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A diet quality score for the Netherlands?

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Abstract

A diet quality score for the Netherlands?

It appeared not possible to construct a valid diet quality score to quantitatively evaluate the diet of the Dutch population. In order to meet still the desire for an overall dietary evaluation tool, we suggest to develop an instrument in which dietary components are included individually and visualized. Both the number of individuals adhering to guidelines, as well as the distribution of intakes should be considered.

To interpret changes in various aspects of food consumption in the Dutch population policy makers have expressed the desire for a score in which the diet is captured as a whole. In a previous report it was concluded that existing methods are inappropriate for a valid quantitative assessment of the diet. For this reason, another approach was investigated, aimed at revealing dietary variables (food groups) to predict health outcome (mortality). The individual contribution of or the weight attached to these variables would be reflected in a composite score. A Proportional Hazard Regression analysis in a Dutch cohort was used to investigate this approach. Results of the analysis described in the report turned out to be highly dataset-specific. Furthermore, various findings were not in line with what could be expected on the basis of established health effect of foods. This approach too then has failed to yield a valid diet quality score.

Keywords: diet quality; diet quality score; dietary assessment; food consumption data; dietary patterns

Rapport in het kort

Een voedingsindex voor Nederland?

Het is niet mogelijk gebleken om een valide voedingsindex op te stellen waarmee de kwaliteit van de voeding van de Nederlandse bevolking in één getal kan worden uitgedrukt. Om toch aan de wens voor een evaluatie-instrument voor het totale voedingspatroon tegemoet te komen, stellen we voor een instrument te ontwikkelen waarin voedingscomponenten afzonderlijk worden gevisualiseerd. Zowel het aantal individuen dat voldoet aan de voedingsnorm als de innemingsverdeling moet daarbij worden meegenomen.
Om veranderingen in het voedingspatroon van de Nederlandse bevolking te kunnen interpreteren hebben beleidsmakers behoefte aan één score waarmee de voeding in zijn geheel kan worden beoordeeld. In een voorgaand rapport is geconcludeerd dat bestaande methoden niet geschikt zijn om (veranderingen in) het voedingspatroon op een valide manier kwantitatief te beoordelen. Om die reden is een andere aanpak voorgesteld om wel een valide score te verkrijgen. In dit rapport zijn de resultaten beschreven van deze aanpak, waarbij overlevingsduuranalyse is toegepast in een Nederlands cohort. Het doel hiervan was voedingsvariabelen (voedselgroepen) te onderscheiden die voorspellend zijn voor sterfte en om de individuele bijdragen daarvan in een samengestelde score te bepalen. De resultaten van de analyses bleken echter in hoge mate dataset-afhankelijk en verschillende bevindingen kwamen niet overeen met wat op basis van bestaande kennis kan worden verwacht. Dit heeft geleid tot de conclusie dat ook deze aanpak niet resulteert in een bruikbare voedingsindex.

Trefwoorden: Kwaliteit van de voeding; voedingsindex; voedselconsumptiebeoordeling; voedselconsumptiegegevens; eetpatronen

Contents

Summary

Various socio-demographic shifts have resulted in significant changes in food choices and eating habits in the Netherlands. These developments in food consumption have both positive and negative effects on nutritional quality of the Dutch diet. Therefore a dietary score is desired by Dutch policy makers to evaluate the total diet of the Dutch population, capturing it as a whole. Such a score would allow food consumption to be quantitatively assessed, especially changes in food consumption and differences between subgroups.
In a previous report existing methods and indexes that attempt to capture the diet in a holistic way have been evaluated and compared. As existing approaches appeared inappropriate for a valid qualitative assessment of the diet another method was proposed to develop a diet quality score. It was suggested to reveal dietary variables (food groups) that predict health outcome (mortality) and to determine the individual contribution or weight of these variables in a composite score by conducting Proportional Hazard Regression analysis in an appropriate Dutch cohort. Prior knowledge on the relation between diet(ary factors) and disease, as well as the rules for a healthy nutrition served as a basis. This approach has been endeavored in this report.

Methods
The combined MORGEN and the Prospect-EPIC cohort was used for the analyses. Included were 31,807 participants, in the age of 20 to 64 years, with a mean follow-up period of 10 years. Food consumption data were collected using a validated semi-quantitative food frequency questionnaire and foods were classified into 14 main food groups and 38 subgroups. Cox Proportional Hazard Regression analysis was conducted, age being the time dependent variable. Analyses were carried out separately for men and women.

Results and discussion
The results of the survival analyses appeared highly dataset-specific. Results for men and women differed importantly. And various findings were not in line with what could be expected on the basis of known health effect of foods. Resulting models contained only a very limited number of predictors (food groups) and these predictors were generally not food groups expected to be included in the model. Also, food groups that are considered important contributors to health were not included in the model. Moreover the association was not always in the expected direction.
Main reason for these findings, inconsistent with our hypotheses, may be that consumption patterns represent other characteristics that are associated with health outcome. Also all cause mortality was, obligatory, the outcome measure, since it was aimed to develop a score to appraise the overall effects of the diet. But total mortality may not be related strong enough to dietary behavior.

Although it may be possible to refine the applied methodology or use a more powerful dataset, it is not likely that this approach will in any way lead to a useful diet quality score.

