Today's Dietitian
The Magazine for Nutrition Professionals
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TODAY'S DIETITIAN

Fiber and Heart Health

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Suggested CDR Learning Codes: 2070, 4040, 5160, 5260
Suggested CDR Performance Indicators: 8.1.3, 8.1.4, 8.1.5, 8.3.6
CPE Level 2

CVD is the leading cause of death worldwide, with an average of 1 in 4 people dying from heart disease annually in the United States.[1] The World Health Organization estimates that 75% of deaths from CVD can be prevented by lifestyle management. According to the USDA, and based on several large group studies, individuals should consume 14 g fiber per 1,000 kcal. The National Academy of Sciences established Dietary Reference Intakes for fiber based on one's age and sex because most people are unfamiliar with the amount of calories they regularly consume. The recommended fiber intake is 38 g/day for men and 25 g/day for women 50 years of age and younger, while men and women older than 50 should have 30 and 21 g/day, respectively. These numbers are based on average caloric consumptions. According to the 2013–2014 National Health and Nutrition Examination Survey, American adults are only getting 50% to 60% of their recommended daily dietary fiber intake.[2] This course looks deeper into the research to see whether consuming adequate amounts of fiber is a promising strategy to decrease CVD and death.

Dietary fiber is the portion of plant material that's unable to go through enzymatic digestion. There are various components of the plant material, such as hemicellulose, cellulose, lignins, oligosaccharides, pectins, and gums, that make up dietary fiber. These are classified by their solubility in water. Cellulose, hemicellulose, and lignins—insoluble fibers—are found in the structural component of the cell wall and aren't soluble in water. Oligosaccharides, pectins, and gums—soluble fibers—are found in the primary cell wall and inner structure of the plant and become viscous in water.[3] Oligosaccharides also are known as a prebiotic, a type of dietary fiber that acts as a fertilizer for the good microflora in the gastrointestinal tract.[4]

The soluble and insoluble properties of dietary fiber have an effect on CVD risk factors such as cholesterol, blood sugar, and weight management. Insoluble fiber adds bulk as food moves through the gut, which may reduce appetite, alleviate constipation, and assist with weight management. While soluble fiber attracts water and creates a viscous consistency during digestion, it traps carbohydrates and bile acids, causing a slower glucose response and halting the rise in lipid levels, respectively.[5] Soluble fiber also ferments bacteria in the large intestine, producing short-chain fatty acids, which can help reduce circulating cholesterol levels.[6]

In addition, some other beneficial components in foods that are high in fiber may influence heart disease risk factors. For example, whole grains that are high in fiber may also be composed of antioxidants, phytosterols, amylase inhibitors, hormonally active lignans, and saponins that could be cardiovascular protective.[6]

This continuing education course reviews the association between dietary fiber consumption and risk factors for CVD, including the possible mechanisms of action and the impact of the specific subgroups of dietary fiber.

Fiber and CVD Mortality

Many studies have shown that high intake of dietary fiber is correlated with lower CVD mortality risk. It's hypothesized that the functionality of dietary fiber on cholesterol levels, blood sugar control, and weight management influence the significant decrease in cardiovascular deaths. For instance, Kim and colleagues performed a meta-analysis of 15 prospective cohort studies and found a pooled risk ratio (RR) of CVD for a dietary fiber increment of 10 g/day was 0.91.[7] And in Threapleton and colleagues, a meta-analysis and systematic review of 22 prospective cohort studies, total dietary fiber from food intake was inversely associated with risk of CVD as well with an RR of 0.91 per 7 g/day of total dietary fiber intake.[6]

The systematic review by Kim and colleagues also assessed insoluble and soluble fiber's effect on CVD independently. Five studies showed that for every 7-g/day increase in insoluble fiber, risk of CVD was decreased. The combined RR for these studies was 0.82. Six studies looked specifically at soluble fiber and found that an additional 4 g/day decreased risk of CVD. The combined RR for these studies was 0.88.[7]

