LITERATURE REVIEW

Dietary Fiber Is Beneficial for the Prevention of Cardiovascular Disease: An Umbrella Review of Meta-analyses

Marc P. McRae, MSc, DC, FACN, DACBN

ABSTRACT

Objective: The purpose of this study was to review previously published meta-analyses on the effectiveness of dietary fiber on cardiovascular disease.
Methods: An umbrella review of all published meta-analyses was performed. A PubMed search from January 1, 1980, to January 31, 2017, was conducted using the following search strategy: (fiber OR glucan OR psyllium OR fructans) AND (meta-analysis OR systematic review). Only English-language publications that provided quantitative statistical analysis on cardiovascular disease, lipid concentrations, or blood pressure were retrieved.
Results: Thirty-one meta-analyses were retrieved for inclusion in this umbrella review, and all meta-analyses comparing highest versus lowest dietary fiber intake reported statistically significant reductions in the relative risk (RR) of cardiovascular disease mortality (RR = 0.77-0.83), as well as the incidences of cardiovascular disease (RR = 0.72-0.91), coronary heart disease (RR = 0.76-0.93), and stroke (RR = 0.83-0.93). Meta-analyses on supplementation studies using β-glucan or psyllium fibers also reported statistically significant reductions in both total serum and low-density lipoprotein cholesterol concentrations.
Conclusion: This review suggests that individuals consuming the highest amounts of dietary fiber intake can significantly reduce their incidence and mortality from cardiovascular disease. Mechanistically, these beneficial effects may be due to dietary fibers' actions on reducing total serum and low-density lipoprotein cholesterol concentrations between 9.3 to 14.7 mg/dL and 10.8 to 13.5 mg/dL, respectively. (J Chiropr Med 2017;16:289-299)
Key Indexing Terms: *Dietary Fiber; Meta-analysis; Cardiovascular Diseases; Coronary Heart Disease; Stroke; Cholesterol; Blood Pressure*

INTRODUCTION

In the United States, at least 21% of adults have undesirably high serum cholesterol concentrations of >240 mg/dL, and 28% have hypertension.[1-3] Both hypercholesterolemia and hypertension are contributing factors in the development of coronary heart disease and stroke, which together contribute to 38% of all deaths caused by cardiovascular disease in the United States.[4-6] Dietary fiber intake has repeatedly been reported to be beneficial in reducing both serum cholesterol and blood pressure, and so it is believed that a deficiency in dietary fiber might be contributing to the epidemic of cardiovascular disease.[7] Dietary fibers are the edible parts of plants that are resistant to digestion and absorption in the human small intestine, and when comparing persons with the highest dietary fiber intakes with those with the lowest, the relative risk of total all-cause mortality dropped by 16% to 23%.[8-10]

Many past clinical trials investigating dietary fiber intake on cardiovascular disease risk have reported protective benefits,[11-14] but not all of these trials are in agreement.[15-18] Many of the clinical trials conducted to study the effects of dietary fiber intake on cardiovascular disease may have had sample sizes that did not provide sufficient statistical power to detect small potentially meaningful changes in effect.[19] Given the inconsistency of the existing literature and the insufficient statistical power as a result of small sample sizes, a pooling of information from individual trials could provide a more precise and accurate estimate of dietary fibers' role in ameliorating cardiovascular disease. To achieve this result, many investigators have turned to performing a powerful statistical method known as meta-analysis. Meta-analyses are fundamental to provide the highest level of evidence to best inform health care decision making. Therefore, the purpose and objective of this paper is to summarize the evidence from

Department of Basic Sciences, National University of Health Sciences, Lombard, Illinois.
Corresponding author: Marc P. McRae, MSc, DC, FACN, DACBN, National University of Health Sciences, 200 E. Roosevelt Rd, Lombard, IL 40148. Tel.: +1 630 889 6592. (e-mail: mmcrae@nuhs.edu).
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previously published meta-analyses regarding the effectiveness of the role of dietary fiber as a therapeutic agent for cardiovascular disease.

Methods

An umbrella review was selected for this study. An umbrella review provides a summary of existing published meta-analyses and systematic reviews and determines whether authors addressing similar review questions independently report similar results and arrive at similar conclusions.[20]

Because meta-analyses started appearing in the medical literature in the early 1980s, a systematic literature search of PubMed and CINAHL from January 1, 1980, to January 31, 2017, was conducted using the following search strategy: "(fiber OR fibre OR chitosan OR fructan OR glucan OR gums OR inulin OR lignin OR pectin OR psyllium OR bran) AND (meta-analysis OR systematic review)." The titles and abstracts from the literature search were scanned, and only English-language publications that provided quantitative statistical analysis on cardiovascular disease, coronary heart disease, stroke, serum lipids, cholesterol, and blood pressure were retrieved. Meta-analyses or systematic reviews that did not present study-specific summary data using a minimum of 4 randomized controlled trials were excluded.

