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Analytical approaches to food-based dietary guidelines in the European setting

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Abstract

Objective: To show the effects of statistical approaches of data analysis to be used in the development of Food-Based Dietary Guidelines (FBDG).
Setting: Databases from dietary surveys in 6 European countries.
Results: Quantile analysis based on iron intake among adult women resulted in differences among European countries regarding (macro) nutrient intake and consumption of food groups. However, in all countries women in the highest quartile had a higher intake of energy and dietary fibre and a higher intake of most food groups. In developing FBDG adjustment of energy intake is recommended. Discriminant analyses showed that among Dutch women potatoes, red meat, sausages, offal, savoury snacks, eggs and total vegetables were found to be the most predictive for differences in iron intake. Relatively high correlations were observed for iron and dietary fibre and iron and (some) B-vitamins. Examples from cluster and factor analysis showed that this type of analysis considers the complexity of the dietary pattern and could also be a helpful instrument in the development of FBDG.
Conclusions: The use of a nutrient distribution can be used as a minimum approach in developing FBDG. More advanced methods can also be used in addition to set priorities for FBDG and to analyse complete dietary patterns.

Keywords
Food-based dietary guidelines
Quantiles
Discriminant analysis
Correlation
Cluster analysis
Factor analysis
Food consumption survey

Introduction

As stated in a recent FAO/WHO report on the preparation and use of Food-Based Dietary Guidelines (FBDG) these guidelines should be developed in a cultural context and should be practical, dynamic, flexible and based on the existing situation[1]. As dietary patterns characterized by the consumption of food products are closer to behaviours that can be modified than nutrient intakes, studies on dietary patterns might be constructive for the design of nutrition-intervention programs. In a dietary pattern several relevant aspects can be identified, with the combinations or associations and discrimination being the basic concepts. In the development of FBDG the most important step is the identification of foods that best discriminate opposite patterns of nutrient intake. The purpose of the present paper was to give brief examples as illustrations of possible statistical techniques that could be helpful in setting priorities in this development, using simple as well as more advanced techniques. Quantiles (a simple technique) and discriminant analyses (a more advanced technique) were used to separate the population into groups on the basis of their nutrient intakes to create contrasts. Associations among food consumption was studied with correlations (simple) and cluster and factor analyses (more advanced techniques).

Methods

Databases from six European dietary surveys were used to investigate the effects of selected statistical techniques including analysis by quantiles, discriminant analysis, correlations and cluster and factor analysis. Of the six databases, five were national[2–5,7] and one was regional[6]. The methodologies used to assess dietary intake varied from retrospective methods (24 h recalls and dietary history) to prospective methods (record method) (see also Tables 1 and 2).

Results and discussion

Analysis by quantiles

By using the prevailing nutrient intake distribution as starting point the population can be separated into groups (tertiles, quartiles or quintiles) on the basis of a nutrient selected to be of special interest. Thereafter, these groups can be characterized with descriptive statistics. This procedure has also been used in the publications of

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Table 1 Mean daily nutrient intake of adult women with low and high iron intake (quartiles) in six European countries

	Finland (3-d record)*		Italy (7-d weighed record)		Ireland (7-d dietary history)		The Netherlands (2-d record)		Spain (2 24-h recalls and FFQ)		United Kingdom (7-d weighed record)	
	Low (n = 248) <10.4 mg/d	High (n = 248) >15.6 mg/d	Low (n = 247) <8.9 mg/d	High (n = 248) >12.8 mg/d	Low (n = 101) <8.1 mg/d	High (n = 101) >12.4 mg/d	Low (n = 505) <8.9 mg/d	High (n = 505) >13.1 mg/d	Low (n = 222) <10.7 mg/d	High (n = 222) >11,9 mg/d	Low (n = 277) <8.0 mg/d	High (n = 277) >12.2 mg/d
Energy (MJ)	5.7	9.9	6.5	9.4	6.7	10.2	6.4	10.1	6.9	8.5	5.4	8.2
Protein (%E)	16.8	16.0	16.1	17.1	14.9	14.4	16.2	15.4	20.0	20.3	15.0	15.6
Carbohydrate (%E)	47.9	50.2	48.3	46.4	47.3	46.9	44.7	43.5	41.2	40.0	43.3	43.8
Total fat (E%)	33.0	33.0	34.6	33.2	31.4	31.6	37.0	37.7	38.2	38.4	39.6	37.6
Dietary fibre (g/d)	14.3	26.6	13.4	23.4	13.9	22.4	9.9	19.2	14.1	17.1	12.7	24.4
Dietary fibre (g/MJ)	2.6	2.7	2.1	2.5	2.2	2.4	1.7	2.0	2.1	2.1	2.4	3.0
Alcohol (%E)	2.4	0.9	1	3.2	1.6	1	2.1	3.4	0.9	1.7	2.3	3.2

* Dietary methodology.

