Empirically Derived Dietary Patterns and Hypertension

Zumin Shi · Anne W. Taylor · Evan Atlantis · Gary A. Wittert

Published online: 3 April 2012
© Springer Science+Business Media, LLC 2012

Abstract The association between dietary patterns and hypertension or systolic blood pressure/diastolic blood pressure was described in 27 papers identified between January 2008 and December 2011. The majority were cross-sectional studies (with only two cohort studies). Most of the empirically derived dietary pattern studies in the literature have used factor analysis methods based on dietary data from food frequency questionnaires. There are six studies using national representative samples. The majority of the studies did not assess intake of salt. The difference in salt intake by dietary patterns is not known. “Western,” “meat and alcohol,” and “processed meat” dietary patterns are positively associated either categorically with hypertension or continuously with blood pressure in most studies. While a “vegetable”-rich food pattern is inversely related to hypertension in Western countries, the traditional Asian vegetable-rich food pattern seems not to be protective against hypertension in Asian populations. Posterior dietary pattern approaches can provide useful information in developing dietary guidelines. Further research is needed in this field.

Keywords Dietary pattern · Factor analysis · Cluster analysis · Hypertension · Blood pressure · Epidemiology study

Z. Shi (✉) · A. W. Taylor · E. Atlantis · G. A. Wittert
Discipline of Medicine, University of Adelaide,
122 Frome Street,
Adelaide, South Australia 5000, Australia
e-mail: zumin.shi@adelaide.edu.au

A. W. Taylor
e-mail: anne.taylor@adelaide.edu.au

E. Atlantis
e-mail: evan.atlantis@adelaide.edu.au

G. A. Wittert
e-mail: gary.wittert@adelaide.edu.au

Introduction

Hypertension is a common chronic condition worldwide and an important risk factor for premature death [1]. During the past several decades, numerous studies have assessed the association between diet and hypertension. Dietary factors such as high sodium intake, low potassium intake, and excessive alcohol intake are established modifiable risk factors for elevated blood pressure (BP) [2]. Other dietary factors possibly related to high BP levels include lower intakes of vegetable protein [3], calcium, non-heme iron [4, 5], magnesium [6], phosphorus [7], polyunsaturated fatty acids [8], and higher intakes of soft drinks [9], cholesterol [10], animal protein [3], and red meat [5].

Human diet is a combination of different foods and nutrients. Interactions between these components are highly likely. Analysis of dietary patterns may account for cumulative and interactive effects and control for dietary confounding [11]. Several review papers have addressed the methods used to construct dietary patterns in population studies [12, 13]. The methods can be classified into two groups: hypothesis-oriented (*priori*) methods using prior information (eg, indexes and scores) and exploratory methods (posterior or empirical) using study-specific data (including factor analysis, principal component analysis, or cluster analysis). Reduced rank regression (RRR) method is a combination of the two groups.

The latest American Society of Hypertension position paper classified vegetarian diets and the Dietary Approaches to Stop Hypertension diet (DASH) as having persuasive clinical trial evidence for lowering BP [2]. However, evidence of other overall dietary factors and hypertension has not been discussed [2]. Three review papers reviewed the association between dietary patterns and hypertension or metabolic syndrome—in 2002 [14], 2004 [12], and 2006 [15]. However, the number of studies identified by these

reviews is very small (<10). A substantial number of studies on the association between overall dietary pattern and hypertension or BP have been published since these reviews. This current paper aims to summarize the latest studies after the previous reviews with a specific focus on dietary patterns derived using factor analysis, principal component analysis, and cluster analysis.

Methods

We searched PubMed, EMBASE, and Web of Knowledge. The following search terms were used: food pattern, dietary pattern, food habit, factor analysis, principal component analysis, cluster analysis, clustering, hypertension, blood pressure, and metabolic syndrome. The search was restricted to human studies reported in English and published between January 2008 and December 2011.

For each study included in the paper, we extracted the following information: country, study design, study population (including whether or not individuals with chronic conditions were excluded in the study/analysis), method of dietary assessment, how the dietary pattern was assessed, and the name and composition of the dietary patterns identified. Multivariable adjusted association between the identified dietary patterns and the risk of hypertension or level of systolic blood pressure (SBP) or diastolic blood pressure (DBP) were extracted.

A substantial number of studies used metabolic syndrome as the outcome variable. In these studies, elevated blood pressure (EBP) refers to SBP ≥ 130 mm Hg and/or DBP ≥ 85 mm Hg, or use of hypertension medication. In other studies in which hypertension is the main outcome variable, hypertension is defined as SBP ≥ 140 mm Hg and/or DBP ≥ 90 mm Hg, or use of hypertension medication.

Results

Overall, we identified 27 papers describing the association between dietary patterns and hypertension or SBP/DBP (Tables 1, 2, and 3); the majority were cross-sectional studies (with only two cohort studies). Factor analysis was the most common method of constructing dietary patterns. Although most of the papers were from Western countries, 13 were from Asia.

Cohort Studies

In the Generation R study in The Netherlands [16], 3,187 women were followed during pregnancy. Two dietary patterns were identified using factor analysis: a “Mediterranean” pattern characterized by high loading of vegetables, vegetable

oils, pasta, fish, and legumes, and a “traditional” pattern high in meat and potatoes. Although no association between the two dietary patterns and incident pregnant hypertension was found, low adherence to a Mediterranean and high adherence to a traditional dietary pattern were associated with a higher BP in pregnancy.

In a 1-year cohort study of 160 patients receiving renal transplantation [17], a dietary pattern in which “fats and sugar” predominated was related to increased risk of EBP during follow-up. In contrast, a Mediterranean dietary pattern was inversely related to the risk of EBP. Comparing extreme tertiles of Mediterranean pattern, the OR for EBP was 0.48 (95 % CI, 0.17–1.05).

Cross-Sectional Studies

Adolescent Study

Although the majority of the studies were done in adult populations, three studies assessed the association between dietary pattern and BP among adolescents.

The Raine Study, involving 1,139 Australian boys and girls aged 14 years living in Western Australia (whose mothers participated in a study during pregnancy) grouped into two dietary patterns (“healthy” and “Western”). Although there were significant differences in fiber intake across the groups, there was no significant relationship between SBP and either dietary pattern [18].

In another Australian study [19] involving 282 adolescents older than 16 years of age completing the 1995 Australian National Nutrition Survey, a dietary pattern of “fruit, salad, cereals, and fish” was associated with significantly lower DBP. “Vegetable” and “high fat and sugar” patterns were not related to BP despite significant difference in fiber and potassium intakes. No association between dietary patterns and SBP was found.

In Tunisia, among 1,019 adolescents randomly selected from 3 regions (capital city, 1 tourism-oriented region, and 1 remote rural inland region), multiple correspondence analysis was used to construct dietary patterns [20]. Two dietary patterns were identified: “modern” dietary pattern (high intake of white bread, dairy products, sugars, added fats, fresh fruits) and “meat and fish” dietary pattern.

Studies in Western Countries

The majority of the identified studies were done in Western countries. In Germany, in a national representative sample of 4,025 adults, a “processed meat” pattern was positively associated and a “health-conscious” pattern was inversely associated with hypertension [21].