For the published meta-analyses that were accepted into this review, the following information was extracted and entered into an Excel spreadsheet: number of publications included in the meta-analysis, number of total participants, fiber type and daily dose, pooled treatment effects for clinical endpoints (such as total cholesterol or systolic blood pressure), and/or summary relative risks (RRs). Although not always present, the meta-analyses were also analyzed for their disclosure of quality assessment, statistical heterogeneity (Cochrane Q test and I^2 statistic), and publication bias (visual inspection of funnel plots and Egger or Begg regression test). A methodological quality appraisal was conducted for all meta-analyses using the Critical Appraisal Checklist for Systematic Reviews, which was developed by the Umbrella Review Methodology Working Group.[20] This checklist consists of 10 items; each item within the instrument can receive 1 point, for an overall quality score that could range from 0 to 10. Meta-analyses with quality scores ranging from 0 to 4 were labeled as low quality, those with scores between 5 and 7 as medium quality, and those with scores of 8 to 10 as high quality. Because this is a descriptive summary review of meta-analyses, no statistical analyses were performed.

Results

The initial search strategy identified 516 articles, and after careful review 31 meta-analyses were retrieved for inclusion into this umbrella review.[21-51] One meta-analysis was excluded because it was not published in English; this

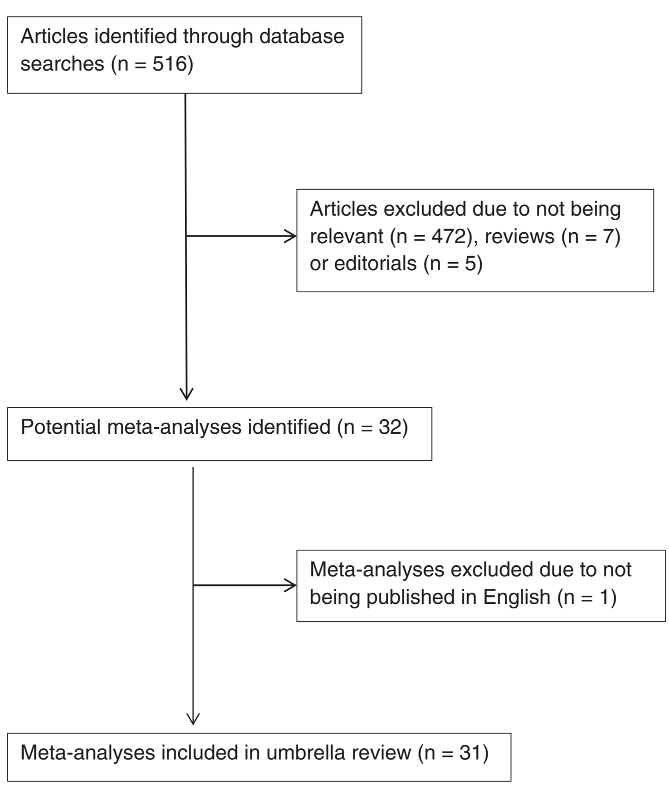

Fig 1. *Flow chart of meta-analysis selection.*

Table 1. *Effect of High vs Low Fiber Intake on the Incidence of Developing Cardiovascular Disease*

Meta-analysis Authors, Year	No. of Studies in Meta-analysis	No. of Participants in Meta-analysis	Main Findings of Meta-analysis	*Q* Test *P* Value	I^2 Statistic	Egger or Begg Test *P* Value	Quality Assessment and Outcome
Anderson et al, 2000[21, a]	5	136 329	RR = 0.72, $P < .05$	$P < .05$			
Ye et al, 2012[22]	15	846 945	RR = 0.81, $P < .05$	NS	21%	$P = .04$	
Threapleton et al, 2013[23]	10	NR	RR = 0.91,[b] $P < .001$	NR	45%	NR	NOS 7/10 high quality

NOS, Newcastle-Ottawa scale; *NR,* not reported; *NS,* not significant; *RR,* relative risk.
[a] Low-quality score on the Critical Appraisal Checklist for Systematic Reviews.
[b] 7 g/d.

meta-analysis investigated the effects of fructans on blood lipid profiles.[52] A flow chart of the meta-analyses selection process is provided in Figure 1.

In regard to the methodological quality of the 31 meta-analyses in this umbrella review, the mean quality appraisal score was 8 of 10, where 22 meta-analyses (71%) satisfied high-quality scoring between 8 and 10; 6 (19%) satisfied medium-quality scoring between 5 and 7; and 3 (10%) satisfied low-quality scoring, with 1 scoring a 4 and the remaining 2 scoring a 3. These 3 low-quality meta-analyses included the paper by Pereira et al.,[24] and both papers by Anderson et al.[21,44] Although these 3 meta-analyses have been deemed lower quality, they were still included in this umbrella review because they provided useful information regarding the effectiveness of dietary fiber as a therapeutic agent for cardiovascular disease.

