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Review

Effects of Dietary Approaches to Stop Hypertension (DASH)-style diet on fatal or nonfatal cardiovascular diseases—Incidence: A systematic review and meta-analysis on observational prospective studies

Amin Salehi-Abargouei M.Sc. Nutr., Ph.D. Cand [a,b,c], Zahra Maghsoudi M.Sc. Nutr., Ph.D. Cand [a,b,c], Fatemeh Shirani M.Sc. Nutr., Ph.D. Cand [a,b,c], Leila Azadbakht Ph.D. [a,b,*]

[a] *Food Security Research Center, Isfahan University of Medical Sciences, Isfahan, Iran*
[b] *Department of Community Nutrition, School of Nutrition and Food Science, Isfahan University of Medical Sciences, Isfahan, Iran*
[c] *Students' Research Committee, Isfahan University of Medical Sciences, Isfahan, Iran*

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ABSTRACT

Background: Cardiovascular diseases (CVDs) are a group of disorders affecting heart and blood vessels. However, protective roles are proposed for Dietary Approaches to Stop Hypertension (DASH)-style diets.
Objective: The aim of this review was to summarize and if possible quantify the longitudinal effects of a DASH-style diet on the incidence of CVDs.
Design: Pubmed, ISI web of science, and EMBASE were searched and cohort studies that examined the DASH-style diet in relation to CVDs, coronary heart disease (CHD), stroke, and heart failure (HF) were selected. Cohort studies which included participants with specific CVD risk factors like diabetes mellitus, metabolic syndrome, obesity or hypertension were excluded from review. Relative risks (RRs) that were reported for fully adjusted models and their confidence intervals were extracted for meta-analysis.
Results: Regarding the adherence to the DASH diet and the incidence of CVDs, stroke, CHD, and HF, only 6 studies met our criteria to be included in this systematic review. Meta-analysis showed that imitating a DASH-like diet can significantly reduce CVDs (RR = 0.80; 95% confidence interval [CI], 0.74–0.86; $P < 0.001$), CHD (RR = 0.79; 95% CI, 0.71–0.88; $P < 0.001$), stroke (RR = 0.81, 95% CI, 0.72–0.92; $P < 0.001$), and HF (RR= 0.71, 95% CI, 0.58–0.88; $P < 0.001$) risk. A linear and negative association was obtained between DASH-style diet concordance and all CVDs, as well.
Conclusion: In conclusion, our results showed that a DASH-like diet can significantly protect against CVDs, CHD, stroke, and HF risk by 20%, 21%, 19% and 29%, respectively. Furthermore, there is a significant reverse linear association between DASH diet consumption and CVDs, CHD, stroke, and HF risk.

Introduction

Cardiovascular diseases (CVDs) are a group of disorders affecting the heart and blood vessels; they are the leading cause of death worldwide. Based on World Health Organization (WHO) reports, 17.3 million people (about 30% of global death) died from CVDs in 2008, of these deaths, 7.3 million and 6.2 million were reported to be due to coronary heart disease (CHD) and stroke, the two major subclasses of CVDs, respectively. Heart failure (HF) also is another highly prevalent group

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* Corresponding author. Tel.: +98 311 792-2719; fax: +98 311 6682509.
E-mail address: azadbakht@hlth.mui.ac.ir (L. Azadbakht).

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of CVDs with a current prevalence of more than 5.8 million in the United States and in excess of 23 million, worldwide [1,2]. Approximately 80% of CVDs are seen in low- and middle-income countries, and they occur almost equally in both genders [3]. Behavioral risk factors are considered to be responsible for about 80% of CHD and cerebrovascular diseases. Based on evidence, unhealthy diet, physical inactivity, tobacco use, and harmful alcohol consumption are major behavioral risk factors for CVDs [3].

The Dietary Approaches to Stop Hypertension (DASH) diet, which is rich in fruits, vegetables, and low-fat dairy products, incorporates grains, poultry, fish, and nuts and limits saturated fat, red meat, sweets, and sugar-containing beverages. This eating pattern was basically designed to normalize blood pressure in patients with hypertension, and a large body of data could confirm its beneficial effects on blood pressure levels [4]. In comparison with usual diets the DASH diet provides lower amounts of total fat, saturated fat, and dietary cholesterol, while providing higher amounts of potassium, calcium, magnesium, fiber, and protein. Therefore, some studies have proposed other useful effects of this dietary approach, such as reducing insulin resistance and controlling fasting blood sugar and lipid profiles [5,6]; thus suggesting it is a good dietary pattern for the prevention of CVDs.

