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Popular diets, body weight and health: What is scientifically documented?*

Susanne Bryngelsson and Nils-Georg Asp

SNF Swedish Nutrition Foundation, Lund, Sweden

Abstract

This overview focuses on the scientific support for selected popular diets; the Atkins diet, glycaemic index methods, the Montignac diet and the palaeolithic diet. The practical application of the diets, and their nutritional composition, in comparison with official dietary recommendations, are also discussed. In conclusion, any diet reducing energy intake may be effective in short-term weight reduction. However, the long-term safety and efficacy of the popular diets need more research to be supported, and the burden of evidence should be placed on the promoters of the diets.

Keywords: *Atkins*; *glycaemic index*; *Montignac*; *palaeolithic diet*

Overweight: a disease risk factor

Overweight, especially abdominal adiposity, contributes considerably to an increased risk of a range of diseases, e.g. type 2 diabetes, coronary heart disease and hypertension, the risk increasing with increased body weight (1). For type 2 diabetes the risk is already substantially increased at a moderate level of overweight. The risk of certain types of cancer, especially gastrointestinal forms, is positively related to body weight (2). Obesity may also cause joint disease and a lower health-related quality of life. In contrast, there is no evidence of risk related to a low body weight, unless this is a result of disease or smoking (3), the possible exception being osteoporosis.

The susceptibility to develop overweight, as well as accompanying diseases, depends on genetic predisposition. For example, the metabolic rate, ability to store fat as adipose tissue, and the connection between high levels of blood lipids and atherosclerosis show large interindividual variation. Physical inactivity is, however, a crucial factor for everyone, and the disease risk is reduced by increased activity, including in overweight individuals (4).

Energy balance: the key factor for body weight

There has been intensive debate over the extent to which different nutrients, especially carbohydrates, contribute to overweight, in addition to their effect on energy intake. Carbohydrates are a preferred source of energy, and fat burning is suppressed when glucose is readily available for the cells. Therefore, sugars are often regarded as fattening. Another common argument is that excess carbohydrates can be used for *de novo* lipogenesis. Fructose, in particular, has been in focus in this respect. However, an absence of carbohydrates impairs fat burning (see below), and *de novo* lipogenesis seems to be of little practical importance under normal conditions; this also applies to fructose (5).

In fact, the single factor indisputably related to body weight is the energy balance (the relation between energy intake and expenditure). For this reason, means for weight reduction should focus on a negative energy balance (expenditure greater than intake), rather than on the intake of single nutrients.

Carbohydrates: the first choice source of energy

Carbohydrates are, under normal conditions, the only source of energy (in the form of glucose) for the nervous system, including the brain, but have not traditionally been considered as an essential

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nutrient. However, in the present American dietary recommendations (6) a recommended daily allowance (RDA) has been set at 130 g carbohydrates day^{-1} (based on the daily glucose needs of the brain, i.e. an average requirement of approximately 100 g). According to this, carbohydrates may be considered as a semi-essential nutrient.

The body aims to keep the level of blood glucose within a fairly narrow range. The regulatory system involves several hormones, especially insulin, which promotes the uptake of glucose to body cells. During fasting, or diets low in carbohydrates, three main mechanisms contribute to maintain a constant blood glucose level: (i) the release of blood glucose from liver glycogen, (ii) the indirect use of muscle glycogen (transport as alanin and lactate to the liver) and (iii) gluconeogenesis (synthesis of glucose from proteins). Primarily, liver glycogen is used, but this reserve normally lasts for less than 24 h. Proteins for gluconeogenesis may be provided by the food or taken from the muscle tissue.

Ketosis: a result of carbohydrate deficiency

When the glucose supply becomes low (e.g. between meals), all cells, except for nerve cells and blood cells, are able to use fatty acids as a source of energy. Fatty acids are initially transformed to acetyl-coenzyme A (acetyl-CoA). Acetyl-CoA enters the citric acid cycle by binding to oxaloacetate, which is made from carbohydrates. A pronounced shortage of carbohydrates reduces the capacity to metabolize acetyl-CoA, owing to a lack of oxaloacetate. To reduce the accumulated excess of acetyl-CoA, two molecules are combined to form acetoacetate, later transformed to hydroxybutyrate and acetone. Together these three compounds are referred to as ketone bodies.

Elevated levels of ketone bodies lead to ketosis, caused by starvation, a severe lack of dietary carbohydrates or uncontrolled diabetes. Under these conditions, ketone bodies become a major source of energy, gradually also for the brain, and the need for gluconeogenesis is thereby minimized (muscle proteins are spared). However, there are several possible risks related to prolonged ketosis, e.g. a reduced level of skeleton calcium, kidney stones, and negative effects on the development and function of the brain. Ketosis caused by the replacement of dietary carbohydrates with fat (saturated fat) may also lead to elevated levels of serum cholesterol. More research is, however, needed to substantiate further the potential risks of ketosis (6).

