Health Benefits of Tea — Learn About the Effects of Tea on Health, Including Its Role in the Prevention of Many Diseases
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Researchers are paying increased attention to the health benefits of tea, a popular beverage consumed worldwide. Tea leaves are naturally high in many antioxidant compounds that help reduce inflammation, obesity, and the risk of chronic diseases such as cancer and cardiovascular disease (CVD). The evidence is largely supported by research in human observational and clinical intervention studies, as well as in animal models showing mechanisms of action.

Tea leaves originate from the plant *Camellia sinensis*, which is grown chiefly in Southeast Asia. For many centuries, practitioners of traditional Chinese medicine have considered tea a healthful beverage. According to the classical work of Li Shizhen of the Ming Dynasty, documented approximately 450 years ago, “tea is cold and lowers the fire.”¹ Based on the emerging evidence in conventional research, tea has been associated with many antioxidant and anti-inflammatory effects, and thus habitual tea drinking could play an important role in the prevention of chronic diseases and conditions that pose great challenges to public health and well-being, such as cancer, metabolic syndrome, obesity, diabetes, and CVD.

There are three main types of tea commonly consumed worldwide based on their processing methods. Black tea (78% of worldwide tea production) is the popular beverage in the Western countries; green tea (20%) is favored in Asian countries, and oolong tea (2%) is mostly consumed in southern China.²

Based on a national survey of the US adult population between the years 2003 and 2012, regular tea consumption was prevalent among 26% of adults. When compared with other popular beverages, such as diet and sugar-sweetened drinks, coffee, and alcohol, tea provided fewer calories (69 kcal), based on participant dietary recalls.³ In this survey, tea consumption included different forms of tea products, and while tea leaves aren’t a significant source of calories, the addition of other substances such as sugar and creamer contribute to this caloric content.³ In comparison with other commonly consumed beverages, tea may have a favorable impact on the energy balance that plays a key role in the pathophysiology of many chronic diseases.

This continuing education course examines relevant research investigations, epidemiologic studies, and meta-analyses of tea’s effects on health, including its role in the prevention of many diseases.
Tea Nutrition: Composition and Effects of Processing

Tea possesses significant antioxidative, anti-inflammatory, antimicrobial, anticarcinogenic, antihypertensive, neuroprotective, cholesterol-lowering, and thermogenic properties.

Plant characteristics, such as type and age of the plant, and its growing conditions significantly affect the composition of tea leaves. The nutritional benefits of tea have been mainly attributed to its polyphenolic flavonoid content, especially the catechins, which account for 6% to 16% of the dry green tea leaves. The four major catechins in green tea are epigallocatechin-3-gallate (EGCG), which represents approximately 59% total catechins, followed by epigallocatechin, epicatechin-3-gallate, and epicatechin. Another group of polyphenolic compounds present in both black and oolong teas are theaflavins. During the manufacturing process, the polymerization of catechins leads to the formation of theaflavins, which are the major polyphenols in black tea (2 g theaflavins/100 g brewed black tea) and also confer the bright color of the black tea leaves.

In addition to supplying these bioactive compounds, tea is a source of tannins, caffeine, and minerals such as calcium, potassium, phosphorus, manganese, magnesium, sodium, copper, and zinc.

In terms of caffeine content, black tea has higher levels than green tea, though, in general, levels are much lower than those found in a similar amount of coffee. Caffeine content also is based on brewing time; when brewed for about three minutes, green tea has been shown to contain lower amounts of caffeine (15 mg to 25 mg/150 mL) compared with both black tea (40 mg to 70 mg/150 mL) and regular coffee (80 mg to 115 mg/150 mL).