Table 2 Mean daily food intake (g/d) of adult women with low and high iron intake (quartiles) in six European countries

	Finland (3-d record)*		Italy (7-d weighed record)		Ireland (7-d dietary history)		The Netherlands (2-d record)		Spain (2 24-h recalls and FFQ)		United Kingdom (7-d weighed record)	
	Low (n = 248) <10.4 mg/d	High (n = 248) >15.6 mg/d	Low (n = 247) <8.9 mg/d	High (n = 248) >12.8 mg/d	Low (n = 101) <8.1 mg/d	High (n = 101) >12.4 mg/d	Low (n = 505) <8.9 mg/d	High (n = 505) >13.1 mg/d	Low (n = 222) <10.7 mg/d	High (n = 222) >11,9 mg/d	Low (n = 277) <8.0 mg/d	High (n = 277) >12.2 mg/d
White bread	9	16	67	109	42	67	40	34	59	83	52	36
Potatoes	75	119	28	45	131	161	78	128	58	75	91	95
Breakfast cereals	1	3	13	23	24	49	1	4	2	7	6	32
Whole milk	10	30	54	58	189	324	35	29	112	133	119	159
Cheese	32	44	36	45	4	7	27	34	15	21	11	19
Butter	8	16	4	5	5	7	2	3	3	4	6	5
Red meat	41	73	44	84	24	43	53	86	59	94	42	62
Sausages	21	31	18	26	5	7	7	17	25	30	7	7
Poultry	16	17	22	31	20	22	13	16	41	62	19	23
Offal	1	8	NA	NA	1	3	1	7	0	7	1	7
Eggs	15	29	12	15	14	21	10	17	24	30	15	22
Savoury snacks	1	1	1	3	2	8	19	31	1	4	5	5
Sweets	3	8	3	4	2	49	6	13	NA	NA	7	13
Total vegetables	130	159	162	290	86	105	103	165	160	262	86	154
Total fruit	156	224	174	253	99	195	119	160	207	374	42	112

* Dietary methodology.
NA = Not available.

Food-based Dietary Guidelines – A Staged Approach'[8]. In this paper, an example is given for the intake of iron. Several dietary studies have indicated that the iron intake among women is lower than recommended and this increases the risk for anaemia. Table 1 presents the intake of selected macronutrients according to low and high iron intake among adult women in 6 European countries (lowest and highest quartile), whereas Table 2 gives information on the consumption of different food groups according to iron intake. In all countries, women in the highest quartile had a higher intake of energy and dietary fibre (in g/d as well as in g/MJ). The contribution of macronutrients to energy intake was not consistent across the countries. In general, adult women with a high iron intake had also a higher consumption of most food groups. The results indicated that women with a higher iron intake are also the larger eaters. Therefore, figures of iron intake adjusted for energy-intake may be needed for an adequate information on the dietary pattern. When the intake figures were calculated based on nutrient density (data not presented), results from Ireland and the Netherlands showed that in both countries women in the highest quartile consumed for instance significantly less white bread, butter, cheese, savoury snacks and sweets (only the Netherlands) and more breakfast cereals, red meat, poultry (only Ireland), offal, eggs (only Ireland), vegetables and fruit than those in the lowest quartile.

When using nutrient densities one should be aware of the phenomenon that a very low energy intake may be accompanied by very high nutrient densities. This has implications in the interpretation and it is emphasized to evaluate the very low energy intake data separately, also because of possible under- reporting problems involved.

