



(REVIEW ARTICLE)



## Dietary fiber and risk of coronary heart diseases

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### Abstract

Dietary fiber is the portion of plant-derived food that cannot be completely broken down by human digestive enzymes. Dietary fibers can be grouped generally by their solubility, viscosity, and fermentation, which affect how fibers are processed in the body. Dietary fiber has two main components: soluble fiber and insoluble fiber, which are components of plant foods, such as legumes, whole grains and cereals, vegetables, fruits, and nuts or seeds. Consumption of cereals, vegetable and fruit may lower the risk of coronary heart disease. Coronary heart disease involves the reduction of blood flow to the heart muscle due to build-up of plaque on the arteries of the heart. Dietary fiber makes three primary contributions: bulking, viscosity and fermentation. The bulking effect of some fibers reduces constipation and the risk of colon disease because they absorb water, which increases bulking and promotes regularity. Viscosity effects on fibers reduce the absorption of cholesterol and other nutrients because of the formation of gels that attenuate postprandial blood glucose and lipid rises. The formation of gels also slows gastric emptying, maintaining levels of satiety and contributing towards less weight gain. In the fermentation process, the bacteria GIT helps to digest fiber through a process of microbial fermentation to generate short chain fatty acids like acetate, propionate and butyrate. Butyrate binds to G-protein coupled receptors on the brush borders of intestinal lining and trigger a signal cascade that release GLP-1 and PYY. These peptides behave like hormones to trigger satiety. One of the reasons for eating fiber rich foods is because they promote satiety and prevent uncontrollable quest for food. People that eat food low in fiber experience over feeding issues. When people over eat they consume more calories leading to weight gain and that contributes to obesity. Obesity is the accumulation of fats in fat tissues. Excess fats are converted to cholesterol (LDL) which accumulates on the walls of the arteries and prevent the flow of blood to the heart. This is prevented when an individual consumes foods rich in fiber.

**Keywords:** Coronary-heart-diseases; Dietary Fiber; LDL-C; Fruits; Vegetables

### 1. Introduction

Cardiovascular diseases (CVD) are a group of conditions that affect the heart and blood vessels and include coronary heart disease, cerebrovascular disease, and peripheral arterial disease<sup>1</sup>. One of the main mechanisms thought to cause Coronary heart disease is atherosclerosis, where the arteries become clogged by atheroma or plaque<sup>1</sup>. Coronary heart disease occurs when the arteries are completely blocked or when blood flow is restricted by a narrowed artery, limiting the amount of blood and oxygen delivered to organs or tissue<sup>1</sup>. Arteries may naturally become harder and narrower with age, although this process may be accelerated by such factors as a sedentary lifestyle, obesity, ethnicity, smoking, high cholesterol, and high blood pressure<sup>1</sup>. Another cause of Coronary heart disease is unstable plaque rupturing.

It is thought that unstable plaques activate an inflammatory response in the body that cause the structure of atherosclerotic plaque to weaken and rupture, leading to the formation of blood clots [1].

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Coronary heart disease is the number-one cause of death and disability globally [2]. Around 30% of total global deaths can be attributed to coronary heart disease, and it is estimated to cause 17 million deaths per year [2]. The World Health Organization (WHO) reports that by 2030, coronary heart disease will account for almost 23.3 million deaths per year. This burden is set to increase as a consequence of ageing populations and increasing level of sedentary lifestyles and obesity [1].

One key public health priority in the prevention of coronary heart disease is targeting modifiable risk factors. One such risk factor is diet, which plays a major role in the etiology of many chronic conditions, including coronary heart disease. Indeed, there are a number of dietary factors that have been found to be associated with a decrease in coronary heart disease risk, such as a low sodium intake, a low-carbohydrate diet [1], intake of whole grains [4] and a high consumption of fruits and vegetables [1]. Such factors are important, not only because they have been linked to coronary heart disease development, but also because they can be modified [4]. This makes them one of the main targets for interventions aimed at primary prevention and management of coronary heart disease [1].

The primary objective of this systematic review was to determine the effectiveness of dietary fiber for the primary prevention of coronary heart disease.

