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REVIEW ARTICLE

Green tea and cancer and cardiometabolic diseases: a review of the current epidemiological evidence

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Abstract

Green tea is commonly consumed in China, Japan, and Korea and certain parts of North Africa and is gaining popularity in other parts of the world. The aim of this review was to objectively evaluate the existing evidence related to green tea consumption and various health outcomes, especially cancer, cardiovascular disease and diabetes. This review captured evidence from meta-analyses as well as expert reports and recent individual studies. For certain individual cancer sites: endometrial, lung, oral and ovarian cancer, and non-Hodgkins lymphoma the majority of meta-analyses observed an inverse association with green tea. Mixed findings were observed for breast, esophageal, gastric, liver and a mostly null association for colorectal, pancreatic, and prostate cancer. No studies reported adverse effects from green tea related to cancer although consuming hot tea has been found to possibly increase the risk of esophageal cancer and concerns of hepatotoxity were raised as a result of high doses of green tea. The literature overall supports an inverse association between green tea and cardiovascular disease-related health outcomes. The evidence for diabetes-related health outcomes is less convincing, while the included meta-analyses generally suggested an inverse association between green tea and BMI-related and blood pressure outcomes. Fewer studies investigated the association between green tea and other health outcomes such as cognitive outcomes, dental health, injuries and respiratory disease. This review concludes that green tea consumption overall may be considered beneficial for human health.

Introduction

Green tea is commonly consumed in East Asian countries such as China and Japan, as well as some parts of North Africa and the Middle East [1]. Green tea's popularity is increasing globally. Green tea is made from leaves that are steamed (Japan) or roasted (China) shortly after harvesting to inactivate enzymes, preventing oxidative fermentation, then pressed and finally dried [2, 3]. A 2014 review includes a useful overview of catechin's composition of brewed green tea based on the USDA Database for the Flavonoid Content [4]. Various potential health benefits of green tea have been reviewed [5] including anti-inflammatory [6], antibacterial [7], neuroprotective [8], and cholesterol-lowering effects [9], which may have an impact on cancer and cardiometabolic risk.

The World Cancer Research Fund Third Expert Report and Continuous Update Project (CUP) [2, 10] includes a discussion on green tea consumption and site-specific cancers, however, evidence was too limited to draw a conclusion [2]. The International Agency for Research on Cancer Monographs Volume 51 published in 1991 also includes an evaluation of green tea carcinogenic risks to humans [3]. Numerous meta-analyses and individual studies exist on the association between green tea and various health outcomes particularly individual cancers [11–14].

Evidence on the health effects of green tea and various health outcomes is accruing, 2020 is an opportune time to review the evidence. Compared to coffee [15] and black tea [16] fewer meta-analyses are available on individual health outcomes and therefore a strict umbrella review, exclusively including meta-analyses, was not deemed the most appropriate design to capture the breadth of evidence for this study. Previous green tea reviews emphasized general health benefits in vitro or specific outcomes. In this review, we aim to deliver an objective overview of the current

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evidence from meta-analyses, individual studies and reports on green tea and health outcomes with a focus on individual cancer sites, cardiovascular disease, and diabetes.

Methods

We searched Pubmed, Web of Science and Cochrane (between 1980 and 2020) with no language restrictions for papers on "green tea" and "meta-analysis" on February 6, 2020 resulting in 551 papers. We hand-searched the references of included papers to identify and include additional possibly relevant studies ($n = 11$). After excluding duplicates, 233 titles remained for screening (Fig. 1). Titles not related to the topic were excluded leaving 107 eligible abstracts. Articles were screened and grouped using Endnote and Rayyan QCRI [17]. After fulltext screening 82 meta-analyses were included in the review. Additionally we consulted the World Cancer Research Fund CUP and IARC Monographs for available expert evidence on cancer-related outcomes as well as major original recently published peer-reviewed papers.

Cancer

The association between green tea consumption and total cancer risk is inconclusive [18–20]. A decreased risk of total cancer mortality was reported among Japanese women HR = 0.91 (0.85–0.98), but not men HR = 1.02 (0.89–1.10) [21].