The results shown in Tables 1 and 2 indicated, as expected, differences in dietary patterns across countries. However, the influence of red meat, offal and vegetables is visible in all countries. In comparing results between countries several other factors should be considered in the interpretation. For instance, in Finland at the time of the survey white wheat flour was fortified with iron (4 mg/100 g). This explains partly the higher intake levels in this country. Using 1997 data from a smaller sample (3-day dietary record) when iron fortification was stopped, the intake values were more in line with the results in other countries (lowest quartile: <8.3 mg/d; highest quartile 12.8 mg/d). Other factors to be considered are varying number of subjects, differences in the definition of foods and in the methodologies used for assessing food and nutrient intake that range from 24h recalls, dietary histories to food records with a varying number of days (2 to 7). In comparing data, the quality of the food composition tables, necessary to convert food consumption data into energy and nutrients, are also crucial. These latter topics will be discussed in other papers in this supplement[9,10].

Discriminant analysis

A more advanced method to study differences in intake is discriminant analysis. This method can be used to statistically distinguish between two or more a priori defined groups by determining how one or more independent variables discriminate. In the case of FBDG these groups will primarily be defined by dietary intake, whereby the starting point can be food groups or nutrients. In line with the concept of FBDG it is suggested to define the population group in the most important (combination of) nutrients and use the consumption of food groups for the discrimination. To distinguish between the defined groups, discriminating variables are selected that measure characteristics on which the groups are expected to differ. The mathematical objective of discriminant analysis is to weight and linearly combine the discrimination variables in such a way that population groups are forced to be as statistically distinct as possible. As to the analysis, the success of the discrimination can be assessed with statistical tests. The coefficients of the function can serve to identify the variables contributing most to the differentiation. To select the most useful discriminating variables a step-wise procedure is advised. This procedure begins by selecting the single best discriminating variables, then the second best, etc.

An example of the usage of discriminant analysis is given in Table 3, using data of the iron intake of adult women in the second Dutch National Food Consumption Survey in the lowest and highest quartile. Variables with standardized discriminant function coefficients greater than 0.30 (or less than −0.30) were considered substantive[11]. As a result, the food groups: potatoes, red meat, sausages, offal, savoury snacks, eggs and total vegetables were found to be the most predictive for differences in iron intake among Dutch women. Together these 7 variables explained 33% of the variance in iron intake.

In comparison with the analysis by quantiles the results showed that in the Dutch situation, despite statistically significant differences in for instance the consumption of breakfast cereals and white bread, when classifying 'new' subjects these food items will not belong to the foods that best predict the likely high or low intake of iron.

Bivariate correlations

Food sources are often the same for many nutrients, resulting in highly correlated variables. A correlation analysis gives insight into the relationship between two variables. A correlation coefficient summarizes the strength of association between two variables and is also an easy means to compare the strength of the relation between one pair of variables and a different pair. The Pearson correlation coefficient is mostly used and the assumption is made that we are dealing with linear relationships. The values range between −1.0 and +1.0, indicating that information on the direction of the association is obtained. When this correlation is squared

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Table 3 Summary of interpretative measures for stepwise two-group discriminant analysis of adult Dutch women (18–60 yr) with low ($n = 505$) and high ($n = 505$) iron intake (mg/d)

	Univariate F ratio	Standardized canonical coefficients
White bread (g/day)	4	−0.10
Potatoes (g/day)	30	0.36
Breakfast cereals (g/d)	22	0.22
Whole milk (g/d)	ns	−0.05
Cheese (g/d)	21	0.22
Butter (g/d)	8	0.17
Red meat (g/d)	62	0.49
Sausages (g/d)	63	0.40
Poultry (g/d)	11	0.16
Offal (g/d)	61	0.47
Eggs (g/d)	28	0.30
Savoury snacks (g/d)	65	0.41
Sweets (g/d)	28	0.27
Total vegetables (g/d)	109	0.36
Total fruit (g/d)	15	0.19

a measure of the strength of association is obtained. This is a measure of variance in the sense that one variable is 'explained' by the other. As a matter of course the explanation is defined in a purely statistically sense and does not imply a causal relationship. An example of the Pearson correlation coefficients for the intake of selected micronutrients and dietary fibre by the Dutch population (1992) is presented in Table 4.

