British Journal of Nutrition (2015), **113**, 16–24
doi:10.1017/S000711451400289X

Systematic Review with Meta-Analysis

Associations of dietary patterns with the risk of all-cause, CVD and stroke mortality: a meta-analysis of prospective cohort studies

Fei Li[1]†, Li-na Hou[2]†, Wei Chen[1], Peng-liang Chen[1], Chen-yong Lei[1], Qiang Wei[1], Wan-long Tan[1]* and Shao-bin Zheng[1]

[1]*Department of Urology, Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong 510515, People's Republic of China*

[2]*Department of Health Management, Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong 510515, People's Republic of China*

(Submitted 17 March 2014 – Final revision received 20 July 2014 – Accepted 14 August 2014 – First published online 28 November 2014)

Abstract

Considerable controversy exists regarding the associations of dietary patterns with the risk of all-cause, CVD and stroke mortality. Therefore, a meta-analysis was conducted to elucidate the potential associations between dietary patterns and the risk of all-cause, CVD and stroke mortality. The PubMed database was searched for prospective cohort studies on the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality published until February 2014. Random-effects models were used to calculate the summary relative risk estimates (SRRE) based on the highest *v.* the lowest category of dietary pattern scores. Stratified analyses were conducted based on sex, geographical region, follow-up duration, and adjustment/non-adjustment for energy intake. A total of thirteen prospective cohort studies involving 338 787 participants were included in the meta-analysis. There was evidence of inverse associations between the prudent/healthy dietary pattern and the risk of all-cause (SRRE = 0·76, 95 % CI 0·68, 0·86) and CVD (SRRE = 0·81, 95 % CI 0·75, 0·87) mortality and an absence of association between this dietary pattern and stroke mortality (SRRE = 0·89, 95 % CI 0·77, 1·02). However, no significant associations were observed between the Western/unhealthy dietary pattern and the risk of all-cause (SRRE = 1·07, 95 % CI 0·96, 1·20), CVD (SRRE = 0·99, 95 % CI 0·91, 1·08) and stroke (SRRE = 0·94, 95 % CI 0·81, 1·10) mortality. In conclusion, the findings provide evidence that greater adherence to a prudent/healthy dietary pattern is associated with a lower risk of all-cause and CVD mortality and not significantly associated with stroke mortality and that the Western/unhealthy dietary pattern is not associated with all-cause, CVD and stroke mortality. Further studies are required to confirm these findings.

Key words: **Dietary patterns: Mortality: All-cause mortality: Meta-analysis**

The proportion of elderly people as well as the incidence of chronic diseases, such as CVD, is increasing globally. CVD remains a major public health problem and represents the leading cause of mortality, affecting millions of people in both developed and developing countries. Furthermore, it is estimated that deaths due to CVD and cancer will account for more than 50 % of total mortality cases in 2030[(1)]. The incidence of CVD is rising at an alarming rate, especially among people aged ≥60 years, which will lead to a heavy social and economic toll worldwide[(2)]. Therefore, strategies to promote health and prevent deaths due to major chronic diseases, such as CVD and stroke, are required to be implemented.

Dietary habits play an important role as determinants of health status. Nutrients and foods can never be eaten in isolation and have complex interactions, resulting in the masking of true associations[(3)]. In recent decades, the dietary pattern analysis has emerged as an alternative and complementary approach to examine the effects of overall diet on all-cause, CVD and stroke mortality instead of the assessment

Abbreviations: FA, factor analysis; PCA, principal component analysis; SRRE, summary relative risk estimates.

* **Corresponding author:** W.-l. Tan, fax +86 020 616 41762, email tanwanlong@gmail.com

† Contributed equally to the present work.

of a single or a few nutrients or foods. Several studies have demonstrated the associations between dietary patterns and major chronic diseases such as CVD, cancer and stroke[4,5]. Furthermore, the associations of dietary patterns with the risk of all-cause, CVD and stroke mortality are gaining considerable attention. Recently, several prospective cohort studies have examined the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality; however, their findings have led to considerable controversy[6–16]. To date, a comprehensive assessment of the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality has not been reported.

Therefore, we conducted a meta-analysis to elucidate the potential associations of dietary patterns with the risk of all-cause, CVD and stroke mortality on the basis of findings from all published prospective cohort studies.

Materials and methods

Literature search strategy

The present meta-analysis was carried out in accordance with the Meta-analysis Of Observational Studies in Epidemiology guidelines[17]. An electronic literature search was conducted to identify prospective cohort studies on the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality published until February 2014 in the PubMed database. The primary search included the following search items: ('cardiovascular disease' OR 'CVD' OR 'heart' OR 'vascular' OR 'myocardial infarction (MI)' OR 'coronary' OR 'CHD' OR 'stroke') AND ('survival' OR 'mortality' OR 'death' OR 'fatal' OR 'lethal') AND ('dietary pattern*' OR 'eating pattern*' OR 'food pattern*' OR 'dietary habit*' OR 'diet' OR 'dietary') AND ('factor analysis' OR 'principal component analysis' OR 'Mediterranean diet' OR 'diet diversity' OR 'diet variety' OR 'quality' OR 'index' OR 'indices' OR 'scores'). The search focused on human studies, without restrictions on language. Furthermore, the reference lists of all the retrieved publications were assessed and searched again to identify relevant publications. Eligible articles were selected for a full-text review after an initial screen by titles and abstracts.

Inclusion and exclusion criteria

Studies that had an original prospective cohort study design and were carried out in human beings; studies that examined the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality; studies that reported risk estimates (i.e. relative risk or OR) and their variability (i.e. 95 % CI); studies that provided sufficient information (e.g. raw data and *P* values) for estimation; and studies that examined food or dietary patterns using factor analysis (FA) and/or principal component analysis (PCA) were eligible for inclusion in the meta-analysis.