What produces green tea is the rapid steaming of freshly harvested leaves, which inactivates the enzyme polyphenol oxidase, thereby preventing fermentation and producing a dry, stable product. During the production of black and oolong teas, the processes of withering and dehydration lead to loss of moisture and the concentration and fermentation of the tea polyphenols. This leads to the formation of theaflavins and thearubigins and a decrease in the naturally occurring catechin content in tea leaves. Tea catechins, especially EGCG, are unstable compounds and have been reported to be lowered by manufacturing processes and even by the household method of brewing tea leaves in hot water. Reports published by the USDA’s Nutrient Data Laboratory show that processing methods such as decaffeination drastically lower the EGCG content in brewed green tea, which has approximately 26 mg/100 g tea compared with fully caffeinated brewed tea, which has approximately 70 mg/100 g tea. A similar loss of green tea bioactive compounds has been identified in ready-to-drink green tea (approximately 4 mg/100 g tea) as compared with freshly brewed tea. Black tea also shows considerable loss of thearubigins when it’s decaffeinated (approximately 49 mg/100 g tea), compared with regular, fully caffeinated tea (approximately 81 mg/100 g tea). Similarly, processing of instant tea powder also leads to loss of thearubigins (approximately 24 mg/100 g tea) compared with regular black tea. Thus, processing considerably lowers the nutritional
compounds in tea and must be considered in making effective dietary recommendations to consumers.

**Antioxidants in Tea**
Oxidative damage to biomolecules has been implicated in the pathology of several chronic diseases, including CVD, cancers, and neurodegenerative diseases. Many studies have demonstrated that tea polyphenols are effective antioxidants and are scavengers of reactive oxygen species in vitro. They also may function indirectly as antioxidants through their effects on genes and enzyme activities related to the pathogenesis of chronic diseases.\(^6,10\) Human studies show an increase in plasma antioxidant capacity following tea consumption, as well as a decrease in biomarkers such as lipid peroxidation and DNA damage following tea supplementation in individuals at risk of CVD. A randomized controlled trial of heavy smokers, who for four months consumed four cups per day of decaffeinated green tea, black tea, or water revealed that only green tea caused a lowering of urinary 8-hydroxydeoxyguanosine, a marker of oxidative damage of DNA, suggesting a protective antioxidant function of green tea.\(^11\) Similarly, a three-month randomized controlled trial of obese participants who took green tea extracts (379 mg/day) showed a remarkable increase in plasma antioxidant status as well as a decrease in BMI and waist circumference compared with the control group.\(^12\) Overall, while both green tea and black tea polyphenols show antioxidant activity, green tea confers greater antioxidant protection, as revealed in these clinical studies.

**Tea as an Anti-inflammatory Beverage**
The anti-inflammatory activity of polyphenols in green tea and black tea has been demonstrated in various animal models of inflammation, and numerous mechanisms have been suggested for their related anticancer activities, including suppression of NF-kappaB, inflammasome, and interleukin (IL)-1β secretion in cells. Synergistic effects of EGCG in combination with drugs has been extensively studied, and it’s claimed that green tea extracts are synergists with anticancer drugs and micronutrients in reducing inflammation.\(^13\) In an animal model of obesity and inflammation, researchers demonstrated green tea, black tea, and oolong tea polyphenol treatment for 20 weeks considerably lowered inflammatory gene expression such as monocyte chemotactic protein-1, which is associated with decreased risks of atherosclerosis, and increased expression of genes with anti-inflammatory activity, such as adiponectin, which is linked with protection against insulin resistance and diabetes.\(^14\)

In an animal model of rheumatoid arthritis (RA) related to chronic inflammation, green tea extracts, but not black tea, were shown to reduce joint inflammation and improve arthritis symptoms.\(^15\) While many such animal models support the anti-inflammatory function of tea, few human studies report similar effects. Using an “anti-inflammatory dietary mix” of resveratrol, green tea extract, alpha-tocopherol, vitamin C, omega-3 polyunsaturated fatty acids, and tomato extract for four weeks, Bakker and colleagues from the Netherlands showed modest changes in inflammation in overweight men. The antioxidant mix contained
approximately 95 mg green tea extracts and was claimed to be equivalent to 300 mL tea per day. However, the study revealed protective associations of the supplement against liver dysfunction, oxidative damage, and endothelial dysfunction in these adults. This study may support the hypothesis that tea’s anti-inflammatory effects may result from the synergistic action with other dietary components in lowering risk factors of chronic diseases in humans.