The meta-analyses presented in Tables 1 through 4 are based on dietary surveys that compare the highest vs lowest daily dietary fiber consumption. For populations who consumed the highest dietary fiber intake, the incidence of cardiovascular disease was significantly reduced in all 3 meta-analyses, with the relative risk ranging between 0.72 and 0.91 (Table 1). Cardiovascular disease mortality was also significantly reduced in all 5 meta-analyses, with the relative risk ranging between 0.77 and 0.83 (Table 2). The incidence of coronary heart disease was significantly reduced in all 4 meta-analyses, with the relative risk ranging between 0.76 and 0.93 (Table 3). And finally, the incidence of stroke was significantly reduced in all 3 meta-analyses, with the relative risk ranging between 0.83 and 0.93 (Table 4).

The meta-analyses presented in Tables 5 and 6 are based on clinical trials using fiber supplementation to determine if such interventions would result in physiological changes associated with cardiovascular disease (such as decreases in serum lipids and blood pressure). Table 5 shows that fiber supplementation, regardless of the type of fiber, significantly reduced total serum cholesterol in 13 of 14 meta-analyses, and low-density lipoprotein (LDL) cholesterol in 14 of 15 meta-analyses. More specifically, the 9 meta-analyses involving dietary supplementation with β-glucan and the 3 meta-analyses involving psyllium supplementation all reported significant reductions for both total serum cholesterol and LDL cholesterol. There were 2 meta-analyses using fructan supplementation with 1 reporting only a significant decrease in triglycerides (↓ 15.1 mg/dL), whereas the second reported no significant change in triglycerides (↓ 1.8 mg/dL) but a significant decrease in LDL cholesterol. Finally, the meta-analysis using chitosan supplementation reported a significant reduction in total cholesterol but not LDL cholesterol. However, there was

Table 2. *Effect of High vs Low Fiber Intake on Cardiovascular Disease Mortality*

Meta-analysis Authors, Year	No. of Studies in Meta-analysis	No. of Participants in Meta-analysis	Main Findings of Meta-analysis	*Q* Test *P* Value	I^2 Statistic	Egger or Begg Test *P* Value	Quality Assessment and Outcome
Pereira et al, 2004[24, a]	10	336 244	RR = 0.81,[b] $P < .001$	NS	NR		
Wu et al, 2014[25]	15	496 858	RR = 0.83, $P < .001$	NS	0%	NS	NOS 12/15 high quality
Liu et al, 2015[26]	16	340 830	HR = 0.77, $P < .05$	NS	25%	NS	
Kim and Je, 2016[27]	7	627 651	RR = 0.77, $P < .05$	NS	13%	NS	3/7 high quality
Hajishafiee et al, 2016[28]	10	842 172	RR = 0.82, $P < .05$	NS	0%	NS	NOS 8/10 high quality

HR, hazard ratio; *NOS,* Newcastle-Ottawa scale; *NR,* not reported; *NS,* not significant; *RR,* relative risk.
[a] Low-quality score on the Critical Appraisal Checklist for Systematic Reviews.
[b] 10 g/d.

Table 3. *Effect of High vs Low Fiber Intake on the Incidence of Developing Coronary Heart Disease*

Meta-analysis Authors, Year	No. of Studies in Meta-analysis	No. of Participants in Meta-analysis	Main Findings of Meta-analysis	*Q* Test *P* Value	I^2 Statistic	Egger or Begg Test *P* Value	Quality Assessment and Outcome
Pereira et al, 2004[24, a]	9	306 064	RR = 0.91,[b] *P* = .005	NS	NR		
Threapleton et al, 2013[23]	12	NR	RR = 0.91,[c] *P* < .001	NS	33%	NR	NOS 10/12 high quality
Wu et al, 2014[25]	16	561 756	RR = 0.93, *P* < .001	NS	0%	NS	NOS 13/16 high quality
Kim and Je, 2016[27]	8	500 672	RR = 0.76, *P* < .05	NS	40%	NS	4/8 high quality

NOS, Newcastle-Ottawa scale; *NR,* not reported; *NS,* not significant; *RR,* relative risk.
[a] Low-quality score on the Critical Appraisal Checklist for Systematic Reviews.
[b] 10 g/d.
[c] 7 g/d.

statistically significant heterogeneity and publication bias associated with this observation.