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## 2. Dietary Fiber

Dietary fiber is the portion of plant-derived food that cannot be completely broken down by human digestive enzymes [5]. Dietary fibers are diverse in chemical composition, and can be grouped generally by their solubility, viscosity and fermentation which affect how fibers are processed in the body [5]. Dietary fiber has two main components: soluble fiber and insoluble fiber [5], which are components of plant foods, such as legumes, whole grains and cereals, vegetables, fruits, and nuts or seeds. A diet high in regular fiber consumption is generally associated with supporting health and lowering the risk of several diseases<sup>6</sup>.

Dietary fiber includes polysaccharides, oligosaccharide, and lignin and associated plant substance. Dietary fiber promotes beneficial physiologic effects including laxation or blood cholesterol and blood glucose attenuation.

Dietary fiber intake has an apparently protective effect on coronary heart disease [6]. Consumption of (whole grain) cereals, vegetable and fruit may lower the risk of coronary heart.

Dietary fiber is one of the food component that has greater beneficial effect on health [8]. Soluble fiber attracts water and forms a viscous gel during digestion, slowing the emptying of the stomach and intestinal transits, shielding carbohydrates from enzymes and delaying absorption of glucose, which lowers variance in blood sugar levels [6]. Soluble fiber, which dissolves in water is generally fermented in the colon into gases and physiologically active by-products, such as short-chain fatty acids produced in the colon by gut bacteria. Examples are beta-glucans (in oats, barley, and mushrooms) and raw guar gum. Psyllium a soluble, viscous, non-fermented fiber is a bulking fiber that retains water as it moves through the digestive system, easing defecation [8]. Soluble fiber is generally viscous and delays gastric emptying which, in humans, can result in an extended feeling of fullness [6]. Inulin (in chicory root), wheat dextrin, oligosaccharides, and resistant starches (in legumes and bananas), are soluble non-viscous fibers [6].

Regular intake of soluble fibers, such as beta-glucans from oats or barley, has been established to lower blood level of LDL cholesterol, a risk factor for cardiovascular diseases.

Insoluble fiber which does not dissolve in water – is inert to digestive enzymes in the upper gastrointestinal tract [6]. Examples are wheat bran, cellulose, and lignin [6]. The primary benefit is to provide bulk to stool and help in the movement through the digestive tract [8]. Most diets have a combination of soluble and insoluble fiber, with 75 percent coming from insoluble fiber and 25 percent coming from soluble fiber.

They Regulate blood sugar which may reduce glucose and insulin levels in diabetic patients and may low the risk of diabetes [6]. Speed the passage of food through digestive system, which facilitate regular defecation [6][7]. Add bulk to the stool, which alleviates constipation [7]. Sources include whole grain like bread, cereal, rice, pasta etc, skin of fruits and vegetables, nuts and seeds. Some forms of insoluble fiber, such as resistant starches, can be fermented in the colon [7]. Both soluble and insoluble fiber balance intestinal fermentation production of short-chain fatty acids which may reduce risk of colorectal cancer [8].

Dietary fiber consists of non-starch polysaccharides and other plant components such as cellulose, resistant starch, resistant dextrins, inulin, lignins, chitins (in fungi), pectins, beta-glucans, and oligosaccharides [6].

Dietary fiber increases the size and weight of the stool and makes it soft [8]. Stool is easier to pass when bulky, decreasing the chance of constipation. Fiber helps to solidify the stool when loose, because it absorbs water and adds bulk to stool [8].

Soluble fiber gotten from oats, beans, flax seed and oat bran may help lower total blood cholesterol levels by lowering low-density lipoprotein. Studies also revealed that high-fiber foods may have other heart-health benefits which includes reducing blood pressure and inflammation [8].

Diet high in fiber may lower the risk of developing hemorrhoids and small pouches in the colon [8]. Studies revealed that a high-fiber diet likely lowers the risk of colorectal cancer [8].

High-fiber foods have more filling than low-fiber foods, so one is likely to eat less and stay satisfied longer [8]. Also high-fiber foods tend to take longer to eat and to be less energy dense. This means they have fewer calories for the same volume of food [8].

Soluble fiber can slow the absorption of sugar and help improve blood sugar levels in people with diabetes [8]. A healthy diet that includes insoluble fiber may also reduce the risk of developing type 2 diabetes.

