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Does the consumption of soya products affect cholesterol levels, blood pressure, or other cardiovascular health indicators?

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Abstract

Introduction and Purpose

Cardiovascular diseases (CVD) are the leading factor of mortality among people in the world. For this reason, people are trying to find factors that could improve the condition of the

circulatory system. Soy is one of the most popular products in Asian cuisine. Its consumption is increasing due to a strong interest in vegetarian cuisine, in which soy is an important element. As its popularity grows, more and more research is being done to see if it has cardiovascular disease-preventing properties.

Aim of the study

This study aims to analyse the current state of knowledge regarding the effect of soy consumption on: hypertension, lipid profile, biomarkers of inflammation, vascular epithelium and impact on mortality caused by cardiovascular diseases.

Material and methods

For this review, we analyzed articles that we found in Pubmed and Google Scholar and that were related to our topic.

Conclusion

Many studies have shown a beneficial effect of soy products on lipid profile, especially in lowering LDL-C levels. Soy consumption may have an impact on modulating inflammatory markers, but further research is needed. Researchers have shown that soy may have a role in lowering blood pressure, especially in people with hypertension or an increased risk of CVD. Soy can be a part of our daily, healthy diet, but its impact on all-cause mortality and CVD depends on many factors such as people's age, comorbidity, dietary context and type of consumed soy (e.g. fermented or not fermented).

Keywords

soy, soy products, isoflavones, hypertension, lipid profile, CVD, LDL

Introduction

Cardiovascular diseases (CVD) are the leading factor of mortality among people. The current state of knowledge indicates that in 2021, 20.5 million people died of cardiovascular diseases, which constituted ⅓ of all causes of death in this year [1].

Many factors are not modifiable in the prevention of cardiovascular diseases, such as age, gender, or genetic diseases. However, there are factors such as blood pressure, physical activity, smoking or diet which are modifiable (Figure 1), this is why, according to scientific societies, promoting and following a healthy lifestyle is currently the best method of preventing cardiovascular diseases [2].

Soy products are used in the diets of various cultures, especially in Asian countries. In recent years, the growing interest in a healthy diet and a vegetarian diet, in which soy constitutes a large part of meals [3] has resulted in greater production and, consequently, consumption of soy products. From 2020 to 2021 alone, the cultivated area with soy increased from 127 million to 129.5 million hectares [4]. Soy is not only a source of high-quantity protein (35-40%) [5] but also valuable isoflavones, which have, among other studies, anti-inflammatory effects [6] and probably affect cardiovascular health.

Scientific studies on the effect of soy products on cardiovascular health have yielded mixed results. Some studies indicate that regular consumption of soy may lead to decreased LDL(Low-Density Lipoprotein) cholesterol [7] and CVD levels [8]. Others do not show clear benefits [11, 39].

Despite numerous studies, there are discrepancies in the results regarding the effects of soy products on cardiovascular health, and not many studies combined their results with the effect on mortality, CVD, hypertension, lipid profile, inflammatory markers and blood vessel condition.

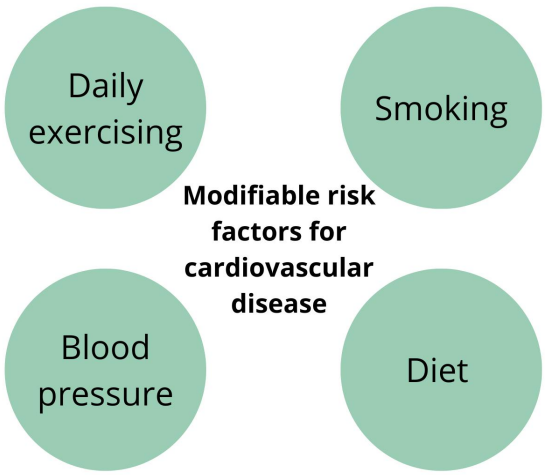

Figure 1. Modifiable risk factors for cardiovascular diseases.