As hypertension is a major risk factor for CVDs, several prospective studies have tried to determine how imitating a DASH-style diet can be associated with the risk for CVDs [7,8] or one or more of its major subclasses like CHD [7–9], stroke [7–10], and HF [11,12] risk. Mentioned cohort studies have yield inconsistent results. Some researchers believe that adherence to the DASH guidelines was not associated with fatal CVDs [7,8], ischemic heart disease [7], CHD [8], and stroke [8,10]; whereas others found a significant independent protective connection with fatal or nonfatal CHD [9], stroke [7, 9], and HF [11,12].

Cohort studies are the best designs to infer cause-and-effect relationship between independent and dependent variables because exposure always takes place before the outcome in a long-term period and a large population size. Although a large body of literature supports the protective effect of a DASH-style diet on CVDs, according to our knowledge there is no systematic review or meta-analysis, quantifying published longitudinal studies in this regard. Therefore, in present study we tried to systematically review and perform a meta-analysis to summarize the information and assess the magnitude of the relation between imitating a DASH-style diet and CVDs or its major subclasses like CHD, stroke, and HF in prospective cohorts.

Materials and methods

Search strategy

Pubmed, ISI web of science, and EMBASE were searched using the following keywords: *dietary pattern, DASH, dietary approach to stop hypertension* in combination with *CVD, CHD, stroke, cardiovascular disease, coronary heart disease, heart failure, and glucose, fasting blood glucose, FBS, insulin*, and *HOMA-IR, LDL, HDL, TG, low-density lipoprotein, high-density lipoprotein, cholestrol,* and *triglyceride* until January 2012. We also searched “Google scholar” using mentioned keywords to assure that maximum studies were found. No filter or limitation was used while searching mentioned databases. References lists of all studies also were reviewed for any other related publication. All of these steps were done by ASA and FS and any disagreements with article selection were resolved through discussion with ZM, who was available to resolve disagreement.

Study selection

Inclusion criteria

Prospective observational studies investigating the relationship between concordance with a DASH dietary pattern and fatal or nonfatal CVDs in total or one of the CVDs such as CHD, stroke, or HF reporting relative risk (RR) and its 95% confidence limits, which was necessary for meta-analysis were selected to include in our systematic review and meta-analysis. Furthermore, we also considered those studies which reported odds ratio (OR) with 95% confidence intervals (CI) or crude data about the incidence of disease in population groups to estimate RR.

Exclusion criteria

We settled to exclude studies if they had a population differed from the general population with respect to life expectancy, or developing CVDs (e.g., diabetes, metabolic syndrome, obesity or hypertension) and followed their cohort for less than than 5 y.

Data extraction

ASA and ZM extracted the data about first author’s last name, publication date, sample size, participants’ age, follow-up period, gender, research location, recruitment procedure, method used for statistical analysis and adjusting other variables, variables included in the model for adjustment and RR (95% CI) reported to compare population groups with those participants who had lowest concordance with a DASH-style diet as reference group.

Statistical analysis

The RRs (95% CI) for comparing incident CVDs, CHD, or stroke between groups with the highest and lowest scores of imitating DASH-like diets—were used to calculate log RR and its SE for meta-analysis. Overall effect was derived by using a random effect model, which takes between-study variation into account [13]. Subgroup analysis was used to find possible sources of heterogeneity, if needed. Statistical heterogeneity between studies was evaluated with Cochran’s Q test and I square [14]. Sensitivity analysis was used to explore the extent to which inferences might depend on a particular study or a number of publications. Publication bias was evaluated by looking over Begg’s funnel plots [15]. Formal statistical assessment of funnel plot asymmetry was done by Egger’s regression asymmetry test and Begg’s adjusted rank correlation test [13]. Additionally, RRs (95% CI) comparing incident CVDs, CHD, HF, or stroke, between population groups with higher concordance scores to reference group were extracted, converted to log RRs (SEs), and used in meta-regression to find any linear trend between DASH-style diet score and occurrence of CVDs. Statistical analyses were conducted using STATA version 11.2 (STATA Corp, College Station, TX). *P*-values <0.05 were considered statistically significant.

