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CARDIOPROTECTIVE EFFECTS OF CURCUMA LONGA L

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The purpose of the study was to analyze the literature on the phytochemistry and basic pharmacological properties that can realize the cardioprotective effect of Curcuma longa L and the results of experimental and clinical studies of its use for cardiovascular pathology. Curcumin is the main active ingredient of turmeric, which has a wide range of biological and pharmacological activities. The article presents an analysis of studies that have investigated the antioxidant, anti-inflammatory effects of curcumin and its influence on endothelial function and lipid metabolism. Curcumin's molecular targets are diverse, ranging from transcription factors, growth factors and their receptors, cytokines and enzymes to proteins that regulate cell proliferation and apoptosis. Experimental studies show that curcumin has a positive effect on myocardial ischemia-reperfusion injury, helps to inhibit cardiomyocyte hypertrophy, myocardial fibrosis and ventricular remodeling, which emphasizes the feasibility of studying additional curcumin administration in heart failure to confirm and quantify its therapeutic effect.

Key words: phytotherapy, Curcuma longa l, curcumin, lipid metabolism, heart remodeling.

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КАРДІОПРОТЕКТОРНІ ЕФЕКТИ CURCUMA LONGA L

Метою дослідження був аналіз літературних джерел щодо фітохімії та основних фармакологічних властивостей, здатних реалізувати кардіопротективну дію Curcuma longa L та результатів експериментальних та клінічних досліджень її використання при серцево-судинній патології. Куркумін основний активний інгредієнт куркуми, який має широкий спектр біологічної та фармакологічної активності. Представлений аналіз досліджень, в яких вивчалась антиоксидантна, протизапальна дія куркуміну та його вплив на функці. ендотелію, ліпідний обмін. Молекулярні мішені куркуміну різноманітні, починаючи від факторів транскрипції, факторів росту та їх рецепторів, цитокінів і ферментів до білків, що регулюють проліферацію та апоптоз клітин. Експериментальні дослідження свідчать про те, що куркумін позитивно впливає на ішемічно-реперфцзійне пощкодження міокарда, сприяє пригніченню гіпертрофії кардіоміоцитів, фіброзу міокарда та ремоделювання шлуночків, що підкреслює доцільність вивчення додаткового призначення куркуміну при серцевій недостатності для підтвердження та кількісної оцінки його терапевтичного ефекту.

Ключові слова: фітотерапія, Curcuma longa l, куркумін, ліпідний обмін, ремоделювання серця.

The work is a fragment of the research project "To determine the features of immuno-cytokine imbalance in comorbid patients with hypertension and type 2 diabetes and cardiovascular and renal complications", state registration No. 0123U101711.

Cardiovascular disease is the leading cause of death worldwide. According to the World Cardiovascular Disease Report 2023, cardiovascular disease affects more than 500 million people worldwide [43]. It is expected that by 2030, the annual number of deaths from cardiovascular disease will increase to 23.6 million [3]. In addition, there is an increase in the frequency of risk factors for cardiovascular disease, the main ones being hypertension, hypercholesterolemia, diabetes mellitus, overweight and obesity [43].

Medicinal plants and their biologically active components have found practical application in the treatment and prevention of various diseases of humans and animals in traditional and non-traditional medicine. Phytomedicines are especially popular in developing countries due to their low cost.

Various medicinal plants have been used in the treatment of cardiovascular diseases, based on tradition and long-standing experience. However, their pharmacological principles of action are much less known [32]. Herbal preparations usually contain a mixture of potentially active compounds that can exert diverse effects.

Turmeric (Curcuma longa L) is a plant of the Curcuma family. This medicinal plant is native to India, but today it is widely cultivated in regions such as China, Sri Lanka, West and East Africa, and other tropical countries. It is used in Asian countries as a flavoring and coloring agent for foods. Turmeric and curcumin are included in the list of food additives by the World Health Organization and the Food and Agriculture Organization of the United Nations.

Curcumin, isolated from the rhizome of Curcuma longa L, has been widely studied in various pathological conditions. The biologically active substances of Curcuma longa have been found to have a variety of pharmacological effects, including immune regulation, antimicrobial activity, antithrombotic,

anti-inflammatory, analgesic, antiviral, antitumor, neuroprotective and antioxidant properties [9]. However, the protective effects of curcumin in cardiovascular diseases are not fully understood.

Curcumin is the main component of Curcuma longa L., which has been shown to have many cardioprotective effects. However, the cardioprotective potential of curcumin remains incompletely understood.

The purpose of the study was to analyze the literature on the phytochemistry and main pharmacological properties capable of realizing the cardioprotective effect of Curcuma longa L, and the results of experimental and clinical studies of its use in cardiovascular pathology.

Chemical composition.

The rhizomes of Curcuma longa contain the greatest diversity of chemical constituents, which include polyphenols, monoterpenes, flavonoids, curcuminoids, carotenes, alkaloids. Turmeric consists of three curcuminoids (2–5 %), namely curcumin, bisdemethoxycurcumin and demethoxycurcumin, with curcumin being the main component (77 %) and giving turmeric its typical yellow color [12].

Turmeric also contains saponins, tannins, anthraquinones, alkaloids, carbohydrates, coumarins, steroids, diterpenes, proteins, and glycosides [9]. Other key components of turmeric include light oils (turmerone, atlantone, zingiberone, etc., 3–7 %), resins (including terpenoids, triterpenoids, phenylpropenes, etc., trace amounts), alkaloids (trace amounts), carbohydrates (60–70 %), fats (5–10 %), proteins (6–8 %), fiber (2–7 %), trace elements (potassium, sodium, magnesium, calcium, manganese, iron, copper, zinc), and water (6–13 %) [29].

Therefore, curcumin is a polyphenolic compound that belongs to a class of substances known as curcuminoids and can interact with various biological macromolecules in the body, including proteins, nucleic acids, and lipids. Curcumin is a potent antioxidant and free radical scavenger that can prevent the production of a variety of oxidative free radicals in the biological environment [35].

Antioxidant effect.

Oxidative stress is closely linked to the aging process and plays a crucial role in the development of chronic inflammation [35]. It occurs when there is an imbalance in the balance between the generation of reactive oxygen species (ROS) and the body's protective antioxidant mechanisms [29]. Increased levels of ROS can lead to lipid peroxidation, which leads to the formation of malondialdehyde (MDA), a marker of oxidative stress-induced damage. MDA has been shown to promote the activation of inflammatory pathways and the release of pro-inflammatory cytokines, which further exacerbate the inflammatory response [35].

Curcumin effectively neutralizes free radicals—unstable molecules that cause oxidative stress and cell damage, contributing to aging and various chronic diseases, including cardiovascular disorders, diabetes, and neurodegenerative diseases.

