Quantifying the contribution of foods with unfavourable nutrient profiles to nutritionally adequate diets

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Abstract

That "all foods can fit" into a healthy diet is a long-standing principle of dietetic practice. This study quantified the relative contributions of foods to encourage and foods to limit, using new techniques of individual diet optimization and nutrient profiling. Individual foods from every food group were assigned into 4 nutrient profile classes based on the French SAIN,LIM system. Foods with the most favourable nutrient profiles were in class-1 and foods with the least favourable nutrient profiles were in class-4. An optimized diet, that met the recommendations for 32 nutrients and that respected the existing eating habits, was designed for each adult in the nationally representative INCA1 dietary survey (n=1,171). The relative proportions of the 4 nutrient profiling classes were assessed before and after the optimization process. The contribution of fruits and vegetables, whole grains, milk, and fish was significantly increased, whereas the contribution of refined grains, meats, mixed dishes, sugars and fats was decreased. The optimized diets derived more energy (30% vs 21% in the observed diets) from class-1 foods and less energy (41% vs 56%) from class-4 foods. They also derived a higher amount of class-1 foods (61% vs 51%) and a lower amount of class-4 foods (22% vs 32%). Thus, nutrient adequacy was compatible with the consumption of foods with an unfavourable nutrient profile (one-fifth the basket weight) provided that the diet also contained almost tho-third of foods with the most favourable profile. Translating these results into concrete and quantified advice may have very tangible public health implications.

Introduction

It is well established that healthful diets[1,2] ought to contain low-fat dairy products, fish and lean meats, beans and legumes, and plenty of vegetables and fruit[3-5]. However, much of dietary advice is still based on nutrients to avoid. Consumers are advised to limit the intake of saturated fatty acids, sugar, and sodium[6-8] and to eat sparingly foods that contain those nutrients in excess[1,4]. Missing from nutrition education messages are many processed foods[9] and mixed foods belonging to more than one food group[10].

The 2005 Dietary Guidelines for Americans[11] identified nutrient density of foods as a novel strategy for nutrition education and positive dietary guidance. Consumers selecting nutrient dense foods and beverages would be able to satisfy daily nutrient requirements without exceeding their daily energy needs [11]. Supplemental "discretionary" calories, defined as the balance of calories remaining after satisfying nutrient needs, could then be consumed in proportion to energy allowance [11]. Nutrient dense foods were described as those that provided relatively more nutrients than calories, whereas the amount of discretionary calories was set low [12].

The new science of nutrient profiling[13-15] can classify individual foods based on their overall nutritional quality. Nutrient profiling can help distinguish between nutrient-rich foods that provide more nutrients than energy and those foods that are energy-rich but nutrient-poor[16]. Given that lower scoring foods can be more enjoyable and may provide energy at a lower cost [17], calculating their relative proportion in a healthy diet is a question of both public health and consumer importance. Coupling the new techniques of nutrient profiling[14] and individual diet optimization[18], the objective of the present study was to quantify the shift in food intakes from different nutrient profile classes needed to reach nutritional adequacy, while taking into account individual dietary patterns and preferences.

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Methods

Dietary data

The data used in the present study were based on dietary data collected from 1171 adults (age > 18 years) in the cross-sectional dietary survey "Enquête Individuelle et Nationale sur les Consommations Alimentaires" (INCA), conducted in 1999 by the French National Agency for Food Safety[19]. Habitual food intakes were estimated using a 7-d food diary recorded by all participants. Energy and nutrient intakes were calculated for each participant using the French food composition database, previously described[20].

The SAIN, LIM nutrient profiling system

The SAIN, LIM scoring system was applied to each food in the food database. After exclusion of drinking water, diet beverages, tea, coffee and fortified foods, the remaining 613 foods were aggregated in 10 food-groups. The French SAIN,LIM system was described in details elsewhere[14]. Briefly, it assigned each food to one of 4 classes, based on two independent subscores. The positive SAIN subscore was the mean percent nutrient adequacy for 5 basic nutrients (proteins, fiber, vitamin C, iron calcium), calculated per 100 kcal of food and a variable number of optional nutrients applied to different food groups in the database. Vitamin D, vitamin E, alpha-linolenic acid and monounsaturated fatty acids were used as optional nutrients for nuts and for foods containing more than 97% of their energy as lipids while only vitamin D was used as optional nutrient for all other foods. The negative LIM subscore was calculated as the mean % of maximal recommended values for 3 nutrients to limit: saturated fatty acids (SFA), added sugar and sodium, and was expressed per 100g.

