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THE IMPACT OF GARLIC USE ON HUMAN HEALTH. A REVIEW OF ITS THERAPEUTIC POTENTIAL AND APPLICATION IN ATHLETES.

Michał Borawski [MB]
Brothers Hospitallers of Saint John of God Hospital in Cracow
Trynitarska 11, 31-061 Cracow, Poland
https://orcid.org/0009-0008-4864-7336
michal.borawski1@gmail.com

Aleksandra Ciuła [AC]
Brothers Hospitallers of Saint John of God Hospital in Cracow
Trynitarska 11, 31-061 Cracow, Poland
https://orcid.org/0009-0000-0425-863X
ciula.aleksandra@gmail.com

Anna Jakubiak [AJ]
National Medical Institute of the Ministry of the Interior and Administration
Wołoska 137, 02-507 Warsaw, Poland
https://orcid.org/0009-0004-0973-7591
jakubiak.anna98@gmail.com

Joanna Miśkiewicz [JM]
Provincial Hospital in Kielce
Grunwaldzka 45, 25-736 Kielce, Poland
https://orcid.org/0009-0002-3300-940X
miskiewiczj10@gmail.com

Patrycja Znamirowska [PZ]
Specialist Hospital Dr Tytus Chałubiński in Radom
Lekarska 4, 26-610 Radom, Poland
https://orcid.org/0009-0002-7538-5315
znamirowskap@gmail.com

Tadeusz Kuźnieców [TK]
Międzylesie Specialist Hospital in Warsaw
Bursztynowa 2, 04-749 Warsaw, Poland
https://orcid.org/0009-0000-2120-9549
tadeusz.kuzniecow@gmail.com

Łukasz Karaban [ŁK]
Międzylesie Specialist Hospital in Warsaw
Bursztynowa 2, 04-749 Warsaw, Poland
https://orcid.org/0009-0001-9285-469X
ukaszkaraban@o2.pl

Monika Paszkowska [MP]
Międzylesie Specialist Hospital in Warsaw
Bursztynowa 2, 04-749 Warsaw, Poland
https://orcid.org/0009-0009-2006-0098
md.mpaszkowska@gmail.com

Klaudia Mularczyk [KM]
Międzylesie Specialist Hospital in Warsaw
Bursztynowa 2, 04-749 Warsaw, Poland
https://orcid.org/0009-0008-3250-7806
klaudia.mularczyk@gmail.com

Magdalena Kupis [MK]
Casimir Pulaski University of Radom, Faculty of Medical Sciences and Health Sciences
Chrobrego 27, 26-600 Radom, Poland
https://orcid.org/0009-0009-4454-5866
magdalenakupis13@gmail.com

Corresponding author: Michał Borawski [MB], michal.borawski1@gmail.com

Abstract

The abundance of bioactive compounds present in garlic positions it as a promising agent in the support of human health. This paper constitutes a review of scientific literature published over the past five years, with sources identified through a search of the PubMed database. The review explores the effects of garlic on hypertension, lipid metabolism, atherosclerosis, retinopathy, physical performance, organ perfusion, and the risk of developing certain malignancies — particularly gastric and prostate cancers. Current research indicates that regular garlic consumption may contribute to the reduction of blood pressure, improvement of lipid profiles, and attenuation of oxidative stress and inflammatory markers. Furthermore, it may decrease the risk of vascular complications and the incidence of selected cancers. Evidence also suggests a beneficial impact on cerebral perfusion and a reduction in symptoms of erectile dysfunction. Nonetheless, further clinical trials employing rigorous methodologies are required to definitively establish its efficacy.

Keywords: garlic, hypertension, cardiovascular disease, exercise, muscle adaptation, phytochemicals, cancer, retinopathy, brain perfusion.

1. Introduction

Allium sativum L., commonly known as common garlic, has had a dual role — culinary and medicinal — in many cultures for centuries. The sulfur compounds, flavonoids and other bioactive substances it contains, such as allicin or flavonoids, have been the subject of interest of scientists for years. Scientific reports suggest that the consumption of this plant may be associated with hypotensive, anti-atherosclerotic, anti-inflammatory and even anti-cancer effects. Despite numerous observations indicating a positive impact on human health, there is still no clear clinical evidence confirming its effectiveness in the prevention and treatment of chronic diseases. The aim of this study is to review the current literature on the effect of garlic on selected aspects of the body's functioning.