In regard to magnitude of change, β-glucan supplementation resulted in total serum cholesterol reductions ranging between 5.1 to 23.2 mg/dL and LDL cholesterol reductions ranging between 7.3 to 25.5 mg/dL. Psyllium supplementation resulted in total serum cholesterol reductions ranging between 9.3 to 14.7 mg/dL and LDL cholesterol reductions ranging between 10.8 to 13.5 mg/dL. Figure 2 shows the frequency of observed reductions with β-glucan and psyllium combined for both total serum cholesterol and LDL cholesterol, respectively. Statistically significant heterogeneity was observed in 2 of the 9 β-glucan meta-analyses for both total serum and LDL cholesterol. The 1 psyllium meta-analysis that tested for heterogeneity reported this to be statistically significant for total serum cholesterol but not for LDL cholesterol. Only 7 of the 9 β-glucan meta-analyses tested for publication bias, and 3 of the 7 noted this to be statistically significant. Only 1 of the 3 psyllium meta-analyses tested for publication bias and reported it to be statistically significant for only LDL cholesterol.

The meta-analyses presented in Table 6 indicate that dietary fiber intake resulted in nonsignificant reductions in systolic blood pressure for all 4 meta-analyses, and only 2 of the 4 meta-analyses reported significant reductions in diastolic blood pressure. The magnitude of change in diastolic blood pressure for these 2 meta-analyses was 1.65 and 1.77 mmHg, but the former also noted statistically significant heterogeneity. The overall range in systolic and diastolic blood pressure reduction for all 4 meta-analyses was 0.92 to 1.92 mmHg and 0.71 to 1.77 mmHg, respectively.

Discussion

Based on the relative risks obtained from the meta-analyses in this umbrella review, it is apparent that individuals consuming the highest amounts of dietary fiber can reduce their chances of developing coronary heart disease and stroke by somewhere between 7% to 24%, as well as reducing their overall morbidity and mortality brought on by cardiovascular disease by 17% to 28%. A greater intake of dietary fiber may reduce the risk of developing cardiovascular disease through a variety of mechanisms, such as improving serum lipid concentrations, lowering blood pressure, and reducing inflammation (Fig 3).

In regard to promoting healthy serum lipids, it appears that both β-glucan and psyllium fiber supplementation significantly reduce total serum and LDL cholesterol concentrations. β-glucan is a water-soluble and fermentable dietary fiber that is derived from oats and barley, and psyllium is a water-soluble, gel-forming mucilaginous functional fiber derived from the seed husk of *Plantago ovata*. Based on the 12 meta-analyses investigating supplementation of either β-glucan or psyllium fibers, the most common reductions in total serum cholesterol and LDL cholesterol ranged somewhere between 9 and 12 mg/dL

Table 4. *Effect of High vs Low Fiber Intake on the Incidence of Having a Stroke*

Meta-analysis Authors, Year	No. of Studies in Meta-analysis	No. of Participants in Meta-analysis	Main Findings of Meta-analysis	*Q* Test *P* Value	I^2 Statistic	Egger or Begg Test *P* Value	Quality Assessment and Outcome
Zhang et al, 2013[29]	11	325 627	RR = 0.83, *P* < .05	NS	39%	NS	NOS 9/11 high quality
Chen et al, 2013[30]	6	314 864	RR = 0.87, *P* < .05	NS	36%	NS	NOS 6/6 high quality
Threapleton et al, 2013[31]	7	488 982	RR = 0.93,[a] *P* < .05	*P* < .05	59%	*P* = .002	

NOS, Newcastle-Ottawa scale; *NS,* not significant; *RR,* relative risk.
[a] 7 g/d.

(Fig 2). This modest reduction is clinically significant in light of the fact that a 12 mg/dL reduction in total cholesterol can potentially translate to a 10% to 20% reduction in the risk for developing cardiovascular disease.[53] However, clinical certainty of this finding is tentative because of the fact that 3 of these 10 meta-analyses using β-glucan or psyllium fibers reported statistically significant heterogeneity, and 4 of the 8 meta-analyses reported statistically significant publication bias. Ideally, the studies combined into any meta-analysis should all have the same experimental protocols; however, increased heterogeneity is inevitable because of the wide variation in study design. Differences in study design include the number of participants; duration of the study; age, sex, body mass index, and total energy intake for the participants; and dose and form of the dietary fiber used in the study. In regard to publication bias, published studies are more likely than unpublished ones to report positive research outcomes, and this can potentially bias the results of the meta-analysis as the effect size of the weighted average of the meta-analysis is overestimated.

Mechanistically, the beneficial effects on reducing total serum cholesterol are attributed to soluble fiber's ability to chelate cholesterol in the lumen of the small intestine and therefore reduced the absorption of cholesterol. Soluble fiber also increases the fecal excretion of bile acids, and this diverts hepatic cholesterol for bile acid production, thus lowering circulating levels of plasma LDL cholesterol as it is taken up by the liver from the plasma to replenish cholesterol levels. Also, the fibers that are freely fermentable by the colonic bacteria are converted into short chain fatty acids such as acetic, propionic, and butyric acids. Propionic acid can be absorbed and inhibit the liver's rate-limiting cholesterol synthesis enzyme HMG-CoA reductase.[54]

Although 1 of the 6 meta-analyses using β-glucan fibers reported a significant reduction in triglyceride concentration, overall there does not appear to be any significant benefit with any fiber type for clinically relevant changes in high-density lipoprotein (HDL) cholesterol and/or triglyceride concentrations.

