Special Article

Diet quality of vegetarian diets compared with nonvegetarian diets: a systematic review

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Objective: *Vegetarian diets are consistently associated with improved health outcomes, and higher diet quality may contribute to improved health outcomes. This systematic review aims to qualitatively compare the a priori diet quality of vegetarian and nonvegetarian diets.* ***Methods:*** *Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, 2 online databases (Web of Science and PubMed) were searched for English language studies comparing diet quality among vegetarian and nonvegetarian adults using an a priori diet quality index. Two reviewers assessed study eligibility. Comparisons were made between total and component (when available) diet quality scores among the 12 studies meeting inclusion criteria.* ***Conclusions:*** *Lacto-ovo vegetarians or vegans had higher overall diet quality (4.5–16.4 points higher on the Healthy Eating Index 2010 [HEI-2010]) compared with nonvegetarians in 9 of 12 studies. Higher HEI-2010 scores for vegetarians were driven by closer adherence to recommendations for total fruit, whole grains, seafood and plant protein, and sodium. However, nonvegetarians had closer adherence to recommendations for refined grains and total protein foods. Higher diet quality in vegetarian diets may partially explain improvements in health outcomes compared with nonvegetarians; however, more research controlling for known confounders like health consciousness is needed.*

INTRODUCTION

Vegetarian diets have been repeatedly and consistently associated with improved health outcomes,[1] including reduced risk of chronic diseases, such as heart disease, type 2 diabetes, and obesity,[2–4] as well as increased life expectancy.[5] Due to the substantial burden of chronic disease, vegetarian diets have been increasingly recommended as a strategy for improving population health,[6] although the mechanism by which vegetarian diets improve health outcomes is not completely understood. Advocates of vegetarian diets often contend that vegetarian diets are more healthful, but the diet quality of vegetarian diets has not been systematically evaluated, making it difficult to exclude competing explanations such as increased health consciousness among vegetarians.

Though lacking a standardized definition, "vegetarian" generally describes a lacto-ovo vegetarian dietary pattern (herein referred to as vegetarian), which is free of meat, poultry, and fish (Table 1[7–9]); however, "vegetarian" is occasionally used interchangeably to describe more and less restrictive dietary patterns such as vegan (additionally eliminates eggs and dairy), semi-vegetarian (varying definitions), and pesco-vegetarian (consumes fish but not meat). Eliminating meat, a defining attribute of vegetarian diets, is commonly presumed to contribute to improved health outcomes

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Table 1 **Types of vegetarian diets**

Type of vegetarian diet	Definition
Lacto-ovo vegetarian	Eliminates meat, poultry, and fish but consumes eggs and dairy; often called "vegetarian"
Vegan	Eliminates all animal products (meat, fish, poultry, eggs, and milk)
Pesco-vegetarian	Eliminates meat and poultry; consumes fish, milk, and eggs
Semi-vegetarian	Varies widely. Studies in this review defined as: consuming red meat, poultry, or fish no more than once per week,[7] no red meat,[8] and restricting red meat (≤1 times per wk) and poultry intake (≤5 times per wk)[9]

because higher consumption of cured, smoked, salted, or otherwise processed meat and/or red meat is consistently associated with increased risk of obesity, diabetes, heart disease, and mortality.[10–12] Vegetarian diets can be rich in protective foods like vegetables, fruits, plant proteins, and whole grains[13,14] that may improve health outcomes if consumed in place of meat.[15–18] However, any healthful dietary pattern (eg, Mediterranean Diet or the Dietary Approaches to Stop Hypertension) can also be rich in these protective foods,[19,20] and less healthful foods can also replace meat in vegetarian diets, underscoring the importance of assessing the diet quality of dietary patterns presumed to be more healthful.

Diet quality typically indicates concordance of a dietary pattern with evidence-based recommendations about food and nutrient intake to promote health and reduce risk of chronic disease.[21] The advantage in assessing diet quality over assessing intake of individual nutrients is that diet quality offers a more holistic assessment, accounting for the synergy between foods and nutrients.[22] Diet quality may be measured using an a priori index where an individual's intake is compared with either a predetermined standard (ie, national nutrition recommendations) or the sample's intake distribution.[23] Alternatively, a posteriori approaches can be used to analyze dietary patterns (eg, principle component analysis); however, this review will focus on the a priori assessment of diet quality because a posteriori methods of assessment are data-driven, rather than recommendation-driven.[24] Components, which collectively determine overall diet quality, reflect intake of specific food groups and/or nutrients.[25] Components can be classified as either adequacy components, which are scored directly (higher intake, higher scores) and represent food groups/nutrients where increased intake is encouraged (ie, fruits and vegetables), or moderation components, which are scored inversely (higher intake, lower score) and represent food groups/nutrients where decreased intake is encouraged (ie, added sugar).[25] Without understanding the diet quality of vegetarian diets compared with nonvegetarian diets, it is difficult to ascertain whether vegetarianism improves adherence to dietary recommendations, subsequently increasing diet quality and reducing the risk of adverse health outcomes,[26–28] or whether health consciousness associated with vegetarian lifestyles improves health outcomes.

Health consciousness is favorably associated with chronic disease and mortality risk regardless of dietary pattern[29] and may be an important confounding or mediating variable in the association between vegetarianism and improved health outcomes. Vegetarians are more likely to engage in healthful behaviors such as avoiding tobacco, limiting alcohol, being physically active, and maintaining a healthy weight.[30–32] Additionally, health is a commonly cited motivation for following a vegetarian diet,[33] and this regard for health may translate to other behaviors, leading to systematic differences between vegetarians and nonvegetarians in many health-related facets. Populations where vegetarian diets are common tend to be health conscious (eg, Seventh Day Adventists[34]), which may confound the understanding of the relationship between vegetarianism and health outcomes. Furthermore, vegetarians and health-conscious nonvegetarians have been found to have similar mortality rates in several studies, [35–37] suggesting that the health benefits associated with vegetarianism may be heavily influenced by health consciousness rather than the exclusion of meat.

To date, it is unclear to what degree the association between vegetarianism and improved health outcomes is explained by health consciousness, elimination of meat, and consumption of healthful foods. Thus far, most studies examining the association between vegetarianism and health outcomes fail to consider diet quality as a confounding and/or mediating variable, making it difficult to identify the mechanism. Assessing and comparing the diet quality of nonvegetarian and vegetarian diets (including more- and less-restrictive diets; ie, vegan, pesco-vegetarian, and semi-vegetarian) can help elucidate the underlying mechanism(s) through which vegetarianism confers protection. Therefore, the purpose of this systematic review is to compare the diet quality (including total and component scores) of vegetarian and nonvegetarian diets.

METHODS

This systematic review complied with the guidelines delineated in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[38] Study inclusion criteria, formed with the PICOS (population, intervention, comparators, outcome, study design)

Table 2 **PICOS criteria for inclusion and exclusion of studies**

Component	Inclusion criteria	Exclusion criteria
Population	Adults (aged ≥18 y) residing in Western countries	Children and adolescents (aged <18 y); adults residing in developing countries
Intervention/exposure	Participants following any form of a vegetarian diet (either due to participant volition or researcher assignment)	Use of a plant-based diet index without identifying vegetarian status
Comparators	Participants following any form of a nonvegetarian diet	Lack of comparator group; lack of comparison with a nonvegetarian diet
Outcome measure	Diet quality measured by an a priori index	Measurement of diet quality with an a posteriori index; assessment of diet quality using pattern analysis
Study design	Any study design, observation or experimental	None

framework (Table 2),[38] were defined as: diet quality measured by an a priori index, adult participants (aged ≥18 y) from Western countries, and self-reported or objectively defined vegetarian dietary pattern(s), including the standard, lacto-ovo vegetarian diet as well as more- (ie, vegan) and less- (ie, pesco-vegetarian and semi-vegetarian) restrictive diets (Table 1[7–9]), compared with any nonvegetarian dietary pattern(s). Eligibility was restricted to studies involving human participants and publication in English, but eligibility was not limited by type of study or publication date. Studies involving children were excluded because of differing dietary needs during childhood, as were studies that solely used pattern analysis or nutrient intake without use of a diet quality index.

Studies were retrieved through electronic database searches and reference list reviews. Study eligibility was assessed by 2 reviewers. Web of Science and PubMed databases were searched in May 2018 using the following search terms: (diet index OR eating index OR diet indices OR diet quality OR diet score OR dietary index OR dietary indices OR dietary quality OR dietary score) AND (semivegetarian OR semi-vegetarian OR vegetarian* OR flexitarian OR vegan OR pescatarian OR pesco-vegetarian OR meatless). Database searches returned 1477 articles (Figure 1[38]), including 738 articles from Web of Science (1991–May 2018) and 739 articles from Pub Med (1978–May 2018). Nine articles were identified from reference lists of the included studies. Of the 1486 total articles, 406 were identified as duplicates and removed. Studies were screened by title and abstract, yielding 36 articles for full-text review. Twelve studies met the inclusion criteria and were incorporated into this qualitative analysis (Table 3[7–9,39–47]). Reasons for study exclusion after a full-text review included use of an a posteriori diet quality index, use of a plant-based diet index without identifying vegetarian status, no comparison of diet quality by diet pattern, or conducted in children.