2. Methodology

The Pubmed search engine uses the search criteria MeSH Terms: *Garlic*. The study included studies from 2020 - 2025 and free access to the full text of the article. Using filters, papers of the "Clinical Trial" and "Randomized Controlled Trial" types were searched for. Then, after a meticulous review of the available literature, articles on the effects of garlic supplementation on human health and effects in athletes were included in the study.

3. Results

The table below shows the 14 articles included in the study.

Table 1. Articles included in the literature review

Aim of the study	Source doi	Brief characteristics
Antihypertensive effect of garlic extract in patients with stage I hypertension and pharmacological therapy.	10.3390/NU15173691	A significant reduction in blood pressure was achieved in the population of patients with stage I hypertension receiving pharmacological treatment.
Effect of Optimized Ripe Garlic Extract on Cardiovascular Disease Risk Factors in Subjects With Moderate Hypercholesterolemia.	10.3390/NU14030405	After 6 weeks of the study, garlic extract lowered diastolic blood pressure compared to placebo, especially in men with DBP > 75 mm Hg.
Oral supplementation of garlic extract after exercise and glycogen replenishment in skeletal muscles.	10.1080/15502783.2024.2336095	Skeletal muscle glycogen supplementation was significantly increased during the 3-hour recovery period for the garlic supplementation group.
Antioxidant and anti-inflammatory effects of	10.1080/15502783.2023.2206809	4 weeks of garlic supplementation alleviates

garlic. Impact on cycling performance.		exercise-induced oxidative inflammation and muscle damage during 40-kilometer cycling, but does not affect the cycling performance of healthy men.

Effects of black garlic consumption on endothelial function and lipid profile.	10.3390/NU15143138	A significant increase in apolipoprotein (Apo)A1 and a reduction in molecules that act destructive to the endothelium were obtained. Thus, endothelial function and lipid profile were improved.
Effects of taking garlic and onion extract in healthy people with elevated cholesterol levels.	10.3390/NU16162811	A significant reduction in LDL and total cholesterol was achieved among the participants. Additionally, improvements in blood pressure, oxidative and inflammatory markers were observed.
Evaluation of the effect of garlic tablet as an adjuvant treatment for patients with diabetic retinopathy.	10.1155/2022/6620661	Corrected visual acuity was significantly improved in patients treated with garlic compared to the placebo group. Intraocular pressure decreased by 1.03 mmHg under the influence of garlic, while it increased by 0.3 mmHg in the placebo group.
Association between lifestyle factors, vitamin supplementation and garlic, and gastric cancer outcomes.	10.1001/jamanetworkopen.2020.6628	It has been shown to reduce the risk of stomach cancer in people who consume garlic. A protective effect on mortality associated with garlic supplementation was observed only among people who did not

		drink alcohol.
Effect of fermented garlic extract containing nitric oxide metabolites on blood flow in healthy participants.	10.3390/NU14245238	There were significant reductions in blood pressure and an increase in blood flow velocity in both common carotid arteries, and a significant increase in regional cerebral blood flow and an increase in body surface temperature.
To evaluate the efficacy of concomitant administration of garlic and tadalafil in patients with erectile dysfunction who do not respond to tadalafil alone.	10.4103/ijp.ijp_310_23	Participants treated with garlic had a statistically significant improvement in the IIEF-EF score at the end of 4 weeks compared to placebo.
Effects of Encapsulated Purple Garlic Oil on Microvascular Functions and Components of Metabolic Syndrome.	10.3390/NU16111755	Peak skin microvascular flow during postocclusal reactive hyperemia increased significantly, hs-CRP levels decreased, and a significant reduction in the average number of MetS components in the study group was observed compared to the placebo group after five weeks of the study.

Effect of ripe garlic extract on the atherosclerotic process.	10.1186/S12906-020-02932-5	Garlic inhibits the progression of coronary artery calcification, lowers IL-6 levels, glucose, and blood pressure in patients at increased risk of cardiovascular events.
Effect of long-term treatment with mature garlic extract on peripheral tissue perfusion in patients with confirmed atherosclerosis.	10.1111/IWJ.13570	Mature garlic extract regenerates peripheral tissue perfusion and increases microcirculation in patients with atherosclerosis.
Did the consumption of garlic-derived allin cause the occurrence of potential bioactive compounds in the prostate?	10.3390/NU14163263	Allin and metabolites were detected in the prostate, but there was no significant difference in the concentrations of these compounds in the prostate of men consuming garlic-derived supplements compared to men not consuming these supplements.

4. Discussion

4.1. Hypertension

Studies have been conducted to evaluate the effect of garlic consumption on blood pressure
in different social groups. The first one concerned the antihypertensive effect of garlic extract in patients with stage I hypertension and pharmacological therapy, and the second evaluated the effect of optimized ripe garlic extract on cardiovascular disease risk factors in people with moderate hypercholesterolemia.

