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SUPPLEMENT

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Comparison of different nutrient profiling schemes to a new reference method using dietary surveys

Abstract A new EU regulation on nutrition and health claims made on foods has entered into force in January 2007. The regulation provides for the use of nutrient profiles to determine which foods may bear claims but does not specify what the profiles should be or how they should be developed. Several nutrient profiling schemes have already been established. Therefore, it is necessary to develop approaches to test if the existing profiling schemes could fulfil the new regulation needs. The aim of the present study is to investigate how reference "indicator foods" derived from national dietary surveys in five different countries, are classified according to three existing nutrient profiling schemes: The UK Food Standards Agency (FSA) model, The Dutch Tripartite classification model and the US FDA model used for regulating health claims. "Indicator foods" that have been shown to be positively or negatively associated with healthy diets in adults in five EU countries were classified according to each of the three profiling schemes. The performance and effectiveness of each profiling scheme in correctly classifying the "indicator foods" were assessed using sensitivity and specificity ratios. The sensitivity and the specificity ratios of the three profiling schemes tested were relatively good. There were only small differences of performance between the three systems. A significant negative correlation between sensitivity and specificity was observed. The level of concordance between the classification of the "indicator foods" that have been selected because of being positively or negatively associated with a healthy diet and the classification by each of the three profiling methods tested was quite good. However, further improvement of the "indicator foods" approach is needed if it is to serve as a "gold standard".

Key words nutrition and health claims – nutrient profiling schemes – evaluation – sensitivity – specificity

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Introduction

Nutrient profiling schemes can be defined as the categorisation of foods for specific purposes based on the assessment of their nutrient composition according to scientific and pragmatic principles. Nutrient profiles of foods are produced by a set of rules and formulas applied to food composition data (the nutrient profiling scheme or model).

Nutrient profiles of foods will be used in the context of the new European regulation on nutrition and health claims to differentiate between foods permitted to bear health and nutrition claims and foods not permitted to bear such claims. Some schemes or models already exist for different applications:

- To help consumers to make reasoned food choices;
- To identify products eligible for health claims;
- For decision making in advertising/marketing programmes directed to children;To evaluate the nutritional quality of food products.

Three different profiling schemes have been selected in this study to be compared to a reference validation method based on dietary surveys presented in a previous article [1].

The WXY model has been developed for the Food Standards Agency (FSA) since 2004 to regulate broadcast advertising of foods for children in UK. It is based on the calculation of scores using the same set of nutrients and mathematical formulas for all food categories [2]. The aim of the Dutch Tripartite model [3] is to help consumers to compare the nutritional quality of foods and make a healthy food choice within a specific food category. In this scheme, the criteria (nutrients, thresholds) used to characterize foods differ between food categories. The FDA nutrient profiling model [4] is intended to identify eligible products for health claims. One of the specific features of this model is the use of the nutrient quantity per serving and not per 100 g.

Different methods are already established to validate the nutrient profiling models for foods. A method based on experts judgement was used by the Food Standards Agency (FSA) in which nutritionists were asked to classify foods according to their more or less positive contribution to the diet and to compare the results with the classification of the same foods by the FSA model. This approach is practical and easy to describe and interpret but it relies on expert judgment only and not on objective criteria.

Another method is based on the definition of a "healthy eating" reference population and on the identification of indicator foods associated with this "healthy diet". This has been performed with the data available from National Dietary Surveys in five different countries [1]. The classification of the indicator foods thus identified as either positively or negatively associated with a "healthy diet" is compared with the classification according to the three nutrient profiling schemes.

The aim of the present study is to investigate how "indicator foods" derived from national dietary surveys in five different countries, are characterized according to three existing profiling schemes: The UK FSA WXY model, The Dutch Tripartite classification model and the US FDA requirements for health claims.

Material and methods

The lists of indicator foods

In order to submit the indicator foods found by the reference method using dietary surveys [1] to the three nutrient profiling systems to be tested, five countries created a list of the indicator foods from their national dietary survey which contained the nutritional composition of each indicator food. Each country used its own national food composition database; these tables were completed, if necessary, for instance for the fruits and vegetables content which is needed for the application of the FSA nutrient profiling model.