Tea as a Weight Loss Agent
Many researchers have identified obesity as a major risk factor for diabetes; CVD; several forms of cancer, such as breast, colon, and prostate; and pulmonary, osteoarticular, and metabolic diseases. Several epidemiologic studies and meta-analyses of clinical trials suggest that tea and its bioactive polyphenolic constituents have antiobesity effects. The two main components of tea, especially green tea, that have been related to energy expenditure are caffeine and the catechins. Both components have independent effects on energy metabolism and subsequent weight loss or weight maintenance. Caffeine is the purine alkaloid of tea and has been shown to increase thermogenesis, fat oxidation, and energy expenditure through various mechanisms such as the inhibition of phosphodiesterase enzyme and stimulation of lipase enzyme and the Cori cycle, thereby increasing oxidation of free fatty acids. The catechins in green tea have been shown to inhibit the catechol-O-methyltransferase enzyme, leading to the prolonged action of the neurotransmitter norepinephrine. This leads to continued stimulation of the sympathetic nervous system, and norepinephrine then connects to β-adenovirus receptors and causes an increase in energy expenditure and fat oxidation.

A comprehensive meta-analysis of 15 randomized controlled trials involving a large sample size of 1,243 patients supplemented with green tea catechins with caffeine showed a considerable loss of body weight (average -1.38 kg) and waist circumference (average -1.93 cm) when compared with the control participants taking caffeine only. Studies on green tea catechins without caffeine, however, didn’t show promising weight loss effects. The green tea catechin doses in these studies had a wide range, approximately 140 mg to 1,200 mg per day, and were administered in various dosage forms, such as green tea extract capsules or green tea beverages. Furthermore, these studies support the role of green tea in effectively reducing body weight without any concomitant dietary or lifestyle modifications. Since obesity is an important risk factor for many chronic diseases, the weight loss effects of tea generally are considered protective against the risks of diabetes, CVD, and cancer.

Role of Tea in Disease
Based on the antioxidant, anti-inflammatory, and antiobesity effects of tea, researchers have further examined the effects of habitual tea drinking on risk factors and the development of chronic diseases that affect the US and global populations.

CVD
Tea drinking was associated with distinct cardiovascular health benefits in the 1990s, supported by a few landmark observational studies in the Netherlands that reported inverse associations of black tea with advanced forms of CVD. The Zutphen Elderly Study in men was initiated in 1985, and researchers followed up with participants for about five years. The study revealed significant protective associations of flavonoid intake from tea, onions, and apples, with a 60% risk reduction in mortality associated with coronary heart disease. The Rotterdam Study, which involved middle-aged to older men and women, showed a strong risk reduction of severe atherosclerosis, approximately 70% among those consuming about 500 mL tea (~2 cups) daily compared with nonconsumers. Since then, various observational and clinical studies have shown benefits of green tea and black tea in reducing CVD risks, especially in reducing CVD events; independent risk factors, such as hypertension and high blood cholesterol levels; and surrogate biomarkers of atherosclerosis, such as oxidized lipids and markers of inflammation. When compared with black tea, green tea has been more strongly associated with CVD health benefits, and these effects have been explained by the presence of intact catechins in green tea. A 2016 meta-analysis of observational studies revealed an approximate 20% risk reduction of myocardial infarction and a 36% risk reduction of stroke in adults who consumed one to three cups green tea per day compared with nonconsumers. This study also showed that drinking about 10 cups or more of green tea was related to a reduction in serum LDL cholesterol when compared with consumption of fewer than three cups per day. In another similar study, increasing green tea consumption by about one cup per day compared with none was correlated with a 5% decrease in CVD mortality. Similar increases in black tea consumption also was associated with an 8% lower risk of CVD mortality. An interesting point of discussion in this 2015 meta-analysis was the combined effects of flavonoids and phytoestrogens in green tea, which, as the authors explain, led to the observation of stronger protective associations in women than in men. Many of these cardioprotective effects have been explained previously by the role of tea catechins as antioxidants and anti-inflammatory, antiobesity, and antiatherosclerotic agents in laboratory-based studies.