The results of both studies indicate the potential benefits of using optimized mature black garlic extract (ABG) in regulating blood pressure, however, with varying degrees of efficacy depending on the study conditions and the participant population.

A study [1] conducted on patients with stage I hypertension showed a small but clinically significant reduction in systolic blood pressure (by 1.8 mmHg) and diastolic blood pressure (by 1.5 mmHg) after 12 weeks of supplementation. Although this reduction was smaller than the values considered breakthrough in cardiovascular prevention, the literature indicates that even a small reduction in blood pressure can reduce the risk of cardiovascular events and mortality [2]. Each reduction in systolic blood pressure by 10 mmHg is associated with a 13% reduction in the risk of cardiovascular events and mortality [3]. Other data say that lowering systolic blood pressure by 2 mmHg can lead to a reduction in mortality from stroke by about 10% and a reduction in the risk of death from coronary heart disease by 7% in middle age [4]. Moreover, the observed effects were more pronounced in home measurements, suggesting greater reliability and a potentially stronger effect of ABGs in the natural living conditions of patients [5].

A study [6] involving people with moderate hypercholesterolemia found a significant reduction in diastolic blood pressure of 5.85 mmHg after six weeks of ABG supplementation, especially among men with baseline DBP above 75 mmHg. Importantly, no significant changes were reported in systolic blood pressure or in the lipid profile of participants, suggesting that the mechanism of action of ABGs may be more targeted at regulating vascular resistance than at lipid effects. In addition, the product was well tolerated and the side effects were few and mild.

Together, the two studies provide evidence of moderate efficacy of ABG extract in regulating blood pressure, especially in diastolic pressure, which may be important for the prevention of cardiovascular disease. The effects of ABGs appear to be dependent on patient characteristics – a greater reduction in diastolic blood pressure in the second study suggests that supplementation may be particularly beneficial for people with elevated DBP. Despite the limited effect on the lipid profile, these results indicate the potential use of ABGs as an adjunct to the treatment of hypertension, especially in milder forms requiring small but clinically significant reductions in blood pressure.

4.2. Sport

In 2023 and 2024, the results of research studies evaluating the effect of garlic supplementation on the effects in athletes were published. Study one [7] describes the effect of post-exercise garlic extract intake on skeletal muscle glycogen replenishment in athletes. The second study [8] had the antioxidant and anti-inflammatory effects of garlic, affecting cycling performance.

Both studies provided valuable information about its potential benefits. In the first study [7], plasma glucose levels in the garlic-supplemented group were significantly lower than in the placebo group after both 30 and 120 minutes of recovery. Despite these differences in glucose levels, no significant differences in insulin response were observed between the two groups. After supplementation with garlic extract, muscle glycogen levels increased significantly compared to the placebo group. However, the expression of GLUT4 mRNA and proteins showed no significant changes after garlic consumption after exercise. On the basis of the analysis of gas exchange, no significant differences in the rate of fat oxidation between the two groups were found. Lipolysis, as assessed by free plasma fatty acid levels, was

comparable to garlic and placebo. In addition, no significant changes in the expression of ATP citrate lyase or citrate synthetase were observed in the garlic-supplemented group. During exercise recovery, there were also no differences in the expression of proteins related to mitochondrial biogenesis between the two groups.

A study [8] that looked at the effects of 4-week GA supplementation on athletic performance and oxidative stress found no improvement in the 40-kilometer cycling trial, but significantly increased the body's total antioxidant capacity and reduced levels of markers of oxidative stress (MDA), inflammation (TNF-α) and muscle damage (LDH). No significant differences were noted in the following parameters: glucose level, free fatty acids, IL-6, creatine kinase, uric acid. The gas exchange coefficient was also comparable in both groups.

The results suggest that garlic extract supplementation may promote muscle recovery by increasing glycogen restoration and reducing oxidative stress and inflammation, which may be beneficial for physically active people. However, the lack of significant effect on GLUT4 expression and mitochondria and the lack of improvement in physical performance indicate that GA supplementation does not have a direct effect on improving performance parameters. However, it can have a protective effect, reducing the negative effects of intense physical exercise, making it a potentially valuable addition to the recovery strategies of athletes and physically active people.