From the included studies, information was collected regarding type(s) of vegetarian diet(s) examined, diet quality index(es) used, and the mean and standard deviation of vegetarian (and/or vegan, semi-vegetarian, and pesco-vegetarian when available) and nonvegetarian diet quality scores for total and component scores when provided. Studies were also evaluated for their risk of bias based on the methods of participant selection and dietary pattern categorization, measurement of diet history and diet quality, study design, statistical analyses, and control for confounding variables.

RESULTS

Eleven of the 12 included studies made comparisons between the diet quality of (lacto-ovo) vegetarian and nonvegetarian diets (4 studies also compared more- and/or less-restrictive diets), and 1 study solely compared a vegan diet with a nonvegetarian diet. Half of the studies were completed in the United States (n = 6), and the other half were completed in various Western countries (Belgium, Canada, Australia, Italy, and Germany).

Throughout the 12 studies, 7 different diet quality indexes were used, including Healthy Eating Index (HEI; n = 6), Alternative Healthy Eating Index (AHEI; n = 2), Mediterranean Diet Score (MDS; n = 2), Dietary Inflammatory Index (DII; n = 1), Rapid Eating and Activity Assessment for Patients (n = 1), Italian Mediterranean Diet Index (n = 1), and Healthy Eating Quiz (n = 1), and 1 study used an index created for the study (note that some studies used multiple indexes). The HEI and AHEI assess both nutrient and food group intake[7,39–43,47] and the remaining indexes either focused on nutrient intake (ie, DII[9]) or food groups (ie, MDS,[7,39] Rapid Eating and Activity Assessment for Patients,[8] Healthy Eating Quiz,[45] Italian Mediterranean Diet Index[46]). Higher scores on all of the indexes (with the exception of the DII, which is scored inversely[9]) are associated with greater adherence to dietary recommendations presumed or shown to improve health outcomes. Overall scores can be compared among the different indexes; however, components vary greatly

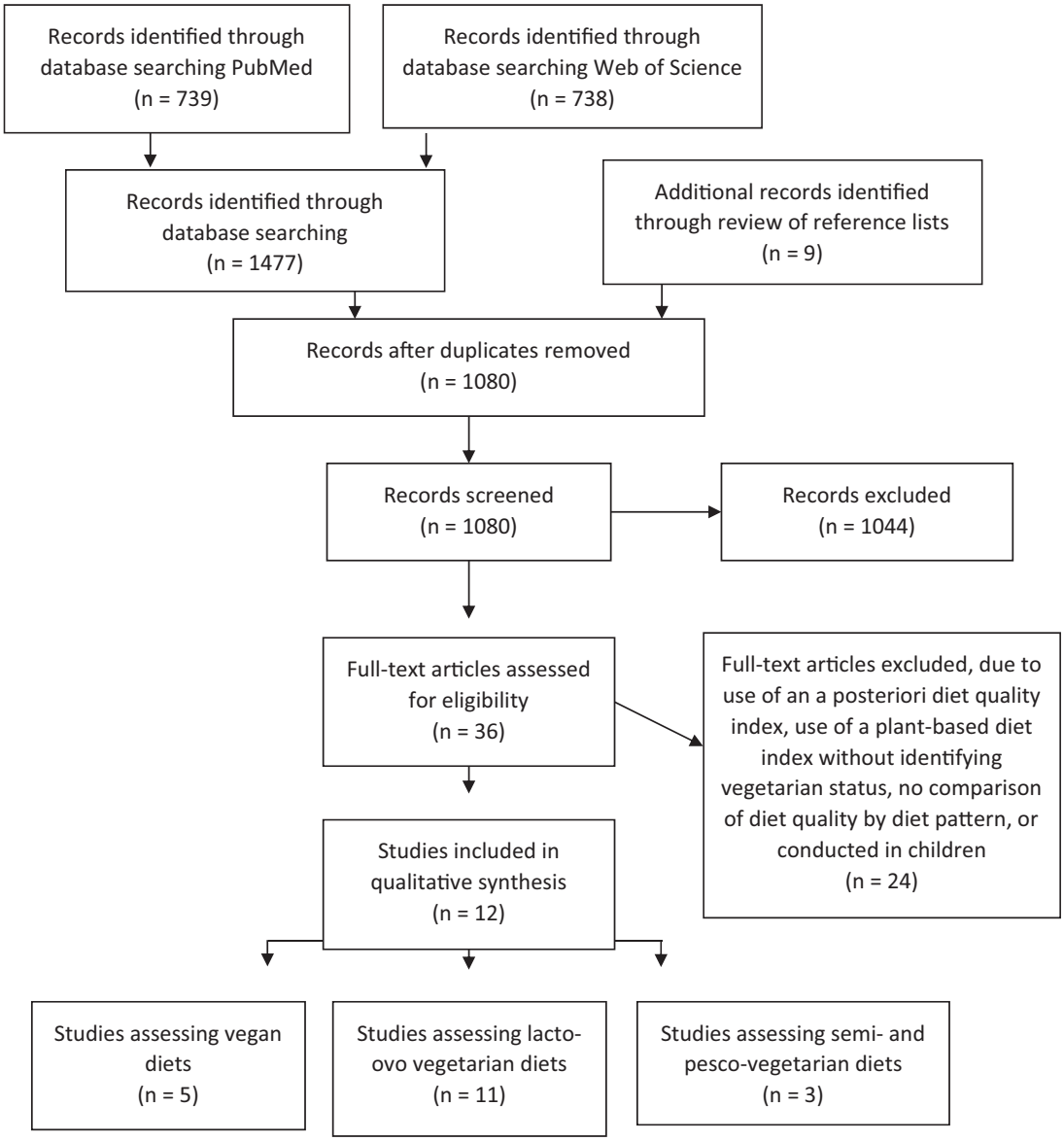

Figure 1 **Study selection flow diagram.**

across indexes and can only be compared across certain, similar indexes (eg, versions of the HEI and AHEI).

Although the diet quality indexes used differed among the included studies, total diet quality was generally calculated using a combination of adequacy and moderation components; adequacy components assessed adherence to recommended food groups, and moderation components were scored inversely and assessed adherence to recommendations to limit food groups or nutrients associated with adverse health outcomes. To elucidate the mechanisms through which diet quality is influenced by vegetarian and nonvegetarian status, results will first compare overall diet quality, followed by diet quality in adequacy and moderation components. Lastly, findings for diet quality among dietary patterns that are more (ie, vegan) and less (ie, semi-vegetarian and pesco-vegetarian) restrictive than lacto-ovo vegetarian will be reported.

Overall diet quality in lacto-ovo vegetarian diets

Overall diet quality was significantly ($P < 0.05$) higher in vegetarian diets compared with nonvegetarian diets in 8 of 11 studies, 2 studies found no differences, and 1 study found that diet quality was significantly ($P < 0.05$) lower in vegetarian diets compared with nonvegetarian diets. Of the 11 studies, 10 were observational studies, and 1 was a randomized control trial. Observational studies categorized dietary patterns in 1 of 2 ways, either using participant self-reported vegetarian status (n = 6) or objectively categorized vegetarian status based on the absence of meat, poultry, and fish in

Table 3 **Overall diet quality of vegetarian diets compared with nonvegetarian diets**

Author	Location	Study population	Diet quality index (maximum high score)	Average scores for vegetarian diets	Average scores for nonvegetarians
Studies comparing diet quality of lacto-ovo vegetarian and nonvegetarian diets					
Clarys et al (2013)[39]	Belgium	n =138; cross-sectional, self-identified vegetarians were purposefully sampled (ads in health food stores and online) and were matched with a participant-provided proxy or with omnivores from a larger convenience sample based on health and lifestyle characteristics (age, sex, BMI, physical activity, alcohol and tobacco use).	MDS (9) HEI-2010 (100)	4.3 ± 1.3* 53.8 ± 11.2**	3.8 ± 1.4 46.4 ± 15.3
Conrad et al (2017)[40]	United States	n =16 810; cross-sectional, NHANES (2007–12). Vegetarians were identified as those who did not eat meat, poultry, or fish on 2 recall days. Scores reflect the first recall day.	HEI-2010 (100) AHEI-2010 (100)	72.81 ± 2.43** 49.73 ± 1.24**	56.44 ± 0.58 38.49 ± 0.27
de Souza et al (2016)[41]	Canada	n = 4880 mother–infant pairs from 4 different birth cohorts; prospective, longitudinal study aiming to harmonize the food frequency questionnaires of the 4 different cohorts. Dietary patterns identified with principal component analysis were validated against self-reported vegetarian status and diet quality scores.	mHEI (60)	Vegetarian diet was strongly associated with "plant-based diet" identified with principle component analysis (OR, 3.85; 95%CI, 3.47–4.29; $P<0.001$). Plant-based diet pattern adherence was associated with mHEI scores in the 4th quartile, and lower plant-based diet pattern adherence was associated with mHEI scores in the 1st quartile.	
Farmer et al (2011)[42]	United States		Total	50.5 ± 0.88	50.1 ± 0.33

