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LITERATURE REVIEW
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Recent Literature Review: The Effects of Tea Consumption on Hypertension

Tinjauan Literatur Terkini: Peranan Konsumsi Teh terhadap Penyakit Hipertensi

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ABSTRACT

Background: In Indonesia, the prevalence of hypertension was found to increase from 25.8% (2013) to 34.1% (2018). In additon, patients with this medical condition are generally required to adhere to lifelong anti-hypertensive drugs for blood pressure control. However, recent studies have suggested the use of tea containing active compounds Epigallocatechin-3-gallate (EGCG), which can lower blood pressure.
Objectives: This study aimed to provide an overview of active compounds in tea with the potential to lower blood pressure.
Methods: The data used were obtained from sources related to randomized controlled clinical trials searched through the Pubmed page in the 2017-2022 period, with various keywords such as tea, blood pressure, and hypertension.
Discussions: Out of 35 studies reviewed, a total of 9 were obtained from the literature search. The results showed that EGCG in capsule form with a dose range of 75-300 mg could reduce blood pressure significantly, as observed in studies with capsules containing anthocyanins and polyphenols. Although 4 studies used tea beverages as intervention materials, there was no significant decrease in blood pressure. Furthermore, 2 studies showed a significant variation due to differences in the levels of active compounds and the presence of caffeine in tea, which affected blood pressure measurements.
Conclusions: The use of active compounds in tea, particularly EGCG, in recent clinical trials on blood pressure regulation has shown a significant reduction in hypertension. Therefore, exploiting the potential of EGCG in a larger sample size could serve as a promising avenue for future studies.

INTRODUCTION

The prevalence of hypertension is experiencing a significant increase globally, affecting approximately 1.28 billion adults (aged 30-79), with two-thirds of cases residing in low- to middle-income countries. Despite the high prevalence, only 42% of individuals diagnosed with this medical condition receive treatment, while 21% are classified as controlled cases[1]. In Indonesia, the prevalence of hypertension has increased from 25.8% in 2013 to 34.1% in 2018[2], showing a concerning trend in the health sector of the country. Hypertension is often referred to as a silent killer, manifesting with or without symptoms typically appearing alongside complications such as heart disease, kidney disease, stroke, retinal hemorrhage, and others.

Hypertension is characterized by elevated systolic blood pressure (SBP) and diastolic blood pressure (DBP). This condition increases the risk of all-cause mortality, with an estimated 17 out of 67 deaths predominantly attributed to cardiovascular and cerebrovascular disease outcomes[3]. Compared to individuals with normal blood pressure (normotension), those with untreated hypertension have a 1.62, 2.23, and 3.01 times higher risk of all-cause mortality, cardiovascular disease, and cerebrovascular disease, respectively. However, when hypertension is treated and controlled, there is no significant difference in mortality rates compared to normotensive individuals[4]. This underscores the importance of blood pressure control for individuals with hypertension and primary prevention such as modifying risk factors, including unhealthy lifestyles, high salt and saturated fat intake, sedentary living, alcohol consumption, and smoking1. Improving healthy lifestyles such as tea consumption has been proven to reduce the risk of hypertension and hypertension-related mortality[5,6].

The habit of consuming tea, made from leaves of the Camellia sinensis plant, is believed to have started approximately 4000-5000 years ago in Southern China, as stated in ancient herbal medicine books such as "The

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Divine Husbandman's Classic of Materia Medica" (Shen Nong Ben Cao Jing). People in ancient China believed that tea could maintain health and prevent various diseases[7]. Currently, the global consumption of tea as a beverage has exceeded 2 billion cups daily, due to its nutritional value and health benefits[3]. Tea is also rich in various minerals, sugars, amino acids, organic acids, and flavonoids offering various benefits for maintaining physiological health. Furthermore, active compounds in tea can regulate blood pressure and endothelial function, along with anti-thrombotic, anti-atherosclerotic, cholesterol-lowering (total cholesterol, triglycerides, and low-density lipoprotein [LDL]), and anti-inflammatory properties[8-15]. These various benefits of active compounds lead to the assumption that tea is capable of reducing hypertension incidence and improving outcomes.

Studies on tea regarding blood pressure control have been shown in preclinical and clinical trials. In various preclinical trials, tea has been shown to lower blood pressure through several mechanisms such as reducing oxidative stress, preventing inflammation, increasing nitric oxide production, and others [16-19]. In clinical trials, there have been inconsistent results where significant reductions are observed in blood pressure with tea consumption[20-22,24,25,28], while others show insignificant decreases[23,26,27]. Therefore, this study aimed to provide up-to-date information on clinical trials of tea consumption regarding blood pressure control. The results are expected to provide insight into the basics of tea nutrition and the molecular mechanism in blood pressure control.