4.3. Atherosclerosis and lipid disorders

Black garlic and endothelial function and lipid profile [9]

The study evaluated the effects of long-term consumption of black garlic on cardiovascular health in people with hypercholesterolemia and healthy people. For 12 weeks, participants consumed 4 cloves (12 g) of black garlic per day.
The results showed:

- significant increase in ApoA1 levels in both groups: hypercholesterolemia (Δ 11.8 mg/dL) vs Healthy (Δ 11.1 mg/dL)

- significant reduction for MCP-1 endothelial adhesion molecules - by 13.9% and 7.2%, respectively, in the hypercholesterolaemia and healthy groups
- significant reduction of ICAM-1 - 10.6% in the hypercholesterolemia group and 15.7% in the healthy group
- reduction of the VCAM-1 molecule - a significant decrease in the hypercholesterolemia group by 12.5%
- An increase in HDL cholesterol levels in healthy people and stabilization of LDL levels in the group with hypercholesterolemia were also noted.

The study suggests that black garlic may benefit endothelial health and reduce inflammation.

Garlic and onion extract in the control of hypercholesterolemia [10]

The study included 66 healthy participants living in the capital city of Granada (Spain) and had LDL cholesterol levels ranging from 100 to 190 mg/dL. Volunteers were given a supplement containing onion and garlic extract for 8 weeks. During the examination, biochemical parameters were measured: LDL cholesterol, total cholesterol, HDL cholesterol, triglycerides, glucose, alanine aminotransferase (ALT), asparraginate aminotransferase (AST), gamma-glutamyl transferase and creatinine. In the group receiving the supplement, a significant reduction in LDL and total cholesterol levels was observed, especially in people with elevated LDL levels above 110 mg/dL. In addition, a reduction in the level of oxidized LDL was demonstrated, which indicates the potential antioxidant effect of the supplement. However, no significant changes were observed in HDL cholesterol or glucose levels, but an improvement in blood pressure was noted, suggesting additional benefits for the cardiovascular system. During the intervention period, various variables associated with oxidative and inflammatory status were assessed, including oxidized LDL, NO, MDA, IL-1β, IL-10, and IL-6. IL-1β and IL-10. Participants treated with the preparation showed a significant reduction in oxidized LDL levels. Other changes were not detected because the participants were healthy subjects. What is important, however, is a significant reduction in oxidized levels of LDL, which serve as a marker of oxidative stress and inflammation and are critical in the pathogenesis of cardiovascular disease, after as little as 2 weeks of treatment, with further improvements noted at 4 weeks and 8 weeks, by 10%, 16%, and 32%, respectively.

Long-term effects of ripe garlic on heart health [11]

A third study focused on evaluating the effects of aged garlic extract (AGE) on the progression of coronary artery calcifications (CACs) and the outcomes of changes in blood pressure, fasting blood glucose, blood lipids, and inflammatory biomarkers in 104 patients at elevated risk of cardiovascular disease. Computed tomography was used to measure CAC.
In the group taking AGE 2400 mg per day for 12 months, a significant reduction in the progression of CAC, IL-6 and blood glucose levels was observed. There was also a significant decrease in systolic blood pressure in the AGE group from an average of 148 mmHg to 140 mmHg after 12 months. Most of the patients in the study had medication for hypertension and hypercholesterolemia when they entered the study.

The presented research provides evidence for the beneficial effects of garlic and its derivatives on cardiovascular health – it can improve endothelial function and lower inflammatory markers, effectively reduce LDL levels, slow the progression of atherosclerosis and lower blood pressure. These results point to garlic's potential as a natural agent to support the prevention and treatment of cardiovascular disease.

4.4. Retinopathy

The study aimed to evaluate the effectiveness of garlic tablets as an herbal medicine in the treatment of diabetic macular edema. The double-blind study involved 91 diabetic patients (117 eyes) who were diagnosed with central macular edema. Participants were randomly assigned to receive garlic tablets (500 mg, 2 tablets per day) or placebo. The treatment lasted four weeks, after which the patients were evaluated by an ophthalmologist.

Corrected visual acuity (BCVA, logMAR), central macular thickness (CMT, μm) and intraocular pressure (IOP) were measured as the main efficacy measures of treatment. Preliminary laboratory results showed that the mean fasting glucose level (FBS) in the garlic

group was 175.06 mg/dL and in the control group was 177.5 mg/dL, which did not indicate a significant difference. Similarly, analysis of glycated hemoglobin (HbA1c) levels showed no significant changes between groups.

At baseline, the mean BCVA (logMAR) was 0.93 in the garlic group and 0.85 in the placebo group. After four weeks, patients taking garlic saw a more significant improvement in visual acuity, with an average logMAR decreaseof 0.18, compared to only 0.06 in the placebo group.