The antioxidant mechanisms of curcumin are multifaceted. For example, curcumin directly scavenges various forms of free radicals, such as reactive oxygen and nitrogen species [46]. In addition, curcumin enhances the body's antioxidant defenses by influencing the expression of antioxidant enzymes (glutathione peroxidase, superoxide dismutase (SOD), and catalase) [29].

Curcumin is involved in the regulation of important signaling pathways related to oxidative stress and inflammation. One of the main pathways is the nuclear factor-κB-related transcription factor Nrf2 pathway, which regulates the expression of detoxification enzymes and antioxidant proteins [46]. Under the influence of curcumin, the Keap1-Nrf2 complex dissociates, and Nrf2 translocates to the nucleus, where it binds to antioxidant response elements and activates the transcription of protective enzymes [23]. This not only increases the innate resistance of the cell to oxidative damage, but also enhances its ability to respond to oxidative stressors.

In vitro research has demonstrated that premature senescence of endothelial cells induced by hydrogen peroxide is attenuated by pretreatment with curcumin for 24 hours, as well as by a decrease in ROS production and an increase in eNOS activation and NO production [46].

Anti-inflammatory effect.

Curcumin exerts its anti-inflammatory effects by regulating inflammatory signaling pathways and inhibiting the production of inflammatory mediators. Its targets include transcription factors such as NF-κB, enzymes such as cyclooxygenase-2 (COX-2), 5-lipoxygenase, proinflammatory cytokines (IL-1β, IL-6, IL-12, TNF-α, IFNγ) and related signaling pathways (AP-1, RANK/RANKL, JAK-STAT) [6]. Normally inactive in the cytoplasm and bound to the inhibitory protein IκB, NF-κB becomes active when IκB is degraded, facilitating its translocation to the nucleus, where it promotes the expression of proinflammatory genes [6].Curcumin effectively blocks this process by preventing the degradation of IκB, thereby reducing the expression of pro-inflammatory cytokines such as TNF-α, IL-1, and IL-6 [11].

Thus, curcumin can activate peroxidase-activated receptor gamma (PPAR-γ) and stop the production of pro-inflammatory cytokines such as TNF-α and IL-1β by blocking signaling pathways including NF-κB [1]. Under the influence of curcumin, the enzymes cyclooxygenase-2 (COX-2) and lipoxygenase (LOG) are inhibited, which catalyze the production of key inflammatory mediators such as prostaglandins and leukotrienes, and reduce the production of the latter. In addition, curcumin affects mitogen-activated protein kinases (MAPKs) and phosphoinositide-3-kinase (PI3K)/Akt, which are known for their role in cellular responses to inflammation [16].

Experimentally it was found that increased levels of mRNA-21 and mRNA-146a in aged animals are associated with higher levels of oxidative stress and inflammation [14]. In an experiment conducted by Shargh Z. et al. [37], it was found that 8-week treatment with curcumin led to a decrease in the level of inflammation (TNF-α, IL-1β and IL-6 in serum), mRNA-21 and mRNA-146a. This effect was enhanced when curcumin was combined with physical exercise. Previously, it was shown that these miRNAs directly affect oxidative stress, thereby reducing the level of MDA in serum and, as a result, reducing inflammation [4].

Endothelial dysfunction.

Endothelial dysfunction is an early marker of atherosclerosis. Flow-mediated dilation (FMD), measured by ultrasound, is a noninvasive measure of endothelial dysfunction. Curcumin, a natural pigment found in turmeric, can improve FMD of the brachial artery and thus endothelial function.

American researchers conducted a systematic review and meta-analysis [7] of 5 randomized clinical trials evaluating the effects of curcumin supplements on endothelial function. They found a significant effect of curcumin supplementation on increasing FMD compared to placebo and thus on endothelial function. However, the changes were not as pronounced in smokers.

Tang W. et al. [40] conducted a comprehensive umbrella meta-analysis that included 10 randomized clinical trials published between 2019 and 2024 to examine the effects of curcumin supplementation on blood pressure (BP) and endothelial function. It was found that curcumin supplementation had a positive effect on diastolic blood pressure (DBP) (mean difference [WMD]=-0.94, 95 % CI: -1.59 to -0.30; p=0.004) and endothelial function (vascular cell adhesion molecule-1 (VCAM-1) [WMD=-39.19; 95 % CI: -66.15 to -12.23; p=0.004; I2=73.0 %, p=0.005]), as well as arterial stiffness as measured by pulse wave velocity (PWV) [WMD=-45.60, 95 % CI: -88.16 to -3.04; p=0.03, I2=0.0 %, p=0.59]. In addition, FMD-mediated dilation was significantly increased [WMD=1.64; 95 % CI: 1.06 to 2.22; p<0.001; I2=0.0 %, p=0.61]. However, curcumin did not significantly alter systolic blood pressure (SBP) [WMD=-0.64, 95 % CI: -1.96 to 0.67; p=0.34, I2=83.5 %, p<0.001]. The authors concluded that high-dose curcumin (≥900 mg/day) can be considered as an adjunctive therapy for lowering SBP and DBP. In addition, curcumin can be considered as a useful agent for improving endothelial function.

Another meta-analysis [22] of 21 randomized clinical trials examined the effects of curcumin supplementation on biomarkers of oxidative stress, inflammation, and endothelial function. Curcumin was found to be an effective adjunctive therapy for improving oxidative stress markers—malondialdehyde (effect size (ES)=-0.81; 95 % CI: -1.39, -0.23, P=0.006), catalase (ES=10.26; 95 % CI: 0.92 to 19.61, P=0.03), glutathione peroxidase (WMD=8.90; 95 % CI: 6.62 to 11.19, P<0.001), and superoxide dismutase (SOD) activity (WMD=20.51; 95 % CI: 7.35 to 33.67, P=0.002). However, no significant changes were found in the curcumin effect on total antioxidant capacity (TAC) (ES=0.29; 95 % CI: -0.09 to 0.66, P=0.059).

These studies also found a positive effect on inflammatory markers: levels of C-reactive protein (WMD=-0.87; 95 % CI: -1.14 to -0.59, P<0.001), TNF-α (WMD=-2.72; 95 % CI: -4.05 to -1.38; P<0.001), IL-6 (WMD=-0.97; 95 % CI: -1.40 to -0.54; P<0.001) and pulse wave velocity (PWV) (WMD=-45.60; 95 % CI: -88.16 to -3.04, P=0.036), as well as an increase in FMD (WMD=1.64; 95 % CI: 1.06, 2.22, P<0.001). Therefore, curcumin supplementation may be an effective adjunctive therapy to reduce inflammation, oxidative stress, and improve endothelial function [22].

Arterial stiffness.