Only patterns sharing most foods with similar factor loadings were selected to minimise errors and combine the results. In this analysis, two common dietary patterns were identified: prudent/healthy dietary pattern, characterised by a high intake of foods such as vegetables, fruits, fish, poultry, whole grains and low-fat dairy products, and Western/unhealthy dietary pattern, characterised by a high intake of processed and/or red meat, refined grains, sweets, desserts, eggs and high-fat diary products. Studies with dietary patterns having similar loadings of foods common to the prudent/healthy or Western/unhealthy dietary pattern were also included in spite of being named differently.

Duplicate studies[1]; studies that reported irrelevant data[2]; studies that involved randomised controlled trials and cross-sectional, case–control and ecological analyses[3]; and studies that used methods other than the FA and/or PCA for identifying dietary patterns[4] were not included in the meta-analysis. If more than one publication of the same or overlapping cohort existed, only the most recent and informative publication was included in the meta-analysis.

Data extraction

Information extracted from each eligible study included the following: first author's name; year of publication; geographical region; number of cases; sample size; participant age range; study duration; follow-up duration; number of exposed cases; dietary intake assessment method; method used for identifying dietary patterns; naming of dietary patterns; endpoints; relative risk or OR and 95 % CI; number of food items in the FFQ; confounding factors that were adjusted for in the analysis. When a study presented different adjustment variables, results from the main multivariable model that included the maximum number of adjusted confounders were considered.

Quality assessment of each study was performed based on the following crucial components: clear definition of participant characteristics; clear examination of exposure and outcome; study duration; sufficient follow-up; person-years of follow-up; no selective loss during follow-up; control for potential confounding factors. If one of the above was not clearly reported by a study, it was assumed that the study underestimated the component rather than assuming that it had not been assessed. Literature search and data extraction were performed independently by two authors. Discrepancy in data extraction was resolved by repeating the study review and discussion.

Statistical analyses

Summary relative risk estimates (SRRE) were calculated for the highest *v.* the lowest category of dietary patterns in terms of tertiles, quartiles or quintiles of dietary factor scores in the included studies. Statistical heterogeneity across the studies was tested using the χ^2 test (significant with a *P* value $<0{\cdot}10$) and measured using the I^2 statistic[18]. By assuming that the studies were carried out in populations with varying effect sizes, calculating the study weights from both in-study and between-study variances, and considering the extent of variation or heterogeneity, the random-effects models were used to study the associations and presented forest plots[19].

British Journal of Nutrition

Some studies had more than one dietary pattern model (i.e. vegetables, fruits, sweets and meat) that met the inclusion criteria of the present meta-analysis for the prudent/healthy or Western/unhealthy dietary pattern. Separate risk estimates in individual studies were combined to obtain a unique study-specific estimate for this dietary pattern.

Publication bias was assessed using Begg's rank correlation test and Egger's linear regression test and funnel plots[20]. Because both tests have a low power to detect potential bias, $P = 0{\cdot}1$ was set as the statistical penalty for these tests in the present meta-analysis. In addition, subgroup analyses were conducted according to sex, geographical region, follow-up duration (≥10 years or <10 years), and adjustment/non-adjustment for energy intake to explore the sources of heterogeneity. All statistical analyses were carried out using Stata statistical software, version 11.0 (StataCorp).

Results

Study selection

The initial search yielded 1664 articles, of which 1419 were excluded after screening by titles and abstracts. Furthermore, 136 articles were excluded as they involved ecological studies, reviews or studies on single nutrients. The remaining 109 articles examining the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality were assessed by full-text review. Of these 109 articles, twenty-two were excluded because their effect sizes and the corresponding 95 % CI were not reported or could not be estimated due to insufficient information. The results of forty-five studies were not related to the purpose of the present meta-analysis. Moreover, twelve studies were excluded as they were not prospective cohort studies. In addition, eighteen articles were excluded because dietary patterns were not examined using the FA or PCA. Another article was excluded due to an overlap of the study population with that of another study[16,21]. Therefore, the informative study was taken into account[16]. The studies carried out by Maruyama *et al.*[7] and Osler *et al.*[16] reported risk estimates for men and women separately and were therefore considered as two studies when the examined items were pooled. Finally, thirteen prospective cohort studies from eleven papers published between 2000 and 2014[6–16] were included in the present meta-analysis. A flow chart of the study selection process is shown in Fig. 1.

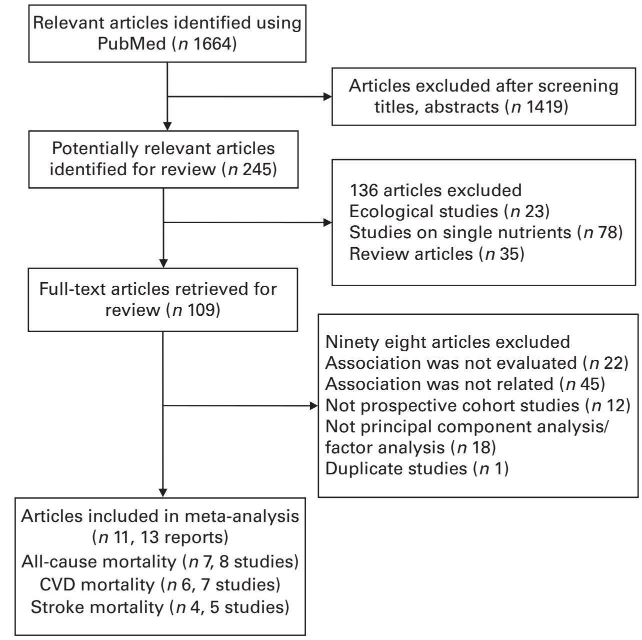

Fig. 1. Flow chart of the study selection process.