Conclusion

Neither existing indexes or patterning methods, nor the proposed methodology can provide a valid diet quality score to evaluate the diet of the Dutch population. As we have acquired a clear understanding of the potential and possibilities, but also the limitations of these methods to assess the diet as a whole, we are confident in this conclusion.
To still meet the desire for a total score we suggest a tool to be developed in which dietary components are included individually. A possibility would be to depict in a figure the extent to which intake of several dietary components meets recommendations. It should be further explored how this can be given shape.

1. Introduction

1.1 Background

Over the last decade food choices and eating habits have changed significantly resulting, among others, from various socio-demographic shifts in the Netherlands. For example consumption of staple foods such as potatoes, vegetables, fruit, and meat has decreased, whereas consumption of grains, fish, nuts and snacks, pre-prepared meals, and beverages has risen (Gezondheidsraad, 2002). In addition consumption of (full-fat) margarine and full-cream milk products was reported to have lost ground to the lighter low-fat margarine and semi-skimmed and skimmed milk products. These developments in food consumption have both positive and negative effects on nutritional quality of the Dutch diet.
The important question is how these positive and negative aspects can be weighted in such a weigh that quantitative statements can be made about the change in the overall quality of the diet. The diet consists of many different foods, either or not consumed in combination, that in turn contain a large variety of nutrients and other constituents. All these dietary components may correlate and interact and affect our health and longevity. For many dietary components or food groups *individual* health effects have been established. However, a dietary score is desired in which the total consumption pattern is captured. Such score would allow policy makers to evaluate the food consumption of the Dutch population, and especially the changes in food consumption and differences between subgroups.

1.2 Conclusions from the previous report

In a previous report existing methods and indexes that attempt to capture the diet in a holistic way have been evaluated and compared (Waijers and Feskens, 2005). Two different approaches exist and were described. In the first place theoretically or ‘a priori’ defined dietary patterns consisting of nutrients and foods that are assumed to be either healthful or detrimental. Such predefined dietary scores are built upon current nutrition knowledge, and some scores are based on dietary guidelines. However, many arbitrary choices need to be made when a score is composed, and associations of existing scores with chronic disease risk or mortality were generally weak. The second approach is the derivation of dietary patterns ‘a posteriori’. Statistical methods like factor and cluster analysis are used to generate patterns from collected dietary data. But although derived patterns may reveal existing eating patterns, they do generally not represent optimal diets.

Therefore another method was proposed to develop a diet quality score. It was suggested to establish a dietary score by relating consumption of several selected food groups (in combination) with health outcome in a Dutch cohort. Prior knowledge on the relation of diet(ary factors) and disease, as well as the rules for healthy nutrition[1] should serve as a basis.

1.3 Outline of this report

The suggested approach to obtain a dietary score to evaluate the total diet has been employed. In this report the methodology and results are described. Chapter 2 contains a description of the methods: the rationale behind the approach, the (choice of the) study population, and the actual analyses are explained. The results are given in Chapter 3. Final conclusions and recommendations can be found in the last chapter.

[1] Spelregels Goede Voeding (Schijf van Vijf) van het Voedingscentrum

2. Methods

2.1 Rationale behind the methodology

Dietary patterns can be derived from collected food consumption data on the basis of correlations in intakes of the various foods. This approach may provide insight into existing eating patterns, and even more and less favorable patterns may be observed that are related with health outcome. However, these patterns do generally not represent optimal diets. This is the main reason why this approach cannot contribute to the construction of a score to appreciate the quality of the diet.
Constructing a dietary score beforehand, or ‘a priori’, based on knowledge of the health impact of individual foods and nutrients seems a more logical way to attain this goal. Such index exists of several foods and nutrients that are quantified and summed to provide an overall measure of dietary quality. However, several difficulties exist in the creation of such score, as has been pointed out previously (Waijers and Feskens, 2005). Many arbitrary choices need to be made considering the components to be included in the score, the cut-offs and way of scoring, and the weight of the individual components to the total score. Existing scores are only moderately related to health outcome.
The predefined indexes do in fact not take into account correlations and interactions between dietary components, as the researcher just adds dietary variables that (s)he considers relevant, based on health effects of these foods or nutrients individually. Furthermore, the relative weight or contribution of the individual index components to the total score is a very complex issue. In most indexes all individual variables have the same weight, i.e. they contribute equally to the total score. It is not plausible though that all index variables do have the same health impact. For that reason it seems better to ascribe greater weights to those items that affect our health to a greater extent. It is extremely difficult however to do statements on the relative contribution of different dietary components to health outcome. In addition, several index items may strongly correlate, so that in fact these variables contribute more heavily to the score. This is for example the case for dietary fat. Some indexes include more than one ‘fat variable’, for example ‘total fat’ and ‘saturated fat’. Additionally foods, for example meat, may be included with relatively high fat content.
Still, this issue is highly important and may determine to a large extent the index’ predictive capacity, and consequently its validity. Therefore a way was searched to select dietary variables that truly contribute to health outcome in a composite score, to objectively determine their contribution to the total score.
With Proportional Hazard Regression the impact of variables on health outcome, mortality or another event, can be revealed. Often this kind of analysis is used to establish whether or not an assumed risk factor involves a higher risk of mortality or for example chronic disease.

This method can also be used exploratory however, revealing possible risk factors and exploring the contribution of a combination of risk factors to health outcome. The regression coefficients of the individual variables then determine the weight of the dietary variables in a composite score. This approach is endeavored in this report. As it is aimed to develop a score to appraise the overall effects of the total diet, total mortality is taken as the outcome measure.