The initial mean macular thickness (CMT) was 513.66 μm in the garlic group and 501.39 μm in the control group. After four weeks, the decrease in CMT in the garlic group was 102.99 μm, and in the placebo group it was 52.67 μm. Although patients using garlic reported a greater reduction in CMT, this difference was not statistically significant.

As for intraocular pressure (IOP), its mean baseline values were 15.40 mmHg in the garlic group and 15.51 mmHg in the placebo group. After four weeks, IOP in the garlic group decreased by an average of 1.03 mmHg, while in the placebo group it increased by 0.3 mmHg. The statistical test showed that the IOP-lowering effect of garlic was significant compared to placebo.

In conclusion, four-week supplementation with garlic tablets contributed to improved visual acuity and reduced intraocular pressure in patients with diabetic macular edema. On the other hand, the decrease in macular thickness, although greater in the garlic group, did not reach statistical significance. [12]

4.5. Stomach cancer

In 2020, the results of an intervention study [13] were published in Linqu. The aim of the study was to assess the effect of two-week Helicobacter pylori eradication therapy and long-term 7.3-year vitamin and garlic supplementation on the progression of precancerous gastric lesions and the risk of gastric cancer [14],[15],[16],[17],[18].

During a total follow-up period of 22.3 years, garlic supplementation was found to reduce mortality from this cancer. However, it was noted that garlic supplementation was associated with reduced mortality among people who had never consumed alcohol, while in people who

drank alcohol, this effect was not seen. Significant interactions between alcohol consumption and garlic supplementation were noted only among participants infected with H. pylori – in non-drinkers, protection against mortality from gastric cancer was statistically significant, while in alcohol users no such effect was observed.

Allyl sulfur compounds contained in garlic exhibit anticancer activity by inhibiting the activation of carcinogens, modulating their metabolism and limiting the formation of DNA adducts with carcinogenic substances [19]. Alcohol, on the other hand, has a harmful effect on the gastric mucosa, causing direct DNA damage [20] and inflammation [21].

4.6. Prostate cancer

A study [22] was conducted to check whether the consumption of alliin derived from garlic and glucoraphanin from broccoli seeds leads to the presence of these bioactive compounds in the prostate. A randomized, double-blind, four-week interventional study on dietary supplementation recruited 42 men enrolled for transperineal prostate biopsy, 39 of whom completed the study. Two active interventions included supplements providing glucoraphanin from broccoli (BroccoMax®) and alliin from garlic (Kwai Heartcare®).

Urinalysis showed significantly higher concentrations of alliin and its metabolites in participants who took the alliin supplement compared to those who did not take it. Despite this, alliin consumption had no effect on its concentration or the concentration of its metabolites in the prostate, even after excluding outliers. Some evidence suggested a higher concentration of alliin metabolites in the prostate transition zone in men taking the supplement compared to controls, but no such relationship was observed in the peripheral zone.

Glucoraphanin supplementation significantly increased sulforaphane levels in the prostate gland. Interestingly, traces of sulforaphane and sulforaphane-N-acetylcysteine were also detected in the prostate of placebo participants. The average intake of cruciferous vegetables during the study period was one serving per week, suggesting that the presence of these compounds in the placebo group may have been due to their habitual consumption.

Results indicate that the presence of alliin and the accumulation of sulforaphane in prostate tissue can have local effects on both healthy and cancerous cells. These mechanisms may explain the reduced risk of prostate cancer and its progression as a result of the consumption of cruciferous vegetables. However, there is a lack of more data to draw unambiguous conclusions.

4.7. Blood flow and tissue perfusion

Four studies have been conducted to evaluate the effects of garlic on tissue perfusion and blood flow in the arteries.

Effect of fermented garlic extract containing nitric oxide metabolites on blood flow in healthy participants [23]

Aged or fermented garlic (FGE) extract is a natural remedy to improve blood vessel function by increasing the bioavailability of nitric oxide (NO). The study looked at the effects of NO_2^- in FGE on blood flow (BF), blood pressure (BP), flow velocity in the common carotid artery (CCA) and internal carotid artery (ICA), regional cerebral blood flow (rCBF) and peripheral blood flow (PBF).

In the placebo group, the initial systolic and diastolic blood pressure were about 133.4 mmHg and 84.20 mmHg, respectively, and the heart rate was an average of 80 beats per minute. After ingestion of the placebo tablet, there was a slight decrease in systolic and diastolic blood pressure, but these changes were not statistically significant. In the FGE group, mean baseline BP values were 124.0 mmHg for systolic blood pressure and 79.4 mmHg for diastolic blood pressure. After 30 minutes after taking the FGE tablet, systolic blood pressure decreased by an average of 16.93 mmHg and diastolic blood pressure by 12.34 mmHg, which was a statistically significant difference compared to baseline.