METHODS

In this study, the literature search regarding the epidemiology of hypertension was conducted using sources from the World Health Organization (WHO) and the Basic Health Research (RISKESDAS) 2018. Nutritional data on tea were obtained from the website https://www.panganku.org/. Furthermore, data retrieval on clinical trials of tea's benefits for hypertension was conducted using PubMed with keywords "tea" AND "hypertension" as well as "tea" AND "blood pressure". This search strategy applied Boolean Operators, where the use of the word "AND" aimed to combine different concepts to refine the study search. As shown in Figure 1, filtering was performed based on publication years from 2017 to 2022 with the selected study type being RCT. The inclusion criteria were studies written in English, recent (published within the last 5 years), randomized controlled trials (RCT), compared with a placebo, and provided data on blood pressure before and after interventions.

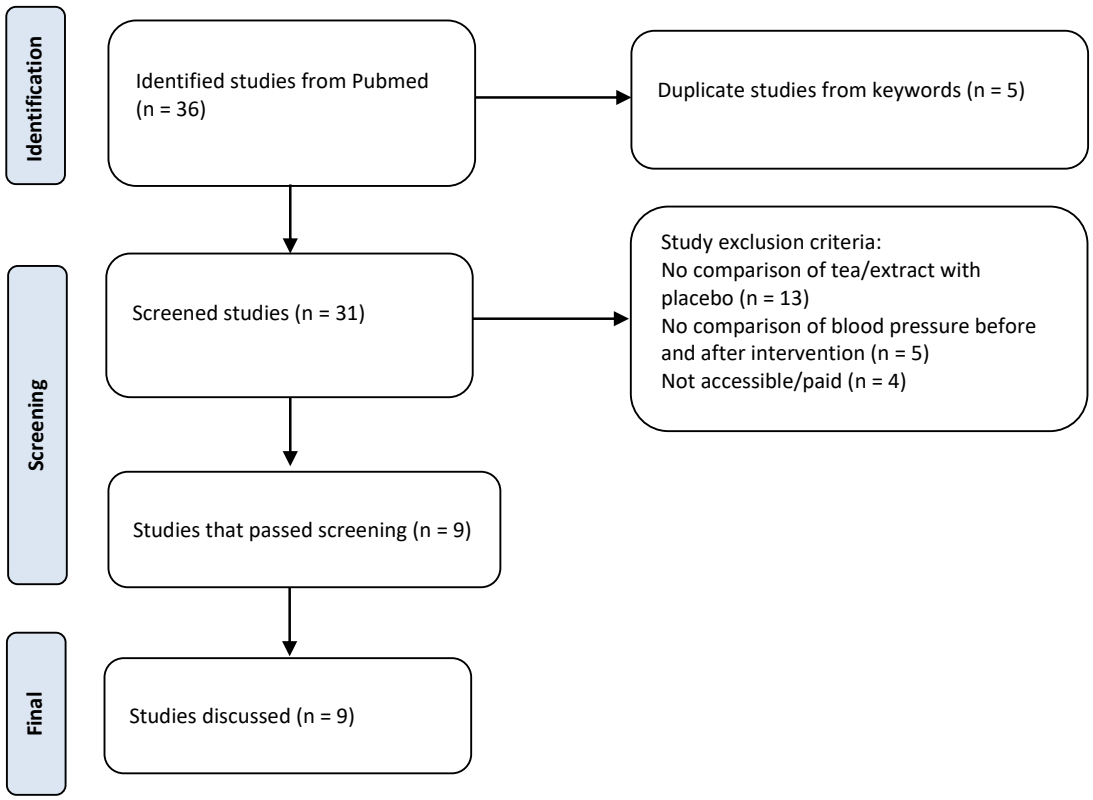

Figure 1. Flowchart of study screening through the PubMed search engine. Out of 36 identified studies after screening, the final result yielded 9 studies for discussion.

DISCUSSIONS

Nutrition in Tea

As shown in Table 1, the nutritional content in tea varies based on the type and processing method applied during cultivation and production [29-31]. The steaming process of tea leaves can lead to a reduction in protein levels, soluble fiber, vitamins (B2, B3, and C), and minerals such as Na, K, Ca, Mg, Fe, and Zn. Conversely, the fermentation process decreases nutritional content such as calcium and vitamins (B1, B2, B3, and C)[27].

