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DIETARY PATTERNS AND BEHAVIOR (LM STEFFEN, SECTION EDITOR)

Dietary Patterns, Smoking, and Cardiovascular Diseases: A Complex Association

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Abstract Diet and cigarette smoking are key determinants of cardiovascular diseases (CVD). The associations of some nutrients/foods with CVD are unclear, however, and the dietary pattern approach may better inform the relationships. Furthermore, diet and smoking often occur together as part of lifestyle patterns. In this article, studies that evaluated the associations of dietary patterns and smoking status with CVD as well as relationships between lifestyle patterns and CVD were reviewed. Evidence supports the protective role of plant-based dietary patterns for coronary artery disease (CAD) and cardiovascular mortality among nonsmokers and smokers. The interrelationships of dietary patterns and smoking status on subclinical CVD, stroke, hypertension, heart failure, and peripheral arterial disease are inconclusive. Dietary patterns high in refined grains, meats, and sugar-sweetened beverages are harmful, especially for smokers. A healthy lifestyle protects against CAD, hypertension, and cardiovascular mortality, and probably stroke. More prospective studies in diverse populations would be beneficial.

Keywords Cardiovascular diseases · Diet quality · Dietary pattern · Lifestyle pattern · Prevention · Smoking

Introduction

Cardiovascular diseases (CVD) remain the leading cause of morbidity and mortality globally accounting for an estimated 12 % of the global disease burden [1••] and approximately US$863 billion in healthcare costs [2•, 3]. Approximately one-third of deaths in adults both globally and in the United States are attributable to CVD [2•, 4•].

Diet is a key determinant of CVD, and a large body of literature has examined the impact of the roles of individual foods, nutrients, and beverages [5–7]. The Global Burden of Disease Study 2010 found that dietary factors that contributed the most to the global CVD burden were diets low in fruits and high in sodium as well as those low in nuts and seeds, whole grains, vegetables, docosahexaenoic acid, and eicosapentaenoic acid [8•]. In the United States, diets high in salt and trans fatty acids and low in omega-3 fatty acids were the most prevalent factors in 2005 [9]. While there is strong evidence for the cardioprotective effects of fruits, vegetables, whole grains, nuts, omega-3 fatty acids, and moderate alcohol intake and harmful effects of *trans* fatty acids and high salt intake [10–12], evidence for the associations of saturated fatty acids, monounsaturated fatty acids, and linoleic acid with CVD is inconclusive due in part to collinearity among the lipids [11, 13–15], which is difficult to examine in "single nutrient" studies. Challenges like these have led to the growing appreciation for considering dietary patterns in nutritional epidemiologic research when examining associations between diet and health outcomes. The dietary pattern approach, which considers the cumulative effects and interactions of nutrients and foods as well as biological interactions among nutrients/foods and other metabolic factors, has emerged as an alternative and complementary approach to the conventional single nutrient/food analysis and is strategic in guiding nutrition policy [6, 7, 16, 17••, 18].

Smoking is an additional lifestyle variable associated with CVD, and tobacco use is the single major preventable cause of mortality, contributing to approximately 10 % of cardiovascular deaths globally and one-third of CVD deaths in the United States [9, 19–21]. Nearly a quarter (24 %) of adults worldwide and one-fifth (19 %) of U.S. adults are cigarette smokers [22, 23]. Compared with nonsmokers,

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smokers have a two- to fourfold risk for both coronary artery disease (CAD) and stroke [21, 24, 25]. Smoking cessation lowers risk of nonfatal myocardial infarction (MI) by approximately 32 % and that of mortality by 36 % among smokers with CAD; approximately 5 years after quitting, smokers' risk of stroke is equivalent to that of nonsmokers [4•, 20, 21]. Notably, improved diet and decreases in cigarette smoking (albeit offset recently by the rising obesity rates) in addition to better treatment have contributed to much of the decline in cardiovascular mortality globally during the past three decades [26].

Whereas smoking and diet both contribute independently to CVD, the two exposures often are correlated and often occur together as part of overall lifestyle patterns, an expansion of the dietary pattern approach in which multiple behaviors are included in a distinct pattern (e.g., diet, smoking, physical activity, sedentary behavior, alcohol use, etc.) [27–38]. The goal of this article was to review studies that have considered the role of smoking status on the relationship between dietary patterns and CVD as well as studies that evaluated associations of lifestyle patterns and CVD.

Dietary and Lifestyle Patterns, Smoking, and CVD

As noted, two types of dietary patterns are commonly used in nutritional epidemiology. *A priori* or theoretical patterns are hypothesis-driven and are based on expert dietary guidelines (such as the Healthy Eating Index [39]), which measures adherence to the U.S. *Dietary Guidelines for Americans* [40]), healthful traditional diets (such as the Mediterranean diet [41]), or composite evidence-based nutrients and foods (such as the Alternate Healthy Eating Index [42]). *A priori* patterns use a score-based approach and are generally termed diet quality indices [16, 43–45]. *A posteriori* or empirical patterns are data-driven and define food and nutrient intake as actually consumed. They are derived statistically mainly by factor analysis and less commonly by cluster analysis. Reduced rank regression, less frequently employed, utilizes food groups that maximally explain intermediary biomarkers of disease to predict health outcomes and derives a hybrid of *a priori* and *posteriori* patterns [16, 43, 46].

In various populations, CVD-protective dietary patterns are characterized by greater consumption of plant-based foods, such as vegetables, fruits, nuts, and whole grains, lean proteins, such as fish, poultry, and soy, unsaturated vegetable oils, and moderate alcohol consumption. Conversely, CVD-promoting patterns generally include higher intakes of refined grains, red and processed meats, *trans* fats, and sugar-sweetened beverages [43–48, 49•]. Dietary intakes are shown to differ by smoking status. For example, nonsmokers and former smokers tend to have higher quality diets [50–55]; the converse is true of smokers [50, 52, 53, 55–58]. Moreover, unhealthy lifestyle habits, including poor quality diet, high alcohol intake, cigarette smoking, and physical inactivity, tend to cluster [27–38]. Thus, smoking can be considered as both a potential confounder and effect modifier of the diet-CVD relationship. Specifically, smoking is correlated with both diet and CVD but is not in the causal pathway, thus it may confound the association if not controlled for in multivariable adjustment. As an effect modifier, smoking may modify the effect of diet on CVD risk or may interact with diet such that its impact on CVD varies depending on whether one is a smoker or not. Studies considering the interrelations of diet, smoking, and CVD have tested for both confounding and interaction (effect modification) effects.

Mechanisms that Link Diet and Smoking with CVD

Atherosclerosis, whereby plaque builds up in the arteries, is one mechanism underlying the development of CVD [4•, 59]. Inflammation is the key underlying feature of atherosclerosis [59]. Such dietary factors as refined carbohydrates and animal fat are hypothesized to induce oxidative stress that stimulates secretion of proinflammatory cytokines [60, 61]. Other foods and nutrients, including fruits, vegetables, fiber, and alcohol are anti-inflammatory and suppress oxidative stress, as do bioactive compounds, such as phenolic compounds in extra virgin oil and resveratrol in red grapes [60, 61]. Smoking similarly causes oxidative stress [21].Additionally, smoking induces insulin resistance that partly underlies the development of obesity, hypertension, glucose intolerance, and dyslipidemias (hypertriglyceridemia, elevated LDL-cholesterol, and low HDL-cholesterol), which are established risk factors for CVD. Furthermore, hypertrophied adipocytes particularly visceral adipocytes produce free fatty acids (FFA), which in turn stimulate insulin resistance, inflammation, and oxidative stress. Adipocytes also produce proinflammatory cytokines. Insulin resistance further enhances lipolysis and increases FFA production, resulting in a vicious circle of lipolysis, increased FFA, insulin resistance, and inflammation. Smoking likewise causes hypertension through the sympathomimetic effects of nicotine [21, 61–63]. Smoking cessation promotes insulin sensitivity thereby improving metabolic profile [21].