2.2 Study population

2.2.1 Choice of the cohort

A representative Dutch cohort was needed for the analyses. The cohort should satisfy a number of criteria:
- It should be representative for the Dutch population
- It should contain a sufficiently large number of participants
- Follow-up time should be long enough (a minimum of 10 years)
- It should contain detailed food consumption data

The Dutch cohorts that seemed most suitable:

- the Netherlands Cohort Study on Diet and Cancer (NLCS): a cohort study initiated in 1986 among 120,852 Dutch men and women aged 55-69y at baseline
- the (local) Rotterdam study (ERGO): a population survey among all inhabitants >55y at baseline (1990-1993) living in a suburb of Rotterdam. In total 7,983 subjects participated, in 2002 another 3,011 were added to the cohort.
- the combined MORGEN (1) and Prospect-EPIC (2) cohort: (1) a population survey (Monitoring Project on Risk Factors and Health in the Netherlands) among 23,100 individuals from three towns in the Netherlands, aged 20-59y at baseline (1993-1997), and (2) a population survey among 17,500 women living in Utrecht and surroundings, aged 50-70y at baseline (1993-1997)

The NLCS cohort seemed most appropriate as it is by far the largest cohort and reasonably representative as participants come from a random sample drawn from 204 municipalities in the Netherlands. The cohort is managed by TNO Quality of Life and Maastricht University. Unfortunately we could not have access to the dataset, due to purely financial constraints. The ERGO-cohort was relatively small and not nationwide. Besides, the dataset is managed by Erasmus University in Rotterdam and therefore less easy accessible.
Therefore it was decided to use the combined MORGEN and the Prospect-EPIC cohort. This option seemed second best, and the data were accessible, as the MORGEN data are owned by the RIVM and the Prospect data could also be accessed easily with permission of the Julius Center.

2.2.2 Description of the study population

Subjects were participants of two large Dutch cohorts: the MORGEN cohort and the Prospect-EPIC cohort. The MORGEN cohort consists of 22,769 men and women, aged 20-64 years, from three towns in the Netherlands: Amsterdam, Doetinchem and Maastricht. The study population has been described in detail elsewhere (Blokstra et al., 1998). The Medical Ethics Committee of TNO (Netherlands Organisation for Applied Scientific Research) approved the study according to the guidelines of the Helsinki declaration. The Dutch Prospect-EPIC cohort is based on volunteers recruited among women participating in a regional breast cancer screening program. It comprises 17,357 women aged 50-69 years at enrolment from Utrecht and vicinity. The study population has been described in detail elsewhere (Boker et al., 2001).
Data on vital status including dates of emigration or death, up until 16 September 2005 for MORGEN and 30 June 2005 for Prospect, were obtained through the National Population Database.

For 39,164 participants all required data were available. 3,180 Individuals were excluded because they reported to have coronary heart disease, stroke, cancer, diabetes or a combination of these at enrollment. Another 4,154 individuals were excluded because they followed a prescribed diet on advice. 23 Individuals deceased within the first year of follow-up and were therefore excluded. The remaining 31,807 participants were included in the study. Mean follow-up period was 10 years.

2.2.3 Dietary intakes

Information on foods and beverages consumed during the year preceding enrolment was collected with the use of a validated semi-quantitative food frequency questionnaire (Ocké et al., 1997a; Ocké et al., 1997b). The questionnaire contained questions on the habitual consumption frequency during the past year. The questionnaire enables estimation of the average daily consumption of 178 food items. The quantity consumed was estimated in commonly used units, household measures, or by colored photographs of foods showing different portion sizes. Intake of each of the foods in grams per day was calculated taking into account standard recipes. Total energy (in kJ per day) and ethanol (gram per day) intake was estimated using an extended version of the 1996 computerized Dutch food composition table (Voedingscentrum, 1996).
Foods were classified in 14 main food groups and 38 subgroups (Appendix 1). Food groups were created on the basis of logical classification (e.g. similarity of products from a consumption or production point of view) as well as knowledge on health effects of individual foods. For each food group units were chosen in proportion with consumed amounts.
For all meat and dairy food groups, as well as for alcohol, consumption of moderate quantities of these food groups is considered beneficial, whereas too high intakes are

detrimental. Therefore new variables ('dummies') were created that indicated whether a person was or was not in a specific range of consumption for these food groups. Meat consumption was classified in 4 categories: 0 to 50 grams, 50 to 100 grams, 100 to 150 grams, and more than 150 grams per day. Dairy consumption was also classified in 4 categories: 0 to 150 grams, 150 to 300 grams, 300 to 450 grams and, and more than 450 grams per day. Daily alcohol intake was subdivided in 3 categories: no alcohol (<1 gram), limited alcohol intake (1 to 20 grams for women, and 1 to 30 grams for men), and high alcohol intake (more than 20 grams for women, and more than 30 grams for men).

2.3 Lifestyle and anthropometric information

Data on a number of lifestyle and health variables were recorded with the use of a core lifestyle questionnaire, including questions on education, history of previous illnesses, and smoking habits.
Physical examinations were conducted by trained paramedics according to a standardized protocol. Weight (to the nearest 100 g on calibrated scales) and height were measured while the participants were wearing only light indoor clothing and no shoes.

