RESEARCH
Review

Diet Quality as Assessed by the Healthy Eating Index, Alternate Healthy Eating Index, Dietary Approaches to Stop Hypertension Score, and Health Outcomes: An Updated Systematic Review and Meta-Analysis of Cohort Studies

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ARTICLE INFORMATION

Article history:
Submitted 20 March 2017
Accepted 16 August 2017
Available online 27 October 2017

Keywords:
Alternate Healthy Eating Index
Dietary Approaches to Stop Hypertension (DASH) diet
Health status
Healthy Eating Index
Meta-analysis

Supplementary materials:
Figures 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, and 15 and Tables 3, 4, 5, 6, 7, and 8 are available at www.jandonline.org

https://doi.org/10.1016/j.jand.2017.08.024

ABSTRACT

Background Diets of the highest quality have been associated with a significantly lower risk of noncommunicable diseases.

Objective It was the aim of this study to update a previous systematic review investigating the associations of diet quality as assessed by the Healthy Eating Index (HEI), Alternate Healthy Eating Index (AHEI), and Dietary Approaches to Stop Hypertension (DASH) score and multiple health outcomes. As an additional topic, the associations of these diet quality indices with all-cause mortality and cancer mortality among cancer survivors were also investigated.

Design A literature search for prospective cohort studies that were published up to May 15, 2017 was performed using the electronic databases PubMed, Scopus, and Embase. Summary risk ratios (RRs) and 95% CIs were estimated using a random effects model for high vs low adherence categories.

Results The updated review process showed 34 new reports (total number of reports evaluated=68; including 1,670,179 participants). Diets of the highest quality, as assessed by the HEI, AHEI, and DASH score, resulted in a significant risk reduction for all-cause mortality (RR 0.78, 95% CI 0.77 to 0.80; I^2=59%; n=13), cardiovascular disease (incidence or mortality) (RR 0.78, 95% CI 0.76 to 0.80; I^2=49%; n=28), cancer (incidence or mortality) (RR 0.84, 95% CI 0.82 to 0.87; I^2=66%; n=31), type 2 diabetes (RR 0.82, 95% CI 0.78 to 0.85; I^2=72%; n=10), and neurodegenerative diseases (RR 0.85, 95% CI 0.74 to 0.98; I^2=51%; n=5). Among cancer survivors, the association between diets for the highest quality resulted in a significant reduction in all-cause mortality (RR 0.88, 95% CI 0.81 to 0.95; I^2=38%; n=7) and cancer mortality (RR 0.90, 95% CI 0.83 to 0.98; I^2=0%; n=7).

Conclusions In the updated meta-analyses, diets that score highly on the HEI, AHEI, and DASH were associated with a significant reduction in the risk of all-cause mortality, cardiovascular disease, cancer, type 2 diabetes, and neurodegenerative disease by 22%, 22%, 16%, 18%, and 15%, respectively. Moreover, high-quality diets were inversely associated with overall mortality and cancer mortality among cancer survivors.
J Acad Nutr Diet. 2018;118:74-100.

IN FEBRUARY 2015, A SYSTEMATIC REVIEW AND META-analysis of prospective cohort studies investigating the associations between diet quality, as assessed by the Healthy Eating Index (HEI), Alternate Healthy Eating Index (AHEI), and Dietary Approaches to Stop Hypertension (DASH) score, and the risk of all-cause mortality, cardiovascular disease mortality or events, cancer mortality or incidence, type 2 diabetes, and neurodegenerative diseases was published.[1] Diets of the highest quality were associated with a lower risk of all-cause mortality, cardiovascular disease, cancer, and type 2 diabetes.[1] However, due to the large number of studies that have been published since the release of the previous meta-analysis, it seems important to update the original analysis.

According to the National Cancer Institute, the number of cancer survivors is growing rapidly, with an estimated number of 26.1 million by 2040 compared to 15.5 million in 2016.[2] Due to the urgent need to establish evidence-based nutrition recommendations for cancer survivors, it was decided not only to re-execute the original search, but to

include associations between diet quality and risk of mortality in cancer survivors as an additional research question.

Therefore, the aim of this study was to update the previous systematic review and meta-analysis conducted in prospective cohort studies that investigated the association of diet quality as assessed by the HEI, AHEI, and DASH score and health status (risk of all-cause mortality, cardiovascular disease mortality or incidence, cancer mortality or incidence, type 2 diabetes, and neurodegenerative disease). The second objective of this study was to summarize the evidence of diet quality as assessed by the HEI, AHEI, and DASH score and the risk of all-cause mortality and cancer mortality among cancer survivors.

RESEARCH SNAPSHOT

Research Question: Does diet quality, measured in term of the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score, influence health status?

Key Findings: In this updated systematic review and meta-analysis of 68 reports including 1,670,179 participants, diets that score highly were associated with a significant reduction in the risk of all-cause mortality (22%), cardiovascular disease (22%), cancer (16%), type 2 diabetes (18%), and neurodegenerative disease (15%). High-quality diets were also associated with a significant reduction in the risk of overall mortality (12%) and cancer mortality (10%) among cancer survivors.

METHODS

The systematic review protocol of the previous meta-analysis is registered in PROSPERO International Prospective Register of Systematic Reviews (crd.york.ac.uk/prospero/index.asp Identifier: CRD42013006561). The protocol has meanwhile been adapted to the updated version of this systematic review.

Data Sources and Searches

A literature search was performed to identify studies published from May 2014 up to May 15, 2017 using the electronic databases PubMed, Embase, and Scopus. For PubMed, the following search terms were used: *healthy* [All Fields] AND (*eating* [medical subject heading {MeSH} Terms] OR *eating* [All Fields]) AND (*abstracting and indexing as topic* [MeSH Terms] OR (*abstracting* [All Fields] AND *indexing* [All Fields] AND *topic* [All Fields]) OR *abstracting and indexing as topic* [All Fields] OR *index* [All Fields]) OR (*dash* [All Fields] AND (*diet* [MeSH Terms] OR *diet* [All Fields]).

The literature search investigating the association of diet quality indices and all-cause mortality and cancer mortality among cancer survivors was based on a recently published meta-analysis[3] using Scopus as an additional database and was updated to include studies published up to May 15, 2017. The following search terms were used for PubMed: (*healthy* [All Fields] AND (*eating* [MeSH Terms] OR *eating* [All Fields]) AND (*abstracting and indexing as topic* [MeSH Terms] OR (*abstracting* [All Fields] AND *indexing* [All Fields] AND *topic* [All Fields]) OR *abstracting and indexing as topic* [All Fields] OR *index* [All Fields]) OR (*dash* [All Fields] AND (*diet* [MeSH Terms] OR *diet* [All Fields]) AND (*cancer* [All Fields]) AND (*survivors* [All Fields] OR *survivor* [All Fields] OR *recurrence* [All Fields] OR *mortality* [All Fields]) AND (*prospective* [All Fields] OR *cohort* [All Fields] OR *longitudinal* [All Fields] OR *follow up* [All Fields]).

Both search strategies had no language restrictions. Moreover, the reference lists from retrieved articles were checked to search for further relevant studies. Literature searches were conducted by one author (L.S.), with questions or uncertainties resolved by discussion with another author.

Study Selection

Prospective cohort studies were included in the meta-analysis if they met all of the following criteria: evaluated the association of diet quality as assessed by the HEI, and/or AHEI, and/or DASH score on all-cause mortality, and/or cardiovascular disease mortality or incidence, and/or cancer mortality or incidence, and/or type 2 diabetes, and/or neurodegenerative disease; presented risk ratios (RRs) and/or hazard ratios (HRs) with corresponding 95% CI. In addition, the meta-analysis was expanded to include cancer survivors from cohort studies investigating the association of diet quality as assessed by the HEI, and/or AHEI, and/or DASH score and all-cause mortality and/or cancer mortality among cancer survivors. Detailed description of study selection is reported in the previous version,[1] the same study selection strategy was used for the additional research questions of the updated systematic review.

Data Extraction and Quality Assessment

The following data were extracted from each study as reported in the previous version[1]: the first author's last name, year of publication, study origin, cohort name, outcome parameter, sample size, study length (follow up in years), age at entry, sex, diet quality score, adjustment factors, study quality score, and risk estimates (most adjusted HR or RR or highest vs lowest category) with their corresponding 95% CIs. The Newcastle-Ottawa Quality Assessment Scale[4] was used to assess study quality. Data extraction and quality assessment were performed by one author and checked by another (B.B.) for accuracy.

HEI, AHEI, and DASH Components and Scoring

A detailed description of the HEI[5-10] (HEI-2005[11-23] and HEI-2010[24-37]), AHEI[5,12,15,38-51] (AHEI-2010[11,20,23,25-33,35,36,52-59]), and DASH score[9,12,20,21,25-36,40,44-47,54-57,59-72] and its different updates and modifications are reported in the previous version of the systematic review.[1,11]

Statistical Analysis

The meta-analysis was performed by combining the multivariable adjusted RRs, HR, or ORs of the highest compared with the lowest quantiles of HEI, AHEI, and DASH scores conformance category based on random-effects model using the DerSimonian-Laird method.[73] Because outcomes were not very rare and heterogeneity modeling was deemed important, the random-effects model was used. To evaluate the weighting of each study, the standard error for the logarithm HR/RR/OR of each study was calculated and regarded as the estimated variance of the logarithm HR/RR/OR, using

an inverse variance method.[73] Meta-analysis was based on the assumption that all measures are RRs.

Studies were grouped according to the different clinical outcomes (ie, all-cause mortality, cardiovascular disease mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative diseases, and all-cause mortality and cancer mortality among cancer survivors). As described previously, subgroup analyses were performed for the HEI, AHEI, and for the DASH score, and by comparing the HEI vs HEI-2005 vs HEI-2010, and the AHEI vs AHEI-2010. Additional subgroup analyses included US studies, longer-term follow-up studies, high-quality studies, stratified analysis by sex, and comparing incidence and mortality outcomes for cardiovascular disease and cancer. Heterogeneity, funnel plots, and test for small study effects were performed as reported in the previous version.[1] The *heterogi* command in STATA was used to calculate the CIs for the heterogeneity estimates.[74] All analyses were conducted using the Review Manager by the Cochrane Collaboration (version 5.3)[75] and STATA.[76]

RESULTS

Literature Search and Study Characteristics

The detailed steps of the updated meta-analysis article search and selection process are given as an adapted PRISMA

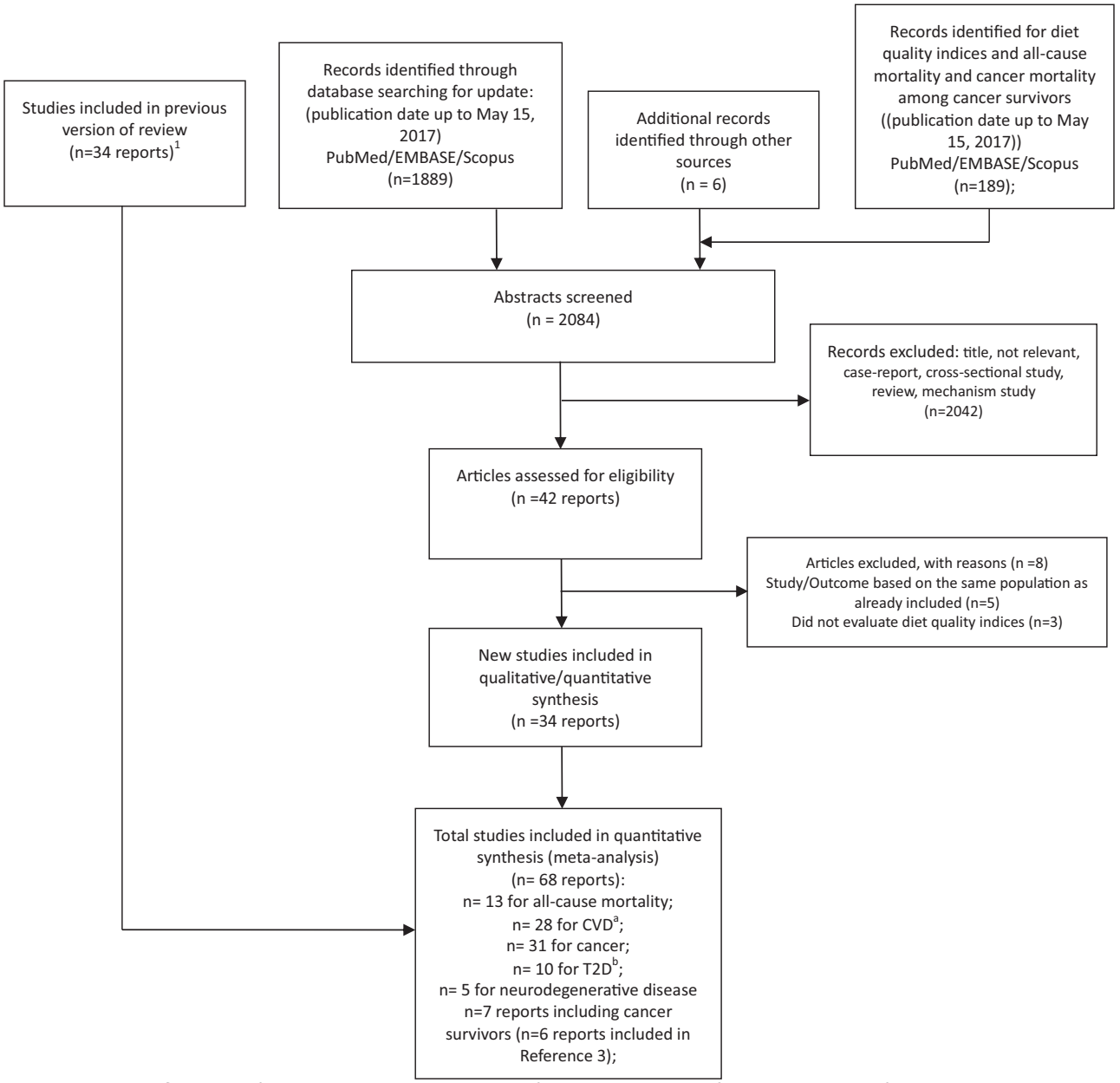

Figure 1. Updated flow chart for the article selection process for a meta-analysis of the associations of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, and Dietary Approaches to Stop Hypertension score and health outcomes. [a]CVD=cardiovascular disease. [b]T2D=type 2 diabetes.

Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Anic and colleagues, 2016[26]	US[e]	National Institutes of Health, American Association of Retired Persons Diet and Health Study cohort	Lung cancer	460,770 10.5	50-71	Both	HEI[f] (2010) AHEI[g] (2010) DASH[h] score	Age, sex, race/ethnicity, education, BMI, physical activity, energy intake, smoking status, cigarettes per day, time since quitting smoking, regular use of cigars/pipes	Lung cancer HEI (2010) HR 0.83 (0.77-0.89) AHEI (2010) HR 0.86 (0.80-0.92) DASH score HR 0.84 (0.78-0.90)	8
Boggs and colleagues, 2015[68]	US	Black Women's Health Study	All-cause mortality	37,001 16	30-69	♀[i]	DASH score	Age, each DASH component, energy intake, education, marital status, physical activity, television watching, smoking status, alcohol consumption	All-cause mortality DASH score HR 0.75 (0.63-0.89)	9
Cespedes and colleagues, 2016[27]	US	WHI[j]-Dietary Modification Trial and WHI-Observational Study	T2D[k]	101,504 15	50-79	♀	HEI (2010) AHEI (2010) DASH score	Age, race/ethnicity, education, physical activity during recreational activities, use of postmenopausal HT[l], family history of diabetes, smoking status, study arm, energy intake, BMI[m]	T2D HEI (2010) HR 0.83 (0.78-0.89) AHEI (2010) HR 0.78 (0.73-0.83) DASH score HR 0.74 (0.69-0.80)	8
Del Gobbo and colleagues, 2015[45]	US	Cardiovascular Health Study	Heart failure incidence	4,490 21.5	≥65	Both	AHEI DASH score	Age, sex, race/ethnicity, enrollment source, education, income, physical activity, walking pace, smoking status, alcohol consumption, BMI, diabetes status, history of coronary heart disease, prevalent treated hypertension	AHEI HR 0.90 (0.74-1.09) DASH score HR 1.05 (0.88-1.26)	7

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Djousse and colleagues, 2014[46]	US	Physicians' Health Study	All-cause mortality CVD[n] mortality Cancer mortality	19,619 20	≥40	♂[o]	AHEI DASH score	NA[p]	All-cause mortality AHEI HR 0.59 (0.52-0.68) DASH score HR 0.81 (0.71-0.93) CVD mortality AHEI HR 0.62 (0.48-0.80) DASH score HR 0.90 (0.70-1.17) Cancer mortality AHEI HR 0.68 (0.54-0.86) DASH score HR 0.93 (0.74-1.18)	Quality assessment not possible because only abstract was available
Dugue and colleagues, 2016[53]	Australia	Melbourne Collaborative Cohort Study	Urothelial cell carcinoma incidence	41,514 21.3	27-76	Both	AHEI (2010)	Sex, country of birth, smoking status, alcohol consumption, BMI; physical activity, education, socioeconomic status	Urothelial cell carcinoma incidence AHEI (2010) HR 1.02 (0.73-1.43)	9

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Fung and colleagues, 2014[54]	US	Nurses' Health Study	All-cause mortality Colorectal cancer mortality	1,201 colorectal cancer survivors 11.2	61-72	♀	AHEI (2010) DASH score	Age, physical activity, BMI, weight change, cancer grade, chemotherapy, smoking status, energy intake, colon or rectal cancer, stage of disease, date of colorectal cancer diagnosis	All-cause mortality AHEI (2010) HR 0.71 (0.52-0.98) DASH score HR 0.98 (0.71-1.35) Colorectal cancer mortality AHEI (2010) HR 0.72 (0.43-1.21) DASH score HR 0.87 (0.52-1.45)	8
George and colleagues, 2011[17]	US	Health, Eating, Activity, and Lifestyle Study	All-cause mortality Breast cancer mortality	670 breast cancer survivors 6	≥18	♀	HEI (2005)	Energy intake, physical activity, race/ethnicity, stage, tamoxifen use, BMI	HEI (2005) All-cause mortality HR 0.40 (0.17-0.94) Breast cancer mortality HR 0.12 (0.02-0.99)	8
George and colleagues, 2014[16]	US	WHI-Dietary Modification Trial and WHI-Observational Study	All-cause mortality Breast cancer mortality	2,317 breast cancer survivors 9.6	50-79	♀	HEI (2005)	Age at screening visit, WHI component, race/ethnicity, income, education, stage of disease, estrogen receptor status, progesterone receptor status, time since diagnosis, energy intake, physical activity, alcohol consumption, use of postmenopausal HT	HEI (2005) All-cause mortality HR 0.74 (0.55-0.99) Breast cancer mortality HR 0.91 (0.60-1.40)	8

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
George and colleagues, 2014[28]	US	WHI-Observational Study	All-cause mortality CVD mortality Cancer mortality	63,805 12.9	50-79	♀	HEI (2010) AHEI (2010) DASH score	Age, energy intake, race/ethnicity, education, marital status, smoking status, physical activity, use of postmenopausal HT, BMI, alcohol consumption (except for AHEI), diabetes status	All-cause mortality HEI (2010) HR 0.76 (0.70-0.83) AHEI (2010) HR 0.82 (0.76-0.90) DASH score HR 0.76 (0.70-0.83) CVD mortality HEI (2010) HR 0.78 (0.65-0.93) AHEI (2010) HR 0.81 (0.68-0.96) DASH score HR 0.76 (0.65-0.90) Cancer mortality HEI (2010) HR 0.77 (0.68-0.89) AHEI (2010) HR 0.93 (0.81-1.06) DASH score HR 0.80 (0.70-0.91)	8

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
George and colleagues, 2015[29]	US	WHI-Observational Study	Endometrial cancer incidence	84,415 13.3	50-79	♀	HEI (2010) AHEI (2010) DASH score	Age, energy intake, race/ethnicity, education, physical activity during recreational activities, diabetes status, use of postmenopausal HT, oral contraceptive use, age at first birth, participant in observational study, participant in HT trial, participant in dietary modification trial, alcohol consumption (except for AHEI (2010), BMI	Endometrial cancer incidence HEI (2010) HR 1.11 (0.93-1.33) AHEI (2010) HR 0.98 (0.82-1.17) DASH score HR 1.00 (0.84-1.19)	8
Haridass, 2015[55]	US	California Teacher Study	Invasive breast cancer incidence	94,404 16	22-104	♀	AHEI (2010) DASH score	Menopausal status, family history of breast cancer, race/ethnicity, age at menarche, smoking status, socioeconomic status, physical activity, BMI, daily vitamin use, energy intake	Invasive breast cancer incidence AHEI (2010) HR 0.87 (0.79-0.97) DASH score HR 0.88 (0.79-0.97)	8
Haring and colleagues, 2016[30]	US	WHI-Memory Study	Mild cognitive impairment or probable dementia incidence	6,425 9	65-79	♀	HEI (2010) AHEI (2010) DASH score	Age, race/ethnicity, education, WHI Hormone Trial randomization assignment, baseline Modified Mini-Mental State Examination score, smoking status, physical activity, diabetes status, hypertension status, BMI, income, depression, history of CVD, energy intake	Mild cognitive impairment or probable dementia incidence HEI (2010) HR 1.12 (0.87-1.44) AHEI (2010) HR 0.82 (0.64-1.07) DASH score HR 0.93 (0.81-1.22)	7

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Harmon and colleagues, 2015[31]	US	Multi-ethnic Cohort	All-cause mortality CVD mortality Cancer mortality	215,782 13-18	45-75	Both	HEI (2010) AHEI (2010) DASH score	Age, BMI, diabetes status, energy intake, race/ethnicity, education, marital status, smoking status, alcohol consumption (except for AHEI (2010)), use of postmenopausal HT (only for ♀), physical activity	All-cause mortality HEI (2010) ♂HR 0.75 (0.71-0.79) ♀HR 0.79 (0.75-0.83) AHEI (2010) ♂HR 0.78 (0.74-0.82) ♀HR 0.78 (0.74-0.82) DASH score ♂HR 0.81 (0.77-0.85) ♀HR 0.80 (0.75-0.84) CVD-mortality HEI (2010) ♂HR 0.74 (0.69-0.81) ♀HR 0.77 (0.71-0.84) AHEI (2010) ♂HR 0.79 (0.72-0.86) ♀HR 0.76 (0.69-0.83) DASH score ♂HR 0.83 (0.76-0.91) ♀HR 0.78 (0.71-0.85) Cancer mortality HEI (2010) ♂HR 0.76 (0.70-0.83) ♀HR 0.89 (0.81-0.98) AHEI (2010) ♂HR 0.83 (0.76-0.90) ♀HR 0.85 (0.77-0.93) DASH score ♂HR 0.78 (0.71-0.85) ♀HR 0.86 (0.78-0.95)	9

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Izano and colleagues, 2013[56]	US	Nurses' Health Study	Breast cancer mortality Non-breast cancer mortality	4,103 breast cancer survivors 9.33	30-55	♀	AHEI (2010) DASH score	Age at diagnosis, energy intake, BMI, BMI change, age at first birth, parity, oral contraceptive use, menopausal status, use of postmenopausal HT, smoking status, stage of disease, radiation treatment, chemotherapy and HT, physical activity	Breast cancer mortality AHEI (2010) RR 1.07 (0.77-1.49) DASH score RR 0.85 (0.61-1.19) Non-breast cancer mortality AHEI (2010) RR 0.57 (0.42-0.77) DASH score RR 0.72 (0.53-0.99)	8
Jacobs and colleagues, 2015[32]	US	Multi-ethnic Cohort	T2D	89,185 NA	45-75	Both	HEI (2010) AHEI (2010) DASH score	Physical activity, smoking status, education, energy intake, BMI	T2D HEI (2010) ♂HR 0.93 (0.85-1.01) ♀HR 0.92 (0.84-1.01) AHEI (2010) ♂HR 0.88 (0.81-0.96) ♀ HR 0.88 (0.80-0.97) DASH score ♂HR 0.79 (0.73-0.87) ♀ HR 0.77 (0.70-0.84)	9

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Jacobs and colleagues, 2016[33]	US	Multi-ethnic Cohort	All-cause mortality Colorectal cancer mortality	4,204 colorectal cancer survivors 6	45-75	Both	HEI (2010) AHEI (2010) DASH score	Age at diagnosis, race/ethnicity, stage at diagnosis, energy intake, smoking status, pack-years of smoking, physical activity, education, radiation treatment, chemotherapy, nonsteroidal anti-inflammatory drug use, family history of colorectal cancer, comorbidities	All-cause mortality HEI (2010) ♂HR 0.91 (0.76-1.09) ♀HR 0.89 (0.72-1.09) AHEI (2010) ♂HR 1.08 (0.90-1.28) ♀HR 0.83 (0.67-1.03) DASH score ♂HR 1.06 (0.87-1.28) ♀HR 0.97 (0.77-1.22) Colorectal cancer mortality HEI (2010) ♂HR 0.85 (0.66-1.08) ♀HR 0.76 (0.58-1.01) AHEI (2010) ♂HR 1.07 (0.84-1.36) ♀HR 0.81 (0.61-1.07) DASH score ♂HR 1.05 (0.81-1.37) ♀HR 0.88 (0.64-1.19)	8
Larsson and colleagues, 2016[70]	Sweden	Cohort of Swedish Men and Swedish Mammography cohort	Ischemic stroke incidence Intracerebral hemorrhages incidence Subarachnoid hemorrhages incidence	74,404 11.9	45-83	Both	m[q]DASH score	Education, family history of myocardial infarction before 60 years of age, smoking status, pack-years of smoking, aspirin use, walking/bicycling, physical activity, BMI, history of hypertension, hypercholesterolemia, diabetes, and atrial fibrillation, energy intake, alcohol consumption	mDASH score Ischemic stroke incidence RR 0.86 (0.78-0.94) Intracerebral hemorrhages incidence RR 0.81 (0.63-1.05) Subarachnoid hemorrhages incidence RR 0.95 (0.60-1.50)	8

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Larsson and colleagues, 2017[69]	Sweden	Cohort of Swedish Men and Swedish Mammography cohort	Extrahepatic biliary tract cancer incidence, Gallbladder cancer incidence, Intrahepatic biliary tract cancer incidence	76,014 13.3	45-83	Both	mDASH score	Age, sex, education, smoking status, pack-years of smoking, diabetes status, BMI, energy intake	mDASH score Extrahepatic biliary tract cancer incidence HR 0.41 (0.26-0.64) Gallbladder cancer incidence HR 0.36 (0.20-0.64) Intrahepatic biliary tract cancer incidence HR 0.36 (0.11-1.21)	8
Lassale and colleagues, 2016[34]	Europe	European Prospective Investigation into Cancer and Nutrition	All-cause mortality CVD mortality Cancer mortality	451,256 12.8	25-70	Both	HEI (2010) DASH score	Dietary score, age, BMI, physical activity, smoking status, education	All-cause mortality HEI (2010) HR 0.82 (0.78-0.86) DASH score HR 0.82 (0.78-0.86) CVD mortality HEI (2010) HR 0.82 (0.75-0.90) DASH score HR 0.77 (0.70-0.84) Cancer mortality HEI (2010) HR 0.87 (0.81-0.92) DASH score HR 0.87 (0.81-0.93)	8

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Mertens and colleagues, 2017[57]	United Kingdom	Caerphilly Prospective Study	Cardiovascular disease	1,867 12	45-59	♂	AHEI (2010) DASH score	Age, smoking, social class, physical activity, energy intake, usual alcohol consumption	Cardiovascular disease AHEI (2010) HR 0.82 (0.66-1.01) DASH score HR 0.81 (0.66-0.99)	7
Morris and colleagues, 2015[71]	US	Rush Memory and Aging Project	Alzheimer's disease incidence	923 4.5	58-98	Both	DASH score	Age, sex, education, apolipoprotein ε4-allele, participation in cognitively stimulating activities, physical activity, energy intake, cardiovascular conditions	Alzheimer's disease incidence DASH score HR 0.60 (0.37-0.96)	6
Neelakantan and colleagues, 2016[58]	China	Singapore Chinese Health Study	Acute myocardial infarction	2,194 NA	45-75	Both	AHEI (2010)	Age, sex, dialect group, year of interview, year blood was collected, age at interview, energy intake, education, smoking status, physical activity, BMI, history of diabetes, history of hypertension, low- and high density lipoprotein cholesterol, triglycerides, high-sensitivity C-reactive protein, glycated hemoglobin, Creatinine, systolic blood pressure	Acute myocardial infarction AHEI (2010) OR[r] 0.64 (0.48-0.86)	7

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Otto and colleagues, 2015[47]	US	Multi-Ethnic Study of Atherosclerosis	T2D	5,160 10	45-84	Both	AHEI DASH score	Age, sex, race/ethnicity, education, field center, smoking, energy intake, physical activity, dietary supplement, BMI, baseline waist circumference	T2D AHEI HR 0.81 (0.65-1.00) DASH score HR 1.02 (0.79-1.30)	7
Park and colleagues, 2016[9]	US	Third National Health and Nutrition Examination Survey	All-cause mortality CVD mortality Cancer mortality	2,103 18.6	30-90	Both	HEI DASH score	Age, sex, race/ethnicity, education, income, smoking status, alcohol consumption, physical activity, energy intake	All-cause mortality HEI HR 0.59 (0.45-0.77) DASH score HR 0.88 (0.71-1.09) CVD mortality HEI HR 0.55 (0.33-0.92) DASH score HR 0.52 (0.35-0.77) Cancer mortality HEI HR 0.53 (0.29-0.97) DASH score HR 0.85 (0.57-1.27)	6
Park and colleagues, 2017[35]	US	Multiethnic Cohort Study	Colorectal cancer	190,949 16	45-75	Both	HEI (2010) AHEI (2010) DASH score	Age, sex, ethnicity, family history of colorectal cancer, history of colorectal polyp, BMI, smoking, multivitamin use, nonsteroidal anti-inflammatory drugs, physical activity, menopausal status, menopausal hormone therapy use, energy intake, alcohol	Colorectal cancer HEI (2010) ♂HR 0.69 (0.59-0.80) ♀HR 0.82 (0.70-0.96) AHEI (2010) ♂HR 0.75 (0.65-0.85) ♀HR 0.90 (0.78-1.04) DASH score ♂HR 0.75 (0.66-0.86) ♀HR 0.86 (0.75-1.00)	9

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Pelser and colleagues, 2014[18]	US	National Institutes of Health-American Association of Retired Persons Diet and Health study cohort	All-cause mortality Colorectal cancer specific mortality	4,213 colorectal cancer survivors 5	50-71	Both	HEI (2005)	Lag time, sex, education, family history of colon cancer, cancer stage, first course of treatment, BMI, physical activity, alcohol consumption, smoking status	HEI (2005) All-cause mortality RR 0.95 (0.78-1.16) Colorectal cancer−specific mortality RR 0.99 (0.77-1.27)	8
Shahar and colleagues, 2009[10]	US	Health, Aging, and Body Composition study	All-cause mortality	298 9	70-82	Both	HEI	Age, race/ethnicity, sex, enrollment source, smoking status, marital status, weight, energy intake, subjective health evaluation, cognitive function score	All-cause mortality HEI HR 1.9 (0.7-5.2)	5
Smyth and colleagues, 2015[48]	Worldwide	ONTARGET[s] and TRANSCEND[t] studies	Cognitive decline	27,860 3	≥55	Both	mAHEI	Age, education, sex, trial enrollment source, treatment allocation, geographical region, baseline Mini-Mental State Examination score, systolic blood pressure, history of stroke/transient ischemic attack, diabetes status, myocardial infarction, microalbuminuria, macroalbuminuria, serum creatinine, statin therapy, b-blocker therapy, antithrombotic use, smoking status, BMI, physical activity, depression	Cognitive decline mAHEI HR 0.76 (0.66-0.86)	6