Study characteristics

All the thirteen studies that were included in the meta-analysis were prospective cohort studies: three studies were conducted in Japan (one in men[7], one in women[7] and one in both men and women[12]); two in Denmark (one in men[16], one in women[16]); one each in Spain[6], Bengal[8], the UK[9], the USA[10], Australia[11], China[13], Italy[14] and the Netherlands[15]. Most of the studies included in the meta-analysis used FFQ based on self-reports or interviewer-administered questionnaires to ascertain dietary intake information, despite variations in the length of item list in the questionnaire across the studies. The outcomes identified were all-cause mortality in nine studies (men[16], women[16], men and women[1,6,9,10,13–15]), CVD mortality in seven studies (men[7], women[7], men and women[8,10–13]) and stroke mortality in five studies (men[7], women[7], men and women[8,12,13]). In summary, thirteen studies with a sample size of 338 787 participants, comprising 9465 cases of all-cause death, 5543 cases of CVD death and 1918 cases of stroke death, were included in the meta-analysis. The characteristics of the included studies are given in Table 1.

Association of the prudent/healthy dietary pattern with the risk of all-cause, CVD and stroke mortality

A significant inverse association was observed between the highest *v.* the lowest category of prudent/healthy dietary pattern and the risk of all-cause mortality, with SRRE of 0·76 (95 % CI 0·67, 0·86). Substantial heterogeneity was observed across the studies (P value for heterogeneity=0·039, $I^2 = 52{\cdot}6$ %; Table 2 and Fig. 2(a)). The Begg test ($P = 0{\cdot}133$) and visual inspection of the funnel plot (not shown) did not indicate a publication bias, but the Egger test (P=0·045) indicated a possible publication bias. Furthermore, greater adherence to a prudent/healthy dietary pattern was found to be associated with a lower risk of CVD mortality (SRRE = 0·81, 95 % CI 0·75, 0·87), with no evidence of heterogeneity being found among the studies on CVD mortality (P value for heterogeneity=0·399, $I^2 = 3{\cdot}5$ %; Table 2 and Fig. 3(a)). However, no significant association was observed between this dietary pattern and the risk of stroke mortality (SRRE = 0·89, 95 % CI 0·77, 1·02). There was no indication of heterogeneity among the studies on stroke mortality (P value for heterogeneity=0·102, $I^2 = 48{\cdot}2$ %; Table 2 and

British Journal of Nutrition

Table 1. Characteristics of the studies included in the present meta-analysis

(Number of cases and number of participants; relative risks (RR) and 95 % confidence intervals)

First author and year	Study location	Cases	No. of participants	Follow-up duration (years)	Study period	FFQ list	Dietary pattern	Endpoints	RR	95 % CI	*P* for trend	Adjustments
Zazpe (2013)[6]	Spain	148	16 008	10	1999–2009	136	Mediterranean	All-cause mortality	0·53	0·34, 0·84	0·010	Age, sex, smoking status, BMI, total energy intake, alcohol consumption, television watching, PA (leisure time), depression, hypercholesterolaemia, hypertension, education level and special diets at baseline
							Western	All-cause mortality	0·79	0·45, 1·38	0·400	
Maruyama (2013) men[7]	Japan	1240	26 598	12·6	1998–2003	40	Vegetables	CVD mortality	0·93	0·78, 1·13	0·730	Age, smoking status, BMI, total energy intake, walking time, hours spent on sports, education level, perceived mental stress, sleep duration, and history of hypertension and diabetes
							Vegetables	Stroke mortality	1·13	0·85, 1·51	0·390	
							Animal food	CVD mortality	0·88	0·73, 1·05	0·500	
							Animal food	Stroke mortality	0·97	0·74, 1·27	0·750	
Maruyama (2013) women[7]	Japan	1071	37 439	12·6	1998–2003	40	Vegetables	CVD mortality	0·82	0·67, 1·00	0·040	
							Vegetables	Stroke mortality	0·91	0·68, 1·22	0·570	
							Animal food	CVD mortality	1·08	0·87, 1·34	0·420	
							Animal food	Stroke mortality	1·03	0·75, 1·41	0·950	
Chen (2013)[8]	Bengal	185	11 116	6·6	2000–2009	39	Gourd and root vegetables	CVD mortality	1·04	0·69, 1·59	0·840	Age, sex, smoking status, BMI and energy intake
							Animal protein	CVD mortality	1·20	0·75, 1·91	0·410	
							Gourd and root vegetables	Stroke mortality	0·99	0·54, 1·86	0·790	
							Animal protein	Stroke mortality	0·74	0·39, 1·41	0·380	
Hamer (2010)[9]	UK	683	1017	9·2	1994–2008	NR	Mediterranean	All-cause mortality	0·82	0·68, 1·00	0·044	Age, sex, smoking status, BMI, energy intake, PA, education level, self-rated health status, medication, mutual adjustment for all diet patterns and supplements
							Health aware	All-cause mortality	0·93	0·76, 1·13	0·532	
							Traditional	All-cause mortality	1·15	0·94, 1·40	0·143	
							Sweets and fat	All-cause mortality	0·93	0·75, 1·15	0·622	
Heidemann (2008)[10]	USA	6011	72 113	18	1984–2002	116	Prudent	Total mortality	0·83	0·76, 0·90	<0·001	Age, smoking status, BMI, total energy intake, PA, follow-up period, hormone replacement therapy, missing FFQ data during follow-up, multivitamin supplement use and history of hypertension
							Prudent	CVD mortality	0·72	0·60, 0·87	<0·001	
							Western	Total mortality	1·21	1·12, 1·32	<0·001	
							Western	CVD mortality	1·22	1·01, 1·48	0·009	
Harriss (2007)[11]	Australia	1104	40 653	10·4	1990–2003	121	Mediterranean foods	CVD mortality	0·70	0·51, 0·96	0·040	Sex, smoking status, BMI, total energy intake, PA, country of birth, education level, waist:hip ratio, social isolation, dietary factors, CVD history, and family history of CVD, diabetes and hypertension
							Vegetables	CVD mortality	0·79	0·61, 1·02	0·140	
							Fresh fruits	CVD mortality	0·75	0·59, 0·96	0·100	
							Meat	CVD mortality	0·91	0·70, 1·18	0·750	
Shimazu (2007)[12]	Japan	801	40 547	7	1994–2001	40	Japanese	CVD mortality	0·74	0·59, 0·91	0·004	Age, sex, smoking status, BMI, total energy intake, walking duration, education level and history of hypertension
							DFA	CVD mortality	0·89	0·69, 1·14	0·190	
							Animal food	CVD mortality	1·24	1·00, 1·54	0·02	
							Japanese	Stroke mortality	0·64	0·48, 0·86	0·004	
							Animal food	Stroke mortality	1·00	0·74, 1·35	0·660	
Cai (2007)[13]	China	1565	74 942	5·7	1996–2004	71	Vegetable rich	Overall mortality	0·97	0·85, 1·12	0·922	Age, smoking status, BMI, education level, marital status, income per person, alcohol consumption, tea consumption, ginseng intake and PA energy expenditure
							Fruit rich	Overall mortality	0·80	0·69, 0·94	0·009	
							Meat rich	Overall mortality	1·04	0·89, 1·22	0·452	
							Vegetable rich	CVD mortality	1·18	0·90, 1·56	0·216	
							Fruit rich	CVD mortality	0·71	0·51, 0·98	0·031	
							Meat rich	CVD mortality	1·04	0·75, 1·44	0·602	
							Vegetable rich	Stroke mortality	1·35	0·92, 1·97	0·238	
							Fruit rich	Stroke mortality	0·53	0·34, 0·82	0·001	
							Meat rich	Stroke mortality	0·70	0·48, 1·19	0·371	
Masala (2007)[14]	Italy	152	5611	6·2	1993–2002	120	Prudent	Overall mortality	0·85	0·47, 1·53	0·590	Age, sex, smoking status, BMI, energy intake, PA (leisure time), waist circumference, marital status, years of education, civil status, and hypertension at enrolment
							Olive oil and salad	Overall mortality	0·50	0·29, 0·86	0·020	
							Pasta and meat	Overall mortality	1·37	0·80, 2·34	0·340	
							Sweets and desserts	Overall mortality	1·47	0·85, 2·54	0·250	
Waijers (2006)[15]	Netherlands	277	5427	8·3	1993–2002	178	Healthy and traditional	Overall mortality	0·70	0·52, 0·95	NR	Age, smoking status, BMI, energy intake, PA, education level, diabetes and waist:hip ratio
Osler (2001) men[16]	Denmark	398	3698	15	1982–1998	28	Prudent	All-cause mortality	0·70	0·49, 1·00	NR	Smoking status, PA, alcohol consumption, education level, BMI, BMI2 and BMI3
							Western	All-cause mortality	0·92	0·69, 1·23	NR	
Osler (2001) women[16]	Denmark	231	3618	15	1982–1998	28	Prudent	All-cause mortality	0·46	0·30, 0·72	NR	
							Western	All-cause mortality	0·87	0·59, 1·29	NR	