In Portugal, using data from 1,868 men and women aged 18 years and older, dietary patterns were explored by cluster

Table 1 Prospective studies on dietary patterns and hypertension (a posteriori methods)

Study/country	Study population	Questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Timmermans et al. [16•]/Netherlands (Generation R study)	3,187 pregnant women	FFQ with 293 items grouped into 20 food groups	Factor analysis	Mediterranean (vegetables, vegetable oils, pasta, fish, and legumes); traditional (meat and potatoes); explained 12.8 % variance	Fiber (tertile 1 vs tertile 3); Mediterranean, 19.3 vs 23.5 g/d; traditional, 24.0 vs 19.4 g/d	No association with incident gestational hypertension; low adherence to a Mediterranean and high adherence to a traditional dietary pattern is associated with a higher blood pressure; most pronounced in mid-pregnancy; β for comparing extreme tertiles: Mediterranean T1 vs T3, SBP, 1.3 (95 % CI, 0.3–2.3); DBP, 1.6 (95 % CI, 0.8–2.4); traditional T3 vs T1, SBP, 1.3 (95 % CI, 0.4–2.3); DBP, 1.3 (95 % CI, 0.5–2.1)
Nafar et al. [17]/Iran	160 adult renal allograft recipients, 1-y follow-up	FFQ with 168 items, administered 2 mo after transplant, collapsed into 24 groups.	Factor analysis; Eigen values >1; Scree test	Factor 1: fats and sugars (high-fat dairy, rice, soft drinks, confectionary, salty snacks, saturated fats, pizza, poultry, refined grain, tea and coffee, processed meat, potatoes); factor 2: whole grain (whole-grain products, negative loading of salt); factor 3: Mediterranean (legumes, nuts, vegetables, fruits, olives, fish, and low-fat dairy)	Fiber intake across tertiles of patterns: factor 1: 34, 23, 20 ($P<0.01$); factor 2: 23, 23, 29 ($P<0.05$); factor 3: 15, 24, 36 ($P<0.01$)	Fats and sugars positively associated with incident EBP; OR across tertiles: 1, 2.87, 7.23 ($P<0.01$); Mediterranean inversely associated with incident EBP; OR across tertiles: 1, 0.68, 0.48 ($P<0.05$); whole-grain pattern not associated with EBP

^a T refers to tertiles of dietary pattern scores (T1 is tertile 1)

EBP elevated blood pressure, DBP diastolic blood pressure, FFQ food frequency questionnaire, SBP systolic blood pressure

Table 2 Cross-sectional studies on dietary pattern and hypertension or blood pressure (*a posteriori* methods): Western countries

Study/country/study name	Study population	Dietary questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Ambrosini et al. [18]/Australia/RAINE study	1,139 boys and girls, aged 14 y, Western Australia	FFQ with 212 items, collapsed into 38 food groups	Factor analysis Eigen value >1 Scree plot Variance explained 84 %	"Healthy" (whole grain, vegetables, fruit, legume) "Western" (takeaway food, processed meats, red meat, refined grains, confectionery) Factor 1: "fruit, salad, cereals, and fish" Factor 2: "high fat and sugar" Factor 3: "vegetable"	Sodium intake (Q4 vs Q1): "healthy": 3,316 vs 3,328 mg/d (not significant); "Western": 3,365 vs 3,074 mg/d ($P<0.0001$) Fiber intake (Q4 vs Q1): "healthy": 31.0 vs 17.8 g/d ($P<0.0001$); "Western": 20.2 vs 27.6 g/d ($P<0.0001$) Fiber intake (T1 vs T3): factor 1: 19.6 vs 23.9 g/d ($P<0.05$); factor 2: 23.9 vs 20.2 g/d ($P<0.05$); factor 3: 20.4 vs 23.0 g/d ($P<0.05$) Potassium (T1 vs T3): factor 1: 3,071 vs 3,333 mg/d ($P<0.05$); factor 2: 3,305 vs 3,116 mg/d ($P<0.05$); factor 3: 3,013 vs 3,405 mg/d ($P<0.05$) Not applicable	No association between dietary patterns and SBP "Fruit, salad, cereals, and fish" inversely associated with DBP Mean DBP: T1 vs T3, 66.5 vs 64.1 ($P<0.05$) Other patterns not associated with BP "Modern" dietary pattern was inversely associated with hypertension "Meat–fish" pattern was not associated with hypertension "Processed foods" positively associated with EBP; OR for extreme quintiles, 1.34 (95 % CI, 0.96–1.86) (P for trend across quintiles=0.04) "Health conscious" inversely associated with EBP; OR for extreme quintiles, 0.70 (95 % CI, 0.54–0.90) Men: using "healthy" as reference, "meat and alcohol" and "intermediate intake" pattern were associated with increased BP; "meat and alcohol" vs "healthy": SBP, 137 vs 133 mm Hg; DBP, 84 vs 81 mm Hg; "intermediate intake" vs "healthy": SBP, 136 vs 133 mm Hg; DBP, no significant difference Women: no difference in SBP or DBP between dietary patterns
McNaughton et al. [19]/Australia/1995 Australian National Nutrition Survey	764 adolescents, aged 12–18 y; only 282 adolescents age >16 had BP measured	FFQ with 108 items (some food items excluded in the analysis due to low consumption); 24-h recall (calculated nutrient intake)	Factor analysis Eigen values >1.25 Scree plot Variance explained 21.7 %	"Modern" dietary pattern (white bread, dairy products, sugars, added fats, fresh fruits) "Meat–fish" dietary pattern	Not applicable	
Aounallah-Skhiri et al. [20]/Tunisia	1,019 boys and girls, aged 15–19 y; collected in 2005 from 3 regions	FFQ with 134 items, collapsed into 43 food groups	Multiple correspondence analysis	"Processed foods" (refined grains, processed meat, red meat, high-sugar beverages, eggs, potatoes, beer, sweets and cakes, snacks and butter) "Health conscious" (vegetables, oils, legumes, fruits, fish, and whole grains)	Fiber (Q5 vs Q1): "processed foods": 2.17 vs 3.96 g/MJ ($P<0.0001$); "health conscious": 3.46 vs 2.43 g/MJ ($P<0.0001$) Potassium (Q5 vs Q1): "processed foods": 0.33 vs 0.49 g/MJ ($P<0.0001$); "health conscious": 0.45 vs 0.34 g/MJ Not applicable	
Heidemann et al. [21]/Germany/German Health Interview and Examination Survey 1998	4,025 men and women, aged 18–79 y, national representative sample	Dietary history interview; 2,678 food items assessed, collapsed into 34 food groups	Factor analysis Eigen value >1 Scree plot	Men: "healthy" (high in vegetable, fruits, dairy products, cereals, low in red meat, fast food, alcoholic beverage), "fish" (high in fish and vegetables); "red meat and alcohol" (red meat, alcohol, fast food); "intermediate intake" (intermediate consumption of most foods, but of white meat) Women: "healthy" (highest in vegetable, lowest in red meat, fast food, soft drinks); "low fruit and vegetable" (lowest in most foods, particular in fruits and vegetables); "red meat and alcohol" (highest in red meat and alcohol); "in transition to fast food" (highest in white meat, sweets, fast food, second highest in red meat, vegetable, dairy products)		
Oliveira et al. [22]/Portugal	1,868 men and women aged >18 y (controls from a case-control study)	FFQ with 82 items, collapsed into 14 food groups	Cluster analysis	Factor 1: "prudent" (processed vegetable juices, potatoes, fresh fruits, fresh vegetables, and legumes)	Fiber intake (T1 vs T3): factor 1: 14.1 vs 21.0 g/d ($P<0.001$); factor 2: 19.9 vs 14.6 g/d	"Prudent" and "high protein/fat" not associated with EBP
Denova-Gutierrez et al. [23]/Mexico/Health Workers Cohort Study	5,240 men and women, aged 20–70 y; employees and their relatives from 3 health	FFQ with 116 items, collapsed into 28 groups	Factor analysis			

