

ORIGINAL ARTICLE

Should nutrient profile models be 'category specific' or 'across-the-board'? A comparison of the two systems using diets of British adults

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Background/Objectives: Nutrient profile models have the potential to help promote healthier diets. Some models treat all foods equally (across-the-board), some consider different categories of foods separately (category specific). This paper assesses whether across-the-board or category-specific nutrient profile models are more appropriate tools for improving diets.

Subjects/Methods: Adult respondents to a British dietary survey were split into four groups using a diet quality index. Fifteen food categories were identified. A nutrient profile model provided a measure of the healthiness of all foods consumed. The four diet quality groups were compared for differences in (a) the calories consumed from each food category and (b) the healthiness of foods consumed in each category. Evidence of healthier diet quality groups consuming more of healthy food categories than unhealthy diet quality groups supported the adoption of across-the-board nutrient profile models. Evidence of healthier diet quality groups consuming healthier versions of foods within food categories supported adoption of category-specific nutrient profile models.

Results: A significantly greater percentage of the healthiest diet quality group's diet consisted of fruit and vegetables (21 vs 16%), fish (3 vs 2%) and breakfast cereals (7 vs 2%), and significantly less meat and meat products (7 vs 14%) than the least healthy diet quality group. The foods from the meat, dairy and cereals categories consumed by the healthy diet quality groups were healthier versions than those consumed by the unhealthy diet quality groups.

Conclusions: All other things being equal, nutrient profile models designed to promote an achievable healthy diet should be category specific but with a limited number of categories. However models which use a large number of categories are unhelpful for promoting a healthy diet.

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Introduction

Many countries use food-based dietary guidelines to frame a recommended diet, which can then be promoted by a series of dietary interventions. Food-based dietary guidelines either indicate that some food categories should be eaten more than others to achieve a healthy diet (for example, WHO (World Health Organisation) statement 3: eat a variety of vegetables and fruits, preferably fresh and local, several times

per day (at least 400 g per day); WHO statement 8: select foods that are low in sugar, and eat refined sugar sparingly, limiting the frequency of sugary drinks and sweets) (WHO Europe, 2000), or they indicate that healthier foods within food categories should be chosen more often than less healthy foods (for example, WHO statement 7: use milk and dairy products (sour milk, yoghurt and cheese) that are low in both fat and salt) (WHO Europe, 2000). The former of these sets of recommendations are referred to as 'displacement', the latter are referred to as 'substitution' (Gibney and Wolmarans, 2004).

Nutrient profile models can be used to generate definitions for 'healthy' and 'unhealthy' as applied to foods based on nutritional content (Scarborough *et al.*, 2007b), and are used as tools to support dietary interventions. At present they are used by a number of food companies, governments and

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non-governmental organisations to support labelling schemes aimed at identifying healthier products (Swedish National Food Administration, 2005; Canadian Heart and Stroke Foundation, 2009; Kraft Foods, 2009); to regulate the broadcast advertising of foods to children in the United Kingdom (Ofcom, 2006); and to regulate health claims on foods in Australia and New Zealand (FSANZ, 2007). In addition, a model has been proposed by the European Commission for the regulation of health and nutrition claims in the EU (European Union) (European Commission, 2009). Nutrient profile models are either 'category specific' (that is, different definitions of unhealthy are applied to different food categories) or 'across-the-board' (that is, the same definition of unhealthy is applied to all food categories) (Scarborough *et al.*, 2007b). Across-the-board models generally support the 'displacement' method for improving diets, whereas category-specific models support the 'substitution' method, although it is worth noting that nutrient profile models do not solely involve food categories to support the substitution message in favour of the displacement message. There may also be technical reasons, such as adjusting calculations for foods with very high water content. Differences between nutrient profile models are of practical importance because in some cases the initiatives supported by these nutrient profile models will co-exist, delivering potentially misleading messages to consumers (for example, health claims being shown on a breakfast cereal that is prohibited from being advertised on children's television).

The research questions for this paper are: (1) Are across-the-board or category-specific nutrient profile models more appropriate tools for improving diets? (2) If category-specific models are appropriate, which food categories should be included in a nutrient profile model?