Associations of *A Priori* Dietary Patterns and Smoking Status with CVD

One cross-sectional study [64] and 17 prospective studies [35, 65–80] in the United States and Europe have evaluated the interrelationships of smoking status and a broad range of diet quality indices with CVD. The Study of Health in Pomerania examined the cross-sectional association between lifestyle factors and carotid atherosclerosis among men and women [64]. Mean carotid intima media thickness values were higher in never smokers with an unfavorable Food

frequency pattern (higher in meats, potatoes, pasta, and lower in vegetables, fruits, fish) compared with those with an optimal pattern (0.750 vs. 0.723 mm; $P<0.04$). Dietary patterns were not associated with carotid atherosclerosis among smokers.

Prospective studies are better able to show clear associations between exposures and disease, and many studies have prospectively examined the effect of smoking status on the relationship between diet quality indices and CAD, stroke, heart failure, total CVD, and cardiovascular mortality [35, 65–80] (Table 1). No statistically significant interactions were reported in any of the studies that tested for interactions [35, 65–67, 69–73, 75–78, 80]. However, interaction effects can be difficult to detect [17••, 81] and statistical interaction must be evaluated in light of biological plausibility. Furthermore, while smoking can occur as part of an overall lifestyle pattern, smoking also can confound diet–CVD relationships. Five studies thus conducted stratified analyses despite the nonsignificant interactions [67, 69–71, 73] and two studies stratified analyses based on *a priori* hypotheses [68, 80]. In the Nurses' Health Study, a higher Alternate Mediterranean Diet (aMED) score (higher in vegetables, fruits, whole grains, legumes, nuts, fish, ratio of monounsaturated to saturated fat, lower in red and processed meats, and moderate in alcohol) conferred lower risk for CAD in all women than a lower score (relative risk (RR) 0.71; 95 % confidence interval (CI) 0.62–0.82), a finding that was attenuated and became insignificant in current smokers (RR 0.81; 95 % CI 0.56–1.77). However, the index was not associated with stroke overall or among nonsmokers and smokers [67].

The Dietary Approaches to Stop Hypertension (DASH) diet that is high in vegetables, fruits, whole grains, legumes, nuts, and low-fat dairy and low in red meats, processed meats, refined grains, sugar-sweetened beverages, and sodium [82] is recommended as an example of a healthy pattern by the U.S. *Dietary Guidelines for Americans* [40] and the American Heart Association [18] for CVD prevention. Women in the Nurses' Health Study with high intakes on foods included in the DASH diet similarly had lower risk for CAD when comparing the extreme quintiles. However, unlike the aMED, risk for CAD was lower among smokers (35 %) than nonsmokers (20 %) as was risk for stroke (33 % vs. 10 % in nonsmokers) [69]. The DASH diet also lowered risk for heart failure among nonsmokers (RR 0.63; 95 % CI 0.48–0.81) in the Swedish Mammography Cohort [70] but was not associated with heart failure among nonsmokers or smokers in the Cohort of Swedish Men [71]. Adjusting for cigarette smoking, which was considered as a confounder, is reported to have had the strongest influence on the inverse association of the DASH diet with total CVD in the Women's Health Study and attenuated the findings. Additional stratified analyses were not done [74].

Health effects of carbohydrate-restricted diets are unclear and likely depend on type of fat and protein consumed as part of the overall dietary pattern. Three low-carbohydrate diets, including an overall low-carbohydrate-diet (high in fat and protein and low in carbohydrate), a vegetable low-carbohydrate (high in vegetable protein and fat), and an animal low-carbohydrate (high in animal protein and fat) were evaluated for their interactions with smoking status on CAD [68•] and cardiovascular mortality [80] in the Nurses' Health Study (NHS) and the Health Professionals Follow-up Study (HPFS). The overall low-carbohydrate-diet index was not associated with CAD in women (NHS) or cardiovascular mortality among women and men (HPFS). However, the vegetable low-carbohydrate score lowered risk for mortality in both women (RR 0.77; 95 % CI 0.66–0.91) and men (RR 0.77; 95 % CI 0.65–0.92), whereas an animal low-carbohydrate score conferred risk for mortality in men only (RR 1.21; 95 % CI 1.01–1.44), comparing the highest and lowest deciles. Smoking status had no effect on these relationships.

The relationship of the dietary behavior score and smoking status with CAD mortality was assessed in the National Institutes of Health–American Association of Retired Persons Diet and Health Study. Participants with a higher score (higher in vegetables, fruits, whole grains, low-fat dairy, lean meats, poultry, and lower in solid fat intake) had a lower risk for CAD mortality relative to those with a lower score. Findings for the stratified analyses were not presented [67].

In summary, limited evidence based on only one cross-sectional study suggests higher quality diet is beneficial for nonsmokers with subclinical CVD. For CAD, evidence supports a protective effect of high-quality diet in nonsmokers than smokers. Findings for stroke based on two studies in one cohort of women are limited and inconclusive, which necessitates more studies in other populations. Studies on stroke subtypes also are essential because subtypes differ in their pathophysiology [83, 84]. Evidence for the associations of diet quality indices and smoking status with heart failure is equivocal. Additionally, studies on heart failure subtypes are needed as underlying mechanisms may vary [85]. Findings for total CVD are uncertain, but studies on individual diseases may be more informative. Accruing evidence for mortality suggests that high-quality diet benefits both nonsmokers and smokers. Conversely, lower diet quality confers risk for both groups of smokers. There are no studies on peripheral artery disease (PAD), yet smoking is the strongest behavioral risk factor for the condition [86].

Associations of *A Posteriori* Dietary Patterns and Smoking Status with CVD

Most of the studies that examined relationships of smoking status and *a posteriori* patterns with CVDs were in the United States and Europe [65, 87–97].

Table 1 Associations of *a priori* dietary patterns and smoking status with cardiovascular diseases in prospective studies[a]

