI contributed by the various types of macronutrients, except that simple carbohydrates were higher in males who ate more frequently. No differences emerged between "frequent" and "conventional" eaters in terms of the energy-adjusted intake of vitamin C, calcium and iron although frequent eaters consumed more of all these micronutrients in absolute terms. Frequent eaters had higher intakes of most food groups studied (fruit, vegetables, dairy products, meat, fish, fats and oils, biscuits/pastry/sweets and soft drinks). One major exception was a higher intake of soft drinks in girls with a conventional eating pattern.
Overweight individuals had on average a lower number of eating occasions than the normal weight ones.

Thus, the paucity of data coupled with internal dichotomies makes it difficult to make generalisations or draw valid conclusions about eating patterns in Belgium and their impact on health. For example, whether or not there exist any typical culturally determined eating occasions like the "goûter" in France can be neither confirmed nor excluded. However, on the basis of the available data—especially the figures describing the skipping of meals in general and breakfast in particular—it would appear that **eating patterns in Belgium are relatively unstructured**, at least in comparison with France.

ITALY

Any discussion of eating behaviour in Italy is associated with the same two problems as were seen in the context of Belgium, namely a lack of information and marked internal cultural diversity, notably between the North and the South. However, some data exists and certain generalisations can be made.

The **typical adult eating pattern in Italy is of three meals a day** (including a hot meal at both lunch time and dinner time) although, for many Italians, breakfast may consist of no more than a coffee, possibly with a brioche. **Most Italian children consume two extra meals (both called "*merenda*"),** one in the middle of the morning and the second in the middle of the afternoon. In a study of 700 children of between 7 and 10 years of age (with both over-reporters and under-reporters excluded from the analysis), a positive correlation was detected between Body Mass Index and energy intake at the evening meal, and this was coupled with a negative correlation between BMI and energy intake at the mid-afternoon merenda. Thus, **the consumption of a substantial merenda appears to be associated with both reduced intake at the evening meal and reduced body weight** [98]. In fact, in the early 1990's, extensive research was carried out into Italian eating habits [99], but Claudio Maffeis worries about the relevance of these findings in the light of the apparently rapid rate of change in eating behaviour in Italy. One factor identified in this study which splits the country into four regions, namely the North-West, the North-East, the Centre and the South was that "traditional diversities among Italian regions are still alive". However, one of the recent changes pointed up by Claudio Maffeis is that **consumption of a Mediterranean-type diet**—which is generally associated with relatively healthy eating—**appears to be on the decrease**, especially in the North. Another disquieting trend which is emerging from the most recent analyses is that teenagers are apparently reducing or skipping their breakfast, and this despite an increase in the amount of physical activity performed before lunch.

Thus, eating behaviour seems to be changing for the worse, especially among children and adolescents, although it is important to point out that the prevalence of obesity is still relatively low in Italy.

SPAIN

Meals are taken three to five times a day in Spain; snacks are consumed between meals, the quantity depending on the age group. Traditionally, there are three main meals: breakfast, lunch and supper. Some groups, for example **children, also have an afternoon meal ("*merienda*")** and perhaps a light mid-morning meal. Many schoolchildren regularly partake of all five of these meals. Among the elderly, 7% take only two meals, 57% take three, and 36% take four [100].

Breakfast, unlike lunch or supper, **is not taken by the entire population**. Although the frequency with which it is taken has risen in the last few years (in part due to experts insisting on the importance of this meal), there is still a long way to go before one might consider the situation adequate. Again, the taking of breakfast depends on the group in question. Some 20% of boys and 37% of girls either take breakfasts that are inadequate from an energetic point of view [101], or take no breakfast at all. Among the elderly, breakfast makes up about 16% of total energy intake with only 17% taking an adequate breakfast [102].

A traditional Spanish lunch starts with a first course of vegetables, soup, pasta, or a dish based on rice or potatoes. The second course may be a stew, fried or roasted fish or meat, or an egg-based dish, usually accompanied by a salad or French fries. Dessert is usually fruit, yoghurt, or a prepared dish. It is in the dessert where the greatest regional differences are to be seen.
Supper is usually lighter but may consist of one or two courses composed of the dishes mentioned above, as well as dessert, though a large percentage of the population takes only fruit or a milk product.

