

The role of fruit consumption in the prevention of obesity

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SUMMARY

The global obesity epidemic is associated with a sedentary lifestyle and diets rich in high-fat, high-energy foods. The potential role of fruit in preventing overweight and obesity is related to their relatively low energy density, high content of dietary fibre, and associated increasing satiety effect. The physical disruption of fruit is of considerable importance for satiety, as shown in studies in which fruit juices were less satisfying compared to sugar-equivalent intakes of purées and whole fruits. The potential role of fruit in the prevention of overweight and obesity may be connected to the dietary pattern of fruit intake, and with the possibility that fruit intake may substitute for other, more energy-dense foods. The majority of human prospective cohort studies in adults suggest a preventive effect of increased fruit intake on body weight gain; whereas a few studies have suggested the opposite, in the case of fruit juices. Prospective studies on children are few and inconclusive, but suggest associations between fruit intake and body weight that are related to the initial nutritional status. In behavioural intervention studies, subjects are often advised to undergo several changes towards a healthy diet and lifestyle, making it impossible to quantify the specific effect of fruit intake on body weight. In the few available intervention studies in adults, the study period was often too short to allow measures of body weight changes, and studies on overweight or obese subjects may not apply to subjects of normal weight. Intervention studies targeted at school children showed that such schemes can be effective in increasing fruit intake, but a convincing role for increased fruit intake in the prevention of overweight and obesity in children still needs to be established. The present evidence suggests that fruit consumption has a potential role in the prevention of overweight and obesity.

The global obesity epidemic is a complex multifactorial condition resulting from an imbalance between energy intake and energy expenditure. Apart from having a predisposing genetic background, overweight and obesity are associated with environmental factors, among which, a sedentary lifestyle and over-consumption of high-energy yielding foods are the main contributors. Many national and international food-based dietary guidelines recommend an increase in fruit and vegetable consumption to protect against several chronic diseases such as cardiovascular diseases and certain types of cancer (WHO, 2003; WCRF, 2007; He *et al.*, 2004). The scientific evidence for an inverse association between the risk of being overweight and obese, and the consumption of fruits and vegetables, was considered convincing (WHO, 2003). However, the roles of fruit alone, and of fruit-derived products, on the risk of becoming obese and overweight have not been addressed separately.

The objective of this paper is to discuss and evaluate the possible role of fruit consumption in the prevention of obesity and overweight.

THE RATIONALE

The rationale for the potential role of an increased consumption of fruit in the prevention of overweight and obesity is related to several features of whole fruits: their high water content, their relatively low energy density, and their relatively high content of dietary fibres, of

which viscous dietary fibres constitute a considerable proportion (Table I). Dietary fibres and, in particular, viscous dietary fibre, which are present in fruit in considerable amounts, have been shown to increase post-prandial satiety and to decrease subsequent hunger in short-term studies (Howarth *et al.*, 2001). In the long term, this may lead to decreases in energy intake and, thereby, in body weight.

Processing of fruits, include drying and cooking, may result in a reduction in their water content, and the addition of sugars or other substances may increase the energy density of the fruit product being consumed (Table I). The processing of fruits into juices produces a beverage that may or may not contain added sugar. The pattern of fruit juice consumption has changed over time. Its role in the diets of adults and, in particular, of children, and its possible association with caloric intake have been discussed extensively throughout the last decade.

An essential aspect of fruit consumption in relation to obesity is the impact of fruit on satiety. In one of the classical studies on the nutritional role of dietary fibre in fruit, the effects of intact apples, apple purée, and fibre-free apple juice were studied on satiety, plasma glucose (blood sugar), and serum insulin (blood insulin) levels (Haber *et al.*, 1977). After ingestion of sugar-equivalent amounts of each, apple juice was significantly less satisfying than apple purée, which, in turn, was less satisfying than whole apples (Figure 1). This study showed that plasma glucose rose to similar levels after all three types of meal, whereas significant differences were recorded in serum insulin levels, with apple juice

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TABLE I
Energy, water, total sugar, and dietary fibre contents of selected fruits and fruit products¹

Fruit/fruit product	Energy (kJ 100 g ⁻¹)	Water content (g 100 g ⁻¹)	Total sugars (g 100 g ⁻¹)	Dietary fibre (g 100g ⁻¹)
Apple	192	87.6	8.1	2.2
Apple, dried	1,666	2.5	41	–
Orange	234	86.6	8.2	2.1
Orange juice	182	89	8.4	–
Orange marmalade	865	47.0	47.0	–
Banana	391	76.6	16	1.6
Grape	274	84	15	1.4
Pear	255	85.1	9.5	2.9
Apricot	185	88.8	ND	1.6
Apricot, dried	1,244	26.1	42	9.3
Watermelon	264	90.2	7.6	0.5

¹Saxholt *et al.* (2006).