Arterial stiffness is an early sign of structural and functional changes in the arterial wall. The gold standard for noninvasive assessment of aortic stiffness and a modifiable cardiovascular risk factor is the PWV. Since arterial stiffness is influenced by inflammation and oxidative stress, it can be improved by curcumin supplementation. These effects have been attributed to restoration of NO bioavailability, reduction of vascular superoxide production and oxidative stress, and reduction of type I collagen deposition [9]. In healthy middle-aged and older men and postmenopausal women, 12 weeks of curcumin supplementation was well tolerated and improved arterial endothelial function, which may be due to increased nitric oxide bioavailability and reduced vascular oxidative stress. In contrast, curcumin administration in a sample of healthy late middle-aged and elderly individuals did not affect large elastic artery stiffness or circulating biomarkers of oxidative stress or inflammation [40].

A randomized, double-blind, placebo-controlled trial [2] examined the effects of curcumin on changes in arterial stiffness in patients with metabolic syndrome. It was found that daily intake of 500 mg of curcumin for 12 weeks resulted in improvements in PWV and weight control in patients with metabolic syndrome.

Meanwhile, in a randomized, double-blind, placebo-controlled trial [15] in diabetic patients, curcumin supplementation at a dose of 80 mg/day for 24 weeks had no effect on carotid intima-media thickness and PWV. However, within-group differences showed a significant reduction in mean PWV in the curcumin group [15]. The authors suggested that the differences in the results regarding the effect on PWV may be due to the characteristics of the study participants, the duration of treatment, and the dosage of curcumin.

Arterial hypertension.

It has been experimentally established that curcumin in arterial hypertension can positively affect vascular remodeling through multiple mechanisms, such as inhibition of vascular contraction, inhibition of smooth muscle cell proliferation and migration, improvement of endothelial function, etc. [25]. Addition of curcumin to treatment regimens significantly reduced blood pressure, reduced oxidative stress, and increased the levels of nitrate/nitrite and glutathione in the blood plasma of rats chronically exposed to lead and cadmium [42].

Fig. 1 schematically presents possible mechanisms affecting blood pressure levels, including antioxidant, anti-inflammatory effects, interference with Ca2+ concentration, stimulation of β2-adrenergic receptors, and inhibition of the renin-angiotensin system.

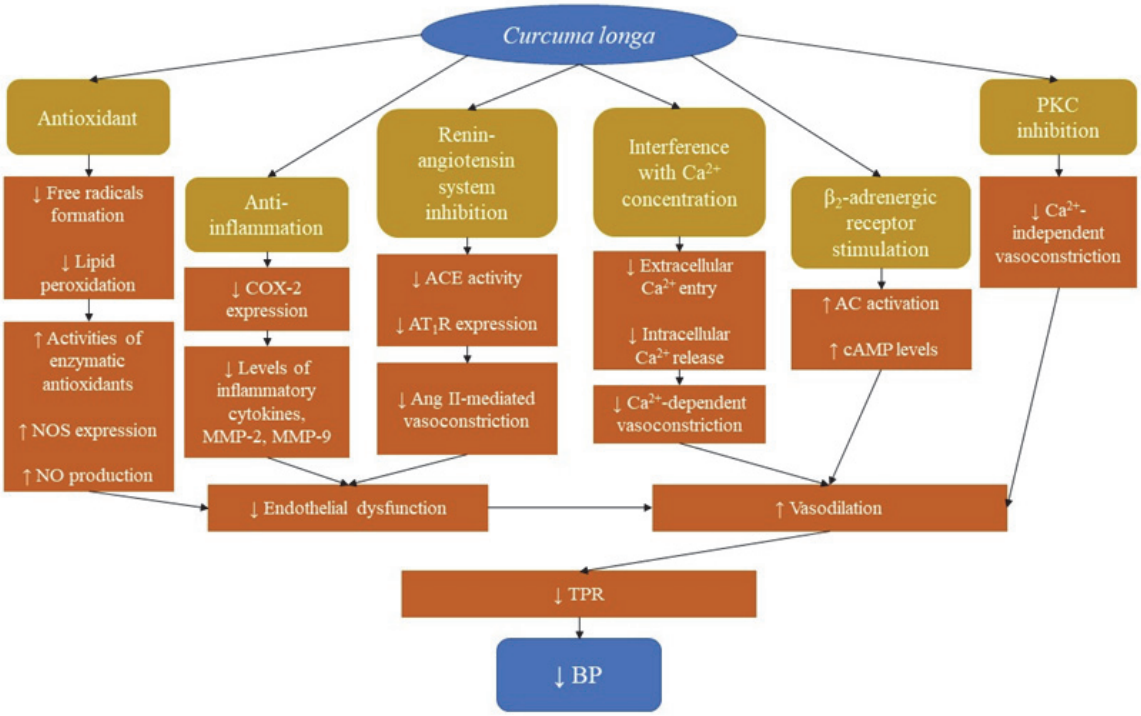

Fig. 1. Mechanisms influencing the reduction of blood pressure under the influence of Curcuma longa L, Leong, X.-F. (2018). Abbreviations: AC – adenylate cyclase; ACE – angiotensin-converting enzyme; Ang II – angiotensin II; AT1R – angiotensin II type 1 receptor; Ca2+ – calcium ion (II); cAMP – cyclic adenosine monophosphate; COX – cyclooxygenase; MMP – matrix metalloproteinase; NO – nitric oxide; NOS – nitric oxide synthase; PKC – protein kinase C; TPR – total peripheral vascular resistance. Symbols indicate: ↑ – increase; ↓ – decrease.

In an experiment [17] involving male Wistar rats with arterial hypertension, daily doses of turmeric extract (50, 100 and 200 mg/kg) or captopril were administered to hypertensive animals for 14 days. Blood pressure, arterial stiffness, heart rate (HR), QRS-T angle and nitric oxide (NO) levels were assessed. It was found that turmeric extract significantly increased the bioavailability of NO-vasodilators, reduced blood pressure, reduced arterial stiffness and prevented ventricular dysfunction.

Several studies have examined the effects of curcumin/turmeric on blood pressure and factors associated with hypertension. Clinical trial data using curcumin/turmeric have shown that blood pressure levels were reduced or did not change significantly. Therefore, the results of meta-analyses of such studies are of interest.

A meta-analysis conducted by Dehzad MJ et al. [8], which included 35 randomized clinical trials involving 4182 people, was devoted to studying the effects of curcumin/turmeric on blood pressure and

factors that are likely responsible for hypertension. Curcumin/turmeric intake was found to significantly improve SBP (WMD: -2.02 mmHg; 95 % CI: -2.85 to -1.18), DBP (WMD: -0.82 mmHg; 95 % CI: -1.46 to -0.18), vascular cell adhesion molecule-1 (VCAM-1) levels (WMD: -39.19 ng/mL; 95 % CI: -66.15 to -12.23), and flow-mediated vasodilation (FMD) (WMD: 2.00 %; 95 % CI: 1.07 to 2.94). However, there was no significant change in intracellular adhesion molecule-1 (ICAM-1) levels (WMD: -17.05 ng/mL; 95 % CI: -80.79 to 46.70) or pulse wave velocity (PWV) (WMD: -79.53 cm/s; 95 % CI: -210.38 to 51.33). These data suggest that curcumin/turmeric supplementation may be considered as an adjunct to improve blood pressure and endothelial function. Further studies are needed to elucidate its effects on inflammatory adhesion molecules in the circulation.