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Thomson and colleagues, 2014[19]	US	WHI-Observational Study and WHI-Clinical Trials	All-cause mortality Cancer mortality	636 ovarian cancer survivors 11	50-79	♀	HEI (2005)	Age at diagnosis, stage at diagnosis, race/ethnicity, diabetes status, physical activity, energy intake, waist circumference, family history of ovarian cancer, clinical trial arms	HEI (2005) All-cause mortality HR 0.73 (0.55-0.97) Cancer mortality HR 0.75 (0.55-1.01)	8
Vargas and colleagues, 2016[36]	US	WHI-Observational Study	Colorectal cancer incidence	78,273 12.4	50-79	♀	HEI (2010) AHEI (2010) DASH score	Age, race/ethnicity, physical activity, education, smoking status, use of postmenopausal HT	Colorectal cancer incidence HEI (2010) HR 0.73 (0.59-0.90) AHEI (2010) HR 0.86 (0.70-1.07) DASH score HR 0.78 (0.62-0.97)	8
Xie and colleagues, 2014[20]	US	Nurses' Health Study	Epithelial ovarian cancer incidence	82,948 24	30-55	♀	HEI (2005) AHEI (2010)	Age, energy intake, family history of ovarian cancer, tubal ligation, BMI, parity, number of additional pregnancies, oral contraceptive use, pack-years of smoking, menopausal status, use of postmenopausal HT (type and duration), age at menarche, hysterectomy, unilateral oophorectomy, lactose intake, caffeine intake, physical activity	Epithelial ovarian cancer incidence HEI (2005) HR 0.85 (0.65-1.12) AHEI (2010) HR 1.03 (0.80-1.34)	8

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Yu and colleagues, 2014[59]	China	Shanghai Men's Health Study and Shanghai Women's Health Study	All-cause mortality CVD mortality Cancer mortality	♂61,239 ♀73,216 ♂6.5 ♀12	40-74	Both	mAHEI (2010) mDASH score	Age, education, income, smoking status, alcohol consumption (except for mAHEI (2010)), multivitamin use, physical activity, BMI, waist-to-hip ratio, history of CVD, diabetes or hypertension, menopausal status and use of postmenopausal HT (only for women), energy intake	All-cause mortality mAHEI (2010) ♂HR 0.68 (0.61-0.76) ♀HR 0.80 (0.73-0.87) mDASH score ♂HR 0.76 (0.69-0.85) ♀HR 0.84 (0.76-0.91) CVD mortality mAHEI (2010) ♂HR 0.56 (0.46-0.68) ♀HR 0.73 (0.62-0.87) mDASH score ♂HR 0.60 (0.49-0.73) ♀HR 0.79 (0.67-0.92) Cancer mortality mAHEI (2010) ♂HR 0.87 (0.74-1.02) ♀HR 0.92 (0.80-1.06) mDASH score ♂HR 0.88 (0.75-1.04) ♀HR 0.90 (0.78-1.03)	8

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Table 1. Summary of characteristics and results from 34 reports that investigate the associations of diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, and the Dietary Approaches to Stop Hypertension score and the risk of all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes mellitus, neurodegenerative diseases, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Author(s), year	Country	Cohort	Outcome	Population, n Follow up, y	Age at entry, y	Sex	Diet quality index/score	Adjustment	RR[a]/HR[b] (95% CI), multivariate adjusted[c]	Newcastle Ottawa Quality Assessment Scale[4] (maximum 9)[d]
Yu and colleagues, 2015[37]	US	Southern Community Cohort Study	All-cause mortality CVD mortality Cancer mortality	84,735 6.2	40-79	Both	HEI (2010)	Race/ethnicity, enrollment source, education, income, marital status, medical insurance, smoking status, BMI, physical activity, sitting time, energy intake, menopausal status and use of postmenopausal HT (only for women), baseline disease status	HEI (2010) All-cause mortality HR 0.80 (0.73-0.86) CVD mortality HR 0.81 (0.70-0.94) Cancer mortality HR 0.81 (0.69-0.95)	9

[a]RR=risk ratio.
[b]HR=hazard ratio.
[c]In case of multiple HR/RR values, the order in which data are given correspond to the respective order of outcomes listed in the "Outcomes" column.
[d]Higher scores indicate higher-quality studies.
[e]US=United States.
[f]HEI=Healthy Eating Index.
[g]AHEI=Alternate Healthy Eating Index.
[h]DASH=Dietary Approaches to Stop Hypertension.
[i]♀=women.
[j]WHI=Women's Health Initiative.
[k]T2D=type 2 diabetes.
[l]HT=hormone therapy.
[m]BMI=body mass index.
[n]CVD=cardiovascular disease.
[o]♂=men.
[p]NA=no data available.
[q]m=modified.
[r]OR=odds ratio.
[s]ONTARGET=Ongoing Telmisartan Alone and in Combination with Ramipril Global Endpoint.
[t]TRANSCEND=Telmisartan Randomized Assessment Study in ACE Intolerant Subjects with Cardiovascular Disease.

(Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram (Figure 1).[77]

Taken together, 34 additional reports were identified that were not included in the previous meta-analysis.[9,10,16-20,26-37,45-48,53-59,68-71]

General study characteristics are summarized in Table 1. Sample size varied between 298 and 460,770, with a follow-up time ranging from 3 to 24 years. Overall, 68 reports,[5-72] including 1,670,179 participants, were included in the updated meta-analysis. According to the different clinical outcomes, all-cause mortality was evaluated in 13 reports,[6,9,10,25,28,31,34,37,46,49,52,59,68] cardiovascular disease mortality or incidence in 28 reports,[6-9,11,21,25,28,31,34,37,41,45,46,49,50,52,57-64,66,70,72] cancer mortality or incidence in 31 reports,[6-9,11,13-15,20,22-26,28,29,31,34-38,41,46,49,52,53,55,59,67,69] type 2 diabetes in 10 reports,[11,12,27,32,40,42,44,47,51,65] neurodegenerative diseases in 5 reports,[30,39,43,48,71] all-cause mortality among cancer survivors in 7 reports,[16-19,33,54,56] and cancer mortality among cancer survivors in 7 reports.[16-19,33,54,56]

Main Outcomes

Using a random-effects model, the highest association of diet quality as assessed by the HEI, AHEI, or DASH score was found to be associated with a reduced risk of all-cause mortality (RR 0.78, 95% CI 0.77 to 0.80; I^2=59%, 95% CI 39% to 72%; n=13) (Figure 2), cardiovascular disease (incidence or mortality) (RR 0.78, 95% CI 0.76 to 0.80; I^2=49%, 95% CI 31% to 64%; n=28) (Figure 3; available online at www.jandonline.org), cancer (incidence or mortality) (RR 0.84, 95% CI 0.82 to 0.87; I^2=66%, 95% CI 56% to 73%; n=31) (Figure 4; available online at www.jandonline.org), type 2 diabetes (RR 0.82, 95% CI 0.78 to 0.85; I^2=72%, 95% CI 58% to 82%; n=10) (Figure 5; available online at www.jandonline.org), and neurodegenerative diseases (RR 0.85, 95% CI 0.74 to 0.98; I^2=51%, 95% CI 0% to 78%; n=5) (Figure 6). Among cancer survivors, the association between diets for the highest quality resulted in a significant reduction in all-cause mortality (RR 0.88, 95% CI 0.81 to 0.95; I^2=38%, 95% CI 0%, 67%; n=7) (Figure 7) and cancer mortality (RR 0.90, 95% CI 0.83 to 0.98; I^2=0%, 95% CI, 0% to 55%; n=7; fixed effect model) (Figure 8; available online at www.jandonline.org). The corresponding enumerative data are summarized in Table 2.

Subgroup and Sensitivity Analysis

Subgroup analysis showed an inverse association between diets that scored highly on the HEI, AHEI, and DASH and risk of colorectal, esophageal, lung, gallbladder, pancreatic, prostate, head/neck, as well as hepatocellular carcinoma (Figure 9; available online at www.jandonline.org). Subgroup analysis suggested that all diets that scored highly on the included dietary indexes (HEI, AHEI, and DASH score) were associated with a reduced risk of all-cause mortality, cardiovascular disease (CVD), cancer, and type 2 diabetes. However, the subgroup analysis for risk of neurodegenerative disease indicated that only diets that scored highly on AHEI were associated with reduced risk (RR 0.77, 95% CI 0.68 to 0.88; I^2=0%). Furthermore, the subgroup analysis for risk of all-cause mortality and cancer mortality or incidence indicated that diets that scored highly on the original version of the HEI were not significantly associated with reduced risk of all-cause mortality (RR 0.75, 95% CI 0.53 to 1.07; I^2=67%) and cancer (RR 0.87, 95% CI 0.76 to 1.00; I^2=89%), and diets that scored highly on the more recent diet quality indices (HEI-2005 and HEI-2010) were inversely associated with all-cause mortality (RR 0.78, 95% CI 0.77 to 0.80; I^2=37%) and cancer risk (RR 0.82, 95% CI 0.77 to 0.88; I^2=67%). Moreover, the original version of the AHEI was not significantly associated with reduced risk of cancer (RR 0.87, 95% CI 0.75 to 1.01; I^2=73%), and diets that scored highly on the more recent AHEI-2010 (RR 0.87, 95% CI 0.85 to 0.90; I^2=49%) were inversely associated with cancer risk.

Among cancer survivors, only diets that scored highly on HEI were inversely related to risk of all-cause mortality (RR 0.85, 95% CI 0.75 to 0.96; I^2=26%) and cancer mortality (RR 0.84, 95% CI 0.73 to 0.97; I^2=18%).

As in the previous version of the meta-analysis, additional subgroup analyses were performed for US studies, long-term studies (≥8 years of follow up), high-quality cohort studies (Newcastle Ottawa score ≥7 points), and comparing men and women. Including only US studies confirmed the results of the primary analysis (Table 3; available at www.jandonline.org). Subgroup analyses taking into account longer-term follow up (Table 4; available at www.jandonline.org) and high-quality studies (Table 5; available at www.jandonline.org) confirmed the results of the main analysis, except for neurodegenerative disease risk, showing no significant associations. No significant differences comparing men and women were observed in the subgroup analysis, except for all-cause mortality and cancer mortality among cancer survivors, showing a significant inverse association only for women (Tables 6 and 7; available at www.jandonline.org).

Because for CVD and cancer, mortality and incidence rates were combined, sensitivity analyses were performed comparing mortality vs incidence (CVD incidence RR 0.79, 95% CI 0.75 to 0.83, cancer incidence RR 0.84, 95% CI 0.82 to 0.86, CVD mortality RR 0.79, 95% CI 0.75 to 0.80, and cancer mortality RR 0.85, 95% CI 0.83 to 0.87). No differences between mortality and incidence analyses were observed. In addition, a fixed-effects sensitivity analysis confirmed all results of the main analysis (Table 8; available at www.jandonline.org).

Publication Bias

Egger linear regression tests (performed with at least 10 studies) provided no evidence of small study effects for risk of all-cause mortality (P=0.78), CVD (P=0.16), overall cancer mortality or incidence risk (P=0.13), and risk of type 2 diabetes (P=0.94), following comparison of the highest vs lowest quantiles of HEI, AHEI, and DASH scores. However, a potential risk of bias for all-cause mortality (P=0.01) and cancer mortality (P=0.03) among cancer survivors was observed.

Funnel plots were only generated when ≥10 studies were available for a comparison. The funnel plots for risk of all-cause mortality (Figure 10; available at www.jandonline.org), cardiovascular disease mortality or incidence (Figure 11; available at www.jandonline.org), indicate little asymmetry, whereas the funnels plots for cancer mortality or incidence (Figure 12; available at www.jandonline.org), for risk of type 2 diabetes (Figure 13; available at www.jandonline.org), as well as all-cause mortality (Figure 14; available at www.jandonline.org), and cancer mortality

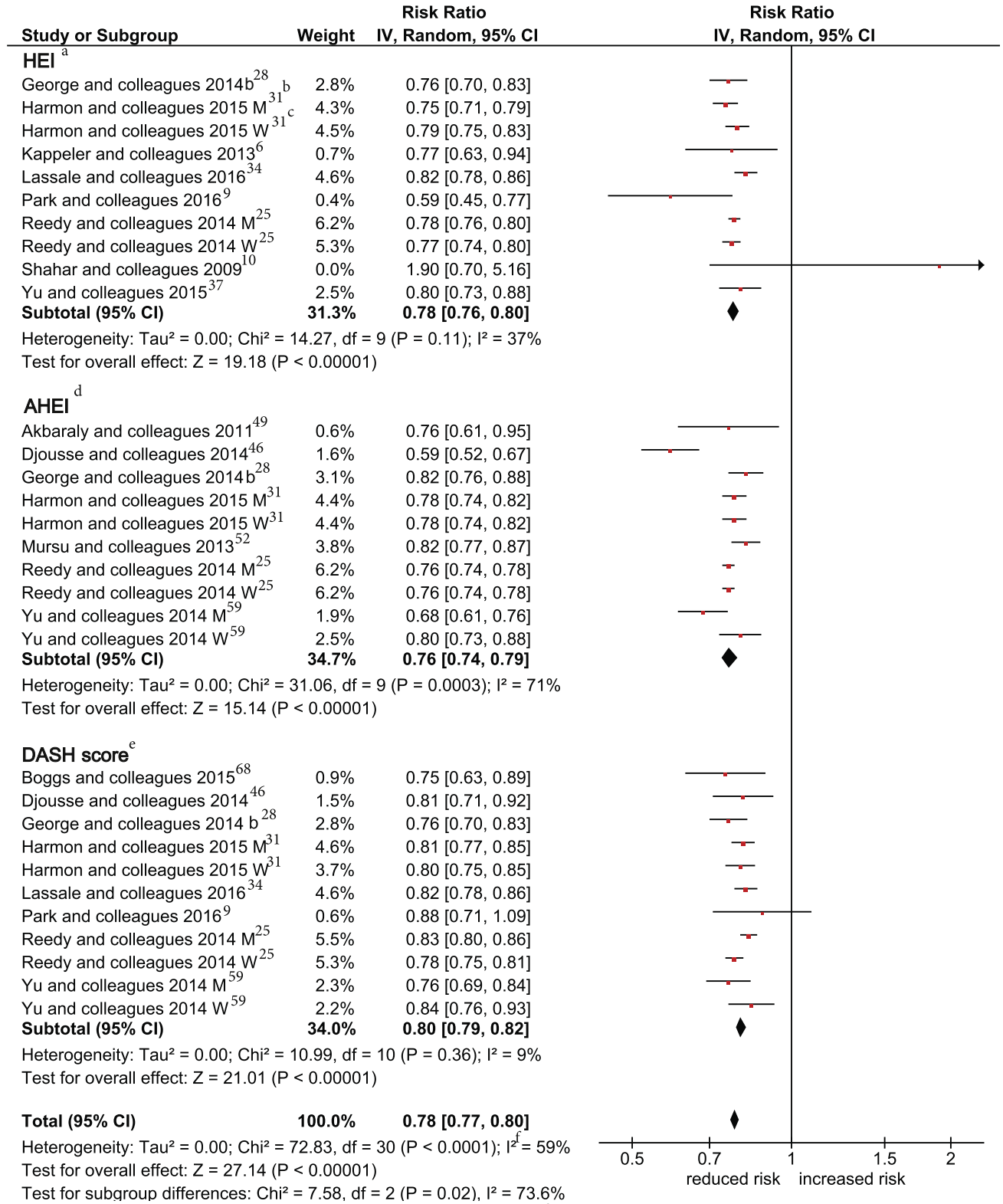

Figure 2. Forest plot showing pooled relative risks (RRs) with 95% CI for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category for all-cause mortality. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=inconsistency.