Table 2 (continued)

Study/country/study name	Study population	Dietary questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Olinto et al. [24]/Brazil	and academic institutions; excluded: known diabetes, hypertension, dyslipidemia, rheumatoid arthritis		Eigen values >1.5	Factor 2: “Western” (high intake of pastries, refined cereals, corn tortillas, and soft drinks; low intake of whole cereals, seafood, and full-fat dairy products)	($P<0.001$); factor 3: 17.1 vs 17.1 g/d ($P=0.9$)	“Western” positively associated with EBP
	4,202 men and women in Pelotas (mean age, 23 y)	FFQ with 82 items; collapsed into 47 groups	Variance explained 20.6 %	Factor 3: “high protein/fat” (red meat, processed meat, margarine [saturated fats], and eggs)		OR comparing T1 and T3: “Western,” 1.20 (95 % CI, 1.01–1.41)
			Principal component analysis Eigen value >1	Factor 1: “common Brazilian” (sugar, white bread, coffee, butter/margarine, rice, and black beans)	Fiber intake (Q1 vs Q5): factor 1: 31.8 vs 64.6 g/d ($P<0.0001$); factor 2: 45.8 vs 51.1 g/d ($P<0.0001$)	Women: “common Brazilian” inversely associated with SBP and DBP; SBP, Q5 2.63 mm Hg lower than Q1; DBP, Q5 1.89 mm Hg lower than Q1 Men: “common Brazilian” trend of inverse association with SBP and DBP; moderate intake of this pattern had lowest SBP and DBP; no association between “processed” pattern and SBP and DBP
Liu et al. [25]/United States/Framingham Offspring Study	2,875 men and women; excluded: diabetes, taking cholesterol-lowering medications		Scree plot test Variance explained 15.7 %	Factor 2: “processed” pattern (red and processed meats, salty snacks, French fries, beer, soda, and other processed foods)		No association between dietary patterns and SBP/DBP
		FFQ with 126 items; collapsed into 40 food groups	Cluster analysis	Cluster 1: “fruits, reduced fat dairy and whole grains”	Sodium intake (mean): cluster 1–4, 2,100, 2,197, 1,945, 1,866 mg/d ($P<0.05$)	
				Cluster 2: “refined grains and sweets”	Potassium intake (mean): cluster 1–4, 3,515, 2,972, 2,794, 2,419 mg/d ($P<0.05$)	
Eilat-Adar et al. [26]/Alaska Eskimos/Genetics of Coronary Artery Disease in Alaska Natives (GOCADAN) study	1,066 men and women, aged 18–92 y, in Norton Sound region of Alaska; excluded: with diabetes		Principal component analysis	Cluster 3: “beer”	Fiber intake (mean): cluster 1–4: 21.7, 17.3, 15.6, 12.7 g/d ($P<0.05$)	
		FFQ with 97 items; collapsed into 28 groups	Eigen value >1	Cluster 4: “soda”		
			Variance explained 25 %	Factor 1: “traditional” (fish, native sea and land mammals, wild greens, rice, noodles, native birds, wild berries)	Fiber intake (Q1 vs Q5): factor 1: 5.1 vs 6.3 g/kJ ($P<0.01$); factor 2: 5.7 vs 5.8 g/kJ ($P=0.05$); factor 3: 4.1 vs 8.1 g/kJ ($P<0.01$); factor 4: 7.2 vs 4.4 ($P<0.01$)	“Traditional” inversely, “Western” positively associated with SBP; mean SBP: factor 1: Q1 vs Q5, 120 vs 118 mm Hg ($P=0.04$); factor 2: Q1 vs Q5, 121 vs 119 mm Hg ($P=0.05$)
Centritto et al. [27]/Italy	7,646 men and women aged ≥ 35 y living in southern Italy; randomly selected; excluded: known cardiovascular disease, diabetes, hypertension, hyperlipidemia		Factor analysis and RRR	Factor 2: “Western” (store-bought meats, chicken, fatty meats, snack chips, pizza, fried potatoes, soda, milk, cheese, ice cream)		
		FFQ with 188 items; collapsed into 45 groups		Factor 3: “purchased healthy” (dry beans, store-bought fruits, vegetables, dark bread, hot cereal)		
				Factor 4: “beverages and sweets” (coffee, tea, candy bars, sugar, syrup, pancakes)		
				Results from factor analysis: factor 1: “olive oil and vegetables” (olive oil, vegetables, legumes, soups, fruits, and fish); factor 2: “pasta and meat” (pasta, cooked tomatoes, red meat, animal fats, and alcoholic beverages, and negative loadings of breakfast cereals and yogurt); factor 3: “eggs and sweets” (eggs, margarines, processed meat, and sugar and sweets)	Not applicable	“Olive oil and vegetable” pattern inversely associated with SBP: Q1 vs Q5, 136.4 vs 134.7 mm Hg ($P=0.0012$); other patterns not associated with SBP
			3 factors explained 15.7 % variance	Results from RRR: 5 factors identified, only first factor (RRR1) retained in the study; RRR1 similar to “pasta and meat” pattern in factor analysis		RRR1 positively associated with SBP: Q1 vs Q5, 134.8 vs 136.6 mm Hg ($P=0.0019$)

Table 2 (continued)

Study/country/study name	Study population	Dietary questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Villegas et al. [28]/Ireland/Cork and Kerry Diabetes and Heart Disease Study	1,018 men and women, aged 50–69 y; stratified random sampling by age and sex was utilized; excluded: none	FFQ, collapsed into 22 groups	Cluster analysis	Cluster 1: “traditional” Cluster 2: “alcohol” Cluster 3: “prudent” (highest intake of pasta, rice, brown breads and unrefined cereals, spreads, poultry, fish, lowfat milk, dairy products, salad dressing, fruit, vegetables) In the analysis, light drinkers (3.5–7 U of alcohol/wk)+“prudent” dietary pattern was defined as “healthy eating cluster”	Not applicable	“Healthy eating cluster” was not associated with hypertension; a combination of 6 protective factors, including “healthy eating cluster,” was associated with lower risk of hypertension
Berg et al. [29]/Sweden/INTERGENE	3,452 men and women, aged 25–74 y; excluded: pregnant women	FFQ with 92 items	Cluster analysis	Cluster 1: “healthy” (high intake of fiber cereals, fruit and vegetables, lowfat milk products, tea, fish) Cluster 2: “sweet” Cluster 3: “coffee” Cluster 4: “traditional” Cluster 5: “fast energy”	Not applicable	Compared with “healthy” cluster, “fast energy” cluster had higher SBP (2.1 mm Hg higher) and DBP (1.6 mm Hg higher) Compared with “healthy” cluster, “coffee” cluster had higher DBP (0.9 mm Hg higher)

^a T refers to tertiles of dietary pattern scores: T1 is tertile 1; Q refers to quartiles or quintiles of dietary pattern scores: Q1 refers to quartile (or quintile) 1.