2.4 Analyses

Correlations of the foods and nutrients with energy intake were examined.
Cox proportional hazard analyses were conducted, age being the time dependent variable. 'Cohort' (MORGEN or Prospect), length (as a proxy for energy requirement), and a variable for smoking were taken up as fixed covariates in the model. In addition total energy intake has been included as a fixed covariate in subsequent analyses. Analyses were carried out separately for men and women. Both the 'stepwise' and 'score' methods were used to determine which set of dietary variable predicted mortality best. Variables that were expected to be related to health outcome were analyzed individually in a model with the 3 covariates. Exploratory analyses were performed with all food groups entered simultaneously, both with and without the dummy variables for meat, dairy, and alcohol. In a next step only a few selected variables were entered into a stepwise proportional hazard analysis. These variables had been selected on the basis of known health effects of individual dietary components and results of the former analyses. Finally a dietary score is obtained.
The SAS 9.1 statistical software package (PHREG) was used to perform the calculations.

3. Results

During the follow-up of the cohort, 948 deaths occurred in 315,655 person years.
Mean intakes and percentiles for all food groups are presented in Appendix 2.

3.1 Results of analyses with individual food groups

Food groups have been entered in a PHREG model individually (but with the covariates 'cohort', 'length', and 'smoking') to gain insight into their individual capacity to predict mortality. Appendix 3 contains the results of these analyses.
Hazard ratios should be considered with care as they should be interpreted in relation to the unit for the food group. For example, if fruit consumption was expressed in grams rather than the used increment of 100 grams, the hazard ratio would have been considerably smaller. Therefore units have been chosen in equivalence with consumption portions (appendix 1). Still, hazard ratios of the different food groups cannot be easily compared.
For men, surprisingly, higher consumption of both refined and whole meal bread increases mortality risk significantly, whereas total bread consumption is not related with mortality risk. Higher consumption of vegetables and fruit seems associated with a decreased mortality risk in both men and women. None of these associations was significant however. In men consumption of whole meal pasta and unpolished rice seems to be associated with a considerably lower mortality risk, although not significant. In contrast to what was expected, higher consumption of nuts and cocktail snacks and also of sweets and cakes decreases mortality risk in men.
For meat and dairy consumption hazard ratios are related to the lowest intake category of 0 to 100 g/day with HR 1.00. Although no significant relationship with mortality was found for any of the categories for meat consumption, trends were generally in the expected direction. For women high meat consumption appeared unfavorable, whereas for moderate consumption no effect was seen. Higher total meat consumption seemed protective in men, although for the highest intake category this effect seemed no longer sustained. In women on the other hand, high consumption levels seemed unfavorable. Higher consumption of fatty meats appeared to increase mortality risk, this also accounts for highest intake category of red meat. Moderate red meat consumption on the other hand, seemed favorable in men. None of these effects was significant however.
Higher fish consumption seems to be associated with decreased mortality risk in men (as expected), but increased risk in women. Use of oil for cooking was protective in women. A higher consumption of added fats showed, in contrast to what was hypothesized, no effect on mortality risk. Relationships of milk intake with mortality risk seemed inconsistent. Only increased consumption of 'all dairy products' increased mortality risk significantly in women.

Several remarks need to be made with these findings. First of all, in an overall model containing combinations of dietary variables, effects of individual components can be very different. This analysis was only aimed at gaining insight into the data. However, it was found that for several food groups associations were not in the expected direction. Also, results differed considerably between men and women.

3.2 Results of stepwise analyses

In a next step food groups were inserted in a model simultaneously with the three covariates (length, cohort, and smoking). The covariates were included obligatory in each model. Two methods ‘stepwise’ and ‘score’ within proportional hazard analysis were executed to determine the dietary predictors. With the ‘stepwise’ method, variables are entered into the model if they fit a statistical criterion (are significant). However after entrance of a new variable (forward step), variable(s) already in the model can be removed (backward elimination step). The stepwise selection process terminates if no further variable can be added to the model or if the variable just entered into the model is the only variable removed in the subsequent backward elimination. A stepwise analysis therefore results in a model with the best set of significant predictors.
With the ‘score’ method a specified number of models is derived with the highest likelihood score (chi-square) for all possible model sizes, from 1, 2, 3 variables, and so on. This method can be used to gain insight into other (combinations of) variables that may not be the best, but still adequate predictors of health outcome and that can be better explained. However, this approach did not result in more plausible models and therefore, only results of the ‘stepwise’ method are shown (these are equal to the models with the highest likelihood score).
In addition total energy intake has been included as a covariate in subsequent analyses. But as this did not significantly change the results, these results are not shown.

Exploratory stepwise Proportional Hazard Regression analysis (PHREG) resulted in models containing only a very limited number of predictors (food groups) as can be seen from table 3.1. More important, resulting food groups were generally not food groups expected to be included in the model. ‘Meat replacer’ and ‘beer’ for women were only marginally consumed and still significant predictors. On the other hand, food groups that are considered important contributors to health were not included in the model. Moreover the association was not always in the expected direction. For example: sweets and cakes were found to decrease mortality risk significantly in men.

In a next step analyses were performed with a selection of food groups on the basis of knowledge on the health effect of dietary components and the Dutch guidelines for a healthy diet[1], and in addition seemed most predictive from the results of the individual analysis (table 3.2). Stepwise analysis did not result in an outcome useful to create a dietary score, as can be seen from table 3.1. Again results for men and women were completely different.