Table 2. Relative risk (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular disease mortality or incidence, cancer mortality or incidence, cancer types, type 2 diabetes, neurodegenerative disease, as well as all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of reports	Index/score	Relative risk	95% CI	I^2, %[a] (95% CI)	H^2[b]	Test for subgroup difference (*P* value)
All-cause mortality	13	All indexes combined	0.78	0.77-0.80	59 (39-72)	2.43	
	8	HEI[c]	0.78	0.76-0.80	37	1.58	0.02
	7	AHEI[d]	0.76	0.74-0.79	71	3.44	
	8	DASH[e] score	0.80	0.79-0.82	9	1.09	
Cardiovascular disease mortality or incidence	28	All indexes combined	0.78	0.76-0.80	49 (31-64)	1.96	
	11	HEI	0.79	0.77-0.82	16	1.19	0.02
	13	AHEI	0.75	0.72-0.77	39	1.64	
	18	DASH score	0.80	0.77-0.84	49	1.96	
Cancer mortality or incidence	31	All indexes combined	0.84	0.82-0.87	66 (56-73)	2.94	
	21	HEI	0.83	0.79-0.87	73	3.70	0.03
	18	AHEI	0.88	0.85-0.91	54	2.17	
	15	DASH score	0.82	0.80-0.86	48	1.92	
Breast cancer	2	All indexes combined	0.94	0.81-1.08	86	1	<0.001
Colorectal cancer	4	All indexes combined	0.77	0.73-0.81	0	1	
Esophageal cancer	1	HEI	0.66	0.46-0.94	43	1.75	
Gastric cancer	1	HEI	0.90	0.72-1.12	0	1	
Pancreatic cancer	1	HEI	0.85	0.74-0.98	NA[f]	NA	
Prostate cancer	1	All indexes combined	0.93	0.89-0.97	NA	NA	
Head and neck cancer	1	HEI	0.61	0.40-0.94	75	4	
Hepatocellular carcinoma	1	HEI	0.72	0.53-0.98	NA	NA	
Lung cancer	1	All indexes combined	0.84	0.81-0.87	NA	NA	
Urothelial cell carcinoma	1	AHEI	1.02	0.73-1.43	NA	NA	
Gallbladder cancer	1	DASH score	0.36	0.20-0.65	NA	NA	
Ovarian cancer	1	All indexes combined	1.03	0.80-1.33	NA	NA	

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Table 2. Relative risk (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular disease mortality or incidence, cancer mortality or incidence, cancer types, type 2 diabetes, neurodegenerative disease, as well as all-cause mortality and cancer mortality among cancer survivors (*continued*)

Outcome	No. of reports	Index/score	Relative risk	95% CI	I^2, %[a] (95% CI)	H^2[b]	Test for subgroup difference (*P* value)
Endometrial cancer	1	All indexes combined	1.03	0.93-1.14	NA	NA	
Type 2 diabetes	10	All indexes combined	0.82	0.78-0.85	72 (58-82)	3.57	
	3	HEI	0.87	0.82-0.93	61	2.56	0.13
	9	AHEI	0.80	0.74-0.86	76	4.16	
	7	DASH score	0.80	0.74-0.86	61	2.56	
Neurodegenerative diseases	5	All indexes combined	0.85	0.74-0.98	51 (0-78)	2.04	
	3	HEI	0.97	0.68-1.39	55	2.22	0.51
	2	AHEI	0.77	0.68-0.88	0	1	
	2	DASH score	0.80	0.53-1.20	66	2.94	
All-cause mortality among cancer survivors	7	All indexes combined	0.88	0.81-0.95	38 (0-67)	1.61	
	5	HEI	0.85	0.75-0.96	26	1.35	0.49
	3	AHEI	0.85	0.70-1.03	65	2.85	
	3	DASH score	0.94	0.82-1.08	27	1.37	
Cancer mortality among cancer survivors	7	All indexes combined	0.90	0.83-0.98	0 (0-55)	1	
	5	HEI	0.84	0.73-0.97	18	1.22	0.51
	3	AHEI	0.95	0.79-1.13	20	1.25	
	3	DASH score	0.93	0.79-1.10	0	1	

[a] I^2=inconsistency, percentage of variation across studies due to heterogeneity.
[b] H^2=total variability.
[c] HEI=Healthy Eating Index.
[d] AHEI=Alternate Healthy Eating Index.
[e] DASH=Dietary Approaches to Stop Hypertension.
[f] NA=not applicable.

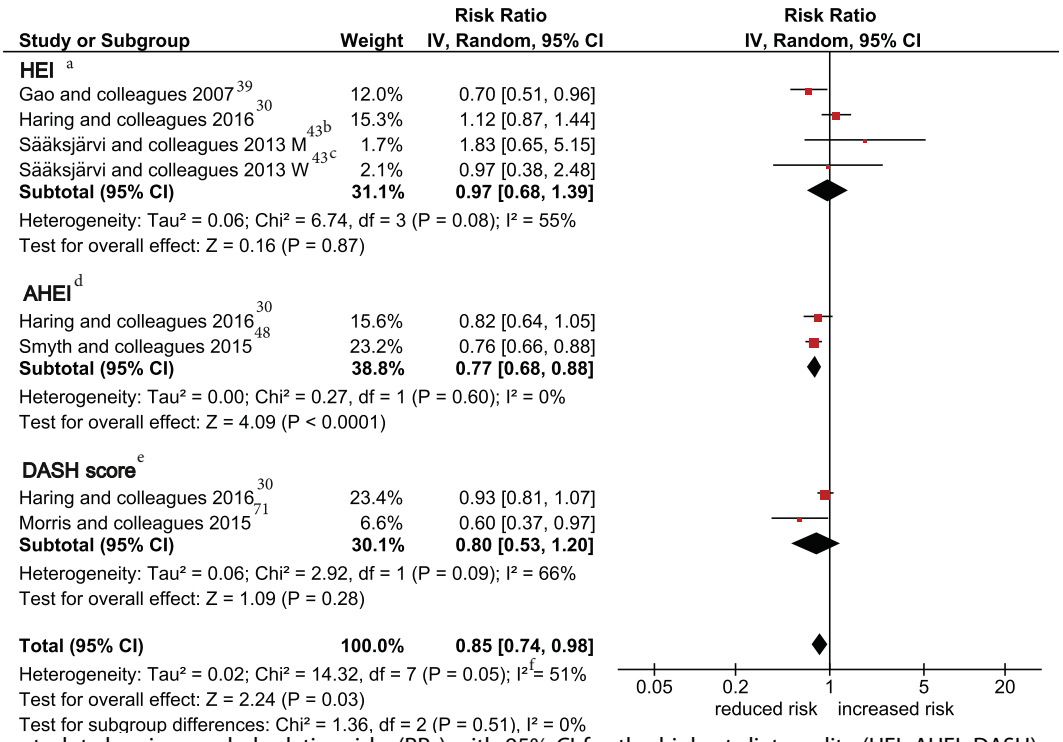

Figure 6. Forest plot showing pooled relative risks (RRs) with 95% CI for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category for neurodegenerative disease. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=inconsistency.

(Figure 15; available at www.jandonline.org) among cancer survivors indicate moderate symmetry.

DISCUSSION

In this updated systematic review and meta-analysis of prospective cohort studies investigating the pooled estimates from studies assessing diet quality using the HEI, AHEI, and DASH score on all-cause mortality, cardiovascular disease mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality among cancer survivors, findings were pooled from 68 reports, including more than 1.6 million participants.

In general, the main results suggest that diets of the highest quality, as assessed by the HEI, AHEI, and DASH score, were associated with a significant reduction in the risk of all-cause mortality, cardiovascular disease, cancer, type 2 diabetes, and neurodegenerative disease by 22%, 22%, 16%, 18%, and 15%, respectively. Moreover, adherence to high-quality diet was inversely associated with overall mortality among cancer survivors by 12%.

The original systematic review and meta-analysis was, to the best of the authors' knowledge, the first approach to investigate the pooled estimates from studies assessing diet quality via these indices.[1] In congruence with the updated version, the original results emphasized the importance of dietary pattern analysis for studying the association between diet and health status. It could be shown that high-quality diets were associated with reduced risk of all-cause mortality as well as onset of disease. The present report represents a substantial update of the original, adding important evidence for a beneficial effect of diets of the highest quality, as assessed by the HEI, AHEI, and DASH score for additional types of neurodegenerative diseases, as well as additional types of cancer both not yet available in 2014 (gallbladder, lung, endometrial), and all-cause and cancer mortality among cancer survivors. This is a target group for nutritional recommendations gaining importance due to improved screening methods, early diagnosis, and enhanced treatment approaches.[2] The inverse association between the included diet quality indices and all-cause mortality in cancer survivors is in line with a previous meta-analysis of cohort studies, showing an inverse association between high diet quality indices or a prudent/health dietary pattern and reduced risk of overall mortality.[3]

Subgroup analyses revealed that the positive influence of adhering to the diet quality indices depends on their chronological development. Inverse associations of high adherence to HEI or AHEI with respect to cancer (incidence or mortality) could only be observed for later versions of both indices, that is, the 2005 and 2010 versions of the HEI and the 2010 version of the AHEI. Assessment of the overall quality of diet via *a priori* approaches instead of single nutrients is a comparatively new approach.[78] The indices used for the present systematic review represent *a priori* defined indices based on already existing national recommendations or data derived from prospective cohort studies for a healthy lifestyle.[1] The HEI and AHEI are continuously updated and improved by implementing new study data. Therefore, there is a time-dependent evolution of the corresponding indices

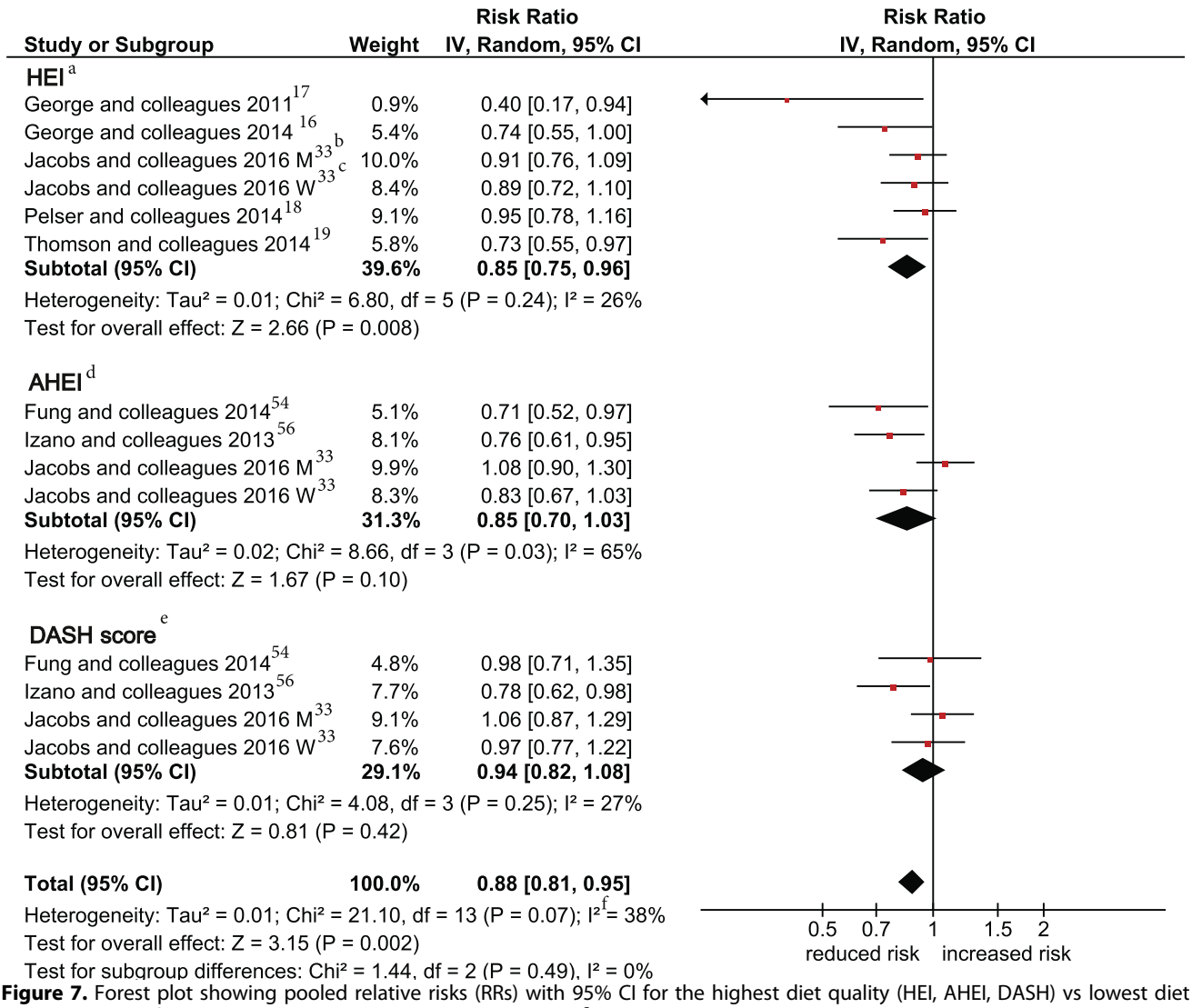

Figure 7. Forest plot showing pooled relative risks (RRs) with 95% CI for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category for all-cause mortality among cancer survivors. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=inconsistency.

as well, for example, the original version of the HEI did not differentiate between refined and unrefined grains,[79] thereby limiting its sensitivity in the evaluation of the interactions between high adherence and onset and progression of type 2 diabetes, CVD, and cancer.[7,8] Likewise, there were differences in the scoring of the AHEI, with additional factors being included in its latest version to incorporate more recent scientific evidence on the relationship between diet and health.[11]

In another subgroup analysis, the impact of scoring highly on one of the diet quality indices with respect to different types of cancer was investigated. It has to be noted that for a number of tumor localizations, data could only be extracted from single epidemiological observations (pancreatic, prostate, hepatocellular, lung, urothelial cell, gallbladder, ovarian, and endometrial carcinoma). However, the inverse associations of high adherence to diet quality indices on the pathogenesis of colorectal cancer were covered by more than one cohort. Regarding colorectal and head and neck cancer, similar results were provided by a systematic review investigating 55 different diet quality scores.[80] In addition, the authors reported for several studies an inverse association between high-quality diets and risk of breast cancer, which could not be observed in present meta-analysis.[80] These discrepancies might be explained by the implementation of different dietary scores by Potter and colleagues, for example, the Mediterranean diet. Data on this *a priori* pattern were synthesized in an earlier meta-analysis finding that the highest adherence to a Mediterranean diet category was associated with a reduced risk of breast cancer by combining cohort and case-control studies.[81,82]

Despite the various differences between the diet quality indices used in the present study, a commonality is that they assess intake of desirable food groups such as fruits, vegetables, whole grains, nuts, and legumes.[83-90] At the same time, potentially detrimental food groups are appropriately taken

into account as well.[83,90-92] Taken together, this might help explain the results of the systematic synthesis of all available data on diet quality indices at hand.