ND = not determined.

resulting in the largest post-prandial levels of insulin, followed by apple purée, then whole apples. The conclusion was that removal of the dietary fibre from fruit, and also the physical disruption of the dietary fibres, resulted in faster and easier ingestion and in decreased satiety. This study formed an important basis for a hypothesis on the existence of a correlation between dietary fibre content, its physical properties, satiety, and subsequent short-term food consumption. This study was repeated with other fruits such as orange and grape (Bolton *et al.*, 1981). The conclusions from the

latter study were that both satiety and post-prandial glucose and insulin responses to the consumption of fruit and fruit products depended on their content of dietary fibre, their physical structure, and on the content of various types of sugars. Fructose, which is the main soluble sugar present in fruit, is metabolised slowly, and therefore contributes to a relatively slow rise in blood glucose after the ingestion of fruit.

GLYCAEMIC INDEX

The post-prandial rise in blood glucose levels following the ingestion of meals containing fixed amounts (usually 50 g) of available carbohydrates is measured as the area under the 2-hour glucose response curve (AUC), and is expressed as the glycaemic index (GI). The GI values of fruits differ considerably, with whole fruits such as cherries, apples, and pears at the lower end of the GI scale (with values between 32 – 54, compared to white bread with a value of 100), compared to tropical fruits such as oranges, bananas, mangoes, kiwi fruit, and watermelons at the higher end of the GI scale (with values between 60 – 103; Table II).

The relationship between GI and satiety is complex. Apart from the putative role of insulin as a major player, low- and high-GI carbohydrates may have an impact on satiety through their different time-courses of hormonal responses. In an earlier review (Anderson and Woodend, 2003), it was concluded that low-GI carbohydrates appear to have a satiating effect over 2 – 3 h, whereas high-GI carbohydrates are associated with a more immediate reduction in appetite and food intake in the short term (1 h). This finding is important in relation to the possible role of fruit intake on the suppression of

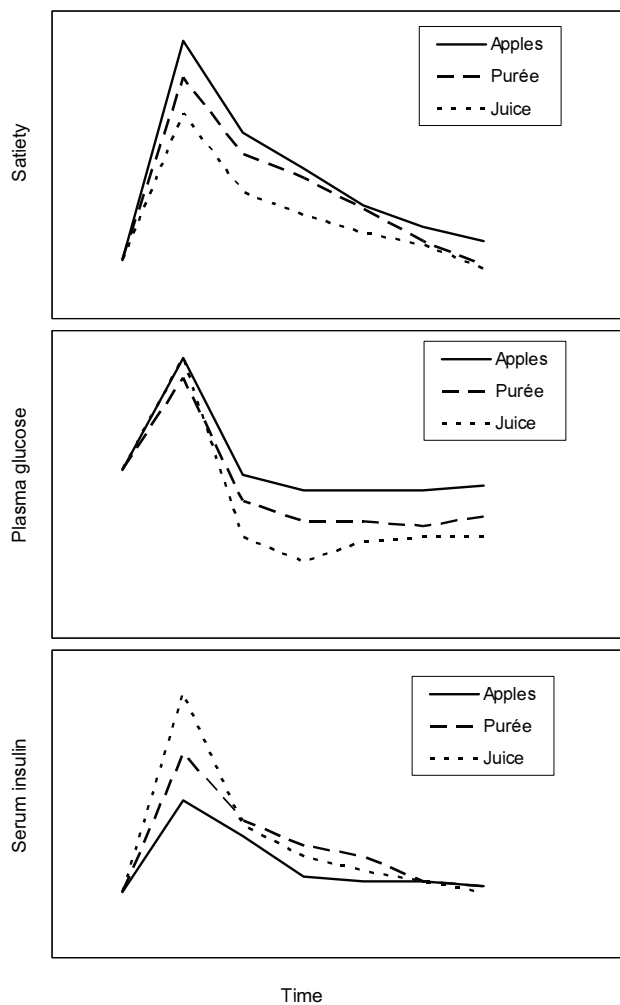


FIG. 1

Satiety, blood sugar (plasma glucose), and serum insulin levels before and after three different test meals consisting of apples, apple purée, or apple juice (from Haber *et al.*, 1977).