Satiety: different contributions of protein and carbohydrates

Among the energy-yielding macronutrients (carbohydrates, proteins and fat), the satiating power is highest for proteins (7). Diets high in proteins may therefore be helpful in weight reduction, owing to a low energy intake, as demonstrated in intervention trials (8). In contrast, diets high in carbohydrates, especially in the form of dietary fibre, are commonly more voluminous than diets high in fat and proteins. Therefore, such diets may also provide high satiety at low energy intake. The preferred type of diet for weight reduction varies between individuals. However, if sustained over a long period, discrepancies between the preferred diet and official dietary recommendations should be considered, to avoid deficiency or overload of selected nutrients. An extremely high intake of protein may potentially affect renal function negatively in the long term, and a high intake of animal protein has been claimed to reduce bone mineral content. However, no adverse effects were found in overweight subjects following a weight-reduction diet high in proteins (25*E*%) during 6 months (9, 10).

Popular diets and their scientific documentation

Willett's food pyramid

The food pyramid, first used in Sweden in the 1970s, has a prominent role in official dietary guidelines for Americans. It illustrates how different food groups should contribute quantitatively to the diet as a whole. A modified food pyramid was recently launched by Willett and Stampfer (11). This alternative pyramid is mainly based on epidemiological studies from the Harvard group. In contrast to the traditional pyramids, based on official nutrition recommendations, many carbohydrate-rich foods, e.g. pasta, rice, potatoes and white bread, are placed at the top, to illustrate that they should be consumed sparingly. The only carbohydrate-rich foods recommended in larger quantities are wholegrain products. Products rich in unsaturated fat (e.g. nuts and cooking oils) are placed in the lower part of the pyramid, i.e. they may be consumed in larger quantities. The importance of physical activity is emphasized by its location in the base of the pyramid.

The claimed rationale behind Willett's food pyramid is that today's recommendations may lead to a diet low in unsaturated fatty acids and a high glycaemic load, both claimed to be disadvantageous. The usefulness of this alternative food pyramid remains to be confirmed by controlled intervention studies.

Low-carbohydrate diets

Low-carbohydrate (low-carb) diets are defined as diets severely restricting the intake of carbohydrates, resulting in a high-protein and/or high-fat diet. The best known is the Atkins diet (12), claimed to be effective for weight reduction without energy restriction. Caloric intake is said to be important only when fat is consumed together with carbohydrates. According to Atkins, carbohydrates should be restricted to a maximum of 20 g day^{-1} during initial weight reduction (phase 1). The amount of carbohydrates is later successively increased to a highest recommended intake of 100 g day^{-1}. The low intake of carbohydrates results in ketosis, which, according to Atkins, is the key factor in burning fat and losing weight.

The Atkins diet is based on protein-rich foods, e.g. meat, fish, chicken, seafood and eggs (Table 1). Fatty foods, e.g. cheese, are allowed in large quantities. Only selected vegetables, low in carbohydrates, are recommended. Very small amounts of rice, lentils, fruits and milk may be used. Sugar is strictly excluded.

Recently, longer term studies (6–12 months) on low-carb diets were reviewed by Astrup et al. (13), and another review discussing low-carb diets has been published (14). Taken together, the studies show that low-carb diets do induce weight loss in the short term (up to 6 months). However, diets high in both protein (25*E*%) and carbohydrates are also effective in weight reduction (8, 15). This supports high protein intake, rather than low carbohydrate intake, as the key factor in successful weight reduction. In the longer term (12 months) no difference in weight loss was found when comparing low-carb diets and diets low in fat (conventional) and energy.

Loss of glycogen and water is a generally accepted explanation of the rapid initial weight loss due to energy restriction, especially when the intake of carbohydrates is low. The efficacy of low-carb diets may also be explained by the high satiating power of proteins, contributing to a reduced energy intake. Suppressed hunger, resulting from ketosis induced by fasting or starvation, as well as limitation of allowed food items, may also contribute. There is no

Table 1. Summary of the food categories included in (yes) or excluded (no) from the diet according to Atkins, Montignac and the palaeolithic diet[a]