These will be addressed by exploring the differences between a healthy diet and an unhealthy diet that is currently attained by the adult population of Great Britain, identifying whether these differences could best be resolved by displacement or substitution, or both, and then applying the results to the design of nutrient profile models.

Materials and methods

The analysis for this study used food intake data from the National Diet and Nutrition Survey (NDNS) for 19–64 year olds conducted in 2000/2001 in Great Britain (Henderson *et al.*, 2002) and food composition data from the UK Nutrient Databank, collected to support the NDNS.

The NDNS assessed the diets of 1722 adults aged 19–64 years living in residential homes in Great Britain between July 2000 and June 2001. Each subject was asked to complete a 7-day diary recording the weighed intake of all foods consumed both in and out of the home, and to complete a 24-h urine sample to assess sodium intakes. The analyses for this paper included all respondents that completed the 7-day

food diary and the 24-h urine sample and did not report feeling unwell during the data collection period ($n = 1117$). All foods and drinks, which were consumed by the NDNS respondents, were allocated to one of 7749 different food codes included in the nutrient databank. There were 4612 separate food and beverages consumed by at least one subject in the survey and that were used in the analyses reported in this paper.

Categorising the sample on the basis of 'healthiness of diet'

Four diet quality groups were identified using the Diet Quality Index (DQI). The DQI is a tool for assessing the nutritional quality of the diet. It has previously been validated against cardiovascular and cancer health outcomes using a large American cohort (Seymour *et al.*, 2003). The DQI categorises diets of individuals on the basis of the percentage of energy from total fat and saturated fat, amounts of cholesterol and sodium, servings of fruits and vegetables and complex carbohydrates, and proportions of the recommended daily allowances of protein and calcium. NDNS participants were allocated to four diet quality groups based on their DQI scores, split by quartiles.

Identifying the healthiness of individual foods

The nutrient profiling model WXYfm was used to identify the healthiness of foods in the Nutrient Databank (Rayner *et al.*, 2005, 2009). This model is used for regulating the broadcast advertising of foods to children in the United Kingdom, (Ofcom, 2006) while a slightly modified version is used by Food Standards Australia New Zealand for regulating the use of health claims for foods (FSANZ, 2007). Validation of this model is described elsewhere (Scarborough *et al.*, 2007a; Arambepola *et al.*, 2008).

Model WXYfm is a scoring system that rates individual foods on a scale from –15 (most healthy) to +40 (least healthy) based on their content of energy, saturated fat, total sugars, sodium, fruit and vegetables, fibre and protein (as a marker for iron and calcium). A detailed description of the algorithm used by the model is provided elsewhere (Rayner *et al.*, 2009). For each individual respondent, the average WXYfm score was defined as the mean WXYfm score for all foods that were consumed by the individual within the 7-day data collection period, weighted by the amount of energy that the food contributed to the diet. This weighting ensures that foods that were eaten frequently or in large portion sizes made a greater contribution to the average WXYfm score of each individual than foods that were eaten infrequently or in small portion sizes. Although weighting by energy provides extra weight to energy dense foods, similar problems arise for the other options of weighting (for example, weighting by grams gives extra weight to foods with high water content). As the results of this paper are predominately presented by food category (see below) the effect of this weighting should be minimised, because energy density of foods within

food categories is more homogeneous than between food categories.

Identifying categories of foods

The food categories chosen for this paper were those that were developed for the February 2009 version of the proposed EU nutrient profile model. The EU nutrient profile model is a category-specific model with threshold criteria (for making a health or nutrition claim) based on saturated fat, sodium and total sugar content. Table 1 shows some aspects of the development of this model between June 2008 and March 2009 (criteria within categories have also changed). For this study, we opted to use the third version of the model. The food categories from the proposed EU nutrient profile model were selected for this paper for two reasons: first because they split all foods into many categories; and second because the proposed EU nutrient profile model is potentially a very important tool that could affect the public health of the residents of the EU—therefore, its development deserves close scrutiny.