Results

Our search retrieved 2367 papers. However, after reading the titles and abstracts of the papers only seven studies had all inclusion criteria for systematic review [7–12,16]. Further readings revealed that one of these publications by Parikh et al. [7] was done in hypertensive adults, so it was excluded; because hypertension may alter the CVD risk. Therefore, six cohort studies were used for systematic review and meta-analysis. Three studies were from United States [8,9,16] and three others were from Europe (one from Italy [10] and two from Sweden [11,12]). Two cohorts reported incident CVDs [8,16], three reported incident CHD [8,9,16] and stroke [8–10], and two studies reported HF incidence [11,12] in relation to concordance with a DASH-style diet. All of these studies used Cox proportional hazard models for statistical analysis. So, no conversions were made between effect sizes, for analysis. The follow-up period ranged between 7 and 24 y. Table 1 shows more details about included studies in the systematic review and meta-analysis.

Definition of DASH diet in the included studies

All included studies, except one that was done by Folsom et al. [8], used a method introduced by Fung et al. [9], which

Table 1
Observational prospective studies eligible to include in the systematic review and meta-analysis

First author (y)	Cohort name, country	Follow-up period	Cohort population and gender	Age range	Dependant variable and reported RR (95% CI)*	Adjusted variables
Fitzgerald et al. (2011) [16]	Women's Health Study, US	14.6 y	34,827 females	≥45 y	CVD: 0.87 (0.70–1.09) CHD: 0.87 (0.61–1.22)	Randomization status (aspirin, vitamin E, and β-carotene), age, smoking status, time-varying postmenopausal status, time varying hormone therapy use, alcohol intake, energy intake, physical activity, cigarettes per day, highest education level, BMI, history of high cholesterol, history of hypertension, and family history of CHD
Agnoli et al. (2011) [10]	EPICOR, Italy	7.89 y	40 681 males and females	35–74 y	Stroke: 0.75 (0.51–1.1)	Sex, smoking status, education, nonalcoholic energy intake, and BMI; stratified for center and age
Levitan et al. (2009) [11]	Cohort of Swedish men	9 y	38 947 males	45–79 y	HF: 0.78 (0.65–0.95)	Age, physical activity, energy intake, education, family history of MI at age < 60 y, cigarette smoking, marital status, self-reported history of hypertension and high cholesterol, BMI, and incident MI
Levitan et al. (2009) [12]	Swedish Mammography cohort	7 y	36 019 females	48–83 y	HF: 0.63 (0.48–0.81)	Age, physical activity, energy intake, education status, family history of MI at age < 60 y, cigarette smoking, living alone, postmenopausal hormone use, self-reported history of hypertension and high cholesterol concentration, BMI, and incident MI
Fung et al. (2008) [9]	Nurses' Health Study, US	24 y	88 517 females	30–55 y	Fatal and nonfatal CHD: 0.76 (0.67–0.85) Stroke: 0.82 (0.71–0.94)	Age, smoking, BMI, menopausal status and postmenopausal hormone use, energy intake, multivitamin intake, alcohol intake, family history, physical activity, and aspirin use
Folsom et al. (2007) [8]	Iowa Women's Health Study US	17 y	20 993 females	55–69 y	All CVD death: 0.93 (0.76–1.12) CHD death: 0.86 (0.67–1.12) Stroke death: 0.82 (0.55–1.23)	Age, energy intake, education, BMI, waist/hip, smoking status, and pack-years, estrogen use, alcohol intake, physical activity and multivitamin use

BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; CVD, cardiovascular disease; MI, myocardial infarction; RR, relative risk
* comparing highest to lowest concordance groups after fully adjusted model.

was based on quintiles of eight DASH dietary pattern components such as fruits, vegetables, nuts and legumes, whole grains, low-fat dairy, sodium, red and processed meats, and sweetened beverages. Because the method for assessing adherence to the DASH diet used by Folsom et al. [8] included all components of the DASH dietary pattern defined by other papers in this field and its results did not have heterogeneity with other papers, we decided to include its results in our meta-analysis.