**Diabetes**

Much research has been focused on the role of tea drinking in reducing risk factors for type 2 diabetes, which continues to be a major public health challenge among chronic diseases. In a comprehensive meta-analysis of 17 randomized controlled trials, consumption of green tea was associated with decreased fasting glucose (average -1.6 mg/dL), insulin (average -1.16 μIU/mL), and hemoglobin A1c (average -0.3%) when compared with the control group, who consumed inactive placebo capsules, water, or low-polyphenol green tea. The clinical trials included in this meta-analysis involved the administration of green tea catechins that ranged from 208 mg to 1,207 mg/day (median: 457 mg/day), and a study duration of two weeks to six months (median: 12 weeks).

In addition to fasting glucose status, postprandial hyperglycemia also plays an important role in the development of CVD complications in diabetes, yet tea supplementation has been shown
to improve it. In a Japanese study of healthy postmenopausal women, acute catechin-enriched green tea consumption (350 mL) with a breakfast meal showed a 3% reduction in postprandial glucose levels when compared with the placebo group.\textsuperscript{25} In an earlier study from the United Kingdom, instant black tea supplementation (1 g tea solids) consumed with a 75 g oral glucose load caused a decrease in postprandial serum glucose in healthy adults.\textsuperscript{26} Tea’s antidiabetic effects have been supported by various mechanisms, such as improvement in antioxidant status, depletion of fat deposition and subsequently reduction of inflammatory cytokines that are secreted from fat cells and cause insulin resistance, reduction of carbohydrate digestion and absorption in the intestinal tract, and improvement in insulin action on target tissues in diabetes animal models.\textsuperscript{27,28}

**Cancer**

In contrast to the role of tea in obesity, diabetes, and CVD, large observational studies from different countries such as Australia and Japan don’t support an association between habitual intake of black or green tea and overall or cause-specific cancer mortality.\textsuperscript{29,30} Based on the findings from observational studies, limited evidence supporting a beneficial role of tea intake against cancer development has been documented. On the other hand, a few reported clinical trials support modest protective effects of green tea against the development of malignant tumors. In a six-month clinical study of 59 patients, Li and colleagues demonstrated a significant effect of green tea treatment (3 g/day orally and topically) in reducing the size of oral premalignant lesions, compared with the placebo group of glycerin treatment.\textsuperscript{31} In another study involving 48 men with prostate cancer awaiting surgery, green tea polyphenol treatment for six weeks (800 mg EGCG) led to a nonsignificant reduction in serum prostate-specific antigen, a biomarker of prostate tissue carcinogenesis. This study also showed a decrease in oxidative DNA damage in white blood cells, thus demonstrating a potential protective function of green tea as an antioxidant.\textsuperscript{32}

Overall, the effects of tea drinking on cancer risk are conflicting and remain an area for further research. This also may be related to the multifactorial causes of cancer, as well as its stages of development in different populations that may modify the outcomes of habitual tea consumption vs acute treatment following diagnosis of the disease. It’s important to note that the mode of delivery of tea polyphenols, such as beverage vs green tea extracts or topical application of green tea-containing pharmaceutical agents must be evaluated for site-specific cancers when compared with other chronic diseases. This is indeed an area of synergy between nutritional and pharmaceutical sciences.

**Neurodegenerative Diseases**

Oxidative stress and inflammation play a pivotal role in neurodegenerative diseases and lead to the formation of β-amyloid plaques and neurofibrillary tangles that characterize Alzheimer’s disease as well as the dopaminergic neuronal death that occurs in Parkinson’s disease. Green tea polyphenols have attracted significant attention based on their emerging role in reducing oxidative stress and inflammation in brain cells underlying these neurodegenerative conditions.
In a meta-analysis of observational studies conducted in Asia, Europe, and the United States, tea consumers were found to have an approximately 40% risk reduction of Parkinson’s disease compared with nonconsumers. On a scale of zero to 10 cups tea per day, the meta-analysis showed a significant dose-dependent linear relationship in which risks of Parkinson’s disease decreased by 26% for every two-cup increase in tea consumption. The researchers further explain that these findings were stronger for studies conducted among the Asian and European populations than for the US population. This could be explained by differences in demographic characteristics, specific forms of tea consumed, and habitual dietary intakes among these populations.