Reference	Study population	Sex (%)	F/U (yrs)	Diet Quality Index	Results
Coronary artery disease					
Osler *et al*., 2002 [65]	Danish MONICA cohort 5,834 adults, aged 30–70 yr	M: 51 F: 49	4–13	Healthy food index	High HFI vs. low HFI: RR (95 % CI) 1.21 (0.8–1.82) (*P*-interaction NS)
Buckland *et al*., 2009 [66]	Spanish EPIC cohort 41,078 adults, aged 20–69 yr	M: 38 F: 62	10.4	Relative Mediterranean Diet score	High rMED vs. low rMED: HR (95 % CI) 0.6 (0.47–0.77) (*P*-interaction NS)
Fung *et al*., *2009* [67]	NHS cohort 74,886 adults, aged 38–63 yr	W: 100	20	Alternate Mediterranean Diet score	Quintiles 5 vs. quintile 1: RR (95 % CI) All women: 0.71 (0.62–0.82) (*P*-interaction NS) Nonsmokers: 0.66 (0.56–0.77); Smokers: NS
Halton *et al*., 2006 [68]	NHS cohort 82,802 women, mean age 56 yr	W: 100	20	Low-Carbohydrate Diet score	Decile 10 vs. decile 1: RR (95 % CI) All adults: 0.94 (0.76–1.18) [Stratified analyses: data not available]
Fung *et al*., 2008 [69]	NHS cohort 88,517 women, aged 34–59 yr	W: 100	24	DASH score	Quintile 5 vs. quintile 1: RR (95 % CI) All women: 0.76 (0.67–0.85) (*P*-interaction NS) Nonsmokers: 0.8) (95 % CI not available; reported as significant); Smokers: 0.65 (95 % CI not available; reported as significant)
Stroke					
Fung *et al*., 2009 [67]	NHS cohort 74,886 women, aged 38–63 yr	W: 100	20	Alternate Mediterranean Diet score	Quintile 5 vs. quintile 1: RR (95 % CI) All women, nonsmokers, and smokers: NS (*P*-interaction NS)
Fung *et al*., 2008 [69]	NHS cohort 88,517 women, aged 34–59 yr	W: 100	24	DASH score	Quintile 5 vs. quintile 1: RR (95 % CI) All women: 0.82 (0.71–0.94) (*P*-interaction NS) Non-smokers: 0.9 (95 % CI not available; reported as significant); Smokers: 0.67 (95 % CI not available; reported as significant)
Heart failure					
Levitan *et al*., 2009 [70]	SMC 36,019 women, aged 48–83 yr	W: 100	7	DASH score	Quartile 4 vs. quartile 1: RR (95 % CI) All women: 0.63 (0.48–0.81) (*P*-interaction NS) Non-smokers: 0.7 (0.47–0.86); Smokers: NS
Levitan *et al*., 2009 [71]	COSM cohort 38,987 men, aged 45–79 yr	M: 100	8	DASH score	Quartile 4 vs. quartile 1: RR (95 % CI) All men: 0.78 (0.65–0.95) (*P*-interaction NS) Non-smokers and smokers: NS
Total cardiovascular diseases					
McCullough *et al*., 2000 [72]	HPFS cohort 38,622 men, aged 40–75 yr	M: 100	8	FFQ-derived Healthy Eating Index (HEI-f)	Quintiles 5 vs. 1: RR (95 % CI) All men: 0.72 (0.6–0.88) [*P*-interaction and stratified analyses not available]

Table 1 (continued)

Reference	Study population	Sex (%)	F/U (yrs)	Diet Quality Index	Results
McCullough *et al.*, 2000 [73]	NHS cohort 67,272 women, aged 38–63 yr	W: 100	12	FFQ-derived Healthy Eating Index (HEI-f)	Quintiles 5 vs. 1: RR (95 % CI) All women: NS (*P*-interaction NS) [Stratified analyses: Data not available]
Fitzgerald *et al.*, 2012 [74]	WHS cohort 34,827 women, aged ≥45 yr	W: 100	14.6	DASH score	Quintiles 5 vs. 1: HR (95 % CI) Multivariable-adjusted: 0.64 (0.53–0.77) MV-adjusted+smoking: 0.82 (0.68–1.00)
Mortality					
Seymour *et al.*, 2003 [75]	ACS CPS II Nutrition Cohort 115,833 adults, aged 50–79 yr	M: 45.5 W: 54.5	4	Diet Quality Index	Low DQI vs. high DQI: RR (95 % CI) Men: NS; Women: NS (*P*-interaction NS)
Kant *et al.*, 2000 [76]	BCDDP cohort 42,254 women, mean age 61 yr	W: 100	5.6	Recommended food score	Quartile 5 vs. quartile 1: RR (95 % CI) CAD: 0.67 (0.47–0.95) Stroke: 0.58 (0.35–0.96) (*P*-interaction NS)
Kaluza *et al.*, 2003 [77]	COSM cohort 40,837 men, aged 45–79 yr	M: 100	7.7	Recommended food score; non-recommended food score	High RFS vs. low RFS HR (95 % CI 0.71 (0.54–0.93) (*P*-interaction NS) High non-RFS vs. low non-RFS: HR (95 % CI) 1.27 (1.05–1.54) (*P*-interaction NS)
Knoops *et al.*, 2004 [35]	HALE cohort 2,339 adults, aged 70–90 yr	M: 64.4 W: 35.6	10	Mediterranean diet score	High MDS vs. low MDS: HR (95 % CI) CAD mortality: 0.61 (0.43–0.88) CVD mortality: 0.71 (0.58–0.88) (*P*-interaction NS)
Kant *et al.*, 2009 [78]	NIH-AARP Diet and Healthy Study 350,886 adults, aged 50–71 yr	M: 57 W: 43	10.5	Dietary behavior score	Quintile 5 vs. quintile 1: RR (95 % CI) CAD mortality Men: 0.77 (0.67–0.88) Women: 0.7 (0.56–0.87) [*P*-interaction and stratified analyses not available]
Kant *et al.*, 1995 [79]	NHANES I Epidemiologic follow-up study 10,337 adults, aged 25–74 yr	Not available	14	Dietary diversity score	Smoking status appears to have attenuated the inverse association of DDS and CVD mortality but data not available
Fung *et al.*, 2010 [80]	NHS cohort 85,168 women, aged 40–65 yr	W: 100	26	Low-carbohydrate diet score	Decile 10 vs. decile 1: RR (95 % CI) Overall low-carbohydrate score: NS Animal low-carbohydrate score Men: 1.21 (1.01–1.44); Women: NS Vegetable low-carbohydrate score Men: 0.77 (0.65–0.92) Women: 0.77 (0.66–0.91) Smokers and non-smokers: Comparable results (data not available)
	HPFS cohort 44,545 men, aged 50–85 yr	M: 100	20		

[a] For each outcome, arranged according to follow-up duration. Diet was assessed using the food frequency questionnaire in all studies.

MONICA = Multinational MONItoring of trends and determinants in CArdiovascular disease; EPIC = European Prospective Investigation into Cancer and Nutrition; NHS = Nurses Health Study; DASH = Dietary Approaches to Stop Hypertension; SMC = Swedish Mammography Cohort; COSM = Cohort of Swedish Men; HPFS = Health Professionals Follow-up Study; WHS = Women's Health Study; ACS CPS II = American Cancer Society Cancer Prevention Study II; BCDDP: Breast Cancer Detection Demonstration Project; HALE = Healthy Ageing: a Longitudinal study in Europe; NIH-AARP = National Institutes of Health–American Association of Retired Persons Diet and Health Study; NHANES = National Health and Nutrition Examination Survey.

Three cross-sectional studies evaluated the interrelationships of dietary patterns and smoking status with subclinical CVD and hypertension [87–89]. A reduced rank regression-derived pattern (high in total fat, saturated fat, processed meats, sodas and low in fiber, vegetables) was positively associated with carotid artery atherosclerosis in the Multi-Ethnic Study of Atherosclerosis [87]. A fruit and milk pattern conferred low risk for hypertension in the Shanghai Men's Health Study comparing the highest to lowest intake [89], as did a fruit and vegetable pattern among military personnel in Cameroon [88]. There were no statistically significant interactions between the patterns and smoking status in all the studies. However, the inverse association between the fruit and milk pattern and hypertension was stronger in smokers.

To elucidate the relationships, nine studies prospectively assessed the associations of empirical patterns and smoking status on subclinical heart disease, CAD, stroke, and cardiovascular mortality [65, 90–97] (Table 2). Stratified analyses were conducted based on *a priori* hypotheses in three studies [90, 92, 93]. Studies that tested for interactions did not report any statistically significant results [65, 94–97]; of these, three studies performed stratified analyses [94–96]. In the Framingham Offspring/Spouse Study, women with a Heart Healthy pattern (higher in vegetables, fruits, low-fat dairy, and legumes and lower in diet beverages) who had never smoked or formerly smoked were less likely to develop subclinical heart disease than current smokers with less heart healthy patterns. Heart healthy never smokers had the lowest risk (83 %) for carotid artery stenosis. Heart healthy former smokers (odds ratio (OR) 0.41; 95 % CI 0.2–0.79), less heart healthy, never smokers (OR 0.33; 95 % CI 0.21–0.53), and less heart healthy, former smokers (OR 0.34; 95 % CI 0.21–0.57) had substantially low risk as well. Only the heart healthy pattern in association with current smoking was not significantly associated with carotid stenosis (OR 0.56; 95 % CI 0.21–1.34), which the authors attributed to the cluster's small sample size. As such, it appears that the heart healthy pattern benefited smokers as well [90].