Of the 4 meta-analyses that investigated dietary fiber's effects on blood pressure, none of them reported any statistically significant reductions in systolic blood pressure, but 2 meta-analyses did report statistically significant reductions in diastolic blood pressure. These significant reductions in diastolic blood pressure of 1.65 and 1.77 mm Hg could potentially translate to a reduction in developing cardiovascular disease of up to 7%, but this potential may be called into question because of the significant heterogeneity reported in the 1 of these 2 meta-analyses.[55] In regard to mechanism of action, dietary fiber forms gels in the stomach and small intestine, slowing the rate of glucose absorption, and this inhibits a postprandial rise of glucose concentrations, which can improve insulin sensitivity by decreasing insulin secretion. It has been documented that hyperinsulinemia plays a mechanistic role in the development of hypertension.[56] It is also possible that small decreases in blood pressure may be due solely to the fact that diets high in fiber may also provide higher amounts of potassium and magnesium, both of which are known to have small effects on reducing blood pressure.[57,58]

Because inflammation plays a direct role in the pathophysiology of cardiovascular disease, it is important to note that dietary fiber intake has been reported to be inversely associated with inflammatory markers that are central in the initiation and progression of cardiovascular disease.[59] Although the mechanisms underlying the association between dietary fiber and inflammation are still unclear, it appears that a diet rich in dietary fibers will also provide a high concentration of phytochemicals, such as polyphenols, and it is possible that these polyphenols can inhibit the transcriptional activity of the proinflammatory transcription factor nuclear factor–κB.[60] Inhibition of nuclear factor–κB by dietary fiber is best revealed through the reduction of inflammatory markers such as C-reactive protein, tumor necrosis factor α, and interleukin 6.[61-63] Also, the increased intake of fiber replaces the consumption of other potentially detrimental foods such as saturated fats and sugars.

This umbrella review did not thoroughly investigate the differential effects the various different dietary forms of fiber could have on cardiovascular disease (soluble vs insoluble fibers or cereal vs fruit vs vegetable fibers), because only a small number of meta-analyses have undertaken subgroup analyses to investigate these potential differences. In regard to soluble vs insoluble fiber's actions on cardiovascular mortality, coronary heart disease incidence, and stroke incidence, there was no difference between the highest and lowest groups for both soluble and insoluble fibers.[25,27,29] In regard to cereal vs fruit and vegetable fiber subgroups, both cereal and fruit fibers performed better than vegetable fibers in reducing cardiovascular mortality.[24,25,27]

The Dietary Guidelines for Americans state that the adequate intake value of dietary fiber consumption is 25 to 38 g/d, but the 2009-2010 National Health and Nutrition Examination Survey reported that the daily intake of fiber in the United States is only 17 g/d.[64] Therefore, emphasizing fiber consumption for health promotion and disease prevention is a critical public health goal, and aggressively promoting the Dietary Guidelines for Americans recommendations of at least 25 to 38 g/d of total dietary fiber may prevent a significant number of chronic diseases (beyond the benefits for cardiovascular disease, dietary fiber may also significantly reduce the incidence of type 2 diabetes and some cancers).[26,65] However, although the evidence in this umbrella review supports the beneficial association of dietary fiber on cardiovascular risk, there are still too few long-term, large-population randomized controlled trials that have undertaken the goal of analyzing this potentially causal relationship between dietary fiber and cardiovascular disease. Finally, although no tolerable upper limit has been established for total fiber intake, it should be noted that