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Table 1. Nutritional composition of tea leaves

Nutritional Composition/100 g Food	Dried Green Tea Leaves	Dried Black Tea Leaves	Dried Jasmine Tea Leaves
Water (g)	7.7	8.0	8.1
Energy (cal)	300	293	299
Protein (g)	28.3	24.5	24.1
Carbohydrates (g)	53.6	58.8	59.0
Fiber (g)	9.6	8.7	9.7
Ash (g)	5.6	5.9	5.3
Calcium (mg)	245	327	320
Iron (mg)	18.9	24.3	31.6
Sodium (mg)	60	50	70
Potassium (mg)	5873.9	5854.8	5848.4
Beta-carotene (µg)	8400	2700	8400
Thiamine (mg)	0.38	0.07	0.07
Riboflavin (mg)	1.24	0.80	0.79
Niacin (mg)	4.6	7.6	7.3
Vitamin C (mg)	230	9	85

Several bioactive components have been identified in tea such as polyphenols, pigments, alkaloids, saponins, amino acids, polysaccharides, and others. Tea, specifically green, white, and yellow, contains high levels of polyphenols (30-42%) such as catechin, epicatechin (EC), epicatechin gallate (ECG), epigallocatechin (EGC), and EGCG. Other polyphenols such as gallic acid, chlorogenic acid, ellagic acid, and kaempferol-3-O-glucoside have also been identified, as shown in Figure 2. Some types of tea, particularly oolong and black, are rich in pigment substances such as theaflavins, thearubigins, and theabrownins. Furthermore, there are alkaloid contents such as caffeine, theobromine, and theophylline, which can transform into flavo-alkaloids. Tea brews and extracts also are rich in various amino acids such as aspartic acid, glutamic acid, arginine, alanine, tyrosine, and theanine[32,33].

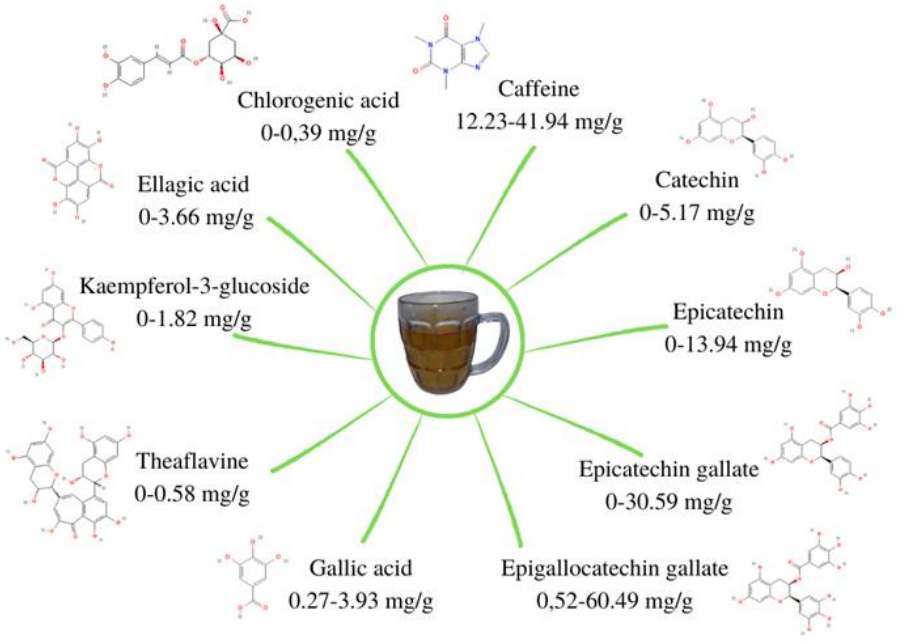

Figure 2. The content of various phytochemicals in tea. The most abundant phytochemicals found in tea are caffeine and catechin, specifically EGCG (data source taken from Tang et al. [2019][34])

Mechanism of Tea on Hypertension

Hypertension is characterized by elevated SBP and DBP, with the diagnosis established when SBP ≥ 140 mmHg and DBP ≥ 90 mmHg are found during measurements in clinics or health facilities[35]. Several systems play a role in regulating blood pressure, including the baroreceptor reflex, antidiuretic hormone, and renin-angiotensin-aldosterone system (RAAS)[36]. However, disturbances in these systems can lead to blood pressure regulation disorders. Other conditions including vascular inflammation and aging can cause blood vessels to become stiffer and narrower[37], thereby increasing blood pressure. Endothelial dysfunction, which leads to increased resistance, is characterized by decreased release of endothelium-derived relaxing factors such as nitric oxide (NO), prostacyclin (PGI2), and endothelium-

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derived hyperpolarizing factor (EDHF). This is followed by high production of endothelium-derived contracting factors such as thromboxane A2 (TxA2), superoxide (O2-), endothelin-1 (ET-1), hydrogen peroxide (H2O2), and angiotensin II (AT-II)[16].