In both the Health Professionals Follow-up Study (HPFS) [92] and the Nurses' Health Study (NHS) [93], the Prudent pattern (high in vegetables, fruits, whole grains, legumes) conferred lower risk for CAD, whereas the western pattern (high in refined grains, red and processed meats, high-fat dairy, sugar sweetened beverages) was associated with greater risk when comparing the highest to the lowest quintile. Comparable findings were observed in smokers and nonsmokers. Among men (HPFS), the Prudent pattern had a greater effect in non-smokers (36 % lower risk vs. 18 % in smokers), whereas associations with the western pattern were stronger in smokers (2.7-fold higher risk vs. 21 % in nonsmokers). In women (NHS), a higher western pattern score likewise increased risk for total stroke (relative risk (RR) 1.58; 95 % CI 1.15–2.15) and ischemic stroke (RR 1.56; 95 % CI 1.05–2.33); the Prudent pattern was not associated with stroke. Both patterns were not associated with hemorrhagic stroke most likely due to the limited number of hemorrhagic stroke cases. Smoking status did not modify these results [94].

Among middle-aged and older participants of the Ohsaki National Health Insurance study, current smoking status attenuated the inverse relationship between the Japanese factor (high in vegetables, fruits, soybean products, fish, seaweeds, green tea) and cardiovascular mortality, which subsequently became insignificant [96]. Another prospective study in Bangladesh showed that the animal protein factor (high in eggs, milk, red meat, poultry, wheat bread, vegetables) was associated with cardiovascular mortality only among smokers (RR 1.17; 95 % CI 1.02–1.34) [95]. Greater consumption of a comparable pattern derived by reduced rank regression (high in meat, soft drinks, beer and lower in vegetables, fruits, whole-meal bread, cereals, dairy products) increased risk for CAD and CVD mortality in a German cohort. In this study, adjustment for smoking status, which was considered as a confounder, attenuated the findings; however, stratified analyses were not conducted [91].

In summary, limited evidence suggests higher quality diet benefits nonsmokers and former smokers with subclinical CVD. Emerging evidence suggests that higher quality diet also is beneficial for both nonsmokers and smokers with CAD. For stroke, there is inconclusive evidence that is based on only one study. More studies, including studies on stroke subtypes, are required. Findings for hypertension based on cross-sectional studies suggest higher quality diet protects against hypertension in both nonsmokers and smokers. Limited evidence for mortality suggests a protective effect of higher quality diet for never smokers and former smokers, but the evidence for smokers is uncertain. Lower quality diet is shown to be harmful, particularly for smokers. There is a need for prospective studies on hypertension, PAD, and heart failure.

Associations of Lifestyle Patterns with CVD

Because lifestyle variables tend to cluster together (e.g., diet, smoking, alcohol use, physical activity, sedentary behavior), investigators have more recently began to examine lifestyle patterns to better understand the relationships between behavioral factors and health outcomes. Several studies in predominantly Caucasian cohorts have prospectively evaluated the combined effect of dietary patterns, smoking, alcohol consumption, physical activity, overweight/obesity, and abdominal obesity on CVD [28–38] (Table 3). In nine prospective studies, having a low-risk lifestyle (a healthy diet, not currently a smoker, low to moderate alcohol intake, physically active, not overweight or obese (body mass index (BMI) <25 kg/m^2), not abdominally obese (WHR <0.85 [women]) was associated

Table 2 Associations of *a posteriori* dietary patterns and smoking status with cardiovascular diseases in prospective studies[a]

Reference	Study population	Sex (%)	F/U (yrs)	Dietary patterns	Results
Subclinical cardiovascular disease					
Millen *et al*., (2004) [90]	FOS cohort 1,423 women, aged 18–76 yr	F: 100	12	5 clusters Heart healthy; light eating; wine and moderate eating; high fat; empty calorie	Carotid artery stenosis Heart healthy, current smoker vs. less heart healthy, current smoker OR: 0.17 (95 % CI: 0.07–0.36)
Coronary artery disease					
Osler *et al*., 2002 [65]	Danish MONICA 5,834 adults, aged 30–70 yr	M: 51 F: 49	4–13	2 factors Prudent Western	HR (95 % CI) per score unit increase All adults: both factors NS (*P*-interaction NS)
Meyer *et al*., 2011 [91]	Augsburg MONICA 981 men, aged 45–64 yr	M: 100	8–17	Reduced rank regression (RRR)-derived pattern	Higher vs. lower score: HR (95 % CI) Multivariable-adjusted: 1.33 (1.06–1.67) MV-adjusted+smoking: 1.15 (0.91–1.45)
Hu *et al*., 2000 [92]	HPFS cohort 44,875 men, aged 40–75 yr	M: 100	8	2 factors Prudent Western	Quintile 5 vs. quintile 1: RR (95 % CI) Prudent factor All men: 0.7 (0.56–0.86) Non-smokers: 0.64) (95 % CI not available; reported as significant); Smokers: 0.82 (95 % CI not available; reported as significant). Western factor All men: 1.64 (1.24–2.17) Non-smokers: 1.21) (95 % CI not available; reported as significant); Smokers: 2.7 (95 % CI not available; reported as significant)
Fung *et al*., 2001 [93]	NHS Cohort 69,017 women, aged 38–63 yr	F: 100	12	2 factors Prudent Western	Quintile 5 vs. quintile 1: RR (95 % CI) Prudent factor: 0.76 (0.6–0.98) Western factor: 1.46 (1.07–1.99) Smokers and nonsmokers: comparable results (data not available)
Stroke					
Fung *et al*., 2004 [94]	NHS Cohort 71,768 women, aged 38–63 yr	F: 100	14	2 factors Prudent Western	Quintile 5 vs. quintile 1: RR (95 % CI Total strokes Prudent factor: 0.78 (0.61–1.01) Western factor: 1.58 (1.15–2.15) Ischemic stroke: comparable to total stroke Hemorrhagic stroke: NS Smokers and nonsmokers: comparable results (data not available) (*P*-interaction NS)
Mortality					
Chen *et al*., 2012 [95]	HEALS Cohort 11,116 adults, aged 18–75 yr	Not available	6.6	3 factors Balanced Animal protein Gourd & root vegetable	HR (95 % CI) per SD ↑ in diet pattern score Animal protein factor All adults and nonsmokers: NS Smokers: 1.17 (1.02–1.34) (*P*-interaction NS)
Shimazu *et al*., 2007 [96]	Ohsaki NHI cohort 40,547 adults, aged 40–79 yr	Not available	7	3 factors Japanese Animal food High-dairy, high-fruit-and-vegetable, low-alcohol (DFA)	Quartile 5 vs. quartile 1: HR (95 % CI) Japanese factor All adults: 0.73 (0.59–0.9) Never-smokers: 0.54 (0.38–0.78) Former smokers: 0.53 (0.32–0.89) Current smokers: 0.92 (0.64–1.33) (*P*-interaction NS)

Table 2 (continued)

Reference	Study population	Sex (%)	F/U (yrs)	Dietary patterns	Results
Meyer *et al.*, 2011 [91]	Augsburg MONICA 981 men, aged, 45–64 yr	M: 100	13–23	RRR-derived pattern (high in saturated and total fat; low in fiber)	Higher vs. lower score: HR (95 % CI) Multivariable-adjusted: 1.38 (1.07–1.79) MV-adjusted+smoking: 1.18 (0.9–1.54)
Heidemann *et al.*, 2008 [97]	NHS cohort 72,113 women, mean age 38–63 yr	W: 100	18	2 factors Prudent Western	Quintile 5 vs. quintile 1: RR (95 % CI) Prudent factor: 0.72 (0.6–0.87) Western factor: 1.22 (1.01–1.48) (*P*-interaction NS)

[a] For each outcome, arranged according to follow-up duration. Diet was assessed using the food frequency questionnaire in all studies.