Table 5. *Effects of Increased Fiber Intake on Serum Lipids Levels*

Meta-analysis Authors, Year	No. of Studies in Meta-analysis	No. of Participants in Meta-analysis	Fiber Type (Average Amount per Day)	Mean Duration (wk)	Main Findings of Meta-analysis	*Q* Test *P* Value	I^2 Statistic	Egger or Begg Test *P* Value	Quality Assessment and Outcome
Brown et al, 1999[32]	66	2975	Dietary fiber (9.5 g)	7	TC ↓ 10.4 mg/dL, $P < .05$	$P < .001$			
					LDL ↓ 10.8 mg/dL, $P < .05$	$P < .001$			
					HDL ↓ 0.8 mg/dL, NS	$P < .001$			
					Trigs 0.9 mg/dL, NS	$P < .001$			
Hartley et al, 2016[33]	17	1067	Dietary fiber (NR)	12	TC ↓ 7.7 mg/dL, $P = .005$	$P < .05$	46%		Cochrane
					LDL ↓ 5.4 mg/dL, $P = .001$	NS	36%		10/17
					HDL ↓ 1.2 mg/dL, NS	NS	0%		
					Trigs 0.0 mg/dL, NS	NS	32%		
Ripsin et al, 1992[34]	12	1603	β-Glucan (4 g)	6	TC ↓ 5.1 mg/dL, $P < .05$	NS			
					LDL NR				
					HDL NR				
					Trigs NR				
Talati et al, 2009[35]	8	391	β-Glucan (6.5 g)	5	TC ↓ 13.4 mg/dL, $P < .05$	NS	0%	$P = .02$	
					LDL ↓ 10.0 mg/dL, $P < .05$	NS	0%	NS	
					HDL 1.0 mg/dL, NS	NS	0%	NS	
					Trigs ↓ 11.8 mg/dL, $P < .05$	NS	0%	NS	
AbuMweis et al, 2010[36]	11	329	β-Glucan (6 g)	5	TC ↓ 11.6 mg/dL, $P < .000$	NS	16%	$P < .05$	Yes, 1 study excluded
					LDL ↓ 10.4 mg/dL, $P < .000$	NS	0%	$P < .05$	
					HDL 0.0 mg/dL, NS	NS	30%	NR	
					Trigs ↓ 4.4 mg/dL, NS	NS	41%	NR	
Tiwari and Cummins, 2011[37]	11	516	β-Glucan (5 g)	6	TC ↓ 23.2 mg/dL, $P < .05$	$P < .000$	77%	NS	
					LDL ↓ 25.5 mg/dL, $P < .05$	$P < .000$	84%	NS	
					HDL 1.2 mg/dL, NS	NS	0%	NS	
					Trigs ↓ 3.5 mg/dL, NS	NS	0%	NS	
Whitehead et al, 2014[38]	28	2519	β-Glucan (5.5 g)	6	TC ↓ 11.2 mg/dL, $P < .05$	NS	28%	$P < .05$	Yes
					LDL ↓ 11.2 mg/dL, $P < .05$	NS	22%	NS	NR
					HDL 1.1 mg/dL, NS	$P < .001$	81%	NR	
					Trigs ↓ 2.0 mg/dL, NS	NS	0%	NR	
Zhu et al, 2015[39]	17	916	β-Glucan (5.5 g)	7	TC ↓ 10.1 mg/dL, $P < .000$	NS	0%	NS	Jadad Scale
					LDL ↓ 8.1 mg/dL, $P < .000$	NS	0%	NS	11/17 high quality
					HDL ↓ 0.8 mg/dL, NS	NS	0%	NS	
					Trigs ↓ 1.8 mg/dL, NS	NS	0%	NS	

Hou et al, 2015[40]	7	453	β-Glucan (NR)	NR	TC ↓ 18.9 mg/dL, $P < .05$ LDL ↓ 11.2 mg/dL, $P < .05$ HDL ↓ 1.9 mg/dL, NS Trigs ↓ 14.2 mg/dL, NS	$P = .016$ NS NS NS	62% 21% 0% 10%		NOS scale 4/7 high quality
Ho et al, 2016[41]	14	723	β-Glucan from barley (6 g)	5	TC NR LDL ↓ 9.7 mg/dL, $P < .000$ HDL NR Trigs NR	NS	0%	NS	MQS 7/14 high quality
Ho et al, 2016[42]	56	3745	β-Glucan from oats (4 g)	6	TC NR LDL ↓ 7.3 mg/dL, $P < .000$ HDL NR Trigs NR	$P < .000$	79%	NS	MQS 9/56 high quality
Olson et al, 1997[43]	12	404	Psyllium (9 g)	6	TC ↓ 12.0 mg/dL, $P < .000$ LDL ↓ 13.5 mg/dL, $P < .000$ HDL 0.0 mg/dL, NS Trigs NR				
Anderson et al, 2000[44, a]	8	656	Psyllium (10 g)	10	TC ↓ 9.3 mg/dL, $P < .000$ LDL ↓ 10.8 mg/dL, $P < .000$ HDL ↓ 0.4 mg/dL, NS Trigs ↓ 5.3 mg/dL, NS				
Wei et al, 2009[45]	21	1717	Psyllium (10 g)	8	TC ↓ 14.7 mg/dL, $P < .05$ LDL ↓ 10.8 mg/dL, $P < .05$ HDL ↓ 1.2 mg/dL, NS Trigs 0.9 mg/dL, NS	$P < .000$ NS NS NS		NS $P = .04$ NR NR	
Brighenti, 2007[46]	16	290	Fructans (14 g)	5	TC NR LDL NR HDL NR Trigs ↓ 15.1 mg/dL, $P = .04$	NS	0%	NS	
Liu et al, 2016[47]	19	585	Fructans (13 g)	5	TC ↓ 1.5 mg/dL, NS LDL ↓ 5.8 mg/dL, $P = .03$ HDL 1.2 mg/dL, NS Trigs ↓ 1.8 mg/dL, NS	NS $P = .04$ NS NS	2% 40% 0% 0%	NS NS NS NS	Cochrane 6/19 high quality
Baker et al, 2009[48]	6	416	Chitosan (2.4 g)	9	TC ↓ 11.6 mg/dL, $P = .02$ LDL ↓ 3.7 mg/dL, NS HDL 1.0 mg/dL, NS Trigs ↓ 4.3 mg/dL, NS	$P < .05$ NS NS NS	70% 0% 26% 0%	$P < .05$ $P < .05$ $P < .05$ $P < .05$	