BP blood pressure, DBP diastolic blood pressure, EBP elevated blood pressure, FFQ food frequency questionnaire, RRR reduced rank regression, SBP systolic blood pressure

Table 3 Cross-sectional studies on dietary pattern and hypertension or blood pressure (*a posteriori* methods): studies in Eastern countries and other regions

Study/country/study name	Study population	Dietary questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Cho et al. [33]/Korea	4,984 women, aged 30–79 y, went for cancer screening in South Korea; excluded: none	FFQ with 16 items	Factor analysis	Factor 1: “Western” (fast foods, animal fat-rich foods, fried foods, grilled meat and seafoods, and sweet foods) Factor 2: “healthy” (green-yellow vegetables, healthy protein foods, seaweeds, and bonefish) Factor 3: “traditional” (salted vegetables and seafoods, cereals, and light-colored vegetables)	Not applicable	Factor 1 and 3 not associated with EBP Factor 2 inversely associated with EBP
Song and Joung [34]/Korea/Third Korean National Health and Nutrition Examination Survey (KNHANES)	4,730 men and women, aged >20 y; excluded: none	24-h diet recall, collapsed into 23 food groups	Cluster analysis	“Traditional” (white rice, vegetable, kimchi) “Meat and alcohol” (white rice, meat, alcohol) “Korean healthy” (grains, fruit, eggs, fish, milk)	Not applicable	OR for extreme quartiles, 0.75 (95 % CI, 0.62–0.91) No difference in SBP, DBP, as well as EBP among 3 patterns
Lee et al. [32]/Korea/Korean Health and Genome Study	3,581 men, aged 40–69 years; excluded: under treatment for cancer, hypertension, or diabetes	FFQ with 130 items, collapsed into 34 groups	Principal component factor analysis Eigen value >1.25	“Animal food” (raw and processed meats, fish, dairy products) “Rice-vegetable” (steamed rice, tofu, kimchi, soybean paste, yellow-green vegetables, vegetables, potatoes, sweet potatoes, salted-fermented fish, pickles, dried anchovies, and seaweed) “Noodle-bread” (instant noodles, noodles, Chinese noodles, and bread)	Sodium intake: “animal food” (not significant); rice-vegetable” (+); “noodle-bread” (-) Potassium intake: “animal food” (+); “rice-vegetable” (+); “noodle-bread” (-)	“Animal food,” “noodle-bread” not associated with hypertension “Rice-vegetable” positively associated with hypertension
Kim and Jo [30]/Korea/second and third KNHANES	9,850 men and women, aged >19 y; excluded: none	1-day 24-h dietary recall, categorized into 23 food groups	Factor analysis Eigen value >1.3 Variance explained 26.7 %	“White rice and kimchi” “Meat and alcohol” (alcohol, meat, noodles, dumplings) “High fat, sweets, and coffee” (oils, sugar and sweets, coffee) “Grains, vegetables, and fish” (vegetables, seasonings, grains) Factor 1: “traditional” (vegetables, fish, cereal) Factor 2: “Western” (fast foods, bread, meats, dairy products) Factor 3: “drinker” (pork, beer, Korean liquor)	Not applicable	Multivariate adjusted OR for extreme quintiles, 1.47 (95 % CI, 1.05–2.07) Mean SBP, 117.8 vs 113.2 mm Hg ($P<0.0001$); mean DBP, 75.9 vs 74.2 mm Hg (not significant) “Meat and alcohol” positively associated with EBP OR comparing extreme tertiles, 1.19 (95 % CI, 1.05–1.35) Other patterns not associated with EBP
Kim [31]/Korea/second KNHANES	1,869 men, aged 20–65 y; excluded: none	FFQ 62 items, collapsed to 38 groups	Factor analysis Eigen value >1.6 Scree plot	Factor 1: “traditional” (vegetables, fish, cereal) Factor 2: “Western” (fast foods, bread, meats, dairy products) Factor 3: “drinker” (pork, beer, Korean liquor)	Not applicable	No association between dietary pattern and hypertension
Wang et al. [37]/China/National Nutrition and Health Survey 2002	23,671 men and women, aged 18–59 y; excluded: known hypertension, diabetes, dyslipidemia, and stroke	FFQ with 33 items, collapsed into 23 groups; alcohol not included in dietary pattern analysis	Factor analysis Eigen value >1	Factor 1: “Western” (beef, lamb, dairy products, soft beverage, cake, juice) Factor 2: “traditional Northern” (high intake of wheat flour, starchy tubers, low intake of rice)	Sodium intake (Q1 vs Q4, mg/d): factor 1: 6196.6 vs 5841.0; factor 2: 5,895.0 vs 6,557.6; factor 3: 5,873.3 vs 6,491.5	“Western” pattern not associated with hypertension “Traditional Northern” positively associated with hypertension in multivariable adjusted model; OR for comparing Q1 and Q4, 1.30

Table 3 (continued)

Study/country/study name	Study population	Dietary questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Lee et al. [35]/China/Shanghai Men's Health Study	39,252 men, aged 40–74 y; excluded: known hypertension, diabetes, coronary heart disease, stroke, took antihypertensive medication	FFQ with 81 items	Scree test Factor analysis Variance explained 41.4 %	Factor 3: "traditional Southern" (fruit, pork, vegetable, aquatic products, poultry, nuts) Factor 1: "vegetable dietary pattern" (vegetables) Factor 2: "fruit and milk" (fruit, bread, and milk) Factor 3: "meat dietary pattern" (meat)	Sodium intake (Q5 vs Q1): factor 1: 2,698 vs 2,595 mg/d ($P=0.01$); factor 2: 2,476 vs 2,641 mg/d (not significant); factor 3: 2,589 vs 2,433 ($P<0.01$) Potassium intake (Q5 vs Q1): factor 1: 2,578 vs 1,651 mg/d ($P<0.01$); factor 2: 2,365 vs 1,820 mg/d ($P<0.01$); factor 3: 2,222 vs 1,954 ($P<0.01$)	(95 % CI, 1.11–1.53); association disappeared after adjusting for body mass index "Traditional Southern" inversely associated with hypertension; OR for comparing Q1 and Q4: 0.73 (95 % CI, 0.59–0.89) "Fruit and milk" pattern inversely associated with SBP, DBP; β for extreme quintiles: SBP: -2.9 (95 % CI, -3.4 to -2.4) mm Hg; DBP: -1.7 (95 % CI, -2.0 to -1.4) mm Hg "Meat" pattern positively associated with DBP, but not SBP; β for extreme quintiles: DBP, 0.3 (95 % CI, -0.0 to 0.6) mm Hg "Vegetable" pattern not associated with SBP or DBP None of the patterns associated with hypertension or SBP/DBP
Ganguli et al. [38]/India	701 women, aged >35 y; urban residents in West Bengal; excluded: acute illness and chronic debilitating diseases	FFQ with 99 items, collapsed into 24 groups; 24-h recall—nutrient intake	Factor analysis Eigen value >1.5	Factor 1: "vegetables, fruits, and pulses" Factor 2: "hydrogenated and saturated fat and vegetable oil" Factor 3: "red meat and high-fat dairy"	Correlation coefficient between fiber intake and dietary patterns: factor 1, -0.02 (not significant); factor 2, -0.18 ($P<0.01$); factor 3, 0.22 ($P<0.001$)	Delhi: "fruit-dairy" positively associated with hypertension; OR for extreme tertiles, 2.20 (95 % CI, 1.47–3.31) Mumbai: "fruit-vegetables" inversely associated with hypertension; OR for extreme tertiles, 0.63 (95 % CI, 0.40–0.99) Men: no association
Daniel et al. [39]/India/India Health Study	Men and women, aged 35–69 y in 3 regions (Delhi, 824; Mumbai, 743; Trivandrum, 2247); excluded: cancer, recent cardiac events, and blood disorders	Computer-based, diet history; 71, 85, 81 food items were entered in the region specific analyses	Factor or principal component analysis Region-specific analyses	Delhi: "fruit-dairy," "vegetables–pulses" Trivandrum: "pulses–rice," "sweets–snacks" Mumbai: "fruit–vegetables," "snack–meat"	Not applicable	Delhi: "fruit-dairy" positively associated with hypertension; OR for extreme tertiles, 2.20 (95 % CI, 1.47–3.31) Mumbai: "fruit-vegetables" inversely associated with hypertension; OR for extreme tertiles, 0.63 (95 % CI, 0.40–0.99) Men: no association
Sadakane et al. [40]/Japan/Jichi Medical School Cohort Study	6,886 men and women, aged 40–69 y, in 12 rural communities; excluded: under treatment for hypertension	FFQ with 30 items (frequency only, no portion size)	Factor analysis Eigen value >1	Factor 1: "vegetable" (vegetables, potatoes, tofu, fermented soybeans, fruits, seaweeds, citrus, beans, dried fish) Factor 2: "meat" (processed meats, beef, pork, poultry, steamed fish paste, high-fat products, butter)	Not applicable	Women: "vegetable" pattern inversely associated with SBP and DBP; SBP: Q1 vs Q5, 128.7 vs 124.1 mm Hg ($P<0.001$); DBP: Q1 vs Q5, 76.4 vs 74.5 mm Hg ($P=0.001$) "Western" pattern inversely associated with SBP; SBP: Q1 vs Q5, 128.0 vs 126.0 mm Hg ($P=0.0036$); DBP: Q1 vs Q5, 76.4 vs 75.4 mm Hg ($P=0.149$) In linear regression, using factor scores as dependent variable, history of hypertension was 1) positively associated with "healthy"
Rezaei et al. [41]/Iran	460 women, aged 20–50 y in Tehran; excluded: none	FFQ with 168 items, collapsed into 37 groups	Principal component analysis Eigen value >1.0	"Healthy" (vegetables, fruits, lowfat dairy products, yogurt drink, poultry, olive, nuts, fruit juice, coffee)	Not applicable	In linear regression, using factor scores as dependent variable, history of hypertension was 1) positively associated with "healthy"

