Dietary pattern analysis: a new direction in nutritional epidemiology

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Recently, dietary pattern analysis has emerged as an alternative and complementary approach to examining the relationship between diet and the risk of chronic diseases. Instead of looking at individual nutrients or foods, pattern analysis examines the effects of overall diet. Conceptually, dietary patterns represent a broader picture of food and nutrient consumption, and may thus be more predictive of disease risk than individual foods or nutrients. Several studies have suggested that dietary patterns derived from factor or cluster analysis predict disease risk or mortality. In addition, there is growing interest in using dietary quality indices to evaluate whether adherence to a certain dietary pattern (e.g. Mediterranean pattern) or current dietary guidelines lowers the risk of disease. In this review, we describe the rationale for studying dietary patterns, and discuss quantitative methods for analysing dietary patterns and their reproducibility and validity, and the available evidence regarding the relationship between major dietary patterns and the risk of cardiovascular disease.

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Abbreviations

CHD	coronary heart disease
DASH	Dietary Approach to Stop Hypertension
FFQ	food frequency questionnaire
HEI	healthy eating index

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Introduction

Traditional analyses in nutritional epidemiology typically examine diseases in relation to a single or a few nutrients or foods. Although this type of analysis has been quite valuable, it has several conceptual and methodological limitations. First, people do not eat isolated nutrients. Instead, they eat meals consisting of a variety of foods with complex combinations of nutrients that are likely to be interactive or synergistic [1]. The 'single nutrient' approach may be inadequate for taking into account complicated interactions among nutrients in studies of free-living people (e.g. enhanced iron absorption in the presence of vitamin C) [1]. Second, the high level of intercorrelation among some nutrients (such as potassium and magnesium) makes it difficult to examine their separate effects, because the degree of independent variation of the nutrients is markedly reduced when they are entered into a model simultaneously [2]. Third, the effect of a single nutrient may be too small to detect, but the cumulative effects of multiple nutrients included in a dietary pattern may be sufficiently large to be detectable [3]. In clinical trials [4,5], interventions altering dietary patterns appeared to be more effective at lowering blood pressure than single nutrient supplementation. Fourth, analyses based on a large number of nutrients or food items may produce statistically significant associations simply by chance [6]. Finally, because nutrient intakes are commonly associated with certain dietary patterns [7,8], 'single nutrient' analysis may potentially be confounded by the effect of dietary patterns. For example, Ursin *et al.* [9] found that low dietary fat was associated with higher intakes of vegetables, fruits, fiber, folate and whole grains. Because intakes of vegetables, fruits, fiber, folate, and whole grains (as a food pattern) may be independently associated with a reduced risk of coronary heart disease (CHD), these dietary components are potential confounders in a study of the relationship between dietary fat and coronary disease. Adjustment for these variables in multivariate analyses may not remove all the confounding effects because these dietary components may interact with each other.

To address these issues, several authors have recently proposed to study overall dietary patterns by considering how foods and nutrients are consumed in combinations [10–14]. In dietary pattern analysis, the collinearity of nutrients and foods could be used to advantage because patterns are characterized on the basis of eating behavior.

An examination of dietary patterns would parallel more closely the real world, in which nutrients and foods are consumed in combination, and their joint effects may best be investigated by considering the entire eating pattern. Analysing food consumption as dietary patterns offers a perspective different from the traditional single nutrient focus, and may provide a comprehensive approach to disease prevention or treatment, which has been used in several settings, including the Dietary Approach to Stop Hypertension (DASH) [4] and the Lyon Diet Heart Study [15].

Studying dietary patterns could have important public health implications because the overall patterns of dietary intake might be easy for the public to interpret or translate into diets [1]. In fact, the prevailing dietary guidelines emphasize dietary patterns in the prevention of cardiovascular disease [16]. Studying dietary patterns in relation to disease outcomes thus provides a practical way to evaluate the health effects of adherence to dietary guidelines by individuals [12]. It can also enhance our conceptual understanding of human dietary practice, and provide guidance for nutrition intervention and education.

Methods for defining dietary patterns

As dietary patterns cannot be measured directly, one must rely on statistical methods to characterize dietary patterns using collected dietary information. The methodology for defining dietary patterns is relatively new and is still in development. Three approaches have been used in the literature: factor analysis, cluster analysis, and dietary indices.