The method based on dietary surveys used the Wilcoxon Mann Whitney test with a *P*-value of 0.001 to characterise the association between the intake of a food and eating a healthy diet: in Belgium there were 42 indicator foods positively associated to a healthy diet and 25 indicator foods negatively associated to a healthy diet. The numbers are 81 and 29 for Denmark, 30 and 19 for France, 46 and 12 for Ireland and 18 and 14 for Italy, respectively.

The characterisation of the three profiling schemes tested

The three profiling schemes tested were chosen because of the differences in their methodology: a per category model and an across the board model, 100 g basis versus per serving basis, threshold versus scoring model were used.

WXY model, FSA, 2005

The WXY model is a nutrient profiling model developed by the Food Standards Agency (FSA) since 2004 to support the work of the independent UK communications regulator, Ofcom, on the regulation of

Table 1 FSA WXY scoring method (per 100 g)

	Points										
	0	1	2	3	4	5	6	7	8	9	10
Negative nutrients											
Energy (kJ)	≤335	>335	>670	>1005	>1,340	>1,675	>2,010	>2,345	>2,680	>3,015	>3,350
SFA (g)	≤1	>1	>2	>3	>4	>5	>6	>7	>8	>9	>10
Total sugars (g)	≤4.5	>4.5	>9	>13.5	>18	>22.5	>27	>31	>36	>40	>45
Sodium (mg)	≤90	>90	>180	>270	>360	>450	>540	>630	>720	>810	>900
Positive nutrients											
Protein (g)	≤1.6	>1.6	>3.2	>4.8	>6.4	>8					
Fibre (g)	≤ 0.7	>0.7	>1.4	>2.1	>2.8	>3.5					
% of fruits and vegetables	≤40	>40	>60	–	–	>80					

broadcast advertising of foods to children in the UK. The final model was delivered on 6 December 2005 to Ofcom after two public consultations; it is both a scoring system and a "across the board" model [2].

Both beneficial and non-beneficial nutrients or ingredients (evaluated as public health priorities by an expert group) are taken into account: energy, saturated fatty acids (SFA), sugars, fruits and vegetables and nuts, sodium, fibre and protein. These items are assessed on a per 100 g basis to avoid unnecessary complexity and manipulation of recommended portion sizes. A unique score is calculated for each product: it is the sum of points from positive nutrients subtracted from the sum of points from negative nutrients. One point for each nutrient corresponds to 3.75% of the UK Guideline Daily Amount of Dietary Reference Values published by HMSO (Her Majesty's Stationery Office), COMA and SACN (Scientific Advisory Committee on Nutrition). A food is classified as "less healthy" when it scores 4 points or more, as "intermediate" when it scores 1, 2 or 3 points and as "healthier choice" when it scores zero or less. A drink is classified as "less healthy" when it scores 1 point or more and as "healthier choice" when it scores zero or less. Table 1 summarises thresholds and calculation formulas.

The Dutch Tripartite classification model for foods, 2005

In 1993 the Voedingscentrum agency proposed a model for nutrient profiling in order to aid consumers in comparing nutritional quality of foods and to make reasoned food choices inside a food category. This scheme was updated in 2005 [3]. The goal is to promote healthy dietary patterns and discourage the consumption of "unhealthy" products.

Nutritional criteria are taken into account according to intrinsic characteristics of each food group and the nutrition policy. Food groups have been defined as following: the basic food groups, which are products that are important in the typical Dutch diet, have a high nutrient density and for which daily intakes are recommended. A tripartite classification is defined for these food groups. The reference basis for all food groups is 100 g. Table 2 summarises the thresholds for each food group.

US requirement for health claim, FDA, 2002

In 2002, the Food and Drug Administration (FDA) developed the US requirements for health claims, i.e. criteria that a food must fulfil to be eligible for bearing health claims [4]. Disqualifying nutrients, total fat, saturated fat, cholesterol and sodium, and qualifying nutrients, vitamin A, vitamin C, iron, calcium, protein and fibre, are considered in this across the board model. The thresholds are based on nutritional recommendations calculated for a 2,000 kcal diet. The levels for disqualifying nutrients correspond to 20% of the daily-recommended value and the levels for qualifying nutrients correspond to 10% of the Reference Daily Intake or the Daily Reference Value. The reference basis is the "reference amount customarily consumed", per label serving size [5]. Only for foods with reference amounts customarily consumed of 20 g or less or two tablespoons or less, the reference basis is per 50 g. To be eligible, a food has to satisfy the four levels for the disqualifying nutrients and at least one of the levels for qualifying nutrients by nature. Table 3 summarises the thresholds for each nutrient.

