International Journal of Physiology, Health and Physical Education

ISSN Print: 2664-7265
ISSN Online: 2664-7273
Impact Factor: RJIF 8
IJPHPE 2025; 7(1): 01-03
www.physiologyjournals.com
Received: 01-10-2024
Accepted: 05-11-2024

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Effects of catechins on cardiovascular disease: A review

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DOI: https://doi.org/10.33545/26647265.2025.v7.i1a.91

Abstract
Catechins, which are polyphenolic compounds, are mainly present in tea, cocoa, and certain fruits, and they have been shown to have a positive impact on health particularly related to cardiovascular disease (CVD). This review article analyses the mechanisms whereby catechins are likely to have a protective effect on the heart through their antioxidant, anti-inflammatory and anti-lipidemic activities. *In vitro* studies, animal studies and clinical trials have shown that catechins enhance vascular endothelial functions, decrease oxidative stress, inhibit platelet activity and activity related to lipid metabolism and possibly also modulate blood pressure and atherosclerotic changes. While It looks promising, there are gaps across studies concerning the recommend dosage, bioavailability and individual response to the metabolism which explains the differences. This has implications of catechins in relation to prevention and management of CVD as functional compounds, while there are some aspects that still need to be assessed.

Keywords: Catechins, cardiovascular disease, antioxidant, endothelial function, lipid metabolism, atherosclerosis, inflammation, polyphenols, bioavailability, blood pressure regulation

1. Introduction
Maintaining a healthy diet is imperative as the World Health Organization indicates cardiovascular diseases rank as the first worldwide cause of mortality and morbidity with over 17 million deaths each year. However, catechins have promising prospects as bioactive compounds that can be used for antioxidative and anti-inflammatory purposes. Yang & Landau (2000) [25] elaborated on how nutrition interventions can be termed as complementary to the otherwise rigorious treatments. Tea, cocoa, and several fruits are distinguished to be rich sources of flavonoids that exhibit cardioprotective qualities, especially catechins. These bioactive compounds demonstrate the aforementioned qualities which are crucial in averting the onset of cardiovascular diseases (CVD). Featured research has illustrated the consumption of catechins leads to enhancement in endothelial function, reduction in oxidative stress, and decreased oxidation of low-density lipoproteins. This consequently reduces the chances of atherosclerosis along with its side effects (Kuriyama, 2008) [11]. In addition to that, looks at the inverse relationship between consumption of meals rich in catechins and the risks of having cardiovascular events say epidemiological studies. The unique nature of catechins in relation with the cardiovascular system brings to contention the fact that it might be a possible drug for the treatment and the prevention of various CVDs.

2. Chemical Composition and Sources of Catechins
Catechins are known to be present in great amounts in green and black tea, in cocoa, and in some fruits including apples and various berries. They are made up of epicatechin, epigallocatechin, epicatechin gallate and epigallocatechin gallate, they are in the class of flavonoids, more specifically of flavan-3-ols (Peluso & Serafini, 2017) [16].

3. Mechanisms of Action
Catechins can be classified as polyphenols that are mainly in tea, cocoa and certain fruits, and have numerous biological activities. Their mechanisms of action are varied and include many biochemical and molecular processes that involve the therapeutic action of catechins.

They can act as antioxidants as they can eliminate free radicals, and also chelate ions, helping to protect against cell damage (Rice-Evans *et al*., 1996) [17]. They are also involved in the modulation of cell signaling pathways like the nuclear factor kappa B (NF-κB) involved in inflammation and immune response regulation (Khan & Mukhtar, 2007) [9]. Furthermore, catechins modulate enzyme activity, inhibit lipid peroxidation, and promote endothelial nitric oxide synthesis with some vascular benefits and disease prevention including cardiovascular and cancer effects. All these underscored mechanisms serve as a testimony to the multifactorial efficacy of catechins towards health promotion and chronic disease control.

Table 1: Summarizing the chemical composition and sources of catechins

Catechin Type	Chemical Formula	Natural Sources	Reference
Epicatechin (EC)	$C_{15}H_{14}O_6$	Green tea, cocoa, apples	Kim *et al*., 2014 [10]
Epigallocatechin (EGC)	$C_{15}H_{14}O_7$	Green tea, black tea, grapes	Cabrera *et al*., 2006 [5]
Epicatechin gallate (ECG)	$C_{22}H_{18}O_{10}$	Green tea, cocoa, berries	Khan & Mukhtar, 2007 [9]
Epigallocatechin gallate (EGCG)	$C_{22}H_{18}O_{11}$	Green tea, white tea, guava leaves	Yang *et al*., 2011 [26]
Catechin (C)	$C_{15}H_{14}O_6$	Dark chocolate, wine, apricots	Friedman *et al*., 2007 [6]
Gallocatechin (GC)	$C_{15}H_{14}O_7$	Green tea, legumes	Balentine *et al*., 1997 [3]

3.1 Antioxidative Properties

Catechins serve to decrease oxidative stress by deactivating free radicals and enhancing internal antioxidant enzyme activity, an important factor in the pathogenesis of endothelial dysfunction and atherosclerosis (Stewart *et al*., 2005) [21].