Strengths and Limitations

Although the number of epidemiological studies is substantially higher compared to the original systematic review, there remains a considerable statistical heterogeneity with respect to all-cause mortality, cancer incidence/mortality, CVD incidence/mortality, type 2 diabetes, and incidence of neurodegenerative diseases. Basically, the limitations of the former analysis still apply for the updated version (heterogeneous scoring systems, risk estimates, population/sex/age and sample size, follow up, development stage of included indices). In addition, gray literature published outside regular academic distribution channels was not searched or inquired via contacting study authors. Publication bias is another important threat to the validity of meta-analysis. Due to the large number of studies, it was possible to test publication bias for all-cause mortality, CVD mortality or incidence, cancer mortality or incidence, and type 2 diabetes, whereas for all other outcomes the size of the meta-analyses were too small.[93] However, because all included studies were published post 2000, publication bias is less of a risk.[94]

However, the study has been strengthened by including additional forms of neurodegenerative diseases, additional types and localizations of cancer, and by enrolling cohorts of cancer survivors. The latter enhances the informative value of the data at hand with regard to secondary preventive measures. This led to a consecutive increase in power of the analyses (68 reports including 1,670,179 participants as compared to 34 reports including 1,020,642 participants in the original analysis). Regardless of the persisting limitations, present data provide good-quality evidence that the consumption of high-quality diets as assessed by the HEI, AHEI, and DASH score is associated with beneficial health effects, stressing the importance of the underlying dietary recommendations.

CONCLUSIONS

In the updated meta-analyses diets that score highly on the HEI, AHEI, and DASH were associated with a significant reduction in the risk of all-cause mortality, cardiovascular disease, cancer, type 2 diabetes, and neurodegenerative disease by 22%, 22%, 16%, 18%, and 15%, respectively. In addition, high-quality diets were inversely associated with overall mortality and cancer mortality among cancer survivors. This stresses the importance of lifestyle adaptations in primary as well as secondary prevention of non-communicable diseases.

References

1. Schwingshackl L, Hoffmann G. Diet quality as assessed by the Healthy Eating Index, the Alternate Healthy Eating Index, the Dietary Approaches to Stop Hypertension score, and health outcomes: A systematic review and meta-analysis of cohort studies. *J Acad Nutr Diet*. 2015;115(5):780-800.e785.
2. Bluethmann SM, Mariotto AB, Rowland JH. Anticipating the "silver tsunami": Prevalence trajectories and comorbidity burden among older cancer survivors in the United States. *Cancer Epidemiol Biomarkers Prevention*. 2016;25(7):1029-1036.
3. Schwedhelm C, Boeing H, Hoffmann G, Aleksandrova K, Schwingshackl L. Effect of diet on mortality and cancer recurrence among cancer survivors: A systematic review and meta-analysis of cohort studies. *Nutr Rev*. 2016;74(12):737-748.
4. Wells G, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed August 13, 2014.
5. Fung TT, Hu FB, McCullough ML, Newby PK, Willett WC, Holmes MD. Diet quality is associated with the risk of estrogen receptor-negative breast cancer in postmenopausal women. *J Nutr*. 2006;136(2):466-472.
6. Kappeler R, Eichholzer M, Rohrmann S. Meat consumption and diet quality and mortality in NHANES III. *Eur J Clin Nutr*. 2013;67(6):598-606.
7. 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(5):1223-1231.
8. 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(5):1214-1222.
9. Park YM, Fung TT, Steck SE, et al. Diet quality and mortality risk in metabolically obese normal-weight adults. *Mayo Clin Proc*. 2016;91(10):1372-1383.
10. Shahar DR, Yu B, Houston DK, et al. Dietary factors in relation to daily activity energy expenditure and mortality among older adults. *J Nutr Health Aging*. 2009;13(5):414-420.
11. Chiuve SE, Fung TT, Rimm EB, et al. Alternative dietary indices both strongly predict risk of chronic disease. *J Nutr*. 2012;142(6):1009-1018.
12. de Koning L, Chiuve SE, Fung TT, Willett WC, Rimm EB, Hu FB. Diet-quality scores and the risk of type 2 diabetes in men. *Diabetes Care*. 2011;34(5):1150-1156.
13. Li WQ, Park Y, Wu JW, et al. Index-based dietary patterns and risk of head and neck cancer in a large prospective study. *Am J Clin Nutr*. 2014;99(3):559-566.
14. Li WQ, Park Y, Wu JW, et al. Index-based dietary patterns and risk of esophageal and gastric cancer in a large cohort study. *Clin Gastroenterol Hepatol*. 2013;11(9):1130-1136.e1132.
15. Reedy J, Mitrou PN, Krebs-Smith SM, et al. Index-based dietary patterns and risk of colorectal cancer: The NIH-AARP Diet and Health Study. *Am J Epidemiol*. 2008;168(1):38-48.
16. George SM, Ballard-Barbash R, Shikany JM, et al. Better postdiagnosis diet quality is associated with reduced risk of death among postmenopausal women with invasive breast cancer in the women's health initiative. *Cancer Dpidemiol Biomarkers Prev*. 2014;23(4):575-583.
17. George SM, Irwin ML, Smith AW, et al. Postdiagnosis diet quality, the combination of diet quality and recreational physical activity, and prognosis after early-stage breast cancer. *Cancer Causes Control*. 2011;22(4):589-598.
18. Pelser C, Arem H, Pfeiffer RM, et al. Prediagnostic lifestyle factors and survival after colon and rectal cancer diagnosis in the National Institutes of Health (NIH)-AARP Diet and Health Study. *Cancer*. 2014;120(10):1540-1547.
19. Thomson CA, Crane E, Wertheim BC, et al. Diet quality and survival after ovarian cancer: Results from the Women's Health Initiative. *J Natl Cancer Inst*. 2014;106(11).
20. Xie J, Poole EM, Terry KL, et al. A prospective cohort study of dietary indices and incidence of epithelial ovarian cancer. *J Ovarian Res*. 2014;7:112.
21. Agnoli C, Krogh V, Grioni S, et al. A priori-defined dietary patterns are associated with reduced risk of stroke in a large Italian cohort. *J Nutr*. 2011;141(8):1552-1558.
22. Arem H, Reedy J, Sampson J, et al. The Healthy Eating Index 2005 and risk for pancreatic cancer in the NIH-AARP study. *J Natl Cancer Inst*. 2013;105(17):1298-1305.
23. Bosire C, Stampfer MJ, Subar AF, et al. Index-based dietary patterns and the risk of prostate cancer in the NIH-AARP diet and health study. *Am J Epidemiol*. 2013;177(6):504-513.
24. Li WQ, Park Y, McGlynn KA, et al. Index-based dietary patterns and risk of incident hepatocellular carcinoma and mortality from chronic liver disease in a prospective study. *Hepatology (Baltimore, Md.)*. 2014;60(2):588-597.
25. Reedy J, Krebs-Smith SM, Miller PE, et al. Higher diet quality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults. *J Nutr*. 2014;144(6):881-889.
26. Anic GM, Park Y, Subar AF, Schap TE, Reedy J. Index-based dietary patterns and risk of lung cancer in the NIH-AARP diet and health study. *Eur J Clin Nutr*. 2016;70(1):123-129.

27. Cespedes EM, Hu FB, Tinker L, et al. Multiple healthful dietary patterns and type 2 diabetes in the Women's Health Initiative. *Am J Epidemiol*. 2016;183(7):622-633.
28. George SM, Ballard-Barbash R, Manson JE, et al. Comparing indices of diet quality with chronic disease mortality risk in postmenopausal women in the Women's Health Initiative Observational Study: Evidence to inform national dietary guidance. *Am J Epidemiol*. 2014;180(6):616-625.
29. George SM, Ballard R, Shikany JM, Crane TE, Neuhouser ML. A prospective analysis of diet quality and endometrial cancer among 84,415 postmenopausal women in the Women's Health Initiative. *Ann Epidemiol*. 2015;25(10):788-793.
30. Haring B, Wu C, Mossavar-Rahmani Y, et al. No association between dietary patterns and risk for cognitive decline in older women with 9-year follow-up: Data from the Women's Health Initiative Memory Study. *J Acad Nutr Diet*. 2016;116(6):921-930.e921.
31. Harmon BE, Boushey CJ, Shvetsov YB, et al. Associations of key diet-quality indexes with mortality in the Multiethnic Cohort: The Dietary Patterns Methods Project. *Am J Clin Nutr*. 2015;101(3):587-597.
32. Jacobs S, Harmon BE, Boushey CJ, et al. A priori-defined diet quality indexes and risk of type 2 diabetes: The Multiethnic Cohort. *Diabetologia*. 2015;58(1):98-112.
33. Jacobs S, Harmon BE, Ollberding NJ, et al. Among 4 diet quality indexes, only the Alternate Mediterranean Diet score is associated with better colorectal cancer survival and only in African American Women in the Multiethnic Cohort. *J Nutr*. 2016;146(9):1746-1755.
34. Lassale C, Gunter MJ, Romaguera D, et al. Diet quality scores and prediction of all-cause, cardiovascular and cancer mortality in a Pan-European Cohort Study. *PLoS One*. 2016;11(7):e0159025.
35. Park SY, Boushey CJ, Wilkens LR, Haiman CA, Le Marchand L. High-quality diets associate with reduced risk of colorectal cancer: Analyses of diet quality indexes in the multiethnic cohort. *Gastroenterology*. 2017;153(2):386-394.e2.
36. Vargas AJ, Neuhouser ML, George SM, et al. Diet quality and colorectal cancer risk in the Women's Health Initiative Observational Study. *Am J Epidemiol*. 2016;184:23-32.
37. Yu D, Sonderman J, Buchowski MS, et al. Healthy eating and risks of total and cause-specific death among low-income populations of African-Americans and other adults in the southeastern United States: A prospective cohort study. *PLoS Med*. 2015;12:e1001830. discussion e1001830.
38. Fung TT, Hu FB, Wu K, Chiuve SE, Fuchs CS, Giovannucci E. The Mediterranean and Dietary Approaches to Stop Hypertension (DASH) diets and colorectal cancer. *Am J Clin Nutr*. 2010;92(6):1429-1435.
39. Gao X, Chen H, Fung TT, et al. Prospective study of dietary pattern and risk of Parkinson disease. *Am J Clin Nutr*. 2007;86(5):1486-1494.
40. Adherence to predefined dietary patterns and incident type 2 diabetes in European populations: EPIC-InterAct Study. *Diabetologia*. 2014;57(2):321-333.
41. 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(6):1261-1271.
42. Qiao Y, Tinker L, Olendzki BC, et al. Racial/ethnic disparities in association between dietary quality and incident diabetes in postmenopausal women in the United States: The Women's Health Initiative 1993-2005. *Ethnicity Health*. 2014;19(3):328-347.
43. Saaksjarvi K, Knekt P, Lundqvist A, et al. A cohort study on diet and the risk of Parkinson's disease: The role of food groups and diet quality. *Br J Nutr*. 2013;109(2):329-337.
44. Tobias DK, Hu FB, Chavarro J, Rosner B, Mozaffarian D, Zhang C. Healthful dietary patterns and type 2 diabetes mellitus risk among women with a history of gestational diabetes mellitus. *Arch Intern Med*. 2012;172(20):1566-1572.
45. Del Gobbo LC, Kalantarian S, Imamura F, et al. Contribution of major lifestyle risk factors for incident heart failure in older adults: The Cardiovascular Health Study. *JACC. Heart Fail*. 2015;3(7):520-528.
46. Djousse L, Petrone A, Gaziano JM. Alternate Healthy Eating Index, Mediterranean and DASH dietary patterns and risk of death in the physician's health study. *Cardiology (Switzerland)*. 2014;128:426. (Abstract).
47. Otto MC, Padhye NS, Bertoni AG, Jacobs DR Jr, Mozaffarian D. Everything in moderation—Dietary diversity and quality, central obesity and risk of diabetes. *PLoS One*. 2015;10(10):e0141341.
48. Smyth A, Dehghan M, O'Donnell M, et al. Healthy eating and reduced risk of cognitive decline: A cohort from 40 countries. *Neurology*. 2015;84(22):2258-2265.
49. Akbaraly TN, Ferrie JE, Berr C, et al. Alternative Healthy Eating Index and mortality over 18 y of follow-up: Results from the Whitehall II cohort. *Am J Clin Nutr*. 2011;94(1):247-253.
50. Belin RJ, Greenland P, Allison M, et al. Diet quality and the risk of cardiovascular disease: The Women's Health Initiative (WHI). *Am J Clin Nutr*. 2011;94(1):49-57.
51. Fung TT, McCullough M, van Dam RM, Hu FB. A prospective study of overall diet quality and risk of type 2 diabetes in women. *Diabetes Care*. 2007;30:1753-1757.
52. Mursu J, Steffen LM, Meyer KA, Duprez D, Jacobs DR Jr. Diet quality indexes and mortality in postmenopausal women: The Iowa Women's Health Study. *Am J Clin Nutr*. 2013;98(2):444-453.
53. Dugue PA, Hodge AM, Brinkman MT, et al. Association between selected dietary scores and the risk of urothelial cell carcinoma: A prospective cohort study. *Int J Cancer*. 2016;139(6):1251-1260.
54. Fung TT, Kashambwa R, Sato K, et al. Post diagnosis diet quality and colorectal cancer survival in women. *PLoS One*. 2014;9(12):e115377.
55. Haridass V. Diet quality scores and risk of incident breast cancer in the California Teachers Study 2015. (Dissertation). http://escholarship.org/uc/item/87t2942b. Accessed July 25, 2017.
56. Izano MA, Fung TT, Chiuve SS, Hu FB, Holmes MD. Are diet quality scores after breast cancer diagnosis associated with improved breast cancer survival? *Nutr Cancer*. 2013;65(6):820-826.
57. Mertens E, Markey O, Geleijnse JM, Lovegrove JA, Givens DI. Adherence to a healthy diet in relation to cardiovascular incidence and risk markers: Evidence from the Caerphilly Prospective Study [published online ahead of print March 14, 2017]. *Eur J Nutr*. https://doi.org/10.1007/s00394-017-1408-0.
58. Neelakantan N, Naidoo N, Koh WP, Yuan JM, van Dam RM. The Alternative Healthy Eating Index is associated with a lower risk of fatal and nonfatal acute myocardial infarction in a Chinese Adult Population. *J Nutr*. 2016;146(7):1379-1386.
59. Yu D, Zhang X, Xiang YB, et al. Adherence to dietary guidelines and mortality: A report from prospective cohort studies of 134,000 Chinese adults in urban Shanghai. *Am J Clin Nutr*. 2014;100(2):693-700.
60. Fitzgerald KC, Chiuve SE, Buring JE, Ridker PM, Glynn RJ. 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(2):189-198.
61. Folsom AR, Parker ED, Harnack LJ. Degree of concordance with DASH diet guidelines and incidence of hypertension and fatal cardiovascular disease. *Am J Hypertens*. 2007;20(3):225-232.
62. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. *Arch Intern Med*. 2008;168(7):713-720.
63. 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(10):1416-1420.
64. Levitan EB, Wolk A, Mittleman MA. Consistency with the DASH diet and incidence of heart failure. *Arch Intern Med*. 2009;169(9):851-857.
65. Liese AD, Nichols M, Sun X, D'Agostino RB Jr, Haffner SM. Adherence to the DASH Diet is inversely associated with incidence of type 2 diabetes: The insulin resistance atherosclerosis study. *Diabetes Care*. 2009;32(8):1434-1436.
66. Lin PH, Yeh WT, Svetkey LP, et al. Dietary intakes consistent with the DASH dietary pattern reduce blood pressure increase with age and risk for stroke in a Chinese population. *Asia Pac J Clin Nutr*. 2013;22(3):482-491.
67. Miller PE, Cross AJ, Subar AF, et al. Comparison of 4 established DASH diet indexes: Examining associations of index scores and colorectal cancer. *Am J Clin Nutr*. 2013;98(3):794-803.
68. Boggs DA, Ban Y, Palmer JR, Rosenberg L. Higher diet quality is inversely associated with mortality in African-American women. *J Nutr*. 2015;145(3):547-554.