Specific thresholds were derived for each subscore so that foods were assigned into 4 broad classes: high SAIN and a low LIM (class-1: most favourable); low SAIN and a low LIM (class-2) high SAIN and a high LIM (class-3); low SAIN and a high LIM (class-4: least favourable).

Most fruits and vegetable, eggs, milk, low fat-low dairy products, most fish and shellfish, potatoes, legumes and whole grains were all class-1 foods (Table 1). Most refined cereals, including white bread, together with some cereal-based products containing low amounts of SFA, sugar and salt were class-2 foods. Many cheeses salted and/or smoked fatty fish, meats with an intermediate fat content, and most nuts and vegetable oils were class-3 foods. Virtually all sweets and desserts, animal fats, sweetened beverages, a high proportion of salted snacks, and mixed dishes, most deli meats and fatty meats, full-fat dairy products and sweetened cereals were class-4 foods.

Diet optimization

We designed a set of 1171 individual-specific nutritionally adequate diets using a recently developed individual diet modelling approach[18]. For each individual, a model started from his or her observed diet (i.e. food intakes and nutrient intakes) to design an isocaloric optimized diet respecting his or her food selections and a set of nutrient goals. Nutritional adequacy was ensured by having each diet meet a set of constraints based on the French recommendations for 32 nutrients: proteins, fibers, total carbohydrates, total lipids, essential fatty acids, 11 vitamins (including vitamin D) and 9 minerals, and nutrients to limit. As previously described (18), the minimum levels imposed for nutrients in the optimized diets were: at least the EAR when the observed intake was lower than the EAR; at least the RDA when the observed intake was greater than the RDA; equal to the observed intake level when it was between the EAR and the RDA. This was done to improve the nutrient intakes of each individual in order to reach at least the EAR level for each nutrient, while ensuring that the optimization process did not deteriorate any nutritional component of the observed diets. This is consistent with the current consensus for diet planning of minimizing the percentage of individual's with dietary intakes below the EAR[21].

For the energy contribution of macronutrients and for essential fatty acids (including linolenic acid, linoleic acid, DHA and EPA), the constraint levels were identical for all individuals but for fibers and micronutrients, the lower constraint bounds depended on gender, age and the individual's observed intake of these nutrients, as previously described[18]. The nutrients to limit were sodium, free sugars, saturated fatty acids and cholesterol. For cholesterol the maximal constraint bound was either 300 mg per day when the observed intake was below 300mg/d or the observed intake when it was above 300mg/d. Safe upper limits for niacin, folate, ascorbic acid, vitamin A, B-6, E, D, zinc and selenium were also included in each optimization model.

Consumption constraints ensured that each optimized diet corresponded as much as possible to the dietary pattern and food preferences of each individual. An upper limit was placed on the quantity of each food, calculating as the 95th percentile amount of the consumer distribution (except when the observed intakes exceeded the 95th percentile).

Each optimized diet created by individual modelling came as close as possible to the corresponding observed diet while simultaneously respecting multiple individual-specific constraints. For each person, the optimization algorithm i) preferentially chose foods that the person habitually consumed, ii) maintained quantities consumed as far as possible, and iii) if necessary to reach nutritional adequacy, introduced novel foods but in the lowest amount possible and by preferentially selecting foods with a high percentage of consumers in the French population (i.e. the most popular ones). The energy content of the optimized diets was the same as in the observed diets, and the weight of foods could not exceed 115% of the observed weight. Population-based consumption constraints on foods and food groups were added to ensure social acceptability to the optimized diets.

Statistical analysis

The relative average contributions of each nutrient profiling class to total weight and energy of the optimized diets were calculated for each diet and tested between observed and optimized diets using a paired Student t-test. The relative contributions of the 10 food groups to total weight were similarly assessed and tested. SAS version 9.2 was used for diet modelling and for statistical analysis, using a 5% alpha level for significance.