All indicators foods are classified or scored applying the method typical for each profiling scheme. The results are new classifications of these indicator foods according to each profiling scheme: for instance "healthier choice", "intermediate" or "high in saturated fatty acids, salt or sugar" for the FSA scoring system; "preferable", "middle course" or "exceptional (use)" for the Dutch tripartite model; "ok" or "not ok" for the FDA Health claim profiling scheme. The number of indicator foods classified according to the three profiling schemes studied may be slightly lower than the initial number of indicator

Table 2 Thresholds of the Dutch Tripartite model

Product group	Thresholds		
	Preferable	Middle course	Exceptional
Potatoes, rice, pasta, pulses	Fibre: min 3/100 g Saturated fat: max 1/100 g	Fibre: 2–3/100 g Saturated fat: max 1/100 g	Fibre: less than 2/100 g
Bread, bread substitutes, breakfast cereals	Fibre: min 6/100 g Saturated fat: max 1/100 g	Fibre: 5–6/100 g or min 6/100 g Saturated fat: min 1/100 g	Fibre: less than 5/100 g
Vegetables, fruit and fruit juices	Vitamin C: min 1 mg/100 g Folate: min 1 mg/100 g Fibre: min 1/100 g Saturated fat: max 1/100 g Sugars: not added	Vitamin C: min 1 mg/100 g Folate: min 1 mg/100 g	Vitamin C: not present
Milk and milk products	Saturated fat: max 0.5/100 g Sugars: max 6/100 g	Saturated fat: 0.6–1/100 g or max 0.5/100 g Sugars: more than 6/100 g	Saturated fat: more than 1/100 g or 0.6–1/100 g Sugars: more than 6/100 g
Cheese	Saturated fat: max 12/100 g Energy: max 300 kcal/100 g	Saturated fat: 13–18/100g or max 12/100 g Energy: more than 300 kcal/100 g	Saturated fat: more than 18/100 g
Meat, prepared meat products, chicken, eggs	Saturated fat: max 4/100 g Energy: max 200 kcal/100 g	Saturated fat: 4–5/100 g or max 4/100g Energy: more than 200 kcal/100 g	Saturated fat: more than 5/100g
Fish	Saturated fat: more than 4/100 g	Saturated fat: 4–5/100 g	Saturated fat: more than 5/100 g
Spread and cooking fats	Saturated fat: max 16/100 g	Saturated fat: 17–24/100 g	Saturated fat: more than 24/100 g
Product groups	"low" in SFA (g)	"high" in SFA (g)	"high" in fibre (g)
Snacks, spicy filling	Max 4/100	>5/100	
Sauces	Max 2/100	>4/100	
Cake, pastry, nuts, savoury snacks	Max 6/100	>6/100	≥2/100
Sweets, sweet filling	Max 3/100	>4/100	≥1/100
Cream	Max 12/100	>18/100	
Evaporated milk	Max 1/100	>3/100	

Table 3 Thresholds of the FDA profiling scheme

Disqualifying nutrients	**Maximum amount (per serving)**
Total fat	13 g
Saturated fatty acids	4 g
Cholesterol	60 mg
Sodium	480 mg
Qualifying nutrients	**Minimum amount for at least one out of the following six nutrients by nature**
Vitamin A	150 µg
Vitamin C	6 mg
Calcium	100 mg
Iron	1.8 mg
Fibre	5 g
Protein	2.5 g

foods because of difficulties in profiling some foods. It is especially the case for the Dutch tripartite model because of the difficulty to classify the indicator foods into food groups.

Statistical methods

After the classification according to the three profiling systems, quantitative criteria of agreement between the validation reference diet and the different profiling schemes are estimated, namely sensitivity and specificity of the three classification systems compared to the reference method. Two sensitivity ratios and two specificity ratios for each profiling model tested and each category of indicator foods (positively associated to healthy eating and negatively associated to healthy eating) are calculated and given as percentages.

The sensitivity of the profiling method #I for the indicator foods "positively correlated to healthy diets" is SeP_I:

$$SeP_I = a_I / A$$

With: P = positive; A = number of foods identified as "positively correlated to a healthy diet" according to the reference method; a_I = number of foods among the A indicator foods considered as "positively correlated to a healthy diet", classified by the nutritional profiling scheme #I as "healthy".