Factor analysis

Factor analysis, as a generic term, includes both principal component analysis and common factor analysis. Principal component analysis is commonly used to define dietary patterns because the principal components are certain mathematical functions of the observed variables, whereas common factors are not expressible by the combination of the observed variables [17]. Factor analysis is a multivariate statistical technique, which uses information reported on food frequency questionnaires (FFQs) [8,18–20,21••] or in dietary records [22] to identify common underlying dimensions (factors or patterns) of food consumption. It aggregates specific food items or food groups on the basis of the degree to which food items in the dataset are correlated with one another. A summary score for each pattern is then derived and can be used in either correlation or regression analysis to examine relationships between various eating patterns and the outcome of interest, such as nutrient intake [8,23], cardiovascular risk factors [18], and other biochemical indicators of health [22,24,25].

Cluster analysis

Cluster analysis is another multivariate method for characterizing dietary patterns. In contrast to factor analysis, cluster analysis aggregates individuals into relatively homogeneous subgroups (clusters) with similar diets. Individuals can be classified into distinct clusters or groups on the basis of the frequency of food consumed [14,26••,27], the percentage of energy contributed by each food or food group [28,29], the average grams of food intakes [30], standardized nutrient intakes [6,11], or a combination of dietary and biochemical measures [31]. When the cluster procedure is completed, further analyses (e.g. comparing dietary profiles across clusters) are necessary to interpret the patterns identified.

Dietary indices

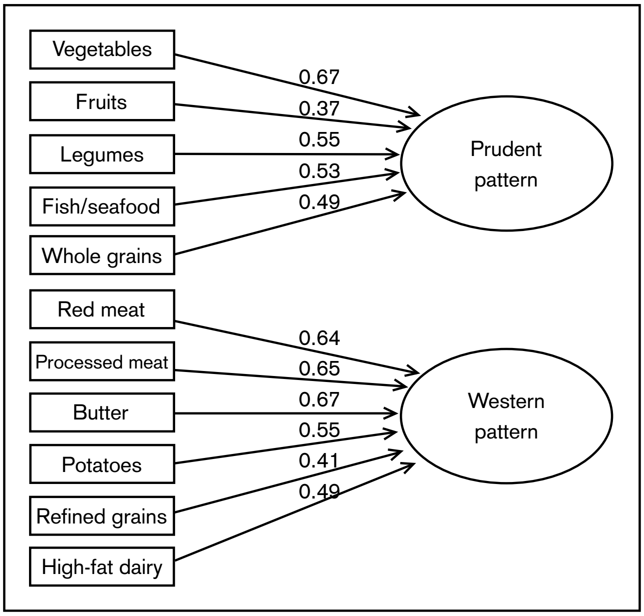
A variety of dietary indices have been proposed to assess overall diet quality [13]. These indices are typically constructed on the basis of dietary recommendations. For example, the healthy eating index (HEI) [32] is a single, summary measure of the degree to which an individual's diet conforms to the serving recommendations of the US Department of Agriculture Food Guide Pyramid [33] for five major food groups and to specific recommendations in the US Dietary Guidelines for Americans [34]. The diet quality index [35] is a summary score of the degree to which an individual's diet conforms to specific dietary recommendations from Diet and Health [1]. Another simple and popular score is the dietary diversity score, which counts the number of food groups (i.e. dairy, meat, grain, fruits, and vegetables) or foods consumed regularly [36–40]. On the other hand, the recommended food score simply tallies the foods recommended by current dietary guidelines [41•].

Both factor analysis and cluster analysis are considered 'a posteriori' because the eating patterns are derived through statistical modelling of dietary data at hand [42•]. The dietary index approach, in contrast, is 'a priori' because the indices are created on the basis of previous knowledge of a 'healthy' diet. Because the a posteriori approaches generate patterns based on available empirical data without a priori hypothesis, they do not necessarily represent optimal patterns. In addition, one should evaluate whether the patterns generated fit into the commonly recognized eating habits in the population, because these patterns are generated simply on the basis of eating behaviors. On the other hand, the dietary index approach is limited by current knowledge and an understanding of the diet–disease relationship, and can be fraught with uncertainties in selecting individual components of the score and subjectivity in defining cut-off points. Typically, dietary indices are constructed on the basis of prevailing dietary recommendations, some of which may not represent the best available scientific evidence.