Figure 2 provides overall risk from most comprehensive and recent meta-analyses for each cancer site. Table 1 provides an overview of meta-analyses on green tea consumption and site-specific cancer risk [13, 21–78]. A 2020 meta-analysis on green tea and breast cancer including 16 studies reported a pooled relative risks of 0.86 (95% CI: 0.75–0.99) [34]. Among reproductive organ-related cancers, meta-analyses on endometrial cancer [78] and ovarian cancer reported inverse associations RR = 0.89 (95% CI 0.84–0.94) and RR = 0.64 (95% CI 0.45–0.90), respectively [76]. An inverse association was also found for lung cancer OR = 0.69 (95% CI 0.48–0.82) [58], non-Hodgkins lymphoma RR = 0.61 (95% CI 0.38–0.99) [62] and oral cancer RR = 0.85 (95% CI 0.75–0.93) [64].

A recent review of green tea and esophageal suggests an inverse association of RR = 0.65 (95% CI: 0.57–0.73) [45] contrary to previous reviews reporting null associations [46, 47]. Some individual studies suggest an increased risk of esophageal cancer among those consuming hot tea [79]. A 2017 review reports a null association with gastric cancer in cohort studies with an inverse association only among case-control studies OR = 0.84 (95% CI 0.74–0.95) [50]. This association may have possible gender differences [80]. An inverse association between green tea and liver cancer risk is supported by recent meta-analyses [53–55]. Some liver-related safety concerns have been raised such as, hepatotoxicity partially induced by green tea, however, a 2016 systematic review concluded that liver-related adverse events are rare [81]. A single original study reported that high doses of green tea may be associated with hepatoxicity due to raised alanine aminotransferase and bilirubin levels in humans [82].

Associations between green tea consumption and cancers of the bladder [26], colorectum [40], pancreas [65] and prostate [69] are not supported by recent meta-analyses. From a previous review, individual studies reported a 30–40% reduced risk of colon cancer conducted in Chinese and Japanese populations where a wider range of green tea intake exists [83].

Cardiovascular disease

Table 2 reports results from meta-analyses on green tea and cardiovascular-related outcomes [14, 21, 22, 84–87]. Three

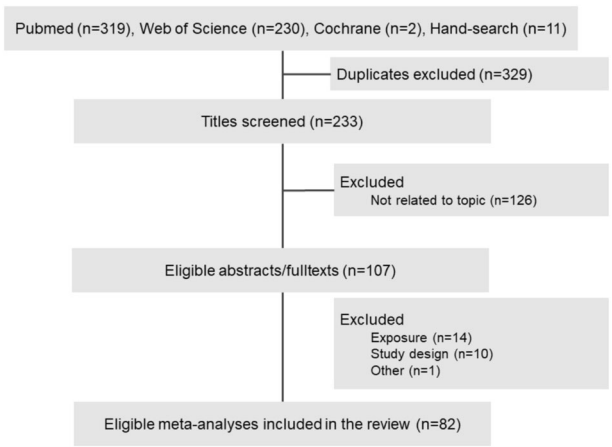

Fig. 1 Flowchart of search strategy and selection of meta-analyses.

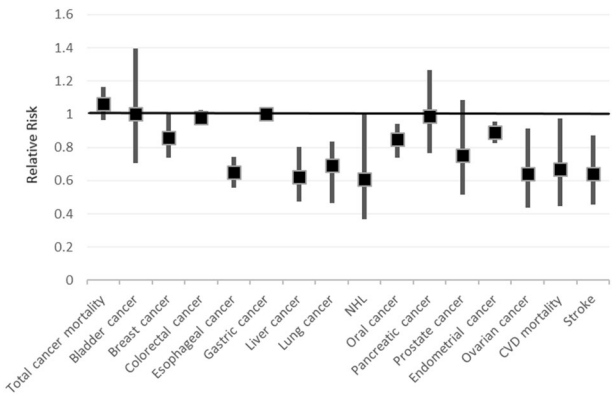

Fig. 2 Green tea consumption and overall risk of cancer and cardiovascular disease from recent meta-analyses. References of meta-analyses included in Fig. 2 [13, 14, 22, 26, 34, 40, 45, 54, 58, 62, 64, 65, 69, 76, 78]. Note: Colorectal, lung and pancreatic cancer risk reported as Odds Ratios.

Table 1 Green tea consumption and summary risk of cancer from meta-analyses.