Karimi A. et al. [21] conducted a dose-response meta-analysis of 17 clinical trials involving 1377 subjects to examine the effects of curcumin supplementation on SBP and DBP. No significant effect of curcumin on SBP (WMD=-0.06 mmHg, 95 % CI -0.62 to 0.50, p=0.85; I2=44.2 %) and DBP (WMD=-0.18 mmHg, 95 % CI -1.17 to 0.82, p=0.62; I2=77.2 %) was found. The dose and duration of curcumin administration were not significantly associated with reductions in SBP and DBP. Subgroup analysis in studies with ≥12 weeks of curcumin supplementation revealed a significant reduction in DBP only (WMD -0.76 mmHg, 95 % CI -1.46 to -0.05; P=0.03). In addition, studies including women who received curcumin supplementation showed significant reductions in SBP (WMD: -1.55 mmHg, 95 % CI -2.85 to -0.25; P=0.01) and DBP (WMD: -1.73 mmHg, 95 % CI 2.67 to -0.79; P<0.01). The authors suggest that curcumin use may have a positive effect on DBP when used for ≥12 weeks. However, further studies are needed to confirm these findings.

Atherosclerosis.

Potential mechanisms of action of curcumin are related to the control of cholesterol levels.

In an experiment on Caco-2 cells, which have the basic properties of small intestinal enterocytes, curcumin supplementation was found to inhibit cholesterol absorption by suppressing the expression of the Niemann-Pick C1-Like 1 (NPC1L1) protein, which is involved in the absorption of cholesterol and phytosterols in small intestinal cells [18].

Curcumin can inhibit the activity of HMG-CoA reductase, an enzyme involved in cholesterol synthesis in the liver, leading to a decrease in cholesterol production in the body [31].

Curcumin may increase cholesterol excretion. Because curcumin stimulates the secretion of bile acids, which are necessary for the digestion and absorption of dietary fats, it results in a reduction in the amount of cholesterol absorbed from food [31].

Another study [33] found that the MIAT/miR-124 axis mediates the effects of curcumin on atherosclerosis and alters apoptosis and cell proliferation both in vivo and in vitro.

In an in vitro study using the human hepatoma cell line HepG2 [46], changes in liver gene expression were detected. Curcumin induced a significant concentration-dependent increase in LDL receptor mRNA levels. The mRNA of genes encoding the sterol biosynthetic enzymes HMG CoA: reductase and farnesyldiphosphatesynthase, were only slightly increased at high concentrations of curcumin.

Lin K. et al. [27] conducted a meta-analysis of experimental studies. It was found that curcumin could significantly reduce the area of atherosclerotic aortic lesions (standardized mean difference (SMD)=-0.89, 95 % CI: -1.36 to -0.41, P=0.0003), improve serum lipid profile (total cholesterol, MD=-1.005, 95 % CI: -1.885 to -0.124, P=0.025; triglycerides, MD=-0.045, 95 % CI: -0.088 to -0.002, P=0.042; low-density lipoprotein, MD=-0.523, 95 % CI: -0.896 to -0.149, P=0.006), and plasma inflammatory markers (TNF-α, MD=-56.641, 95 % CI: -86.848 to -26.433, P<0.001; interleukin (IL)-1β, MD=-5.089, 95 % CI: -8.559 to -1.619, P=0.004). Curcumin dosages ranging from 0 to 347 mg/kg body weight per day were found to be safe and non-toxic.

Systematic reviews and meta-analyses of randomized controlled trials have shown that curcumin can reduce plasma and hepatic lipid levels, thus protecting against hypercholesterolemia and subsequent atherosclerosis [9, 10, 31].

A meta-analysis by Dehzad MJ. and Sung [8] of 64 randomized clinical trials examined the effects of curcumin/turmeric supplementation on lipid profiles. It was found that curcumin/turmeric supplementation resulted in statistically significant improvements in total cholesterol [TC] (mean difference [WMD]=-3.99 mg/dL; 95 % CI -5.33 to -2.65), triglycerides [TG] (WMD=-6.69 mg/dL; 95 % CI -7.93 to -5.45), and low-density lipoprotein cholesterol [LDL-C] (WMD=-4.89). mg/dL; 95 % CI -5.92 to -3.87) and high-density lipoprotein cholesterol [HDL-C] (WMD=1.80 mg/dL; 95 CI 1.43 to 2.17). However, curcumin/turmeric supplementation was not associated with increases in blood Apo-A or Apo-B levels. Thus, curcumin/turmeric supplementation appears to be effective in reducing HDL, TG, LDL-C and

increasing LDL-C; but may not be able to improve their respective apolipoproteins. However, the authors noted that these findings should be interpreted with caution, as the evidence was rated as low to very low.

Deng Z. et al. [10] conducted a systematic review of randomized controlled trials to evaluate the effects of curcumin on TG, LDL, and HDL levels in Asian populations with metabolic diseases. According to 23 RCTs for TG, 21 RCTs for VLDL and LDL, and 22 RCTs for HDL, curcumin intake significantly reduced TG (MD: -18.07 mg/dL, 95 % CI: -30.30 to -5.85, P<0.01), VLDL (MD: -13.29 mg/dL, 95 % CI: -20.43 to -6.16, P<0.01) and LDL (MD: -10.44 mg/dL, 95 % CI: -16.87 to -4.00, P<0.01), but had no effect on HDL (MD: 1.66 mg/dL, 95 % CI: -0.13 to 3.44, P=0.07). A non-linear dose-response analysis revealed a significant effect of curcumin dose on TG levels (P-non-linearity = 0.022). The authors concluded that curcumin may be beneficial in reducing TG, LDL-C, and LDL-C levels in Asian populations with metabolic diseases. Curcumin dose may be a major factor affecting TG levels.