DASH diet and risk for CVDs

2From included cohorts, two had data on DASH-style diets in relation to all CVDs [8,16]. Both of these studies found a significant result when comparing those in the group with the highest adherence to a DASH diet compared with those in the lowest adherence group in a minimally adjusted model (for age, sex, and energy intake). However, this result did not replicate after adjusting for other variables in a fully adjusted model (variables are listed in Table 1). We found four other studies that did not examine the relation to all CVDs but reported incident stroke [9,10], CHD [9], and HF [11,12] as major subtypes of CVDs. Therefore, we included these in a meta--analysis combined with papers on CVDs. We had two surveys on stroke risk in this group. There was a significant inverse association in minimally adjusted models for the association between DASH eating patterns and stroke (age, sex, and energy intake) [9,10], but the relationship remained significant in the fully adjusted model in a study done by Fung et al. [9]. Two papers also were published on risk for HF. Both of these showed a reverse and statistically significant relationship between DASH-style diets and risk for HF in the fully adjusted model (variables are listed in Table 1) [11,12]. Furthermore, there was one study in this group that reported an independent negative association for CHD [9]. Meta-analysis on six found cohort studies in a total of 260,011 adults, showed that high imitating from a DASH-style diet can significantly decrease risks for CVDs (RR, 0.80; 95% CI; 0.74–0.86; $P < 0.001$). There was no evidence of heterogeneity between studies using Q statistic (Q test, $P = 0.321$, $I^2 = 14.3\%$). Forest plot showing RR for CVDs in the highest concordance groups compared with reference groups with lowest score from a DASH-style diet is depicted in Figure 1. Meta-regression using log RRs comparing higher ntiles with lowest ntlie (reference ntile) as dependent variable and ntile numbers as covariate showed that there is a significant negative trend between imitating a DASH-like diet score and a risk for CVD ($\beta = -0.005$; $P < 0.001$).

DASH diet and risk for CHD

Of six prospective observations, three studies included data on a DASH-style diet in relation to CHD [8,9,16]. All three studies found significant results when comparing highest to lowest concordance groups in minimally adjusted models (for age and energy intake). However, this result did not replicate after adjusting for other variables in a fully adjusted model in two of the studies (Table 1) [8,16]. Meta-analysis on mentioned cohorts in 144,337 adults, showed that high imitating of a DASH-style diet can significantly decrease risk for CHD (RR, 0.79; 95% CI, 0.71–0.88; $P < 0.001$), whereas heterogeneity between studies was not significant (Q test, $P = 0.583$, $I^2 = 0.0\%$). Forest plot showing RR for CHD in the highest concordance groups compared with reference groups with lowest

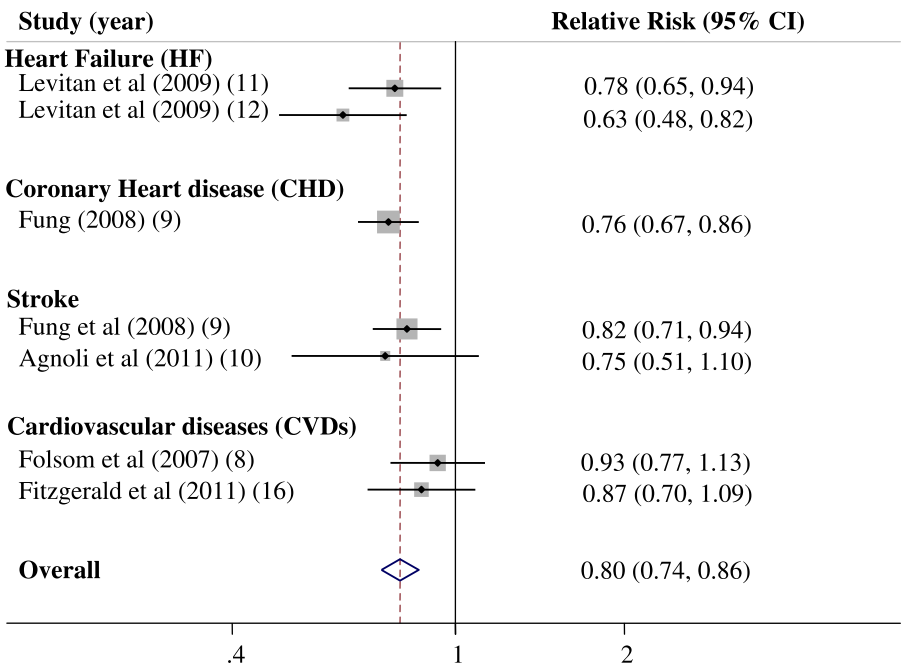

Fig. 1. Forest plot illustrating weighted relative risk (RR) using random effects model for all CVDs, arranged by CVD type, comparing highest with lowest DASH diet concordance ntiles.