Purpose of the study

The purpose of the study is to determine the current state of knowledge on the effect of soy product consumption on lipid profile, biomarkers of inflammation, condition of blood vessels, hypertension and its impact on mortality from CVD. Consumption of soy products among the population is on an upward trend, so it is worth investigating whether its consumption may be associated with positive effects on cardiovascular disease.

Material and methods

Studies for this review were searched from available on Pubmed, Google Scholar databases and other specific resources. Key search terms included "soy", "isoflavones", "cardiovascular diseases", "hypertension", "lipid profile" and variations of these terms. Each article was published in English. Research published between 2012 and 2024 was taken into account. The types of studies searched were cohort and randomised trials.

The current state of knowledge

Consumption of soy products and its impact on lipid profile

Dyslipidemia is one of the major risk factors for circulatory system diseases. The increase in the concentration of LDL cholesterol level leads to an increased risk of atherosclerosis and consequently ischemic heart disease [9].

The impact of soy products on lipoprotein levels is worth investigating, because the chemical structure of isoflavones, which are contained in soy, is similar to fibrates called PPAR-α agonists (Peroxisome Proliferator-Activated Receptor Alpha agonists) which are used to treat hyperlipidemia [10]. This fact would indicate why they may have a therapeutic effect. The relationship between consuming soy products and lowering blood cholesterol has been shown in several studies.

In a randomised, double-blind, placebo-controlled study of 177 people with hypercholesterolemia, a significant reduction in blood triglycerides and uric acid was observed with soy protein supplementation. The whole study lasted for 6 months and did not indicate a change in HDL, LDL and total cholesterol levels [11]. On the other hand among 203 postmenopausal women during a 6-month randomised, double-blind, placebo-controlled study, there was a significant reduction in triglycerides and total cholesterol level when consuming 40 g of soy flour [12]. In another randomised study of 26 people with the risk factors for CVD disease, patients consumed a fermented soy snack every day for 12 weeks. This study ended with a significant reduction in LDL and total cholesterol levels in the blood [13].

A meta-analysis of 35 RCTs (Randomised Controlled Trials) studies showed a significant reduction in LDL and total cholesterol levels. The effect on HDL level was negligible but statistically significant. The influence on triglycerides was not demonstrated. [7]

There are also studies which do not show any significant impact of soy consumption on lipid profile. In a cohort study conducted between 2002 and 2006, on 3885 men with no previous history of chronic disease, no significant reductions in lipid profile levels were found [14].

In conclusion, the results of numerous studies indicate a beneficial effect of soy products on lipid profile, especially in lowering LDL levels. Although the available evidence is promising, there is a need for further studies with well-defined study and control groups. Particular attention should be paid to differences in response between different age groups, genders and people with different diseases such as diabetes or hypertension.

The first author of the research	Yu Qin [11]	Zhao-min Liu [12]	Sarah M Jung [13]	Oluwabunmi A Tokede [7]	Danxia Yu a, Xianglan Zhang [14]
Publication year	2014	2014	2017	2015	2014
Type of research	Randomised controlled trial	Randomised controlled trial	Randomised controlled trial	Meta-analysis	Prospective cohort study
Country	China	China	USA	USA	China
Duration of the study	6 months	6 months	24 weeks	-	2002-2006
Sample size/ amount of research	177	270	27	35	3885
Gender	Women and	Women	Women and	Women and	Men

		men		men	men	
Age		40-65	48-65	29-75	28-83	40-74
Intervention	Research group	Soy isolated protein group with 40mg (DAI40) or 80 mg (DAI80)	70g/day of soy nuts with 101mg isoflavones	25g/day fermented soy	Depending on the study	-
	Placebo group	Soy isolated protein group (5 g/d) with 0 mg daidzein	65g/day of placebo cookies	30g/day germinated brown rice		-
Impact on HDL		No changes	No changes	No changes	↑	No changes
Impact on LDL		No changes	↓	↓	↓	No changes
Impact on triglycerides		↓	No changes	No changes	↓	No changes
Impact on total cholesterol		No changes	No changes	↓	No changes	No changes

Table 1. Summary of research related to lipid profile.