The foods in the nutrient databank were assigned to the EU model categories by assigning whole sub-food groups (of which there are 117 in the UK nutrient databank, for example, ‘wholemeal bread’, ‘fruit pies’, ‘ice cream’, and so on) to one of the 13 food categories used by the proposed EU model. In most instances, the choice of which food category each sub-food group should be assigned to was unproblematic. However, the ‘cereal products, except breakfast cereals’ and ‘other foods’ categories were not straightforward. For these two categories, the following sub-food groups were included: cereal products, except breakfast cereals—‘pasta’, ‘rice’, ‘other cereals’ (such as, semolina, dumplings, Yorkshire pudding, and so on), ‘white bread’, ‘crisps and savoury snacks’, ‘biscuits’, ‘fruit pies’, ‘buns, cakes and pastries’, ‘cereal-based milk puddings’, ‘sponge puddings’, ‘other cereal-based puddings’; other foods—‘other dairy desserts’ (such as, chocolate cream desserts, junket, egg custard, and so on), ‘sugar’, ‘preserves’, ‘sweet spreads, fillings, icing’, ‘sugar confectionery’, ‘chocolate confectionery’, ‘savoury sauces, pickles and condiments’.

Table 1 Food categories and exemptions of foods during the four developmental stages of the proposed EU nutrient profile model

<i>Euro 1 June 2008</i>	<i>Euro 2 October 2008</i>	<i>Euro 3 February 2009</i>	<i>Euro 4 March 2009</i>
<i>Food categories</i>			
Vegetable oils Spreadable fats	Vegetable oil and spreadable fats Fruit, vegetable, nut and their products	Vegetable oils and spreadable fats Fruits, vegetables and their products except oils	Vegetable oils, butter and spreadable fats Products of fruit and vegetables except oil
Fruits, vegetables and their products	Nut, seeds, kernels	Seeds and their products except oils	Seed products except oil
Meat and meat products	Meat or meat product	Meat or meat-based products	Meat-based products
Fish and fish products	Fish	Fish, fishery products, crustaceans and molluscs	Fishery products, crustaceans and molluscs
Dairy products	Dairy product except cheese	Dairy-based products, except cheese	Dairy products except cheeses
Cereal and cereal products	Cheese	Cheeses	Cheeses
Other foods	Cereal products except breakfast cereals	Breads containing at least 3 g of fibre per 100 g or at least 1.5 g fibre per 100 kcal	Cereal and cereal products except breakfast cereals and fine bakery wares
	Breakfast cereals	Cereal and cereal products except breakfast cereals	Biscuits and other fine bakery wares
	Ready meal, soup and sandwich	Breakfast cereals	Breakfast cereals
	Non-alcoholic beverages	Ready meals, soups, sandwiches	Ready meals, soups, sandwiches
	Other foods	Non-alcoholic beverages	Soy-based products 3 < 10% soy protein
		Other foods	Soy-based products 10% < soy protein
			Non-alcoholic beverages
			Other foods
<i>Exemptions</i>			
Fruit and vegetables	Fruit, vegetables and juices without added sugar.	Fruits, vegetables, and their products if they do not contain added sugars, salt or fat except vegetable oils. Honey Table top sweeteners	Fruits, vegetables, and their products (not containing added sugars, salt or fat except vegetable oils) Meats and edible meat offal Fishes and crustaceans, molluscs and other aquatic invertebrate Milks falling Eggs falling Breads containing at least 3 g fibre per 100 g, or at least 1.5 g fibre per 100 kcal Honey Table top sweeteners

Comparisons between healthy and unhealthy diet quality groups

For each respondent to the NDNS, an average WXYfm food score was calculated for each of the 13 food categories, as well as for all foods consumed. In addition, the total energy consumed from foods in each of the 13 food categories, as well as for all foods combined, was calculated. These variables were used to calculate the average WXYfm score for each food category (and also for all foods) and each of the four diet quality groups. In addition, the average energy consumption for each of the 13 food categories (and also for all foods) and each of the four diet quality groups was calculated.

Average WXYfm scores and average energy consumptions for different diet quality groups were then compared, and the results were examined for evidence of whether the healthy and unhealthy diet quality groups differed by eating different amounts of the food categories (indicating that the displacement message and hence across-the-board nutrient profile models may be appropriate for supporting dietary advice) or by eating foods from within the food categories that were more or less healthy (indicating that the substitution message and hence category-specific nutrient profile models may be appropriate), or both.