Table 3 (continued)

Study/country/study name	Study population	Dietary questionnaire	Dietary pattern identification method	Dietary pattern composition	Sodium, potassium, fiber intake comparison across levels of dietary patterns ^a	Main results ^a
Ammini et al. [42]/Iran	425 men and women, aged 35–55 y with impaired glucose tolerance	FFQ with 39 items	Variance explained 14.9 % Factor analysis.	“Unhealthy” (processed meat, mayonnaise, soft drinks, sweets, refined grains, snacks, industrial juice, red meat, nuts, fats, French fries, high-fat dairy products, egg, organ meats, sugars) Factor 1: “Western” Factor 2: “prudent” Factor 3: “chicken and plants” Factor 4: “vegetarian” Factor 5: “high-fat dairy”	Not applicable	pattern score (β , 0.36 [95 % CI, 0.01–0.71]) and 2) not associated with “unhealthy” pattern score (β , -0.24 [95 % CI, -0.54 to 0.03]) “Western” positively associated with EBP; OR comparing T1 and T3, 2.62 (95 % CI, 1.32–5.23) Other patterns not associated with EBP
Nkondjock and Bizome [43]/Cameroon	571 member of defense forces, aged 21–60 y (89 % men)	FFQ with 100 items, collapsed into 29 groups	Factor analysis Eigen value >1.7 Scree plot Variance explained 17.5 %	Factor 1: “fruit and vegetable” (fresh fruits and green and dark yellow vegetables, tubers, legumes) Factor 2: “meat” (high intake of bush meat, poultry, red meat, with reduced intake of sweets, cakes, and sugar)	Not applicable	“Fruit and vegetable” inversely associated with hypertension; OR for extreme quartiles, 0.41 (95 % CI, 0.20–0.83)

^aT refers to tertiles of dietary pattern scores: T1 is tertile 1; Q refers to quartiles or quintiles of dietary pattern scores: Q1 refers to quartile (or quintile) 1
DBP diastolic blood pressure, EBP elevated blood pressure, FFQ food frequency questionnaire, SBP systolic blood pressure

analysis [22]. In the study, participants were controls from a community-based nonfatal acute myocardial infarction case–control study. Different dietary patterns were identified in men and women. No association between dietary patterns and BP was found in women. However, compared with the “healthy” dietary pattern, “meat and alcohol” and “intermediate intake” patterns (intermediate consumption of most foods, but of white meat) were associated with increased BP in men.

In Mexico, among 5,240 men and women 20 to 70 years of age, 3 dietary patterns were identified using factor analysis [23]. The participants in this study were employees and their relatives from three health and academic institutions. Those with known diabetes, hypertension, dyslipidemia, or rheumatoid arthritis were excluded from the analysis. A “Western” dietary pattern (high intake of pastries, refined cereals, corn tortillas, and soft drinks; low intake of whole cereals, seafood, and full-fat dairy products) was positively associated with EBP. Comparing tertile three with tertile one of the Western pattern, OR for EBP was 1.20 (95 % CI, 1.01–1.41). “Prudent” and “high protein/fat” dietary patterns were not associated with EBP.

In Southern Brazil, among 4,202 men and women (mean age, 23 years) in a birth cohort study in the city of Pelotas, “common Brazilian” (sugar, white bread, coffee, butter/margarine, rice, and black beans) was inversely associated with SBP and DBP in women [24]. Comparing the fifth with the first quintile of this pattern, the mean difference in SBP and DBP was 2.63 and 1.89 mm Hg lower, respectively. However, the “processed” food pattern (red and processed meats, salty snacks, French fries, beer, soda, and other processed foods) was not associated with BP in either gender.

In the Framingham Offspring study, among 2,875 participants without diabetes or not taking cholesterol-lowering medications, although a diet rich in fruit, vegetables, whole grains, and reduced fat dairy protected against insulin-resistant phenotypes, no association between dietary patterns and SBP or DBP was found [25].

A study of Alaskan Eskimos recruited 1,066 men aged 18 to 92 years. Dietary patterns were identified by factor analysis based on dietary information from a food frequency questionnaire (FFQ). It was found that a “traditional” pattern, which was rich in fish, native sea and land animal food, was inversely associated with SBP [26], whereas a “Western” diet was positively associated with SBP.

In a randomly selected Italian sample of 7,646 adults without known cardiovascular diseases, diabetes, hypertension, and hyperlipidemia, Centritto et al. [27] reported that an “olive oil and vegetable” pattern was inversely associated with SBP (quartile 1 vs quartile 5, 136.4 vs 134.7 mm Hg [$P=0.0012$]). In the study, both factor analysis and RRR were used to construct dietary patterns. A dietary pattern derived by RRR was similar to a “pasta and meat” pattern

from the factor analysis. This pattern was positively associated with SBP.