69. Larsson SC, Hakansson N, Wolk A. Healthy dietary patterns and incidence of biliary tract and gallbladder cancer in a prospective study of women and men. *Eur J Cancer*. 2017;70:42-47.
70. Larsson SC, Wallin A, Wolk A. Dietary Approaches to Stop Hypertension Diet and incidence of stroke: Results from 2 prospective cohorts. *Stroke*. 2016;47(4):986-990.
71. Morris MC, Tangney CC, Wang Y, Sacks FM, Bennett DA, Aggarwal NT. MIND diet associated with reduced incidence of Alzheimer's disease. *Alzheimer Dement*. 2015;11(9):1007-1014.
72. Bertoia ML, Triche EW, Michaud DS, et al. Mediterranean and Dietary Approaches to Stop Hypertension dietary patterns and risk of sudden cardiac death in postmenopausal women. *Am J Clin Nutr*. 2014;99(2):344-351.
73. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials*. 1986;7(3):177-188.
74. Ioannidis JP, Patsopoulos NA, Evangelou E. Uncertainty in heterogeneity estimates in meta-analyses. *BMJ*. 2007;335(7626):914-916.
75. *Review Manager (RevMan)* [computer program]. Version 5.3. Copenhagen, The Netherlands: The Nordic Cochrane Centre, The Cochrane Collaboration; 2014.
76. *STATA* [computer program]. Release 14. College Station, TX: StataCorp LP; 2015.
77. Stovold E, Beecher D, Foxlee R, Noel-Storr A. Study flow diagrams in Cochrane systematic review updates: An adapted PRISMA flow diagram. *Syst Rev*. 2014;3:54.
78. Hu FB. Dietary pattern analysis: A new direction in nutritional epidemiology. *Curr Opin Lipidol*. 2002;13(1):3-9.
79. Kennedy ET, Ohls J, Carlson S, Fleming K. The Healthy Eating Index: Design and applications. *J Am Diet Assoc*. 1995;95(10):1103-1108.
80. Potter J, Brown L, Williams RL, Byles J, Collins CE. Diet quality and cancer outcomes in adults: A systematic review of epidemiological studies. *Int J Mol Sci*. 2016;17(7).
81. Schwingshackl L, Hoffmann G. Adherence to Mediterranean diet and risk of cancer: An updated systematic review and meta-analysis of observational studies. *Cancer Med*. 2015;4(12):1933-1947.
82. Schwingshackl L, Hoffmann G. Does a Mediterranean-Type diet reduce cancer risk? *Curr Nutr Rep*; 2015:1-9.
83. Schwingshackl L, Hoffmann G, Lampousi AM, et al. Food groups and risk of type 2 diabetes mellitus: A systematic review and meta-analysis of prospective studies. *Eur J Epidemiol*. 2017;32(5):363-375.
84. Schwingshackl L, Hoffmann G, Missbach B, Stelmach-Mardas M, Boeing H. An umbrella review of nuts intake and risk of cardiovascular disease. *Curr Pharm Des*. 2017;23(7):1016-1027.
85. Schwingshackl L, Lampousi AM, Portillo MP, Romaguera D, Hoffmann G, Boeing H. Olive oil in the prevention and management of type 2 diabetes mellitus: A systematic review and meta-analysis of cohort studies and intervention trials. *Nutr Diabetes*. 2017;7(4):e262.
86. Schwingshackl L, Chaimani A, Bechthold A, et al. Food groups and risk of chronic disease: A protocol for a systematic review and network meta-analysis of cohort studies. *Syst Rev*. 2016;5(1):125.
87. Eichelmann F, Schwingshackl L, Fedirko V, Aleksandrova K. Effect of plant-based diets on obesity-related inflammatory profiles: A systematic review and meta-analysis of intervention trials. *Obes Rev*. 2016;17(11):1067-1079.
88. Schwingshackl L, Hoffmann G, Kalle-Uhlmann T, Arregui M, Buijsse B, Boeing H. Fruit and vegetable consumption and changes in anthropometric variables in adult populations: A systematic review and meta-analysis of prospective cohort studies. *PLoS One*. 2015;10(10):e0140846.
89. Schwingshackl L, Missbach B, Konig J, Hoffmann G. Adherence to a Mediterranean diet and risk of diabetes: A systematic review and meta-analysis. *Public Health Nutr*. 2015;18(7):1292-1299.
90. Schwingshackl L, Schwedhelm C, Hoffmann G, et al. Food groups and risk of all-cause mortality: A systematic review and meta-analysis of prospective studies. *Am J Clin Nutr*. 2017;105(6):1462-1473.
91. 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(7):659-669.
92. Fardet A, Boirie Y. Associations between food and beverage groups and major diet-related chronic diseases: An exhaustive review of pooled/meta-analyses and systematic reviews. *Nutr Rev*. 2014;72(12):741-762.
93. Sterne JA, Gavaghan D, Egger M. Publication and related bias in meta-analysis: Power of statistical tests and prevalence in the literature. *J Clin Epidemiol*. 2000;53(11):1119-1129.
94. Kicinski M, Springate DA, Kontopantelis E. Publication bias in meta-analyses from the Cochrane Database of Systematic Reviews. *Stat Med*. 2015;34(20):2781-2793.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT

There is no funding to disclose.

ACKNOWLEDGEMENTS

L. Schwingshackl, B. Bogensberger, and G. Hoffmann collected the data. L. Schwingshackl and G. Hoffmann wrote the first draft with contributions from B. Bogensberger. All authors reviewed and commented on subsequent drafts of the manuscript.

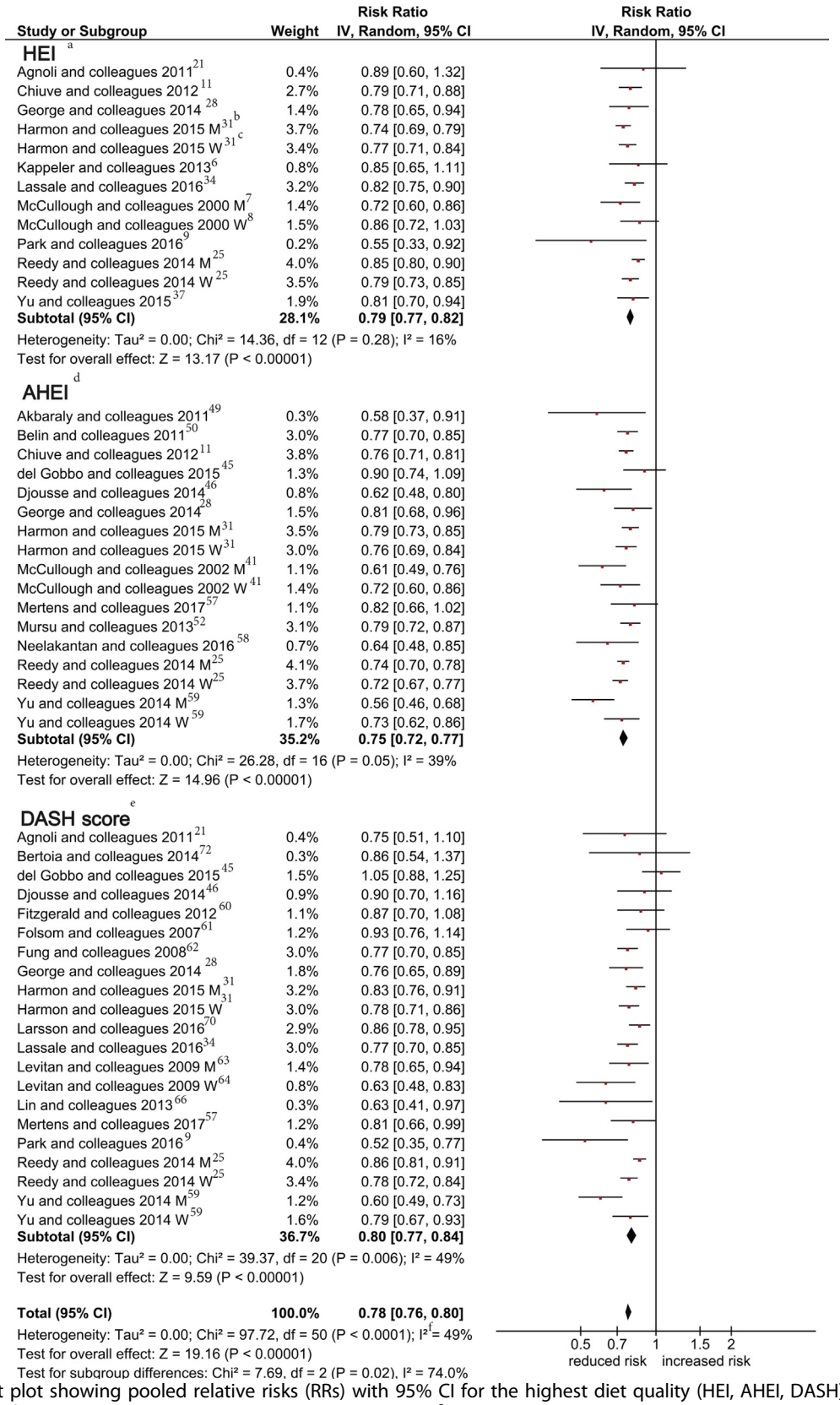

Figure 3. Forest plot showing pooled relative risks (RRs) with 95% CI for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category for cardiovascular disease mortality or incidence. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=inconsistency.

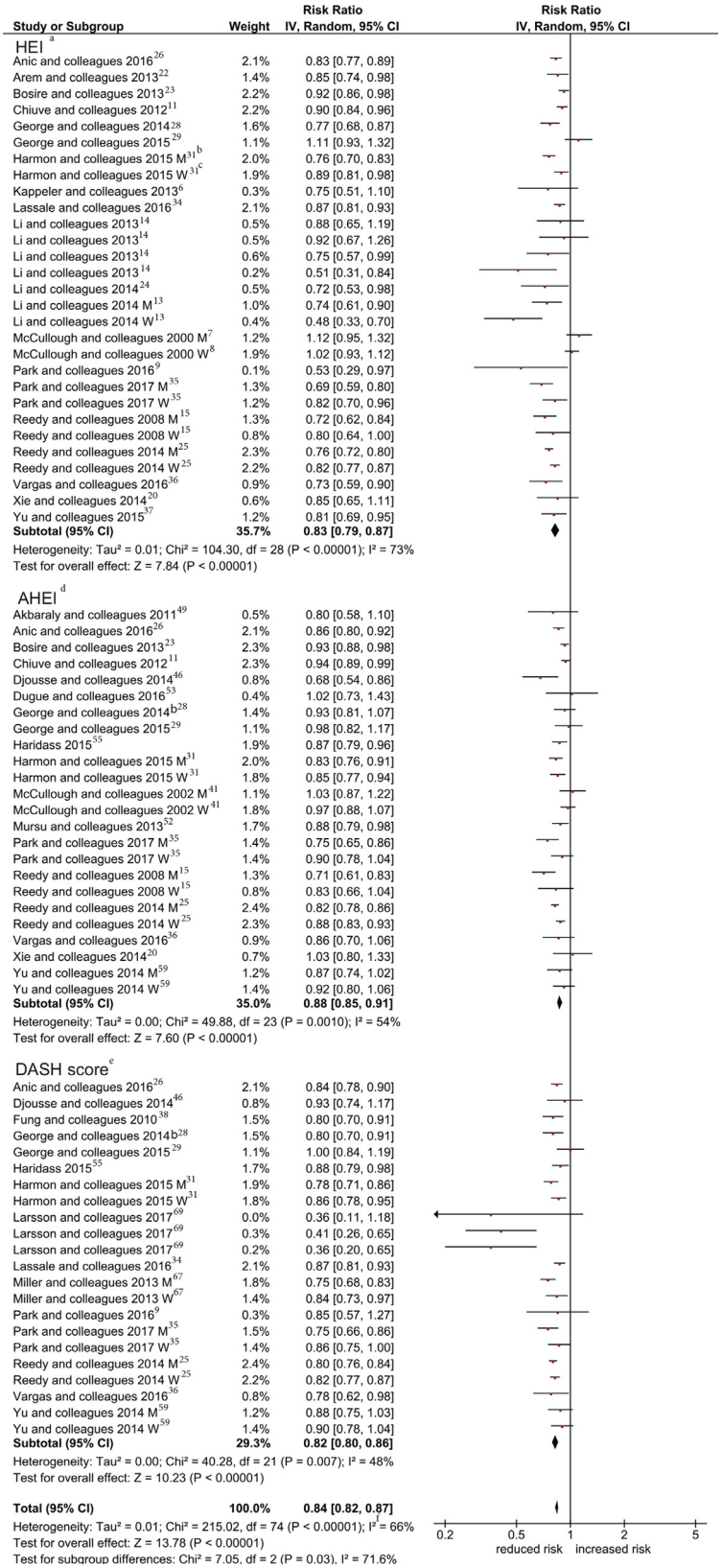

Figure 4. Forest plot showing pooled relative risks (RRs) with 95% CI for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category for cancer mortality or incidence. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=inconsistency.

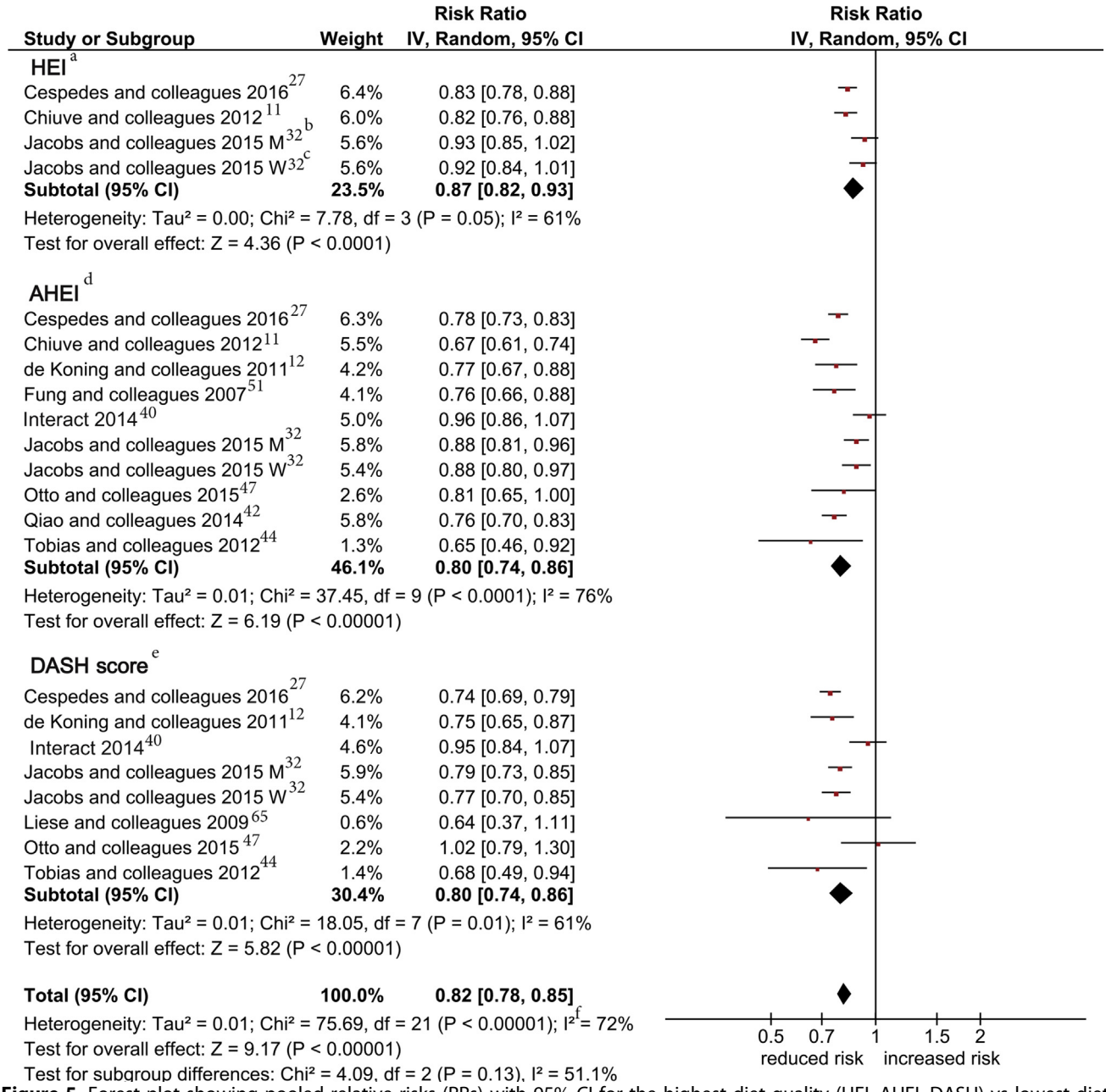

Figure 5. Forest plot showing pooled relative risks (RRs) with 95% CI for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category for type 2 diabetes. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=inconsistency.