The reproducibility and validity of dietary patterns

Although the concept of studying dietary patterns has elicited considerable interest, few studies have examined the reproducibility and validity of these methods. In a previous study [20], we examined the reproducibility and validity of dietary patterns defined by factor analysis, using dietary data collected by an FFQ and diet records among participants in the Health Professionals' Follow-up Study, who were enrolled in a nutrient validation study in 1986. Using factor analysis, we identified two major eating patterns, which were qualitatively similar across the two FFQs and the diet records. The first factor, which we labelled the 'prudent pattern' was characterized by a higher intake of vegetables, fruits, legumes, whole grains, and fish, whereas the second factor, labelled the 'western pattern', was characterized by a higher intake of processed meat, red meat, butter, high-fat dairy products, eggs, and refined grains (Fig. 1). The reliability correlations for the factor scores between the two FFQs were 0.70 for the prudent pattern, and 0.67 for the western pattern. The correlations (corrected for week-to-week variation in diet records) between the two FFQs and diet records ranged from 0.45 to 0.74 for the two patterns. In addition, the correlations between the factor scores and nutrient intakes and plasma concentrations of biomarkers were in the expected direction. These data indicate reasonable reproducibility and validity of the major dietary patterns defined by factor analysis using data from the FFQ. In a subsequent study [43••], we found similar major dietary patterns in women.

Figure 1. Factor loadings for selected foods loaded on the two major dietary patterns identified from the food frequency questionnaire in a subsample of the Health Professionals' Follow-up Study (*n* = 127)



Although several studies have examined the validity of dietary patterns derived from cluster analysis by comparing nutrient or biochemical profiles between the clusters or patterns [26••,28], no data are available on the reproducibility or stability of the clusters over time. Also, it is not clear whether different sources of dietary data (e.g. dietary records and FFQs) would produce the same clusters in a given population. Studies are also needed to evaluate the reproducibility and validity of the proposed diet quality indices.

Dietary patterns and risk of coronary heart disease

Numerous studies have examined the relationship between intakes of individual nutrients or foods and the risk of CHD [44], but few data are available on the effects of overall dietary patterns. Recently, we examined the associations between major eating patterns derived from factor analysis and the risk of CHD in two large ongoing cohort studies, the Nurses' Health Study and the Health Professionals' Follow-up Study. In both studies, we identified two major dietary patterns: 'prudent' and 'western', and calculated factor scores of each pattern for individuals in the cohorts. In the Health Professionals' Follow-up Study [21••], after adjustment for age, smoking, body mass index, and other coronary risk factors, the RR from the lowest to the highest quintiles of the prudent pattern score were 1.0, 0.87, 0.79, 0.75, and 0.70 [95% confidence interval (CI) 0.56–0.86], *P* for trend equals 0.0009. In contrast, the RR across increasing quintiles of the western pattern score were 1.0, 1.21, 1.36, 1.40, and 1.64 (95% CI 1.24–2.17), *P* for trend less than 0.0001. These associations persisted in subgroup analyses according to cigarette smoking, body mass index, and parental history of myocardial infarction.

Although the two dietary pattern scores were statistically independent through the orthogonal transformation procedure, it is possible for one individual to have high or low scores on the two patterns at the same time. We therefore examined CHD risk according to joint classifications of the western diet and prudent diet scores (Fig. 2). In multivariate analyses, the observed associations for the two patterns appeared to be independent of each other. Compared with those with the lowest score for the prudent pattern and the highest score for the western pattern, the RR of CHD for men in the highest category of the prudent pattern and the lowest category of the western pattern was 0.50 (95% CI 0.34–0.74). Similar results were observed in the Nurses' Health Study [43••].

In a separate study [45], we examined the relationship between the major eating patterns and biochemical markers of CHD and obesity. We observed significant