	Atkins[b]	**Montignac**[c]	**Palaeolithic diet**
Sugar	No	No	No
Bread	No (whole grain)	No (whole grain)	No (whole grain)
Breakfast cereals	No (whole grain)	No (whole grain)	No
Pasta	No	No (whole grain)	No
Rice	No	No	No
Potatoes	No	No	No
Root vegetables	No (low-carb)	Yes (not boiled carrots and reed beets)	Yes
Vegetables	Yes (only low-carb)	Yes (not corn)	Yes
Fruits, berries	No	Yes (separate from meals)	Yes
Milk/yoghurt	No	Yes (low-fat)	No
Cheese	Yes	Yes	No
Fish, meat, seafood, chicken	Yes	Yes	Yes
Egg	Yes	Yes	Yes
Beans, lentils	No	Yes	No
Nuts	Yes	Yes	Yes
Cooking fat	Yes (not hardened vegetable oil)	Yes (not butter)	No
Alcohol	No	Yes (wine)	No

Exceptions to the main rule are noted in parentheses.

[a] Yes/No indicates general recommendations according to the actual diet, and may be variously strict for different food categories/diets.

[b] Phase 1 (initial weight reduction): <20 g carbohydrates day^{-1} (successively increased to <100 g day^{-1}).

[c] Phase 1 (weight reduction): glycaemic index <35.

evidence that low-carb diets lead to weight loss without reducing the caloric intake.

During weight reduction, low-carb diets may affect blood lipids beneficially (lower low-density lipoprotein cholesterol) (16). However, it is likely that adverse effects appear during weight stability owing to a high intake of saturated fat. This is to be further investigated.

Glycaemic index methods

The glycaemic index (GI) was developed for ranking foods high in carbohydrates according to their effect on the postprandial blood glucose response (17). GI methods are based on the assumption that a low GI (low and slow blood glucose increase) is beneficial for body weight, body composition and health, the possible exception being after physical exercise. However, there is widespread confusion regarding the applicability of the GI concept for weight reduction, and diets excluding most foods for which GI is relevant (e.g. bread, breakfast cereals, pasta and rice) are sometimes referred to as GI methods.

One example of a popular "GI method", although many foods high in carbohydrates are limited, is the diet advocated by Montignac (18). During weight reduction (phase 1) only foods with GI $\leq$35 (glucose reference) are allowed. No bread, except for wholegrain bread, is allowed during this phase (Table 1). Potatoes, pasta and rice are excluded, as are boiled carrots, reed beets and corn. Meat, fish, egg, cheese, milk, yoghurt, mayonnaise and berries are examples of allowed food items. Fruit is allowed, but only if eaten 3 h before other meals to avoid presumed gastrointestinal problems, not related to weight loss.

A recent report considering the relevance of GI to health, dietary recommendations and food labelling concluded that the effect of GI on body weight and composition, as well as on appetite, needs further investigation (19). There are indications that low GI may affect body composition advantageously, but further intervention studies are required to support this hypothesis.

The palaeolithic diet

The palaeolithic diet (i.e. the diet that humans are supposed to have eaten during 2 million years as hunter–gatherers) includes meat, fish, seafood, fruit, vegetables, root vegetables and nuts (20) (Table 1). Foods based on cereals, beans and dairy products, and refined foods, e.g. sugar and cooking fat, are not included. The basic idea is that these food items should also be excluded from the modern diet, since humans are not genetically adapted to them. No upper or lower limits for the intake of allowed food items or carbohydrates, proteins and fat are specified.

The palaeolithic diet is not primarily a weight-reduction diet, but may provide high satiety at a low energy intake, and could therefore contribute to weight control or weight loss. The palaeolithic diet is also claimed to help prevent several diseases, e.g. stroke, coronary heart disease and cancer, as well as to treat diseases related to food allergy. Although observational studies indicate the virtual absence of cardiovascular diseases and the metabolic syndrome in populations still eating palaeolithic diets (21), there have been no intervention studies to support the claimed effects of such a diet.

Popular diets in practice and comparison with the Nordic Nutrition Recommendations

A revised version of the Nordic Nutrition Recommendations (NNR) was presented in 2004 (22, 23). These recommendations are not primarily designed for weight reduction, but various studies indicate that subjects maintaining weight reduction over a longer period, achieved by different methods, had dietary habits close to official recommendations (14).

In summary, NNR 2004 comprise no major changes considering recommendations regarding the proportions of energy-yielding nutrients (Table 2). One new feature is an emphasis on the importance of physical activity. The recommendation for adults is 30 min of physical activity, in addition to normal inactive living. For weight reduction 60 min of physical activity is recommended.