score from a DASH-style diet is depicted in Figure 2. Linear regression using log RRs comparing higher ntiles with lowest ntile (reference ntile) as a dependent variable and ntile numbers as a covariate showed that there is a significant negative trend between imitating a DASH-like diet score and risk for CHD ($\beta = -0.004$; $P = 0.003$).

DASH diet and risk for stroke

From included cohorts, three had data on a DASH-style diet in relation to stroke [8,16]. Two [9,10] found a significant result when comparing highest with lowest concordance groups in a minimally adjusted model (age and energy intake). However, except for the study done by Fung et al. [9], this result did not replicate after adjusting for other variables in the fully adjusted model. Meta-analysis in 150,191 adults, participated in the three previously mentioned cohorts, showed that high imitating of a DASH-style diet can significantly decrease the risk for stroke (RR, 0.81; 95% CI, 0.72–0.92; $P < 0.001$), and heterogeneity between studies was not found (Q test, $P = 0.912$; $I^2 = 0.0\%$). Forest plot showing the RR for stroke in the highest concordance groups compared with reference groups with the lowest score from a DASH-style diet is depicted in Figure 3. Linear regression using log RRs comparing higher ntiles with lowest ntile (reference ntile) as a dependent variable and ntile numbers as a covariate showed that there is a significant negative trend between imitating a DASH-like diet score and the risk for stroke ($\beta = -0.005$; $P = 0.001$).

DASH diet and risk for HF

Two of six studies found cohorts had data on a DASH-style diet in relation to risk for HF [11,12]. Both found a significant association even after adjusting for other variables in a fully adjusted model. Meta-analysis showed that in 74 966 Swedish adults participating in these two surveys, high imitating of

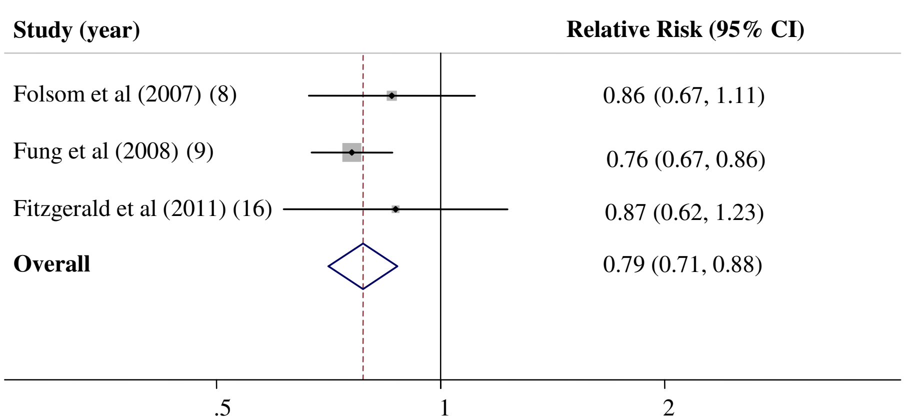

Fig. 2. Forest plot illustrating weighted relative risk (RR) using random effects model for CHD, comparing highest with lowest DASH diet concordance ntiles.