When taken by schoolchildren and preschoolers, the teatime ***merienda*** is usually a sandwich, a bun, fruit juice or yoghurt. For adults, *merienda* usually involves coffee or tea and toast. While nearly all schoolchildren take a *merienda*, only 10% of the elderly do so.
The mid-morning meal is also important for many schoolchildren. The food eaten is usually easy to carry, *e.g.* a sandwich, a bun, a piece of fruit or juice. About 70% of schoolchildren take this meal. For adults, it usually involves fruit, coffee, and maybe a piece of toast or a pastry. Only 20% of the independently-living elderly take a mid-morning meal.

The Spanish are also **inveterate snackers**, notably in the form of *tapas* (appetizers and *hors d'oeuvres* of many different kinds usually provided by bars). Such 'meals' consist of some kind of drink (wine, beer or a soda) and various *tapas*, and are difficult to quantify.
In line with data from other countries, negative correlations between eating frequency and BMI on the one hand and serum cholesterol levels on the other have been specifically documented in Spanish 9-13 year-olds [103].

Ana-Maria López-Sobaler indicates as a conclusion **that the Spanish are concerned about the relationship between health** (including concerns over bodyweight) **and food habits** (for example, cholesterol, vitamin and mineral intakes) **but this concern is not reflected by accurate knowledge** about nutritional matters, and few people know the correct criteria to observe. For example, the popular perception identifies certain foodstuffs which should be avoided by people wanting to lose weight but, unfortunately, they are not those with the highest calorie content [104].
In general, the Spanish diet could be improved, and there is still much to be done in terms of educating the population in matters of food and nutrition.

POLAND

In Poland, the traditional meal pattern consists of **two breakfasts**, the first between 6 and 8 a.m. and the second between 11 a.m. and 1 p.m., with the **main meal ("dinner")** between 3 and 5 p.m. and finally a **supper** between 7 and 9 p.m. Commonly, another meal is eaten between dinner and supper, *i.e.* in the late afternoon. Thus, the traditional meal pattern consists of five meals per day. However, according to Jadwiga Charzewska who presented her own recent work [105], the reality is somewhat different.
In 1,433 subjects living in Warsaw and the surrounding regions ranging in age from 11 to 75 years old, the most frequent meal pattern was of four meals per day (47.8% of persons), next was three meals (24.8%), followed by five meals (24.2%) with just 3.2% of the sample eating only once or twice a day. Age-related differences emerged with the four-meals-a-day pattern common among adolescents, but less so in the elderly, in whom three meals a day was more frequent.
About 60% of the subjects ate some form of snack (defined as food or drink taken between the main meals for reasons other than hunger). Snacking was more common in adolescents. The caloric intake from snacks was at least 250 Kcal per day for adolescent

boys and girls, a little over 100 Kcal for the adult and elderly women, and approximately 200 Kcal for adult men. As well as the energy consumed in the form of snacks, their composition also differs in different age groups. However, the frequency of snacking was more or less independent of the number of meals consumed.

The most frequently skipped meal was the small, late afternoon meal, followed by the second breakfast.

Over 90% of individuals ate all three of the main meals (breakfast, dinner and supper) every day. The dinner is still traditionally prepared and consumed at home but this now corresponds to the late afternoon meal. This is consistent with the findings of another large-scale survey [106] which found that 94% of Polish households eat hot dinners prepared at home, only 12% of dinners being eaten as a midday meal at the workplace or school.

The composition of main meals tends to be fairly constant: breakfast usually consists of tea and bread with cold meats, cheeses and jam; the second breakfast is usually a sandwich; and supper resembles breakfast.

In this study, a **negative correlation between eating frequency and BMI was observed in adolescents but not adults, and in the elderly, a highly significant positive gender-independent correlation emerged**.

Thus, **eating patterns in Poland appear to remain relatively structured** although there is evidence that the traditional five-meal-a-day pattern is being replaced by a more conventional European meal frequency of between three and four major eating episodes a day.