FOS = Framingham Offspring/Spouse Study; MONICA = Multinational MONItoring of trends and determinants in CArdiovascular disease; HPFS = Health Professionals Follow-up Study; NHS = Nurses Health Study; HEALS = Health Effects of Arsenic Longitudinal Study; NHI = National Health Insurance study.

with a lower risk for MI, total CAD, hypertension, total CVD, and cardiovascular mortality [28–31, 34–38]. Findings for stroke were inconsistent with one study by Ford et al. [29] showing no association with total stroke. Hemorrhagic stroke also was not associated with a healthy lifestyle in the Women's Health Study [32] perhaps due to the small sample size. Additionally, individual factors independently lowered risk for CVD except the Alternate Healthy Eating Index, which was found to increase risk for stroke in the Women's Health Study [32].

In summary, substantial evidence supports a protective role of a low-risk lifestyle for CAD, total CVD, and cardiovascular mortality. Ischemic stroke may benefit from a low-risk lifestyle; however, findings for hemorrhagic stroke are inconclusive. Limited evidence based on one study suggests that a low-risk lifestyle protects against hypertension. These findings thus indicate a need for more studies on stroke, stroke subtypes, and hypertension. The relationships of healthy behaviors with subclinical CVD, heart failure, and PAD are yet to be evaluated.

Discussion

Together, the evidence from *a priori* and *a posteriori* dietary patterns as well as lifestyle patterns show that lifestyle patterns may better inform the associations of diet and smoking with CVD. First, it is well established that smoking confounds the association between diet and CVD. Thus, all studies reviewed adjusted for smoking in their analysis [35, 64–80, 87–97] and showed that the effect of diet is attenuated when smoking is considered [73, 91]. However, as discussed, smoking may interact with diet and modify the effect of diet on CVD, which has been an increasing focus of more recent studies. The studies show that higher quality diet protects against CAD, cardiovascular mortality, hypertension, and subclinical CVD in nonsmokers and smokers [35, 64, 66, 67, 69, 76–78, 80, 88–90, 92, 93, 95, 97]. That said, a healthy diet might similarly potentially benefit nonsmokers and smokers with stroke and heart failure [69–71]. However, lack of a detected interaction between dietary patterns and smoking status in the studies is not unusual because interaction effects can be difficult to detect. Moreover, even when observed, effect modification often is not replicable [17••, 81]. Thus, some studies stratified analyses by smoking categories and demonstrated that a healthy diet protects against CAD [69, 92, 93] and probably subclinical CVD [90], ischemic stroke [94], hypertension [89], as well as cardiovascular mortality [80] among both nonsmokers and smokers.

Perhaps in part because of the difficulty in teasing out the complex associations between diet and smoking, specifically due to its impact as both a confounder and

Table 3 Associations of lifestyle patterns with cardiovascular diseases in prospective studies[a]

Reference	Study population	Sex (%)	F/U (yr)	Low-risk lifestyle	Results
Coronary artery disease					
Akesson *et al.*, 2007 [28]	SMC 24,444 women, aged 48–83 yr	W: 100	6.2	WHR <0.85; nonsmoking status PA: ~40 min/d+ 1 hr exercise/wk Alcohol intake: >5 g/d Healthy dietary pattern: Quintiles 3–5	Myocardial infarction 5 vs. 0 factors RR: 0.08 (95 % CI: 0.02-0.28)
Ford *et al.*, 2009 [29]	EPIC-Postdam cohort 23, 153 men and women, aged 35–65 yr	M: 38.7 W: 61.3	7.8	BMI <30 kg/m^2; PA: ≥3.5 hr/week Never-smoking status Healthy dietary pattern: Score>median	4 vs. 0 factors RR (95 % CI) 81 % (47–93 %) lower risk
Stampfer *et al.*, 2000 [30]	NHS cohort 84,129 women, aged 34–59 yr	W: 100	14	BMI <25 kg/m^2; Nonsmoking status PA: ≥30 min/d (moderate to vigorous) Alcohol intake: 5–15 g/d (moderate) AHEI-based diet: Top 40 % of score	All: 5 vs. 0 factors RR: 0.17 (95 % CI: 0.07–0.41) Nonsmokers RR: 0.25 (95 % CI: 0.1–0.6)
Chiuve *et al.*, 2006 [31]	HPFS cohort 42,847 men, aged 40–75 yr	M: 100	16	BMI <25 kg/m^2; Nonsmoking status PA: ≥30 min/d; Alcohol intake: 5–30 g/d; AHEI-based diet: Top 40 % of score	5 vs. 0 factors RR: 0.13 (95 % CI: 0.09–0.19)
Stroke					
Ford *et al.*, 2009 [29]	EPIC-Postdam cohort 23,153 men and women, aged 35–65 yr	M: 38.7 W: 61.3	7.8	BMI <30 kg/m^2; PA: ≥3.5 hr/week Never-smoking status Healthy dietary pattern: Score>median	4 vs. 0 factors NS
Kurth *et al.*, 2009 [32]	WHS cohort 37,636 women, aged ≥45 yr	W: 100	10	Health index BMI <22 kg/m^2; PA: ≥4 times/wk Nonsmoking status Alcohol intake: 4–10.5 drinks/ week AHEI-based diet: Top 40 % of score	Higher score vs. lower score Total stroke HR: 0.45 (95 % CI: 0.24–0.83) Ischemic stroke HR: 0.29 (95 % CI: 0.14–0.63) Hemorrhagic stroke NS
Chiuve *et al.*, 2008 [33]	NHS cohort 71,243 women, mean age 50 yr HPFS cohort 43,685 men, mean age 54 yr	W: 100 M: 100	14	BMI <25 kg/m^2 PA: ≥30 min /d (moderate to vigorous) Never smoking status Alcohol intake: moderate (Men; 5–30 g/d; women: 5–15 g/d) AHEI-based diet: Top 40 % of score	5 vs. 0 factors RR (95 % CI) Total stroke Men: 0.31 (0.19–0.53) Women: 0.21 (0.12–0.36) Ischemic stroke Men: 0.2 (0.1–0.42) Women: 0.19 (0.09–0.4) Hemorrhagic stroke No data (small sample)
Hypertension					
Forman *et al.*, 2009 [34]	NHS cohort 83,882 women, aged 27–44 yr	W: 100	14	BMI <25 kg/m^2; PA: ≥30 min/d; Never smoking status; Alcohol intake: 5–10 g/d; DASH diet: Top 20 % of score Non-narcotic analgesics use Supplemental folate use: ≥400 μg/d	6 vs. 0 factors HR: 0.22 (95 % CI 0.1–0.51)
Total cardiovascular diseases					
Stampfer *et al.*, 2000 [30]	NHS cohort 84,129 women, aged 34–59 yr	W: 100	14	BMI <25 kg/m^2; PA: ≥30 min/d; Nonsmoking status; Alcohol intake: 5–15 g/d; AHEI-based diet: Top 40 % of score	5 vs. 0 factors RR: 0.17 (95 % CI: 0.07–0.41)
Mortality					
Knoops *et al.*, 2004 [35]	HALE cohort 2,339 adults, aged 70–90 yr	M: 64.4 W: 35.6	10	BMI <25 kg/m^2; PA: Moderate to vigorous; Nonsmoking status Alcohol intake: >0 g/d (Moderate) Mediterranean diet score: higher score	4 vs. 0 factors HR (95 % CI) CAD: 0.27 (0.14–0.53) CVD: 0.33 (0.22–0.47)