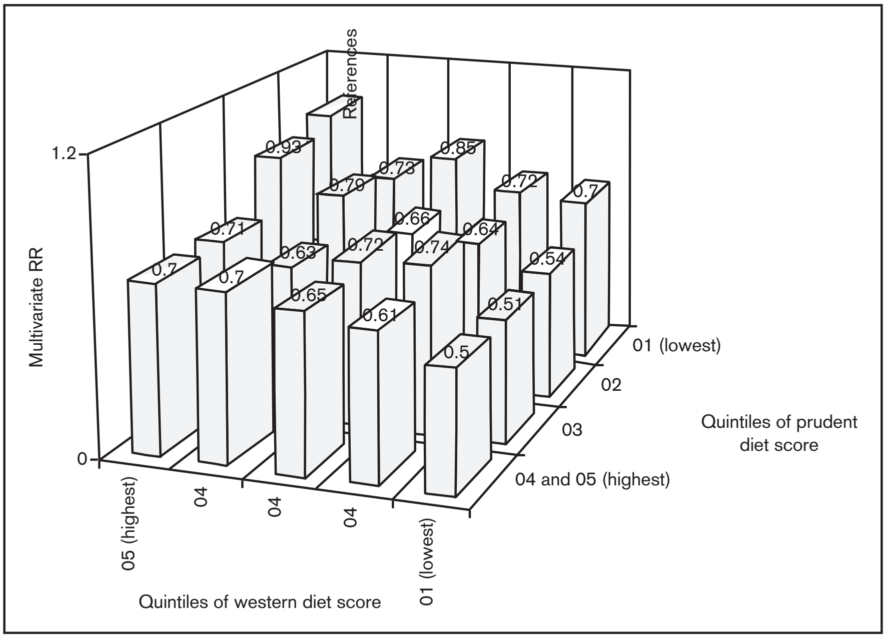


Figure 2. Multivariate relative risks of coronary heart disease according to joint classifications of western and prudent pattern scores (Health Professionals' Follow-up Study 1986–1994) [21••]

Adjusted for age, smoking, alcohol use, body mass index, and other coronary heart disease risk factors. RR, relative risks.

positive correlations between the western pattern and tissue plasminogen antigen (0.19, $P < 0.01$), fasting insulin (0.32, $P < 0.01$), C-peptide (0.31, $P < 0.01$), leptin (0.28, $P < 0.0001$), C-reactive protein (0.22, $P < 0.0001$), and homocysteine (0.23, $P < 0.01$) after adjusting for various potential confounders. In addition, a significant inverse correlation was observed between plasma folate (-0.39, $P < 0.0001$) and the western pattern. In contrast, inverse correlations were observed between the prudent pattern and fasting insulin (-0.25, $P < 0.05$) and homocysteine (-0.20, $P < 0.01$); a positive correlation was observed with folate (0.28, $P < 0.0001$). These data suggest that the relationship between eating patterns and CHD risk may act through the biochemical risk factors of CHD.

The major patterns identified through factor analyses are consistent with an a priori expectation of patterns. The lower rate of CHD in Asia and the Mediterranean region may be partly due to their respective dietary patterns [46]. Traditional diets in Japan and Crete, for example, are in some ways similar to the prudent pattern in this study, with low animal products, and higher amounts of vegetables and whole grains. Intervention studies have demonstrated the effectiveness of modifying multiple aspects of the diet in the prevention or treatment of diseases. The DASH trial emphasized fruits, vegetables and low fat dairy products, and successfully reduced both diastolic and systolic blood pressure in hypertensive subjects [4] and serum homocysteine levels [47]. The combination of the DASH diet and sodium reduction lowered blood pressure even further [48]. Also, in the Lyon Diet Heart Study [15], patients with a history of myocardial infarction who followed a diet with a high amount of alpha-linolenic acid, fruits and vegetables had dramatically fewer subsequent cardiac events and lower mortality rates compared with those who followed a regular low-fat diet.

The two major patterns were also similar to those observed in several other studies [49–51]. In a study of 3698 men and 3618 women aged 30–70 years in Denmark, Osler *et al.* [50] also derived a prudent and a western pattern using factor analysis of 28 food items from an FFQ. The authors found that the prudent pattern score was significantly associated with a lower risk of cardiovascular disease and total mortality during 15 years of follow-up. However, the association with the western pattern was not significant. Tseng and DeVillis [51] examined major dietary patterns and their correlates in a representative US sample based on the Third National Health and Nutrition Examination Survey. The major derived patterns resembled those found in our cohorts. In a study conducted in Germany [52], however, the dietary patterns were more diverse; somewhat different from the US patterns.

Besides factor analysis, several studies have evaluated whether dietary indices predict disease risk or mortality. In a study of elderly rural Greek individuals [53], greater adherence to the traditional dietary pattern in the Mediterranean region (reflected by a composite score for intakes of vegetables, fruits, legumes, ethanol, dairy products, cereal, and the ratio of monounsaturated to saturated fats) was significantly associated with a reduction in total mortality rates. Similarly, Huijbregts *et al.* [12] found that a dietary indicator for a healthy dietary pattern, based on the World Health Organization's guidelines for the prevention of chronic diseases, was significantly associated with reduced overall mortality rates.