A previous study has conducted a trial on the benefits of EGCG in mice with hypertension by injecting AT-II. These mice were divided into 4 groups, namely control, control + EGCG (50 mg/kg body weight), control + AT-II, and EGCG + AT-II. The results showed that mice receiving EGCG had a significantly lower SBP by 40% compared to those without EGCG. EGCG-treated mice also showed significant improvement in acetylcholine-induced relaxation compared to those without treatment. EGCG administration significantly reduced total nitrate and nitrite levels in plasma, increased vascular tetrahydrobiopterin (BH_4) and cyclic guanosine monophosphate (cGMP), decreased reactive oxygen species (ROS) levels, and Nox-2 protein levels16. In another study, salt-sensitive Dahl rats were divided into 3 groups, consisting of rats receiving 0.5% NaCl, 8% NaCl, and 8% NaCl + EGCG (50 mg/kg body weight). The results showed that EGCG administration for 6 weeks significantly reduced SBP compared to control and those receiving 8% NaCl. Additionally, there was reduction in urinary protein excretion, followed by improved creatinine clearance, decreased oxidative stress (malondialdehyde), reduced infiltration of macrophage and T cells, decreased expression of 67-Laminin receptor (67LR), and inhibited renal fibroblast proliferation[17].

Another study tested mice divided into 4 groups, consisting of samples receiving a standard diet, a high-fat high-sucrose (HFHS), an HFHS diet + 1.6% white tea extract (WTE), and an HFHS diet + 1.6% complex tea extract (CTE). The intervention was administered for 20 weeks, where CTE and WTE supplementation significantly mitigated the increase in blood pressure due to obesity. Furthermore, there was a significant increase in acetylcholine-induced relaxation, and expression levels of the endothelial nitric oxide synthase enzyme (eNOS) gene [only with CTE supplementation], followed by decreased expression levels of IL-1β, IL-6, and NOX-4. CTE supplementation increased the gene expression of antioxidant enzymes glutathione peroxidase-3 (GPX-3) and superoxide dismutase-1 (SOD-1)[18]. A previous experiment also investigated mice divided into 4 groups, namely model control (MC), green tea (GT), oolong tea (OT), and normal control (NC). All mice received a high-salt diet except for NC, which was given a standard diet. The results showed that GT and OT administration prevented the increase in blood pressure due to a high-salt diet after 8 weeks of intervention. Additionally, GT and OT showed potential in preventing structural damage to the heart and kidneys caused by a high-salt diet, including hypertrophy, cardiomyocyte necrosis, arterial wall thickening, glomerular capillary dilation, vacuolization, degeneration, and renal tubular necrosis. The administration of GT and OT also reduced mRNA expression of ACE and ET-1, decreased aldosterone and angiotensin II levels, increased eNOS expression regulation, and minimized oxidative stress as well as inflammation. GT and OT supplementation increased the number and diversity of gut microbiota and the abundance of beneficial bacteria but decreased the population of pathogenic bacteria[19].

The summary of the anti-hypertensive mechanism of tea is depicted in Figure 3. From various in-vivo results, tea and extract supplementation have shown the potential to prevent an increase in blood pressure, providing protective effects on the kidneys and heart. This mechanism included an increase in BH4, eNOS, and cGMP as well as a decrease in ROS and protein NOx-2. In terms of NO production, nicotinamide adenine dinucleotide phosphate (NADPH), L-arginine, eNOS, and BH4 are required. During the production process, the eNOS monomer will form a homodimer to bind with BH4 and L-arginine. The presence of BH_4 is expected to facilitate electron transfer from NADPH to the oxygen domain for the conversion of L-arginine into NO and L-citrulline. The formed NO acts as a paracrine regulator activating soluble guanylyl cyclase (sGC) into cGMP, and inducing vascular smooth muscle relaxation[16,38,39]. NOx-2 can increase ROS production, leading to endothelial dysfunction, vascular remodeling, and BH4 degradation, thereby triggering hypertension[16,40]. EGCG administration in tea is capable of activating the 67LR signal to inhibit inflammation in endothelial cells, adipocytes, and intestinal epithelial cells, triggering fibroblast cell apoptosis. The role of 67LR requires further investigation[17] due to a significant increase observed in mice fed with a high-salt diet compared to the control. Meanwhile, EGCG administration decreased 67LR expression, serving as a biomarker for kidney damage[17]. The decrease in fibroblast infiltration in the kidneys has also been shown to possess the capacity to prevent fibrosis. When kidney tubular cells are injured, there is a release of various cytokines such as CXCL1, FGF2, TGF-β1, CCL2, and osteopontin to provide signals, capable of activating fibroblasts and macrophages to trigger fibrosis[41].