TABLE II
Glycaemic index (GI) of selected fruits and fruit products compared to white bread as the reference meal (GI = 100)¹

Fruit/fruit product	GI
Cherry	32 [†]
Apple	52 ± 3 [*]
Apple juice	57 ± 2
Apple, dried	41 ± 7
Pear	54 ± 3
Orange	60 ± 5
Orange juice	74 ± 4
Orange marmalade	69 ± 12
Banana	74 ± 5
Mango	73 ± 8
Kiwi	75 ± 8
Watermelon	103 [†]

¹Foster-Powell *et al.* (2002).

^{*}All values are means (± SD).

[†]SD not reported.

appetite and on subsequent food intake. However, this complexity may increase when possible differences in responses between healthy subjects and overweight subjects are considered. In a recent study of different breakfast meals, the role of blood glucose and insulin levels in short-term appetite sensations, and on subsequent energy intake, in normal weight and overweight subjects was studied (Flint *et al.*, 2007). It was found that insulin, but not blood glucose, was associated with short-term appetite regulation, but only in healthy subjects, whereas this relationship did not apply to overweight and obese subjects (Flint *et al.*, 2007).

DIETARY PATTERNS

Fruits may play a role in the prevention of obesity because they can add to dietary variety both between and within food groups, and add palatability to the overall diet. Palatability has been shown to be an important predictor of body fat (McCrary *et al.*, 2000). Several studies have also shown that fruit intake is related to a pattern that is distinct and different compared to the intake of other foods. In a Dutch study on eating patterns, fruit intake at morning, afternoon, and evening snack times contributed substantially (> 50%) to the total fruit intake, while high consumers of fruit were not necessary also high consumers of vegetables (Kearney *et al.*, 2001). In the same way as in other studies, a Danish intervention study targeted at healthy adults showed that a high fruit intake was part of a 'Modern' diet (Lau *et al.*, 2008). These examples are important as they provide substantial scope for dietary changes related to fruit intake in the 'healthy' direction.

Several prospective human cohort studies have investigated simultaneous changes in fruit and vegetable intake and the degree of obesity and have suggested that an increase in fruit and vegetable consumption can contribute to a reduction in the intake of other, especially energy-dense, foods and thereby result in body weight maintenance and/or even prevent body weight gain (Hallund *et al.*, 2007). In a recent fruit intervention study carried out at various workplaces, undertaken as part of the ISAFRUIT Project, the results showed that this conclusion may also be true when considering fruit consumption alone. During the fruit intervention study, the intervention group substituted fruit for more energy-dense foods rich in added sugar (data not shown).

HUMAN STUDIES

Prospective cohort studies and cross-sectional studies

Different types of human studies are available to elucidate the possible association between exposure to different dietary factors and the risk of disease. Prospective human cohort studies are studies in which different exposure factors in the diet, or in the general lifestyle, that are hypothesised to promote diseases, or to protect against them, are assessed. Typically, the information is self-reported at the beginning of the study in a defined population (the cohort). The cohort is then followed forward in time until sufficient disease events have accrued. Not all the exposed subjects will develop a disease, just as some unexposed subjects might develop a disease. The relative risk of developing a disease is

estimated by comparing the incidence of disease in the exposed group with the incidence in the unexposed group.

In cross-sectional studies, data on exposure factors and their outcome are assessed at a single point in time, preferably in a representative sample from the population. One of the limitations in this type of study is that it cannot be determined whether the dietary exposure preceded the disease, or *vice versa*.

In a review focussing on previous epidemiological studies on fruit and vegetable intake and body weight, 15 cross-sectional studies and one prospective cohort study in adults, were identified (Tohill *et al.*, 2004). Five of the studies, all cross-sectional, had assessed fruit intake and weight status separately (Flood *et al.*, 2002; Lin and Morrison, 2002; Liu *et al.*, 2000; Serdula *et al.*, 1996; Trudeau *et al.*, 1998). Three studies (Flood *et al.*, 2002; Lin and Morrison, 2002; Trudeau *et al.*, 1998), two of which (Flood *et al.*, 2002; Lin and Morrison, 2002) included fruit juice in the fruit category, found an inverse association between fruit intake and body weight. Since then, several prospective cohort studies on fruit and/or fruit juice intake and changes in body weight, among adults, have been published. The overall findings in adults suggested an inverse association between the consumption of whole fruit and body weight, while the consumption of fruit juice appeared to increase the risk of excess body weight gain. However, this finding needs further support through other studies.