The blood flow velocity in CCA and ICA was assessed by Doppler ultrasonography before and after ingestion of the study specimens. In the placebo group, the peak systolic velocity (Psv) in the right CCA was 22.2 cm/s before and 22.4 cm/s after 30 minutes. In the FGE group, the right CCA was 24.4 cm/s before ingestion and 19.9 cm/s after 30 minutes. Statistical analysis showed a significant reduction in Psv and peak diastolic flow velocity

(Edv) in the right CCA, right ICA and left CCA in the FGE group. No significant changes in these parameters were noted in the placebo group.

Changes in regional cerebral blood flow (rCBF) were assessed by Tc-99m HMPAO SPECT imaging before and after ingestion of the study specimens. In the FGE group, statistically significant changes were observed in the right and left frontal cortex - Brodmann areas 6, 9 and 10, and in the right parietal cortex - Brodmann area 2, while no significant differences were found in the placebo group.

Similar statistically significant changes in blood flow were noted in the extremities, especially in the back of the forearm, palms and soles of the feet, but these effects were only in the FGE group. There were no significant changes in perfusion of these areas in the placebo group.

To evaluate the efficacy of concomitant administration of garlic and tadalafil in patients with erectile dysfunction who do not respond to tadalafil alone [24]

The aim of the study was to determine the efficacy of the concomitant use of garlic as a hydrogen sulphide donor – H2S and tadalafil in patients with erectile dysfunction who responded poorly to tadalafil alone. The participants were divided into two groups – one took garlic twice a day and the other a placebo, while taking tadalafil at the same time. The results showed a significant improvement in erectile function in the garlic group, as assessed by the International Index of Erectile Function (IIEF-EF). This suggests that the synergistic effects of H2S and NO may improve erectile function and provide an alternative treatment strategy for patients who do not achieve satisfactory results with PDE5 inhibitor alone.

Effects of encapsulated purple garlic oil on microvascular functions and components of metabolic syndrome [25]

The ENDOTALLIUM study evaluated the effects of encapsulated purple garlic oil on microvascular function, endothelial biomarkers, and metabolic syndrome (MetS) parameters in individuals with cardiometabolic risk factors. The study involved 52 subjects with at least one component of MetS, randomized to an intervention group and placebo. After five weeks of using garlic oil, an improvement in microvascular function, a reduction in inflammation (reduction of hs-CRP levels) and a reduction in the number of MetS ingredients were noted.

Analysis of endothelial biomarkers showed a significant reduction in VCAM-1, although the differences between the groups were not statistically significant. In addition, metabolic parameters such as glucose, triglycerides, and HDL cholesterol levels were improved in the garlic group, while no significant changes were observed in the placebo group.

Effect of long-term treatment with aged garlic extract on peripheral tissue perfusion in patients with confirmed atherosclerosis [26]

The aim of the study was to investigate the effect of long-term supplementation of aged garlic extract (AGE) on peripheral tissue perfusion in patients with atherosclerosis. The study involved 93 patients who took either AGE or placebo for one year. Perfusion assessment was performed using Laser Speckle Contrast Imaging before and after the intervention period. The results showed a significant increase in tissue perfusion in the AGE group compared to placebo. Similarly, endothelial function was improved, as measured by iontophoresis and acetylcholine (Ach) challenge. The relative improvement in tissue perfusion and microcirculation function suggests that AGEs may support wound healing processes and improve peripheral circulation in patients with atherosclerosis.

5. Summary

Allium sativum L. It has numerous health-promoting properties that can support the prevention and treatment of many diseases. Studies have shown that:

- It lowers blood pressure, reducing cardiovascular risk.
- It improves lipid metabolism, reducing total cholesterol, LDL cholesterol and triglycerides.
- It inhibits the progression of atherosclerosis thanks to its anti-inflammatory and antioxidant effects.
- It protects microcirculation and the retina of the eye by reducing oxidative stress and improving blood flow.
- Improves visual acuity in patients with diabetic retinopathy
- Supports muscle regeneration by increasing glycogen regeneration and reducing oxidative stress and inflammation

- It can reduce the risk of certain cancers, such as stomach cancer, by affecting detoxification enzymes and inflammatory processes. However, no direct effect on prostate cancer has been demonstrated.
- Improves tissue perfusion – a significant increase in regional cerebral blood flow and an increase in body surface temperature and a reduction in erectile dysfunction have been demonstrated.