Tea extract administration can increase GPX-1 and SOD-1 levels, showing significant antioxidant properties. However, the role of GPX-3 still requires further investigation because certain conditions such as old age, kidney disorders, and selenium deficiency are associated with a decrease in GPX-3 levels. In chronic inflammatory diseases such as asthma and metabolic syndrome, an increase in GPX-3 levels in the extracellular fluid has been found[42]. The role of SOD-1 also requires further investigation, considering that pathological conditions such as Parkinson's disease, cancer, heart failure, and amyotrophic lateral sclerosis are associated with SOD-1 overexpression[43]. Tea consumption has shown potential to reduce ACE (angiotensin-converting enzyme) expression, the enzyme needed to convert angiotensin I into angiotensin II (a potent vasoconstrictor). Additionally, tea decreases ET-1 levels, which is a vasoconstrictor and plays a role in hypertension in salt-sensitive individuals. The diversity of gut microbes is essential in blood pressure regulation through mechanisms such as short-chain fatty acid production, trimethylamine N-oxide (TMAO), hormone regulation, bioactive peptide secretion, serotonin, steroid hormones, and immune response such as inflammation[19,44]. Bond and Derbyshire (2019) in a systematic review found that green tea can increase the

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number of bacteria in the gut, specifically from the Bifidobacterium group. Meanwhile, black, oolong and Fuzhuan tea can modulate and influence the ratio of Firmicutes and Bacteroidetes bacteria[45].

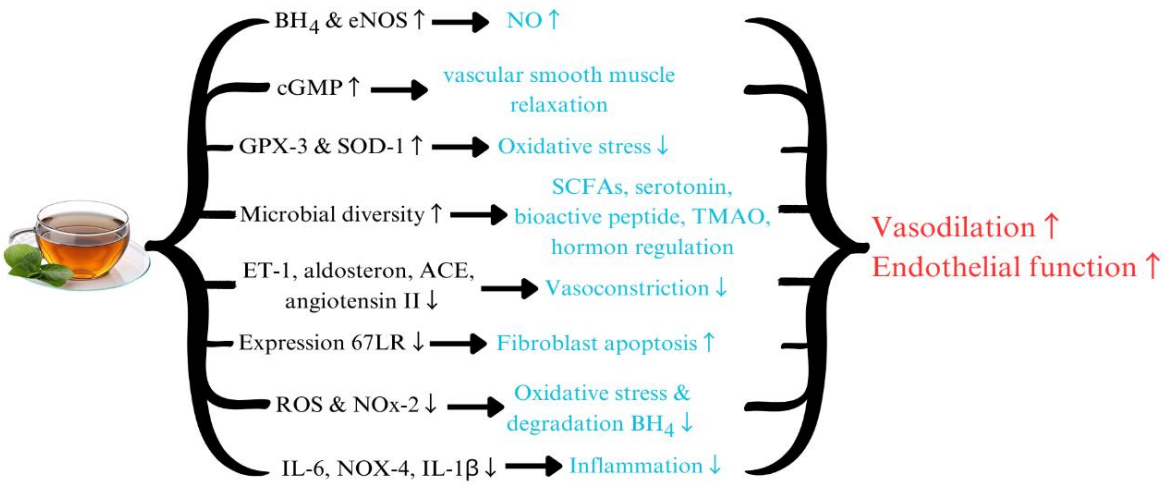

Figure 3. Mechanism of blood pressure regulation by tea. Effects of tea in reducing hypertension include reducing inflammatory responses, increasing antioxidant activities, direct vascular relaxation, and influencing gut microbiota diversity.

Clinical Trials of Tea on Hypertension

The summary of various clinical trials of tea and its extract on blood pressure is shown in Table 2. Out of 36 studies searched through the PubMed database, 9 RCT studies were included in the discussion, which used interventions such as capsule extracts, tea beverages, and their combination.