Statistical analysis

Descriptive statistics were developed for each of the diet quality groups that included the sex, age, socioeconomic and ethnic distribution of the groups. Significance tests of the differences between diet quality groups were conducted using a non-parametric test for trends. All statistical analyses were conducted using the Stata software package, version 10 (Statacorp, 2007).

Results

Table 2 reports descriptive statistics of the different diet quality groups and shows that healthy eaters were more

likely to be female, older, non-manual workers and vegetarians. As has been shown elsewhere (Arambepola *et al.*, 2008), the average healthiness of foods consumed by the diet quality group (average WXYfm score, measured by the nutrient profile model) is positively associated with the healthiness of the diet quality group.

Table 3 shows a breakdown of the average diet of the four diet quality groups by the food categories. In general, there was a strong trend for greater absolute consumption of all food categories by the less healthy diet quality groups (results for absolute consumption are available from the investigators). The exceptions to this were the 'seeds and their products, except oils' and 'fruits, vegetables and their products, except oils' (which includes potato and potato products) categories in which there was similar absolute consumption across the diet-groups, and the 'fish or fish products, crustaceans and molluscs' and 'breakfast cereals' categories in which there was greater absolute consumption in the healthier diet quality groups.

In relative terms (that is, the percentage of the diet that consisted of each food category), there was similar consumption across the diet quality groups of the 'seeds and their products, except oils', 'dairy products, except cheeses', 'cheeses', 'breads with minimum fibre requirement', 'cereal products, except breakfast cereals' and 'ready meals, soups and sandwiches' categories. There were considerable differences in consumption of the 'fruits, vegetables and their products, except oils', 'fish or fish products, crustaceans and molluscs' and 'breakfast cereals' categories, from which the healthier diet quality groups received a greater proportion of their dietary energy, and the 'meat or meat-based products', 'vegetable oils and spreadable fats', 'non-alcoholic beverages' and 'other foods' categories, from which the healthier diet quality groups received a smaller proportion of their dietary energy.

The 'cereal products, except breakfast cereals' category includes many cereal-based biscuits, cakes and desserts, as well as pasta, rice and other savoury cereal-based dishes. When the 'breads with minimum fibre content', 'cereal

Table 2 Descriptive characteristics of diet quality groups

Characteristic	Diet quality groups				P for trend
	1 (most healthy)	2	3	4 (least healthy)	
Males (%)	23.9	37.4	48.2	72.5	<0.001
Age (years, mean)	45.0	42.8	42.1	41.4	0.010
White ethnicity (%)	95.1	95.4	95.6	94.6	0.941
Non-manual workers (%)	72.5	63.0	62.4	48.4	<0.001
Vegetarian (%)	11.4	4.6	5.5	1.4	<0.001
Body mass index (kg/m ² , mean)	26.4	26.1	26.8	27.0	0.312
Energy consumption (kcal/day, mean)	1667	1844	2013	2324	<0.001
Average WXYfm score, across all foods consumed in 7 days:	4.6	6.1	7.4	8.2	<0.001
N	184	307	346	280	

Lower WXYfm scores indicate healthier foods. Respondents split into diet quality groups by quartiles of the Diet Quality Index score. The term 'vegetarians' include all those who identified themselves as either vegetarian or vegan, and therefore include some individuals who consume fish or white meat.

Table 3 Percentage contribution (weighted by energy) to total diet of food categories by diet quality groups