Impact of soy food on inflammatory biomarkers

Searching for ways to reduce inflammatory markers in our body is an important aspect of preventing cardiovascular disease. Studies showed a significant correlation between elevated levels of neutrophils, TNF-α, IL-6, IL-1 and CRP with the occurrence of CVD for example myocardial infarction, hypertension or heart failure [15,16].

Many studies have focused on demonstrating whether soy consumption can reduce levels of these biomarkers.

A cohort study investigating the effect of consuming soy products, conducted in China on a study group of 55474 men, aged 40-74 years with no history of chronic disease showed an increase in IL-8 and PAI-1 levels, while other biomarkers did not statistically change their value [14]. This study would not indicate that soy products have a beneficial effect on inflammatory markers, because an increase in IL-8 level occurs in conditions such as arteriosclerosis. This interleukin is associated with increased cardiovascular risk [17,18].

Similar impacts were obtained in a randomised, double-blind study among 17 people. During 4 weeks of soy nut intake, there was no reduction in CRP levels [19]. Another randomised

trial from 2013, conducted on a group of 102 people and lasting 8 weeks, showed that taking 40g of soy protein nutrition per day had no significant effect on biomarker levels such as CRP, IL-6 or TNF-α [20].

On the other hand, in a randomised study conducted in 2014 among 270 postmenopausal women, it was indicated that daily consumption of 40g of soy flour led to a significant reduction in CRP level [12]. In a comparison with another 2-month randomised study among 57 postmenopausal women, there was no significant reduction in inflammatory biomarkers apart from a reduction in TNF-α levels [21], despite consuming a soy diet.

In a meta-analysis of 31 systematic studies and 31 meta-analyses, significant reductions in IL-6 and TNF-α were observed during soy protein supplementation. In the age subgroup analysis, there was a significant reduction in TNF-α over 60-year-old patients. In the group in which the supplementation period lasted less than 8 weeks and with participants with BMI ≤ 25 kg/m2 a significant reduction in CRP was observed [22].

Soy products containing soy protein, isoflavones and other bioactive components show potential in modulation level of biomarkers of inflammation. Many studies indicate that soy intake can reduce levels of selected inflammatory markers, but even so, the results are inconclusive and depend on several factors such as population, dose and form of soy intake. Soy products may play a role in the modulation of inflammatory markers, especially in the context of the prevention of chronic diseases such as CVD. Nevertheless, further research on different populations and more emphasis on standardising interventions is needed.

Impact of soy food on vascular condition

Studies have shown that improving aortic elasticity allows the aorta to better cushion pulsatile blood pressure and reduce the load on peripheral vessels. Disorders of elasticity, such as aortic stiffness, are often associated with hypertension, atherosclerosis and coronary artery disorders. Higher elasticity of the vessels may protect the cardiovascular system from damage caused by the high pressure generated by the left ventricle [23].

A randomised study of 270 postmenopausal women, in which patients took 40g of soy per day in comparison with the control group showed no improvement in vascular health in CIMT (Carotid Intima-Media Thickness) which is an examination of the thickness of the carotid measured by ultrasound [12].

Another study showed a statistically significant improvement in the augmentation index during a 4-week intake of a soy snack compared to the control group [19]. The augmentation

index is a measurement of arterial stiffness, which is calculated as the fraction of augmentation pressure divided by the difference between systolic and diastolic pressure x100 [24].

The randomised controlled trial conducted on 102 people after 8 weeks of taking 40g of soy protein, showed a significant reduction in e-selectin protein [20]. E-selectin is an adhesion protein that allows leukocytes to migrate through the vascular wall to the site of inflammation, so its increased level is a marker of endothelial activation to oxidative stress. Along with leukocyte migration, epithelial damage can occur, which can ultimately lead to diseases such as hypertension [25]. A decrease in e-selectin would be associated with a decrease in inflammation in patients' bodies and a decrease in vascular epithelial degeneration.