In Ireland, in the Cork and Kerry Diabetes and Heart Disease study, Villegas et al. [28] assessed the effect of core lifestyle behaviors on hypertension. A total of 1,018 adults aged 50 to 69 years were randomly selected with no exclusion of those with chronic diseases. Dietary patterns were constructed by cluster analysis. A “healthy eating cluster” was defined as light drinkers (3.5–7 U of alcohol per week) with a “prudent” dietary pattern (highest intake of pasta, rice, brown breads and unrefined cereals, spreads, poultry, fish, lowfat milk, dairy products, salad dressing, fruit, and vegetables). Although the “healthy eating cluster” was not associated with hypertension, its combination with other protective factors was inversely related to hypertension.

Based on data from the INTERGENE population study of women and men aged 25 to 74 years in western Sweden, Berg et al. [29] found “fast energy” and “coffee” clusters had higher BP as compared with the “healthy” cluster. In the analysis excluding those with known chronic diseases, the association did not change.

Studies in Asian Countries

Five studies have been performed in the Korean population, four of which used factor analysis to define dietary patterns [30, 31–33] and one used cluster analysis [34]. Based on the third Korean National Health and Nutrition Examination Survey (KNHANES) data, using cluster analysis, three dietary patterns were identified: “traditional,” “meat and alcohol,” and “Korean healthy.” There were no difference in SBP and DBP between the three patterns [34]. In the Korean Health and Genome study [32], among 3,581 men aged 40 to 69 years, a “rice–vegetable” dietary pattern was positively associated with hypertension. Comparing the extreme quintiles of the pattern, the OR for hypertension was 1.47 (95 % CI, 1.05–2.07). Using data from the second and third KNHANES, Kim and Jo [30] found the “meat and alcohol” pattern defined by factor analysis was positively associated with EBP, while no association between the “grain, vegetable, and fish” pattern and EBP was seen. Using data from the second KNHANES, three dietary patterns (“traditional,” “Western,” and “drinker”) were identified and were not associated with hypertension [31]. None of these studies found an inverse association between the “traditional” vegetable-rich food pattern and hypertension. In a cohort of 4,984 Korean women aged 30 to 79, a “traditional” pattern with high loading of cereals, green-yellow vegetables, salted vegetables, and light-colored vegetables was not related to the risk of hypertension [33]. However, a “healthy” pattern with high loading of green-yellow vegetables, healthy-protein foods, seaweeds, and bonefish was inversely related to the risk of hypertension (OR for extreme

quartiles, 0.75 [95 % CI, 0.62–0.91]). In all five studies, intake of salt and different types of fat was not assessed. Only one study assessed the association between dietary pattern and sodium intake [32].

Two of the largest studies were undertaken in China, with each sample size more than 20,000 (one was a regional study in Shanghai, the other a nationwide study). In the Shanghai Men's Health study, the largest study (with 39,252 men aged 40–74 years without known hypertension), three dietary patterns were identified: “vegetable,” “fruit and milk,” and “meat” dietary patterns [35]. These patterns were similar to patterns found in another Chinese study, the Jiangsu Nutrition Study [36]. No association between a “vegetable” pattern and SBP/DBP was found. A “fruit and milk” pattern was inversely associated with both SBP and DBP. The difference in SBP/DBP between extreme quintiles of this pattern was substantial (SBP, -2.9 [95 % CI, -3.4 to -2.4] mm Hg; DBP, -1.7 [95 % CI, -2.0 to -1.4] mm Hg). The second largest study from China involved 23,671 participants aged 18 to 59 years [37]. It is based on the 2002 China National Nutrition and Health Survey. The analysis excluded those with known hypertension, diabetes, dyslipidemia, and stroke before the survey. Three dietary patterns were identified using factor analysis: “Western” (meat, dairy products, soft drinks, cake, and juice), “traditional Northern” (high intake of wheat flour but low in rice), and “traditional Southern” (fruit, vegetable, aquatic products). The three dietary patterns were all associated with new hypertension after adjusting for age and gender. The traditional Northern patterns were positively associated, and the traditional Southern pattern was inversely associated with hypertension in multivariable analyses; the Western pattern was without effect. The association between the traditional Northern dietary pattern and hypertension was substantially attenuated (until it was nonsignificant) after adjusting for body mass index.

In a cohort of 701 randomly selected Indian women living in urban West Bengal, the prevalence of hypertension was 47.8 %. Dietary intake was assessed by FFQ and 24-hour recall. Despite an inverse association between the “vegetables, fruits and pulse” pattern and total cholesterol (low-density lipoprotein cholesterol), this dietary pattern was not related to hypertension or SBP/DBP. None of the other identified dietary patterns were associated with hypertension [38]. In the India Health Study, men and women aged 35 to 69 years living in three regions (Delhi, Mumbai, and Trivandrum) were randomly selected. Different dietary patterns were identified in each region [39]. In Delhi, a “fruit–dairy” pattern was positive associated with hypertension; OR for extreme tertiles was 2.20 (95 % CI, 1.47–3.31). In Mumbai, a “fruit–vegetables” pattern was inversely associated with hypertension; OR for extreme tertiles was 0.63 (95 % CI, 0.40–0.99). In Trivandrum, no association between dietary patterns and hypertension was found.

In Japan, in the Jichi Medical School Cohort study [40], a “vegetable” pattern was inversely associated with SBP and DBP in women, but not in men. The difference in SBP between extreme quartiles reached 4.6 mm Hg. However, in the study, a “Western” pattern was inversely related to BP in women. The dietary information in this study was based on a 30-item FFQ without portion size.

Two studies from Iran (each sample size <500) assessed the association between dietary pattern and hypertension. In the study by Rezazadeh et al. [41] among 460 randomly selected women in Tehran, it was found that history of hypertension was positively related to “healthy” pattern score. In the study by Amini et al. [42] among 425 participants with impaired glucose tolerance, a “Western” dietary pattern was positively associated with EBP. No association between other dietary patterns and hypertension was found.

Other Regions

A cross-sectional study of 571 members of defense forces in Cameroon found an inverse association between a “fruits and vegetables” pattern and hypertension [43]. The OR for hypertension comparing extreme quartiles was 0.41 (95 % CI, 0.20–0.83).

Discussion

The majority of the dietary patterns in this paper were identified using factor analysis based on dietary data from FFQs. The number of patterns ranged from two to six. A few dietary patterns were based on dietary data from 24-hour recall. In general, a “Western” and a “prudent” dietary pattern were seen across populations. However, the associations between dietary patterns seem different according to populations. In Western populations, a positive association between a “Western” dietary pattern and hypertension or SBP/DBP was often observed, while an inverse association between a “prudent” pattern and hypertension or SBP/DBP was found. The association between a “prudent” pattern and hypertension was not seen in some Asian countries.

Western Dietary Pattern and Hypertension

Half the studies in Western countries found a positive association between “Western,” “processed meat,” and “meat and alcohol” patterns and hypertension [21–23, 26, 29]; others found no association [18, 19, 24, 25, 27]. In general, no such association between “meat and alcohol” and “Western” pattern and hypertension or BP was found in studies undertaken in Asia [31–34, 37, 38, 39, 41], with the exception of four studies that

demonstrated a positive association between this pattern and hypertension or BP [30•, 35, 40, 42].

Typical Western diets contain processed foods low in fiber and high in refined carbohydrates, fats (especially saturated fats), and salt. High trans-fatty acid content in Western diet is also a concern, as it increases the risk of cardiovascular disease. From existing studies, it is difficult to explain the Eastern-Western difference with regard to Western diet and BP. Most of the studies included did not provide information on intake of type of fat, fiber, and sodium. Lifestyle factors and socioeconomic status related to dietary patterns may also explain the difference. Smoking and alcohol consumption are common in men living in Asia. Furthermore, people in Asia have lower body mass index in general than their counterparts in Western countries. The association between a Western dietary pattern and BP could be confounded by these factors in Asia.