Musazadeh V. et al. [31] conducted an umbrella meta-analysis of clinical trials on the efficacy of curcumin on lipid profile in adults. The clinical benefits of curcumin on lipid profile in patients with various metabolic disorders. Curcumin supplementation was found to be effective in reducing LDL (effect size (ES)=-0.81 mg/dL; 95 % CI: 1.39 to -0.24, p=0.006; I2=68.8 %, p<0.001), TG (ES: 0.84 mg/dL, 95 % CI: 1.42 to -0.27, p=0.004; I2=84.2 %, p<0.001), and LDL cholesterol (ES: 0.49 mg/dL, 95 % CI: 0.85 to -0.13, p=0.007; I2=51.9 %, p=0.004). In addition, curcumin significantly increased HDL cholesterol levels (ES: 1.34 mg/dL, 95 % CI: 0.37 to 2.31, p=0.007; I2=97.8 %, p<0.001). The data obtained allowed the authors to conclude that curcumin can be recommended as an adjunctive antihyperlipidemic agent.

However, meta-analyses of studies have conflicting results. Thus, according to the meta-analysis by Hosseini H. et al. [19] curcumin and piperine significantly reduced HDL and LDL cholesterol, but did not affect triglyceride concentrations in patients with metabolic syndrome. Moreover, the results were independent of the dose of curcumin, the dose of piperine, or the duration of treatment. The authors concluded that further long-term randomized controlled trials are needed to better assess the clinical benefit.

Effect on cardiomyocyte apoptosis.

Reactive oxygen species (ROS), their oxidation products, and other secondary messenger molecules generated by ROS have been shown to induce apoptosis [30]. Antioxidants are known to inhibit programmed cell death pathways. Hu Z. [20] analyzed the role of curcumin in protecting against doxorubicin-induced cardiotoxicity using network pharmacology and molecular docking. Protein-protein interactions (PPIs) were used to predict key targets. Topological analysis of the PPI network revealed 10 major targets, which included TP53, TNF-α, AKT1, vascular endothelial growth factor A (VEGFA), prostaglandin endoperoxide synthase 2 (PTGS2), signal transducer and activator of transcription 3 (STAT3), hypoxia-inducible factor 1-alpha (HIF1A), MYC, epidermal growth factor receptor (EGFR), and CASP3 (Caspase-3). In addition, the analysis of enrichment products showed that the effects of curcumin were mediated by genes related to oxidation, inflammation, cell proliferation, migration, apoptosis, metabolism, proteolysis and calcium (Ca2+) signaling pathway. Molecular docking showed that curcumin can bind to target proteins with high molecular force, showing good docking activity. Thus, the key target proteins were identified and the theoretical basis for further study of curcumin in the prevention and treatment of doxorubicin-induced cardiotoxicity was determined.

A meta-analysis conducted by Li T. et al. [26], which included 24 experimental and 4 clinical studies, was devoted to studying the effect of curcumin on myocardial ischemia-reperfusion injury. According to experimental studies, curcumin significantly reduced myocardial infarction size (p<0.00001) and improved cardiac function indicators (left ventricular ejection fraction, left ventricular fractional shortening, end-diastolic and end-systolic left ventricular dimensions, (p<0.01) compared with the control group. Curcumin also had a positive effect on markers of myocardial damage, oxidative stress, myocardial apoptosis, inflammation, and myocardial fibrosis (p<0.05). Analysis of clinical trials demonstrated that in patients with ischemic heart disease, curcumin administration after revascularization reduced the incidence of cardiac dysfunction, in-hospital myocardial infarction, and major adverse cardiovascular events during a short observation period, which may be related to its anti-inflammatory and antioxidant properties. A dose-response meta-analysis found that a curcumin dose of 200 mg/kg/day is the optimal dose (in the range of 10-200 mg/kg/day) and is safe.

Cardiomyocyte hypertrophy.

Left ventricular hypertrophy is a physiologically adaptive response to increased hemodynamic stress that initially improves systolic function but eventually leads to heart failure. The development of left ventricular hypertrophy and heart failure involves the reprogramming of gene expression, a process that is largely dependent on epigenetic regulation. Histone acetylation is dynamically regulated by cardiac stress.

Histone acetyltransferases (HATs) play an important role in epigenetic remodeling in left ventricular hypertrophy and heart failure [13]. The activity of the HAT p300 is closely associated with cardiac hypertrophy and heart failure. GATA-binding protein 4 (GATA4) has been identified as a master regulator of adult cardiac hypertrophy, which can be activated by p300-HAT [24]. GATA4 regulates the gene expression of various genes involved in cardiac development and left ventricular hypertrophy and heart failure [13]. Curcumin, which has inhibitory effects on the histone acetyltransferase p300-HAT, has been shown to inhibit GATA4 acetylation and prevent heart failure [38].

Increased expression of Na/Ca exchange may be part of the genetic reprogramming in cardiac remodeling [38]. It has been established that the expression activity of Na/Ca exchange may be increased, unchanged, or even decreased during cardiac remodeling. Increased expression activity of Na/Ca exchange is considered to compensate for contractile function, but with negative side effects, including an increased risk of arrhythmias [34]. At the same time, changes in the expression activity of Na/Ca exchange may be a consequence of changes in other Ca2+ fluxes or in Na+ homeostasis. The role of Na/Ca exchange expression in changes in left ventricular contractility and arrhythmogenesis varies depending on different stimuli or stages of cardiac remodeling. Curcumin has been shown to inhibit myocardial hypertrophy by increasing the expression of Na/Ca exchange in the myocardium and vascular endothelium [47].

Myocardial fibrosis.

Myocardial fibrosis plays an important role in the development of myocardial remodeling. Myocardial fibrosis is based on the activation of fibroblasts, which are normally part of the structure of cellular elements of the heart muscle. Transforming growth factor beta 1 (TGF-β1) is a multifunctional profibrotic cytokine that controls the composition of the cellular matrix and can induce the transformation of fibroblasts into myofibroblasts. The review [44] presents an assessment of experimental studies on the effect of curcumin on the processes of myocardial fibrosis and shows that curcumin inhibits TGF-β1-induced proliferation of cardiac fibroblasts and collagen deposition by inhibiting the SMAD-2 and p38 MAPK signaling pathways. The antifibrotic effect of curcumin was shown to be mediated by reducing angiotensin II-induced fibroblast proliferation, both through a decrease in TGF-β1 and the ratio of metalloproteinase to tissue inhibitor of matrix metalloproteinases (TIMP) [36], and by inhibiting connective tissue growth factor (CTGF), collagen III, and fibronectin by increasing PPAR-γ expression and activity [24].

Another study [5] found that curcumin administration resulted in a significant increase in the ratio of angiotensin II type 2 receptor (AT2) to AT1 receptor compared to the angiotensin II group; a significant decrease in the population of macrophages and α-muscle myofibroblasts expressing actin, which was accompanied by a decrease in the expression of TGF-β and phosphorylated Smad 2/3.

Ventricular remodeling.