In a recent study [54], we evaluated whether the HEI, a measure of adherence to the Dietary Guidelines for Americans, predicted the risk of major chronic disease in the Health Professionals' Follow-up Study. The HEI was weakly inversely associated with the risk of major chronic disease (comparing the highest with the lowest quintile of the HEI, RR 0.89; 95% CI 0.79, 1.00; $P<0.001$ for trend). The HEI was associated with a moderately lower risk of cardiovascular disease (RR 0.72; 95% CI 0.60, 0.88; $P<0.001$), but was not associated with a lower cancer risk. These results indicate that the HEI was only weakly associated with the risk of major chronic disease, suggesting that improvements to the HEI may be warranted. Similar results were found in women [55].

In an analysis of the Nurses' Health Study data [56], we computed a composite dietary score based on intakes of cereal fiber, folate, marine n-3 fatty acids, the ratio of polyunsaturated to saturated fats, trans fatty acids, and glycemic load. We selected these variables a priori on the basis of available evidence on the relationship between diet and CHD. This score strongly predicted the risk of CHD in the Nurses' Health Study (Fig. 3). Although each individual component of the composite score was significantly associated with the risk of CHD, the association with the composite score appeared to be even stronger, suggesting cumulative effects of multiple dietary components on CHD risk. Also, the association with the composite score was stronger than that with the major dietary patterns derived from factor analysis, suggesting that the 'a priori' approach can be more advantageous than the 'a posteriori' approaches when important dietary factors for the disease have been clearly defined.

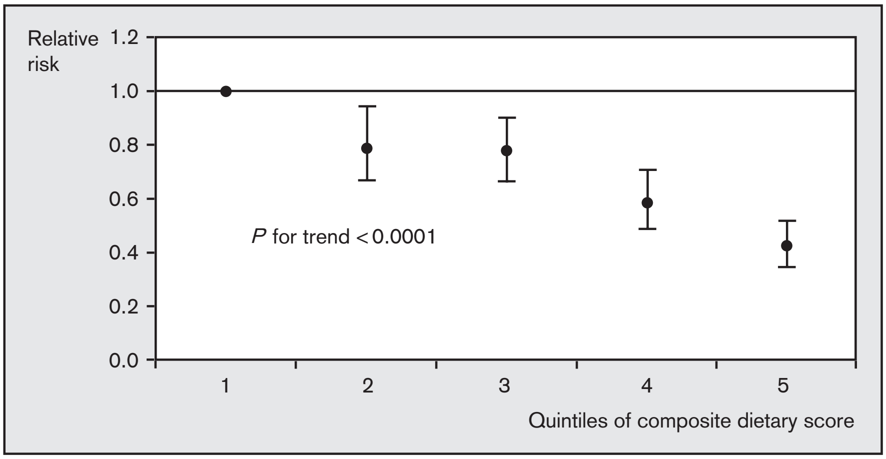
Limitations of dietary pattern analysis

A major challenge in studying dietary patterns and disease risk is to establish a quantitative method to identify eating patterns, unless a specific pattern (e.g. Mediterranean) has been specified. The factor analysis approach involves several arbitrary but important decisions, including the consolidation of food items into food groups, the number of factors to extract, the method of rotation, and even the labelling of the components [57]. Sensitivity analyses are thus needed to examine whether these choices affect the reproducibility of the findings. Another type of sensitivity analysis would be to conduct the factor analysis in randomly split samples. In addition, confirmatory factor analysis [58] can be used to examine the robustness and goodness of fit of the factor structures derived from the conventional or exploratory factor analysis.

In contrast to the traditional analytical approach used in nutritional epidemiology, dietary pattern analysis considers overall diet rather than individual nutrients or foods. Because there are many potential differences in nutrients between dietary patterns, this approach cannot be specific about the particular nutrients responsible for

Figure 3. Multivariate relative risks of coronary heart disease according to quintiles of a composite dietary score in the Nurses' Health Study (1980–1994) [56]

Adjusted for age, smoking, and other coronary heart disease risk factors. To compute the composite score, intakes for trans fat, cereal fiber, glycemic load, marine omega-3 fatty acids, and folate and the ratio of polyunsaturated to saturated fat were categorized into quintiles, and for each participant the quintile values for the nutrients (a higher quintile score represents a better diet) were summed.



the observed differences in disease risk, and it may thus not be very informative about biological relationships between dietary components and disease risk. Therefore, the observed association should be evaluated in the light of results from individual nutrient or food analyses.