PA, physical activity; NR, not reported; DFA, a high-dairy, high-fruit-and-vegetable, low-alcohol dietary pattern.

Table 2. Summary of the results of the meta-analysis of the associations of dietary patterns (high intake *v.* low intake*) with the risk of all-cause, CVD and stroke mortality

(Summary relative risk estimates (SRRE) and 95 % confidence intervals)

Analysis specifications	Studies	SRRE	95 % CI	*P*†	I^2
Prudent/healthy dietary pattern					
All-cause mortality	8	0·76	0·67, 0·86	0·039	52·6
Non-Europe	2	0·84	0·78, 0·91	0·583	0
Europe	6	0·67	0·55, 0·82	0·029	59·8
Women	4	0·76	0·64, 0·91	0·04	64·0
Men	2	0·64	0·48, 0·85	0·39	0
Follow-up duration (< 10 years)	4	0·84	0·76, 0·92	0·298	18·5
Follow-up duration (≥ 10 years)	4	0·65	0·48, 0·87	0·014	71·6
Adjustment for energy intake	4	0·80	0·74, 0·87	0·117	49·0
Non-adjustment for energy intake	4	0·76	0·62, 0·94	0·034	65·4
CVD mortality	7	0·81	0·75, 0·87	0·399	3·5
Non-Asia	2	0·74	0·65, 0·83	0·744	0
Asia	5	0·86	0·78, 0·95	0·640	0
Follow-up duration (< 10 years)	3	0·84	0·72, 0·97	0·480	0
Follow-up duration (≥ 10 years)	4	0·80	0·73, 0·87	0·217	32·6
Stroke mortality	5	0·89	0·77, 1·02	0·102	48·2
Western/unhealthy dietary pattern					
All-cause mortality	7	1·07	0·96, 1·20	0·073	48·0
Non-Europe	2	1·14	0·99, 1·32	0·095	64·1
Europe	5	1·02	0·91, 1·15	0·300	18·0
Men	3	1·07	0·89, 1·30	0·120	52·8
Women	4	1·16	1·08, 1·24	0·138	45·6
Follow-up duration (< 10 years)	3	1·06	0·96, 1·18	0·306	15·7
Follow-up duration (≥ 10 years)	4	1·00	0·80, 1·26	0·061	59·3
Adjustment for energy intake	3	1·10	0·95, 1·30	0·10	57·0
Non-adjustment for energy intake	4	1·01	0·92, 1·12	0·744	0
CVD mortality	7	0·99	0·91, 1·08	0·135	38·6
Non-Asia	2	1·07	0·80, 1·42	0·076	68·3
Asia	5	0·95	0·85, 1·05	0·400	1·2
Follow-up duration (< 10 years)	3	1·06	0·90, 1·25	0·855	0
Follow-up duration (≥ 10 years)	4	0·96	0·81, 1·15	0·034	6·4
Stroke mortality	5	0·94	0·81, 1·10	0·611	0

* The intake contrast (i.e. exposure *v.* referent group) for each study is reported in Table 1.
† *P* value for heterogeneity.