Results

The mean weight of the optimized diets was 1,598g/d as compared to 1,425g/d for the observed diets. The mean energy density of the optimized diets was accordingly reduced from 623 kJ/100g

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(149 kcal/100g) to 552 kJ/100g (132 kcal/100g). Table 1 shows the average contribution of each food group to the total weight of observed and optimized diets. The total amount of fruits and vegetable increased from 23.1% to 33.6%. Unrefined starches increased from 5.4% to 7.9%, and refined cereals increased from 12.6% to 13.7%. Fresh dairy products such as yogurts and milk rose from 13.2% to 15.6%, whereas the amount of fish rose from 2.5% to 4.1%. The optimization process reduced the amounts of meat, cheese, added fats and sweets, the greatest drop being observed for mixed dishes and salted snacks (from 13.9% to 5.5%). When a given food group was increased, foods which had an augmentation mainly came from the SAIN,LIM class-1 (results not shown). When a given food group was decreased, foods which had a diminution mainly came from the SAIN,LIM classes 3-4 (results not shown).

Both the observed diets and the optimized diets were composed of foods from all four SAIN, LIM classes (Figure 1). Following the optimization process, the energy contribution of class-1 foods increased from 21% to 30% and that of class-4 foods decreased from 56% to 41% (Figure 1A). Following the optimization process, the weight contribution of class-1 and class-2 foods increased and that of class-3 and class-4 foods decreased (Figure 1B). The relative weight contribution of class-1 foods increased from 51% to 61% and that of class-4 foods decreased from.32% to 22%.

Discussion

Foods from all nutrient profile classes can be part of nutritionally adequate diets. The present results show that foods with the least favourable nutrient profiles can still contribute as much as 41% of energy to a nutritionally adequate food pattern, provided that nutrient dense foods with the most favourable nutrient profile account for the majority of food weight (61%). The present data used new techniques to quantify the relative contribution of different type foods to a nutritionally adequate food pattern that, moreover, respected individual food choices. Early fears that nutrient profiling would perpetuate the dichotomy between “good” and “bad” foods are not borne out by our use of profiling methods and diet optimization techniques.

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Nutrient profile systems can help quantify the relative amounts of foods that need to be reduced or increased in order to achieve a healthy diet[14,22]. Moreover, they show that foods with an unfavorable nutrient profile need not be avoided altogether. Indeed, only a partial replacement of class-4 (and class-3) foods by class-1 (and class-2 foods) was needed to design a nutritionally adequate diet for each person from our sample of French adults.

The present study has some limitations. First, the results of diet optimization depends on the design of a particular model, including the constraints used to define nutritional adequacy[23]. However, in an earlier linear programming study, we used three different official sets of nutritional recommendations and this did not change our conclusions about the foods and nutrients limiting the design of optimal diets for young children in a developing country[24]. Moreover, in the present study, the use of individual diet modelling is likely to limit the risk of drawing conclusions that are too specific to the model applied. Indeed, the present conclusions were based on the results obtained from 1171 individual-specific models, each of them being unique in terms of objective function and constraints[18].

A second limitation is that the nutrient profiling approach may fail to correctly classify some key foods[25,26]. Nevertheless, our results were fully consistent with studies from the UK[22] showing that foods deemed as least healthy using the UK Food Standard Agency nutrient profile contributed as much as 39% of energy to the most healthy diets (based on the Diet Quality Index), a figure in close agreement with the present estimate of 41%. Given that the two studies, conducted in the UK and France respectively, differed in methodology (observational and modelling studies, respectively), such correspondence suggests that the amount of "discretionary" calories can be higher than previously envisaged. According to MyPyramid, most discretionary calorie allowances are very small, between 100 and 300 calories, that is to say between 5 and 15% of daily energy intakes[3]. Limiting so much the amount of discretionary calories could be more restrictive than effectively needed to reach nutritional adequacy.

Nutritionally adequate diets were in accordance with habitual dietary advice as they had a low energy density and contained plenty of foods of plant origin and reasonable amounts of animal products. The current debate on nutrient profiling leaves the consumer and the health professional alike with the impression that only the most nutrient rich foods have a place in a healthy diet. Based on sophisticated mathematical techniques, the present study showed, to the contrary, that foods from all SAIN,LIM classes could be a part of individually-tailored nutritionally adequate food diets. In this population of French adults, current nutrient recommendations were compatible with the consumption of one-fifth of energy-dense foods that were nutrient-poor (class-4), provided that the diets also contained almost two-third of nutrient-dense foods (class-1).