Table 3.1: Results of exploratory stepwise proportional hazard regression[1]

MODEL	**MEN**	**WOMEN**
All major food groups	-all bread (+) -sweets and cakes (-)!	-fruit and vegetables (-)
all food groups (excl dummies)	-sugar rich beverages (+) -white&wheat bread (+) -sweets and cakes (-)! -sugar (+) -cheese (+)	-meat replacer (+)! -oil (-) -beer (+)
all food groups (incl dummies)	-sugar rich beverages (+) -white&wheat bread (+) -sweets and cakes (-)! -sugar (+) -cheese (+)	-total milk (prod) 150-300g/d (+) -fat milk (prod) 300-450g/d (+) -meat replacer (+) -oil (-) -beer (+)
selected food groups[2]	-sugar rich beverages (+) -white&wheat bread (+) -sweets and cakes (-)!	-oil (-) -alcoholic beverages (+) -total milk (prod) 150-300g/d (+)

[1] (+) indicates increased mortality risk with higher consumption
(-) indicates decreased mortality risk with higher consumption
[2] Table 3.2 presents the selected food groups

Table 3.2: Selected food groups

Classification	**Selected variables**[1]
Bread, cereals, potatoes	breadref, breadwhole, potatoe, ricepastaref, ricepastawhole
Meat, fish, dairy	meat2 meat3 meat4, fish, milktot2 milktot3 milktot4
Vegetables and fruit	fruit, vegetable
Fats	oil
Drinks	bevsugar, teacoff
Alcohol	alcoholv2 alcoholv3, bevalc
Others	sweetscakes, sauces, snack

[1] See Appendix 1 for a description of the selected variables

[1] Richtlijnen Goede Voeding ('Schijf van Vijf') van het Voedingscentrum

3.3 Example of a dietary score

Although previous results do not provide a basis for a valid score, to be complete, an example for a dietary score was obtained. For this purpose a sub selection of food groups was entered simultaneously into a model in order to obtain coefficients for a score with these food groups. P-values and hazard ratios are presented in Appendix 4. Resulting scoring coefficients are given in the box below.
Given the previously presented results it is not surprisingly that scoring coefficients differ considerably between men and women. Also the direction of the coefficients are not always in concordance with known health effects of food groups and sometimes opposite for men and women.

Score for men ~
- 0.33 fish - 0.066 fruit + 0.0018 oil - 0.17 vegetable + 0.056 breadtot - 0.037 potpasta
- 0.0027 allfats - 0.36 meat2 - 0.21 meat3 - 0.027meat4 - 0.035 alcoholm2 - 0.22 alcoholm3

Score for women ~
+ 0.46 fish - 0.054 fruit - 0.029 oil - 0.058 vegetable - 0.0067 breadtot + 0.12 potpasta
- 0.0048 allfats + 0.015 meat2 -0.0085 meat3 + 0.090 meat4 - 0.072 alcoholv2 + 0.094 alcoholv3

4. Discussion and conclusions

It was aimed to develop a dietary score with which the total diet of the Dutch population could be quantitatively evaluated. For this purpose in a previous phase, existing diet quality scores and dietary patterning methods have been evaluated (Waijers and Feskens, 2005). It was concluded that with existing methods the Dutch dietary habits could not be adequately assessed and monitored. For this reason another approach was suggested and performed. The methodology and results have been described in this report.

4.1 Discussion of the findings

Although a large dataset was used, almost 32.000 individuals were included in the study of which 948 deceased, the results appear highly dataset-specific. Various findings were not in line with what could be expected on the basis of known health effect of foods. Also results for men and women differed importantly. We therefore think that this approach will and can not result in a useful score.

Several reasons can be thought of why the approach did not yield satisfactory results. An important reason is that consumption patterns may represent other characteristics that are associated with health outcome. It is not achievable to adjust for all possible disturbing factors. On the contrary, taking up a large number of covariates in the model would make it difficult to detect additional effects of dietary variables. Moreover, application of the thus obtained score would require knowledge of the covariates in the dataset in which the score is applied. This might not always be possible.

Another reason may be that total mortality was considered and not a subset of mortality, for example cardiovascular or cancer mortality. Several dietary factors are related with either coronary heart disease or (a specific type of) cancer. Overall mortality is a sum of mortality from all causes and could therefore be less easily related to dietary factors. Moreover, also deaths from accidents or other fatal events that are not nutrition related could disturb the results. However, as it was aimed to develop a score to appraise the overall effects of the total diet, overall mortality was the obligatory outcome measure. To by-pass this problem it would have been possible to limit the age range and to include only elderly people, as it is more likely that events among elderly are nutrition related. However, that would have resulted in a lower number of individuals, especially men, and therefore a lower chance to detect associations. In addition 'high risk' patterns could be missed. Although it would be possible to apply the methodology to another more powerful dataset, and to identify the causes of death that may be diet related we expect that inconsistent results will still be obtained.

The MORGEN cohort consists of men and women drawn from a random sample of the Dutch population from three towns in the Netherlands (Amsterdam, Doetinchem, and Maastricht). The Dutch Prospect-EPIC cohort is based on volunteers recruited among women from Utrecht and vicinity participating in a regional breast cancer screening program. The study population is expected to be reasonably well representative for the Dutch population (Blokstra et al., 1998; Boker et al., 2001), and the choice of the cohort is therefore not expected to lie underneath the unsatisfactory results.

Exploratory stepwise Proportional Hazard Regression analysis resulted in models containing only a very limited number of predictors (food groups), that were generally not hypothesized to fit in a dietary score. Moreover, associations with health outcome were not always in the expected direction. Although it may be possible to ameliorate the applied methodology, it is not likely that this approach will in any way lead to a useful dietary score.