In one other study, while taking 25,5g of soy protein daily for 16 weeks, there was a significant improvement in the FMD test (Endothelium-dependent flow-mediated dilatation test [26]) compared to the control group, which would indicate improved vascular epithelial function and better responsiveness to higher blood pressure [27].

A meta-analysis of 17 randomised trials from 2012 showed that consumption of isoflavone-rich soy products was associated with significant improvements in endothelial function measured by FMD. The benefits were dependent on the amount of isoflavones consumed. Higher doses (above 50 mg per day) had greater effects. Products rich in natural isoflavones, such as tofu, miso, or soy milk, were more effective than isoflavone supplements [28].

From the above studies, it can be concluded that isoflavone-rich soy products such as tofu can be an effective natural dietary element to support endothelial function and cardiovascular health.

The first author of the publication	Zhao-min Liu [12]	Elizabeth J Reverri [19]	CM Rebholz [20]	Lea Tischmann [27]	D.P. Beavers [28]
Publication year	2014	2015	2013	2022	2012
Type of research	Randomised controlled trial	Randomised controlled trial	Randomised controlled trial	Randomised controlled trial	Meta-analysis
Country	China	USA	USA	Netherlands	Depending on the study
Duration of the study	6 months	4 weeks	8 weeks	16 weeks	Depending on the study
Gender	Women	Women and men	Women and men	Women and men	Women and men

Sample size/ amount of research		270	17	102	23	17 RCTs
Age range(years)		48-65	>45	>22	60-70	Depending on the study
Intervention	Research group	40g/day soy flour (whole soy group) 40g/day low-fat milk powder + 63mg daidzein (daidzein group)	70g/day of soy nuts with 101mg isoflavones	40g/day of soybean protein supplement (89.3mg isoflavones),	67g/day of soy nuts providing 25.5g protein and 174mg isoflavones	Depending on the study
	Placebo group	40g day low-fat milk powder (placebo group)	65g/day of cookies	40g of milk protein supplement and 40g of complex carbohydrate placebo	Diet without soy nuts	Depending on the study
Results		No differences in CIMT test	Soy nut consumption reduced arterial stiffness	Soy protein supplementation reduces plasma levels of E-selectin	Brachial artery flow-mediated vasodilation was 1.48 percent points higher during soy nut intake.	There was a significant improvement in FMD test in response to isolated isoflavone

Table 2. Summary of research related to vascular condition.

Impact of soy food on blood pressure

Hypertension is a condition when the pressure in blood vessels is too high and it's above 140mmHg for systolic blood pressure and/or above 90mmHg for diastolic blood pressure.

This disease is a worldwide problem. The WHO estimates that 1.28 billion people aged 30-79 worldwide have hypertension, mostly stage II and about 46% of patients are unaware that they have the disease [29].

One meta-analysis searched 21 RCTs that described the consumption of various nuts on blood pressure in the adult population. The final analysis did not show that soy nut consumption affected blood pressure [30].

Another randomised, double-blind study was conducted among an interesting group-peritoneal dialysis patients. Patients in the soy isoflavones group received 100mg of soy isoflavones in two tablets daily for 8 weeks. Finally, the results did not indicate that systolic or diastolic blood pressure decreases significantly [31].

Another meta-analysis of 17 studies indicates that consumption of soy products was significantly associated with lowering systolic and diastolic blood pressure in comparison with the control group. Subgroup analyses showed greater reductions in blood pressure in participants under 56 years old and with lower baseline diastolic blood pressure. Additionally diastolic and systolic blood pressure were significantly reduced when the duration of soy consumption was < 16 weeks [32].

The next study on 60 postmenopausal women observed that taking 25g of soy protein per day for 4 weeks leads to a significant reduction in systolic blood pressure. It should be noted that better results were obtained in women with metabolic syndrome. Women without metabolic syndrome also achieved a decrease in blood pressure but only those that produced equal [33]. Equal is a metabolite produced from the soy protein daidzein by the gut microflora [34].