% of total diet (<i>s.e.</i>) ^a	Diet-group 1 (most healthy)	Diet-group 2	Diet-group 3	Diet-group 4 (least healthy)	P for trend (for % total diet)
Vegetable oils and spreadable fats	2.6 (0.2)	3.5 (0.2)	4.1 (0.2)	4.8 (0.2)	<0.001
Fruits, vegetables and their products, except oils	20.7 (0.6)	17.6 (0.4)	16.9 (0.3)	15.5 (0.4)	<0.001
Seeds and their products, except oils	0.7 (0.1)	0.6 (0.1)	0.5 (0.1)	0.6 (0.1)	0.021
Meat or meat-based products	6.9 (0.4)	9.5 (0.4)	10.4 (0.3)	14.2 (0.4)	<0.001
Fish or fish products, crustaceans and molluscs	3.1 (0.2)	2.8 (0.2)	2.3 (0.2)	2.2 (0.2)	<0.001
Dairy products, except cheeses	9.8 (0.4)	9.5 (0.3)	9.3 (0.3)	9.2 (0.3)	0.109
Cheeses	2.6 (0.2)	2.7 (0.2)	3.1 (0.2)	2.9 (0.2)	0.231
Breads with minimum fibre requirement ^b	12.7 (0.4)	12.7 (0.4)	12.5 (0.3)	13.0 (0.4)	0.819
Cereal products, except breakfast cereals	9.5 (0.4)	9.6 (0.4)	10.2 (0.4)	10.2 (0.5)	0.540
Breakfast cereals	7.2 (0.4)	5.2 (0.3)	4.1 (0.3)	2.4 (0.2)	<0.001
Ready meals, soups and sandwiches	8.9 (0.5)	8.8 (0.4)	8.9 (0.3)	8.6 (0.4)	0.529
Non-alcoholic beverages	0.7 (0.2)	1.1 (0.1)	1.2 (0.1)	1.2 (0.1)	<0.001
Other foods	6.7 (0.4)	8.2 (0.4)	9.7 (0.3)	8.8 (0.4)	<0.001

^aWeighted by energy intake. Note that totals do not sum to 100%, since the figures for each food category are the mean of the % of total diet for each respondent within the diet-group.

^bMinimum 3 g fibre per 100 g or 1.5 g fibre per 100 kcal.

Table 4 Average WXYfm score by food category of the proposed EU nutrient profile model and diet quality group

Average WXYfm score (<i>s.e.</i>) ^a	Diet-group 1 (most healthy)	Diet-group 2	Diet-group 3	Diet-group 4 (least healthy)	P for trend
Vegetable oils and spreadable fats	23.6 (0.03)	24.2 (0.02)	24.5 (0.01)	25.1 (0.01)	<0.001
Fruits, vegetables and their products, except oils	-1.0 (0.01)	-0.0 (0.01)	1.0 (0.01)	1.8 (0.01)	<0.001
Seeds and their products, except oils	3.1 (0.05)	3.2 (0.06)	3.8 (0.06)	3.9 (0.04)	0.156
Meat or meat-based products	6.5 (0.04)	8.2 (0.02)	9.6 (0.02)	11.3 (0.01)	<0.001
Fish or fish products, crustaceans and molluscs	1.9 (0.04)	2.8 (0.04)	3.2 (0.04)	2.7 (0.04)	0.112
Dairy products, except cheeses	1.7 (0.01)	2.7 (0.01)	3.5 (0.02)	3.5 (0.01)	<0.001
Cheeses	18.5 (0.07)	20.8 (0.03)	21.8 (0.02)	22.2 (0.02)	<0.001
Breads with minimum fibre requirement ^b	1.8 (0.01)	2.4 (0.01)	2.6 (0.01)	2.8 (0.01)	<0.001
Cereal products, except breakfast cereals	9.3 (0.03)	10.6 (0.02)	12.6 (0.02)	13.6 (0.02)	<0.001
Breakfast cereals	6.5 (0.04)	8.0 (0.03)	8.8 (0.03)	8.4 (0.04)	0.018
Ready meals, soups and sandwiches	2.6 (0.03)	4.2 (0.02)	4.3 (0.02)	5.1 (0.02)	<0.001
Non-alcoholic beverages	1.8 (0.01)	1.7 (0.01)	1.8 (0.01)	1.8 (0.01)	0.030
Other foods	15.9 (0.03)	16.3 (0.02)	17.1 (0.01)	17.4 (0.02)	<0.001

^aWeighted by energy intake. Note that lower WXYfm scores indicate healthier foods.

^bMinimum 3 g fibre per 100 g or 1.5 g fibre per 100 kcal.

products, except breakfast cereals' and 'breakfast cereals' categories are combined, there was greater relative consumption in the healthier diet-groups than the unhealthy diet-groups. This is in general agreement with dietary advice to eat more cereals and starchy foods (for example, WHO statement 2: eat bread, grains, pasta, rice or potatoes several times per day (WHO Europe, 2000)).