Table 3 (continued)

Reference	Study population	Sex (%)	F/U (yr)	Low-risk lifestyle	Results
Odegaard *et al.*, 2011 [36]	SCHS cohort 50,466 adults, aged 45–74 yr	Not available	13.5	BMI: 18.5–21.5 kg/m^2; PA: ≥2 hr/wk Never-smoked status; Alcohol: 1–14 drinks/wk Healthy dietary pattern: Top 60 % of score Sleep: 6–8 hr/d	6 vs. 0 factors HR (95 % CI) All: 0.24 (0.17–0.34) Men: 0.23 (0.14–0.37) Women: 0.2 (0.1–0.41)
van Dam *et al.*, 2008 [37]	NHS cohort 77,782 women, aged 34–59 yr	W: 100	24	BMI: 18–25 kg/m^2 PA: ≥30 min/d Never-smoked status Alcohol intake: ≥1–<15 g/d AHEI-based diet: Top 40 % of score	HR (95 % CI) All: 5 vs. 0 risk factors 8.17 (4.96 3–13.47) Never smokers: 4 vs. 1 risk factors 3.94 (2.35–6.60)
Chiuve *et al.*, 2011 [38]	NHS cohort 81,722 women, aged 34–59 yr	W: 100	26	BMI <25 kg/m^2; PA: ≥30 min/d Nonsmoking status; Alternate Mediterranean diet: Top 40 % of score	Sudden cardiac death 4 factors vs. 0 factors RR: 0.08 (95 % CI: 0.03-0.23)

[a] For each outcome, arranged according to follow-up duration.

SMC = Swedish Mammography Cohort; EPIC = European Prospective Investigation into Cancer and Nutrition; NHS = Nurses Health Study; AHEI = Alternate Healthy Eating Index; HPFS = Health Professionals Follow-up Study; WHS = Women's Healthy Study; DASH = Dietary Approaches to Stop Hypertension; HALE = Healthy Ageing: a Longitudinal study in Europe; SCHS = Singapore Chinese Health Study.

effect modifier, the more recent studies on overall lifestyle patterns have contributed to our understanding of relationships between diet and CVD. Findings show that it is important to consider all CVD lifestyle factors together and that a healthy lifestyle is protective of CVD. Although most of the studies were performed in whites, findings may be generalizable to other racial/ethnic populations because the underlying biological mechanisms of lifestyle factors and CVD are likely similar in humans, although genetics may account for any within- and between-population differences. For example, the INTERHEART study [98, 99] showed that low intakes of vegetables and fruits, smoking, high alcohol consumption, and physical inactivity contributed to much of the MI and stroke burdens in all world regions. The study also demonstrated that the western pattern conferred risk for MI, whereas a healthy pattern protected against MI and stroke in all populations, which included Africans, Asians, Hispanics, and Caucasians [99, 100]. Thus, a standardized approach can be adopted for CVD prevention.

Conclusions

The current body of scientific evidence, albeit mainly from western countries, supports the protective role of diets high in plant-based foods, fish, poultry, and low-fat dairy as well as moderate alcohol consumption for CAD and cardiovascular mortality among both nonsmokers and smokers. The associations of dietary patterns and smoking status on subclinical CVD, stroke, hypertension, and heart failure are inconclusive, whereas relationships on PAD are yet to be examined. "Western"-type diets high in refined grains, meats, high-fat dairy, and sugar-sweetened beverages appear to confer risk in all individuals, and the effect appears to be larger among smokers. A growing body of literature considering diet and smoking together alongside other lifestyle variables has shown that a healthy lifestyle is beneficial for CAD, hypertension, and cardiovascular mortality, and potentially protective against stroke; this approach may offer more insight into the complex relationships of diet and smoking status with CVD. To move forward our understanding of CVD outcomes, including subclinical heart disease, heart failure, and PAD, more prospective studies are needed, and studies in diverse populations would be beneficial.

Conflict of Interest Ruth W. Kimokoti declares that she has no conflict of interest.

P.K. Newby declares that she has no conflict of interest.

References

Papers of particular interest, published recently, have been highlighted as:

- • Of importance
- •• Of major importance

1. •• Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2013;380:2197–223. *This article presents the most current data on the trends and global burden of disease globally.*
2. • Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2013;380:2095–128. *This article shows that over the last 2 decades there has been a shift from communicable to non-communicable diseases as the as the main causes of death*.
3. Bloom DE, Cafiero ET, Jané-Llopis E, et al. The Global Economic Burden of Noncommunicable Diseases. Geneva: World Economic Forum. 2011. Available at http://www.weforum.org/reports/global-economic-burden-non-communicable-diseases (Accessed December 2012).
4. • Go AS, Mozaffarian D, Roger VL, et al. Heart Disease and Stroke Statistics–2013 Update: A Report From the American Heart Association. Circulation. 2013;127:e6–e245. *This article presents the most current data and trends on cardiovascular diseases and their risk factors in the US.*
5. WHO. Diet, Nutrition and the Prevention of Chronic Diseases: Report of the joint WHO/FAO Expert Consultation. WHO Technical Report Series, No. 916 (TRS 916). World Health Organization, 2003. http://www.who.int/dietphysicalactivity/publications/trs916/download/en/ (Accessed November 2012).
6. Reddy SK, Katan MB. Diet, nutrition and the prevention of hypertension and cardiovascular diseases. Public Health Nutr. 2004;7:167–86.
7. IOM. Promoting Cardiovascular Health in the Developing World: A Critical Challenge to Achieve Global Health. Institute of Medicine, 2010. Washington, DC: The National Academies Press. Available at http://www.nap.edu/catalog.php?record_id=12815 (Accessed December 2012).
8. • Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2013;380:2224–60. *This article presents the most current data and trends on risk factors for diseases globally.*
9. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. PLoS Med. 2009;6:e1000058.
10. Mozaffarian D, Appel LJ, Van Horn L. Components of a cardioprotective diet: new insights. Circulation. 2011;123:2870–91.
11. Mente A, de Koning L, Shannon HS, Anand SS. A systematic review of the evidence supporting a causal link between dietary factors and coronary heart disease. Arch Intern Med. 2009;169:659–69.
12. He FJ, MacGregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. J Hum Hypertens. 2009;23:363–84.
13. Baum SJ, Kris-Etherton PM, Willett WC, et al. Fatty acids in cardiovascular health and disease: a comprehensive update. J Clin Lipidol. 2012;6:216–34.
14. Ramsden CE, Zamora D, Leelarthaepin B, et al. Use of dietary linoleic acid for secondary prevention of coronary heart disease and death: evaluation of recovered data from the Sydney Diet Heart Study and updated meta-analysis. BMJ. 2013;346:e8707.
15. Hooper L, Summerbell CD, Thompson R, et al. Reduced or modified dietary fat for preventing cardiovascular disease. Cochrane Database Syst Rev. 2012;5:CD002137.
16. Moeller SM, Reedy J, Millen AE, et al. Dietary patterns: challenges and opportunities in dietary patterns research an Experimental Biology workshop, April 1, 2006. J Am Diet Assoc. 2007;107:1233–9.
17. •• Willett W. Nutritional Epidemiology. 3rd ed. New York: Oxford University Press; 2012. *This is the most recent version of Nutritional* "*Epidemiology*," *which is the standard textbook for nutritional epidemiology.*
18. American Heart Association Nutrition Committee, Lichtenstein AH, Appel LJ, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. Circulation. 2006;114:82–96.
19. WHO. WHO Global Report: Mortality Attributable to Tobacco. World Health Organization, 2012. Available at http://www.who.int/tobacco/publications/surveillance/rep_mortality_attributable/en/index.html (Accessed November 2012).
20. ITC Project, World Health Organization, and World Heart Federation (April 2012). Cardiovascular harms from tobacco use and secondhand smoke: Global gaps in awareness and implications for action. Waterloo, Ontario, Canada and Geneva, Switzerland. Available at http://www.who.int/tobacco/publications/surveillance/cardiovascular_harms_tobacco_use/en/index.html (Accessed November 2012).
21. U.S. Department of Health and Human Services. How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease: A Report of the Surgeon General. U.S. Department of Health and Human Service, Public Health Service, Office of the Surgeon General. Rockville, MD, 2010. Available at http://www.surgeongeneral.gov/library/reports/index.html (Accessed November 2012).
22. Méndez D, Alshanqeety O, Warner KE. The potential impact of smoking control policies on future global smoking trends. Tob Control. 2013;22:46–51.
23. Centers for Disease Control and Prevention. Current cigarette smoking among adults – United States, 2011. MMWR. 2012;61:889–94.
24. Teo KK, Ounpuu S, Hawken S, et al. Tobacco use and risk of myocardial infarction in 52 countries in the INTERHEART study: a case-control study. Lancet. 2006;368:647–58.
25. U.S. Department of Health and Human Services. The Health Consequences of Smoking: A Report of the Surgeon General. U.S. Department of Health and Human Service, Public Health Service, Office of the Surgeon General. Rockville, MD, 2004. Available at http://www.surgeongeneral.gov/library/reports/index.html (Accessed November 2012).
26. Ford ES, Capewell S. Proportion of the decline in cardiovascular mortality disease due to prevention versus treatment: public health versus clinical care. Annu Rev Public Health. 2011;32:5–22.
27. Chiolero A, Faeh D, Paccaud F, Cornuz J. Consequences of smoking for body weight, body fat distribution, and insulin resistance. Am J Clin Nutr. 2008;87:801–9.
28. Akesson A, Weismayer C, Newby PK, Wolk A. Combined effect of low-risk dietary and lifestyle behaviors in primary prevention of myocardial infarction in women. Arch Intern Med. 2007;167:2122–7.
29. Ford ES, Bergmann MM, Kröger J, et al. Healthy living is the best revenge: findings from the European Prospective Investigation Into Cancer and Nutrition-Potsdam study. Arch Intern Med. 2009;169:1355–62.
30. 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.