The specificity of the profiling method #I for the indicator foods "positively correlated to a healthy diet" is SpP_I :

$$SpP_I = b_I / B$$

With: P = positive; B = number of foods identified as not "positively correlated to a healthy diet" according to the reference method; b_I = number of foods among the B indicator foods not considered as "positively correlated to a healthy diet" not classified by the nutritional profiling scheme #I as "healthy".

The sensitivity of the profiling method #I for the indicator foods "inversely correlated to healthy diets" is SeN_I:

$$SeN_I = c_I / C$$

With: N = negative; C = number of foods identified as "inversely correlated to a healthy diet" according to the reference method; c_I = number of foods among the C indicator foods identified as "inversely correlated to a healthy diet", classified by the nutritional profiling scheme #I as "unhealthy".

The specificity of the profiling method #I for the indicator foods "inversely correlated to healthy diets" is SpN_I :

$$SpN_I = d_I / D$$

With: N = negative; D = number of foods not identified as "inversely correlated to a healthy diet" according to the reference method; d_I = number of foods among the D indicator foods not identified as "inversely associated to a healthy diet", not classified by the nutritional profiling scheme #I as "unhealthy".

The sensitivity ratio aims to check if the foods classified as "healthy" (resp. "unhealthy") by the profiling method also belong to the indicator foods "positively correlated to a healthy diet" (resp. "inversely associated to a healthy diet").

The specificity ratio aims to check if the foods not classified as "healthy" (resp. "unhealthy") by the profiling model also belong to the foods not considered as "positively correlated to a healthy diet" (resp. "inversely associated to a healthy diet").

An ideal nutrient profiling scheme will result, for both indicator foods correlated positively and negatively to the healthy diet, in a sensitivity ratio and a specificity ratio equal to one. In the case of the use of a nutrient profiling scheme for the regulation of the access to health and nutritional claims, a high sensitivity ratio for positive indicator foods is necessary to give access to health claims to all the foods, which really contribute to a healthy diet. A high specificity for these positive indicator foods is necessary if one wants to prevent foods that are not positively associated to healthy diets from accessing to health and nutritional claims.

Results

Results given for *P* = 0.001

The Wilcoxon Mann–Whitney test has been applied with three thresholds of statistical significance corresponding to the *P*-values of 0.05, 0.01 and 0.001. Because there are enough indicator foods with *P* = 0.001 and because the number of statistical tests is high, we present only the results with *P* = 0.001. The number of foods classified by each model is sometimes different because of difficulties in the interpretation of the criteria of each model. For example, some foods could not be classified because they did not fit into the food groups of the tripartite model or did not allow determining the reference amount customarily consumed in the FDA model.

Results per country for each model

Classification of the indicator foods according to the FSA WXY model (Table 4)

All the results using a *P*-value of 0.001 are better than those received with *P* = 0.05 or *P* = 0.01 even if not really different. By applying a *P*-value of 0.001, a score of 100% of foods classified in the same way by the reference method and by the FSA model for foods preferably consumed in a healthy diet for Italy is achieved. This score is slightly lower for France (87%), Ireland (71%), Belgium (68%) and Denmark (66%). Inversely, most of the indicator foods less consumed in a healthy diet in the five countries are classified by the FSA model as "high in saturated fat, salt or sugar".

Classification of the indicator foods according to the Dutch Tripartite model (Table 5)

All the results are better with a *P*-value of 0.001 in comparison with 0.05 or 0.01. A large majority of the indicator foods preferably consumed in a healthy diet in the five countries are classified by the Dutch Tripartite Model as "preferable or low in Sat Fat (SFA)". Inversely, most of the indicator foods sparingly consumed in a "healthy diet" are classified as "Exceptional or high in SFA".