Studies suggest that increased intake of dietary fiber especially cereal fiber is associated with a reduced risk of dying from cardiovascular disease and all cancers [8].

You may need to boost your fiber intake, if you are not getting enough fiber each day. Good choices include [8]:

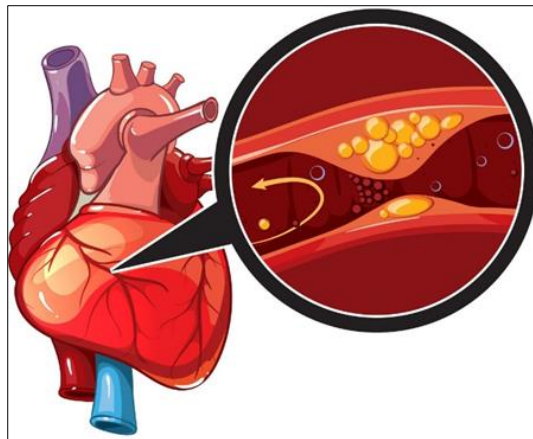
- Vegetables
- Beans, peas and other legumes
- Nuts and seeds
- Whole-grain products
- Fruits

Processed or refined foods such as canned fruits and vegetables, pulp-free juices, white breads and pastas, and non-whole-grain cereals are lower in fiber [8]. The grain-refining process removes the outer coat (bran) from the grain, which lowers its fiber content [8]. Enriched foods have some of the B vitamins and iron added back after processing, but not the fiber [8].

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### 3. Coronary Heart Disease

Coronary artery disease (CAD), also called coronary heart disease involves the reduction of blood flow to the heart muscle due to build-up of plaque (atherosclerosis) in the arteries of the heart [9]. It is the most common of the cardiovascular diseases [10]. This occurs when the flow of oxygen-rich blood to the heart is blocked or reduced as a result of blood clot or by buildup of fat deposits inside the artery which causes the artery to harden and narrow [11] [12].



<https://www.thekeyholeheartclinic.com/blog/coronary-artery-disease-causes-treatments-and-prevention-methods/>

**Figure 1** Diagrammatic representation of atherosclerosis

The most common symptom is angina (chest pain or discomfort) the pain occurs when the heart is not getting enough blood or oxygen. Other symptoms include shortness of breath, fatigue with activity and general weakness [10]. Someone affected with CHD may be told to treat blood pressure diabetes, or high cholesterol levels [13]. Increment in consumption of fiber rich food can help reduction of this metabolic disorders, and can also help in improving blood profiles, insulin sensitivity and lytic activity of fiber.

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#### 4. Risk Factors of Coronary Heart Disease

Risk factors for coronary artery disease include: Generally, men are at greater risk of coronary artery disease. The risk for women increases after menopausal age [11].

Aging increases the risk of damaged and narrowed arteries [11] Age over 45 years of age for men or a post-menopausal woman [11][14].

The risk of coronary heart disease increases with age. Based on age alone as a risk factor, men have a greater risk for the disease beginning at age 45 and women have a greater risk beginning at age 55[11].

Smokers have a significantly increased risk of heart disease [11]. Breathing in second hand smoke also raises a person's chance of developing coronary heart disease [11][14].

A family with history of heart disease is associated with a higher risk of coronary heart disease [14], especially if a close relative experienced heart disease at an early age [11]. One's risk is highest if the father or a brother was diagnosed with heart disease before age 55 or if the mother or a sister developed it before age Sixty-Five [12].

Unchecked high blood pressure may result in hardening and thickening of the arteries, narrowing the channel through which blood flows to the heart [14].

High levels of cholesterol level increases the risk of formation of plaque and atherosclerosis [14]. High cholesterol can be contributed by a high level of low-density lipoprotein cholesterol, also known as the "bad" cholesterol [11]. A low level of high-density lipoprotein (HDL) cholesterol, known as the "good" cholesterol, can also lead to the development of atherosclerosis [14].

Diabetes is associated with an increased risk of coronary artery disease [14]. Coronary artery disease and type 2 diabetes share a common risk factors, such as obesity and high blood pressure [11].