While the results of many analyses are encouraging, it is important to note that not all data are conclusive. It is necessary to conduct further, well-designed clinical trials that will allow for a reliable assessment of the impact of this plant on human health.

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Authors do not report any disclosures.

Author's contributions

Conceptualization: MB, AC;
Methodology: MB, AC
Software: n/a; check: MB, TK, ŁK;
Formal analysis: ŁK, AC, TK;
Investigation: MB, ŁK, AC, MP, KM;
Resources: MB;
Data curation: MB, ŁK, MP, KM, PZ, JM, AC, AJ, MK;
Writing - rough preparation: MB, AC, ŁK, JM;
Writing - review and editing: MB, MP, KM, PZ, JM, AC, AJ, MK;
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Conflict of Interest Statement

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References:

[1] Serrano JCE, Castro-Boqué E, García-Carrasco A, et al. Antihypertensive Effects of an Optimized Aged Garlic Extract in Subjects with Grade I Hypertension and Antihypertensive Drug Therapy: A Randomized, Triple-Blind Controlled Trial. *Nutrients*. 2023; 15(17):3691. Published 2023 Aug 23. doi:10.3390/nu15173691

[2] Canoy D, Nazarzadeh M, Copland E, et al. How Much Lowering of Blood Pressure Is Required to Prevent Cardiovascular Disease in Patients With and Without Previous Cardiovascular Disease?. *Curr Cardiol Rep*. 2022; 24(7):851-860. DOI:10.1007/S11886-022-01706-4

[3] Ettehad D, Emdin CA, Kiran A, et al. Blood pressure lowering for prevention of cardiovascular disease and death: a systematic review and meta-analysis. *Lancet*. 2016; 387(10022):957-967. doi:10.1016/S0140-6736(15)01225-8

[4] Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies [published correction appears in Lancet. 2003 Mar 22; 361(9362):1060]. *Lancet*. 2002; 360(9349):1903-1913. doi:10.1016/s0140-6736(02)11911-8

[5] Bliziotis IA, Destounis A, Stergiou GS. Home versus ambulatory and office blood pressure in predicting target organ damage in hypertension: a systematic review and meta-analysis. *J Hypertens*. 2012; 30(7):1289-1299. doi:10.1097/HJH.0b013e3283531eaf

[6] Valls RM, Companys J, Calderón-Pérez L, et al. Effects of an Optimized Aged Garlic Extract on Cardiovascular Disease Risk Factors in Moderate Hypercholesterolemic Subjects: A Randomized, Crossover, Double-Blind, Sustained, and Controlled Study. *Nutrients*. 2022; 14(3):405. Published 2022 Jan 18. doi:10.3390/nu14030405

[7] Cheng IS, Tsao JP, Bernard JR, Tsai TW, Chang CC, Liao SF. Oral post-exercise garlic extract supplementation enhances glycogen replenishment but does not up-regulate mitochondria biogenesis mRNA expression in human-exercised skeletal muscle. *J Int Soc Sports Nutr*. 2024; 21(1):2336095. doi:10.1080/15502783.2024.2336095

[8] Tsao JP, Bernard JR, Tu TH, et al. Garlic supplementation attenuates cycling exercise-induced oxidative inflammation but fails to improve time trial performance in healthy adults. *J Int Soc Sports Nutr*. 2023; 20(1):2206809. doi:10.1080/15502783.2023.2206809

[9] Villaño D, Marhuenda J, Arcusa R, et al. Effect of Black Garlic Consumption on Endothelial Function and Lipid Profile: A Before-and-After Study in Hypercholesterolemic and Non-Hypercholesterolemic Subjects. *Nutrients*. 2023; 15(14):3138. Published 2023 Jul 14. doi:10.3390/nu15143138

[10] Vezza T, Guillamón E, García-García J, et al. LDL-Cholesterol-Lowering Effects of a Dietary Supplement Containing Onion and Garlic Extract Used in Healthy Volunteers. *Nutrients*. 2024; 16(16):2811. Published 2024 Aug 22. doi:10.3390/nu16162811

[11] Włosińska M, Nilsson AC, Hlebowicz J, et al. The effect of aged garlic extract on the atherosclerotic process - a randomized double-blind placebo-controlled trial. *BMC Complement Med Ther*. 2020; 20(1):132. Published 2020 Apr 29. doi:10.1186/s12906-020-02932-5