The same systematic review also looked at intake of dietary fiber found in cereal, fruit, and vegetables and its relationship with CVD risk. Five studies showed that consuming 7 g/day more of cereal fiber was associated with 8% decreased risk of CVD. Four studies showed that each 4-g/day greater intake of fruit fiber was associated with a 4% decreased risk of CVD. The dose-response curve showed that lower risk of CVD is associated with higher fruit fiber intake of about two to four servings of fruit. Data were limited for those who consumed more than two to four servings and should be interpreted cautiously. Four studies showed that each 4 g/day greater intake of vegetable fiber was associated with an RR of 0.92. The dose-response curve was associated with four to six portions of vegetables, but, again, data on those who consumed more than four to six servings were inconclusive.[7]

In a systematic review and meta-analysis of 45 prospective cohort studies and 21 randomized controlled trials (RCTs), Ye and colleagues looked at whole grain consumption and relative risk of CVD. Compared with those who rarely or never ate whole grains, those who consumed 48 to 80 g whole grains/day (three to five servings/day) had a ~21% lower risk of CVD (RR=0.79). Those who consumed more whole grains consistently gained less weight during the eight to 13 years they were followed (1.27 vs 1.64 kg, p=0.001). According to the authors, weighted mean differences in postintervention circulating concentrations of fasting glucose and total and LDL cholesterol were significantly lower in the whole grain intervention group vs control. Fasting glucose was 0.93 mmol/L lower, total cholesterol 0.83 mmol/L lower, and LDL cholesterol 0.72 mmol/L lower in the whole grain group. Overall, the results show a positive impact of consumption of whole grains with decreasing CVD risk. However, the mechanism of action isn't conclusive and larger intervention studies are needed.[8]

Fiber and Stroke Risk

Dietary fiber may reduce key risk factors for stroke, such as overweight and high cholesterol levels.[9]

In a systematic review and meta-analysis of eight cohort studies, risk of hemorrhagic and ischemic stroke was inversely correlated with fiber intake (RR of 0.93 per 7 g/day). While overall total fiber was associated with lower risk of first-time stroke, individually assessing soluble vs insoluble fiber for the risk of stroke didn't show a risk reduction. However, this may be due to insufficient studies.[9]

A meta-analysis of cohort studies involving 257,551 individuals (4,917 stroke events) with an average of 13 years of follow-up looked at fruit and vegetable intake and relation to stroke risk. Compared with participants who consumed fewer than three daily portions of fruit and vegetables, stroke was reduced by 11% for those who consumed three to five daily portions and 26% for participants who consumed more than five daily portions. Subgroup analysis showed a protective effect on both ischemic and hemorrhagic stroke of fruit and vegetable consumption, but the studies didn't extrapolate the results to the fiber in the fruits and vegetables.[10]

Fiber and Blood Pressure

There's an association between dietary fiber intake and blood pressure regulation, but the mechanism of action is unknown.[11] However, many studies have looked at the association between dietary fiber and reduction in systolic and/or diastolic blood pressure in individuals with hypertension.

In two meta-analyses of RCTs, dietary fiber caused a nonsignificant change in systolic blood pressure but a significant change in diastolic blood pressure. In Streppel and colleagues' meta-analysis of 24 RCTs, fiber supplementation with a mean dose of 11.5 g/day caused a nonsignificant change in systolic blood pressure of -1.13 mm Hg and a significant change in diastolic blood pressure of -1.26 mm Hg. Blood pressure reductions were larger in hypertensive populations, but, after adjustment for older age, this difference lost statistical significance. Some of the studies assessed in this meta-analysis may be confounded by magnesium and potassium supplementation.[11]