<u>Dietary patterns identified among Dutch older women</u>

In the introduction it was mentioned that ‘a posteriori’ dietary patterns analysis is not useful to construct a diet quality score. Still, we want to shortly present the results of a recent dietary patterning study in a dataset that largely overlaps (subset of women aged 60 and above) with the dataset of the presented proportional hazard analyses. The obtained results give confidence in the quality of the data.

Within the framework of the EPIC-Elderly we derived *a posteriori* dietary patterns among 5,427 Dutch women aged 60 to 69 years at baseline (Waijers et al., 2005), a sub cohort of the cohort described in this report. Dietary patterns were identified by means of principal components analysis on 22 food groups and Cox proportional hazard analysis was used to assess mortality ratios for the major principle components.

Three components, or dietary patterns, were identified: a ‘Mediterranean-like’ pattern (high in vegetable oils, pasta/rice, sauces, fish, and wine), a ‘Traditional Dutch dinner’ pattern (high in meat, potatoes, vegetables, and alcoholic beverages) and a ‘Healthy (variant of the) Traditional’ pattern (high in vegetables, fruit, non-alcoholic drinks, dairy products, and potatoes). Only the ‘Healthy Traditional’ pattern score was found to be significantly associated with a lower mortality rate. Women in the highest tertile of this pattern experienced a 30 percent reduced mortality risk.

Similar effects have been found for ‘prudent’ or ‘healthy’ patterns identified in other populations, comparable to the ‘Healthy Traditional’ pattern. But surprisingly the ‘Healthy Traditional’ pattern was not found in two other Dutch studies (van Dam et al., 2003; Balder et al., 2004). A possible explanation may be that participants in these other cohorts were younger, which would suggest that the ‘Healthy Traditional’ pattern is disappearing. From this study it seems that adherence to a diet resembling the ‘Healthy traditional’ pattern is feasible and may be promoted, since it fits to the Dutch consumption habits.

These findings are not directly useful for the construction of a dietary score, but give insight into existing eating patterns and their relationship with health outcome. In addition, as mentioned, they provide confidence in the dataset used for analysis in this report.

4.2 Alternative approaches

Reduced Rank Regression

In the previous report it was suggested to explore the potential of Reduced Rank Regression to identify dietary patterns. To apply this method ‘responses’ need to be specified. Responses can be disease-related nutrients, biomarkers for disease, or other indicators of health. These responses ideally should be strongly associated with (represent) ‘health’. We did not have access to data on cause specific mortality, neither to biomarkers for diseases. It was therefore not possible to select relevant responses. But for a dietary score we are interested in the overall effects of nutrition, therefore risk factors for a specific disease are in fact not appropriate.
Nevertheless, to explore the method, we did perform some analyses using intakes of a variety of nutrients as responses. If relevant responses are available Reduced Rank Regression may be an interesting method to gain insight into existing patterns related with these responses. However, essentially the same applies for this approach as for other *a posteriori* approaches: this method can not help in the construction of a dietary score. In addition, data for selected responses will not be available, or the same, in other datasets.

Predefined dietary scores

In the previous report existing dietary scores have been evaluated and discussed. It was then concluded that existing dietary indexes are not appropriate to assess the diet quantitatively. A priori indexes are not necessarily good predictors of health outcome. Although various foods and/or nutrients are generally included in a score, correlations and interactions between foods, food groups, and nutrients are in fact not taken into account when developing the score. The researcher decides which components are finally included and how intakes are appreciated (scored). Generally each component contributes equally to the final score. However, several components may be highly correlated or represent similar dietary factors. For example, total fat, saturated fatty acids, and unsaturated fatty acids intake on the one hand, and oil, fish, and meat consumption on the other hand. Inclusion of all these items results in a high emphasis of the fatty acids composition of the diet in the score. And how large is the health effect of the fatty acid composition in relation to for example fruit and vegetable consumption? There is insufficient scientific evidence to answer this question. We tried to tackle this problem by entering all these variables together in a proportional hazard model, but as described above, this did not result in a useful outcome.

Health simulation models

In relation to this topic we want to shortly discuss another model in use at the RIVM: the Chronic Disease Model (CDM) (Hoogenveen, 1998). The CDM aims to estimate the health (and cost) effects of (changes in) various life style factors. It is a multistate transition model that links prevalence of risk factors to the incidence of 28 chronic diseases. The model allows computing effects on disease incidence and mortality of changes in several risk factors in a population. The number of life years gained and impact of the quality of life may subsequently be estimated. The model is described in detail elsewhere. The CDM has been employed to calculate the health effects of five nutritional variables (risk factors): the consumption of fruit, vegetables, saturated fatty acids, trans fatty acids, and fish. Relative risks for these variables were obtained from a review of the results of observational and experimental studies. Actual consumption data are obtained from the Dutch national food consumption surveys (Van Kreijl et al., 2004). The model is complex, and we do not intend to go deeper into it. The CDM is a valuable tool to assess health gain or loss due to changes in established risk factors for several diseases. But the results of the CDM cannot be used as the outcome for the dietary score. Limitations and choices that have to be made for the CDM are similar as for predefined dietary scores. For example, a severe limitation of the CDM is that correlations between risk factors cannot be accounted for, and effects are treated as being independent. Moreover, for some dietary variables (like vegetable and fruit consumption) the relative risks from the literature are attributed to quintiles of intake because insufficient scientific knowledge is available to attribute relative risks to specific levels of intake.

4.3 Recommendations: how to proceed

We have by now acquired a clear understanding of the potentials and possibilities, but also the limitations of methods to assess diet quality in a holistic way. And we are therefore confident in our conclusion that it is not possible to construct a composite score to assess the quality of the diet objectively and validly. Thus neither existing indexes or patterning methods, nor the proposed methodology can provide a valid diet quality score to evaluate the diet of the Dutch population.