Overweight worsens other risk factors associated with CHD [11]. Unrelieved stress damages the arteries as well as worsen other risk factors for coronary heart disease [14]. Lack of physical activity such as exercise is associated with coronary artery disease [11]. Consumption of food that has high amounts of saturated fat, trans fat, salt and sugar can increase the risk of coronary heart disease [14].

Sometimes coronary artery disease develops without any classic risk factors. Researchers are studying other possible risk factors, including [11]:

Homocysteine, an amino acid the body use to make protein and build and maintain tissue. Homocysteine at high levels of may increase the risk of coronary artery disease<sup>14</sup>.

This causes repeated stop and start breathing cycle during sleep [14]. Sudden drops in blood oxygen levels that occur during sleep apnea increase blood pressure and strain the cardiovascular system, possibly leading to coronary heart disease [11] [14].

High levels of triglycerides may raise the risk of coronary artery disease, especially for women [11]. Inflammation increases the amounts hs-CRP [11]. High hs-CRP levels may be a risk factor for heart disease [14]. As coronary arteries narrow, more hs-CRP accumulates in the blood [11].

This condition develops in women during pregnancy raises the blood pressure [14] and a higher amount of protein in urine [11]. It can lead to a higher risk of heart disease later in life.

Heavy alcohol intake can lead to the damage of heart muscles [11]. And worsens other risk factors of coronary artery disease [11] [14].

Individuals who have conditions such as rheumatoid arthritis and lupus (and other inflammatory conditions) [14] have an increased risk of atherosclerosis [11].

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## 5. Symptoms of coronary heart disease

As plaque builds up continually in the coronary arteries, however, one may develop the following coronary artery disease signs and symptoms:

This develops when the heart can't pump enough blood to meet the body's needs [11]. This is the feeling of pressure or tightness in the chest, as if there is a load standing on one's chest [11]. This pain, usually occurs on the middle or left side of the chest. Generally, heart is triggered by physical or emotional stress. The pain usually disappears within minutes after stopping the stressful activity [11]. In some individuals, especially women, the pain may be brief or sharp and felt in the neck, arm or back [11].

Heart attack also happens when the coronary artery is completely blocked [11]. The classic signs and symptoms of a heart attack include crushing pressure in your chest and pain in the shoulder or arm, sometimes with shortness of breath and sweating [11]. Other symptoms include: pain throughout the body, Feeling faint, Feeling sick (nausea).

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## 6. Prevention of coronary heart disease

A healthy lifestyle can help keep the arteries strong and clear of plaque. In order to improve the heart health, do the following: Eat healthy diet, especially fiber rich foods. Quit smoking. Control high blood pressure, high cholesterol and diabetes. Be physically active [15]. Eat a low-fat, low-salt diet that is rich in fruits, vegetables and whole grains, Maintain a healthy weight, Reduce and manage stress

Protective effect of dietary fiber on the risk of coronary heart disease is biologically plausible, greater dietary fiber intake associated with lower risk of coronary heart disease [15]. Many observational studies have since examined the relationship between dietary fiber and total coronary heart disease risk factors such as hypertension, central obesity, insulin sensitivity and elevated plasma cholesterol.

Viscous soluble fiber is able to bind with cholesterol in the intestine and prevent its uptake into the body by allowing it to be eliminated in the stool [15]. Potential mechanisms through which fiber may act on individual risk factors [15].

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## 7. Relationship between dietary fiber and coronary heart disease

The specific mechanisms through which dietary fiber reduces CHD risk are unknown. Soluble fibers, when exposed to water forms a gel in the stomach and small intestine that helps slow gastric emptying, hurry small intestine movement, and control nutrient absorption. In doing so, it is thought that soluble fiber reduces the effect of postprandial blood glucose and lipid increases [16], which are CHD risk factors. Furthermore, both soluble and insoluble fiber are known to increase gastric distension and have an effect on gut hormones that elevates satiety [16], leading to a reduced food intake and, in the long term, weight reduction and improved glucose metabolism [16].

Experiments have shown that dietary fiber increase the rate of bile acid excretion, which reduces total and low-density lipoprotein (LDL) cholesterol. However, once fermented in the colon, dietary fiber produces short-chain fatty acids that inhibit the synthesis of cholesterol [17].