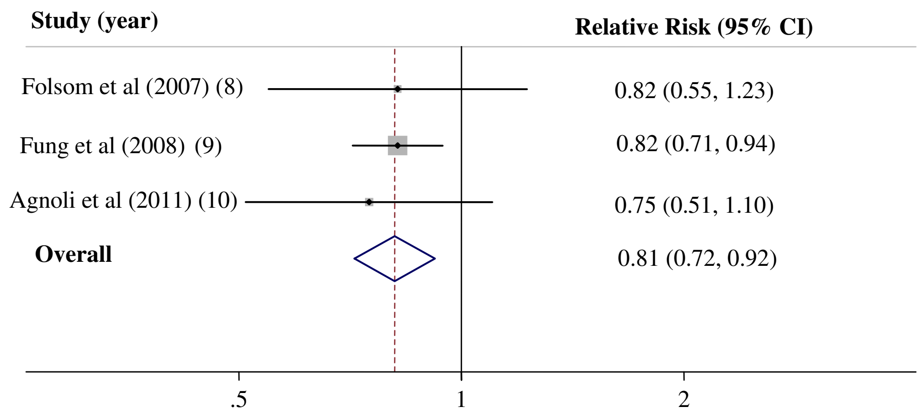

Fig. 3. Forest plot illustrating weighted relative risk (RR) using random effects model for Stroke, comparing highest with lowest DASH diet concordance ntiles.

a DASH-style diet can significantly decrease the risk for HF (RR = 0.71, 95% CI, 0.58–0.88; $P < 0.001$), and heterogeneity between studies is not significant (Q test, $P = 0.195$, $I^2 = 40.4\%$). Forest plot showing the RR for HF in the highest concordance groups compared with reference groups with lowest score from a DASH-style diet is depicted in Figure 4. Linear regression using log RRs comparing higher ntiles with lowest ntile (reference ntile) as a dependent variable and ntiles number as a covariate showed that there is a significant negative trend between imitating a DASH-like diet score and a risk for CVD ($\beta = -0.009$; $P = 0.002$).

Publication bias and sensitivity analyses

Although a slight asymmetry was seen in Begg's funnel plot (Fig. 5) with regard to CVDs, stroke, and CHD, we could not find any evidence of publication bias using Egger's test (*P* for bias = 0.80, 0.55, 0.45, respectively). Sensitivity analysis showed that none of studies (or group of studies on a subtype of CVDs) included for the DASH diet and risk for CVDs, could considerably modify the summary effect. However, for papers regarding the DASH diet and risk for CHDs and stroke, excluding a study done by Fung et al. [9], could apparently change the overall effect to nonsignificant [RR, 0.76; 95% CI, 0.70–1.06 and RR, 0.78; 95% CI, 0.59–1.03 for CHD and stroke, respectively]. This may be due to the large population size or the limited number of studies included for meta-analysis. Because of the limited number of studies exploring the relation for incident HF, we did not examine the publication bias or sensitivity analysis for this group.

Discussion

Our results showed that imitating a DASH-like diet can significantly reduce risk for CVDs, CHD, stroke, and HF by 20%, 21%, 19%, and 29%, respectively. Furthermore, a significant linear association was shown between concordance with a DASH diet and CVD risk reduction. We are not aware of any systematic review and meta-analysis in this regard quantifying published cohort studies; however, literature reviews have mentioned a DASH-style diet as a practical protective approach for decreasing the risk for CVDs, largely according to the results of published clinical trials in this field [4,17,18]. Literature reviews have mentioned the cohort studies in the field of DASH diets and stroke [17] and CHD [4]. However, all published cohorts are not offered collectively. Hankey [17] could find only one cohort on DASH-style diets and stroke [9]. However, Bhupathiraju and Tucker could find five cohort studies on CVDs [7–9,11,12] with a study that met our exclusion criteria because it included participants with hypertension at baseline [7], whereas we included six studies for meta-analysis on CVDs [6,8,9,11,12,16] and we could quantify the effect of concordance with a DASH--style diet on CHD, stroke, and HF, as well.

The blood pressure–lowering effect of the DASH diet is mentioned as the diet's major characteristic because hypertension is found to be a major risk factor for most CVDs [4]. Several components of the DASH diet have been linked to beneficial effects on blood pressure. The fruits and vegetables (plant-based foods in general) included in the diet are associated with lower blood pressure, as shown in observational and interventional studies [19–23]. High amounts of fiber,