In many countries, consumers already receive information about the nutrient profile of individual foods and this is considered as a possible way of favourably influencing food choices. For instance, in Sweden, the 'Green Keyhole' symbol has been in use since 1989, to help consumers identify low-fat and high-fibre alternatives[27], and in France, the ministry of health is currently considering the introduction of a healthy food label based on nutrient profiling[28]. Thus, translating the results of the present study into concrete and quantified advice to increase the consumption of food with a favourable nutrient profile (to at least two-third the basket weight) at the expense of foods with an unfavourable nutrient profile (to a maximum of one-fifth the basket weight), may have very tangible public health implications.

All too often dietary advice is either vague or solely based around avoiding or severely restricting a specific nutrient or food. Nutrient profiling models that accurately capture the nutrient density of foods can be an effective platform for nutrition education.

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Author's contributions: MM and ND conceived the study. MM conducted data modeling and statistical analyses. AD participated substantially in interpretation of the results and writing of the report. All authors participated in the interpretation of the results and writing of the report.

Table 1. Number of foods from each food group in each SAIN,LIM class and average contribution of each food group to total diet weight among observed and optimized diets.

Figure 1 Title.

Relative contributions of each nutrient profiling class to total diet energy (Panel A) and to total diet weight (Panel B) among observed and optimized diets.

References

1. World Health Organization Europe (2000) CINDI dietary guidelines. Copenhagen Available at: www euro who int/Document/E70041 pdf (accessed 5 january 2010).

2. USDA (2005) The Food Guide Pyramid. Washington; 2005-7 Available at: http://www.mypyramid.gov/.

3. Britten P, Marcoe K, Yamini S et al. (2006) Development of food intake patterns for the MyPyramid Food Guidance System. J Nutr Educ Behav **38**, S78-S92.

4. Hercberg S, Chat-Yung S & Chauliac M (2008) The French National Nutrition and Health Program: 2001-2006-2010. Int J Public Health **53**, 68-77.

5. Katamay SW, Esslinger KA, Vigneault M et al. (2007) Eating well with Canada's Food Guide (2007): development of the food intake pattern. Nutr Rev **65**, 155-166.

6. Euro diet (2000) Nutrition and diet for healthy lifestyles in Europe, science and policy implications, 1998-2000. Core report available at: ec.europa.eu/health/ph_determinants/life_style/nutrition/report01_en.pdf.

7. Joint WHO-FAO expert consultation (2003) Diet, nutrition and the prevention of chronic diseases. Geneva, World Health Organisation, Technical report **Series 916**.

8. Nordic Council of Ministers (2004) Nordic nutrition recommendations 2004. Integrating nutrition and physical activity. Copenhagen Available at: http://www.norden.org/da/publikationer/publikationer/2004-013/ (accessed January 5 2010).

9. Monteiro CA (2009) Nutrition and health. The issue is not food, nor nutrients, so much as processing. Public Health Nutr **12**, 729-731.

10. Darmon N (2009) We eat foods, we need nutrients (comment on "The good, the bad, and the ultra-processed" by Carlos Monteiro). Public Health Nutr **12**, 1967-1968.

11. US Department of Health and Human Services USDGAC (2005) Dietary Guidelines for Americans. *[Monograph on the Internet]*. 6th Edition, Washington, DC: U S Government Printing Office, January 2005 (Available at: http://www health gov/dietaryguidelines/dga2005/document/):Accessed January 5, 2010.

12. Murphy SP, Britten P & Eds (2006) Development of the MyPyramid Food Guidance System. J Nutr Educ Behav 38, (November-December 2006)-USDA Center for Nutrition Policy and Promotion.

13. Scarborough P, Rayner M & Stockley L (2007) Developing nutrient profile models: a systematic approach. Public Health Nutr **10**, 330-336.

14. Darmon N, Vieux F, Maillot M et al. (2009) Nutrient profiles discriminate between foods according to their contribution to nutritionally adequate diets: a validation study using linear programming and the SAIN,LIM system. Am J Clin Nutr **89**, 1227-1236.

15. Drewnowski A & Fulgoni V, III (2008) Nutrient profiling of foods: creating a nutrient-rich foot index. Nutr Rev **66**, 23-39.