In a recently reported eight-month clinical trial of patients with Alzheimer’s disease, an antioxidant beverage supplement improved markers of oxidative stress in the early phases of the disease. The antioxidant beverage was a combination of green tea and apple extracts, rich in polyphenolic antioxidants and antioxidant vitamins and minerals. Though these findings are preliminary, long-term green tea consumption alone and in combination with other polyphenol-rich beverages may offer significant neuroprotection.

**Arthritis**
RA is a chronic inflammatory disease of the joints in which systemic overproduction of proinflammatory cytokines, such as IL-6 and tumor necrosis factor-α (TNF-α), may accelerate CVD complications. EGCG found in green tea has been shown to possess cardiovascular benefits and antirheumatic activity in independent studies using in vitro and preclinical models of these pathologies. Some of these benefits of EGCG are achieved via inhibition of markers and mediators such as IL-6, TNF-α, C-reactive protein, and excess body fat that play important roles in the initiation and propagation stages of both CVD and RA. However, a meta-analysis of observational studies found no protective associations between tea drinking and RA. Though there’s a lack of large clinical studies on tea’s effects on RA, cross-sectional studies provide evidence of the protective association of tea drinking and physical function, as assessed by gait, balance, and the ability to perform activities of daily living in older adults. The researchers used a summation of scores on all types of tea consumption and explained these findings as due to the antioxidant properties of catechins, theaflavins, and thearubigins in tea, which may improve physical performance and muscle strength in older adults. While this emerging research calls for further study, it supports tea’s role in relieving symptoms of arthritis, a major debilitating condition in the aging population.

**Osteoporosis**
Osteoporosis is a major challenge for the aging population, and strategies for prevention rather than treatment are essential for preserving quality of life and reducing health care costs. Observational studies have reported an association between tea consumption and better bone health in populations worldwide. Most of these studies involved postmenopausal women and investigated the association between tea consumption and bone health using a measurement of bone mineral density at one or multiple skeletal sites, commonly the hip and/or spine, using
dual X-ray absorptiometry as a measure of bone health and a surrogate measure for risk of fragility fracture. Animal models of osteoporosis support the role of tea polyphenols in preventing bone loss and maintaining optimal bone architecture that promotes bone strength and prevents osteoporosis. These osteoprotective effects have been shown to be mediated through tea’s antioxidant or anti-inflammatory effects on other cellular signals that affect bone metabolism.\textsuperscript{37,38} In addition to green tea’s effects per se, clinical studies also reveal promising effects of a combination of green tea (500 mg polyphenols/day) and tai chi exercise (60 minutes three times/week) for six months in reducing oxidative stress in postmenopausal women with osteopenia.\textsuperscript{39} While further studies are needed in this area, the emerging evidence supports tea’s protective role in the management of osteoporosis.

**Risks and Contraindications**

While the scientific evidence may support the health benefits of tea drinking, it’s also important to acknowledge some of the health concerns that have been identified as a result of overconsumption of tea. The caffeine content in different tea varieties has been a concern, especially when consumed in doses greater than 400 mg/day.\textsuperscript{40} The reported negative effects produced by caffeine that are present in many tea products are nervousness, restlessness, tremors, palpitations, sleep disorders, vomiting, diarrhea, headaches, epigastric pain, and tachycardia.\textsuperscript{40} Owing to tannins present in black tea, its consumption with meals reduces the absorption of nonheme iron, as reported in animal studies. However, this causation hasn’t been consistently supported by human studies. In a systematic review of 16 studies in Western populations, tea consumption didn’t influence iron status; most of these studies included participants with adequate iron stores, as determined by serum ferritin concentrations. The study also revealed a negative association between tea consumption and iron status only in individuals with marginal iron status.\textsuperscript{41} Thus, tea consumption must be exercised with some caution in those with clinical symptoms of anemia or iron deficiency. Finally, in relation to the safety of large doses of tea polyphenols, studies have shown doses of up to 1,200 mg tea polyphenols (~10 to 12 cups) produce side effects such as excess intestinal gas, nausea, heartburn, stomachache, abdominal pain, dizziness, and muscle pain. Large doses of tea polyphenols (such as 1,500 mg/kg body weight) also have been shown to cause liver damage in animal studies of toxicities.\textsuperscript{42} Drinking smaller amounts of tea (approximately four cups/day), as reported in most clinical and epidemiologic studies, hasn’t been associated with significant side effects.