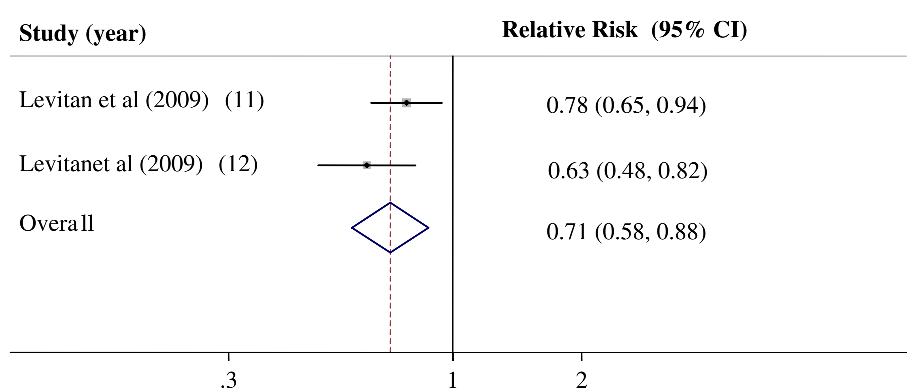

Fig. 4. Forest plot illustrating weighted relative risk (RR) using random effects model for HF, comparing highest with lowest DASH diet concordance ntiles.

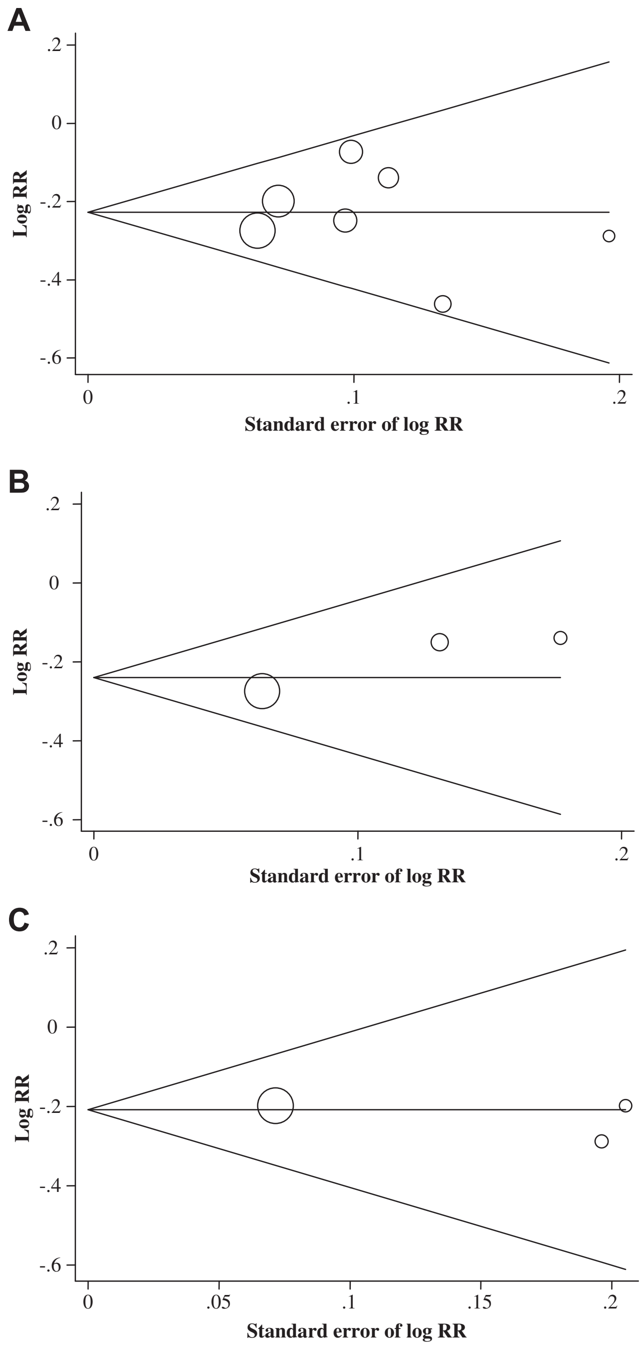

Fig. 5. Begg's funnel plots (with pseudo 95% CIs) of the relative risks (RRs) versus the SEs (standard errors) of the RRs in studies that evaluated the relationship between dash diet concordance and all CVDs (A), CHD (B) and Stroke (C) incidence. The horizontal line shows the pooled RRs calculated with the DerSimonian and Laird random-effects model [49].

potassium, magnesium, and calcium in the DASH diet have made this approach an effective therapy for battling hypertension [24–26], although some studies have shown that the DASH diet reduces blood pressure in obese patients with hypertension beyond potassium, magnesium, and fiber [27]. On the other hand, red meat [22,28] and refined grain intake, which are limited in a DASH-style diet, have been linked to increased blood pressure.