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Table 2. Clinical trials of tea on blood pressure

Author (Year)	Title	Sample Size	Description	Result	Ref
Izadi et al. (2021)	Effects of sour tea supplementation on liver enzymes, lipid profile, blood pressure, and antioxidant status in patients with non-alcoholic fatty liver disease: A double-blind randomized controlled clinical trial	61 patients with non-alcoholic fatty liver disease Mean age of intervention group vs control (years): 43.3 ± 10.2 vs 42.8 ± 10.6	Subjects were divided into 2 groups during the 8 weeks of intervention. The first group received 1 capsule per day containing tea powder (450 mg capsule containing 250 mg anthocyanins) and the second was given placebo (microcrystalline cellulose).	The group receiving tea powder capsule supplementation experienced a significant decrease in both SBP (p = 0.03) and DBP (p = 0.04) compared to the placebo group.	20
Taati et al. (2021)	Interaction effects of green tea consumption and resistance training on office and ambulatory cardiovascular parameters in women with high-normal/stage 1 hypertension	44 women with stage 1 hypertension or high-normal blood pressure. Subject distribution: ET + LF = 11 subjects ET = 10 subjects LF = 10 subjects CO = 13 subjects Mean age of intervention group (years), according to the order above: 47.63 ± 4.75 vs 49.5 ± 5.6 vs 45.3 ± 5.94 vs 46.15 ± 5.33	There were 2 types of capsule exposure, which contained tea extract, ET (245 mg polyphenols, 75 mg EGCG, and 25 mg caffeine), and 490 mg maltodextrin, CO (control). Subjects consumed 2 capsules per day and engaged in physical exercise, LF. The intervention lasted for 3 weeks of ET consumption, followed by 6 weeks of LF.	Compared to before the intervention, there was a significant decrease in SBP measurements at the office (Δ -5 ± 6.2 mmHg, p = 0.03, d = 0.8) in the ET group. This reduction in blood pressure would be greater when physical exercise was also implemented.	21
Chatree et al. (2021)	Epigallocatechin gallate decreases plasma triglyceride, blood pressure, and serum kisspeptin in obese human subjects	30 individuals with obesity (BMI ≥ 25 kg/m^2) Median age of intervention group vs control (years): 38 vs 39	Subjects were divided into 2 groups, intervention (15 individuals) receiving 150 mg EGCG capsules and control (15 individuals) receiving starch capsules. Capsules were administered twice daily and the intervention lasted for 8 weeks.	EGCG supplementation significantly decreased SBP after 8 weeks of administration (115.85 ± 1.99 mmHg, $p < 0.05$) compared to baseline (122.77 ± 2.46 mmHg). Similarly, DBP showed a significant decrease after 8 weeks of intervention (80.0 ± 1.79 mmHg, $p < 0.05$) compared to baseline (84.67 ± 1.05 mmHg).	22
Dardashti Pour et al. (2021)	Forecast of the ameliorating effects of dietary flavonol consumption in white tea with or without aerobic training on type 2 diabetes (T2D) in females	49 women with type 2 diabetes mellitus Mean age of intervention group (years), according to the order beside: 58.32 ± 3.75 vs 55.41 ± 5.22 vs 57.33 ± 5.56 vs 59.66 ± 6.17	The intervention which lasted for 6 months was divided into 4 groups. These included control, white tea (WT, 150 mL/day) treatment, aerobic training (AT), and combined WT + AT.	The results showed a decrease in blood pressure in group 2, but this was not significant compared to the control or before the intervention. A significant decrease was observed in groups 3 and 4 compared to the control and before the intervention.	23