Cancer site	Meta	Effect	Size	(95% CI)	Studies	Study design	Reference
Total cancer mortality	2	HR	1.02	(0.89–1.10) men	8	Cohort	[21]
		HR	0.91	(0.85–0.98) women			
		RR	1.06	(0.98–1.15)	6	Cohort	[22]
Bladder cancer	7	OR	0.81	(0.68–0.98)	NA	Cohort	[23]
						Case-control	
		OR	0.95	(0.73–1.24)	3	Cohort	[25]
					4	Case-control	
		RR	1.03	(0.82–1.31)	3	Case-control	[28]
					2	2 Cohort	
		RR	1	(0.72–1.38)	6	NA	[26]
		OR	0.76	(0.66–0.95)	5	NA	[24]
		OR	0.97	(0.73–1.21)	3	Cohort	[27]
					2	HCC	
		RR	1.02	(0.95–1.11)	3	Cohort	[13]
Breast cancer	12	OR	0.85	(0.80–0.92)	5	Case-control	[30]
					7	Cohort	
					2	Follow-up	
		OR	0.81	(0.66–0.98)	9	Case-control	[35]
		OR	0.99	(0.81–1.14)	4	Cohort	
		RR	0.85	(0.75–1.12)	2	Cohort	[31]
		OR	0.81	(0.81–0.88)	5	Case-control	
		RR	0.89	(0.71–1.10)	3	Cohort	[36]
		OR	0.44	(0.14–1.31)	2	Case-control	
		RR	0.85	(0.66–1.09)	3	Cohort	[32]
		OR	0.47	(0.26–0.85)	1	Case-control	
		RR	0.82	(0.64–1.04)	4	Cohort	[37]
					5	Case-control	
		OR	0.9	(0.75–1.10)	7	Case-control	[38]
		RR	1.03	(0.96–1.10)	4	Cohort	
		OR	0.79	(0.65–0.95)	3	Cohort	[33]
					13	Case-control	
		RR	0.86	(0.75–0.99)	9	Case-control	[34]
					7	Cohort	
		RR	0.97	(0.90–1.06)	4	Cohort	[39]
		OR	0.83	(0.72–0.96)	14	Case-control	[29]
		RR	0.99	(0.96–1.02)	4	Cohort	[13]
Colorectal cancer	6	OR	0.98	(0.96–1.01)	10	Cohort/Case-control	[40]
		RR	0.97	(0.97–1.16)	4	Cohort	[44]
		OR	0.74	(0.63–0.86)	4	Case-control	
		OR	0.95	(0.81–1.11)	13	Case-control	[41]
		RR	0.9	(0.72–1.08)	6	Cohort	[42]
		RR	1	(0.94–1.07)	5	Cohort	[39]
		RR	0.98	(0.95–1.02) colon	5	Cohort	[13]
		RR	1.01	(0.98–1.05) rectum			

Table 1 (continued)

Cancer site	Meta	Effect	Size	(95% CI)	Studies	Study design	Reference
Esophageal cancer	4	RR	1.09	(0.76–1.55) total	4	PCC	[46]
					2	HCC	
					1	Cohort	
					5	NCC	
		RR	0.65	(0.57–0.73)	17	Case-control	[12]
					3	Cohort	
		RR/OR	0.76	(0.49–1.02)	6	PCC	[48]
					2	Cohort	
					2	HCC	
		OR	0.77	(0.57–1.04)	14	Case-control	[47]
					2	Cohort	
Gastric cancer	6	OR	1.05	(0.90–1.21)	5	Cohort	[50]
		OR	0.84	(0.74–0.95)	8	Case-control	
		RR	1.56	(0.93–2.60)	4	Cohort	[49]
		OR	1.12	(0.70–1.77)	4	HCC	
		OR	0.67	(0.49–0.92)	6	PCC	
		RR	1.00	(0.98–1.02)	8	Cohort	[13]
		RR	1.04	(0.93–1.17)	5	Cohort	[51]
		OR	0.73	(0.64–0.83)	8	Case-control	
		RR	0.99	(0.94–1.05)	4	Cohort	[39]
		RR	1.03	(0.92–1.16)	7	Cohort	[52]
		OR	0.74	(0.63–0.86)	11	Case-control	
Liver cancer	6	RR	0.88	(0.81–0.97)	9	Cohort	[53]
		RR	0.77	(0.57–1.03)	5	Cohort	[56]
					3	HCC	
		RR	0.62	(0.49–0.79)	6	Cohort	[54]
					4	Case-control	
		RR	0.93	(0.75–1.17)	3	Cohort	[39]
		RR	0.99	(0.97–1.01)	6	Cohort	[57]
					1	Case-control	
		RR	0.68	(0.56–0.82)	9	Cohort	[55]
					3	Retrospective	
					1	Cross-sectional	
Lung cancer	5	OR	0.69	(0.48–0.82)	7	PCC	[58]
					3	HCC	
					4	Cohort	
						NCC	
		RR	0.75	(0.62–0.91)	4	Cohort	[61]
					11	Case-control	
		RR	1.19	(0.86–1.65)	2	Prospective	[13]
						Observational	
		RR	0.67	(0.48–0.79)	6	NA	[60]
		RR	0.78	(0.61–1.00)	5	Prospective	[59]
					7	Case-control	
NHL	1	RR	0.61	(0.38–0.99)	2	Cohort	[62]
					1	Case-control	