A 2021 randomised trial also examined the effects of soy on hypertension but they tried to correlate it with gut microbiota. Soy consumption was associated with reduced systolic blood pressure but only in a subgroup of people with a specific gut microbiome, which can suggest that the response to soy may depend on the composition of the gut microbiome.

Soy consumption was associated with differences in specific microbial taxa, mainly belonging to the genera Dialister and Prevotella, which appeared to be suppressed by high soy consumption. It was observed that the presence of Prevotella was associated with higher blood pressure and worse cardiometabolic profile, but only in the absence of Dialister bacteria [35].

A randomised controlled trial conducted among 80 participants tested the effect of consuming soy for 8 weeks. The study confirmed the effect of a few metabolites on reduced blood pressure levels such as 1-linoleoyl-GPE (18:2), 1-oleoyl-GPE (18:1), 1-stearoyl-2-linoleoyl-GPC (18:0/18: 2), 1-palmitoyl-2-oleoyl-GPE (16:0/18:1), maltose, N-stearoyl-sfinganine (d18:0/18:0) and N6-carbamoyltreonyladenosine. This study demonstrates the effects of these lipids in regulating blood pressure [36].

A meta-analysis analysing 11 randomised trials indicated that consumption of soy isoflavones was associated with a reduction in systolic blood pressure by an average of 2.5mmHg and 1.5mmHg for diastolic pressure compared to the control groups. Subgroup analysis showed that a greater reduction of blood pressure was seen in hypertensive subjects than in those with normal pressure, with a reduction in SBP (Systolic blood pressure) of 5.9mmHg (P = 0.01) and DBP (Diastolic blood pressure) of 3.4mmHg (P = 0.04). There were no significant changes in blood pressure in the subgroup of subjects with correct blood pressure. This study confirms that blood pressure can be lowered by soy isoflavones but only in hypertensive individuals, not in normotensive [37].

Another meta-analysis of 24 studies with a total of 1945 participants showed that soy isoflavones supplementation led to significant reductions in both SBP and DBP. Subgroup analyses suggested a more pronounced reduction in SBP and DBP for interventions lasting ≥6 months and also among patients with metabolic syndrome or prehypertension. However, no significant associations were detected between the supplementation dose and the duration of the intervention for changing the level of SBP and DBP [38].

Studies indicate that soy products may lead to lowering blood pressure, particularly in individuals with hypertension or an increased risk of CVD. This effect is mainly attributed to the content of soy protein such as isoflavones and other bioactive components that interact with mechanisms involved in blood pressure regulation.

The first author of the publication	Noushin Mohammadifard [30]	Mina Movahedian [31]	Zahra Mosallanezhad [32]	Subroto Acharjee [33]	Rachana D Shah [35]	X.X. Liu [37]	Yixi Sun [36]	Lifu Lei [38]
Publication year	2015	2021	2021	2014	2020	2012	2024	2024
Type of research	Meta-analysis	Randomised controlled trial	Meta-analysis	Randomised controlled trial	Case control study	Meta-analysis	Randomised controlled trial	Meta-analysis
Country	Depending on the study	Iran	USA/Asia/Europe	USA	USA	Depending on the study	USA	Depending on the study
Duration of the study	Depending on the study	8 weeks	Depending on the study	8 weeks	Single day study visit	Depending on the study	8 weeks	Depending on the study

Gender		Men and Women	Men and Women	Men and Women	Women	Men and Women	Men and Women	Men and Women	Men and Women
Sample size/ amount of research		1652	38	1898	60	132	1192	1131	1945
Age range (years)		18-86	≥ 18	50.32–66.8	50-59	18-50	≥ 18	medium 47,6	44-74
Intervention	Research group	Depending on the study	Received 100mg/day of isoflavones in tablets	Depending on the study	Therapeutic Lifestyle Changes (TLC) diet in which 0.5 cups of soy nuts	Obtained blood samples, stool samples and 3-day food records completed by patients	Depending on the study	I group- carbohydrate diet II group- milk protein diet III group - soy protein diet	Depending on the study
	Placebo group		Received two doses of corresponding placebo containing starch		Therapeutic Lifestyle Changes (TLC) diet alone				
Results		Meta-analysis did not show that soy nut consumption affected blood pressure.	The results did not indicate that blood pressure decreased significantly in the isoflavones group.	Results showed that soy consumption improves SBP and DBP.	Only equol producers among women with metabolic syndrome had significant reductions in diastolic blood	The specific microbiome may protect from hypertension while eating soy products	Soy isoflavone supplementation significantly decreased SBP and DBP	Dietary protein intervention might reduce BP	Soy isoflavone supplementation significantly decreased SBP and DBP