Table 2: Antioxidative Properties of Catechin Based on Published Studies

Catechin Type	Mechanism of Action	Findings	Reference
Epigallocatechin Gallate (EGCG)	Scavenges free radicals and inhibits lipid peroxidation.	Demonstrated potent antioxidant activity by reducing oxidative stress in endothelial cells.	Nakagawa *et al*., 2002 [15]
Epicatechin (EC)	Enhances endogenous antioxidant enzyme activities (e.g., superoxide dismutase, catalase).	Improved oxidative damage in cardiac tissue of rat models.	Schroeter *et al*., 2006 [19]
Catechin	Inhibits production of reactive oxygen species (ROS) and reduces LDL oxidation.	Lowered oxidized LDL levels in human subjects consuming catechin-rich beverages.	Arts *et al*., 2001 [2]
Epicatechin Gallate (ECG)	Protects DNA and proteins from oxidative damage.	Shown to shield against oxidative stress-induced apoptosis *in vitro*.	Li *et al*., 2006 [12]
Epigallocatechin (EGC)	Chelates metal ions, reducing their catalytic role in ROS generation.	Reduced ROS production in neuronal cells under oxidative stress conditions.	Khan & Mukhtar, 2007 [9]

3.2 Anti-inflammatory Effects

Chronic inflammation is a hallmark of CVD. Catechins inhibit pro-inflammatory cytokines, including tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), through modulation of nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) signaling pathways (Santangelo *et al*., 2007) [18].

Table 3: Anti-inflammatory Effects of Catechins Based on Published Studies

Catechin Source	Inflammatory Pathway/Marker Targeted	Mechanism	Study/Reference
Green Tea	NF-κB pathway	Inhibits activation of the NF-κB signaling pathway, reducing pro-inflammatory cytokines (e.g., IL-6, TNF-α).	Khan & Mukhtar (2007) [9]
Cocoa	COX-2 enzyme	Downregulates COX-2 expression, reducing prostaglandin-mediated inflammation.	Mao *et al*. (2010) [13]
Apples	TNF-α and IL-1β	Suppresses the production of inflammatory cytokines TNF-α and IL-1β.	Serra *et al*. (2012) [20]
Grapes	ICAM-1 and VCAM-1	Reduces expression of adhesion molecules, limiting leukocyte adhesion to endothelial cells.	Wang *et al*. (2008) [23]
Black Tea	IL-8	Reduces IL-8 levels, decreasing neutrophil infiltration and inflammation.	Gardner *et al*. (2007) [7]
Epigallocatechin gallate (EGCG)	JNK and p38 MAPK pathways	Inhibits the JNK and p38 MAPK pathways, reducing inflammatory responses in macrophages.	Ahmed *et al*. (2002) [1]

3.3 Lipid Metabolism

There is evidence of the ability of catechins to reduce low density lipoproteins LDL cholesterol and raise high density lipoproteins HDL cholesterol which favorably alters the lipid profile and decreases the risk of atherogenesis (Tokunaga *et al*., 2002) [22].

3.4 Endothelial Function

The promotion of vascular endothelial function through increased availability of nitric oxide (NO) is also one of the mechanisms. This facilitates enhanced vascular dilation with a consequent decrease in blood pressure (Balzer *et al*., 2008) [4].

4. Clinical Evidence

4.1 Epidemiological Studies

The studies have indicated that there is lower occurrence of cardiovascular events among the populations that consume more catechin containing food products. For example, it was noted in meta analysis that the risk of coronary heart disease decreased by 20% among people with high green tea intake (Hodgson & Croft, 2006).

4.2 Randomized Controlled Trials (RCTs)

RCTs are also strong in providing evidence in support of the beneficial effects of catechins. In the case of Nagao *et al*, 2007 hypertensive patients were given green tea catechins for a month and it was found that their systolic and diastolic blood pressure was significantly less when compared to baseline.

5. Conclusion

In general, catechins that are mainly bioactive compounds found in green tea have been useful in reducing the risk of cardiovascular disease (CVD). Evidence suggests that catechins have antioxidant, anti-inflammatory and lipid lowering effects thus, resulting to increased cardiovascular health. Regular intake of foods or supplements rich in catechins has been shown to lower arterial stiffness, improve endothelial function, and reduce high blood pressure and the incidence of atherosclerosis.

There is, however, a substantial amount of heterogeneity regarding study design, active ingredient dosage, and safety data available long-term. As such, there is room for further development regarding this matter. In the future, well controlled clinical trials should be conducted to assess the optimal target dose, establish the bioavailability of adjustment of catechins, and ascertain possible risks of dosage alteration. Furthermore, research into the synergistic effects of other food nutrients could be beneficial when formulating comprehensive dietary approaches aimed at reducing the risk of CVD.

To conclude, studying adherence to evidence-based practical guidelines remains, for now, the greatest challenge in achieving the expected benefits through natural treatment of cardiovascular system with catechins as their health protective effects are already evident.

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