THE CZECH REPUBLIC

Although there is a lack of scientific information on eating patterns in the Czech Republic, there are many similarities to its neighbour Poland, not only because of geographical and cultural links but also by virtue of the two countries' shared recent histories of authoritarian government with a strong inclination towards social engineering on a massive scale. According to Zuzana Brazdova, many *idées reçues* and behavioural traits—which appear to be particularly deeply entrenched in today's Czech mentality—can be attributed not to tradition but rather to profound, politically motivated social changes implemented in the 1950's. For example, **meals tend to be eaten very quickly**, with a traditional three-course lunch usually being disposed of within fifteen minutes.

The main meal of the day **(lunch)** is very commonly eaten at school or in the workplace (with companies with a workforce of over 20 obliged to provide a canteen). Conversation while eating is generally frowned upon. "Pickiness" on the part of children is not tolerated and well brought-up children finish everything on their plate. Serving sizes tend to be relatively uniform, with differences in total food intake being determined more by meal frequency.

Between-meal eating is discouraged, at least in the institutional context (*i.e.* work or school). There are major dietary differences between men and women, with men eating

more meat and vegetables (which are perceived as more "masculine" than fruit). Finally, differences related to class and social background may be exacerbated as a result of segregation at a relatively young age in the Czech educational system, *e.g.* in a recent survey of eating habits and health, the worst patterns were systematically observed for all parameters in the 20% of the population who had performed poorly in an academic context and who had been in consequence diverted towards apprenticeship and vocational training.
Presumably unrelated to the country's political past, a major problem with the diet of modern Czech children is their **fluid intake** which is generally **far from adequate**. One reason for this is the deeply entrenched idea that drinking while eating is unhealthy.

Interestingly, Didier Chapelot pointed out that, although this and two other particularities of the Czech eating pattern—the rapidity of eating and the prohibition of conversation during meals—may seem strange to those with other customs, the scientific data may tend to suggest that they actually have some benefit in physiological terms: firstly, drinking while eating can raise the glycaemic index of food as much as two-fold [107]; secondly, it has been shown [108] that conversation during meals (and eating in company) is associated with higher food intake; and thirdly, in both rats [109] and new-born babies [110], the vast majority of intake (80%) is accomplished in the first quarter of any meal, with eating thereafter being for pleasure alone.

Thus, **eating patterns in the Czech Republic are conditioned by fairly rigid assumptions and tend to be fairly homogenous**. There is little scientific information about eating frequency *per se* but, broadly speaking, the pattern appears to be the familiar one of **four meals a day** during childhood which subsequently drops to **three meals a day** during adolescence. A disturbing feature is the large proportion of young people who skip breakfast, notably university students.

CONCLUSION

Thus, although there is evidence that **eating habits are changing in Europe**, in those countries for which comprehensive data are available, they seem to suggest that eating frequency remains fairly structured with the major part of the total energy intake (TEI) of most people still confined **to three or four discrete, principal eating episodes per day** (with the corollary assumption that most food is consumed in the hungry state). This picture is in marked contrast to the impression of near anarchy sometimes promulgated by the media.
Nevertheless, the fact that eating frequency may be one of the most rapidly evolving eating habits in post-industrial society, with an ever-increasing fraction of TEI consumed in the form of snacks, justifies close monitoring of this parameter, and rigorous evaluation of the repercussions of associated changes. Such analysis may prove a useful tool in the scientific assessment of the relationship between eating frequency and health.

CHAPTER 5

RECOMMENDATIONS

THE EFFECTS OF HIGHER EATING FREQUENCY WITH CONSTANT ENERGY INTAKE

There is some evidence that a higher eating frequency may have a positive effect on certain key health parameters, notably glucose tolerance, insulin economy and serum cholesterol levels. Effects on other parameters (*e.g.* body weight control) are more controversial but what certainly seems clear is that dividing food intake between more rather than fewer daily episodes has never been shown to have any adverse effects. Recommendations to increase eating frequency have been issued in the past to certain target populations (the obese, hypertensive, diabetic and hyperlipidaemic) but more often than not, outcomes have been the opposite of those intended because insufficient emphasis was placed on the necessity of maintaining overall energy intake at a constant level [57].