Fig. 4(a)). No statistical evidence of publication bias was indicated by the Begg or Egger tests among the studies on CVD mortality (Begg: $P = 0·37$ and Egger: $P = 0·22$) and stroke mortality (Begg: $P = 1·00$ and Egger: $P = 0·94$).

Association of the Western/unhealthy dietary pattern with the risk of all-cause, CVD and stroke mortality

No significant association was observed between the Western/unhealthy dietary pattern and the risk of all-cause mortality (SRRE = 1·07, 95 % CI 0·96, 1·20), although variability was detected (P value for heterogeneity=0·073, $I^2 = 48·0$ %; Table 2 and Fig. 2(b)). The Begg ($P = 0·368$) and Egger ($P = 0·137$) tests, as well as visual inspection of the funnel plot (not shown), did not indicate a publication bias. Furthermore, there was no evidence of any association between the Western/unhealthy dietary pattern and the risk of CVD mortality (SRRE = 0·99, 95 % CI 0·91, 1·08; Table 2 and Fig. 3(b)) and stroke mortality (SRRE = 0·94, 95 % CI 0·81, 1·10; Table 2 and Fig. 4(b)). There was less evidence of heterogeneity among the studies on CVD mortality (P value for heterogeneity=0·135, $I^2 = 38·6$ %) and stroke mortality (P value for heterogeneity=0·611, $I^2 = 0$ %). There was also no statistical evidence of publication bias among the studies on CVD mortality (Begg: $P = 0·55$ and Egger: $P = 0·70$) and stroke mortality (Begg: $P = 0·31$ and Egger: $P = 0·14$).

Subgroup analyses

When studies were stratified by sex, geographical region, follow-up duration, and adjustment/non-adjustment for energy intake in models, the results of the subgroup analyses were found to be consistent with the primary findings. The Begg and Egger tests provided no evidence of a substantial publication bias in any subgroup (not shown).

Discussion

The method used for the analysis of dietary patterns may yield a more comprehensive understanding of how dietary patterns affect diseases compared with analysing a single nutrient and food using traditional nutritional epidemiological analyses[22–24]. To the best of our knowledge, this is the fist meta-analysis on the associations of dietary patterns with the risk of all-cause, CVD and stroke mortality. A total of thirteen prospective cohort studies involving 338 787 participants were included in the meta-analysis. The results indicated that a prudent/healthy dietary pattern may decrease the risk of all-cause

https://doi.org/10.1017/S000711451400289X Published online by Cambridge University Press

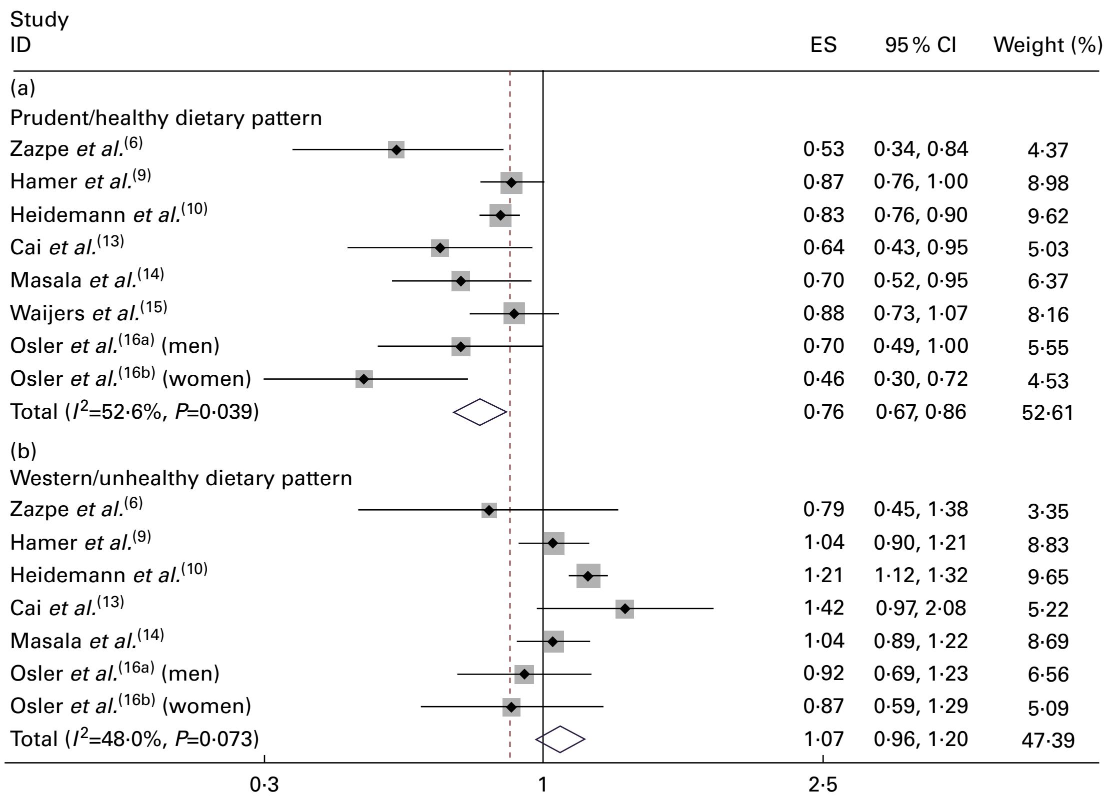

Fig. 2. Meta-analysis of studies that examined the associations of all-cause mortality with the (a) prudent/healthy dietary pattern and (b) Western/unhealthy dietary pattern. ES, effect size. A colour version of this figure can be found online at http://www.journals.cambridge.org/bjn.