In Whelton and colleagues' meta-analysis of 25 RCTs, dietary fiber was assessed as the only significant intervention for blood pressure regulation between the intervention and control group. The results showed that dietary fiber was associated with a significant 1.65-mm Hg reduction in diastolic blood pressure and a nonsignificant 1.15-mm Hg reduction in systolic blood pressure. Studies on hypertensive patients showed a reduction in both systolic and diastolic blood pressure (systolic -5.95 mm Hg, diastolic -4.2 mm Hg) with increased dietary fiber intake. Systolic and diastolic blood pressure also were reduced in increased-fiber groups in studies eight weeks or longer in duration (systolic -3.12 mm Hg, diastolic -2.57 mm Hg). More studies are needed to assess dietary fiber's impact on blood pressure in normotensive individuals and the optimal duration of intervention.[12]

Another study used data from the INTERMAP study to assess intake of insoluble vs soluble dietary fiber and blood pressure levels. Blood pressure readings, 24-hour dietary recalls, and 24-hour urine samples of 2,195 middle-aged (40–59 years old) men and women in the United States were analyzed. After multivariable adjustment, consumption of 4 to 6 g more of insoluble fiber per 1,000 kcal was associated with 1.81 mm Hg lower systolic blood pressure, adjusted for soluble fiber, and urinary potassium excretion. Soluble fiber wasn't correlated with blood pressure changes. Raw fruit was the leading source of total and insoluble fiber, followed by whole grains and vegetables.[13]

Studies have shown mixed results concerning the effects of whole wheat and whole grain consumption on blood pressure regulation. In Tighe and colleagues' RCT, 206 participants were assigned to consume either three servings of whole grain foods each day (either whole wheat only or wheat and oats) or refined grain foods (eg, refined cereal and white bread) for 12 weeks. In the whole grain intervention group, the three servings of whole wheat foods comprised 70 to 80 g whole wheat bread and 30 to 40 g whole grain cereals, while the oats and wheat arm of the intervention group was given one serving of whole wheat foods and two servings of oats. Researchers provided the refined or wheat- or oat-based foods, and participants selected any other foods they consumed.[14]

After six weeks of the intervention, the whole grains group saw a significantly larger decrease in systolic blood pressure than that of the refined group (5 mm Hg vs 1.3 mm Hg, respectively), and this difference was still significant at 12 weeks ($p=0.01$). Diastolic blood pressure remained unchanged. At 12 weeks of intervention, pulse pressure, the difference between systolic and diastolic blood pressure that represents the force the heart generates each time it contracts, was significantly lower (3 mm Hg) in the intervention group. The wheat and oats arm of the whole grains group achieved a significantly lower pulse pressure by six weeks. The systolic blood pressure reduction shown in this study could decrease coronary artery disease and stroke incidence by 15% and 25%, respectively.[14]

However, in the WHOLEheart study, a randomized controlled dietary intervention, 316 participants consuming <30 g whole grains/day were randomly assigned to control, intervention 1 (60 g/day for 16 weeks), or intervention 2 (60 g/day for eight weeks followed by 120 g/day for eight weeks). Participants in the intervention groups were able to choose from whole wheat bread, shredded wheat cereal, Cheerios, porridge oats, brown basmati rice, oat porridge, whole wheat pasta, Weetabix, Quaker oat bars, and Sun Chips (wholegrain crisps). The most frequently selected were breakfast cereals. BMI, percentage body fat, waist circumference, fasting plasma lipid profile, glucose, insulin, and indicators of inflammatory, coagulation, and endothelial function were assessed. Markers of CVD risk didn't differ between the groups.[15] More studies are needed to assess the impact of subgroups of dietary fiber and normotensive individuals.

Fiber and Cholesterol

Several physicochemical properties of dietary fiber have been proposed to lower blood cholesterol. Dietary fiber alters metabolic pathways of hepatic cholesterol and lipoprotein metabolism, which lowers plasma LDL cholesterol levels.