During the Mougins Expert Meeting, participants were asked to give their opinion by vote on each parameter that had been previously presented and discussed. Each of them had to indicate if, in his/her mind, on the basis of the data presented, increasing the EF had a beneficial effect, no effect, a detrimental effect, or if the data presented were inconclusive. The results of the votes were as follows:

	Effect of increasing eating frequency				
Parameter	**Beneficial**	**Neutral**	**Detrimental**	**Data inconclusive**	**Total of votes**
Carbohydrate metabolism	**13**	0	0	2	15
Lipid metabolism	**10**	2	0	3	15
Body weight and adiposity	**6**	3	0	**6**	15
Energy balance	**5**	1	1	**6**	13*
Dietary composition	**5**	**4**	1	**5**	15
Treatment of obesity	**3**	2	2	**8**	15

* One missing vote and one vote "it depends"

Wherever data were deemed inconclusive, participants were asked to go a step further and suggest which types of studies/markers could help to reach a conclusion (see *Table I*).

Table I. Recommended studies (markers to help strenghthen the data on eating frequency and health parameters (suggestions of the Mougins Expert Meeting)

Parameter	Recommended studies	Recommended markers
Carbohydrate & Lipid metabolism	● Long-term intervention studies but also prospective studies (*e.g.* mandatory change in eating frequency then becoming spontaneous) ● Definition (in order to compare results): meals / snacks, eating episodes ● Characteristics of the subjects (all types of subjects; diabetics (I & II); hyperlipidaemics; obese patients; pregnant / lactating women ?; athletes ?): genetic profile, eating pattern…; animal studies (*e.g.* knock-out animals) ● Define the best eating episode composition ● Evaluate the practicability in everyday life	● Carbohydrate metabolism: glucose tolerance, insulin sensitivity, tryptophan/large neutral amino acids ratio related with serotonin synthesis, leptin, ghrelin, neuropeptide Y, non esterified fatty acids, C-peptide, enzymes of the glycolytic pathways ● Lipid metabolism: Total, HDL, LDL, TG, Apos, Free Chol, Esterified Chol, lipoproteins, free fatty acids, nutrient oxidation & storage, activity of enzymes, concentration of mRNA ● Diet composition (food choice in free-living conditions), energy & macronutrient intakes, glycaemic index ● Subjective / psychobiological: satiety, hunger, taste/food preferences in different physiological states of hunger/satiety… ● Physical activity ● Body weight & composition ● Social characteristics, performance and well-being
Body weight and adiposity	● Prospective studies, cross-sectional and intervention studies All types of subjects In different settings (schools, laboratories, hospitals) ● Changes in spontaneous energy intake and diet composition ● Comparison between different interventions: macronutrient composition & energy intake, physical activity and a meal frequency, during a weight loss, weight maintenance study	● Bodyweight, BMI, body composition (fat mass, lean mass), waist/hip ratio ● Metabolic parameters (insulin, leptin, glucose, ghrelin, metabolic risk markers…) + study of gene expression ● Physical activity ● Social parameters
Energy balance	● Cross-sectional and prospective longitudinal cohort (observation / intervention) ● All types of subjects	● Anthropometry (BMI, waist/hip ratio, body composition…) ● All components of energy balance (total energy expenditure, resting E.E., activity E.E., intake, 24h respiratory quotient), use of chamber calorimeter ● Metabolic parameters (glucose, insulin, leptin, ghrelin), including the role of circadian rhythms (e.g. leptin and melatonin) ● Dietary assessment, macronutrients ● Satiety
Dietary composition	● Influence of type of carbohydrate (*e.g.* glycaemic index) and carbohydrate/fat ratio ● Prospective studies (*e.g.* adapt new meal patterns to reality of everyday life) ● Intervention with different kinds and numbers of meals ● All types of subjects	● Marked carbon on fatty acid and carbohydrates ● Physiological markers related to satiety, well-being, performance, social conflicts, co-ordination between family members ● Variability in energy intake ● Weight, BMI, waist/hip ratio, adipose tissue and lean body mass ● 24h food quotient & food quotient at different meals, controlled for total energy expenditure and total energy intake, physical activity level, body composition ● Metabolic parameters ● Mental function, attention, mental concentration ● Physical activity (using diary)
Weight management and treatment of obesity	● Both clinical & epidemiological studies Cross-sectional, prospective (longitudinal) Lab-controlled and in normal life ● All types of subjects ● Animal studies for mechanisms	● Anthropometry, bodyweight, body composition, risk factors ● Metabolic parameters ● Psychometric parameters (frustration score etc.), quality of life parameters, feelings of control/regulating eating ● Recording of hunger/satiety throughout the day ● Change of carbohydrate/fat ratio

WHAT CONSTITUTES A BENEFICIAL BETWEEN-MEAL EATING EPISODE (BMEE)?