The molecular mechanisms of cardiac remodeling, in addition to cardiomyocytes, include the extracellular matrix. Dysregulation of the latter contributes to the development of structural and functional changes in the myocardium. Degradation of the extracellular matrix occurs with the participation of enzymes with proteolytic properties, the most active of which are matrix metalloproteinases. Previously, in an experimental model of myocardial infarction, it was shown that pretreatment with curcumin (100, 150 and 200 mg/kg/day) led to a decrease in the levels of metalloproteinase-2 and metalloproteinase-9, and, thus, prevented ventricular remodeling [44]. In addition, it was shown that curcumin nanoparticles inhibit the development of right ventricular remodeling through anti-inflammatory (decrease in TNF-α levels) and antioxidant properties [44].

In the review by Zhang Z. et al. [45], an analysis of experimental studies on the effects of curcumin in a myocardial infarction model was presented. The protective role of curcumin against myocardial ischemia-reperfusion injury by activating RISK/GSK-3β and inhibiting p38 MAPK and JNK signaling pathways was noted, as well as the protection of cardiac function due to the implementation of anti-inflammatory properties of curcumin (reducing the levels of pro-inflammatory cytokines TNF-α, IL-6, IL-1α and IL-1β).

In an animal study, it was determined that downregulation of dickkopf related protein 3 (DKK-3) contributes to the enhancement of ventricular remodeling induced by pressure overload. It was found that the addition of curcumin (100 mg/kg/day) in chronic heart failure contributes to the suppression of ventricular remodeling through the inhibition of p38 and JNK signaling pathways and the increase in DKK-3 protein expression [44].

A clinical trial [39] involving patients with acute myocardial infarction examined the effect of curcumin supplementation on myocardial injury. Patients were given curcumin capsules supplemented with piperine (500 mg/day, 95 % curcuminoids) or placebo for 8 weeks. No significant differences were found

between the groups in terms of ejection fraction and serum troponin I (cTnI) levels. In addition, there was a significant reduction in HbA1C (-0.3±2.2 vs. +1.1±1.3, P=0.002), LDL-C (-10.3±20.7 vs. +0.2±22.5, P=0.039) and an increase in HDL-C (+4.5±8.9 vs. -1.6±7.7, P=0.002) compared to the placebo group.

A randomized, double-blind, placebo-controlled clinical trial [41] in patients undergoing coronary artery bypass grafting (CABG) investigated the effects of curcumin-piperine supplementation on CRP levels, total antioxidant capacity (TAC), cardiometabolic factors, clinical outcomes, and 28-day mortality. Patients were additionally administered curcumin-piperine or placebo for 5 days after surgery. It was found that the addition of curcumin-piperine resulted in a significant decrease in CRP (P=0.028), an increase in TAC (P=0.033), and a slight decrease in MB-creatine phosphokinase (MB-CPK) (P=0.077). However, no significant changes were observed in troponin I and ejection fraction.

A systematic review [28] analyzed the effects of curcumin in modulating vascular function and structure during menopause. It was shown that curcumin supplementation during menopause positively affects endothelial function, arterial compliance, hemodynamic parameters, and slows the formation of atherosclerotic lesions.

A triple-blind, parallel-group, randomized controlled trial [12] of postmenopausal women examined the effects on clinical status, serum TAC, MDA, and hs-CRP levels. Treatment included curcumin 500 mg twice daily, or vitamin E 500 mg twice daily, or placebo two capsules daily for 8 weeks. It was found that general menopausal symptoms, depression, anxiety, psychological, vasomotor, and physical domains were significantly reduced in all groups (P<0.05). Curcumin was shown to have a positive effect on biomarkers of oxidative stress (MDA and TAC) and inflammation (hs-CRP). Vitamin E may also improve antioxidant status by increasing TAC levels. The reduction in anxiety in the vitamin E group was greater than in the placebo group.

Conclusions

1. Curcumin is the main active ingredient in turmeric, which gives turmeric its bright yellow color. Curcumin has a wide range of biological and pharmacological activities.

2. The antioxidant mechanisms of curcumin are multifaceted: it directly absorbs various forms of free radicals, enhances the body's antioxidant defenses by influencing the expression of antioxidant enzymes (glutathione peroxidase, superoxide dismutase, and catalase).

3. Curcumin exerts anti-inflammatory effects by regulating inflammatory signaling pathways and inhibiting the production of inflammatory mediators.

4. Curcumin may be considered a useful agent for improving endothelial function. According to a dose-response meta-analysis, curcumin consumption may have a positive effect on diastolic blood pressure when used for ≥12 weeks.

5. Curcumin regulates cholesterol levels by several mechanisms: inhibition of cholesterol absorption, cholesterol synthesis, increased cholesterol excretion, etc. Data from meta-analyses on the effect of curcumin on the lipid profile indicate the possibility of recommending curcumin as an auxiliary antihyperlipidemic agent.

6. The molecular targets of curcumin are diverse, ranging from transcription factors, growth factors and their receptors, cytokines and enzymes to proteins regulating cell proliferation and apoptosis. Experimental studies indicate that curcumin has a positive effect on myocardial ischemia-reperfusion injury, promotes the inhibition of cardiomyocyte hypertrophy, myocardial fibrosis and ventricular remodeling, which emphasizes the feasibility of studying the additional use of curcumin in heart failure to confirm and quantify its therapeutic effect.

References

1. Abolfazli S, Butler AE, Kesharwani P, Sahebkar A. The beneficial impact of curcumin on cardiac lipotoxicity. J Pharm Pharmacol. 2024;76(10):1269-1283. doi: 10.1093/jpp/rgae102.

2. Alidadi M, Sahebkar A, Eslami S, Vakilian F, Jarahi L, Alinezhad-Namaghi M, et al. The effect of curcumin supplementation on pulse wave velocity in patients with metabolic syndrome: A randomized, double-blind, placebo-controlled trial. Adv Exp Med Biol 2021;1308:1–11.

3. Angell SY, McConnell MV, Anderson CAM, Bibbins-Domingo K, Boyle DS, Capewell S, et al. The American Heart Association 2030 Impact Goal: A Presidential Advisory From the American Heart Association. Circulation. 2020; 141(9):e120-e138. doi: 10.1161/CIR.0000000000000758.

4. Atabaki M, Shariati-Sarabi Z, Tavakkol-Afshari J, Taghipour A, Jafari MR, Nikpoor AR, et al. Curcumin as an effective suppressor of miRNA expression in patients with knee osteoarthritis, Avicenna J Phytomed. 2022; 12(4): 346–356, https://doi.org/10.22038/ajp.2021.19380.

5 Banks TE, Rajapaksha M, Zhang LH, Bai F, Wang NP, Zhao ZQ. Suppression of angiotensin II-activated NOX4/NADPH oxidase and mitochondrial dysfunction by preserving glucagon-like peptide-1 attenuates myocardial fibrosis and hypertension. Eur J Pharmacol. 2022; 927:175048. doi: 10.1016/j.ejphar.2022.175048.