Finally, dietary fiber has been shown to have an impact upon plaque stability by decreasing pro-inflammatory cytokines known to affect plaque stability [1].

Recently meta-analysis of prospective cohort studies has shown a reduced risk of total mortality with increased fiber intake (pooled adjusted relative risk of total mortality for the highest category of dietary fiber intake versus the lowest was 0.77 (95%CI 0.74 to 0.8) [1]. This has been confirmed in a recent observational cohort analysis of the predimed trial. A number of observational studies have also shown dietary fiber to have a beneficial association with CVD risk factors<sup>1</sup>. One study showed an inverse relationship between dietary fiber and CVD risk in 39,876 female health professionals, and another study showed that a high intake of fiber is associated with a lower risk of incident ischemic

CVD in both men and women after a mean follow-up of 13.5 years [18]. Further evidence on the beneficial association between dietary fiber and blood pressure and lipid levels can be found from systematic reviews of observational studies. Threapleton 2013 viewed at evidence on dietary fiber and CVD risk from prospective cohort studies and found that a low risk of both CVD and coronary heart disease was associated with high dietary fiber intake. Reyna-Villasmil 2007 found that oat-derived beta-glucan, when added to the American Heart Association Step 2 diet, improved the lipid profile of male participants with mild to moderate hypercholesterolaemia [18]. In another study, ingesting oat cereal for six weeks was found to significantly reduce systolic blood pressure and diastolic blood pressure in hypertensive and hyperinsulinaemic participants when compared to a low-fiber cereal [1].

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## 8. Mechanism of action of dietary fiber

Dietary fibers make three primary contributions: bulking, viscosity and fermentation. Some fibers (i.e., wheat bran, cellulose and psyllium) may help reduce constipation and reduce the risk of colon disease because they absorb water, which increases bulking and promotes regularity [20]. Different types of dietary fiber contribute a wide range of bulking effects, with wheat bran (cellulose) and psyllium contributing 4-5 grams of bulking effects per gram of dietary fiber in the food.

Most bulking fibers are not fermented or are minimally fermented throughout the intestinal tract [21].

Viscous fibers (beta-glucan and psyllium) reduce the absorption of cholesterol and other nutrients because of the formation of gels that attenuate postprandial blood glucose and lipid rises (notably shown with cholesterol absorption). The formation of gels also slows gastric emptying, maintaining levels of satiety and contributing towards less weight gain [21]. Health benefits related to viscosity include lower blood cholesterol levels and reduced glycemic response (slowing down how quickly blood sugar levels rise after eating). Soluble, viscous fiber types can affect absorption from the small intestine because soluble fiber and resistant starch molecules are additionally fermented by bacteria in the large intestine, producing short chain fatty acids, which help reduce circulating cholesterol levels [21].

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 [22].

Some viscous fibers may also be partially or fully fermented within the intestinal tract (guar gum, beta-glucan, glucomannan and pectins), but some viscous fibers are minimally or not fermented (modified cellulose such as methylcellulose and psyllium).

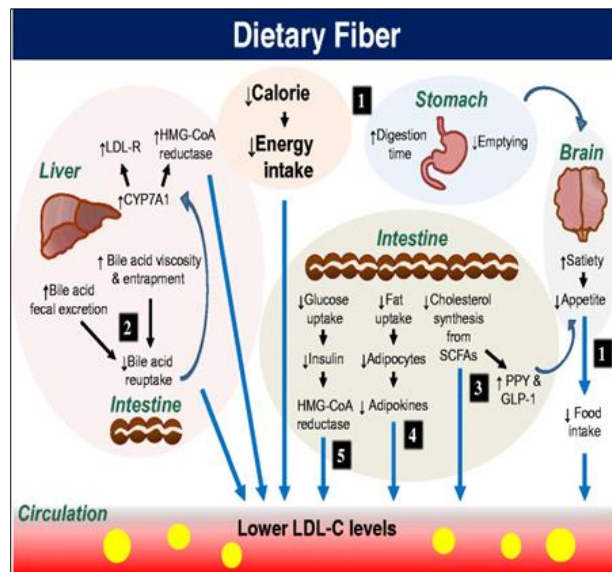
The colon is heavily inhabited with bacteria, and some types of dietary fibers play a key role in 'feeding' the microflora. The colonic bacteria produce, among other things, short chain fatty acids, which helps in maintaining the integrity of the colonic cells as well as triggering a cascade of additional beneficial effects.