Classification of the indicator foods according to the FDA requirement for health claim model (Table 6)

Nearly all the results are better with a *P*-value of 0.001 in comparison to 0.05 or 0.01. The results are better for the indicator foods less consumed in a

Table 4 Classification of the indicator foods according to the FSA WXY model, $P = 0.001$ (number and %)

	Indicator foods more consumed in a "healthy diet" Belgium	Indicator foods more consumed in a "healthy diet" Denmark	Indicator foods more consumed in a "healthy diet" France	Indicator foods more consumed in a "healthy diet" Ireland	Indicator foods more consumed in a "healthy diet" Italy	Indicator foods less consumed in a "healthy diet" Belgium	Indicator foods less consumed in a "healthy diet" Denmark	Indicator foods less consumed in a "healthy diet" France	Indicator foods less consumed in a "healthy diet" Ireland	Indicator foods less consumed in a "healthy diet" Italy
Healthier choice	28 (68%)	49 (66%)	26 (87%)	25 (71%)	18 (100%)	3 (14%)	4 (14%)	3 (16%)	3 (27%)	2 (14%)
Intermediate	3 (8%)	8 (11%)	1 (3%)	2 (6%)	0 (0%)	2 (9%)	0 (0%)	2 (10%)	0 (0%)	3 (22%)
High in saturated fat, salt or sugar	10 (24%)	17 (23%)	3 (10%)	8 (23%)	0 (0%)	17 (77%)	25 (86%)	14 (74%)	8 (73%)	9 (64%)
Total	41 (100%)	74 (100%)	30 (100%)	35 (100%)	18 (100%)	22 (100%)	29 (100%)	19 (100%)	11 (100%)	14 (100%)

Table 5 Classification of the indicator foods according to the Dutch Tripartite model, $P = 0.001$ (number and %)

	Indicator foods more consumed in a "healthy diet" Belgium	Indicator foods more consumed in a "healthy diet" Denmark	Indicator foods more consumed in a "healthy diet" France	Indicator foods more consumed in a "healthy diet" Ireland	Indicator foods more consumed in a "healthy diet" Italy	Indicator foods less -consumed in a "healthy diet" Belgium	Indicator foods less consumed in a "healthy diet" Denmark	Indicator foods less consumed in a "healthy diet" France	Indicator foods less-consumed in a "healthy diet" Ireland	Indicator foods less consumed in a "healthy diet" Italy
Preferable or low in Sat Fat (SFA)	26 (70%)	43 (65%)	20 (69%)	22 (67%)	14 (78%)	3 (14%)	2 (8%)	2 (11%)	1 (9%)	3 (25%)
Middle course	2 (5%)	13 (20%)	6 (21%)	7 (21%)	1 (4%)	0 (0%)	3 (11%)	5 (26%)	2 (18%)	2 (17%)
Exceptional or high in SFA	9 (25%)	10 (15%)	3 (10%)	4 (12%)	3 (16%)	18 (86%)	21 (81%)	12 (63%)	6 (67%)	7 (58%)
Total	37 (100%)	66 (100%)	29 (100%)	33 (100%)	18 (100%)	21 (100%)	26 (100%)	19 (100%)	9 (100%)	12 (100%)

Table 6 Classification of the indicator foods according to the FDA requirement for foods carrying a health claim model, $P = 0.001$

	Indicator foods more consumed in a "healthy diet" Belgium	Indicator foods more consumed in a "healthy diet" Denmark	Indicator foods more consumed in a "healthy diet" France	Indicator foods more consumed in a "healthy diet" Ireland	Indicator foods more consumed in a "healthy diet" Italy	Indicator foods less consumed in a "healthy diet" Belgium	Indicator foods less consumed in a "healthy diet" Denmark	Indicator foods less consumed in a "healthy diet" France	Indicator foods less consumed in a "healthy diet" Ireland	Indicator foods less consumed in a "healthy diet" Italy
Ok	31 (76%)	41 (56%)	24 (80%)	25 (71%)	14 (78%)	7 (32%)	3 (10%)	1 (5%)	1 (11%)	4 (29%)
Not ok	10 (24%)	32 (44%)	6 (20%)	10 (29%)	4 (22%)	15 (68%)	25 (90%)	18 (95%)	8 (89%)	10 (71%)
Total	41 (100%)	73 (100%)	30 (100%)	35 (100%)	18 (100%)	22 (100%)	28 (100%)	19 (100%)	9 (100%)	14 (100%)