Table 4 shows the weighted average WXYfm score for the foods that are consumed by each of the diet quality groups within each of the food categories. In this study, lower average WXYfm scores indicate healthier versions of foods from within the food categories were consumed by the diet quality groups (for example, within the 'bread with minimum fibre requirement' category wholemeal bread scores -3 and white bread scores 1). In general, there was a strong trend towards consumption of healthier versions of foods from within food categories (indicated by lower WXYfm

scores) in the healthier diet quality groups. The exceptions to this were the 'seeds and their products, except oils', 'fish or fish products, crustaceans and molluscs' and 'non-alcoholic beverages' in which the healthiness of the foods consumed by the diet quality groups were similar.

Discussion

It is shown in this paper that, to achieve a diet consumed by those in the healthy diet quality groups, consumers of unhealthy diets would have both to consume different quantities of food categories (displacement) and consume healthier versions of foods from within food categories (substitution), suggesting that food-based dietary guidelines are correct in adopting both displacement and substitution messages. The results also have implications for the

development of nutrient profile models, with regard to the choice of whether to include food categories and if so how many. In this study, it is important to consider that the introduction of food categories has costs as well as benefits. Food categories are very difficult to define accurately, which is especially problematic when there is a need for a model that is compulsory rather than voluntary. Regulatory bodies designing nutrient profile models for use in food legislation generally favour models with as few categories as possible to simplify enforcement. Moreover, the ability of a nutrient profile model to support interventions encouraging displacement is weakened by including many food categories, because this results in the healthier versions of two different food categories being equated by the nutrient profile model, whereas displacement advice may recommend that consumption of foods from one of the food categories is reduced in favour of the other food category. In spite of this, the results presented here indicate that nutrient profile models—all other things being equal—should have a limited number of food categories. This paper presents a useful starting point for deciding which food categories to include in a nutrient profile model. It suggests food categories should be included in which there is evidence that those with a healthy diet consume healthier versions of foods within those categories than those with an unhealthy diet, but that there is no need to include categories in which there is no evidence that healthier versions of foods within those categories are consumed by those who achieve a healthier diet.

In this analysis, we found that those with healthy diets in Great Britain consume healthier foods within the following categories: 'meat or meat-based products', 'dairy products, except cheeses', 'breads with minimum fibre content', 'cereal products, except breakfast cereals', 'ready meals, soups and sandwiches' and 'breakfast cereals'. It seems reasonable that these categories should be included within nutrient profiling models. Conversely, we found no evidence that those with healthy diets consumed healthier versions of foods within the categories 'seeds and their products, except oils', 'fish or fish products, crustaceans and molluscs' and 'non-alcoholic beverages', so there is no need to include these categories in nutrient profile models. In three other categories, healthier versions were consumed by the healthy diet-groups than the less healthy diet-groups: 'vegetable oils and spreadable fats', 'fruits, vegetables and their products, except oils' and 'cheeses'. As greater consumption of all the foods in the 'fruits, vegetables and their products, except oils' is generally recommended by food-based dietary guidelines, there is no need to include a separate food category for fruits and vegetables in a nutrient profile model. The 'vegetable oils and spreadable fats' category can have a substantial effect on the levels of saturated fat in the diet, and for this reason it may be prudent to include it as a food category to direct consumers towards products with lower levels of saturated fat. Some people have made a similar argument for the inclusion of 'cheeses' as a separate category because cheese is an important source of calcium for many people and hence

the consumption of healthier versions of cheese should be encouraged. This is less compelling, though, as in general the distinction between 'healthy' and 'unhealthy' versions of cheese is because of levels of salt and saturated fat rather than calcium. Second, calcium is readily available in other food categories (most notably 'dairy products, except cheese') which generally have a more favourable nutrient profile than cheese.

The food categories used for this analysis were developed for the European Commission nutrient profile model, which will be used for the compulsory regulation of health and nutrition claims. According to our analysis, many of the suggested food categories are unnecessary. This may also be the case for food categories used by nutrient profile models developed for voluntary purposes by food companies. For example, the Sensible Solution scheme used by Kraft to identify foods that can either be marketed to children or carry a logo is based on a nutrient profile model that has 16 different food categories, including cookies, salted snacks and mayonnaise (Kraft Foods, 2009), and the nutrition profiling system introduced by Nestle to identify foods, which can be advertised to children has 25 food categories including salty and savoury biscuits, ice creams and chocolate (Nestle, 2008). It would seem unlikely that people who achieve a healthy diet do so by consuming healthier versions of ice cream than those who consume an unhealthy diet. Nutrient profile models that include such categories encourage substitution within food categories when there is no evidence that this is appropriate advice for consumers seeking to achieve a healthy diet.