(continued)

Table 3 **Continued**

Author	Location	Study population	Diet quality index (maximum high score)		Average scores for vegetarian diets		Average scores for nonvegetarians	
		n =13 292; cross-sectional, NHANES (1999–2004). Vegetarians were identified as those who did not eat meat, poultry, or fish on the recall day. Dietary patterns were further divided into dieters (consuming at least 500 kcals below estimated energy needs) and nondieters.	HEI-2005 (100)	Dieting Nondieting	47.3 ± 1.27** 53 ± 0.91**		51 ± 0.47 49.7 ± 0.34	
Kennedy et al (2001)[43]	United States	n = 10 014; cross-sectional, Continuing Survey of Food Intake by Individuals (1994–96). Vegetarians were identified as those who did not eat meat, poultry, or fish on the recall day.	HEI-95 (100)		60.8 ± 0.8*		63.2 ± 0.2	
Thiele et al (2004)[44]	Germany	n =4030; cross-sectional, data from the German Nutrition Survey of 1998, sampled from population registry. Method of dietary pattern categorization was not reported and the index used was created for this study—higher scores are more desirable. Regression coefficients were the basis of comparison.	Deficient Index (3000) Excess Index (600)		Women (β coefficient) 45.457** −0.035	Men (β coefficient) 96.437** 15.869	Women Referent	Men Referent
Williams et al (2017)[45]	Australia	n = 93 252; individuals who accessed and voluntarily completed the Healthy Eating Quiz between March 2013 and July 2016 in a generally cross-sectional study with some longitudinal data from participants with multiple responses. Vegetarian status was self-reported.	Healthy Eating Quiz (73)		37.3 ± 9.9**		33.8 ± 9.6	

(continued)

Table 3 **Continued**

Author	Location	Study population	Diet quality index (maximum high score)			Average scores for vegetarian diets		Average scores for nonvegetarians	
Studies comparing diet quality of multiple vegetarian-related dietary patterns (lacto-ovo vegetarian, vegan, semi-vegetarian, pesco-vegetarian) and nonvegetarian diets									
Clarys et al (2014)[7]	Belgium	n =1475; cross-sectional, evaluating 5 self-identified dietary patterns (vegan, [lacto-ovo] vegetarian, semi-vegetarian, pesco-vegetarian, nonvegetarian) using a survey sent to 4000 members of an ethical vegetarian group and university staff members.	MDS (9)	Vegetarian		4.6 ± 1.5**		4.1 ± 1.6	
				Semi-vegetarian		5.2 ± 1.5**			
				Pesco-vegetarian		5.5 ± 1.4**			
				Vegan		5.8 ± 1.3**			
			HEI-2010 (100)	Vegetarian		58.7 ± 8.9**		54.2 ± 9.0	
				Semi-vegetarian		59.4 ± 7.4**			
				Pesco-vegetarian		58.7 ± 7.9**			
				Vegan		65.4 ± 8.3**			
Turner-McGreivy et al (2015)[9]	United States	n = 63; randomized weight loss trial, during a 2-mo weight loss trial where participants were randomized to 5 different diets (vegan, [lacto-ovo] vegetarian, semi-vegetarian, pesco-vegetarian, nonvegetarian) in addition to a low-fat and low-glycemic index. Diet quality was assessed at baseline, 2 mo, and 6 mo.	DII (−10)	Vegetarian	0 mo	0.4 ± 0.6		0 mo	−0.1 ± 0.6
					2 mo	−1.0 ± 0.5		2 mo	0.2 ± 0.7
					6 mo	−0.2 ± 0.7		6 mo	−0.5 ± 0.8
				Semi-vegetarian	0 mo	0.9 ± 0.6			
					2 mo	1.3 ± 0.6			
					6 mo	0.2 ± 0.7			
				Pesco-vegetarian	0 mo	0.9 ± 0.6			
					2 mo	−0.7 ± 0.5			
					6 mo	−0.2 ± 0.6			
				Vegan	0 mo	0.3 ± 0.6			
					2 mo	−1.2 ± 0.5			
					6 mo	0.1 ± 0.6			
Turner-McGreivy et al (2016)[8]	United States	n = 422; cross-sectional, distance runners (half, full, or ultra marathoners) were recruited via social media and self-identified their dietary pattern	Rapid Eating and Activity Assessment for Patients (52)			38.5 ± 3.6**[a]		32.8 ± 4.5	
Rosi et al (2017)[46]	Italy	n = 153; cross-sectional, volunteers were purposefully recruited at 4 different locations. Among the dietary patterns, diet quality and environmental impact was compared	Italian Mediterranean Diet Index (11)			Vegan	7.0 ± 2.0*	4.0 ± 3.0	
						Vegetarian	6.0 ± 2.0*		

(continued)

Table 3 **Continued**

Author	Location	Study population	Diet quality index (maximum high score)		Average scores for vegetarian diets	Average scores for nonvegetarians
Studies comparing vegan and nonvegetarian diets						
Turner-McGreivy et al (2008)[47]	United States	n = 99; randomized weight loss trial, participants with type 2 diabetes were randomized to a low-fat vegan diet or the American Diabetes Association (nonvegetarian) diet for a 22-wk intervention.	AHEI (70)	Baseline Change from baseline at 22 wk	31.6 ± 11.8 +22.5 ± 18.7**	35.1 ± 10.1 −0.9 ± 18.1

Scores for vegetarian diets are for lacto-ovo vegetarian diets unless noted otherwise.

Abbreviations: AHEI, Alternative Healthy Eating Index; BMI, body mass index; CI, confidence interval; DII, Dietary Inflammatory Index (low score reflects better adherence to recommendations); HEI, Healthy Eating Index; MDS, Mediterranean Diet Score; mHEI, Modified Alternative Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio.

*Significantly different from nonvegetarians at $P < 0.05$.

**Significantly different from nonvegetarians at $P < 0.01$.

[a]Vegetarians and vegans scored an average of 38.5 collectively; separate scores were not reported.

participant-reported dietary recalls (n = 3). The categorization method used was not reported for 1 study.[44] Because research shows that approximately 64%–80% of self-identified vegetarians also report meat intake on diet recalls,[13,48,49] use of self-reported vegetarian status may lead to misclassification. In the 6 studies examining self-reported vegetarian status in convenience samples, vegetarians had consistently higher diet quality compared with nonvegetarians (4.5–7.4 points higher on the HEI and 0.5 points higher on the MDS).[7,8,39,41,45,46] Vegetarians also had higher diet quality in 2 nationally representative samples, including 1 study within the 2007–2012 National Health and Nutrition Examination Survey (NHANES) using objective categorization[40] and 1 study from Germany (categorization method not provided).[44] Among NHANES 2007–2012 participants, those who reported no meat, fish, or poultry on their 24-hour recall had significantly higher scores on the HEI-2010 (72.81 vs 56.44; $P < 0.001$) and AHEI-2010 (49.73 vs 38.49; $P < 0.001$) scores compared with participants who reported meat, fish, or poultry on their recalls.[40]

In the remaining 3 studies, there were either no differences in diet quality among vegetarians and non-vegetarians[9,42] or vegetarians had significantly lower diet quality than nonvegetarians ($P < 0.05$).[43] In a 2-month weight loss trial, participants were randomized to consume 1 of 5 avoidance diets (vegan, vegetarian, pesco-vegetarian, semi-vegetarian, or nonvegetarian) and were given advice on foods to exclude as well as guidelines for a low-glycemic-index and low-fat diet.[9] At baseline, 2 months, and 6 months, diet quality was measured by the DII.[9] Although no differences in diet quality between the vegetarian and nonvegetarian groups were detected,[9] adherence to assigned dietary pattern was low (for vegetarian, 77% adhered to the diet at 2 months and 39% at 6 months[50]) and may have resulted in misclassification bias. It is also difficult to discern the influence of dietary pattern on diet quality in a weight loss trial because the goal of weight loss may have increased diet quality independent of dietary pattern. Similarly, a study examining the NHANES 1999–2004 data did not detect any differences in HEI-2005 scores between vegetarians and nonvegetarians (50.5 vs 50.1), although diet quality differed by dieting status.[42] Among dieters (consuming at least 500 kcals below estimated energy needs), vegetarians had lower HEI-2005 scores than nonvegetarians (47.3 vs 51.0, $P < 0.01$), and the finding was reversed for nondieters (53.0 vs 49.7; $P < 0.01$),[42] indicating that differences in diet quality between dietary patterns may be influenced by restricted energy intake. Lastly, in a study examining data from the Continuing Survey of Food Intake by Individuals (1994–1996), vegetarians scored significantly lower on the HEI-1995 than nonvegetarians (60.8 vs 63.2; $P < 0.05$).[43] However, it is important to note that the diet quality indexes used may influence conclusions about diet quality among vegetarians and nonvegetarians. The HEI-1995 and HEI-2005 assessed total protein foods (called "meat and beans" in the earlier HEI).[51,52] However, unlike the more recent HEI-2010, a subscore for plant and seafood protein was not included in HEI-1995 and HEI-2005.[51–53] Thus, it is likely that differences between the HEI-1995/HEI-2005 and HEI-2010 contributed to the differing conclusions drawn as findings from a more recent NHANES 2007–2012 study indicated significant differences between vegetarians and nonvegetarians when assessing diet quality with the HEI-2010 ($P < 0.05$).[40]