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Author (Year)	Title	Sample Size	Description	Result	Ref
Al-Shafei et al. (2019)	Regular consumption of green tea improves pulse pressure and induces regression of left ventricular hypertrophy in hypertensive patients	200 patients with hypertension (SBP 150-180 mmHg and/or DBP 95-120 mmHg). Mean age (years): 53 ± 4	Subjects were divided into 2 groups. Group 1 consumed 4 cups of non-caffeinated green tea (250 mL) per day for the first 4 months and 4 cups of warm water (250 mL) per day for the next 4 months. Group 2 followed the opposite intervention sequence of Group 1. The intervention lasted for 8 months.	Group 1 experienced a significant decrease in SBP of 3.3, 5.4, 8.4, and 10.7 mmHg in the measurements at months 1, 2, 3, and 4 of the intervention, respectively. The results showed a total decrease of 6.6% at the end of month 4 compared to the baseline. When the intervention was stopped, there was an increase in SBP of 4.9% (7.5 mmHg) compared to the end of month 4. DBP decreased by 5.1% after the green tea intervention. In Group 2, green tea administration decreased SBP by 5.4% (8.8 mmHg) and 4% (6.4 mmHg) compared to baseline and the end of warm water administration in the first 4 months, respectively. Green tea administration resulted in a decrease in cases of left ventricular hypertrophy in both groups.	24
Shi et al. (2018)	Epigallocatechin Gallate Enhances Treatment Efficacy of Oral Nifedipine Against Pregnancy-Induced Severe Pre-Eclampsia: A Double-Blind, Randomized and Placebo-Controlled Clinical Study	304 pregnant women with severe pre-eclampsia Mean age of intervention group vs control (years): 30.2 ± 5.1 vs 29.4 ± 4.7; Mean gestational age of intervention group vs control (weeks): 37.5 ± 1.3 vs 37.2 ± 1.7	Subjects were divided into 2 groups. The first group received nifedipine + 100 mg EGCG capsules (148 patients) and the second was given nifedipine + placebo/starch capsules (156 patients). The intervention was only given once to both groups and blood pressure measurements were taken every 15 minutes until the patients' blood pressure was below 150/100 mmHg.	The administration of EGCG capsules + nifedipine significantly accelerated blood pressure control (p = 0.03) better (31.2±16.7 minutes) compared to nifedipine + placebo (45.3±21.9 minutes). Additionally, the time interval until the occurrence of hypertensive crisis after successful blood pressure control was longer in the EGCG group (7.2±2.9 hours) compared to the control (4.1±3.7 hours).	25
Ahmad et al. (2018)	Effects of adding milk to black tea on vascular function in healthy men and women: a randomized controlled crossover trial	17 healthy subjects Mean age (years): 22.4 ± 3.04	There were 3 interventions, namely providing 200 mL of black tea, 200 mL of black tea + low-fat milk (20 mL), and 200 mL of warm water. The beverages were consumed 3 times/day for 4 weeks. Each participant completed these 3 interventions without a washout period between each intervention.	Black tea consumption did not significantly affect SBP (p = 0.17) and DBP (p = 0.17) compared to warm water consumption. The addition of milk to black tea increased SBP (p = 0.03) and DBP (p < 0.0001) compared to warm water consumption.	26
Lane et al. (2018)	ProDiet: A Phase II Randomized Placebo-controlled Trial of Green Tea Catechins and Lycopene in Men at	133 men with prostate-specific antigen levels of 2.0-2.974 ng/ml or 2.975-19.95 ng/ml with biopsy (-)	The intervention was carried out by supplementing with lycopene (capsules), green tea (from a beverage of 600 mL/day or 300 mg EGCG capsules), and a placebo. The intervention lasted for 6	There was an increase in SBP after 6 months of green tea beverage administration (146.3 vs 148.1 mmHg), but EGCG capsule administration resulted in a decrease in blood pressure (144.9 vs 142.6 mmHg).	27

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Author (Year)	Title	Sample Size	Description	Result	Ref
	Increased Risk of Prostate Cancer	Mean age of group according to the order beside (years): 64.0 ± 5.8 vs 63.3 ± 5.4 vs 63.2 ± 4.0 vs 64.0 ± 5.1	months.		
Nogueira et al. (2017)	Short-term Effects of Green Tea on Blood Pressure, Endothelial Function, and Metabolic Profile in Obese Prehypertensive Women: A Crossover Randomized Clinical Trial	20 women with a BMI of 30-39.9 kg/m^2 and diagnosed with pre-hypertension Mean age (years): 41.1 ± 8.4	The intervention was divided into 2 groups, namely green tea extract (260 mg polyphenols) and placebo (cellulose). The intervention lasted for 4 weeks with a 2-week washout period.	Green tea extract supplementation significantly reduced 24-hour SBP (p = 0.02), daytime SBP (p = 0.04), and nighttime SBP (p = 0.02) compared to placebo. A decrease in DBP was found, but it was not significant compared to the placebo group.	28

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From the search results, 5 studies used capsules[20-22,25,28], 3 studies applied tea beverages[23,24,26], and 1 study used a combination intervention (capsules and tea beverages)[27]. Almost all studies engaged subjects aged > 40 years and only 1 study used young subjects (< 30 years)[26]. Additionally, approximately all studies used sick subjects and only 1 study included healthy subjects[26]. Intervention duration across various studies ranged from 4 weeks to 8 months, with only 1 study using a short-term to observe the speed of blood pressure reduction in pregnant women with pre-eclampsia using nifedipine and EGCG[25].