HDL, high-density cholesterol lipoproteins; *LDL,* low-density lipoproteins; *MQS,* methodological quality score; *NR,* not reported; *NS,* not significant; *TC,* total cholesterol; *Trigs,* triglycerides.

[a] Low-quality score on the Critical Appraisal Checklist for Systematic Reviews.

Table 6. *Effects of Increased Fiber Intake on Blood Pressure*

Meta-analysis Authors, Year	No. of Studies in Meta-analysis	No. of Participants in Meta-analysis	Fiber Dose (Average Amount per Day)	Mean Duration (wks)	Main Findings of Meta-analysis	*Q* Test *P* Value	I^2 Statistic	Egger or Begg Test *P* Value	Quality Assessment and Outcome
Streppel et al, 2005[49]	24	1404	11.5 g	9	SBP ↓ 1.13 mmHg, NS DBP ↓ 1.26 mmHg, NS				Yes NR
Whelton et al, 2005[50]	21	1477	11 g	8	SBP ↓ 1.15 mmHg, NS DBP ↓ 1.65 mmHg, $P < .005$	$P < .05$ $P < .05$	NR NR	NS NS	
Evans et al, 2015[51]	18	1333	6 g	NR	SBP ↓ 0.92 mm Hg, NS DBP ↓ 0.71 mm Hg, NS	$P = .023$ $P = .001$	43% 58%	NS NS	Cochrane NR
Hartley et al, 2016[33]	10	661	NR	12	SBP ↓ 1.92 mm Hg, NS DBP ↓ 1.77 mm Hg, $P = .000$	$P = .001$ NS	69% 7%		

DBP, diastolic blood pressure; *NR,* not reported; *NS,* not significant; *SBP,* systolic blood pressure.

minor side effects have been reported, such as flatulence, abdominal bloating, loose stools or diarrhea, and abdominal cramping.[66]

Limitations

This umbrella review has several limitations that should be acknowledged. First, confounding factors are always a potential threat to the validity of any meta-analysis. For instance, people with high dietary fiber intake tend to have other healthy behaviors such as being physically active and avoiding smoking and excessive alcohol intake. Fortunately, the majority of studies included in the meta-analyses that were involved in this umbrella review did adjust for potential confounding factors, but the possibility of residual confounders cannot be excluded. Second, self-reported dietary fiber intake is most often assessed using food frequency questionnaires, and because these dietary assessment tools were not specifically developed for dietary fiber intake, misclassifications and measurement errors regarding fiber doses and types are quite likely. This problem may also be compounded by the fact that dietary fiber may be defined differently by the various food frequency questionnaire databases in use.[66] A third limitation is that the meta-analyses reviewed here represent a heterogeneous group of clinical studies composed from a diverse group of participants of different ages, genders, races, and ethnic groups, and therefore readers are cautioned against specifying these results to any one specific sociodemographic group. Finally, as in all literature reviews, the quality of this umbrella review is directly related to the quality of the included meta-analyses, which are dependent on the design and reporting quality of the individual meta-analysis itself, as well as on the quality of the individual studies used to conduct the meta-analysis. Fortunately, the majority (90%) of the meta-analyses in this umbrella review were appraised as having moderate to high methodological quality.