**Putting It Into Practice**

Based on various sources of scientific evidence, it may be concluded that drinking at least two cups of freshly brewed tea on a daily basis will confer protection against the development of chronic diseases. Larger doses, such as those of up to four cups of a tea beverage or an average of 500 mg tea polyphenols, may be needed to lower clinical biomarkers of diabetes and CVD, especially for lowering blood glucose and lipids. Evidence on the protective effects of tea in cancer, arthritis, neurodegenerative diseases, and osteoporosis are emerging and somewhat conflicting. Nevertheless, based on significant findings from large observational
studies, including those in older adults, tea drinking may be safely incorporated in the primary prevention of many chronic diseases. In most studies, green tea appears to be more protective than black tea, and, in both cases, consuming freshly brewed tea compared with concentrated doses of tea polyphenols remains a safer and cheaper preventive strategy. Consumers also should be cautious about the ready-to-drink bottled and canned tea in which the catechins are mostly less bioactive due to heat processing and storage. In addition, the added sugar in some of these commercial tea drinks can outweigh the benefits of the tea polyphenols. Keeping in view the low prevalence of green tea drinking in the western populations, RDs may advise their clients to incorporate some freshly brewed green tea into fruit juices, smoothies, and vegetable soups to mask the astringency characterizing green tea and to provide the benefits of the synergistic action of green tea catechins with other nutrients.

In light of the current evidence, RDs should advocate tea drinking as part of a healthful diet and as a superior choice to other beverages, especially the sugar-sweetened beverages readily available to consumers. Tea as a beverage has many established and emerging health benefits that support its role in the management of chronic disease conditions.

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References


Quiz

1. Tea is a rich source of polyphenols. Which of the following polyphenols are most abundant in green tea and black tea, respectively?
   A. Catechins and epigallocatechin-3-gallate (EGCG)
   B. EGCG and epigallocatechin
   C. EGCG and theaflavins
   D. Theaflavins and thearubigins

2. Which of the following chemical processes in tea production leads to the characteristic flavor, color, and polyphenols in black tea compared with green tea?
   A. Drying
   B. Fermentation
   C. Decaffeination
   D. Storage

3. Based on the USDA database, which of the following reduces flavonoid/polyphenol content of tea?
   A. Adding water
   B. Decaffeination
   C. Brewing
   D. Adding sugar

4. Which of the following can be associated with the antioxidant protection of tea beverages based on findings in human studies?
   A. Decrease in liver enzymes
   B. Increase in plasma antioxidant capacity
   C. Increase in DNA damage
   D. Increase in appetite

5. Which of the following can be related to the weight loss effects of tea catechins?
   A. Decrease in lipids
   B. Increase in carbon dioxide output
   C. Decrease in catechol-O-methyltransferase enzyme activity
D. Decrease in inflammation

6. Which is the main finding of the Zutphen Elderly Study and the Rotterdam Study associated with the health benefits of tea drinking?
A. Tea reduces oxidative stress and inflammation.
B. Tea reduces breast cancer incidence.
C. Tea reduces risks of atherosclerosis and deaths from coronary heart disease.
D. Tea promotes cardiovascular health.

7. The meta-analysis of clinical trials on green tea’s effects on type 2 diabetes shows that green tea consumption does which of the following?
A. Decreases fasting blood glucose only
B. Decreases both fasting and postprandial blood glucose
C. Decreases inflammation
D. Decreases fasting blood glucose, insulin, and hemoglobin A1c

8. Based on evidence from clinical trials on tea in cancer, EGCG may do which of the following?
A. Act as an antioxidant
B. Decrease serum prostate-specific antigen
C. Decrease bone mass
D. Increase interleukin-10

9. Emerging evidence from clinical trials in osteoporosis shows that green tea may promote bone health in combination with which of the following?
A. Caffeine
B. Dietary fats
C. Tai chi
D. Vitamin E

10. In high doses, tea may cause which of the following?
A. Sodium deficiency
B. Liver damage
C. Heart attack
D. Loss of sensation