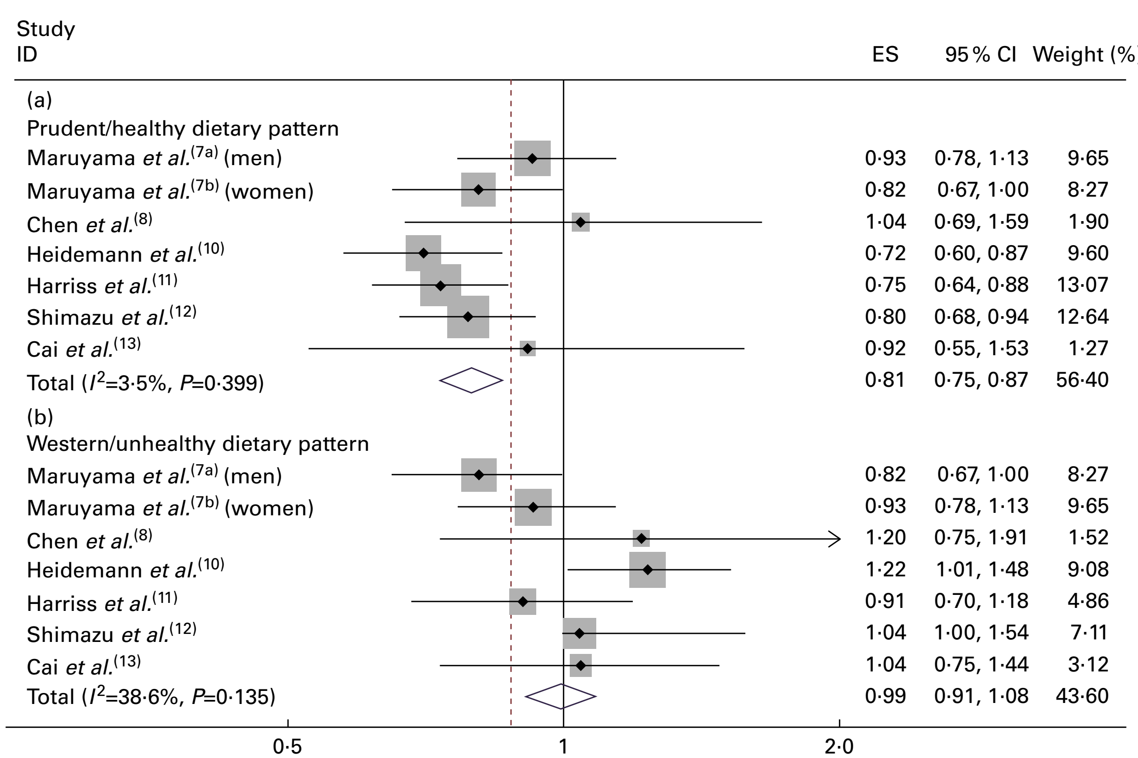

Fig. 3. Meta-analysis of studies that examined the associations of CVD mortality with the (a) prudent/healthy dietary pattern and (b) Western/unhealthy dietary pattern. ES, effect size. A colour version of this figure can be found online at http://www.journals.cambridge.org/bjn.

British Journal of Nutrition

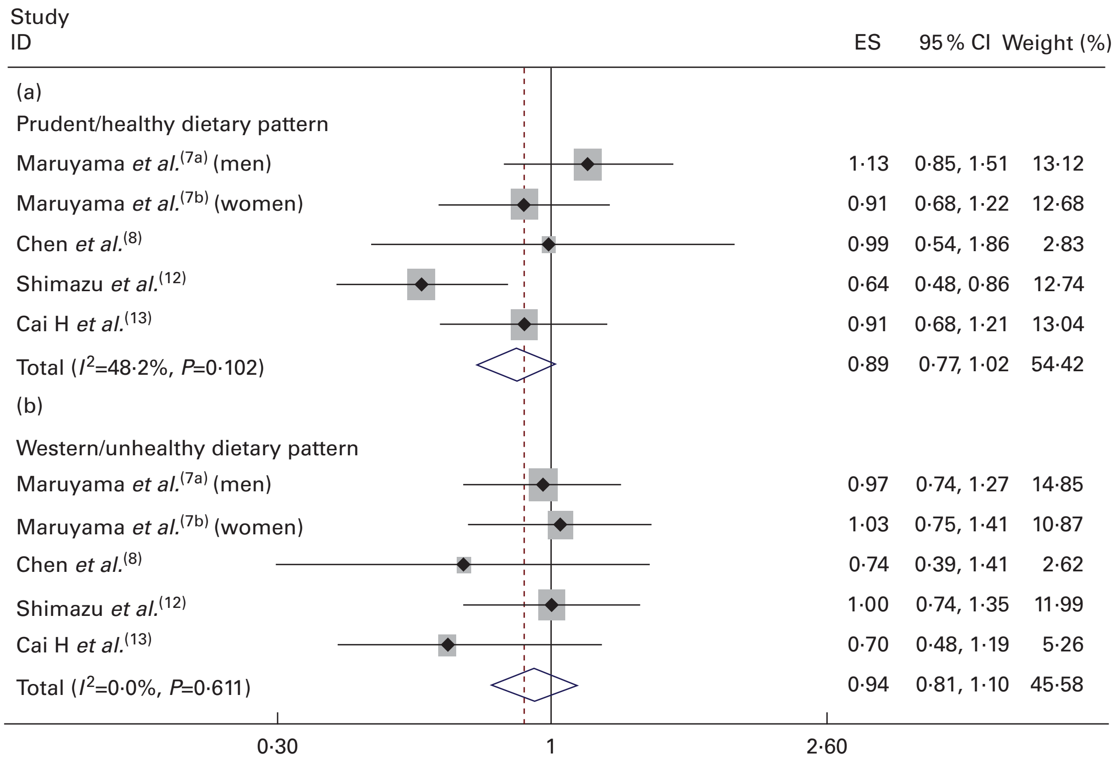

Fig. 4. Meta-analysis of studies that examined the associations of stroke mortality with the (a) prudent/healthy dietary pattern and (b) Western/unhealthy dietary pattern. ES, effect size. A colour version of this figure can be found online at http://www.journals.cambridge.org/bjn.

and CVD mortality, but may not be associated with stroke mortality. Furthermore, no significant overall associations were observed between the Western/unhealthy dietary pattern and the risk of all-cause, CVD and stroke mortality.