It seems that the best way to evaluate dietary behavior and changes in dietary patterns would still be to consider relevant dietary components individually. Besides, if one aspect of the diet has become more in line with dietary recommendations, that does not mean that another aspect can be neglected. Moreover, dietary interventions are generally directed towards individual or a limited number of aspects of the diet, for example increasing fruit and vegetable consumption, or decreasing fat intake.

Still the need to monitor (changes in) dietary behavior is evident. To meet the desire for an evaluation tool an instrument could be developed in which the extent to which intake or consumption of a number of dietary components meets recommendations is visualized. Ideally, for a number of relevant dietary factors the number of individuals adhering to guidelines, as well as distribution of intakes (and thus information on the extent to which guidelines are not met) should be visible in one figure. The exact way to do this should be further explored.

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Appendix 1a: Overview of created food groups

Variable	Explanation	Unit
Alcstrong	strong alcoholic beverages	100g
Bakingfat	baking fat; margarine, halvarine, animal fat	1g
Beer	beer	100g
Bevsugar	sugar-rich beverages	100g
Breadref	white and wheat bread and cereals	30g (~1 slice)
Breadwhole	wholemeal bread	30g (~1 slice)
Butter	butter	1g
Cakes	cakes, pastry, biscuits, gingerbread, etc.	10g
Cheese	cheese	10g
Egg	egg	100g
Fish	fish	100g
Fruit	fruit	100g
Fruitjuice	fruit juice	100g
Halvarine	halvarine	1g
Margarine	margarine	1g
Meatfat	fat meat	100g
Meatlean	lean meat	100g
Meatsnack	meat snack	100g
Meatred	red meat	100g
Meatwhite	white meat (chicken)	100g
Milkfat	full fat milk and milk products, incl pudding	100g
Milklowfat	(semi-)skimmed milk and low fat milk products	100g
Oil	oil	1g
Potatoe	cooked potatoes	100g
Replacer	meat replacer	100g
Ricepastaref	rice and pasta, refined	100g
Ricepastawhole	wholemeal pasta, unpolished rice	100g
Saucesfat	fatty sauces: mayonaise, peanut sauce	100g
Sauceslean	lean sauces: halvanaise, lettuce sauce	100g
Saucespasta	sauce for pasta	100g
Snack	nuts, cocktail snacks	100g
Sugar	sugar	10g
Sweets	sweets, sweet sandwich filling	10g
Teacoff	tea and coffee	100g
Vegfresh	fresh vegetables	100g
Vegprep	prepared vegetables	100g
Water	water	100g
Wine	wine	100g

Appendix 1b: Overview of main food groups

Variable	Explanation	Unit
Vegetable	all vegetables	100g
Fruittot	fruits and fruit juices	100g
Fruitandveg	fruits and vegetables	100g
Breadtot	all bread	30g (~1 slice)
Milktotfat	full fat milk and milk products inc cheese	100g
Milktot	all milk and milk products	100g
Meat	meat	100g
Ricepasta	rice and pasta	100g
Potpasta	potatoes, pasta, rice	100g
Sweetscakes	sweets and cakes	10g
Sauces	sauces	100g
Margfat	baking fat, butter, and margarines	100g
Allfats	margarine, halvarine, and other fats	1g
Bevalc	alcoholic beverages	100g

Appendix 2a: Intake characteristics of food groups in grams/day

Variable	mean	sd	P5	P10	P25	P50	P75	P90	P95
Alcstrong	18	43	0	0	0	1	14	57	100
Bakingfat	1	3	0	0	0	0	0	4	7
Beer	103	262	0	0	0	2	67	343	577
Bevsugar	72	111	0	0	8	33	91	194	270
Breadref	80	75	0	4	16	62	128	182	219
Breadwhole	62	66	0	0	0	50	98	154	192
Butter	5	7	0	1	2	3	6	13	19
Cakes	29	24	3	5	12	24	41	59	72
Cheese	36	28	3	7	18	30	46	68	88
Egg	16	14	1	3	7	14	21	29	43
Fish	10	11	0	0	3	8	14	19	28
Fruit	174	132	17	34	80	125	243	356	415
Fruitjuice	82	98	0	0	9	47	134	145	278
Halvarine	6	9	0	0	0	0	9	18	24
Margarine	10	11	0	0	2	7	14	24	31
Meatfat	69	42	12	21	39	65	92	122	143
Meatlean	34	21	5	9	18	31	46	61	72
Meatsnack	6	10	0	0	1	2	10	19	19
Meatred	97	55	18	32	57	93	127	166	194
Meatwhite	12	13	0	1	4	9	16	26	35
Milkfat	160	130	17	34	76	136	208	306	392
Milklowfat	236	217	6	15	66	187	340	508	642
Oil	4	4	0	0	1	2	5	9	11
Potatoe	87	63	13	23	43	73	119	171	206
Replacer	2	6	0	0	0	0	0	5	10
Ricepastaref	45	48	3	6	14	32	58	95	130
Ricepastawhole	5	10	0	0	0	2	6	15	23
Saucesfat	8	11	0	1	2	5	11	18	25
Sauceslean	2	2	0	0	0	1	2	4	5
Saucespasta	10	12	0	0	0	8	18	18	36
Snack	12	15	0	1	2	7	15	27	40
Sugar	15	22	0	0	0	4	22	44	59
Sweets	24	24	1	2	8	18	34	53	67
Teacoff	780	345	250	363	563	753	975	1200	1325
Vegfresh	33	29	3	6	13	25	46	70	89
Vegprep	101	44	38	50	72	97	126	160	179
Water	360	327	15	35	146	301	490	777	959
Wine	42	80	0	0	0	10	44	114	200