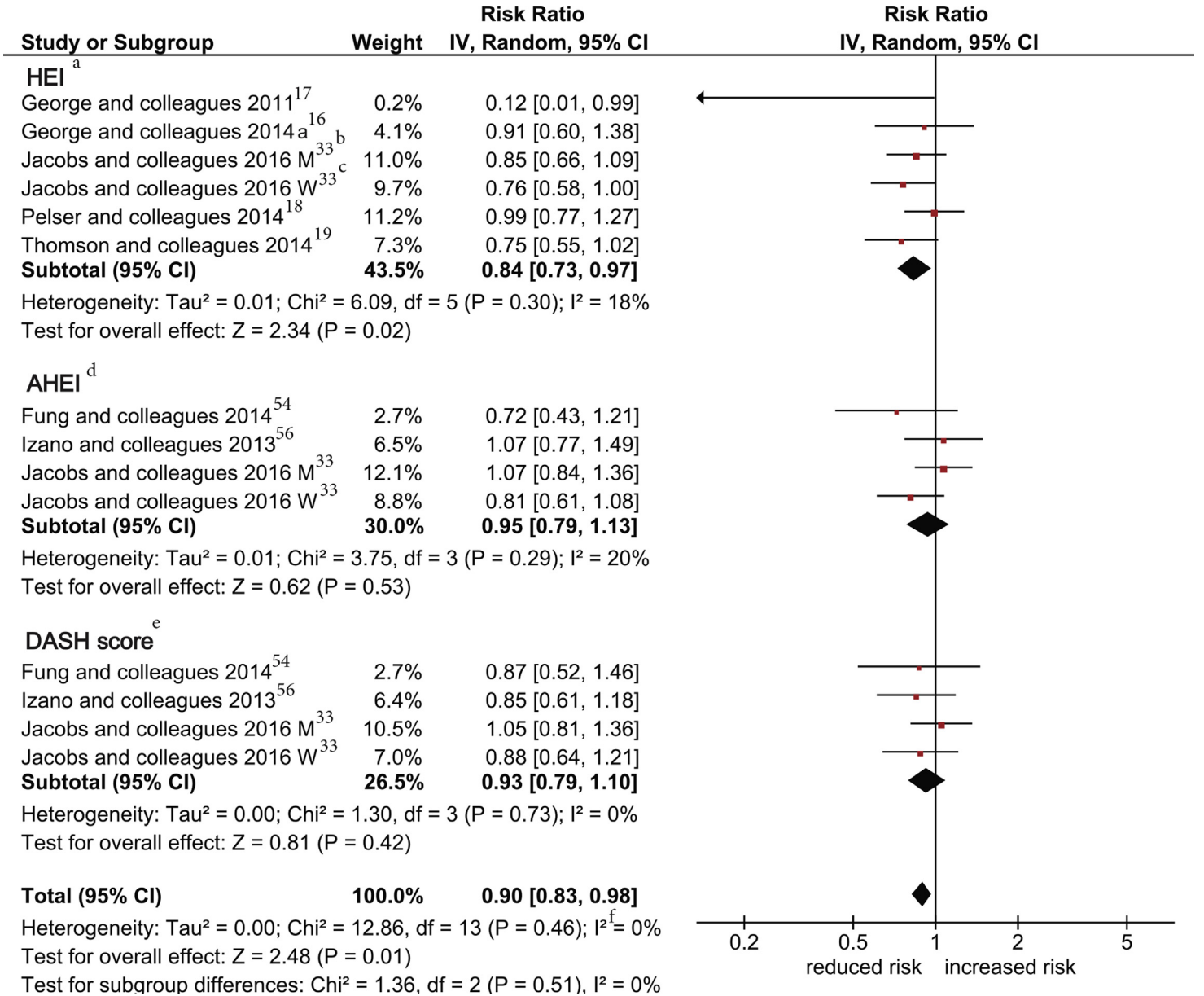

Figure 8. Forest plot showing pooled relative risks (RRs) for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category with 95% CI for cancer mortality among cancer survivors. [a]HEI=Healthy Eating Index (includes the original version, HEI-2005, HEI-2010). [b]Men. [c]Women. [d]AHEI=Alternate Healthy Eating Index (includes the original version, and AHEI-2010). [e]DASH=Dietary Approaches to Stop Hypertension score. [f]I^2=Inconsistency.

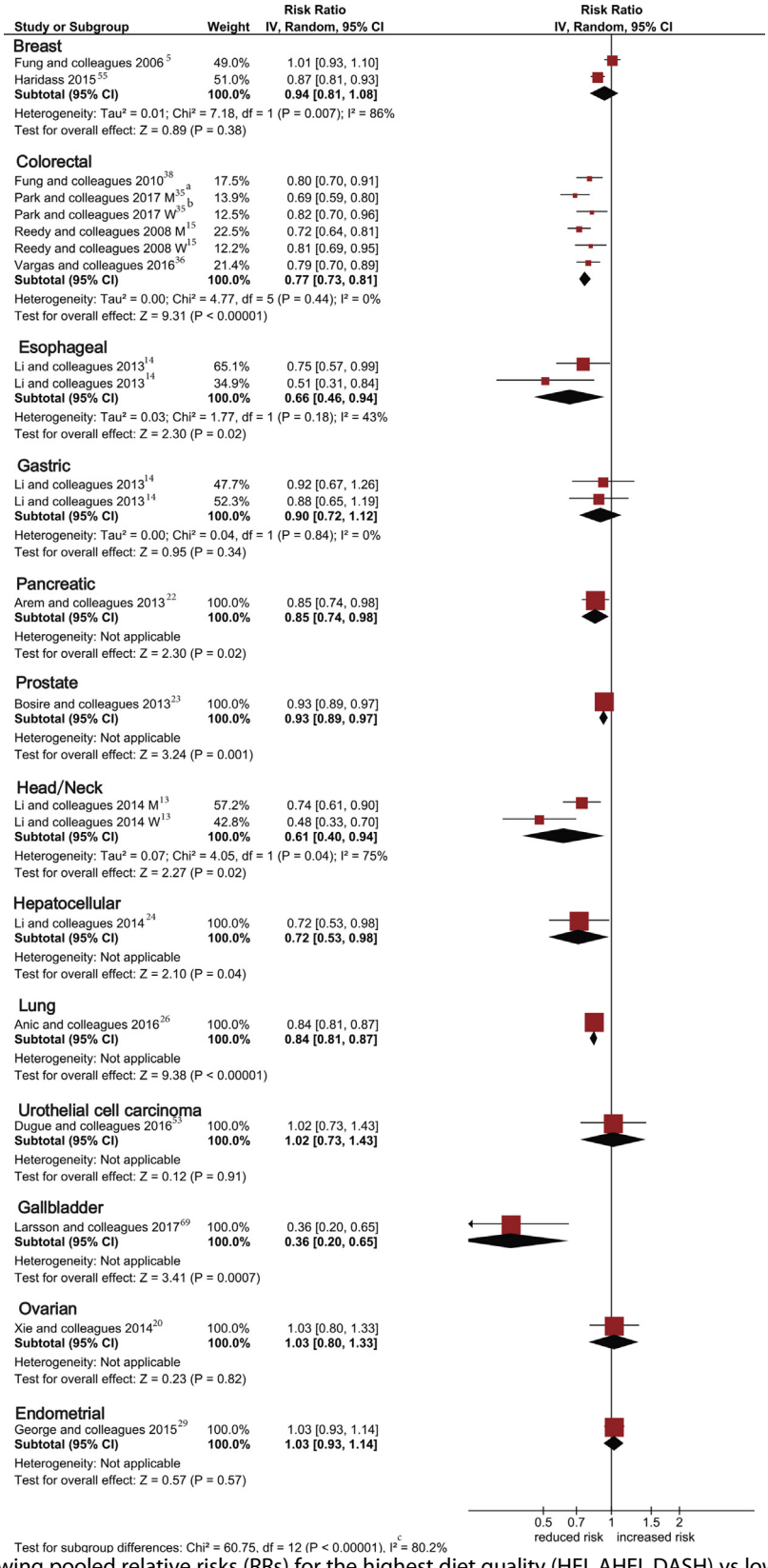

Figure 9. Forest plot showing pooled relative risks (RRs) for the highest diet quality (HEI, AHEI, DASH) vs lowest diet quality category with 95% CI for different cancer types. [a]Men. [b]Women. [c]I^2=inconsistency.

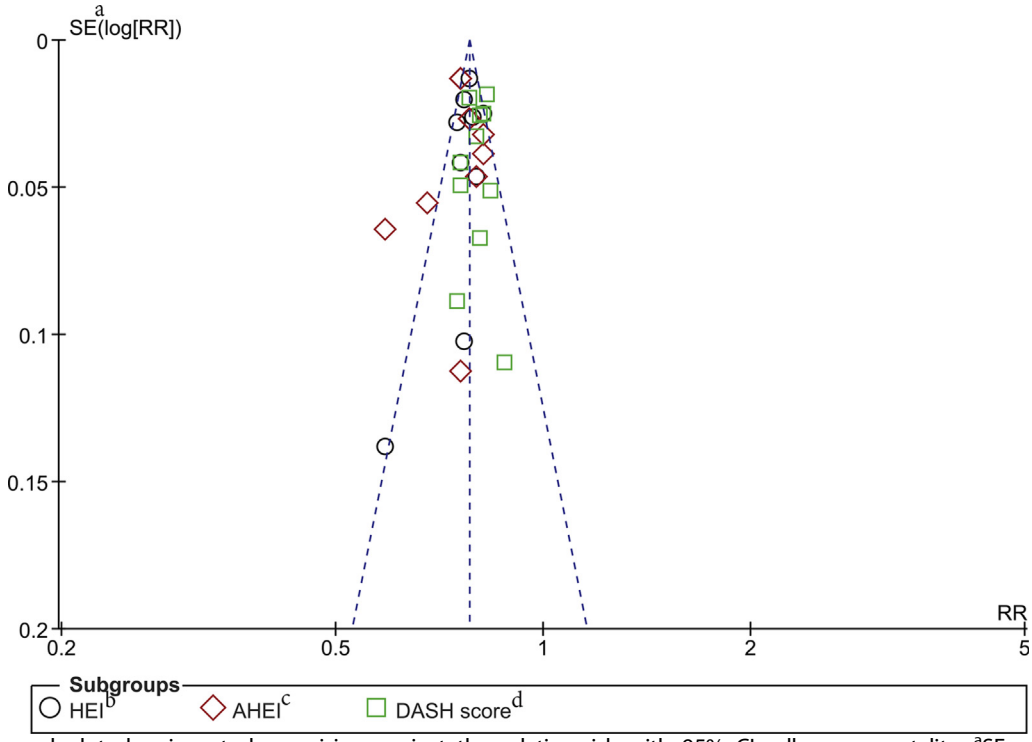

Figure 10. Funnel plot showing study precision against the relative risk with 95% CIs all-cause mortality. [a]SE=standard error. [b]HEI=Healthy Eating Index. [c]AHEI=Alternate Health Eating Index. [d]DASH=Dietary Approaches to Stop Hypertension.

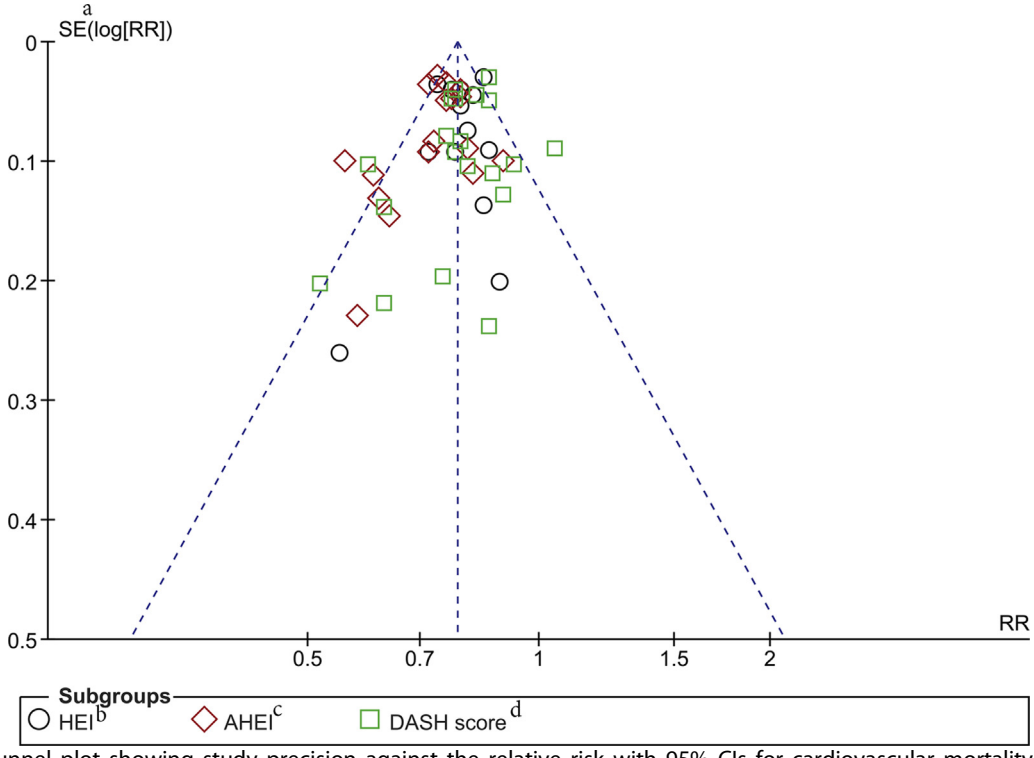

Figure 11. Funnel plot showing study precision against the relative risk with 95% CIs for cardiovascular mortality or incidence. [a]SE=standard error. [b]HEI=Healthy Eating Index. [c]AHEI=Alternate Health Eating Index. [d]DASH=Dietary Approaches to Stop Hypertension.