A greater heterogeneity was detected among the studies on all-cause mortality probably due to various causes of death and differences in study populations, model selection, analytical methodology and exposure assessment. A significant proportion of the observed heterogeneity may be explained through the subgroup analyses based on sex, geographical region, follow-up duration, and adjustment/non-adjustment for energy intake. Furthermore, little variability was observed among the studies on CVD or stroke mortality and their subgroup analyses. In addition, there was no significant publication bias in these analyses with either the Begg or Egger test, except that the Egger test carried out on studies examining the association of the prudent/healthy dietary pattern with the risk of all-cause mortality indicated a possible publication bias.

The prudent/healthy dietary pattern was found to be associated with a lower risk of all-cause and CVD mortality. This dietary pattern, mainly characterised by a higher intake of vegetables, fruits, fish, poultry, whole grains and low-fat dairy products, has beneficial effects on health because of the higher content of vitamins, minerals, antioxidants, fibre, MUFA and n-3 fatty acids in the diet[25]. In particular, it has been demonstrated that greater adherence to this dietary pattern could be favourably correlated with the reduction of the incidence of lipid abnormalities, hypertension, arrhythmias, diabetes and obesity and some psychological disorders through the amelioration of insulin sensitivity and their anti-inflammatory and antioxidant actions[11,26,27], which would be a possible explanation for the primary preventive effects of the prudent dietary pattern on all-cause and CVD mortality observed in the present meta-analysis. Furthermore, oxidised LDL concentrations play a vital role in the early development of atherosclerotic lesions. The prudent dietary pattern is also associated with increased total antioxidant capacity and decreased oxidised LDL concentrations[26,28], which may explain the inverse association between this dietary pattern and the risk of CVD mortality. However, the quantitative analysis indicated that the summary association between this dietary pattern and the risk of stroke mortality was not statistically significant.

The Western/unhealthy dietary pattern identified in the present meta-analysis was characterised by frequent consumption of processed and/or red meat, refined grains, sweets, desserts, eggs and high-fat diary products. Although some studies have reported that this dietary pattern, which is rich in saturated fat, has positive associations with the risk of weight gain[29] and plasma concentrations of systemic inflammatory and endothelial markers[9,29], no overall associations were observed between this dietary pattern and the risk of all-cause, CVD and stroke mortality in the analyses carried out, which is consistent with the results of most of the included studies. Several explanations are possible for the unexpected lack of associations. One explanation is that the cardioprotective effects of overall diet mediated primarily through plant products may have been attenuated because of greater intakes of meat products instead of more beneficial plant foods from the diet[30]. It is also possible that unmeasured or unknown residual confounders that were not considered in the analyses may have contributed to this lack of associations. Another explanation is that the participants exhibiting greater adherence to the Western/unhealthy dietary pattern may have also consumed more amounts of some potentially beneficial foods, such as olive oil, fish and poultry[6].

The present meta-analysis has several important strengths. This is the first systematic epidemiological assessment of the associations between dietary patterns and the risk of all-cause, CVD and stroke mortality. This meta-analysis included only prospective cohort studies involving a large sample size and a long follow-up period, which significantly enhanced the statistical power to detect more stable associations and provide more reliable estimation. Furthermore, dietary patterns in the studies included in the meta-analysis were identified by the FA/PCA, which has long-term reproducibility and stability and could minimise the risk of bias[24]. Another strength is the robustness of the findings from the multiple subgroup analyses. The overall findings were consistent with the results of the subgroup analyses independent of sex, geographical region, follow-up duration, and adjustment/non-adjustment for energy intake.

There are several potential limitations that should be considered when interpreting the results of the present meta-analysis. First, the FA/PCA used to derive dietary patterns has reasonable reproducibility and validity compared with other approaches, but it involves subjective aspects with opportunities for variation throughout the analytical process and could result in different results based on different choices[22,29], which may lead to the masking of the true diet–disease associations[9]. Second, although studies included in the meta-analysis had adjusted for a wide range of dietary and lifestyle variables and established risk factors, i.e. age, sex, smoking status, BMI, family history and total energy intake, the possibility that other unmeasured or unknown confounding factors might play roles in the summary associations cannot be excluded. Third, a low level of heterogeneity was detected in some pooled risk estimates, which may have been caused by differences in the follow-up duration, various characteristics of the participants, such as age, sex, and education level, and other factors. However, the major sources of heterogeneity were explored through subgroup analyses. An additional limitation is that the geographical regions covered in this meta-analysis included Asia (China, Bengal and Japan)[7,8,13], Europe (Spain, the UK, Demark, the Netherlands and Italy)[6,9,14–16], the USA[10] and Australia[11]; therefore, the results of the meta-analysis have limited generalisation to other regions (e.g. Latin America and Africa).

Conclusions

In summary, the findings from the present meta-analysis provide evidence that greater adherence to a prudent/healthy dietary pattern is associated with a lower risk of all-cause and CVD mortality, but is not significantly associated with stroke mortality. Furthermore, these findings suggest that there are no significant associations between the Western/unhealthy dietary pattern and the risk of all-cause, CVD and stroke mortality. Further studies are required to confirm these findings and elucidate the pathogenic mechanisms.

Acknowledgements

The authors' contributions are as follows: F. L., L.-n. H. and W.-l. T. designed and conducted the analysis; W. C. and P.-l. C. conducted the literature search and extracted the data; C.-y. L. and Q. W. conducted the statistical analyses and interpreted the data; F. L. and L.-n. H. wrote the first draft of the manuscript and edited the manuscript; S.-b. Z. and W.-l. T. contributed to the writing, editing and proofreading of the final version of the article. All authors read and approved the final manuscript.