Table 7 Sensitivity ratios, $P = 0.001$

	Indicator foods more consumed in a "healthy diet" (%)	Indicator foods less consumed in a "healthy diet" (%)
FSA WXY versus intake Belgium	68.3	77.2
FSA WXY versus intake Denmark	66.2	86.2
FSA WXY versus intake France	86.7	73.6
FSA WXY versus intake Ireland	71.4	54.5
FSA WXY versus intake Italy	66.6	64.3
FSA WXY versus Intakes	73.7	76.8
Tripartite versus intake Belgium	70.2	85.7
Tripartite versus intake Denmark	65.3	80.7
Tripartite versus intake France	68.9	63.1
Tripartite versus intake Ireland	66.7	66.7
Tripartite versus intake Italy	77.8	58.3
Tripartite versus Intakes	68.3	73.6
FDA requirement versus intake Belgium	75.6	68.2
FDA requirement versus intake Denmark	56.1	89.6
FDA requirement versus intake France	80	94.7
FDA requirement versus intake Ireland	71.4	88.9
FDA requirement versus intake Italy	77.8	71.4
FDA requirement WXY versus intakes	68.5	82.6

"healthy diet" with this model because in this model there is not an intermediate category. For instance, 95% of the foods sparingly consumed in a healthy diet are classified as "not ok" in France and 90% in Denmark. If there was an intermediate category, the percentages of indicator foods less consumed in a "healthy diet" classified in the "not ok" category would have been less important and closer to the other models' results.

Broadly, the sensitivity ratios calculated for the different countries and profiling schemes are not very different (Table 7).

For all countries together, there is no statistically significant difference in the sensitivity ratios for each tested model for foods preferably consumed in a healthy diet.

However, for all countries together, there is a statistically significant difference for the percentage of well-classified indicator foods sparingly consumed in a "healthy diet" between the FDA model and the FSA model (Chi-square test, $P < 0.0001$) and a nearly significant difference between the FSA model and the Dutch tripartite model ($P < 0.10$). For Denmark, the FSA model has a higher sensitivity ratio than the FDA model (Chi-square test, $P < 0.001$) for foods preferably consumed in a healthy diet.

The order of magnitude of the specificity ratios is comparable to the sensitivity ratios (Table 8).

When combining the sensitivity and specificity ratios for 18 "3 profiling model × 3 country × 2 type of indicator foods" cases graphically, an inverse relationship between the two ratios is apparent: the higher the sensitivity, the lower is the specificity (Fig. 1). The data from three countries (Denmark, France, Italy) were used for this presentation because the calculation of sensitivity and specificity was possible in the same way.

This result illustrates the difficulty of building a profiling scheme. The more restrictive it is in the definition of the "healthier" foods, the higher is the risk not to classify foods contributing positively to the "healthy diet" as "healthier", but the lower is the risk to classify foods not contributing positively to the "healthy diet" as "healthier".

Table 8 Specificity ratios

	Model WXY, FSA		Model Tripartite		Model requirement for health claim, FDA	
	Indicator foods more consumed in a "healthy diet" (%)	Indicator foods less consumed in a "healthy diet" (%)	Indicator foods more consumed in a "healthy diet" (%)	Indicator foods less consumed in a "healthy diet" (%)	Indicator foods more consumed in a "healthy diet" (%)	Indicator foods less consumed in a "healthy diet" (%)
Belgium	52	65	54	65	46	60
Denmark	79	59	72	67	75	40
France	65	66	56	66	55	51
Italy	45	70	37	79	44	59

Discussion

Comparison between models

The FSA model WXY

In this model, all foods are classified according to the same criteria, it is an "across the board" model. These criteria do not allow to classify all types of foods adequately. For instance, several meats are identified as indicator foods negatively associated to a healthy diet according to the reference method. However, the same meats, except very salty or fatty meats, are classified in the healthier category by the FSA model. This model, therefore, tends to classify more meats as "healthier" than the reference method, maybe because the protein content of foods is considered positively in the score of the FSA model.

Similar observations can be made for other products. Light products (indicator foods positively associated to a healthy diet), like light cheeses, are disqualified by the FSA model because of the strictly negative saturated fatty acid criterion, while low fat yoghurts or similar products are classified in the intermediate category of the model due to the simple sugars (lactose) criterion.

The Tripartite classification model for foods

This model is the only tested model using food categories. It is sometimes difficult to place a food present in a dietary survey in one of the food groups of the model: the products based on meat and vegetables could be considered as prepared meat products but also as vegetables depending on the proportions of meat and vegetables in the product.