Diet quality in adequacy component scores

In diet quality indexes, adequacy components assess adherence to recommended food groups. Findings for component scores reflect studies (n = 4) for which comparisons by dietary pattern for HEI component scores were reported (Table 4[7,39,42,43]). Although 4 additional studies compared component scores within the DII,[9] MDS,[7,39] and the Healthy Eating Quiz,[45] they are not presented in the component score analysis because the version of the DII used only assessed nutrients (not food groups)[9]; the studies for which component scores for the MDS were reported also presented HEI-2010 scores, which were included in this analysis[7,39]; and the Healthy Eating Quiz assesses both diet quality and variety simultaneously,[45] the latter of which was not the focus of this review. In the few studies comparing HEI (either -2010, -2005, or -1995), vegetarians generally scored higher on components for total fruit, whole grains, and plant and seafood protein and lower on total protein foods compared with nonvegetarians; no consistent associations were observed for other adequacy components (including vegetables, dairy, and dietary fat).[7,39,42,43]

Fruit. All 4 studies assessing component scores for total fruit found higher scores in vegetarian versus nonvegetarian diets.[7,39,42,43] Differences in total fruit scores between dietary patterns were larger in convenience samples (0.9–1.2 points)[7,39] compared with nationally representative studies (0.33–0.7 points).[42,43] Three of the studies separately analyzed whole fruit scores (excluding juice), 2 of which found that vegetarians also scored higher on whole fruit than nonvegetarians within health-conscious convenience samples of Belgian adults.[7,39] However, a nationally representative US study found no differences in whole fruit scores between vegetarians and nonvegetarians,[42] suggesting that fruit juice intake may be high in the broader vegetarian

Table 4 **Comparisons of average Healthy Eating Index adequacy component scores between vegetarian and nonvegetarian dietary patterns**

Components		Reference and HEI version							
		Clarys et al (2013)[39]		Clarys et al (2014)[7]		Farmer et al (2011)[42]		Kennedy et al (2001)[43]	
		HEI-2010		HEI-2010		HEI-2005		HEI-1995	
		Vegetarian	Nonvegetarian	Vegetarian	Nonvegetarian	Vegetarian	Nonvegetarian	Vegetarian	Nonvegetarian
Fruit	Total	3.8*	2.6	4.1*	3.2	2.4*	2.1	4.4*	3.7
	Whole	3.9*	3.1	4.1*	3.5	2.2	1.9	–	–
Vegetables		2.1	1.7	4.8	4.6	2.7*	3.0	–	–
Whole grains		9.1*	8.2	7.6	6.8	1.6*	0.9	–	–
Protein	Total protein foods[a]	3.0*	4.7	3.0*	4.7	3.7*	8.5	–	–
	Seafood and plant protein	1.7*	0.9	3.5*	2.9	–	–	–	–
Fatty acids[b]		2.6*	3.9	2.2*	1.6	5.2	5.3	–	–
Dairy		3.5	2.8	2.8	3.0	5.7*	4.7	–	–

A dash (–) indicates this was not assessed/reported.
Abbreviation: HEI: Healthy Eating Index.
*Significantly different from nonvegetarian at $P < 0.05$.
[a]Named meat and beans in the HEI-2005.
[b]Scores reported for the HEI-2005 reflect the oils component score.

population, thus obscuring differences in total fruit intake between dietary patterns. Therefore, although total fruit scores were consistently higher in vegetarians, scores for whole fruit intake were less consistent.

Whole grains. Whole-grain component scores were generally higher in vegetarians compared with nonvegetarians, with vegetarians scoring significantly higher in 2 of 3 studies,[7,42] and a third study found scores to be comparable between dietary patterns.[39] Vegetarians in an NHANES 1999–2004 sample scored more than 50% higher than nonvegetarians on the whole-grain component score (1.55 vs 0.92 out of 5; $P < 0.01$) of the HEI-2005.[42] Another study, which used the HEI-2010, also found that vegetarians scored significantly higher than nonvegetarians (7.6 vs 6.8 out of 10; $P < 0.01$). In the third study, although insignificant, vegetarians scored marginally higher when matched with nonvegetarians by sex, age, body mass index, physical activity, alcohol use, and tobacco use on the HEI-2010 whole-grains component score (9.1 vs 8.2 pts; $P = 0.052$).[39] Overall, whole-grain intake appears to be higher in vegetarians.

Protein. In all 3 studies assessing component scores for total protein foods, vegetarians scored lower than nonvegetarians.[7,39,42] In an NHANES 1999–2004 analysis using the HEI-2005, vegetarians obtained an average score of less than half that of nonvegetarians (3.66 vs 8.46 of 10 total points; $P < 0.01$) on the meat and beans component.[42] However, plant protein consumption was not assessed in the HEI-2005 as it was in later versions of the HEI,[53] and further food group analyses indicated that the vegetarians consumed significantly more plant proteins (including soy, nuts, and legumes) than nonvegetarians ($P < 0.01$).[42] For the HEI-2010, the meat and beans component from the HEI-2005 was divided into total protein foods and seafood and plant protein, where some plant proteins could contribute points in both categories.[53] This modification allowed vegetarian diets to obtain higher scores on the HEI-2010 compared with the HEI-2005, as indicated in 2 other studies that assessed seafood and plant protein with the HEI-2010 and found that vegetarians scored higher than nonvegetarians.[7,39] Therefore, although vegetarians scored lower in the total protein foods component, they scored higher on the seafood and plant protein component.

Vegetables. Less consistent findings were observed for other adequacy components. Vegetable intake was assessed in 3 studies; 2 found no significant differences between dietary patterns,[7,39] and 1 found that vegetarians scored lower than nonvegetarians in an NHANES 1999–2004 sample (3.04 vs 2.74 points on total vegetables HEI-2005 score; $P < 0.01$).[42] However, subgroup analyses revealed that vegetarians consumed significantly more dark green vegetables (0.15 vs 0.11 cups per day; $P < 0.01$) and significantly less potatoes (0.25 vs

Table 5 **Comparisons of average Healthy Eating Index moderation component scores between vegetarian and nonvegetarian dietary patterns**

Components	Study author, year, and HEI version					
	Clarys et al (2013)[39]		Clarys et al (2014)[7]		Farmer et al (2011)[42]	
	HEI-2010		HEI-2010		HEI-2005	
	Vegetarian	Nonvegetarian	Vegetarian	Nonvegetarian	Vegetarian	Nonvegetarian
Empty calories	7.3	5.0	6.0	5.7	8.6	8.4
Sodium	7.9	7.4	8.7*	6.8	5.6*	4.1
Refined grains	3.3*	4.2	7.1*	8.5	–	–

Inverse scoring was used on all moderation components, therefore higher scores are more desirable. A dash (–) indicates this was not assessed/reported.

Abbreviation: HEI, Healthy Eating Index.

*Significantly different from nonvegetarian at $P < 0.05$.

0.41 cups per day; $P < 0.01$) than nonvegetarians,[42] potentially revealing differences in the quality of vegetables consumed between these groups. Although unprocessed potatoes are a rich source of nutrients such as potassium and fiber,[54] in the United States, potatoes are commonly consumed with added fat and sodium (eg, French fries, potato chips, etc),[55,56] which may diminish the health benefits associated with vegetable consumption,[57] making potato preparation method an important consideration in the contribution of vegetables to diet quality. Therefore, although vegetarians and nonvegetarians appeared to consume similar amounts of total vegetables, higher vegetable scores in nonvegetarians may have been driven by increased potato consumption, and the relative quality of vegetables consumed among vegetarians may be higher.

Dietary fat. Findings in the dietary-fat component scores varied across studies. The HEI components for fats were recently restructured from the oils (unsaturated fats from plants and fish) and saturated fat components used in the HEI-2005 to the fatty-acids component (ratio of unsaturated to saturated fat) in the HEI-2010,[53] making direct comparisons difficult. In 2 studies using the HEI-2010, vegetarians scored higher on the fatty-acids component (unsaturated fat/saturated fat) in 1 unadjusted analysis[7]; however, in a second study, vegetarians matched with nonvegetarians by lifestyle factors scored lower (the increased score in nonvegetarians was attributed to fish intake).[39] Using the HEI-2005, a study within NHANES 1999–2004 found no difference in oils (unsaturated fats from plants and fish) scores between dietary patterns, but saturated fat scores were significantly higher (lower consumption, in line with recommendations) in vegetarians ($P < 0.01$).[42] Overall, vegetarians appear to have lower intake of saturated fat, and unsaturated fat intake appears to be similar between vegetarians and nonvegetarians.