[12] Afarid M, Sadeghi E, Johari M, Namvar E, Sanie-Jahromi F. Evaluation of the Effect of Garlic Tablet as a Complementary Treatment for Patients with Diabetic Retinopathy. *J Diabetes Res*. 2022;2022:6620661. Published 2022 Jul 14th doi:10.1155/2022/6620661

[13] Guo Y, Li ZX, Zhang JY, et al. Association Between Lifestyle Factors, Vitamin and Garlic Supplementation, and Gastric Cancer Outcomes: A Secondary Analysis of a Randomized Clinical Trial. *JAMA Netw Open*. 2020; 3(6):e206628. Published 2020 Jun 1. doi:10.1001/jamanetworkopen.2020.6628

[14] Gail MH, You WC, Chang YS, et al. Factorial trial of three interventions to reduce the progression of precancerous gastric lesions in Shandong, China: design issues and initial data. *Control Clin Trials*. 1998; 19(4):352-369. doi:10.1016/s0197-2456(98)00016-6

[15] You WC, Brown LM, Zhang L, et al. Randomized double-blind factorial trial of three treatments to reduce the prevalence of precancerous gastric lesions. *J Natl Cancer Inst*. 2006; 98(14):974-983. DOI:10.1093/jnci/DJJ264

[16] Ma JL, Zhang L, Brown LM, et al. Fifteen-year effects of Helicobacter pylori, garlic, and vitamin treatments on gastric cancer incidence and mortality. *J Natl Cancer Inst*. 2012; 104(6):488-492. doi:10.1093/jnci/djs003

[17] Li WQ, Ma JL, Zhang L, et al. Effects of Helicobacter pylori treatment on gastric cancer incidence and mortality in subgroups. *J Natl Cancer Inst*. 2014; 106(7):d ju116. Published 2014 Jun 12. doi:10.1093/jnci/dju116

[18] Li WQ, Zhang JY, Ma JL, et al. Effects of *Helicobacter pylori* treatment and vitamin and garlic supplementation on gastric cancer incidence and mortality: follow-up of a randomized intervention trial. *BMJ.* 2019; 366:L5016. Published 2019 Sep 11. doi:10.1136/bmj.l5016

[19] Milner JA. A historical perspective on garlic and cancer. *J Nutr*. 2001; 131(3s):1027S-31S. doi:10.1093/jn/131.3.1027S

[20] Capurso G, Lahner E. The interaction between smoking, alcohol and the gut microbiome. *Best Pract Res Clin Gastroenterol*. 2017; 31(5):579-588. doi:10.1016/j.bpg.2017.10.006

[21] Lee IC, Baek HS, Kim SH, et al. Effect of diallyl disulfide on acute gastric mucosal damage induced by alcohol in rats. *Hum Exp Toxicol*. 2015; 34(3):227-239. doi:10.1177/0960327114537095

[22] Livingstone TL, Saha S, Bernuzzi F, et al. Accumulation of Sulforaphane and Alliin in Human Prostate Tissue. *Nutrients*. 2022; 14(16):3263. Published 2022 Aug 10. doi:10.3390/nu14163263

[23] Baik JS, Min JH, Ju SM, et al. Effects of Fermented Garlic Extract Containing Nitric Oxide Metabolites on Blood Flow in Healthy Participants: A Randomized Controlled Trial. *Nutrients*. 2022; 14(24):5238. Published 2022 Dec 8. doi:10.3390/nu14245238

[24] Bhat G.S., Shastry A. Prospective, randomized, placebo-controlled, two-arm study to evaluate the efficacy of coadministration of garlic as a hydrogen sulfide donor and tadalafil in patients with erectile dysfunction not responding to tadalafil alone - A pilot study. *Indian J Pharmacol*. 2024; 56(4):242-247. doi:10.4103/ijp.ijp_310_23

[25] Bara-Ledesma N, Jimenez-Esteban J, Fabregate M, et al. Effect of Encapsulated Purple Garlic Oil on Microvascular Function and the Components of Metabolic Syndrome: A Randomized Placebo-Controlled Study-The ENDOTALLIUM Study. *Nutrients*. 2024; 16(11):1755. Published 2024 Jun 3. doi:10.3390/nu16111755

[26] Lindstedt S, Włosinska M, Nilsson AC, Hlebowicz J, Fakhro M, Sheikh R. Successful improved peripheral tissue perfusion was seen in patients with atherosclerosis after 12 months of treatment with aged garlic extract. *Int Wound J*. 2021; 18(5):681-691. doi:10.1111/iwj.13570