Some fibers stimulate the growth of specific bacteria (microbes) beneficial to humans within the large intestines. For instance, bifidobacteria and lactobacillus have been recognized as a beneficial organisms which increases with dietary consumption of inulin, fructo-oligosaccharides and galactooligosaccharides [23]. The bacteria produce a range of short-chain fatty acids, primarily acetate, propionate and butyrate when they consume the fiber in a process known as fermentation [23].

Fermentable fibers contribute moderate bulking benefits by increasing the microbial mass; inulin, resistant starch [24], pectin and legumes each contribute 1-2 grams of bulking effect per gram of dietary fiber [23].

The SCFAs effectively reduces the pH of the intestinal tract, making minerals such as calcium and magnesium more soluble and thus more absorbable [24]. The SCFAs also contribute benefits because they are used as energy by the colon cells as well as absorbed into bloodstream and used as energy within the body [24]. Finally, emerging research is demonstrating that specific SCFAs also trigger important biochemical pathways linked to a wide range of health benefits [24]. Furthermore, fibers stimulate peristalsis, and help to promote regularity. They increase the production of hormones beneficial to satiety and insulin sensitivity (GLP-1, PYY, adiponectin, etc.), and they assist in maintaining a healthy immune system [24].

Dietary fibers can change the nature of the contents of the gastrointestinal tract and can change how other nutrients and chemicals are absorbed through bulking and viscosity [23]. Some types of soluble fibers bind to bile acids in the small intestine, making them less likely to re-enter the body; this in turn lowers cholesterol levels in the blood from the actions of cytochrome P450-mediated oxidation of cholesterol [23][24].



Prasanth, S., Byambaa, E., Erdembileg, A. and Lars, B. (2016). Lipid Lowering with Soluble Dietary Fiber. *Curr Atheroscler Rep* (2016) 18: 75

**Figure 2** Various mechanisms through which dietary fiber lowers LDL-C

The Potential mechanisms associated with lipid lowering by soluble dietary fiber.

Firstly, lower intake of calorie associated with consumption of dietary fiber [25], a prolonged digestion time with delayed gastric emptying, an increase in satiety and bulk-forming, as well as viscosity-induced reduced absorption of cholesterol, contribute to lower LDL-C concentration.

Secondly, dietary fiber causes increased fecal excretion of bile acid, reduces its re-absorption in the small intestine, and prevents bile acid permeation [25]. A decrease in the enterohepatic pool of bile acid upregulates the rate-limiting enzyme involved in bile acid synthesis (CYP7A1) which, in turn, enhances liver uptake of LDL-C from blood through upregulation of LDL-R and CYP51, and impacting HMG-CoA reductase [25].

Thirdly, reduced cholesterol production from short-chain fatty acids (SCFAs) produced by dietary fiber fermentation in the intestine contributes to lower LDL-C concentration. Some SCFAs like propionate stimulate the secretion of peptide YY and glucagon-like peptide 1 (GLP-1), which may help to decrease LDL-C concentration by maintaining a level satiety [25].

Fourth, reduction in the uptake of fat due to fiber alters production of adipokines (e.g leptin, resistin, and TNF- $\alpha$ ) that play crucial roles in lipid metabolism by fat cells and leads to improved cholesterol concentration [25].

Furthermore, the viscosity of fiber delays intestinal absorption of glucose which, in turn, decreases insulin secretion. Insulin then activates HMG-CoA reductase; thus, lower insulin concentration could contribute to lower LDL-C concentration.

## 9. Conclusion

Greater intake of food rich in fiber can substantially reduce the risk of coronary heart disease, and particularly coronary death. Dietary fiber is important for healthy living rather than the nutritional values.

Therefore it is unavoidable for people with coronary heart disease and also for prevention. Findings are aligned with general recommendations to increase fiber intake.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare no conflict of interest.

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