One way by which it does this is by binding with bile acids during the formation of micelles, which results in reduction of cholesterol content in hepatic cells and increases LDL cholesterol excretion from blood circulation. Other proposed mechanisms include inhibition of hepatic fatty acid synthesis by fermentation byproducts of soluble fibers, such as short-chain fatty acids in the small intestine, which lowers plasma lipid levels as well.[16]

Whitehead and colleagues' meta-analysis of 28 randomized controlled trials showed that oat β-glucan in doses of ≥3 g/day reduced LDL and total cholesterol by 0.25 mmol/L ($p<0.0001$) and 0.3 mmol/L ($p<0.0001$), respectively, vs controls. There was no significant effect on HDL cholesterol or triglycerides. There was no evidence that dose, ranging from 3 to 12.4 g/day across studies, or duration of treatment, which ranged from two to 12 weeks across the studies, influenced the results. The study showed that the effect may be greater in individuals who had diabetes and higher LDL cholesterol levels; however, due to a limited number of studies, the findings didn't reach statistical significance. However, as this study didn't take into account participants' other fiber sources, they may have affected the mixed results shown.[17]

Similar results were found in a ***Cochrane*** systematic review of 23 RCTs by Hartley and colleagues. In 17 of the studies reviewed, increased fiber intake reduced cholesterol levels by a mean difference of 0.2 mmol/L and LDL cholesterol levels by a mean difference of 0.14 mmol/L. The results had no impact on triglyceride levels, and there was a small but statistically significant decrease in HDL levels (mean difference 0.03 mmol/L). These studies varied in dietary fiber source and type involved. Of 15 studies that involved use of a fiber supplement, 12 used soluble fiber, two used insoluble fiber, and one used a combination of both fibers. The other eight studies involved provision of a variety of foods high in fiber; five of the studies involved soluble fiber sources, two involved insoluble fiber sources, and two relied on a combination of soluble and insoluble food sources. Soluble fiber has been strongly associated with reduction in cholesterol levels, particularly total and LDL. However, there have been fewer comparative studies of insoluble and a combination of insoluble and soluble fiber, so it's difficult to establish an association.[16]

The impact of supplemental oligosaccharides on cholesterol was assessed in small studies. In a double-blinded RCT by Forcheron and colleagues, 17 healthy, normolipidemic subjects were studied before and after six months of daily administration of placebo or 10 g of a mix of inulin and oligofructose. Participants in each group were asked to consume their usual diets and not to modify their everyday lifestyles. The intervention group had no statistical difference in plasma total, LDL, or HDL cholesterol levels compared with the control group. More research on prebiotic dietary fiber and cholesterol levels is needed, preferably with larger sample sizes, to show a conclusive finding.[18]

Fiber and Blood Sugar

One of the suggested mechanisms for how greater fiber intake can improve risk of CVD is by slowing absorption of sugar into the blood from the gut. Greater fiber intake also has been associated with improvements in insulin resistance, which may cause hypertension through compensatory hyperinsulinemia.[19]

It's also been proposed that soluble fiber's viscosity can delay absorption of nutrients through slowed digestion, possibly lowering postprandial glucose and improving insulin resistance.[19] In an RCT by Abutair and colleagues, 40 participants with type 2 diabetes were assigned to an intervention group receiving 10.5 g of soluble fiber from psyllium or a control group on a regular diet. At eight weeks, participants who consumed psyllium improved their fasting blood sugar levels (163 to 119 mg/dL), HbA1c (8.5% to 7.5%), insulin levels (27.9 to 19.7 µIU/mL), homeostatic model assessment (HOMA) of insulin resistance (11.3 to 5.8), and HOMA beta cell function (103% to 141%).[20]

Chandalia and colleagues conducted a crossover study wherein 13 patients with type 2 diabetes were randomly assigned to two diet groups, each for six weeks. One diet contained moderate amounts of fiber, comprising 24 g total, 8 g soluble, and 16 g insoluble, as recommended by the American Diabetes Association. The other was a high-fiber diet with 50 g total, 25 g soluble, and 25 g insoluble, all from food not fortified with fiber. Both diets were equal in macronutrient ratios and calories and comprised food prepared specifically for the study in a research kitchen. Participants following the high-fiber diet had a 13 mg/dL lower mean daily fasting plasma glucose concentration than that of those following the moderate-fiber diet and mean urinary glucose excretion of 1.3 g. The high-fiber diet also lowered the area under the curve for 24-hour plasma glucose and insulin concentrations, which were measured every two hours by 10% ($p=0.02$) and 12% ($p=0.05$), respectively. Given the small sample size, more studies are needed to replicate statistical significance.[21]