Dairy. Findings for dairy component scores were also inconsistent; 1 study found that vegetarians scored higher than nonvegetarians,[42] and in 2 studies, scores were comparable.[7,39] In an NHANES 1999–2004 sample, dairy component scores were higher in vegetarians compared with nonvegetarians (5.66 vs 4.86; $P < 0.01$).[42] However, 2 studies examining convenience samples of Belgian adults found no differences in dairy scores between dietary patterns,[7,39] although 1 study included soy beverages as protein food rather than as a dairy food,[7] which could have artificially decreased dairy component scores in participants who consumed calcium-fortified soymilk. It should be noted that dairy is assessed as an adequacy component on the HEI,[53] but on other indexes such as the MDS,[20] dairy is a moderation component. Consequently, the influence of dairy intake on overall diet quality depends on both the index used and the foods contributing to the dairy component.

Diet quality in moderation component scores

Moderation components in diet quality indexes assess consumption of food groups or nutrients where moderation is recommended due to associations with adverse health outcomes. Reverse scoring (ie, higher score indicates lower consumption) is used to assess intake of moderation components in diet quality indexes. Among the 3 studies assessing moderation components, vegetarians generally consumed more refined grains, similar amounts of empty calories, and less sodium than nonvegetarians (Table 5).[7,39,42]

Among samples of Belgian adults, refined-grain component scores in vegetarians were 0.9–1.3 HEI-2010 points lower than the nonvegetarians scores.[7,39] Similarly, in an NHANES 1999–2004 analysis where refined-grain intake was assessed but not as a component score (the HEI-2005 only accounted for total and whole-grain intake), vegetarians consumed more refined grains (6.64 vs 6.11 ounces per day; $P < 0.01$).[42] No differences between dietary patterns in empty

calorie scores (comprised of calories from solid fat, added sugar, and alcohol in excess of recommendations) were observed in any of these 3 studies.[7,39,42] Vegetarians consumed less sodium per day compared with nonvegetarians in 2 of 3 studies: 1068 mg less in a convenience sample[7] and 467 mg less in an NHANES 1999–2004 sample.[42] However, in a sample where vegetarians and nonvegetarians were matched by lifestyle characteristics, they had similar sodium component scores,[39] so in this population, sodium intake may be related to health consciousness. Compared with nonvegetarians, vegetarians appear to have higher refined-grain intake, similar empty calorie intake, and potentially lower sodium intake.

Diet quality in more- and less-restrictive diets

To better understand the contribution of vegetarianism to overall diet quality, it is pertinent to examine the diet quality of more- and less-restrictive dietary patterns (relative to lacto-ovo vegetarian). The vegan diet is similar to the vegetarian diet but further restricts all animal products, including eggs and dairy. Less-restricted vegetarian diets, such as semi-vegetarian and pesco-vegetarian, have been recently popular as liberalized vegetarian diets.[58] Pesco-vegetarian is commonly defined as a vegetarian diet that includes fish, whereas the definitions for semi-vegetarian vary widely but involve limited meat intake.[58]

Of the 12 included studies, 5 studies examined more- and/or less-restrictive vegetarian diets; 1 weight loss trial compared a vegan and nonvegetarian diet,[47] 1 observational study compared vegan, lacto-ovo vegetarian, and nonvegetarian diets,[46] and 2 studies (a weight loss trial and an observational analysis) examined vegan, pesco-vegetarian, semi-vegetarian, lacto-ovo vegetarian, and nonvegetarian diets.[7,9] Lastly, 1 observational study examined many different dietary patterns, including vegan, vegetarian, semi-vegetarian, pesco-vegetarian, paleo, and low carbohydrate; however, diet quality scores of the individual dietary patterns were not reported.[8]

Vegan diets. Five total studies assessed the diet quality of vegan diets, and findings generally indicated that vegans scored higher than nonvegetarians. One study compared AHEI scores among individuals participating in a 22-week weight loss trial who were assigned to either a low-fat vegan diet or a nonvegetarian, control diet (the American Diabetic Association diet); those assigned to the vegan diet significantly increased AHEI total and all component scores from baseline ($P < 0.01$), whereas the control group did not change AHEI scores.[47] Another study examined diet quality among various dietary patterns in distance runners using the Rapid Eating and Activity Assessment for Patients and found that self-identified vegans and vegetarians (data not shown for individual patterns) had better diet quality scores compared with nonvegetarians (38.5 ± 3.6 vs 32.8 ± 4.5; $P < 0.001$).[8]

In the remaining 3 studies, diet quality scores were compared across a range of diets, including vegan, vegetarian, and nonvegetarian, and in 2 studies, pesco-vegetarian and semi-vegetarian diets were also compared.[7,9,46] A dose–response relationship between dietary pattern restriction and diet quality was seen in 2 observational studies where vegans had the highest diet quality, followed by vegetarians, then nonvegetarians.[7,46] In a purposefully selected sample of Italian adults, Rosi et al[46] found that on the Italian Mediterranean Diet Index, vegetarians scored (6.0 ± 2.0) significantly higher than nonvegetarians (4.0 ± 3.0; $P < 0.05$) and significantly lower than vegans (7.0 ± 2.0; $P < 0.05$). Similarly, in a cross-sectional study among a convenience sample of Belgian adults, vegans scored significantly higher on the HEI-2010 and MDS compared with vegetarians and nonvegetarians ($P < 0.01$).[7] Higher HEI-2010 scores in vegans compared with vegetarians were driven by higher component scores for total protein foods, seafood and plant protein, fatty acids, sodium, refined grains, and empty calories.[7] One experimental study where participants were randomly assigned to 1 of 5 dietary patterns did not observe any differences among DII scores for those assigned to vegan, vegetarian, and nonvegetarian diets at both the 2- and 6-month follow-ups.[9] However, in weight loss trials, overall energy restriction, rather than dietary pattern, may be more influential on diet quality. Additionally, the version of the DII used in the included study solely assessed nutrient intake,[9] which may lead to potential confounding by fortified foods otherwise not recommend in a healthful dietary pattern. Preliminary evidence suggests that the diet quality of vegan diets are, at minimum, comparable with vegetarian diets, and there is some indication of a dose–response relationship between restrictiveness of vegetarian dietary pattern and diet quality, suggesting that diet quality of vegan diets may be higher than vegetarian diets.

Less-restrictive diets (semi-vegetarian and pesco-vegetarian). Only 2 studies examined the diet quality of semi-vegetarians and pesco-vegetarians, and both studies made comparisons among semi-vegetarian, pesco-vegetarian, vegan, vegetarian, and nonvegetarian diets.[7,9] One experimental trial found that 6 months after the intervention, there were no differences in DII scores across the 5 dietary patterns.[9] However, at 2 months, participants assigned to vegan, vegetarian, and pesco-vegetarian diets had better DII scores

(-1.2 ± 0.5, -1.0 ± 0.5, -0.7 ± 0.5, respectively; lower scores are desirable) than those assigned to a semivegetarian diet (1.3 ± 0.6).[9] In an observational study using the HEI-2010, scores were similar among self-reported vegetarians (58.7 ± 8.9), semi-vegetarians (59.4 ± 7.4), and pesco-vegetarians (58.7 ± 7.9), all of whom scored significantly higher than nonvegetarians (54.2 ± 9.0; $P < 0.01$) and significantly lower than vegans (65.4 ± 8.3; $P < 0.01$).[7] On the MDS, pesco-vegetarians scored similar to vegans, whereas semi-vegetarians scored significantly lower than vegans ($P < 0.01$).[7] However, vegans, semi-vegetarians, and pesco-vegetarians all scored significantly higher ($P < 0.01$) than both vegetarians and nonvegetarians.[7] Because only 2 studies to date have made diet quality comparisons involving semi-vegetarian and pesco-vegetarian diets and the findings were inconsistent, more research is needed to determine the relative diet quality of these dietary patterns.

RISK OF BIAS WITHIN STUDIES

The risk of bias varied considerably amonng the 12 included studies. For participant selection, although most studies (n = 8) featured convenience samples, nationally representative studies were also common (n = 4). Although 2 of the 4 nationally representative studies did not find that vegetarian diets were higher in diet quality than nonvegetarian diets, this was likely due to the diet quality indexes used rather than the sample.[42,43] Aside from these 2 studies, findings were similar in both convenience samples and nationally representative studies, indicating that there is a low risk of bias from participant selection in the overall findings.

For dietary pattern categorization, all studies in this review (n = 6) that categorized participants using self-identified dietary patterns found that vegetarians had higher diet quality than nonvegetarians. Because research suggests that self-identified vegetarians often report meat consumption on dietary assessments,[13,48,49] studies using self-report are at increased risk for misclassification of dietary patterns. Some included studies (n = 3) categorized dietary patterns objectively (based on diet recall) within nationally representative samples, 1 of which found that vegetarians had higher diet quality than nonvegetarians.[40] Although 2 of the studies using objective categorization in nationally representative samples did not find that diet quality was higher in vegetarians, this is likely due to the diet quality indexes and not the classification method used.[42,43] Therefore, dietary pattern categorization is an unlikely source of bias.