Moreover, the last version of this model does not allow to classify drinks according to nutritional criteria but directly gives the drinks classification. Water, coffee, tea and non soft and light drinks are classified in the *preferable* category whereas alcoholic drinks and soft but not light drinks are classified in the *exceptional* category. Drinks are not classified in the same way according to the FSA model or the FDA model.

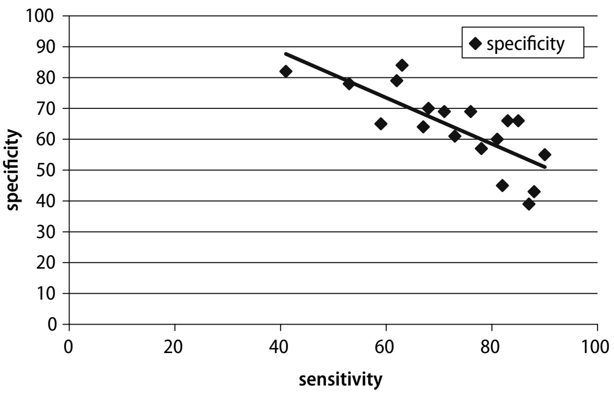

Fig. 1 Relationship between sensitivity and specificity ratios. Based on three countries (Denmark, France, Italy), 3 profiling models and 2 types of indicator foods = 18 points

The FDA model

This model also classifies foods according to the same criteria. However, it allows taking into account differences between food categories by defining thresholds for serving portions. The serving portions values do not correspond to the usually consumed portions in the different European countries. For instance, the meat portion is 55 g, which is low; the drinks portion is 240 ml, which seems high when applied to coffee. This influences the classification of some foods in the "ok" or "not ok" categories.

A food is classified in the "ok" category if it fulfils the four negative criteria and at least one of the positive criteria: this can discriminate some foods, like water. Water, essential for life, would be considered as "not ok" by the FDA model because it fulfils none of the positive criteria. The criterion for fibre in a food with a serving portion of 50 g corresponds to the maximal attainable score in the FSA model, so it can be considered as particularly restrictive. This is the reason why vegetables with an intermediate fibre content are classified as "not ok" by the FDA model.

The purpose of this model is to discriminate "negative" foods: consequently, the sensitivity ratio is higher for "negative" foods (82%) than for "positive" foods (68%). Olive oil for example is considered as "not ok" by the FDA model whereas it is classified as positively associated to a healthy diet with the reference method. Thus, foods classified in the "not ok" category are evaluated again by an expert group so as to reconsider their classification if necessary by the FDA.

Comparison between countries

A result common to all countries is that the number of foods positively associated to a healthy diet is greater than the number of foods negatively associated to a healthy diet, which is coherent with the idea that a more diversified diet is more likely to be a healthy diet.

With regard to the observed differences, it should be noted that foods were entered in different numbers and levels by the different countries in this study and therefore a comparison between countries is difficult. The food composition tables used were also different; in some cases it was necessary to estimate the mean composition for some aggregated foods. However, we show that in a country of the South of Europe, like Italy, where the intake of fruit and vegetable in adults is high, some fruit and vegetables could be less consumed in a healthy diet and thus be considered as indicator foods negatively associated to the "healthy diet". This situation doesn't occur in the countries of northern Europe. The chosen approach is apparently less sensitive for countries like Italy.

There are more and more composite foods on the market like ready to eat dishes. The methodology used by dietary survey managers to codify these foods may be different across countries. Food classification and codification needs to be harmonized across countries in order to be able to manage this kind of validation study with a minimum of unanswered methodological questions.

In a next step of this validation study, it would be useful to include the number of countries in which an indicator food has been identified as such into the model. The higher this number is, the more confident we can be in the association (positive or negative) of this food to "healthy eating".

Sensitivity and specificity ratios

Defining the indicator foods from intake data seems to favour across the board models

The sensitivity and specificity ratios calculated for the three profiling schemes tested are of the same order of magnitude. However, the profiling schemes based on "across the board" approaches like the FSA and FDA profiling schemes have significantly higher sensitivity ratios for the indicator foods less consumed in a "healthy diet" (Table 7).