6. Buhrmann C, Brockmueller A, Mueller A.-L, Shayan P, Shakibaei M. Curcumin attenuates environment-derived osteoarthritis by Sox9/NF-kB signaling Axis. Int. J. Mol. Sci. 2021; 22:7645. doi:10.3390/ijms22147645.
7. Changal KH, Khan MS, Bashir R, Sheikh MA. Curcumin preparations can improve flow-mediated dilation and endothelial function: A meta-analysis. Complement Med Res. 2020;27:272–81.
8. Dehzad MJ, Ghalandari H, Amini MR, Askarpour M. Effects of curcumin/turmeric supplementation on lipid profile: A GRADE-assessed systematic review and dose-response meta-analysis of randomized controlled trials. Complement Ther Med.. 2023;75:102955. doi: 10.1016/j.ctim.2023.102955.
9 Dehzad MJ, Ghalandari H, Askarpour M. Curcumin/turmeric supplementation could improve blood pressure and endothelial function: A grade-assessed systematic review and dose-response meta-analysis of randomized controlled trials. Clin Nutr ESPEN. 2024;59:194-207. doi: 10.1016/j.clnesp.2023.12.009.
10. Deng Zhifang, Yang Ke, Cai Xiaonan, Mei Hong, Han Xiao, Wenqi Gao. The beneficial effects of curcumin supplementation on blood lipid levels among patients with metabolic related diseases in Asia area: a systematic review and meta-analysis of randomized controlled trials. Frontiers in Sustainable Food Systems. 2023. DOI 10.3389/fsufs.2023.1167913
11. Edwards, RL, Luis PB, Nakashima F, Kunihiro AG, Presley SH, Funk JL, et al. Mechanistic differences in the inhibition of NF-κB by turmeric and its curcuminoid constituents. J. Agric. Food Chem. 2020;68:6154–6160. doi:10.1021/acs.jafc.0c02607.
12. Farshbaf-Khalili A, Ostadrahimi A, Mirghafourvand M, Ataei-Almanghadim K, Dousti S, Iranshahi AM. Clinical Efficacy of Curcumin and Vitamin E on Inflammatory-Oxidative Stress Biomarkers and Primary Symptoms of Menopause in Healthy Postmenopausal Women: A Triple-Blind Randomized Controlled Trial. J Nutr Metab. 2022;2022:6339715. doi: 10.1155/2022/6339715.
13. Funamoto M, Imanishi M, Tsuchiya K, Ikeda Y. Roles of histone acetylation sites in cardiac hypertrophy and heart failure. Front Cardiovasc Med. 2023;10:1133611. doi: 10.3389/fcvm.2023.1133611.
14. Ginckels P, Holvoet P. Oxidative stress and inflammation in cardiovascular diseases and cancer: role of non-coding RNAs, Yale J. Biol. Med. 2022. 95 (1): 129–152.
15. Ghasemiadl M, Ghasemi S, Soleimani A, Esfahani MM, Azadbakht J, Gilasi HR et al. The Effects of Curcumin Administration on Carotid Intima-Media Thickness and Pulse Wave Velocity in Diabetic Hemodialysis Patients: A Randomized, Double-Blinded, Placebo-Controlled Trial. International Journal of Preventive Medicine 2024;15:3. DOI: 10.4103/ijpvm.ijpvm_55_22.
16. Guo G-X, Wu K-Y, Zhang X-Y, Lai F-X, Tsim K W-K, Qin Q-W et al. The extract of Curcuma Longae Rhizoma suppresses angiogenesis via VEGF-induced PI3K/Akt-eNOS-NO pathway. J. Ethnopharmacol. 2023;308: 116299. doi:10.1016/j.jep.2023.116299.
17. Hasimun P, Sulaeman A, Hidayatullah A, Mulyani Y. Effect of Curcuma longa L. extract on noninvasive cardiovascular biomarkers in hypertension animal models. J Appl Pharm Sci, 2021; 11(08):085–089.
18. Hong T, Zou J, Jiang X, Yang J, Cao Z, He Y, et al. Curcumin Supplementation Ameliorates Bile Cholesterol Supersaturation in Hamsters by Modulating Gut Microbiota and Cholesterol Absorption. Nutrients. 2022;14(9):1828. doi: 10.3390/nu14091828.
19. Hosseini H, Ghavidel F, Panahi G, Majeed M, Sahebkar A. A Systematic Review and Meta-Analysis of Randomized Controlled Trials Investigating the Effect of the Curcumin and Piperine Combination on Lipid Profile in Patients with Metabolic Syndrome and Related Disorders. Phytother. Res. PTR 2023, 37 (3), 1212–1224. 10.1002/ptr.7730.
20. Hu Z. Exploring the mechanism of curcumin in the treatment of doxorubicin-induced cardiotoxicity based on network pharmacology and molecular docking technology. Medicine (Baltimore). 2024;103(7):e36593. doi: 10.1097/MD.0000000000036593.
21. Karimi A, Moini Jazani A, Darzi M, Doost Azgomi RN, Vajdi M. Effects of curcumin on blood pressure: A systematic review and dose-response meta-analysis. Nutr Metab Cardiovasc Dis. 2023;33(11):2089-2101. doi: 10.1016/j.numecd.2023.07.003.
22. Kavyani Z, Najafi K, Naghsh N, Karvane HB, Musazadeh V. The effects of curcumin supplementation on biomarkers of inflammation, oxidative stress, and endothelial function: A meta-analysis of meta-analyses. Prostaglandins Other Lipid Mediat. 2024;174:106867. doi: 10.1016/j.prostaglandins.2024.106867.
23. Khin Aung ZM, Jantaratnotai N, Piyachaturawat P, Sanvarinda P. A pure compound from Curcuma comosa Roxb. protects neurons against hydrogen peroxide-induced neurotoxicity via the activation of Nrf-2. Heliyon. 2022;8: e11228. doi:10.1016/j.heliyon.2022.e11228.
24. Li H, Tian X, Ruan Y, Xing J, Meng Z. Asiatic acid alleviates Ang-II induced cardiac hypertrophy and fibrosis via miR-126/PIK3R2 signaling. Nutr Metab (Lond). 2021;18(1):71. doi: 10.1186/s12986-021-00596-7.
25. Li KX, Wang ZC, Machuki JO, Li MZ, Wu YJ, Niu MK, et al. Benefits of Curcumin in the Vasculature: A Therapeutic Candidate for Vascular Remodeling in Arterial Hypertension and Pulmonary Arterial Hypertension? Front Physiol. 2022;13:848867. doi: 10.3389/fphys.2022.848867.
26 Li T, Jin J, Pu F, Bai Y, Chen Y, Li Y, et al. Cardioprotective effects of curcumin against myocardial I/R injury: A systematic review and meta-analysis of preclinical and clinical studies. Front Pharmacol. 2023;14:1111459. doi: 10.3389/fphar.2023.1111459.
27. Lin K, Chen H, Chen X, Qian J, Huang S, Huang W. Efficacy of Curcumin on Aortic Atherosclerosis: A Systematic Review and Meta-Analysis in Mouse Studies and Insights into Possible Mechanisms. Oxid Med Cell Longev. 2020;2020:1520747. doi: 10.1155/2020/1520747.
28. Mad Azli AA, Salamt N, Aminuddin A, Roos NAC, Mokhtar MH, Kumar J, et al. The Role of Curcumin in Modulating Vascular Function and Structure during Menopause: A Systematic Review. Biomedicines. 2024;12(10):2281. doi: 10.3390/biomedicines12102281.
29. Maithilikarpagaselvi N, Sridhar MG, Sripradha R. Evaluation of free radical scavenging activities and phytochemical screening of Curcuma longa extracts. J. Young Pharm. 2020;12: 113–117. doi:10.5530/jyp.2020.12.23.
30. Mohammed HS, Hosny EN, Khadrawy YA, Magdy M, Attia YS, Sayed OA, et al. Protective effect of curcumin nanoparticles against cardiotoxicity induced by doxorubicin in rat. Biochim Biophys Acta Mol Basis Dis. 2020;1866(5):165665. doi: 10.1016/j.bbadis.2020.165665.
31. Musazadeh V, Roshanravan N, Mohammadizadeh M, Kavyani Z, Dehghan P, Mosharkesh E. Curcumin as a novel approach in improving lipid profile: An umbrella meta-analysis. Nutr Metab Cardiovasc Dis. 2022;32(11):2493-2504. doi: 10.1016/j.numecd.2022.07.021.
32 Nevoit G, Vlasova O, Ryabushko M, Moisieieva N, Zviagolska I, Potyazhenko M. Magnetoelectrochemical theory of metabolism and life: what is it, when is it needed and what to expect from it for medicine and reflexology (literature reviw). Phytotherapy. Journal. 2024;2:48-62.
33. Ouyang S, Zhang O, Xiang H, Yao Y-H, Fang Z-Y. Curcumin improves atherosclerosis by inhibiting the epigenetic repression of lncRNA MIAT to miR-124. Vascular. 2022;30(6):1213-1223. doi:10.1177/17085381211040974.