Measurement of diet history and diet quality are also unlikely sources of bias in the overall conclusions. Almost all studies used reputable methods (24-hour recalls, weighted food records, or food frequency questionnaires) for diet history collection. Although 1 study used a nonvalidated, modified subset of questions from a validated food frequency questionnaire, this is unlikely to impact the overall risk of bias.[45] For measurement of diet quality, 6 studies used validated indexes,[8,39,42,43,46,47] 1 study developed a new index for the purpose of the study and did not validate it,[44] and 5 studies made alterations to validated indexes.[7,9,40,41,45] In the cases of modifications, the validity of the measurement of diet quality may have been compromised, thus modestly increasing the risk of bias. For example, Clarys et al[7] categorized all soy beverages as protein foods instead of dairy foods on the HEI-2010. This alteration likely led to lower dairy component scores and higher component scores for both total protein foods and plant and seafood protein for soymilk consumers, resulting in an overall increase in total HEI-2010 scores. Without further validation it is not clear whether the scores obtained with this change (and similar changes in other studies) accurately reflect diet quality. However, the influence of the nonvalidated diet quality indexes on the overall conclusions is likely modest because most modifications were minor and most studies used validated and commonly used diet quality indexes (ie, HEI and MDS) where higher scores are correlated with more favorable health outcomes[20,59–62] and findings were similar between the studies that did and did not use validated indexes.

Lack of control for confounding variables in this body of evidence was identified as a potential source of bias in the overall conclusions. Because vegetarians are more likely to be health conscious[30–33] and health consciousness is related to diet quality,[34] health consciousness can confound the relationship between vegetarian diets and diet quality. Despite the repeated indications of increased health consciousness in vegetarians, only 1 study in this review controlled for covariates related to health consciousness by matching vegetarians and nonvegetarians on lifestyle characteristics such as smoking, physical activity, and body mass index.[39] Even with controlling for some lifestyle factors, vegetarians still scored significantly higher than nonvegetarians on the HEI-2010 and MDS ($P < 0.05$),[39] suggesting that health consciousness is not exclusively driving the association between vegetarian diet and improved health outcomes.

Study design should also be considered when examining confounding by health consciousness, which is mainly a concern in observational studies due to lack of randomization. Two included studies were randomized control trials, 1 of which found no differences in diet quality 6 months after assignment to 1 of 5 dietary patterns,[9] and the other study found that participants assigned to a low-fat vegan diet significantly improved

diet quality scores over those assigned to a diabetic diet ($P < 0.01$).[47] However, these were weight loss trials where the assigned dietary pattern may have played a relatively minor role in diet quality. Therefore, it is difficult to decipher the influence that the lack of control for confounding by health consciousness had in the overall conclusions. Overall, there is an indication that vegetarian diets are higher in diet quality compared with nonvegetarian diets; however, conclusions should be interpreted cautiously because some level of confounding due to health consciousness is expected.

DISCUSSION

This systematic review compared diet quality between vegetarian and nonvegetarian diets in an effort to understand the role of diet quality in the relationship between vegetarian diets and improved health outcomes. Collectively, observational studies suggest that vegetarian diets are higher in overall diet quality compared with nonvegetarian diets. In studies using the HEI-2010 (most commonly used index), vegetarians scored between 4.5 and 16.4 points (out of 100 points) higher than nonvegetarians.[7,39,40] Few observational studies (n = 2) in this review found that vegetarians had similar or lower diet quality than nonvegetarians, and those that did used versions of the HEI that assessed adherence to older dietary recommendations.[42,43] The limited number of studies examining HEI component scores (n = 4) suggests that higher diet quality in vegetarians may have been driven by higher scores for whole grains, total fruits, plant and seafood protein, and sodium and lower scores for refined grains and total protein foods. However, few studies controlled for lifestyle characteristics, which may confound these findings. Diet patterns more and less restrictive than the lacto-ovo vegetarian diet had less consistent associations with diet quality. Although limited evidence suggests that diet quality in vegan diets is comparable with or better than the diet quality of vegetarian diets, findings for less-restrictive vegetarian diets were inconsistent, which may be due in part to variable definitions of semi-vegetarian.

Studies included in this review were published between 2001 and 2017, spanning a period of time where changes in the definition of a high-quality diet in accordance with dietary recommendations occurred due to progressive understanding of healthy diets.[63] For example, elucidation of the health benefits associated with plant protein consumption prompted changes in dietary recommendations calling for increased consumption as well as increased acceptance of vegetarian diets, which were previously thought to be nutritionally inadequate but are now regarded as safe and protective against chronic diseases.[64] In this review, several studies using diet quality indexes that reflected previous dietary recommendations (ie, HEI-1995 and HEI-2005)[42,43] had findings that were inconsistent with studies using indexes reflecting more recent dietary recommendations (ie, HEI-2010).[7,39,40] For example, Farmer et al[42] analyzed NHANES 1999–2004 data with the HEI-2005 and noted that vegetarians scored substantially lower than nonvegetarians on the meat and beans component but consumed significantly ($P < 0.01$) more plant proteins and met the protein recommended dietary allowance. Had diet quality been evaluated with a more recent version of the HEI where plant protein scores more favorably than animal proteins (excluding fish), vegetarians may have scored higher than nonvegetarians. Furthermore, although none of the included studies used the most recent version of the HEI, the HEI-2015, changes made to the HEI-2010 in developing the HEI-2015 involved further incentives for the consumption of legumes. On the HEI-2010, legumes contributed points in only 2 categories (either total vegetables and greens and beans or total protein foods and seafood and plant protein)[53]; however, the HEI-2015 allows legumes to contribute points in all 4 categories,[65] a change that is likely to increase scores for vegetarians.

Substitutions that increase diet quality

The diet quality of vegetarian diets compared with nonvegetarian diets is somewhat dependent on the index used but more so determined by the foods consumed in place of meat, fish, and poultry. Many diet quality indexes penalize red and processed meat consumption[19,20,61] due to associations with increased risk of chronic disease and mortality.[10–12] Therefore, replacing red and processed meat, which is void of fiber and generally contains saturated fat and added sodium, with fiber-rich plant proteins, will likely increase diet quality and improve health outcomes.[66] Furthermore, some vegetarian replacements for red meat have been shown to reduce cardiovascular disease risk in substitution analyses: risk of coronary heart disease was reduced by 30% when 1 serving of red meat per day was replaced with 1 serving of nuts[67] and replacing red meat with vegetables also resulted in decreased risk of myocardial infarction.[68]

Although replacing red meat with vegetables may be beneficial, this review did not find that vegetarians consumed more vegetables than nonvegetarians. However, it is important to note that there was some suggestion that nonvegetarians may have higher potato intake than vegetarians, potentially obscuring the relationship between vegetable intake and dietary pattern. This speculation is consistent with findings from a nationally representative study where diet recall– and self-

identified nonvegetarians had higher fried potato consumption compared with diet recall– and/or self-identified lacto-ovo vegetarians.[13] Consumption of tomatoes, lettuce, and other vegetables were descriptively higher in diet recall– and/or self-identified lacto-ovo vegetarians compared with diet recall– and self-identified nonvegetarians.[13] Total vegetable intake also varied by categorization method; participants who consumed meat, regardless of self-identified dietary pattern, had similar vegetable intake, whereas vegetable intake in diet recall–identified vegetarians was significantly higher than nonvegetarians (250 ± 14 g vs 159 ± 8 g; $P < 0.05$).[13] Taken together, this also suggests that the health consciousness associated with identifying as vegetarian may substantially contribute to diet quality and health outcomes.

Substitutions that lead to decreases in diet quality

Not all vegetarian substitutions for meat, fish, and poultry will result in improved diet quality and health outcomes. For instance, replacing fatty fish is more controversial because fatty fish consumption is associated with a reduced risk of mortality.[69,70] Additionally, poultry consumption is generally not associated with mortality risk.[71] In a substitution analysis, substituting vegetables for poultry did not impact myocardial infarction risk, although risk increased when vegetables replaced fatty fish.[68] Fatty fish is weighted more heavily on many diet quality indexes (compared with vegetables and plant proteins) because of differences in recommendations. For example, on the AHEI, 2 servings of fatty fish per week, 1 serving of nuts and legumes per day, and 5 servings of vegetables per day are considered optimal.[61] Therefore, consuming any vegetarian food in place of fatty fish could negatively impact diet quality. Consequently, one might expect pesco-vegetarian diets to be higher in diet quality than vegetarian diets. However, in this review, only 1 study found that pesco-vegetarian diets were higher in diet quality compared with vegetarian diets when assessing diet quality with the MDS; when diet quality was assessed with the HEI-2010, scores were similar.[7]

Substitutions that lead to variable changes in diet quality

Although the evidence is limited, articles in this review suggested that vegan diets may be higher in diet quality than vegetarian and nonvegetarian diets. Elimination of eggs and dairy distinguishes vegan from vegetarian diets, and there is currently a lack of consensus regarding the health impacts of these foods. Dairy foods may be protective against some cardiovascular diseases[72] but are generally not associated with all-cause and cardiovascular disease mortality,[73] and findings regarding egg consumption and mortality and disease are inconsistent.[69,74–76] On the HEI, dairy is an adequacy component and eggs contribute to total protein foods[53] but other diet quality indexes rarely assess total protein foods, and dairy consumption is penalized on some indexes.[20] Therefore, the health outcomes associated with egg and dairy consumption are not well established, and the effects of consumption on diet quality are dependent on the index used.