Many studies have inconsistent diet protocols, which makes it difficult to conclude whether high fiber intake itself is improving blood sugar response. For instance, in two studies, the diet containing more fiber also had less fat and more carbohydrates than did the diet containing less fiber.[22,23] Many studies are also limited based on small population sample size, short time frame of evaluating impact of dietary intervention, insufficient randomization, and unexplained weight loss with diets that contained more fiber.[24-26]

Fiber and Body Weight

Excess body weight may increase CVD risk, but most studies have shown an inverse relationship between consumption of dietary fiber and alterations in body weight. In a 2009 prospective cohort study by Tucker and Thomas, fiber intake and body fat composition (measured via a BodPod) were assessed in 252 women. During the 20-month study, almost 50% of the women had an increase in their body weight and body fat. For every additional 1 g of total fiber intake, however, weight was reduced by 0.25 kg ($p=0.006$) and fat was reduced by 0.25% ($p=0.005$). Controlling for potential confounders (such as age, baseline fiber and fat intakes, activity level, and baseline energy intake) didn't affect the relationships; however, increased energy intake above their needs weakened the associations by 24% to 32%. Among participants who lost weight, every 8-g increase in fiber per 1,000 kcal resulted in 4.4 lbs of weight loss.[27]

In Koh-Banerjee and colleagues' prospective cohort study of 27,082 middle-aged men, additional whole grain consumption was inversely correlated with long-term weight gain ($p<0.0001$). For every additional 40 g of whole grains consumed from all foods, weight gain was decreased by 0.49 kg.

When bran was added to the diet or obtained from fortified grain foods, it reduced weight gain by 0.36 kg for every additional 20 g/day of bran consumed (p=0.01).[28]

Dietary fiber may reduce body weight through several mechanisms. One proposed idea is that soluble fiber, when fermented in the large intestine, produces glucagonlike peptide and peptide YY, two gut hormones that play a critical role in inducing satiety. Another theory is that dietary fiber may reduce energy intake or decrease a diet's metabolizable energy—energy consumption minus the energy lost in body excretions via stool or urine. In one study, increased dietary fiber intake decreased metabolic energy of the diet, which may be due to the reduction of fat digestibility with both high- and low-fat diets. However, studies have shown inconclusive results concerning whether the metabolic energy lost was due to soluble or insoluble fiber or a combination.[29]

Some studies have looked at the impact of oligosaccharides and body weight. In a double-blinded RCT by Parnell and Reimer, 48 healthy adults with BMI >25 received 21 g oligofructose/day or a placebo (maltodextrin) for 12 weeks. The study evaluated body composition by dual-energy X-ray absorptiometry, satiety hormone response, and food intake, and subjective appetite ratings were determined. Results showed a body weight reduction of 1.03 ± 0.43 kg with oligofructose supplementation, whereas the control group experienced an increase in body weight of 0.45 ± 0.31 kg over 12 weeks (p=0.01). This may be in part due to a decrease in ghrelin, the hunger hormone, and an increase in peptide YY, a reducer of appetite. There was a lower area under the curve for ghrelin (p= 0.004) and a higher area under the curve for peptide YY with oligofructose (p= 0.03), with a reduction in self-reported caloric intake (p< 0.05). This reduction may have decreased actual body weight. Oligofructose supplementation had no effect on plasma active glucagonlike peptide-1 secretion. Supplementation of oligosaccharides has potential to promote weight loss possibly due to an influence on satiety hormones. There aren't enough studies looking at just this type of dietary fiber to allow for a conclusive finding.[30]

Putting It Into Practice

Overall, research has found a positive impact of total dietary fiber on heart health. The physicochemical properties of total dietary fiber have a positive influence on lowering CVD mortality, cholesterol, blood pressure, blood sugar, and weight. It's uncertain whether the dietary fiber causes a positive impact on heart health or if it works with a combination of other cardioprotective components, such as the blood pressure–lowering potassium found in fruit and vegetables.