Vegetable-Rich Pattern and Hypertension

Dietary patterns rich in vegetables are associated with reduced risk of hypertension or lower levels of BP in Western populations [19, 21, 22, 24, 26, 27, 29]. In Asian populations, the association between a vegetable-rich dietary pattern and hypertension or BP remains uncertain. The majority of the studies found no association between a vegetable-rich diet and BP. Only two studies found an inverse association between a vegetable-rich pattern and BP [37•, 40]. In contrast, one Korean study [32] found a positive association between a vegetable-rich pattern and hypertension. Some researchers suggest that the cooking method for vegetables may partially explain the null association. In Asian countries such as China and Korea, vegetables are often stir-fried or cooked with salt. A vegetable-rich dietary pattern was positively associated with obesity [44] and higher weight gain over 5 years in a Chinese population [36]. In the Shanghai Women's Health Study, there was no association between a vegetable-rich dietary pattern and mortality, while a fruit-rich diet was related to a lower risk of mortality [45].

Methodologic Issues

Posterior dietary pattern approaches need subjective judgments, including the collapsing of food items and number of factors or clusters to be retained. The validity and reproducibility of these identified dietary patterns have yet to be tested. Although such tests have been done in the United States [46], they are not available in Asian countries. Studies comparing posterior dietary patterns with *priori* dietary pattern in association with BP are limited.

There are six studies using national representative samples. In contrast, many of the other studies were not representative

of the general population, as some studies recruited patients and controls in a case-control study, workers in the workplace, and individuals going for cancer screening. While most of the studies done in general populations excluded participants with known chronic diseases, including hypertension, some studies included all the participants in the analysis. Direct comparison between studies is not possible due to the substantial difference in the samples.

Salt intake is an important factor influencing BP. However, the majority of the studies did not assess salt intake. The difference in salt intake by dietary patterns is not known. Associations between dietary patterns without salt intake and BP may not be the same as those dietary patterns with salt intake. Further study is needed in this field. Some studies have the potential to clarify this. For example, in the China National Nutrition and Health Survey 2002, salt intake was assessed using weighted food records. It is a limitation that cooking oil is not incorporated in dietary pattern analysis in most studies. In Asia, stir-frying vegetables using oil is common. The liberal use of cooking oil is of concern.

Another limitation in the studies is the lack of information on nutrient intake, including sodium, potassium, and type of fatty acids. Without this information, it is difficult to interpret the associations between dietary patterns and BP.

Because most of the identified studies are cross-sectional, no conclusion on causation can be made. Despite excluding known hypertension and other chronic diseases in some studies, reverse causation is possible. People with unknown hypertension may have changed their dietary habits due to other chronic conditions, including overweight/obesity. Excluding those with known chronic conditions may attenuate the association between dietary patterns and hypertension if these chronic conditions were caused by the dietary patterns.

Future Directions

To better understand the association among diets, dietary patterns, and hypertension, the following research is needed: 1) direct comparison of these dietary patterns (posterior and *priori* methods) within the same study; 2) investigation of the effects of individual dietary components independent of the overall dietary pattern, especially the interaction between salt and dietary patterns; 3) investigation into whether dietary patterns using FFQs are similar to those using 24-hour recall in the same study (Schwenke [47••] summarized some of the recent studies using these analytical approaches regarding to dietary patterns and health outcomes); and 4) migrant studies and international comparison studies. Finally, more prospective studies are needed.

Conclusions

Posterior dietary patterns are related to hypertension, although substantial regional differences exist. There is an Eastern–Western difference in the association between dietary patterns and hypertension. Posterior dietary pattern approaches can provide useful information in creating dietary guidelines. However, further research is needed in this field.

Disclosure No potential conflicts of interest relevant to this article were reported.

References

1. Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJ. Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. *Lancet*. 2006;367(9524):1747–57.
2. Appel LJ, Giles TD, Black HR, Izzo Jr JL, Materson BJ, Oparil S, et al. ASH position paper: dietary approaches to lower blood pressure. *J Am Soc Hypertens*. 2010;4(2):79–89.
3. Altorf-van der Kuil W, Engberink MF, Brink EJ, van Baak MA, Bakker SJ, Navis G et al. Dietary protein and blood pressure: a systematic review. *PLoS ONE*. 2010;5(8):e12102.
4. Galan P, Vergnaud AC, Tzoulaki I, Buyck JF, Blacher J, Czernichow S, et al. Low total and nonheme iron intakes are associated with a greater risk of hypertension. *J Nutr*. 2010;140(1):75–80.
5. Tzoulaki I, Brown IJ, Chan Q, Van Horn L, Ueshima H, Zhao LC et al. Relation of iron and red meat intake to blood pressure: cross sectional epidemiological study. *Br Med J*. 2008;337(7663).
6. Champagne CM. Magnesium in hypertension, cardiovascular disease, metabolic syndrome, and other conditions: a review. *Nutr Clin Pract*. 2008;23(2):142–51.
7. Elliott P, Kesteloot H, Appel LJ, Dyer AR, Ueshima H, Chan Q, et al. Dietary phosphorus and blood pressure: international study of macro- and micro-nutrients and blood pressure. *Hypertension*. 2008;51(3):669–75.
8. Ueshima H, Stamler J, Elliott P, Chan Q, Brown IJ, Carnethon MR, et al. Food omega-3 fatty acid intake of individuals (total, linolenic acid, long-chain) and their blood pressure: INTERMAP study. *Hypertension*. 2007;50(2):313–9.
9. Brown IJ, Stamler J, Van Horn L, Robertson CE, Chan Q, Dyer AR et al. Sugar-Sweetened Beverage, Sugar Intake of Individuals, and Their Blood Pressure: International Study of Macro/Micro-nutrients and Blood Pressure. *Hypertension*. 2011.
10. Sakurai M, Stamler J, Miura K, Brown IJ, Nakagawa H, Elliott P, et al. Relationship of dietary cholesterol to blood pressure: the INTERMAP study. *J Hypertens*. 2011;29(2):222–8.
11. • Imamura F, Jacques PF. Invited Commentary: Dietary Pattern Analysis. *American Journal of Epidemiology*. 2011;173(10):1105–8. *This commentary describes the methodologic issues related to dietary pattern analysis.*
12. Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. *Nutr Rev*. 2004;62(5):177–203.
13. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol*. 2002;13(1):3–9.
14. Schulze MB, Hu FB. Dietary patterns and risk of hypertension, type 2 diabetes mellitus, and coronary heart disease. *Curr Atheroscler Rep*. 2002;4(6):462–7.
15. Baxter AJ, Coyne T, McClintock C. Dietary patterns and metabolic syndrome—a review of epidemiologic evidence. *Asia Pac J Clin Nutr*. 2006;15(2):134–42.
16. • Timmermans S, Steegers-Theunissen RP, Vujkovic M, Bakker R, den Breeijen H, Raat H et al. Major dietary patterns and blood pressure patterns during pregnancy: the Generation R Study. *Am J Obstet Gynecol*. 2011;205(4):337 e1–e12. *This large cohort study described the association between dietary patterns and BP among pregnant women.*
17. Nafar M, Noori N, Jalali-Farahani S, Hosseinpanah F, Poorrezagholi F, Ahmadpoor P, et al. Mediterranean diets are associated with a lower incidence of metabolic syndrome one year following renal transplantation. *Kidney Int*. 2009;76(11):1199–206.
18. Ambrosini GL, Huang RC, Mori TA, Hands BP, O'Sullivan TA, de Klerk NH, et al. Dietary patterns and markers for the metabolic syndrome in Australian adolescents. *Nutr Metab Cardiovasc Dis*. 2010;20(4):274–83.
19. McNaughton SA, Ball K, Mishra GD, Crawford DA. Dietary patterns of adolescents and risk of obesity and hypertension. *J Nutr*. 2008;138(2):364–70.
20. Aounallah-Skhiri H, Traissac P, El Ati J, Eymard-Duvernay S, Landais E, Achour N, et al. Nutrition transition among adolescents of a south-Mediterranean country: dietary patterns, association with socio-economic factors, overweight and blood pressure. A cross-sectional study in Tunisia. *Nutr J*. 2011;10:38.
21. Heidemann C, Scheidt-Nave C, Richter A, Mensink GB. Dietary patterns are associated with cardiometabolic risk factors in a representative study population of German adults. *Br J Nutr*. 2011;106(8):1253–62.
22. Oliveira A, Rodriguez-Artalejo F, Gaio R, Santos AC, Ramos E, Lopes C. Major habitual dietary patterns are associated with acute myocardial infarction and cardiovascular risk markers in a southern European population. *J Am Diet Assoc*. 2011;111(2):241–50.
23. Denova-Gutierrez E, Castanon S, Talavera JO, Gallegos-Carrillo K, Flores M, Dosamantes-Carrasco D, et al. Dietary patterns are associated with metabolic syndrome in an urban Mexican population. *J Nutr*. 2010;140(10):1855–63.
24. Olinto MT, Gigante DP, Horta B, Silveira V, Oliveira I, Willett W. Major dietary patterns and cardiovascular risk factors among young Brazilian adults. *Eur J Nutr*. 2011.
25. Liu E, McKeown NM, Newby PK, Meigs JB, Vasan RS, Quatromoni PA, et al. Cross-sectional association of dietary patterns with insulin-resistant phenotypes among adults without diabetes in the Framingham Offspring Study. *Br J Nutr*. 2009;102(4):576–83.
26. Eilat-Adar S, Mete M, Nobmann ED, Xu J, Fabsitz RR, Ebbesson SO, et al. Dietary patterns are linked to cardiovascular risk factors but not to inflammatory markers in Alaska Eskimos. *J Nutr*. 2009;139(12):2322–8.
27. Centritto F, Iacoviello L, di Giuseppe R, De Curtis A, Costanzo S, Zito F, et al. Dietary patterns, cardiovascular risk factors and C-reactive protein in a healthy Italian population. *Nutr Metab Cardiovasc Dis*. 2009;19(10):697–706.
28. Villegas R, Kearney PM, Perry IJ. The cumulative effect of core lifestyle behaviours on the prevalence of hypertension and dyslipidemia. *BMC Public Health*. 2008;8:210.
29. Berg CM, Lappas G, Strandhagen E, Wolk A, Toren K, Rosengren A, et al. Food patterns and cardiovascular disease risk factors: the Swedish INTERGENE research program. *Am J Clin Nutr*. 2008;88(2):289–97.