Although there is no strong consensus regarding the health impacts of egg and dairy consumption, whole grains have been consistently shown to protect against chronic disease and mortality.[77] Therefore, in diet quality indexes, whole-grain consumption is commonly incentivized (adequacy component), whereas refined-grain consumption is penalized.[53,61] In this review, vegetarians consumed more whole and refined grains, suggesting that these foods may be used to take the place of meat, fish, and poultry. Consuming refined grains in place of saturated fat (commonly found in meats and dairy) increases cardiovascular disease risk, although the association reverses when whole grains replace saturated fat.[78] Because some vegetarian exchanges can result in lower diet quality and poorer health outcomes, it's important that healthful exchanges are highlighted in the promotion of vegetarian diets.

Limitations and strengths

This systematic review adds to the understanding of the diet quality of vegetarian diets by synthesizing the current research using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. This review featured a variety of study designs in diverse populations and using various diet quality indexes, contributing to the quality of insight provided on vegetarian diets and their impacts on diet quality. Some limitations of the present review must also be noted. Relatively few studies included component score analyses, and of the studies that did include component score analyses, there were a variety of indexes used. Because compatibility between indexes is low, it was not possible to make direct comparisons. Additionally, the lack of control for confounding variables related to health consciousness limits the strength of the conclusions drawn in this review.

On a broader scale, limitations involved with examining diet quality should be considered. Although examining diet quality offers a more holistic assessment of the overall diet compared with examining individual nutrients/food groups, little is known about the relative importance of the individual components. Although

diet quality scores from various indexes have been shown to be associated with mortality and chronic disease risk,[26–28] scoring criteria (ie, component point values, maximum score criteria) are oftentimes arbitrary, and indexes may not adequately account for the synergistic relationships present within and between nutrients and food groups.[23] Nevertheless, although refinements to diet quality indexes have the potential to improve their predictive validity, examining overall diet quality rather than the contributions of individual foods and nutrients toward health provides an avenue to begin exploring the interrelationships between foods and nutrients that exist within complex dietary patterns.

CONCLUSION

Findings indicated that vegetarians generally have higher diet quality than nonvegetarians. However, these results should be interpreted with caution because the studies included in this review largely did not control for confounding by health consciousness. Further research controlling for confounding variables is needed to ascertain whether vegetarian diets, or the health consciousness associated with vegetarian diets, leads to improved diet quality. Additionally, interventions involving vegetarian diets are vital to understand the impact of vegetarian diet interventions on diet quality because they can help to reduce confounding by health consciousness, which may be present when analyzing self-selected dietary patterns. In guidance for individuals seeking to follow vegetarian diets, recommendations must clearly suggest healthful substitutions (eg, plant-based protein sources, fruits, vegetables, and whole grains) for animal products because some substitutions may reduce diet quality and attenuate observed health benefits (eg, refined grains and other processed foods).

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REFERENCES

1. Craig WJ. Nutrition concerns and health effects of vegetarian diets. *Nutr Clin Pract.* 2010;25:613–620.
2. Huang T, Yang B, Zheng J, et al. Cardiovascular disease mortality and cancer incidence in vegetarians: a meta-analysis and systematic review. *Ann Nutr Metab.* 2012;60:233–240.
3. Kahleova H, Pelikanova T. Vegetarian diets in the prevention and treatment of type 2 diabetes. *J Am Coll Nutr.* 2015;34:448–458.
4. Fraser GE. Vegetarian diets: what do we know of their effects on common chronic diseases? *Am J Clin Nutr.* 2009;89:1607S–1612S.
5. Singh PN, Sabaté J, Fraser GE. Does low meat consumption increase life expectancy in humans? *Am J Clin Nutr.* 2003;78(3 suppl):526S–532S.
6. Jacobs DR, Haddad EH, Lanou AJ, et al. Food, plant food, and vegetarian diets in the US dietary guidelines: conclusions of an expert panel. *Am J Clin Nutr.* 2009;89:1549S–1552S.
7. Clarys P, Deliens T, Huybrechts I, et al. Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet. *Nutrients*. 2014;6:1318–1332.
8. Turner-McGrievy GM, Moore WJ, Barr-Anderson D. The interconnectedness of diet choice and distance running: results of the Research Understanding the Nutrition of Endurance Runners (RUNNER) study. *Int J Sport Nutr Exerc Metab*. 2016;26:205–211.
9. Turner-McGrievy GM, Wirth MD, Shivappa N, et al. Randomization to plant-based dietary approaches leads to larger short-term improvements in Dietary Inflammatory Index scores and macronutrient intake compared with diets that contain meat. *Nutr Res*. 2015;35:97–106.
10. Larsson SC, Orsini N. Red meat and processed meat consumption and all-cause mortality: a meta-analysis. *Am J Epidemiol*. 2014;179:282–289.
11. Micha R, Michas G, Mozaffarian D. Unprocessed red and processed meats and risk of coronary artery disease and type 2 diabetes—an updated review of the evidence. *Curr Atheroscler Rep*. 2012;14:515–524.
12. Rouhani MH, Salehi-Abargouei A, Surkan PJ, et al. Is there a relationship between red or processed meat intake and obesity? A systematic review and meta-analysis of observational studies. *Obes Rev*. 2014;15:740–748.
13. Haddad EH, Tanzman JS. What do vegetarians in the United States eat?. *Am J Clin Nutr*. 2003;78:626S–632S.
14. Jaacks LM, Kapoor D, Singh K, et al. Vegetarianism and cardiometabolic disease risk factors: differences between South Asian and US adults. *Nutrition*. 2016;32:975–984.
15. Slavin JL, Lloyd B. Health benefits of fruits and vegetables. *Adv Nutr*. 2012;3:506–516.
16. Craig WJ. Phytochemicals: guardians of our health. *J Am Diet Assoc*. 1997;97(10 suppl 2): S199–S204.
17. Smith CE, Tucker KL. Health benefits of cereal fibre: a review of clinical trials. *Nutr Res Rev*. 2011;24:118–131.
18. Bouchenak M, Lamri-Senhadji M. Nutritional quality of legumes, and their role in cardiometabolic risk prevention: a review. *J Med Food*. 2013;16:185–198.
19. Fung T, Chiuve S, McCullough M, et al. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. *Arch Intern Med.* 2008;168:713. doi:10.1001/archinte.168.7.713.
20. Sofi F, Macchi C, Abbate R, et al. Mediterranean diet and health status: an updated meta-analysis and a proposal for a literature-based adherence score. *Public Health Nutr.* 2014;17:2769–2782.
21. Wirt A, Collins CE. Diet quality—what is it and does it matter? *Public Health Nutr.* 2492;12:2473. doi:10.1017/S136898000900531X.
22. Kant AK. Indexes of overall diet quality. A review. *J Am Diet Assoc*. 1996;96:785–791.
23. Waijers PMCM, Feskens EJM, Ocké MC. A critical review of predefined diet quality scores. *Br J Nutr*. 2007;97:219–231.
24. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol.* 2002;13:3–9.