Table 1 (continued)

Cancer site	Meta	Effect	Size	(95% CI)	Studies	Study design	Reference
Oral cancer	2	RR	0.85	(0.75–0.93)	12	Case-control	[64]
					3	Cohort	
		RR	0.8	(0.67–0.94)	4	Case-control	[63]
					1	Cohort	
Pancreatic cancer	5	OR	1.15	(0.89–1.48)	4	Cohort	[66]
		RR	1.01	(0.84–1.20)	11	Cohort/case-control	[68]
		OR	0.96	(0.79–1.16)	4	Cohort	[67]
					2	PCC	
					1	HCC	
		OR	0.99	(0.78–1.25)	5	Cohort	[65]
					3	Case-control	
		RR	1.01	(0.98–1.04)	5	Cohort	[13]
Prostate cancer	6	RR	0.98	(0.80–1.19)	4	Cohort	[69]
			0.45	(0.25–0.82)	3	Case-control	
		OR	0.73	(0.52–1.02)	5	Cohort	[72]
					4	HCC	
		OR	0.79	(0.43–1.14)	4	Cohort	[70]
					1	HCC	
					4	PCC	
		OR	0.43	(0.25–0.73)	3	Case-control	[71]
		RR	1	(0.66–1.53)	4	Cohort	
		RR	0.99	(0.88–1.11)	4	Cohort	[39]
		RR	1.01	(0.97–1.05)	4	Cohort	[13]
Endometrial cancer	3	OR	0.78	(0.62–0.98)	5	Case-control	[73]
					1	Cohort	
		RR	0.85	(0.77–0.94)	4	NA	[77]
		RR	0.89	(0.84–0.94)	5	Case-control	[78]
					1	Cohort	
Ovarian cancer	4	OR	0.66	(0.54–0.80)	4	Case-control	[73]
		OR	0.81	(0.73–0.89)	6	Case-control	[74]
		OR	0.58	(0.33–1.01)	3	Case-control	[75]
		RR	0.64	(0.45–0.90)	5	Case-control	[76]

Meta: number of meta-analyses; studies: number of original studies included; study design: study design of included original studies.

HCC hospital-based case-control study, *NA* not available, *NCC* nested-based case-control study, *NHL* non-Hodgkins lymphoma, *PCC* population based case-control.

meta-analyses on green tea consumption and cardiovascular disease mortality support a reduced risk ranging between 18% and 33% [21, 22, 84] (Table 2). The findings from four other meta-analyses were similar for stroke incidence with a reduced risk of 17% to 36% [14, 84, 85]. While one meta-analysis on tea and coronary artery disease (CAD) including five studies on green tea reported a summary relative risk of 0.72 (95% CI 0.58–0.89) [87], a meta-analysis including a single original study reported a null association of RR = 1.02 (95% CI 0.92–1.13) for coronary heart disease (CHD) [84] (Table 2). The two terms are often used interchangeably however CHD is actually a result of CAD [88]. Another meta-analysis including nine studies reported an inverse association with myocardial infarction both in the 1–3 cup/day consumption group and greater than or equal to four cups but not for intracerebral hemorrhage, CVD and cerebral infarction [14] (Table 2).

Metabolic-related diseases

Table 3 shows the findings for type 2 diabetes-related markers, BMI-related outcomes, and blood pressure (systolic and diastolic) [89–106]. Three meta-analyses including randomized control trials (RCTs) [89–91] and one including

Table 2 Green tea consumption and risk of cardiovascular disease from meta-analyses.