In agreement with NNR, the diets according to Atkins and Montignac, as well as the palaeolithic diet, prescribe three main meals a day, large portions of vegetables and limited snacking. However, in contrast to NNR, the popular diets limit drastically the choice of selected foods, such as cereals or dairy products (Table 1). Sugar is strictly excluded by all three diets. The intake of meat, fish and eggs is commonly not limited. As a consequence of excluding certain food groups, the composition of meals may be very different to

Table 2. Nutrient composition of one hypothetical food day according to Atkins, Montignac and the palaeolithic diet, in comparison to recommendations according to the new Nordic Nutrition Recommendations (NNR) (22, 23)

		NNR	Atkins[a, b]	Montignac[a, b]	Palaeolithic[a]
Energy	(MJ/kcal)	9.4/2240[c]	5.1/1225	7.1/1680	5.2/1240
Carbohydrates	(*E*%)	50–60	5	37	33
	(g)	280–336	15	155	102
Protein	(*E*%)	10–20	36	31	33
	(g)	56–112	110	126	102
Fat	(*E*%)	25–35	59	27	34
	(g)	62–87	80	50	46
Saturated fat	(*E*%)	10	23	12	8
	(g)	25	31	22	11
Dietary fibre (g)	(g)	25–35	8	16	26
Vitamin C (mg)		75	145	163	278
Iron (mg)		9–15	8	15	17
Calcium (mg)		800	610	1725	434

[a] Based on a typical food day designed by dietitian Gunilla Lindeberg (Mat & Rörelse, Linköping, Sweden).

[b] Phase 1 (initial weight reduction).

[c] Women aged 18–30 years with sedentary work and limited physical activity in leisure time.

common Scandinavian eating habits. The breakfast meal, in particular, may appear odd.

Examples of one hypothetical "typical" food day according to Atkins, Montignac and the palaeolithic diet indicate that all three methods provide a low energy intake (5.1–7.1 MJ day^{-1} or 1200–1700 kcal day^{-1}) (Table 2). Compared with recommendations according to NNR, the relative protein intake (31–36*E*%) is higher for all three diets, and the selected "Atkins day" also provides a high relative intake of fat (total fat 59*E*%, saturated fat 23*E*%). However, the absolute intake (g day^{-1}) of fat and protein does not necessarily reach high levels provided that the energy intake is low (Table 2). The intake of carbohydrates and dietary fibre is lower than recommended, especially for the Atkins day (5*E*% and 8 g, respectively). However, both Atkins and Montignac divide their programme into different phases, the first phase (weight reduction) being the most extreme (strictly restricting the carbohydrate intake and GI, respectively). A typical food day later in the Atkins programme may provide a higher intake of carbohydrates, including dietary fibre. Both the Atkins day and the palaeolithic day were low in calcium, and the Atkins day was also low in iron.

The food days used for Table 2 were designed using general instructions and suggested menus given by each method. However, it should be emphasized that data from one single hypothetical food day may not completely mirror the average intake over a longer period. Personal choice may also affect the nutrient intake substantially.

Take-home messages

The number of overweight people is increasing, and so is the number of popular diets, claimed to be useful for weight reduction and improved health. The probable reasons for the strong impact of popular diets are their simple messages (e.g. "avoid carbohydrates"), and their frequent appearance in the media and commercial advertising. Despite the fact that most popular diets clash with official dietary recommendations, the validity of the diets or scientific support for the diets is rarely questioned. Consequently, the media debate is seldom helpful in separating beliefs and hypotheses from science-based conclusions regarding connections between food and body weight, or health in general.

There are good reasons to assume that overweight/obese individuals will reduce their risk of disease, and experience improved physical and mental well-being by losing weight. In combination with physical activity, weight reduction may be obtained by any diet low in energy, regardless of the diet's nutritional composition (24). However, weight stability requires an energy-balanced diet that can be followed in a life-long perspective. Many popular diets rely on consumers changing their normal food habits drastically (e.g. excluding categories of foods). With willpower, and supported by clear instructions and tools (e.g. list of allowed foods), the diets may be followed for a limited period. However, in the long run normal food habits tend to be re-established. Therefore, exclusion diets may provide effective methods for short-term weight reduction, but are likely to be less effective for weight stability over a longer duration. Furthermore, if followed for longer periods, exclusion diets may cause deficiency of certain vitamins and minerals. Some popular diets, especially low-carb diets, may also provide a high intake of saturated fat and low intake of dietary fibre, which may contribute to an increased risk of disease.

In conclusion, the safety, as well as the efficacy and mechanisms of popular diets need more research to be supported. It is of great importance that diets clashing with official dietary recommendations are critically evaluated, including by the media, and that the burden of evidence is placed on the promoters of the diet.

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Susanne Bryngelsson
SNF Swedish Nutrition Foundation, Ideon Research Park, SE-223 70 Lund, Sweden
E-mail: susanne.bryngelsson@snf.ideon.se