Appendix 2b: Intake characteristics of major food groups in grams/day

Variable	mean	sd	P5	P10	P25	P50	P75	P90	P95
Fruitandveg	309	152	112	141	200	281	392	507	584
Vegetable	135	53	60	74	99	127	163	204	232
Fruittot	256	175	35	65	126	235	356	488	572
Breadtot	142	69	52	67	96	131	175	228	270
Milktot	432	289	72	116	226	384	584	794	954
Milktotfat	196	134	44	65	110	172	246	346	433
Meat	109	59	23	39	66	107	142	181	210
Potpasta	137	78	40	53	82	123	178	235	278
Ricepasta	50	52	3	6	17	37	65	103	148
Sweetscakes	54	39	8	13	27	47	72	101	122
Sauces	10	12	1	1	4	7	13	20	27
Margfat	1630	1319	197	323	664	1290	2242	3385	4177
Allfats	22	15	3	5	11	20	30	42	50
Bevalc	163	277	0	0	9	64	201	429	639

Appendix 3: Results of PHREG with individual food groups

Variable	MEN		WOMEN	
	p-value	HR[1]	p-value	HR[1]
Breadref	**0.01**	1.05	0.26	0.98
Breadwhole	**0.02**	1.05	0.45	0.98
Breadtot	0.63	0.99	0.61	1.01
Vegetable	0.16	**0.85**	0.18	0.91
Vegfresh	0.68	**0.83**	0.24	0.84
Vegprep	0.16	**0.83**	0.82	**0.37**
Fruit	0.25	0.94	**0.05**	0.94
Fruittot	0.21	0.95	0.12	0.96
fruit&vegetable	0.12	0.93	**0.03**	0.94
Potatoe	0.88	1.01	0.12	1.11
Ricepastaref	0.58	0.93	0.97	1.00
Ricepastawhole	0.10	**0.29**	0.91	1.06
Potpasta	0.72	0.98	0.16	1.09
Ricepasta	0.40	0.90	0.99	1.00
Snack	**0.05**	**0.43**	0.46	**1.25**
Sugar	**0.03**	1.04	0.90	1.00
Sweets	0.21	0.97	0.16	1.03
Sweetscakes	**0.04**	0.97	0.85	1.00
Sauces	0.65	1.21	0.82	1.12
Teacoff	0.80	1.00	0.11	1.02
Bevalc	0.65	1.01	0.14	1.04
Alc2	0.68	0.93	0.26	0.91
Alc3	0.42	0.85	0.59	1.06
Meat2	0.19	**0.70**	0.84	1.02
Meat3	0.35	0.80	0.96	1.01
Meat4	0.87	0.96	0.48	1.11
Meatfat2	0.90	0.98	0.78	0.98
Meatfat3	0.32	1.20	0.71	1.05
Meatfat4	0.61	1.13	0.53	1.21
Meatred2	0.27	0.77	0.97	1.00
Meatred3	0.25	0.78	0.44	1.09
Meatred4	0.78	1.06	0.16	**1.25**
Meatwhite	0.85	0.93	0.81	1.09
Fish	0.36	**0.58**	0.40	**1.33**

[1] HR = Hazard Ratio

Appendix 3 (continuation)

Variable	**MEN**		**WOMEN**	
	p-value	**HR[1]**	**p-value**	**HR[1]**
Oil	0.57	0.99	**0.02**	0.97
Halvarine	0.96	1.00	0.18	0.99
Margarine	0.15	1.01	0.77	1.00
Margfat	0.33	1.00	0.93	1.00
Allfats	0.39	1.00	0.40	1.00
Milkfat2	0.96	1.01	0.33	0.92
Milkfat3	0.98	1.01	0.31	**1.36**
Milkfat4	0.55	0.84	0.44	0.80
Milklowfat2	0.40	0.88	0.63	0.95
Milklowfat3	0.58	0.90	0.23	0.87
Milklowfat4	0.69	0.92	0.60	0.94
Milktotfat2	0.53	1.09	0.81	0.98
Milktotfat3	0.88	1.03	0.49	1.10
Milktotfat4	0.81	1.06	0.98	1.01
Milktot2	0.24	0.81	**0.00**	1.04
Milktot3	0.35	0.84	0.41	**1.36**
Milktot4	0.37	0.86	**0.05**	**1.32**

[1] HR = Hazard Ratio

Appendix 4: Results of PHREG with selected food groups

Variable	MEN		WOMEN	
	p-value	HR[1]	p-value	HR[1]
Fish	0.58	0.72	0.17	1.59
Fruit	0.24	0.94	0.10	0.95
Oil	0.91	1.00	0.02	0.97
Vegetable	0.18	0.84	0.48	0.94
Breadtot	0.04	1.06	0.81	0.99
Potpasta	0.63	0.96	0.05	1.13
Allfats	0.52	1.00	0.18	1.00
Meat2	0.19	0.70	0.89	1.02
Meat3	0.39	0.81	0.94	0.99
Meat4	0.91	0.97	0.56	1.09
Alcoholv2	0.84	0.97	0.42	0.93
Alcoholv3	0.25	0.81	0.41	1.10