31. Chiuve SE, McCullough ML, Sacks FM, Rimm EB. Healthy lifestyle factors in the primary prevention of coronary heart disease among men: benefits among users and nonusers of lipid-lowering and antihypertensive medications. Circulation. 2006;114:160–7.
32. Kurth T, Moore SC, Gaziano JM, et al. Healthy lifestyle and the risk of stroke in women. Arch Intern Med. 2006;166:1403–9.
33. Chiuve SE, Rexrode KM, Spiegelman D, et al. Primary prevention of stroke by healthy lifestyle. Circulation. 2008;118:947–54.
34. Forman JP, Stampfer MJ, Curhan GC. Diet and lifestyle risk factors associated with incident hypertension in women. JAMA. 2009;302:401–11.
35. Knoops KT, de Groot LC, Kromhout D, et al. Mediterranean diet, lifestyle factors, and 10-year mortality in elderly European men and women: the HALE project. JAMA. 2004;292:1433–9.
36. Odegaard AO, Koh WP, Gross MD, et al. Combined lifestyle factors and cardiovascular disease mortality in Chinese men and women: the Singapore Chinese health study. Circulation. 2011;124:2847–54.
37. van Dam RM, Li T, Spiegelman D, et al. Combined impact of lifestyle factors on mortality: prospective cohort study in US women. BMJ. 2008;337:a1440.
38. Chiuve SE, Fung TT, Rexrode KM, et al. Adherence to a low-risk, healthy lifestyle and risk of sudden cardiac death among women. JAMA. 2011;306:62–9.
39. Kennedy ET, Ohls J, Carlson S, Fleming K. The Healthy Eating Index: design and applications. J Am Diet Assoc. 1995;95:1103–8.
40. U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2010. 7th Edition, Washington, DC: U.S. Government Printing Office, December 2010. Available at http://www.cnpp.usda.gov/dietaryguidelines.htm (Accessed January 2013).
41. Trichopoulou A. Traditional Mediterranean diet and longevity in the elderly: a review. Public Health Nutr. 2004;7:943–7.
42. McCullough ML, Feskanich D, Stampfer MJ, et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. Am J Clin Nutr. 2002;76:1261–71.
43. Kant AK. Dietary patterns: biomarkers and chronic disease risk. Appl Physiol Nutr Metab. 2010;35:199–206.
44. Wirt A, Collins CE. Diet quality–what is it and does it matter? Public Health Nutr. 2009;12:2473–92.
45. Sofi F, Abbate R, Gensini GF, Casini A. Accruing evidence on benefits of adherence to the Mediterranean diet on health: an updated systematic review and meta-analysis. Am J Clin Nutr. 2010;92:1189–96.
46. Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev. 2004;62:177–203.
47. Bhupathiraju SN, Tucker KL. Coronary heart disease prevention: nutrients, foods, and dietary patterns. Clin Chim Acta. 2011;412:1493–514.
48. Sherzai A, Heim LT, Boothby C, Sherzai AD. Stroke, food groups, and dietary patterns: a systematic review. Nutr Rev. 2012;70:423–35.
49. • Kimokoti RW, Fung TT, Millen BE. Dietary patterns/diet and health of adults in economically developing countries. In Bioactive Foods as Dietary Interventions for the Aging Population. Edited by Watson RR and Preedy VR. BFCD_Aging, UK: Academic Press; 2013:83-107. *This article presents findings of associations between dietary patterns and non-communicable diseases in low and middle-income countries*.
50. O'Doherty MG, Skidmore PM, Young IS, et al. Dietary patterns and smoking in Northern Irish men: a population at high risk of coronary heart disease. Int J Vitam Nutr Res. 2011;81:21–33.
51. Mahe G, Carsin M, Zeeny M, De Bosschere JP. Dietary pattern, a modifiable risk factor that can be easily assessed for atherosclerosis vascular disease prevention in clinical practice. Public Health Nutr. 2011;14:319–26.
52. Touvier M, Niravong M, Volatier JL, et al. Dietary patterns associated with vitamin/mineral supplement use and smoking among women of the E3N-EPIC cohort. Eur J Clin Nutr. 2009;63:39–47.
53. Cai H, Zheng W, Xiang YB, et al. Dietary patterns and their correlates among middle-aged and elderly Chinese men: a report from the Shanghai Men's Health Study. Br J Nutr. 2007;98:1006–13.
54. Tseng M, DeVillis R. Correlates of the "western" and "prudent" diet patterns in the US. Ann Epidemiol. 2000;10:481–2.
55. Whichelow MJ, Prevost AT. Dietary patterns and their associations with demographic, lifestyle and health variables in a random sample of British adults. Br J Nutr. 1996;76:17–30.
56. Deshmukh-Taskar PR, O'Neil CE, Nicklas TA, et al. Dietary patterns associated with metabolic syndrome, sociodemographic and lifestyle factors in young adults: the Bogalusa Heart Study. Public Health Nutr. 2009;12:2493–503.
57. Kesse-Guyot E, Bertrais S, Péneau S, et al. Dietary patterns and their sociodemographic and behavioural correlates in French middle-aged adults from the SU.VI.MAX cohort. Eur J Clin Nutr. 2009;63:521–8.
58. Engeset D, Alsaker E, Ciampi A, Lund E. Dietary patterns and lifestyle factors in the Norwegian EPIC cohort: the Norwegian Women and Cancer (NOWAC) study. Eur J Clin Nutr. 2005;59:675–84.
59. Libby P, Ridker PM. Hansson GK; Leducq Transatlantic Network on Atherothrombosis. Inflammation in atherosclerosis: from pathophysiology to practice. J Am Coll Cardiol. 2009;54:2129–38.
60. Bulló M, Casas-Agustench P, Amigó-Correig P, et al. Inflammation, obesity and comorbidities: the role of diet. Public Health Nutr. 2007;10:1164–72.
61. Dandona P, Aljada A, Chaudhuri A, et al. Metabolic syndrome: a comprehensive perspective based on interactions between obesity, diabetes, and inflammation. Circulation. 2005;111:1448–54.
62. Reaven GM. Insulin resistance/compensatory hyperinsulinemia, essential hypertension, and cardiovascular disease. J Clin Endocrinol Metab. 2003;88:2399–403.
63. Mathieu P, Lemieux I, Després JP. Obesity, inflammation, and cardiovascular risk. Clin Pharmacol Ther. 2010;87:407–16.
64. Luedemann J, Schminke U, Berger K, et al. Association between behavior-dependent cardiovascular risk factors and asymptomatic carotid atherosclerosis in a general population. Stroke. 2002;33:2929–35.
65. Osler M, Helms AA, Heitmann B, et al. Food intake patterns and risk of coronary heart disease: a prospective cohort study examining the use of traditional scoring techniques. Eur J Clin Nutr. 2002;56:568–74.
66. Buckland G, González CA, Agudo A, et al. Adherence to the Mediterranean diet and risk of coronary heart disease in the Spanish EPIC Cohort Study. Am J Epidemiol. 2009;170:1518–29.
67. Fung TT, Rexrode KM, Mantzoros CS, et al. Mediterranean diet and incidence of and mortality from coronary heart disease and stroke in women. Circulation. 2009;119:1093–100.
68. Halton TL, Willett WC, Liu S, et al. Low-carbohydrate-diet score and the risk of coronary heart disease in women. N Engl J Med. 2006;355:1991–2002.
69. Fung TT, Chiuve SE, McCullough ML, et al. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med. 2008;168:713–20.
70. Levitan EB, Wolk A, Mittleman MA. Consistency with the DASH diet and incidence of heart failure. Arch Intern Med. 2009;169:851–7.
71. Levitan EB, Wolk A, Mittleman MA. Relation of consistency with the dietary approaches to stop hypertension diet and incidence of heart failure in men aged 45 to 79 years. Am J Cardiol. 2009;104:1416–20.