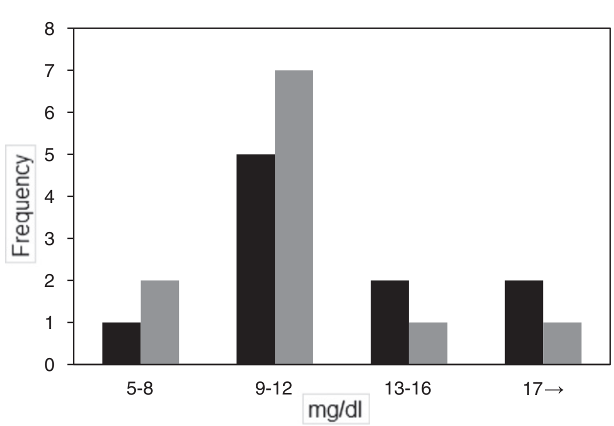

Fig 2. *Observed frequencies in the reduction of total serum cholesterol (black bars) and low-density lipoprotein cholesterol (gray bars) from the meta-analyses on β-glucan and psyllium supplementation.*

Conclusion

The meta-analyses in this umbrella review indicate that individuals consuming the highest amounts of dietary fiber intake can significantly reduce their incidence of and mortality from cardiovascular disease. Mechanistically, these beneficial effects may be due to dietary fibers' actions on reducing total serum and LDL cholesterol concentrations, and these outcomes are most notable in particular with water-soluble, gel-forming dietary fibers such as β-glucan at 6 g/d or psyllium at 10 g/d.

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No funding sources or conflicts of interest were reported for this study.

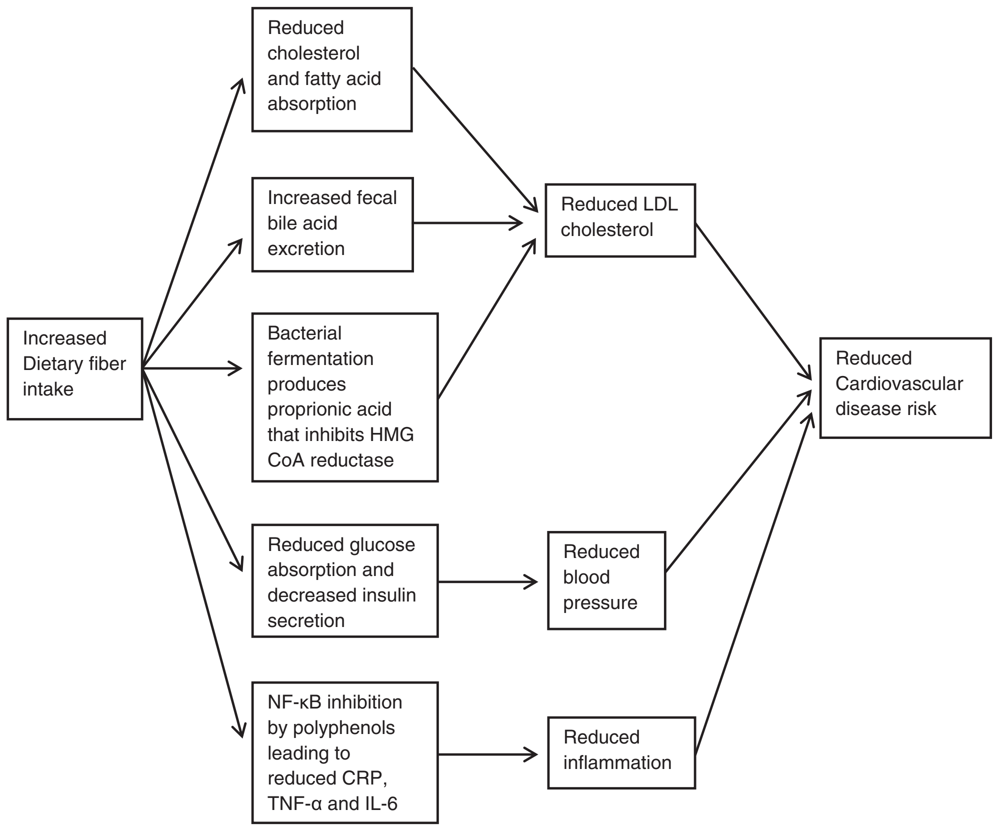

Fig 3. *Proposed mechanisms underlying the observed association between individuals with the highest dietary intakes of fiber and their reduced rates in cardiovascular disease incidence and mortality.* CRP, *C-reactive protein*; IL-6, *interleukin 6*; LDL, *low-density lipoprotein*; NF-κB, *nuclear factor–κB*; TNF-α, *tumor necrosis factor α*.

Contributorship Information

Concept development (provided idea for the research): M.P.M.
Design (planned the methods to generate the results): M.P.M.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): M.P.M.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): M.P.M.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): M.P.M.
Literature search (performed the literature search): M.P.M.
Writing (responsible for writing a substantive part of the manuscript): M.P.M.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): M.P.M.

Practical Applications

- Dietary fiber consumption has been postulated to reduce the incidence of cardiovascular disease through reductions in total serum cholesterol and blood pressure.
- Unfortunately, there is much discrepancy when it comes to randomized controlled studies on dietary fiber's effects on these important clinical conditions.
- By combining the meta-analyses on these clinical outcomes as an umbrella review, we can report that increased dietary fiber intake does appears to be beneficial in the prevention of cardiovascular disease.

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