It is certain that food eaten outside of conventional meals accounts for a significant fraction of total dietary intake in many people, of the order of 20 to 30% [111], and there is evidence both that this proportion is on the rise across the board and that it is generally higher among the young.
Of course, the composition of the diet is going to be a more important health determinant than eating frequency, and in the final working session, the properties of different types of food—especially "snack foods"—were examined in the perspective of establishing criteria which can be used to distinguish between the detrimental and beneficial aspects of BMEEs, and then stipulating the corresponding positive aspects. The discussion ranged from the consideration of objective scientific parameters such as blood glucose levels (and the physiological consequences thereof) to more psycho-social aspects, and certain areas of consensus emerged, resulting in a limited but well-defined set of general recommendations (*see Table II next page*).

As can be seen, the participants tended to refer to two over-riding principles in order to distinguish between what is beneficial and what is detrimental:
- firstly, metabolic consequences, notably the composition of the BMEE on the one hand and whether or not it is consumed in the hungry state on the other hand;
- and secondly, ideas of fulfilment and pleasure, *i.e.* all other things being equal, any factor that enhances the pleasure and relaxation derived from a BMEE must be good.

As mentioned above, these criteria are highly inter-dependent so that a factor that is positive in the sense that it enhances the pleasure of a snack (*e.g.* high fat content) may be negative on the metabolic side of the equation. Therefore, in a synthetic approach, the most solid recommendations, in order of priority, can be summarised as follows.

An ideal BMEE is:
- low in calories, fat and glycaemic load / relatively high in carbohydrate;
- driven by hunger (*i.e.* consumed when blood glucose/insulin levels are low);
- moderately satiating (not compromising appetite for the subsequent meal);
- pleasurable (taste, social dimension, relaxation).

Table II. Tentative definition of a beneficial between-meal eating episode (BMEE) by the participants of the Mougins Expert Meeting

Criterion	Recommended value of the criterion for a beneficial BMEE
Context	
Environment	Pleasant place
Social aspects	In good company
Motivation:	Hunger (= low blood glucose/insulin)
- *hunger*	
- *lethargy (a "pick-up")*	
- *mood regulation*	
Timing	
Time of day / regularity	-
Interval with respect to previous/next meal	Dependent on hunger and compensation (anticipatory/retrospective)
Duration	Not rushed
Composition	
Macronutrients	
- *total energy*	Low
- *fat*	Low
- *carbohydrate*	High
- *sugar*	Low
- *protein*	Neutral (assuming adequate protein intake at main meals)
Micronutrients	High
Fibre	High
Glycaemic Index	Low
Liquid/solid	Combination
Taste	Tasty
Number of foodstuffs	Not more than two – "keep it simple"
Effects	
Satiety	Should provide moderate satiety (prevents hypoglycaemia and hyperinsulinaemia)
Pleasure, mood	Should improve the mood and/or relationship with others

CONCLUSIONS

The Expert Meeting on "Eating Frequency" was the opportunity to disclose and share nearly everything that can be said at the moment about eating frequency. Not surprisingly, it appears that eating frequency does matter, in the sense that there are consequences; and these consequences are not the same for everybody.

One of the interesting features of this Meeting was that it brought together people from the natural sciences and the social sciences. The act of eating indeed is both a physiological act and a social act, and the fact that these two views have been shared, has been very illuminating.

Participants unearthed features that they still need to know about, and exchanged views about what could be the next steps of research in the field.

This Meeting also allowed us to browse the fantastic diversity in the eating patterns throughout Europe – and the features of this diversity can under certain circumstances be detrimental and beneficial. On the other hand, a lot of the literature on the subject is American. Studies that have been done in the USA do not necessarily apply to Europe. They have been done on different people, in different circumstances, in a different culture, a different intellectual arena.

Hopefully, participants can now collaborate together, to enlarge understanding of the eating frequency in Europe, with European population, and add a European dimension to science.

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