Category	Meta	Green tea	Effect	Size	(95% CI)	Studies	Study design	Reference
Cardiovascular disease mortality	3	Highest vs lowest	RR	0.67	(0.46–0.96)	6	Cohort	[22]
		≥5 Cups per day	HR	0.82 0.75	(0.75-0.90) men (0.68–0.84) women	8	Cohort	[21]
		3 Cups per day	RR	0.81	(0.68–0.97)	6	Prospective	[84]
Stroke	4	3 Cups/day	RR	0.78	(0.69–0.88)	3	Mixed	[85]
		3 Cups Per day	RR	0.83	(0.72–0.96)	5	Cohort	[86]
		1–3 Cups vs <1	OR	0.64	(0.47–0.86)	3	Cohort	[14]
		3 Cups per day	RR	0.66	(0.46–0.93)	4	Prospective	[84]
Coronary artery disease	1	Highest	RR	0.72	(0.58–0.89)	2 3	Cohort case-control	[87]
Coronary heart disease	1	3 Cups per day	RR	1.02	(0.92–1.13)	1	Prospective	[84]
Myocardial infarction	1	1–3 Cups vs <1	OR	0.81	(0.67–0.98)	2	Cohort	[14]

Meta: number of meta-analyses; studies: number of original studies included; study design, study design of included original studies.

cohort studies (2) [92] reported type 2 diabetes-related outcomes such as hemoglobin A1C(HbA1c), homeostatic model assessment for insulin resistance (HOMA-IR), fasting insulin and fasting glucose found no associations with green tea (Table 3). Other meta-analyses including RCTs reported an inverse association between green tea and fasting blood glucose (FBG) [93, 94] and HbA1c [94] specifically. A meta-analysis on alternative medicine for treatment of type 2 diabetes found one of three small trials reduced FBG, while three open label trials did not report a change in HbA1c values [95] (Table 3). In a 2009 review which included two original studies on green tea and type 2 diabetes mellitus [107], the Singapore Chinese Health Study reported a null association RR = 1.12(95% CI 0.98–1.29) for daily vs non [108] while the Japan Collaborative Cohort Study for Evaluation of Cancer Risk found a RR of 0.49 (95% CI 0.30–0.79) in women but not men RR = 0.91 (95%CI 0.55 to 1.52) in the ≥6 cups/day consumption category [109].

Four meta-analysis on green tea reported a decrease in weight or BMI [96–98, 101] (Table 3). One meta-analysis found catechins had a small effect on weight loss [99] and a Cochrane systematic review found a small insignificant weight loss in overweight and obese adults [100]. Green tea (extract/capsule) did not show effect on prevention of weight regain [102] (Table 3). All four meta-analyses on the association between green tea and blood pressure reported reductions both in systolic and diastolic blood pressure [103–106]. One of these meta-analyses reported possible adverse events such as rash, elevated blood pressure and abdominal discomfort [105].

Other

Some evidence is available on green tea and dental or oral health. For example, a 2019 meta-analysis evaluating sanitization of toothbrushes including natural agents found garlic, green tea, and tea-tree oil sterilized toothbrushes with a mean difference of −483.34, CI (−914.79, −51.88) [110]. Only a few studies examined the association between green tea and respiratory diseases as well as external health outcomes [21, 111]. There is a dearth of studies on green tea consumption and cognitive-related outcomes, a 2017 meta-analysis suggests an inverse association, OR = 0.64 (95% CI 0.53–0.77) [112].

Discussion

This review concentrates on green tea consumption and major health outcomes such as cancer, cardiovascular disease, type 2 diabetes, BMI, blood pressure, and others. Compared to the 2019 umbrella review [12] on tea and health outcomes, the current study includes type 2 diabetes-related outcomes, narrative reports, recent 2019 meta-analyses, published subsequent to the umbrella review and some recent individual studies. The overall risk sourced from the most comprehensive and recent meta-analysis on each health outcome is presented in Fig. 2.

Green tea was inversely associated with several site-specific cancers such as endometrial, lung, non-Hodgkins lymphoma, oral, and ovarian cancer, ranging from 19% to 42% reduced risk (Table 1). Mixed findings were observed for breast, esophageal, gastric, liver and mostly null association for colorectal, pancreatic, and prostate cancer (Table 1). This may also be due to the limited number of meta-analyses for some cancer sites. No studies reported cancer-related adverse effects specific to green tea consumption. Several mechanisms have been proposed by which green tea may affect cancer risk: polyphenol may inhibit cell proliferation and stimulate antioxidant activity [113, 114] leading to a decreased risk. Epigallocatechin gallate (EGCG) with other catechins could start apoptosis [20].

Table 3 Green tea consumption and metabolic health outcomes from meta-analyses.