Dietary patterns are likely to vary according to sex, socioeconomic status, ethnic group and culture. It is thus necessary to replicate the results in diverse populations. It is possible that different eating patterns are derived from different populations. This does not necessarily refute the validity of pattern analysis, because these differences may well be true as a result of a different social and cultural background. In addition, because of changes in food preferences and food availability, the meaning of a dietary pattern could change over time.

Conclusion

Diet is a complex exposure variable, which calls for multiple approaches to examine the relationship between diet and disease risk. Dietary pattern analysis is one of these approaches. It will certainly not replace nutrient or food analysis, but instead serves as a complementary approach to more traditional analysis. Evidence is enhanced when the results from multiple lines of research (i.e. biomarkers of nutrient intake, nutrients, foods, and dietary patterns) are consistent. Clearly, further research is needed to evaluate the validity of dietary patterns and whether they predict long-term disease risk in diverse populations.

The dietary pattern approach would not be optimal if the effect is caused by a specific nutrient (e.g. folic acid and neural tube defect), because the effect of the nutrient would be diluted. Therefore, the dietary pattern approach may be more useful when traditional nutrient analyses have identified few dietary associations for the disease (e.g. breast cancer). On the other hand, when many dietary associations have been demonstrated for the disease (e.g. CHD), dietary pattern analysis may also prove to be useful because it goes beyond nutrients and foods, and examines the effects of overall diet. In addition, a dietary pattern can be used as a covariate when examining a specific nutrient, to determine whether the effect of the nutrient is independent of the overall dietary pattern. Furthermore, dietary pattern analysis can be useful in evaluating dietary guidelines.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1 National Research Council – Committee on Diet and Health. Diet and health: implications for reducing chronic disease risk. Washington, DC: National Academy Press; 1989.

2 Lee CN, Reed DM, MacLean CJ, *et al.* Dietary potassium and stroke. N Engl J Med 1988; 318:995–996.

3 Sacks FM, Obarzanek E, Windhauser MM, for the DASH investigators. Rational and design of the Dietary Approaches to Stop Hypertension Trial (DASH): a multicenter controlled-feeding study of dietary patterns to lower blood pressure. Ann Epidemiol 1994; 5:108–118.

4 Appel L, Moore TJ, Obrazanek E, for the DASH collaborative research group. A clinical trial of the effects of dietary patterns on blood pressure. N Engl J Med 1997; 336:1117–1124.

5 The Trials of Hypertension Prevention Collaborative Research Group. The effects of nonpharmacologic interventions on blood pressure of persons with high normal levels. JAMA 1992; 267:1213–1220.

6 Farchi G, Mariotti S, Menotti A, *et al.* Diet and 20-y mortality in two rural population groups of middle-aged men in Italy. Am J Clin Nutr 1989; 50:1095–1103.

7 Kant AK, Schatzkin A, Block G, *et al.* Food group intake patterns and associated nutrient profiles of the US population. J Am Diet Assoc 1991; 91:1532–1537.

8 Randall E, Marshall JR, Graham S, Brasure J. Patterns in food use and their associations with nutrient intakes. Am J Clin Nutr 1990; 52:739–745.

9 Ursin G, Ziegler RG, Subar AF, *et al.* Dietary patterns associated with a low-fat diet in the National Health Examination Follow-up Study: identification of potential confounders for epidemiologic analyses. Am J Epidemiol 1993; 137:916–927.

10 Jacobson HN, Stanton JL. Pattern analysis in nutrition. Clin Nutr 1986; 5:249–253.

11 Huijbregts PPCW, Fesjens EJM, Kromhout D. Dietary patterns and cardiovascular risk factors in elderly men: the Zutphen Elderly Study. Int J Epidemiol 1995; 24:313–320.

12 Huijbregts P, Feskens E, Rasanen L, *et al.* Dietary pattern and 20 year mortality in elderly men in Finland, Italy, and the Netherlands: longitudinal cohort study. BMJ 1997; 315:13–17.