34. Pelat M, Barbe F, Daveu C, Ly-Nguyen L, Lartigue T, Marque S, et al. SAR340835, a Novel Selective Na+/Ca2+ Exchanger Inhibitor, Improves Cardiac Function and Restores Sympathovagal Balance in Heart Failure. J Pharmacol Exp Ther. 2021;377(2):293-304. doi: 10.1124/jpet.120.000238.
35. Peng Y, Ao M, Dong B, Jiang Y, Yu L, Chen Z, et al. Anti-Inflammatory Effects of Curcumin in the Inflammatory Diseases: Status, Limitations and Countermeasures. Drug Des Devel Ther. 2021 Nov 2;15:4503-4525. doi: 10.2147/DDDT.S327378.
36. Qiu H, Huang ZY, Cao H, Zhang Z, Ma J, Li XQ, et al. Deciphering mechanism of the herbal formula WuShen in the treatment of postinfarction heart failure. Phytomedicine. 2022; 95:153878. doi: 10.1016/j.phymed.2021.153878.
37. Shargh Z, Asghari K, Asghariehahari M, Chodari L. Combined effect of exercise and curcumin on inflammation-associated microRNAs and cytokines in old male rats: A promising approach against inflammaging. Heliyon. 2025;11(2):e41895. doi: 10.1016/j.heliyon.2025.e41895.
38. Sunagawa Y, Ishida A, Yamazato M, Ohya Y, Kusunose K. Combined effects of hypertension and arterial stiffness on target organ damage among community-based screening participants. Hypertens Res. 2025 Feb 19. doi: 10.1038/s41440-025-02163-6.
39. Tabaee S, Sahebkar A, Aghamohammadi T, Pakdel M, Dehabeh M, Sobhani R, et al. The Effects of Curcumin Plus Piperine Supplementation in Patients with Acute Myocardial Infarction: A Randomized, Double-Blind, and Placebo-Controlled Trial. Adv Exp Med Biol. 2021;1328:199-211. doi: 10.1007/978-3-030-73234-9_13.
40. Tang WW, Huang FF, Haedi AR, Shi QY. The effect of curcumin supplementation on endothelial function and blood pressure in patients with metabolic disorders: A meta-analysis of meta-analyses. Prostaglandins Other Lipid Mediat. 2024;175:106900. doi: 10.1016/j.prostaglandins.2024.106900.
41. Tehrani SD, Hosseini A, Shahzamani M, Heidari Z, Askari G, Majeed M, et al. Evaluation of the effectiveness of curcumin and piperine co-supplementation on inflammatory factors, cardiac biomarkers, atrial fibrillation, and clinical outcomes after coronary artery bypass graft surgery. Clin Nutr ESPEN. 2024;62:57-65. doi: 10.1016/j.clnesp.2024.05.003.
42. Tubsakul A, Sangartit W, Pakdeechote P, Kukongviriyapan V, Apaijit K, Kukongviriyapan U. Curcumin Mitigates Hypertension, Endothelial Dysfunction and Oxidative Stress in Rats with Chronic Exposure to Lead and Cadmium. Tohoku J. Exp. Med. 2021;253: 69–76. 10.1620/tjem.253.69.
43. World Heart Report . Confronting the World's Number One Killer. World Heart Report; Geneva, Switzerland: 2023.
44. Yang C, Zhu Q, Chen Y, Ji K, Li S, Wu Q, et al. Review of the Protective Mechanism of Curcumin on Cardiovascular Disease. Drug Des Devel Ther. 2024;18:165-192. doi: 10.2147/DDDT.S445555.
45. Zhang Z, Chen F, Wan J, Liu X. Potential traditional Chinese medicines with anti-inflammation in the prevention of heart failure following myocardial infarction. Chin Med. 2023;18(1):28. doi: 10.1186/s13020-023-00732-w.
46. Zhang P, Liu H, Yu Y, Peng S, Zhu S. Role of Curcuma longae Rhizoma in medical applications: research challenges and opportunities. Front. Pharmacol. 2024; 15:1430284. doi: 10.3389/fphar.2024.1430284.
47. Zheng RH, Zhang WW, Ji YN, Bai XJ, Yan CP, Wang J, et al. Exogenous supplement of glucagon like peptide-1 protects the heart against aortic banding induced myocardial fibrosis and dysfunction through inhibiting mTOR/p70S6K signaling and promoting autophagy. Eur J Pharmacol. 2020; 883::173318. doi: 10.1016/j.ejphar.2020.173318.

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