None of the authors has any conflicts of interest to declare.

References

1. Zazpe I, Beunza JJ, Bes-Rastrollo M, *et al.* (2011) Egg consumption and risk of cardiovascular disease in the SUN Project. *Eur J Clin Nutr* **65**, 676–682.
2. Roger VL, Go AS, Lloyd-Jones DM, *et al.* (2012) Heart disease and stroke statistics – 2012 update: a report from the American Heart Association. *Circulation* **125**, e2–e220.
3. Hu FB (2002) Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* **13**, 3–9.
4. Kant AK (2004) Dietary patterns and health outcomes. *J Am Diet Assoc* **104**, 615–635.
5. Newby PK, Muller D, Hallfrisch J, *et al.* (2004) Food patterns measured by factor analysis and anthropometric changes in adults. *Am J Clin Nutr* **80**, 504–513.
6. Zazpe I, Sánchez-Tainta A, Toledo E, *et al.* (2014) Dietary patterns and total mortality in a Mediterranean cohort: the SUN Project. *J Acad Nutr Diet* **114**, 37–47.
7. Maruyama K, Iso H, Date C, *et al.* (2013) Dietary patterns and risk of cardiovascular deaths among middle-aged Japanese: JACC Study. *Nutr Metab Cardiovasc Dis* **23**, 519–527.
8. Chen Y, McClintock TR, Segers S, *et al.* (2013) Prospective investigation of major dietary patterns and risk of cardiovascular mortality in Bangladesh. *Int J Cardiol* **167**, 1495–1501.
9. Hamer M, McNaughton SA, Bates CJ, *et al.* (2010) Dietary patterns, assessed from a weighed food record, and survival among elderly participants from the United Kingdom. *Eur J Clin Nutr* **64**, 853–861.
10. Heidemann C, Schulze MB, Franco OH, *et al.* (2008) Dietary patterns and risk of mortality from cardiovascular disease, cancer, and all causes in a prospective cohort of women. *Circulation* **118**, 230–237.
11. Harriss LR, English DR, Powles J, *et al.* (2007) Dietary patterns and cardiovascular mortality in the Melbourne Collaborative Cohort Study. *Am J Clin Nutr* **86**, 221–229.
12. Shimazu T, Kuriyama S, Hozawa A, *et al.* (2007) Dietary patterns and cardiovascular disease mortality in Japan: a prospective cohort study. *Int J Epidemiol* **36**, 600–609.
13. Cai H, Shu XO, Gao YT, *et al.* (2007) A prospective study of dietary patterns and mortality in Chinese women. *Epidemiology* **18**, 393–401.

14. Masala G, Ceroti M, Pala V, *et al.* (2007) A dietary pattern rich in olive oil and raw vegetables is associated with lower mortality in Italian elderly subjects. *Br J Nutr* **98**, 406–415.
15. Waijers PM, Ocké MC, van Rossum CT, *et al.* (2006) Dietary patterns and survival in older Dutch women. *Am J Clin Nutr* **83**, 1170–1176.
16. Osler M, Heitmann BL, Gerdes LU, *et al.* (2001) Dietary patterns and mortality in Danish men and women: a prospective observational study. *Br J Nutr* **85**, 219–225.
17. Stroup DF, Berlin JA, Morton SC, *et al.* (2000) Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA* **283**, 2008–2012.
18. Higgins JP & Thompson SG (2002) Quantifying heterogeneity in a meta-analysis. *Stat Med* **21**, 1539–1558.
19. DerSimonian R & Laird N (1986) Meta-analysis in clinical trials. *Control Clin Trials* **7**, 177–188.
20. Li F, An SL, Zhou Y, *et al.* (2011) Milk and dairy consumption and risk of bladder cancer: a meta-analysis. *Urology* **78**, 1298–1305.
21. Osler M, Heitmann BL, Høidrup S, *et al.* (2001) Food intake patterns, self rated health and mortality in Danish men and women. A prospective observational study. *J Epidemiol Community Health* **55**, 399–403.
22. Brennan SF, Cantwell MM, Cardwell CR, *et al.* (2010) Dietary patterns and breast cancer risk: a systematic review and meta-analysis. *Am J Clin Nutr* **91**, 1294–1302.
23. Bertuccio P, Rosato V, Andreano A, *et al.* (2013) Dietary patterns and gastric cancer risk: a systematic review and meta-analysis. *Ann Oncol* **24**, 1450–1458.
24. Magalhaes B, Peleteiro B & Lunet N (2012) Dietary patterns and colorectal cancer: systematic review and meta-analysis. *Eur J Cancer Prev* **21**, 15–23.
25. Willett WC, Sacks F, Trichopoulou A, *et al.* (1995) Mediterranean diet pyramid: a cultural model for healthy eating. *Am J Clin Nutr* **61**, 1402S–1406S.
26. Tourlouki E, Matalas AL & Panagiotakos DB (2009) Dietary habits and cardiovascular disease risk in middle-aged and elderly populations: a review of evidence. *Clin Interv Aging* **4**, 319–330.
27. Panagiotakos DB, Tzima N, Pitsavos C, *et al.* (2005) The relationship between dietary habits, blood glucose and insulin levels among people without cardiovascular disease and type 2 diabetes; the ATTICA study. *Rev Diabet Stud* **2**, 208–215.
28. Pitsavos C, Panagiotakos DB, Tzima N, *et al.* (2005) Adherence to the Mediterranean diet is associated with total antioxidant capacity in healthy adults: the ATTICA study. *Am J Clin Nutr* **82**, 694–699.
29. Martinez ME, Marshall JR & Sechrest L (1998) Invited Commentary: factor analysis and the search for objectivity. *Am J Epidemiol* **148**, 17–19.
30. Trichopoulos D & Lagiou P (2001) Dietary patterns and mortality. *Br J Nutr* **85**, 133–134.

British Journal of Nutrition