In addition to blood pressure, although inconsistent, the effect of a DASH diet on other risk factors such as fasting glucose 2[5,29], total cholesterol (TC) and low-density lipoprotein (LDL)-cholesterol [5,30,31], inflammation as a pathway in atherosclerosis [32], and homocysteine levels [33] is proposed by a number of clinical trials, providing a field for further research.

Adherence to the DASH dietary pattern, which is based on amounts of specific food groups, may have the potential to prevent diabetes as a major predictor of CVDs [34]. Some clinical trials have evaluated the effect of DASH on fasting glucose, fasting insulin, and other insulin resistance indices that have led to inconsistent results [5,6,27,29,31,35–41]. Among these, only Lien et al., in a large-scale clinical trial, were able to show that DASH can significantly reduce fasting blood glucose levels both in participants with and without metabolic syndrome [31]. Two studies proposed that the DASH diet could improve insulin action beyond the effect of other treatments for insulin sensitivity like weight loss, reduced sodium intake, increased physical activity, and moderate alcohol intake [40,41].

Several studies aroused the hypothesis of the advantageous effects of DASH on the lipid profile as a risk factor for CVDs [5,6,27,29–31,35–39,41–48]. Obarzanek et al. showed the beneficial effect of DASH on TC and LDL-cholesterol [30], whereas their results were replicated in most of their later clinical trials. However, results for triglycerides and high-density lipoprotein-cholesterol were inconsistent.

Researchers have proposed many mechanisms for beneficial effects of following a DASH diet on CVDs risk although their pathways are not clearly known. Greater intakes of fiber especially soluble fiber; folate, vitamin C, and phytochemicals such as flavons, flavonons, carotenoids, and phytoesterol in the DASH diet may result in incensement of antioxidant capacity, may have a blood pressure–lowering effect and a beneficial effect on lipid profile insulin sensitivity, and reduction in oxidative stress [29].

Although studies that were included in our meta-analysis used different possible confounders for adjustment in their model, we used fully adjusted RRs reported by each study for our meta-analysis (variables are listed in Table 1). However, all studies adjusted the relationship for confounders like age, sex, smoking status, energy intake, body mass index (BMI), and physical activity. Fung et al. [9] included ω-3 and trans-fat intake as additional variables to other conventional possible confounders. None of other studies included adjusted effect for these two dietary factors. So, we preferred not to include this model in our analysis. However, even after adjusting for ω-3 and trans-fats the results were unchanged. Fung et al. did not adjust for education level, whereas all other studies included this variable as a confounder in their multivariate models (Table 1). Furthermore, we have to note that removing this study in sensitivity analysis made the results for CHD and stroke insignificant. This problem leads us to conclude that the relationship between the DASH dietary pattern and CHD or stroke should be reviewed with more caution.

Although the relationship between the DASH dietary pattern and CVDs remained significant even after removing the study done by Fung et al. or any group of studies examining the relation of HF, stroke, or CHD, when we excluded Nurse's Health Study [9] and two studies on HF [11,12] simultaneously, the association disappeared (RR, 0.8; 95% CI, 0.77–1.01; $P = 0.07$).

We found six cohort studies from the United States and European countries that show that data about the possible longitudinal effect of concordance with DASH in eastern and African countries are not still sufficient. Developing countries that are experiencing nutritional transition and Westernization are settled in these regions. Furthermore, these countries have different and variable diets compared with Western countries; future data in this field from these areas would help researchers to arrive at conclusions on the relation between the DASH diet and CVDs with more strength.

Conclusions

In conclusion, our results showed that a DASH-like diet could significantly protect against CVDs, CHD, stroke, and HF risk by 20%, 21%, 19%, and 29%, respectively. Furthermore, there is a significant reverse linear association between adherance to the DASH diet, CVDs, CHD, stroke, and HF risk. Results found for CHD and stroke must be of course declared with caution because of sensitivity to a single study. More prospective observational studies, particularly from Asian and African regions, are recommended for future research.

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