72. 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;72:1223–31.
73. 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;72:1214–22.
74. Fitzgerald KC, Chiuve SE, Buring JE, et al. Comparison of associations of adherence to a Dietary Approaches to Stop Hypertension (DASH)-style diet with risks of cardiovascular disease and venous thromboembolism. J Thromb Haemost. 2012;10:189–98.
75. Seymour JD, Calle EE, Flagg EW, et al. Diet Quality Index as a predictor of short-term mortality in the American Cancer Society Cancer Prevention Study II Nutrition Cohort. Am J Epidemiol. 2003;157:980–8.
76. Kant AK, Schatzkin A, Graubard BI, Schairer C. A prospective study of diet quality and mortality in women. JAMA. 2000;283:2109–15.
77. Kaluza J, Håkansson N, Brzozowska A, Wolk A. Diet quality and mortality: a population-based prospective study of men. Eur J Clin Nutr. 2009;63:451–7.
78. Kant AK, Leitzmann MF, Park Y, et al. Patterns of recommended dietary behaviors predict subsequent risk of mortality in a large cohort of men and women in the United States. J Nutr. 2009;139:1374–80.
79. 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;14:233–8.
80. Fung TT, van Dam RM, Hankinson SE, et al. Low-carbohydrate diets and all-cause and cause-specific mortality: two cohort studies. Ann Intern Med. 2010;153:289–98.
81. Aschengrau A, Seage GR. Essentiails of Epidemiology in Public Health. 2nd ed. London: Jones and Bartlett Publishers International; 2007.
82. Appel LJ, Moore TJ, Obarzanek E, et al. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. N Engl J Med. 1997;336:1117–24.
83. Helgason CM, Wolf PA. American Heart Association Prevention Conference IV: prevention and rehabilitation of stroke: executive summary. Circulation. 1997;96:701–7.
84. Amarenco P, Bogousslavsky J, Caplan LR, et al. Classification of stroke subtypes. Cerebrovasc Dis. 2009;27:493–501.
85. Schocken DD, Benjamin EJ, Fonarow GC, et al. Prevention of heart failure: A scientific statement from the American Heart Association Councils on Epidemiology and Prevention, Clinical Cardiology, Cardiovascular Nursing, and High Blood Pressure Research; Quality of Care and Outcomes Research Interdisciplinary WorkingGroup; and Functional Genomics and Translational Biology Interdisciplinary Working Group. Circulation. 2008;117:2544–65.
86. Bartholomew JR, Olin JW. Pathophysiology of peripheral arterial disease and risk factors for its development. Cleve Clin J Med. 2006;73 Suppl 4:S8–S14.
87. Nettleton JA, Steffen LM, Schulze MB, et al. Associations between markers of subclinical atherosclerosis and dietary patterns derived by principal components analysis and reduced rank regression in the Multi-Ethnic Study of Atherosclerosis (MESA). Am J Clin Nutr. 2007;85:1615–25.
88. Nkondjock A, Bizome E. Dietary patterns associated with hypertension prevalence in the Cameroon defence forces. Eur J Clin Nutr. 2010;64:1014–21.
89. Lee SA, Cai H, Yang G, et al. Dietary patterns and blood pressure among middle-aged and elderly Chinese men in Shanghai. Br J Nutr. 2010;104:265–75.
90. Millen BE, Quatromoni PA, Nam BH, et al. Dietary patterns, smoking, and subclinical heart disease in women: opportunities for primary prevention from the Framingham Nutrition Studies. J Am Diet Assoc. 2004;104:208–14.
91. Meyer J, Döring A, Herder C, et al. Dietary patterns, subclinical inflammation, incident coronary heart disease and mortality in middle-aged men from the MONICA/KORA Augsburg cohort study. Eur J Clin Nutr. 2011;65:800–7.
92. 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;72:912–21.
93. Fung TT, Willett WC, Stampfer MJ, et al. Dietary patterns and the risk of coronary heart disease in women. Arch Intern Med. 2001;161:1857–62.
94. Fung TT, Stampfer MJ, Manson JE, et al. Prospective study of major dietary patterns and stroke risk in women. Stroke. 2004;35:2014–9.
95. Chen Y, McClintock TR, Segers S, et al. Prospective investigation of major dietary patterns and risk of cardiovascular mortality in Bangladesh. Int J Cardiol. 2012. (In press).
96. Shimazu T, Kuriyama S, Hozawa A, et al. Dietary patterns and cardiovascular disease mortality in Japan: a prospective cohort study. Int J Epidemiol. 2007;36:600–9.
97. Heidemann C, Schulze MB, Franco OH, et al. Dietary patterns and risk of mortality from cardiovascular disease, cancer, and all causes in a prospective cohort of women. Circulation. 2008;118:230–7.
98. Yusuf S, Hawken S, Ounpuu S, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. Lancet. 2004;364:937–52.
99. O'Donnell MJ, Xavier D, Liu L, et al. Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): a case-control study. Lancet. 2010;376:112–23.
100. Iqbal R, Anand S, Ounpuu S, et al. Dietary patterns and the risk of acute myocardial infarction in 52 countries: results of the INTERHEART study. Circulation. 2008;118:1929–37.