				pressure.				

Table 3. Summary of research related to blood pressure.

Impact of soy food on cardiovascular disease mortality

Several studies have emphasised that soy intake aggregately reduces the risk of death from cardiovascular disease.

One prospective cohort study involving 66832 Chinese women without any CVD disease found that high isoflavone intake was correlated with an increased risk of ischemic stroke [39], however, another prospective cohort study involving 13355 men and 15724 women aged ≥35 years from Japan found that natto (fermented soybean) consumption was associated with lower CVD mortality. This effect was attributed to natto's high nattokinase content, which promotes vascular health. Nattokinase is a serine proteinase that has a strong fibrinolytic effect [40]. Other soy products have not shown a clear effect [41].

Another case-control study examined the effect of dietary patterns (including soy) and showed that a diet rich in soy and legumes was associated with a lower risk of myocardial infarction, but that dietary patterns as a whole (healthy diet, low trans fat) had a greater effect than individual products [42].

A prospective cohort study of 40622 participants in Spain, followed for 13.6 years found that higher intakes of flavonoids and lignans, including isoflavones from soy, were associated with lower CVD mortality. The effect was stronger in populations adhering to a Mediterranean diet [43].

Another study of 1063 women over the age of 75 proved that women who had higher levels of salt intake including flavonoids showed a moderate protective effect on cardiovascular disease [44].

A prospective cohort study of 35303 women and 27954 men aged 45-74 from China did not find a significant association between soy consumption and CVD mortality. The possible effect may have been masked by other dietary and lifestyle factors in this population [45].

Similarly, a prospective cohort study of 12490 participants from Japan also demonstrated that soy consumption had no significant effect on CVD mortality. The effect may have depended on the type of soy products consumed (fermented vs. non-fermented)[46].

A meta-analysis from 2018 which included 20 cohort studies indicates that the highest soy intake was not associated with a lower CVD mortality. The differences in results may be due to the type of soy consumed and differences in study populations [47].

Based on the study it is likely that fermented soy products (e.g. natto) have greater cardiovascular protective potential probably because of additional components such as nattokinase. Soy may be part of a healthy diet, but its effect on CVD mortality depends on the dietary context and individual characteristics of the subjects.

Conclusions

The analysed studies highlight the potential impact of soy and soy product consumption on cardiovascular health. The evidence collected includes both interventional and observational studies demonstrating the diverse mechanism of action of isoflavones and other bioactive components of soy. The most important finding is that these effects are dependent on many factors, such as the type of soy consumed, the metabolic status of the subject, gut microbiota and overall health. It should be emphasised that it is reasonable that more studies should be generated regarding the effects of soy on lipidogram, inflammatory markers and other factors which have an impact on the cardiovascular system.

More attention should be paid to the diversity of the study group in terms of origin ensuring that the results are not limited to one country, as the results may vary depending on factors such as diet or lifestyle in that country. The effect of diet on people with hypertension is worth noting, as numerous studies have shown that isoflavones can help lower blood pressure. This lowering could lead to significant improvements in patients' overall health and quality of life.

Disclosure

Author's contribution

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Supervision: Aleksandra Walendzik, Łukasz Sencerek

Project administration: Aleksandra Walendzik, Łukasz Sencerek

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Conflict of Interest

The authors declare no conflict of interest.

All authors have read and agreed with the published version of the manuscript.

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