16. Maillot M, Darmon N, Darmon M et al. (2007) Nutrient-Dense Food Groups Have High Energy Costs: An Econometric Approach to Nutrient Profiling. J Nutr **137**, 1815-1820.

17. Drewnowski A, Maillot M & Darmon N (2009) Testing nutrient profile models in relation to energy density and energy cost. Eur J Clin Nutr **63**, 674-683.

18. Maillot M, Vieux F, Amiot J et al. (2010) Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices. Am J Clin Nutr **91**, 421-430.

19. Volatier J-L (2000) Enquête INCA (Individuelle et Nationale sur les Consommations Alimentaires).AFSSA, Agence Française de Sécurité Sanitaire des Aliments, Editor. Lavoisier, Paris, 158p pp.

20. Maillot M, Ferguson EL, Drewnowski A et al. (2008) Nutrient profiling can help identify foods of good nutritional quality for their price: a validation study with linear programming. J Nutr **138**, 1107-1113.

21. Beaton GH (2006) When is an individual an individual versus a member of a group? An issue in the application of the dietary reference intakes. Nutr Rev **64**, 211-225.

22. Arambepola C, Scarborough P & Rayner M (2008) Validating a nutrient profile model. Public Health Nutr **11**, 371-378.

23. Wilde PE & Llobrera J (2009) Using the Thrifty Food Plan to assess the cost of a nutritious diet. J Consum Affairs **43**, 274-304.

24. Darmon N, Ferguson E & Briend A (2002) Linear and nonlinear programming to optimize the nutrient density of a population's diet: an example based on diets of preschool children in rural Malawi. Am J Clin Nutr **75**, 245-253.

25. Quinio C, Biltoft-Jensen A, De Henauw S et al. (2007) Comparison of different nutrient profiling schemes to a new reference method using dietary surveys. Eur J Nutr **46 (suppl 2)**, 37-46.

26. Azais-Braesco V, Goffi C & Labouze E (2006) Nutrient profiling: comparison and critical analysis of existing systems. Public Health Nutr **9**, 613-622.

27. Larsson I, Lissner L & Wilhelmsen L (1999) The 'Green Keyhole' revisited: nutritional knowledge may influence food selection. Eur J Clin Nutr **53**, 776-780.

28. Proposition de loi (2010) Proposition de loi "visant à instaurer un label PNNS pour les produits alimentaires permettant d'informer les consommateurs et d'encadrer la publicité sur les écrans enfants, déposée par Mme Valérie Boyer et d'autres députés devant l'Assemblée Nationale. n°2474.

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Table1. Number of foods from each food group in each SAIN,LIM class and average contribution of each food group to total weight among observed and optimised diets.

	Number of foods in each SAIN,LIM Class				Contribution to total diet weight, %			
	Class 1	Class 2	Class 3	Class 4	Observed		Optimised	
					Mean	SE	Mean	SE
Fruits & vegetable[1]	87	11	7	1	23.1	11.4	33.6*	7.4
Unrefined starches	13	5	0	2	5.4	3.6	7.9*	3.8
Refined starches	0	6	0	5	12.6	6.6	13.7*	4.7
Milk[2] & yogurts	15	1	6	13	13.2	9.8	15.6*	7.1
Cheese	0	0	35	17	3.0	2.3	1.4*	1.1
Meats	34	1	26	40	11.9	5.5	7.9*	3.0
Fish	45	5	13	1	2.5	2.5	4.1*	1.9
Mixed dishes & salted snacks	18	11	18	46	13.9	9.2	5.5*	4.7
Added fats	9	0	18	11	2.4	1.3	1.3*	0.8
Sweets[3]	1	5	4	83	11.9	8.6	9.1*	5.1

* Mean values are significantly different from that of observed diets.

[1] The mean contribution of fruit juice to total weight was 3% and 2.5% in observed and modelled diets, respectively

[2] The mean contribution of milk to total weight was 8.1% and 8.4% in observed and modelled diets, respectively

[3] The mean contribution of soft drinks to total weight was 2.5% and 1.4% in observed and modelled diets, respectively

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Figure 1. Relative contributions of each nutrient profiling class to total diet energy (Panel A) and to total diet weight (Panel B) among observed and optimized diets.