13 Kant AK. Indexes of overall diet quality: a review. J Am Diet Assoc 1996; 96:785–791.

14 Millen BE, Quatromoni PA, Gagnon DR, *et al.* Dietary patterns of men and women suggest targets for health promotion: the Framingham Nutrition Studies. Am J Health Prom 1996; 11:42–53.

15 de Lorgeril M, Renaud S, Mamelle N, *et al.* Mediterranean alpha-linolenic acid-rich diet in secondary prevention of coronary heart disease. Lancet 1994; 343:1454–1459.

16 Krauss RM, Eckel RH, Howard B, *et al.* AHA Dietary Guidelines Revision 2000: a statement for healthcare professionals from the nutrition committee of the American Heart Association. Circulation 2000; 102:2284–2299.

17 Kleinbaum DG, Kupper LL, Muller KE. Chapter 24. Variable reduction and factor analysis. Applied regression analysis and other multivariable methods. PWS – KENT Publishing Company, Boston, Massachusetts; 1988. pp. 595–640.

18 Nicklas TA, Webber LS, Thompson B, Berenson G. A multivariate model for assessing eating patterns and their relationship to cardiovascular risk factors: the Bogalusa Heart Study. Am J Clin Nutr 1989; 49:1320–1327.

19 Herbert JR, Kabat GC. Implications for cancer epidemiology of differences in dietary intake associated with alcohol consumption. Nutr Cancer 1991; 15:107–119.

20 Hu FB, Rimm E, Smith-Warner SA, *et al.* Reproducibility and validity of dietary patterns assessed by a food frequency questionnaire. Am J Clin Nutr 1999; 69:243–249.

21 •• Hu FB, Rimm EB, Stampfer MJ, *et al.* Prospective study of major dietary patterns and risk of coronary heart disease in men. Am J Clin Nutr 2000; 72:912–921.
This large prospective study showed that major dietary patterns derived from factor analysis predicted the long-term risk of CHD in men.

22 Barker ME, McClean SI, Stain JJ, Thompson KA. Dietary behavior and health in Northern Ireland: an exploration of biochemical and haematological associations. J Epidemiol Commun Health 1992; 46:151–156.

23 Gex-Fabry M, Raymond L, Jeanneret O. Multivariate analysis of dietary patterns in 939 Swiss adults: sociodemographic parameters and alcohol consumption profiles. Int J Epidemiol 1988; 17:548–555.

24 Schwerin HS, Stanton JL, Riley AM, *et al.* Food eating patterns and health: a reexamination of the Ten-State and HANES I Survey. Am J Clin Nutr 1981; 34:568–580.

25 Schwerin HS, Stanton JL, Smith JL, *et al.* Food, eating habits, and health: a further examination of the relationship between food eating patterns and nutritional health. Am J Clin Nutr 1982; 35:1319–1325.

26 Millen BE, Quatromoni PA, Copenhafer DL, *et al.* Validation of a dietary pattern
•• approach for evaluating nutritional risk: the Framingham Nutrition Studies. J Am Diet Assoc 2001; 101:187–194.

A carefully conducted study to examine the validity of cluster analysis in defining dietary patterns.

27 Pryer JA, Nichols R, Elliott P, *et al.* Dietary patterns among a national random sample of British adults. J Epidemiol Commun Health 2001; 55:29–37.

28 Tucker KL, Dallal GE, Rush D. Dietary patterns of elderly Boston-area residents defined by cluster analysis. J Am Diet Assoc 1992; 92:1487–1491.

29 Wirfalt AKE, Jeffery RW. Using cluster analysis to examine dietary patterns: nutrient intakes, gender, and weight status differ across food pattern clusters. J Am Diet Assoc 1997; 97:272–279.

30 Akin JS, Guilkey DK, Popkin BM, Fanelli MT. Cluster analysis of food consumption patterns of older Americans. J Am Diet Assoc 1986; 86:616–624.

31 SENECA investigators. Food patterns of elderly Europeans. Eur J Clin Nutr 1996; 50 (Suppl.):S86–S100.

32 Kennedy ET, Ohls J, Carlson S, Fleming K. The healthy eating index: design and applications. J Am Diet Assoc 1995; 95:1103–1108.

33 The Food Guide Pyramid. Homes and Garden Bulletin no. 252. Washington, DC: US Department of Agriculture, Human Nutrition Information Service; 1992.

34 US Department of Agriculture US Department of Health and Human Services. Nutrition and your health: dietary guidelines for Americans. Homes and Garden Bulletin no. 232. Washington, DC: US Printing Office; 2000.