Strengths and weaknesses of study

The methods and results described in this paper illustrate a novel use for nutrient profiling, that of exploring whether the difference between healthy diets and unhealthy diets is due to different consumption patterns within food categories, between food categories or both. The advantage of using a nutrient profile model in such a way is that the differences in foods consumed within food categories by the different diet quality groups can be assessed objectively, as opposed to relying on value judgments regarding the relative 'healthiness' of different foods within categories. However, it should be noted that both the categorisation of foods by the nutrient profile model and the categorisation of diets by the dietary quality index are imprecise measures of 'healthiness', which could introduce error into the results. In addition, as with all situations involving food categories, the results are affected by the decisions regarding which foods are included in which of the categories.

The NDNS that provided the data for this analysis was well suited to measuring dietary intake of a representative sample from Great Britain. In spite of the intrusive nature of the data collection, a large sample was attained although the response rate was disappointingly low, increasing the likelihood of non-response bias (Henderson *et al.*, 2002). As with

all dietary surveys, the results may be affected by differential under-reporting. It is generally found with dietary surveys that individuals who report a healthy diet are more likely to under-report than those who do not (Becker and Welten, 2001; Scagliusi *et al.*, 2008), and this differential under-reporting has been shown for a national survey of young people, conducted in 1997 using similar methods to the NDNS (Gibson and Neate, 2007). Under-reporting in the NDNS may be one reason for the difference in overall energy intake between the four dietary groups examined here—from an average energy intake of 1667 kcal/day in the healthiest diet-group to 2324 kcal/day in the least healthy diet-group. If some of this difference is due to differential under-reporting, then the gradients in amount of food consumed between dietary groups is likely to be shallower than reported here, as are the differences in proportion of diet consumed for the different food groups and the difference in healthiness of foods consumed in each group, because respondents are more likely to under-report unhealthy foods than healthy foods (Becker and Welten, 2001).

The data used in this analysis are cross-sectional. Ideally, the analysis should consider individuals who have moved from an unhealthy diet to a healthy one (or vice versa) and assess whether that change was the result of displacement, substitution or both. Such an analysis would require a longitudinal data set with at least two dietary data collection points, which was not available to the authors.

The analysis only looked at one categorisation of foods. Further work could be conducted using different methods for categorising foods. Similarly, the dietary data analysed here were collected from British adults, and it is not clear whether similar results would be found using other national data sets because different countries tend to have different diets (Tukker *et al.*, 2009). However, the methods used here could easily be reproduced with other national dietary data sets.

Unanswered questions and further research

An important question that has not yet been addressed is whether the potential health gains that could be achieved by displacement are greater than by substitution or vice versa. One way of answering this question would be to model the effect of the unhealthy diet quality group moving to a healthier diet through substitution alone and through displacement alone and compare the results. Addressing this issue could lead to more informed prioritisation of dietary interventions.

Conclusions

Healthy diets of British adults are characterised by a greater consumption of fruit and vegetables, breakfast cereals and fish, smaller consumption of meat and 'other foods' (including sugary and fatty foods, such as confectionery) and greater consumption of healthier foods from within the

meat, dairy and cereals groups, and healthier versions of meals, soups and sandwiches than for unhealthy diets. Nutrient profile models designed to promote this healthy diet should, all other things being equal, be category specific but with a limited number of categories focused on meat, dairy, cereals and ready meals. Nutrient profile models of this kind will also be broadly in agreement with food-based dietary guidelines. However models which use a large number of categories are unhelpful for promoting a healthy diet. Nutrient profiling model WXYfm used for regulating the broadcast advertising of foods to children in the UK and, in an adapted form, for regulating health claims for foods in Australia, continues to be one of the best validated nutrient profiling models and the most appropriate for its applications.

Conflict of interest

The authors declare no conflict of interest.

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