The results show that positive associations were observed only. This might be due to the confounding of energy (or food intake) in the sense that a higher consumption will result in a higher intake of all nutrients. This is one of the reasons that the starting point of FBDG is based on nutrient densities. In Table 5 the correlation coefficients among nutrient densities for the selected micronutrients are presented. Again only positive correlations are observed, indicating that the confounding of energy and/or quantity of food per se is not very important in the associations among the intake of micronutrients. However, most associations appeared to be lower. Concerning iron, relatively high correlations were observed for iron and dietary fibre and iron and the B vitamins. After adjustment for energy the correlation coefficients for iron and vitamin B-1 and iron and vitamin B-6 were much lower.

Cluster analysis/factor analysis

Traditionally, the relationship between diet and health has been studied with respect to single nutrients or components of the diet in general and this might mask relevant dietary patterns among subgroups. Foods are consumed in a number of combinations, providing a range of nutrients and other dietary factors, which interact in very complex ways. Cluster analysis empirically identifies patterns by grouping individuals with similar characteristics, producing homogeneous and non-overlapping exposure categories. Cluster analysis has successfully been used to identify food patterns that characterize different population sub-groups and for identifying patterns that differentially predict disease risk[12–15]. For instance, data of the first Dutch National Food Consumption Survey (1987–1988; 2-day dietary record) showed that in comparison with the guidelines, in 4 of the 8 observed clusters the dietary quality was poor. The cluster with the poorest dietary intake (high intake of fat, cholesterol, and alcohol; low intake of dietary fibre) showed on average a high consumption of animal products (except milk), fats and oils, and a low consumption of fruit, potatoes, vegetables and sugar rich products. Furthermore, smoking, body mass index, dietary regimen on own initiative, hours of sleep, gender, age, socio-economic status and day of the week were found to discriminate among the clusters[12].

Factor analysis is another patterning methodology and aims to explore interrelationships among variables to detect underlying and unobservable factors. For instance, this method was used in a Finnish study among male smokers ($n = 17784$). Information on the dietary intake was obtained using a dietary history method. The aim of the study was to explore the structure of the diets of the participants, the conformity of their diets to dietary guidelines and associations between a prudent diet, nutrient intake and cardiovascular risk factors[16]. The dimensions of the diet of male smokers were examined by exploratory factor analysis. Of the eight factors found, type of milk, type of bread and type of fat on bread were similar to dimensions noticed in earlier Finnish dietary studies. The other five factors reflected differences in variation of meals: vegetables; sausages and eggs; fish and chicken; potato, meat and sauces; and porridge. A diet

Table 4 Pearson correlation coefficients between selected nutrients expressed in absolute amounts, in the second Dutch National Food Consumption Survey 1992 ($n = 6.218$)

	Dietary fibre	Calcium	Iron	Vit. A	Vit. B-1	Vit. B-2	Vit. B-6	Vit. C
Dietary fibre	1.00	0.39	0.72	0.32	0.66	0.43	0.70	0.37
Calcium		1.00	0.35	0.15	0.25	0.77	0.35	0.14
Iron			1.00	0.35	0.46	0.41	0.65	0.19
Vitamin A				1.00	0.10	0.26	0.17	0.05
Vitamin B-1					1.00	0.37	0.47	0.16
Vitamin B-2						1.00	0.47	0.13
Vitamin B-6							1.00	0.24
Vitamin C								1.00

Table 5 Pearson correlation coefficients between selected nutrients expressed in MJ in the second Dutch National Food Consumption Survey 1992 ($n = 6.218$)

	Dietary fibre	Calcium	Iron	Vit. A	Vit. B-1	Vit. B-2	Vit. B-6	Vit. C
Dietary fibre	1.00	0.24	0.64	0.24	0.55	0.27	0.60	0.46
Calcium		1.00	0.39	0.31	0.16	0.79	0.20	0.06
Iron			1.00	0.34	0.16	0.39	0.15	0.18
Vitamin A				1.00	0.06	0.50	0.26	0.32
Vitamin B-1					1.00	0.34	0.31	0.12
Vitamin B-2						1.00	0.36	0.17
Vitamin B-6							1.00	0.32
Vitamin C								1.00

meeting the dietary guidelines was more common among men of higher education level or higher socio-economic status. Greater urbanization also had an association with prudent diet. The relative incidence of a prudent diet was confirmed by odds ratios[16].