35 Haines PS, Siega-Riz AM, Popkin BM. The diet quality index revised: a measurement instrument for populations. J Am Diet Assoc 1999; 99:697–704.

36 Kant AK, Schatzkin A, Harris TB, *et al.* Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. Am J Clin Nutr 1993; 57:434–440.

37 Kant AK, Schatzkin A, Ziegler RG. Dietary diversity and subsequent cause-specific mortality in the NHANES I Epidemiologic Follow-up Study. J Am Coll Nutr 1995; 14:233–238.

38 Randall E, Marshall J, Graham S, Brasure J. Frequency of food use data and the multidimensionality of diet. J Am Diet Assoc 1989; 89:1070–1075.

39 Miller WL, Crabtree BF, Evans DK. Exploratory study of the relationship between hypertension and diet diversity among Saba Islanders. Public Health Reports 1992; 107:426–432.

40 McCann SE, Randall E, Marshall JR, *et al.* Diet diversity and risk of colon cancer in Western New York. Nutr Cancer 1994; 21:122–141.

41 Kant AK, Schatzkin A, Graubard BL, Schairer C. A prospective study of diet
• quality and mortality in women. JAMA 2000; 283:2109–2115.

This study demonstrated that the recommended food score, a simple dietary index counting the number of foods recommended by current dietary guidelines predicted total and cancer mortality.

42 Trichopoulos D, Lagiou P. Dietary patterns and mortality. Br J Nutr 2001;
• 85:133–134.

An elegant editorial regarding the pros and cons of various approaches defining dietary patterns.

43 Fung TT, Willett WC, Stampfer MJ, *et al.* Dietary patterns and risk of coronary
•• heart disease in women. Arch Intern Med 2001; 161:1857–1862.

This large prospective cohort study showed that dietary patterns derived from factor analysis predicted the long-term risk of CHD in women.

44 Willett WC. Nutritional epidemiology, 2nd ed. New York, NY: Oxford University Press; 1998.

45 Fung TT, Rimm EB, Spiegelman D, *et al.* Association between dietary patterns and plasma biomarkers of obesity and cardiovascular disease risk. Am J Clin Nutr 2001; 73:61–67.

46 Willett WC. Diet and health: what should we eat? Science 1994; 264:532–537.

47 Appel LJ, Miller III ER, Jee SH, *et al.* Effect of dietary patterns on serum homocysteine: results of a randomized, controlled feeding study. Circulation 2000; 102:852–857.

48 Sacks FM, Svetkey LP, Vollmer WM, *et al.* Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH Sodium Collaborative Research Group. N Engl J Med 2001; 344:3–10.

49 Slattery ML, Boucher KM, Caan BJ, *et al.* Eating patterns and risk of colon cancer. Am J Epidemiol 1998; 148:4–16.

50 Osler M, Heitmann BL, Gerdes LU, *et al.* Dietary patterns and mortality in Danish men and women: a prospective observational study. Br J Nutr 2001; 85:219–225.

51 Tseng M, DeVillis R. Correlates of the 'western' and 'prudent' diet patterns in the US. Ann Epidemiol 2000; 10:481–482.

52 Schulze MB, Hoffmann K, Kroke A, Boeing H. Dietary patterns and their association with food and nutrient intake in the European Prospective Investigation into Cancer and Nutrition (EPIC) – Potsdam Study. Br J Nutr 2001; 85:363–373.

53 Trichopoulou A, Kouris-Blazos A, Walhlqvist M, *et al.* Diet and overall survival in elderly people. BMJ 1995; 311:1457–1460.

54 McCullough ML, Feskanich D, Rimm EB, *et al.* Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in men. Am J Clin Nutr 2000; 72:1223–1231.

55 McCullough ML, Feskanich D, Stampfer MJ, *et al.* Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in women. Am J Clin Nutr 2000; 72:1214–1222.

56 Stampfer MJ, Hu FB, Manson JE, *et al.* Primary prevention of coronary heart disease in women through diet and lifestyle. N Engl J Med 2000; 343:16–22.

57 Martinez ME, Marshall JR, Sechrest L. Invited commentary: factor analysis and the search for objectivity. Am J Epidemiol 1998; 148:17–19.

58 Long JS. Confirmatory factor analysis: a preface to LISREL. Beverly Hills: Sage; 1983.