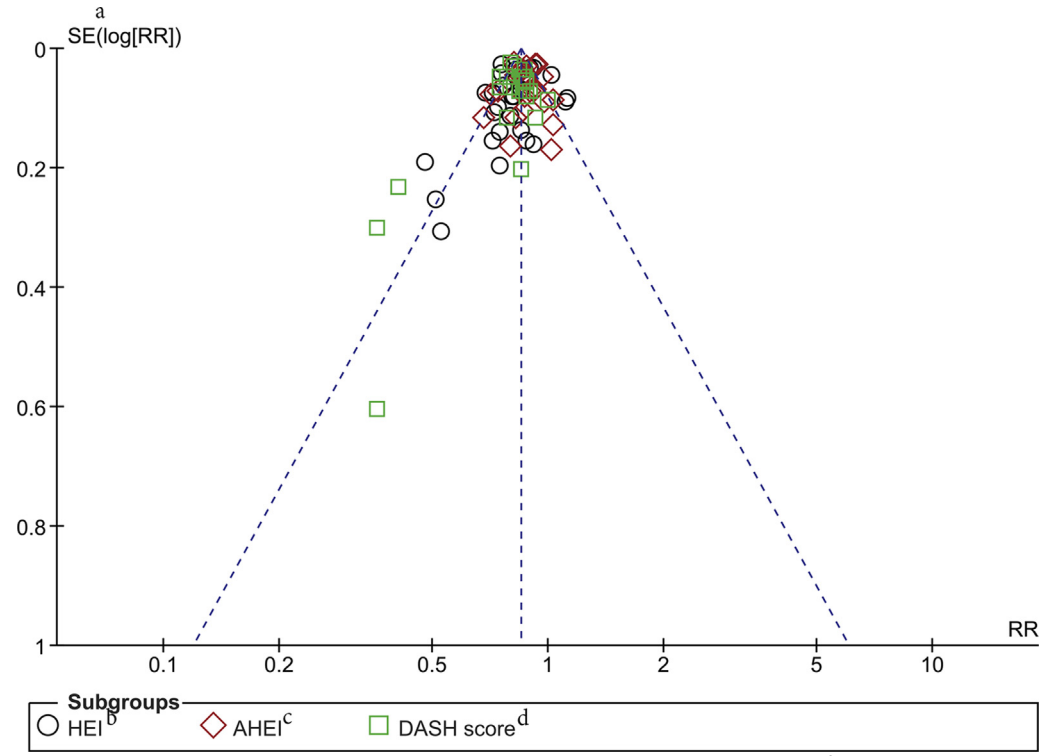

Figure 12. Funnel plot showing study precision against the relative risk with 95% CIs for cancer mortality or incidence. [a]SE=standard error. [b]HEI=Healthy Eating Index. [c]AHEI=Alternate Health Eating Index. [d]DASH=Dietary Approaches to Stop Hypertension.

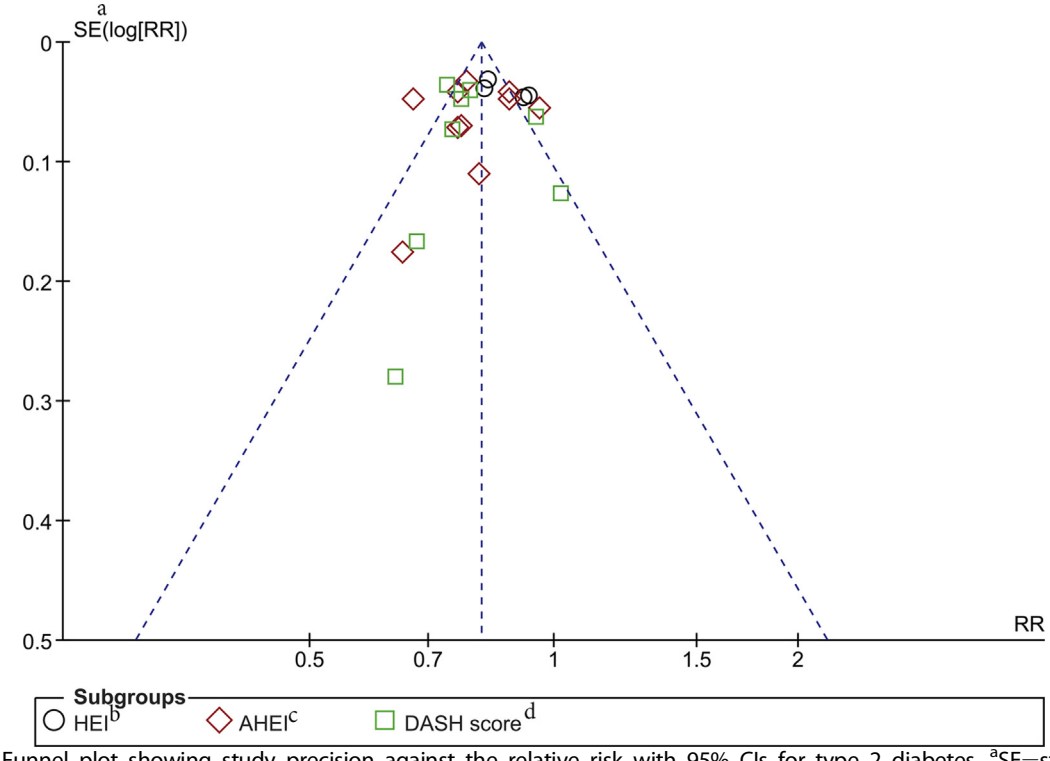

Figure 13. Funnel plot showing study precision against the relative risk with 95% CIs for type 2 diabetes. [a]SE=standard error. [b]HEI=Healthy Eating Index. [c]AHEI=Alternate Health Eating Index. [d]DASH=Dietary Approaches to Stop Hypertension.

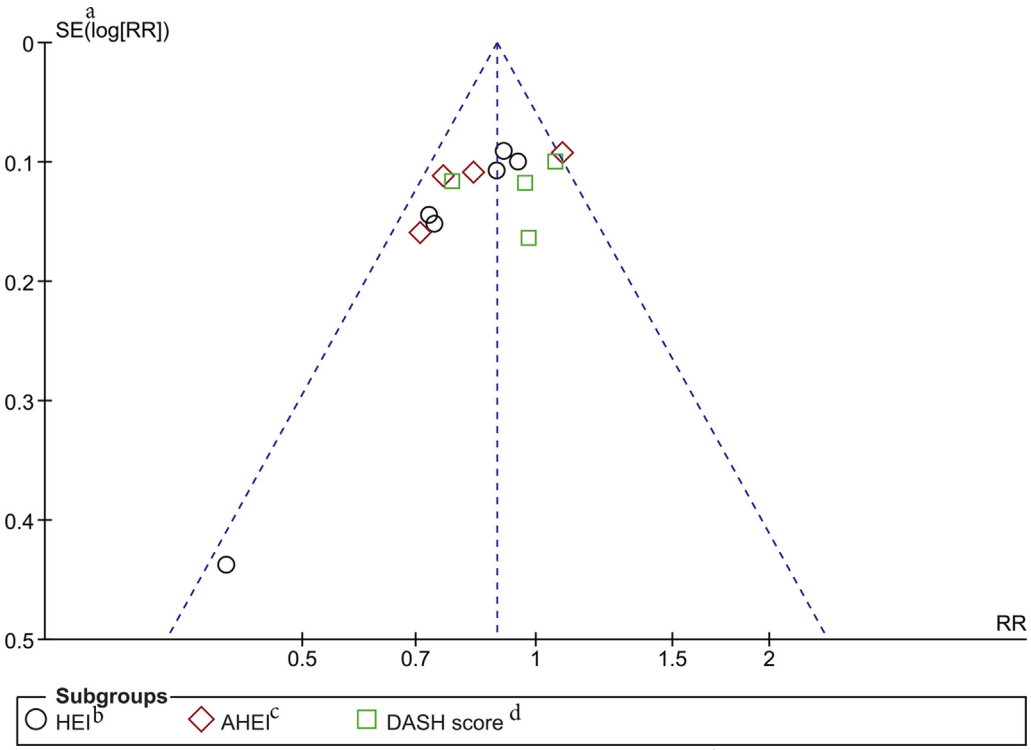

Figure 14. Funnel plot showing study precision against the relative risk with 95% CIs for all-cause mortality among cancer survivors. [a]SE=standard error. [b]HEI=Healthy Eating Index. [c]AHEI=Alternate Health Eating Index. [d]DASH=Dietary Approaches to Stop Hypertension.

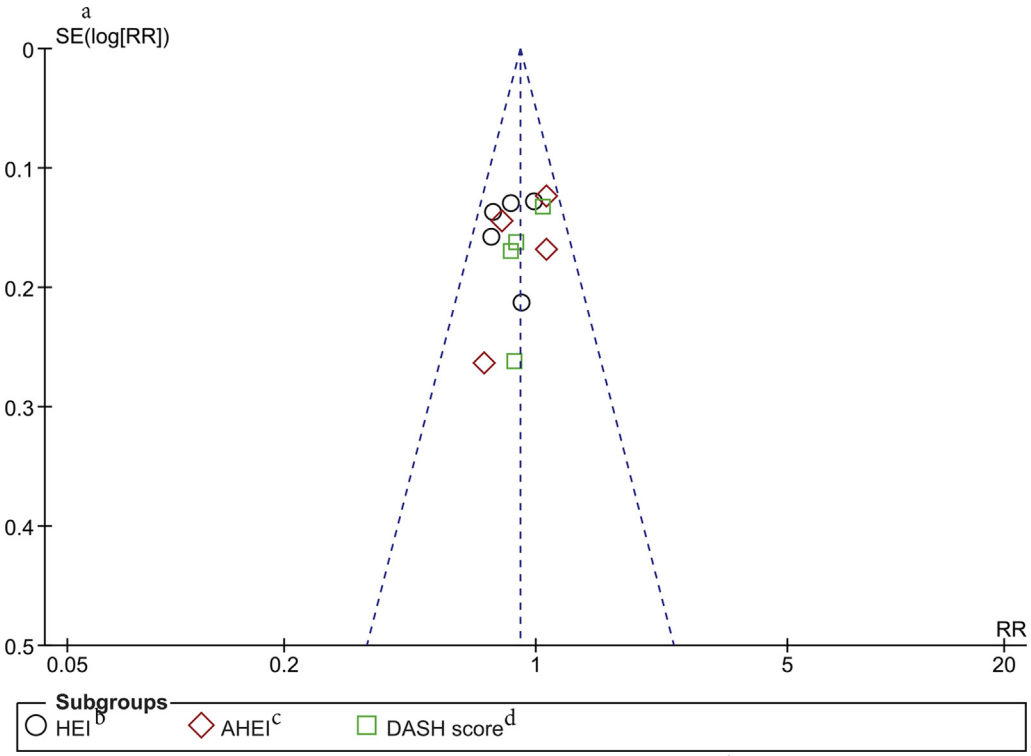

Figure 15. Funnel plot showing study precision against the relative risk with 95% CIs for cancer mortality among cancer survivors. [a]SE=standard error. [b]HEI=Healthy Eating Index. [c]AHEI=Alternate Health Eating Index. [d]DASH=Dietary Approaches to Stop Hypertension.

Table 3. US cohort studies: relative risk ratios (with 95% confidence intervals) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of studies	Index	Risk ratio	95% CI	I^2, %
All-cause mortality	9	All indexes combined	0.78	0.76-0.80	59
Cardiovascular disease mortality or incidence	17	All indexes combined	0.79	0.76-0.81	49
Cancer mortality or incidence	26	All indexes combined	0.84	0.82-0.86	67
Type 2 diabetes	9	All indexes combined	0.80	0.76-0.84	68
Neurodegenerative disease	4	All indexes combined	0.84	0.73-0.97	59
All-cause mortality among cancer survivors	7	All indexes combined	0.88	0.81-0.95	38
Cancer mortality among cancer survivors	7	All indexes combined	0.90	0.83-0.98	0

Table 4. Long-term follow up (≥8 years): Relative risk ratios (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of studies	Index	Risk ratio	95% CI	I^2, %
All-cause mortality	12	All indexes combined	0.78	0.77-0.80	59
Cardiovascular disease mortality or incidence	25	All indexes combined	0.79	0.77-0.81	40
Cancer mortality or incidence	29	All indexes combined	0.85	0.83-0.87	67
Type 2 diabetes	7	All indexes combined	0.80	0.75-0.85	72
Neurodegenerative disease	4	All indexes combined	0.91	0.78-1.06	35
All-cause mortality among cancer survivors	4	All indexes combined	0.77	0.69-0.86	0
Cancer mortality among cancer survivors	4	All indexes combined	0.86	0.74-1.01	0

Table 5. High-quality studies (≥7 points Newcastle Ottawa scale): Relative risk ratios (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of studies	Index	Risk ratio	95% CI	I^2, %
All-cause mortality	9	All indexes combined	0.79	0.77-0.80	47
Cardiovascular disease mortality or incidence	22	All indexes combined	0.78	0.76-0.80	49
Cancer mortality or incidence	28	All indexes combined	0.85	0.83-0.87	67
Type 2 diabetes	8	All indexes combined	0.82	0.79-0.86	75
Neurodegenerative disease	2	All indexes combined	0.90	0.76-1.05	50
All-cause mortality among cancer survivors	7	All indexes combined	0.88	0.81-0.95	38
Cancer mortality among cancer survivors	7	All indexes combined	0.90	0.83-0.98	0

Table 6. Women: relative risk ratios (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of studies	Index	Risk ratio	95% CI	I^2, %
All-cause mortality	6	All indexes combined	0.78	0.77-0.79	2
Cardiovascular disease mortality or incidence	13	All indexes combined	0.77	0.75-0.79	0
Cancer mortality or incidence	14	All indexes combined	0.88	0.85-0.91	53
Type 2 diabetes	5	All indexes combined	0.80	0.76-0.84	63
Neurodegenerative disease	2	All indexes combined	0.94	0.84-1.05	1
All-cause mortality among cancer survivors	6	All indexes combined	0.82	0.75-0.89	1
Cancer mortality among cancer survivors	6	All indexes combined	0.83	0.74-0.93	0

Table 7. Men: Relative risk ratios (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of studies	Index	Risk ratio	95% CI	I^2, %
All-cause mortality	4	All indexes combined	0.77	0.74-0.79	80
Cardiovascular disease mortality or incidence	8	All indexes combined	0.76	0.72-0.80	73
Cancer mortality or incidence	10	All indexes combined	0.83	0.79-0.87	79
Type 2 diabetes	2	All indexes combined	0.83	0.77-0.90	68
Neurodegenerative disease	1	All indexes combined	1.83	0.65-5.15	NA[a]
All-cause mortality among cancer survivors	1	All indexes combined	1.01	0.91-1.13	2
Cancer mortality among cancer survivors	1	All indexes combined	0.99	0.85-1.14	0

[a]NA=not applicable.

Table 8. Fixed-effects meta-analysis: Relative risk ratios (with 95% CIs) of the association of diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, or Dietary Approaches to Stop Hypertension score for all-cause mortality, cardiovascular mortality or incidence, cancer mortality or incidence, type 2 diabetes, neurodegenerative disease, and all-cause mortality and cancer mortality among cancer survivors

Outcome	No. of studies	Index	Risk ratio	95% CI	I^2, %
All-cause mortality	13	All indexes combined	0.78	0.77-0.79	59
Cardiovascular disease mortality or incidence	28	All indexes combined	0.78	0.77-0.80	49
Cancer mortality or incidence	31	All indexes combined	0.85	0.84-0.86	66
Type 2 diabetes	10	All indexes combined	0.81	0.80-0.83	72
Neurodegenerative disease	5	All indexes combined	0.85	0.78-0.92	51
All-cause mortality among cancer survivors	7	All indexes combined	0.89	0.84-0.95	38
Cancer mortality among cancer survivors	7	All indexes combined	0.90	0.83-0.98	0