30. • Kim J, Jo I. Grains, vegetables, and fish dietary pattern is inversely associated with the risk of metabolic syndrome in South Korean adults. *J Am Diet Assoc.* 2011;111(8):1141–9. *This large cross-sectional study was based on data from two national nutrition surveys in Korea.*
31. Kim YO. Dietary patterns associated with hypertension among Korean males. *Nutr Res Pract.* 2009;3(2):162–6.
32. Lee JE, Kim JH, Son SJ, Ahn Y, Lee J, Park C, et al. Dietary pattern classifications with nutrient intake and health-risk factors in Korean men. *Nutrition.* 2011;27(1):26–33.
33. Cho YA, Kim J, Cho ER, Shin A. Dietary patterns and the prevalence of metabolic syndrome in Korean women. *Nutr Metab Cardiovasc Dis.* 2011;21(11):893–900.
34. Song Y, Joung H. A traditional Korean dietary pattern and metabolic syndrome abnormalities. *Nutr Metab Cardiovasc Dis.* 2011.
35. Lee SA, Cai H, Yang G, Xu WH, Zheng W, Li H, et al. Dietary patterns and blood pressure among middle-aged and elderly Chinese men in Shanghai. *Br J Nutr.* 2010;104(2):265–75.
36. Shi Z, Yuan B, Hu G, Dai Y, Zuo H, Holmboe-Ottesen G. Dietary pattern and weight change in a 5-year follow-up among Chinese adults: results from the Jiangsu Nutrition Study. *Br J Nutr.* 2011;105(7):1047–54.
37. • Wang D, He Y, Li Y, Luan D, Yang X, Zhai F et al. Dietary patterns and hypertension among Chinese adults: a nationally representative cross-sectional study. *BMC Public Health.* 2011;11(1):925. *This was one of the largest cross-sectional studies using data from national nutrition surveys in China.*
38. Ganguli D, Das N, Saha I, Biswas P, Datta S, Mukhopadhyay B, et al. Major dietary patterns and their associations with cardiovascular risk factors among women in West Bengal, India. *Br J Nutr.* 2011;105(10):1520–9.
39. Daniel CR, Prabhakaran D, Kapur K, Graubard BI, Devasenapathy N, Ramakrishnan L, et al. A cross-sectional investigation of regional patterns of diet and cardio-metabolic risk in India. *Nutr J.* 2011;10:12.
40. Sadakane A, Tsutsumi A, Gotoh T, Ishikawa S, Ojima T, Kario K, et al. Dietary patterns and levels of blood pressure and serum lipids in a Japanese population. *J Epidemiol.* 2008;18(2):58–67.
41. Rezazadeh A, Rashidkhani B, Omidvar N. Association of major dietary patterns with socioeconomic and lifestyle factors of adult women living in Tehran, Iran. *Nutrition.* 2010;26(3):337–41.
42. Amini M, Esmailzadeh A, Shafaeizadeh S, Behrooz J, Zare M. Relationship between major dietary patterns and metabolic syndrome among individuals with impaired glucose tolerance. *Nutrition.* 2010;26(10):986–92.
43. Nkondjock A, Bizome E. Dietary patterns associated with hypertension prevalence in the Cameroon defence forces. *Eur J Clin Nutr.* 2010;64(9):1014–21.
44. Shi Z, Hu X, Yuan B, Hu G, Pan X, Dai Y, et al. Vegetable-rich food pattern is related to obesity in China. *Int J Obes.* 2008;32(6):975–84.
45. Cai H, Shu XO, Gao YT, Li H, Yang G, Zheng W. A prospective study of dietary patterns and mortality in Chinese women. *Epidemiology.* 2007;18(3):393–401.
46. Hu FB, Rimm E, Smith-Warner SA, Feskanich D, Stampfer MJ, Ascherio A, et al. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *Am J Clin Nutr.* 1999;69(2):243–9.
47. •• Schwenke DC. Nutrition and metabolism—dietary patterns: evidence for the critical importance of vegetables builds. *Curr Opin Lipidol.* 2011;22(3):239–42. *This is an excellent editorial on dietary patterns and health outcomes.*