The examples indicate that compared to a priori segmentation multivariate methodologies such as cluster and factor analysis may provide a better insight into the complexity of several dietary patterns and could be an useful approach in the development of FBDG for a risk group.

A factor analytical approach was also used in a Finnish study to investigate which factors in the nutrient content of foods were connected with the ability of foods to improve the nutrient density of the Finnish diet, i.e. which nutrients appear simultaneously in certain foods or food groups[17]. This kind of analysis elucidates the potential of different food groups as source of certain nutrients under consideration. A sample of regularly used 143 basic foods and 244 dishes was chosen from the food database (total number of foods in the database ca. 1200). The factor analysis was performed both using the energy adjusted and weight based nutrient composition of the foods in the whole sample. The analysis was based on the correlation of nutrients (based on standardized nutrient vectors). After a principal component analysis with Varimax rotation a five-factor solution was chosen best to describe nutrient space of the foods. The factor solutions were found to explain 77–83% of the total variation of the data. The five-factor solution of the energy adjusted nutrient content of foods and dishes is presented in Table 6. The factors were named according the most representative foods of the factors. The main factors to explain the ability of Finnish foods to improve the diet (expressed as nutrient density index) were vegetables (vegetable factor explaining 31% of the variation) and the low fat content bound to high carbohydrate content (low fat-high carbohydrate factor explaining 12%) in the energy adjusted foods and dishes. When foods and dishes were taken to the analysis by weight basis (results not shown), the main factors explaining the nutrient density were low fat end energy content (negatively associated fat-energy factor explaining 50% of the variation) and the grain-nut factor (explaining 7%)[17].

This study shows that certain nutrients seem to be naturally (or because of fortification/contamination) present together in certain types of foods depending on the ingredients of the foods. The fat content of a food to a large extent affects the nutrient density of a food. Analyses done with energy adjusted nutrient content of foods show only the possible food groups important in enhancing the nutrient density of a certain diet. It is, however, a totally

Table 6 Five-factor solution of the energy adjusted nutrient content of foods and dishes (nutrient loadings to the factors)

Loading name	Factor 1 vegetable factor	Factor 2 fish factor	Factor 3 contaminant factor	Factor 4 offal factor	Factor 5 anti fat-high CHO factor
>0.7	Potassium Magnesium Cadmium	Protein Sulfur Selenium	Aluminum Silicon Chromium	Vitamin B-2 Copper	Low fat CHO
0.4–0.7	Vitamin B-1 Vitamin A Vitamin C Calcium Manganese Zinc Fluoride Aluminum Boron Copper Nickel Nutrient density index	Niacin Phosphorus Zinc Fluoride Mercury Arsenic	Calcium Fluoride Bromine Manganese	Vitamin A Niacin Zinc	

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different issue to study which nutrients go together in real diets (which foods are eaten and in which amounts). This example illustrates the complexity of the composition of food and the presented analytical approach can be a helpful tool in exploring underlying factors when developing FBDG.

Conclusions and recommendations

The quantile analyses based on iron intake resulted in differences among European countries regarding the consumption of food products. This underlines the importance of FBDG being country or region specific. Only by taking the cultural context into account can realistic and sensible FBDG be created. On the other hand some general (or Pan-European) tendencies were observed as well. This might be the basis for a hybrid approach in that FBDG are partly formulated for Europe and thereafter adjusted for a country or region. The country has to decide whether the European findings and conclusions are relevant enough in the perspective of all the information about that country. The European findings and conclusions can be of great help in this priority-setting process.

The analyses show important differences between analyses adjusted or not for energy intake. Therefore we recommended that analysis needed for FBDG are adjusted for energy intake.

It is also recommended to start with simple methods since they can provide relevant information for the population in general that can be disseminated to policy makers and nutrition educators in an understandable way. The more complex techniques can provide extra information on the most discriminating factors, the existence of underlying and unobservable dietary factors. Insight into these aspects will strengthen (by extra focus) FBDG when they are in line with the priorities set for the population. In case of conflicting goals and recommendations a clear policy trade off has to be made. The results of the analysis give the necessary ingredients for this decision making process.

The awareness of the fact that the analysis of data is instrumental to a decision making process is of utmost importance. It is through changes in supply and consumption of food that nutrition policies try to realize nutrition-oriented goals.

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