Prospective cohort studies in children, involving fruit and/or fruit juice intake, are rare, and the majority are from the USA. In a US cohort of pre-school children, no significant relationship was found between whole fruit intake and body weight changes after 1 year (Newby *et al.*, 2003). Another US cohort study of pre-school children, from low-income families, showed that an increased intake of fruit juice was associated with excess weight gain among those children who were either initially at risk of becoming overweight, or were already overweight (Faith *et al.*, 2006). Thus, this study supported a recommendation from the US Institute of Medicine to reduce fruit juice intake as a strategy to prevent overweight in high-risk children (Fait *et al.*, 2006). In an Australian prospective cohort study, children were followed from mid-childhood into early adolescence. At the 5-year follow-up, no association was found between the intake of fruit juice and excess weight gain (Tam *et al.*, 2006). In a recent study in Germany (the DONALD longitudinal study), the consumption of beverages and body weights were measured at the beginning of the study and at the 5-year follow-up. Separate analyses of different types of beverages revealed that, for girls only, the intake of fruit juice was positively correlated with an increase in excess body weight gain (Libuda *et al.*, 2008).

Thus, prospective studies on the role of fruit or fruit juice intake and the prevention of overweight and obesity in children and adolescents are few, and direct comparisons are difficult.

Intervention studies

Intervention studies can be divided into two types: (i) relatively long-term behavioural or structural intervention studies in which the subjects, often free-living individuals, are advised to make overall healthy

changes in their lifestyles including their dietary habits; or (ii) clinical trials, with strict dietary restrictions enforced for a relatively short period. If designed properly, both types of study are randomised and have a control group, with which the intervention group can be compared. Randomised, controlled intervention studies are one of the highest-graded studies in medical science (Harbour and Miller, 2001). This point of view has also been adopted in nutritional science.

A recent review of intervention studies examined the effect of increased fruit intake on body weight among adults (Rolls *et al.*, 2004). This review identified two clinical trials and four behavioural intervention studies. In the clinical trials, subjects received low energy-dense diets that were high in fruits and vegetables and low in fat. In the behavioural intervention studies, subjects were advised to increase both their fruit and vegetable consumption. The results showed that the subjects in the clinical trials reduced their body weight significantly, whereas the body weights of those in the behavioural intervention studies remained unchanged, and even increased in one of the studies (Rolls *et al.*, 2004). However, the subjects in the latter study also increased their intake of fruit juice, although fried potatoes, dried fruits, and tomato sauce were included in the fruit category! For future intervention studies, it is therefore important to distinguish between fruits and vegetables, and also to assess detailed information on the type and form of preparation of the fruits and vegetables. Short-term clinical trials suggested that increased fruit intake decreased body weight. However, it was not possible to determine whether the reduction in body weight was caused by an increased fruit intake or by a reduced fat intake. Furthermore, it could not be confirmed whether the weight reduction would persist in the long-term. Additional long-term intervention studies that consider the aforementioned criteria are needed before any firm conclusions can be made on the effects of fruit intake on body weight gain or loss in adults.

In a recent review of the effectiveness of school intervention programmes to promote fruit and/or vegetables consumption, 30 studies that fulfilled the criteria of having a control group, and at least a 3-month follow-up period, were identified (de Sa and Lock, 2008). Seventy-percent of the studies resulted in an increased consumption of fruits and vegetables. Twenty-three studies had follow-up periods of >1 year, and thus provided some evidence that such fruit and vegetable promotion schemes can have long-term impacts on consumption. However, only one study was identified

that led to both increased fruit and vegetable intakes and to reductions in body weight (De Sa and Lock, 2008).

The European Pro-Children Study is a school-based randomised controlled intervention study carried out in Norway, Spain, and The Netherlands, which focussed on both fruit and vegetable intakes (Te Velde *et al.*, 2008). Here, the intervention consisted of different components, including the provision of fruit and vegetables (for free, or as part of the school meals), and a special fruit break. The study showed that, in the short term, school-based interventions are a promising means to increase fruit intake. In Norway, where the intervention was implemented most extensively, it might also have resulted in longer-term effects (Te Velde *et al.*, 2008). Such long-term effects are necessary in order to show any modification of body weight status.

CONCLUSIONS

The consumption of fruit plays a vital role in the overall diet by providing diversity and palatability. Unprocessed fruits have a low energy density and relatively high dietary fibre contents which, overall, have been shown to increase post-prandial satiety and to decrease subsequent hunger in subjects of normal weight. Prospective human cohort studies, in adults, suggest an inverse association between fruit intake and body weight gain, whereas an association, if any, with processed fruit is less definitive. Human intervention studies are often inconclusive regarding the specific role(s) of fruit in the prevention of overweight and obesity, due to the confounding effects of simultaneous changes in fruit and vegetable intake, initial body weight, and other lifestyle changes. The length of time over which most intervention studies have been conducted in both adults and children is too short to modify body weight status. Fruit intervention strategies targeted at children and adolescents suggest a promising perspective that warrants further study. Based on the present evidence, we conclude that fruit consumption has a potential role in the prevention of overweight and obesity.

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