Studies have shown an additional 7 g of dietary fiber daily may significantly lower risk of CVD by 9%. Lower risk of CVD has been seen with greater intakes of insoluble, soluble, cereal, fruit, and vegetable fiber. An additional 7 g fiber can be provided by the consumption of ¼ cup of beans, 1 cup of vegetables, one to two servings of fruit, one to two servings of whole grain bread, and ½ to 1 cup of high-fiber whole grain cereal.

A limitation of results in many of the meta-analyses is that they were from observational cohort studies, which have the potential of multiple confounding factors. Higher dietary fiber intake is linked with other health-promoting behaviors such as higher physical activity and lower

incidence of smoking, which both influence CVD risk. Another limitation is that some of the RCTs available were small and of short duration. Many of the tools utilized for dietary intake were from food intake surveys, which can reduce reliability, resulting in inaccurate data. While overall total fiber has led to statistically significant findings for all parameters, further explorations of types of fiber and specific food sources have been inconclusive. Whole grains seem to have the greatest impact, but it's unclear whether these benefits are due to fiber or other health-promoting attributes of whole grains. More studies are needed to decipher the exact amount of insoluble and soluble fiber, specific food sources of fiber, and the duration of consumption necessary to produce a significant positive impact on each risk factor for CVD.

It can be concluded that total dietary fiber consumption decreases CVD risk and risk factors such as high cholesterol, high blood pressure, high blood sugar, and overweight/obesity. More research is needed to fully assess dietary fiber's role in blood pressure regulation. RDs can advise their patients to include balanced amounts of each subgroup of dietary fiber in their diets. It may be necessary to personalize recommendations based on each client's risk factors to reach their goals and lower their overall CVD risk.

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Quiz

1. How many additional grams of dietary fiber may lower risk of CVD by 9%?
A. 2 g
B. 5 g
C. 7 g
D. 15 g

2. According to the 2013–2014 National Health and Nutrition Examination Survey, what percentage of the recommended daily dietary fiber intake do American adults consume?
A. 10% to 20%
B. 20% to 40%
C. 50% to 60%
D. 60% to 70%

3. What type of fiber are pectins?
A. Soluble
B. Insoluble
C. Prebiotics
D. Probiotics

4. How many daily fruit and vegetable servings would decrease risk of stroke by 26%?
A. One to two servings
B. Two to three servings
C. Three to five servings
D. More than five servings

5. What's one way soluble fiber lowers postprandial glucose?
A. It binds with bile acids during the formation of micelles.
B. It increases HDL levels.
C. It delays absorption of nutrients in the gastrointestinal tract.
D. It activates pancreatic enzymes.

6. What source of fiber taken in doses of more than 3 g/day would cause a reduction in LDL cholesterol by 0.25 mmol/L?
A. Oat β-glucan
B. Raw fruit
C. Oligosaccharides
D. Refined cereals

7. In a study by Tucker and Thomas, how many grams of fiber caused an average 4.4-lb weight loss?
A. 1 g/1,000 kcal
B. 4 g/1,000 kcal
C. 8 g/1,000 kcal
D. 20 g/1,000 kcal

8. An additional 7 g of fiber can be found in which of the following servings of foods?
A. ¼ cup of whole grain breakfast cereal
B. ½ medium banana
C. 1 cup milk
D. ¼ cup beans

9. How many grams of dietary fiber is the recommended minimum for a male over the age of 50?
A. 20 g
B. 30 g
C. 40 g
D. 50 g

10. How might oligosaccharide supplementation reduce body weight?
A. Increase in ghrelin
B. Decrease in peptide YY
C. Increase metabolic rate
D. Decrease in ghrelin