This result may be explained by the fact that the validation approach by dietary surveys is close to the Food Based Dietary Guidelines approach in that the Eurodiet goals serve as the criteria for the definition of a "healthy eating" index. The rationale behind food based dietary guidelines and formulated dietary goals is to recommend a change of the consumer choices between food groups, for instance in increasing fruit and vegetables intake. The indicator foods list in our validation study has been built on the same principles. For instance, there are a lot of fruit and vegetables among the foods contributing positively to the "healthy diet" and no or almost no fruit and vegetables among the foods contributing negatively to the "healthy diet". "Across the board" profiling schemes are based on the same rationale. A profiling scheme like the FSA WXY, which explicitly encourages fruit and vegetable consumption will be more in agreement with this validation model than profiling schemes, which apply different criteria to different food groups and which may encourage consumers to change their choices within food groups. For instance, the Dutch tripartite model will classify the fruit and vegetables that contain a minimum level of fibre (>1/100 g) as "preferable" and may thus exclude from this category some fruit or vegetables like cucumber, watermelon, raw melon, grapes, black radish. This may explain why some sensitivity ratios are higher for the FSA and the FDA profiling schemes. However, this explanation is valid only for the three profiling schemes studied and the results may be different for other schemes. It is possible to improve the coherence between profiling models built on food based dietary guidelines and a profiling method by food categories by refining the choice of the threshold levels. For instance, if the minimum fibre content of fruit and vegetables in the Tripartite model would have been lower (e.g. >0.5/100 g), all the fresh fruit and vegetables would have been classified as "preferable". As yet no general conclusions can be drawn from our study.

Choice of the validity indicators: sensitivity or specificity

High sensitivity for indicator foods less consumed in a healthy diet is important to prevent health claims on foods not classified as "healthy" whereas high specificity is important to avoid that "healthy" foods can not bear health claims. Both validity indicators are thus important. In this study, both indicators foods positively and negatively correlated to the healthy diet may be used in the validation study. In the case of a profiling scheme intended to regulate access to health and nutritional claims, one may pay more attention to the indicator foods negatively associated to the healthy diet, because the aim of the nutrient profile is to prevent or exclude such foods from bearing claims.

Determination of the acceptable proportion of misclassified foods

In the context of this study we can determine the proportion of foods that are classified differently by the method based on dietary surveys and by the three nutrient profiling schemes tested (foods named misclassified foods). However, as mentioned earlier, the use of the reference method as a final validation tool of nutrient profiling schemes may require some modifications and further refinement.

The reasons for the presence of misclassified foods

Several facts can explain the occurrence of misclassified foods in addition to the reasons linked to the properties of each model or to peculiarities of dietary habits (e.g. habitual consumption of bread together with marmalade).

First of all, data are not precise enough for some foods in the composition tables. Such foods will easily be misclassified by the profiling schemes.

The lack of precision in the categorization of the surveyed foods can increase the number of misclassified foods. Thus, the composition of pork meat is different between the roast, the chop or the loin of pork and changes with preparation (addition of fats or salt). Categorizing all these foods under the generic denomination "pork meat" does not permit a correct classification.

The population considered to consume a healthy diet did not fulfil all of the Eurodiet criteria, so it is the diet of a less than perfect eating population which is used as a reference to define the list of indicator foods that should serve as a gold standard—this will give some misclassification.

Last but not least, the Eurodiet criteria used in the method based on dietary surveys are global for fruits and vegetables whereas the profiling schemes use several criteria. This contributes to the differences between the classification of foods according to the method based on dietary surveys and the profiling schemes.

How to diminish/decrease the proportion of misclassified foods?

In addition to improving the food composition tables or the denomination of the foods, it could be possible to be more specific in the determination of the indicator foods by choosing the lowest possible Wilcoxon Mann–Withney test *P*-value. Indeed, the lower it is, the easier it is to select only the significant indicator foods and to decrease the risk of misclassification. On the other hand, the lower the *P*-value, the lower is the number of indicator foods, for a given sample size of the dietary survey used. Thus, it is necessary to increase as much as possible the sample size of the dietary surveys used for the identification of the indicator foods.

Conclusion

The approach presented in this paper to evaluate the performance of nutrient profiling schemes is complementary to expert judgement models. However, this evaluation tool using dietary surveys from different countries has to be discussed and improved to be able to test more accurately profiling models.

Linking profiling models to nutrient intake and nutritional status data is advisable to introduce more objective criteria into the scientific discussion on nutrient profiling schemes.

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