Regarding blood pressure, 6 studies (20-22,24,25,28) showed positive results in the form of a significant decrease. Meanwhile, 3 studies (23,26,27) did not observe a significant decrease or difference in blood pressure compared to the control group. One study found that green tea consumption slightly increased blood pressure, but when EGCG capsules were administered, a decrease in blood pressure was observed[27]. These different results could be caused by several factors, including:

Differences in Active Ingredient Content in Various Tea

EGCG is the main active ingredient in tea responsible for lowering blood pressure[19]. Generally, tea contains EGCG ranging from 0.52 to 60.49 mg/g and caffeine ranging from 12.23 to 41.94 mg/g. As shown in Figure 1, a total of 4 studies used capsules containing EGCG with doses ranging from 75 to 300 mg, 1 study applied capsules containing 250 mg anthocyanins, and another used capsules containing 260 mg polyphenols. These studies show that active compounds in tea, particularly EGCG, can lower blood pressure. However, further investigations with larger and more diverse samples are required for confirmation. In the other 3 studies with different results, the intervention included tea beverages (green, black, and white tea). One study used green tea beverages as the intervention, but the absence of caffeine led to the reduction in bias[24]. Consumption of beverages with caffeine levels around 200-300 mg can increase SBP by 8.14 mmHg and DBP by 5.75 mmHg for at least 3 hours[46]. However, the long-term effects of caffeine on blood pressure are still unknown. Besides differences in caffeine content, the amount of active compounds such as EGCG in tea can also affect the differences in blood pressure outcomes. For example, green tea has a high EGCG content (50.78 mg/g) and caffeine content (41.46 mg/g), black tea has a lower EGCG (10.89 mg/g) and caffeine (27.08 mg/g) content, while white tea has a lower EGCG (6.01 mg/g) and caffeine (27.47 mg/g) content[32].

Differences in Beverage Volume in Interventions

The 3 studies with different results had differences in the volume of beverages consumed. For example, Lane et al. (2018)[27] intervened by providing green tea beverages at a volume of 600 mL/day, while others used white tea (150 mL/day) and black tea (600 mL/day)[23, 26]. The study using white tea showed an insignificant decrease in blood pressure due to differences in caffeine content between various types of tea and the volume of beverages consumed. This showed that the amount of caffeine in green tea could be significantly higher compared to white tea.

Differences in Study Subjects

A total of 2 studies used subjects with an average age of over 50 years[23, 27], with aging serving as a strong risk factors for hypertension. Additionally, aging is associated with lower metabolism and clearance of a substance compared to younger individuals. When an individual is over 65 years old, there is a 33% decrease in caffeine metabolism[47], which can affect the ineffectiveness of tea in lowering blood pressure. Although black tea was used as the intervention, the young age of the subjects (average in their 20s) suggested that caffeine did not influence blood pressure changes[26].

The limitations of this study include first, the use of a single search engine and limitations in data extraction. Second, there is little information about the amount of active compounds and caffeine in tea beverages tested. Third, the impact of the intervention on blood pressure reduction was not analyzed. Fourth, most studies used fewer than 100 subjects, making generalization of results difficult. Despite these limitations, the literature search suggested the importance of focusing on harnessing the potential of active compounds in tea, specifically EGCG, for lowering or controlling blood pressure in larger and more diverse populations. Additionally, further studies are required to avoid bias such as the presence of blood pressure-raising substances (caffeine), old age, use of antihypertensive drugs, and comorbidities.

CONCLUSIONS

In conclusion, this study showed that tea contained various bioactive compounds such as polyphenols, pigments, alkaloids, saponins, amino acids, and polysaccharides. In terms of lowering blood pressure, active compounds in tea showed the potential to reduce various inflammatory mediators, increase vasodilator substances, decrease vasoconstrictor substances, and enhance gut microbiota diversity. Recent clinical trials conducted from 2017-2022 investigated the efficacy of tea in blood pressure control. Among these trials, 6 studies showed positive results, namely a significant decrease in blood pressure, while 3 studies reported no substantial effects. Therefore, further studies are recommended to determine the benefits of tea in controlling blood pressure for larger populations.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors declared that there is no conflict of interest. This study received no funding from any organization.

AUTHOR CONTRIBUTIONS

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