25. Alkerwi A. Diet quality concept. *Nutrition*. 2014;30:613–618.
26. Sotos-Prieto M, Bhupathiraju SN, Mattei J, et al. Changes in diet quality scores and risk of cardiovascular disease among US men and women. *Circulation*. 2015;132:2212–2219.
27. 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;115:780–800.e5.
28. 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;144:881–889.
29. O'Doherty MG, Cairns K, O'Neill V, et al. Effect of major lifestyle risk factors, independent and jointly, on life expectancy with and without cardiovascular disease: results from the Consortium on Health and Ageing Network of Cohorts in Europe and the United States (CHANCES). *Eur J Epidemiol*. 2016;31:455–468.
30. Alewaeters K, Clarys P, Hebbelinck M, et al. Cross-sectional analysis of BMI and some lifestyle variables in Flemish vegetarians compared with non-vegetarians. *Ergonomics*. 2005;48:1433–1444.
31. Bedford JL, Barr SI. Diets and selected lifestyle practices of self-defined adult vegetarians from a population-based sample suggest they are more "health conscious." *Int J Behav Nutr Phys Act*. 2005;2:4. doi:10.1186/1479-5868-2-4.
32. Tonstad S, Butler T, Yan R, et al. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. *Diabetes Care*. 2009;32:791–796.
33. De Backer CJ, Hudders L. From meatless Mondays to meatless Sundays: motivations for meat reduction among vegetarians and semi-vegetarians who mildly or significantly reduce their meat intake. *Ecol Food Nutr*. 2014;53:639–657.
34. Orlich MJ, Singh PN, Sabate J, et al. Vegetarian dietary patterns and mortality in Adventist Health Study 2. *JAMA Intern Med*. 2013;173:1230–1238.
35. Key TJ, Appleby PN, Davey GK, et al. Mortality in British vegetarians: review and preliminary results from EPIC-Oxford. *Am J Clin Nutr*. 2003;78:533S–538S.
36. Appleby PN, Crowe FL, Bradbury KE, et al. Mortality in vegetarians and comparable nonvegetarians in the United Kingdom. *Am J Clin Nutr*. 2016;103:218–230.
37. Chang-Claude J, Hermann S, Eilber U, Steindorf K. Lifestyle determinants and mortality in German vegetarians and health-conscious persons: results of a 21-year follow-up. *Cancer Epidemiol Biomarkers Prev*. 2005;14:963–968.
38. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6:e1000097.
39. Clarys P, Deriemaeker P, Huybrechts I, et al. Dietary pattern analysis: a comparison between matched vegetarian and omnivorous subjects. *Nutr J*. 2013;12:82. doi:10.1186/1475-2891-12-82.
40. Conrad Z, Karlsen M, Chui K, Jahns L. Diet quality on meatless days: National Health and Nutrition Examination Survey (NHANES), 2007–2012. *Public Health Nutr*. 2017;20:1564–1573.
41. de Souza RJ, Zulyniak MA, Desai D, et al. Harmonization of food-frequency questionnaires and dietary pattern analysis in 4 ethnically diverse birth cohorts. *J Nutr*. 2016;146:2343–2350.
42. Farmer B, Larson BT, Fulgoni VL, et al. A vegetarian dietary pattern as a nutrient-dense approach to weight management: an analysis of the National Health and Nutrition Examination Survey 1999–2004. *J Am Diet Assoc*. 2011;111:819–827.
43. Kennedy ET, Bowman SA, Spence JT, et al. Popular diets: correlation to health, nutrition, and obesity. *J Am Diet Assoc*. 2001;101:411–420.
44. Thiele S, Mensink GB, Beitz R. Determinants of diet quality. *Public Health Nutr*. 2004;7:29–37.
45. Williams RL, Rollo ME, Schumacher T, et al. Diet quality scores of Australian adults who have completed the healthy eating quiz. *Nutrients*. 2017;9:880. doi:10.3390/nu9080880.
46. Rosi A, Mena P, Pellegrini N, et al. Environmental impact of omnivorous, ovo-lacto-vegetarian, and vegan diet. *Sci Rep*. 2017;7:6105. doi:10.1038/s41598-017-06466-8.
47. Turner-McGrievy GM, Barnard ND, Cohen J, et al. Changes in nutrient intake and dietary quality among participants with type 2 diabetes following a low-fat vegan diet or a conventional diabetes diet for 22 weeks. *J Am Diet Assoc*. 2008;108:1636–1645.
48. Barr SI, Chapman GE. Perceptions and practices of self-defined current vegetarian, former vegetarian, and nonvegetarian women. *J Am Diet Assoc*. 2002;102:354–360.
49. Vinnari M, Montonen J, Harkanen T, et al. Identifying vegetarians and their food consumption according to self-identification and operationalized definition in Finland. *Public Health Nutr*. 2009;12:481. doi:10.1017/S1368980008002486.
50. Turner-McGrievy GM, Davidson CR, Wingard EE, et al. Comparative effectiveness of plant-based diets for weight loss: a randomized controlled trial of five different diets. *Nutrition*. 2015;31:350–358. doi:10.1016/j.nut.2014.09.002.
51. Guenther PM, Reedy J, Krebs-Smith SM. Development of the Healthy Eating Index–2005. *J Am Diet Assoc*. 2008;108:1896–1901.
52. Kennedy ET, Ohls J, Carlson S, et al. The Healthy Eating Index: design and applications. *J Am Diet Assoc*. 1995;95:1103–1108.
53. Guenther PM, Casavale KO, Reedy J, et al. Update of the Healthy Eating Index: HEI-2010. *J Acad Nutr Diet*. 2013;113:569–580.
54. King JC, Slavin JL. White potatoes, human health, and dietary guidance. *Adv Nutr*. 2013;4:393S–401S.
55. Storey ML, Anderson PA. Contributions of white vegetables to nutrient intake: NHANES 2009-2010. *Adv Nutr*. 2013;4:335S–344S.
56. Kimmons J, Gillespie C, Seymour J, et al. Fruit and vegetable intake among adolescents and adults in the United States: percentage meeting individualized recommendations. *Medscape J Med*. 2009;11:26.
57. Schwingshackl L, Schwedhelm C, Hoffmann G, et al. Potatoes and risk of chronic disease: a systematic review and dose–response meta-analysis. *Eur J Nutr*. 2018. doi:10.1007/s00394-018-1774-2.
58. Derbyshire EJ. Flexitarian diets and health: a review of the evidence-based literature. *Front Nutr*. 2016;3:55. doi:10.3389/fnut.2016.00055.
59. Guenther PM, Kirkpatrick SI, Reedy J, et al. The Healthy Eating Index–2010 is a valid and reliable measure of diet quality according to the 2010 Dietary Guidelines for Americans. *J Nutr*. 2014;144:399–407.
60. Guenther PM, Reedy J, Krebs-Smith SM, et al. Evaluation of the Healthy Eating Index–2005. *J Am Diet Assoc*. 2008;108:1854–1864.
61. Chiuve SE, Fung TT, Rimm EB, et al. Alternative dietary indices both strongly predict risk of chronic disease. *J Nutr*. 2012;142:1009–1018.
62. Tabung FK, Smith-Warner SA, Chavarro JE, et al. Development and validation of an empirical dietary inflammatory index. *J Nutr*. 2016;146:1560–1570.
63. Schneeman BO. Evolution of dietary guidelines. *J Am Diet Assoc*. 2003;103(12 suppl 2):S5–S9.
64. Leitzmann C. Vegetarian nutrition: past, present, future. *Am J Clin Nutr*. 2014;100(suppl 1):496S–502S.
65. National Cancer Institue. Comparing the HEI-2015, HEI–2010 & HEI–2005. 2017. Available at: https://epi.grants.cancer.gov/hei/comparing.html. Accessed August 6, 2017.
66. McGill CR, Birkett A, Fulgonii III VL. Healthy Eating Index–2010 and food groups consumed by US adults who meet or exceed fiber intake recommendations NHANES 2001–2010. *Food Nutr Res*. 2016;60:29977. doi:10.3402/fnr.v60.29977.
67. Bernstein AM, Sun Q, Hu FB, et al. Major dietary protein sources and risk of coronary heart disease in women. *Circulation*. 2010;122:876–883.
68. Würtz AML, Hansen MD, Tjønneland A, et al. Substitution of meat and fish with vegetables or potatoes and risk of myocardial infarction. *Br J Nutr*. 2016;116:1602–1610.
69. 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;105:1462–1473.
70. Zheng J, Huang T, Yu Y, et al. Fish consumption and CHD mortality: an updated meta-analysis of seventeen cohort studies. *Public Health Nutr*. 2012;15:725–737.
71. Abete I, Romaguera D, Vieira AR, et al. Association between total, processed, red and white meat consumption and all-cause, CVD and IHD mortality: a meta-analysis of cohort studies. *Br J Nutr*. 2014;112:762–775.
72. Drouin-Chartier J-P, Brassard D, Tessier-Grenier M, et al. Systematic review of the association between dairy product consumption and risk of cardiovascular-related clinical outcomes. *Adv Nutr*. 2016;7:1026–1040.
73. Guo J, Astrup A, Lovegrove JA, et al. Milk and dairy consumption and risk of cardiovascular diseases and all-cause mortality: dose–response meta-analysis of prospective cohort studies. *Eur J Epidemiol*. 2017;32:269–287.
74. Nakamura Y, Okamura T, Tamaki S, et al. Egg consumption, serum cholesterol, and cause-specific and all-cause mortality: the National Integrated Project for Prospective Observation of Non-communicable Disease and Its Trends in the Aged, 1980 (NIPPON DATA80). *Am J Clin Nutr*. 2004;80:58–63.
75. Djoussé L, Gaziano JM. Egg consumption in relation to cardiovascular disease and mortality: the Physicians' Health Study. *Am J Clin Nutr*. 2008;87:964–969.
76. Fuller N, Sainsbury A, Caterson I, et al. Egg consumption and human cardiometabolic health in people with and without diabetes. *Nutrients*. 2015;7:7399–7420.
77. Aune D, Keum N, Giovannucci E, et al. Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. *BMJ*. 2016;353:i2716.
78. Briggs MA, Petersen KS, Kris-Etherton PM. Saturated fatty acids and cardiovascular disease: replacements for saturated fat to reduce cardiovascular risk. *Healthcare*. 2017;5:29. doi:10.3390/healthcare5020029.