Outcome	Meta	Green tea	Results	Studies	Study design	Reference
Diabetes-related outcomes	7	6 vs <1 cup/day	RR = 0.99 (0.97–1.24)	2	Cohort	[92]
		Green tea/extract vs. placebo	Fasting plasma glucose: SMD = 0.04 (−0.15 to 0.24)	7	RCTs	[90]
			Fasting serum insulin: SMD = −0.09 (0.30–0.11)			
			2-h plasma glucose in the oral glucose tolerance test: SMD −0.14 (−0.63 to 0.34)			
			HbA1c: SMD = 0.10 (−0.13 to 0.33)			
			HOMA-IR: SMD = −0.06 (−0.35 to 0.23)			
		Green tea or green tea extract vs. placebo	HbA1c: SMD = −0.32 (−0.86 to 0.23)	6	RCTs	[89]
			Insulin resistance SMD = −0.10 (−0.17 to 0.38)			
			Fasting insulin SMD = −0.25 (−0.64 to 0.15)			
			Fasting glucose SMD = −0.10 (−0.50 to 0.30)			
		Gtea vs. placebo/water	FBG: mean difference = −2.10 mg/dL (−3.93 to −0.27)	11	RCTs	[93]
		Green tea	FBG: weighted mean difference: −0.09 mmol/L (−0.15, −0.03 mmol/L)	17	RCTs	[94]
			HbA1c: weighted mean difference −0.30% (95% CI: −0.37, −0.22%)			
		Green tea	FBG: reduced levels in 1 of 3 small trials.	3	Human clinical trials	[95]
			HbA1c: no change			
		Green tea or green tea extract	FBG: −0.07 (−0.60 to 0.47)	8	RCTs	[91]
			FSI: 1.51 (0.05–2.97)	6		
			HbA1c: −0.28 (−0.61 to 0.04)	6		
			HOMA-IR: −0.00 (−0.68 to 0.68)	5		
BMI and fat	7	Green tea catechins	BMI: −0.55 (−0.65 to −0.40)	15	RCTs	[96]
			Weight −1.38 kg (−1.70 to −1.06)			
		Daily green tea (EGCG 100 to 460 mg/day)	Body fat and body weight reduction periods of ≥12 weeks. caffeine doses between 80 and 300 mg/day has been shown to be an important factor	15		[97]
		Catechins	Microcirc = −1.31 kg	11	Mixed	[99]
		Green tea	No improvement in weight loss or maintenance	2	RCTs	[102]
		Green tea preparations vs. control	Mean difference in weight loss of −0.04 kg (95% CI −0.5 to 0.4) non-Japanese	14	RCTs	[100]
			Mean difference range −0.2 kg to −3.5 kg in Japanese			
		Green tea	Reduced weight −0.65 kg (−1.10 to −0.20)	20	RCTs	[101]
			BMI −0.26 kg/m(2) (−0.43 to −0.10)			
			waist circumference −1.11 cm (−1.99 to −0.23)			
			Percent of body fat (PBF) (−1.42%, 95% CI: −3.02 to 0.18, $P = 0.08$)			
		Green tea catechin	Reduced total fat area: −17.7 cm^2 (−20.9 to −14.4)	6	Human trials	[98]
			Visceral fat area (−7.5 cm^2, 95% CI: −9.3 to −5.7)			
			Subcutaneous fat area (−10.2 cm^2, 95% CI: −12.5 to −7.8)			

Table 3 (continued)

Outcome	Meta	Green tea	Results	Studies	Study design	Reference
Blood pressure	4	Green tea	SBP: −2.08 mmHg (−3.06 to −1.05) DBP: −1.71 mmHg (−2.86, −0.56)	13	RCTs	[103]
		Green tea	SBP: 2.1 (− 2.9 to − 1.2) mmHg DBP: 1.7 (− 2.9 to − 0.5)	15	RCTs	[104]
		Green tea	SBP: MD: −1.94 mmHg (−2.95 to −0.93)	20	RCTs	[105]
		Green tea vs control	SBP: −1.98 mmHg (−2.94 to −1.01 mmHg) DBP: −1.92 mmHg (−3.17 to −0.68 mmHg)	13	RCTs	[106]

BMI body mass index, *DBP* diastolic blood pressure, *FBG* fasting blood glucose, *HbA1c* glycosylated hemoglobin, *HOMA-IR* Homeostatic model assessment for insulin resistance, *meta* number of meta-analyses, *RCTs* randomized control trial, *SBP* systolic blood pressure, *SMD* standardized mean difference.

All included meta-analyses reporting cardiovascular disease-related outcomes reported inverse associations (Table 2) except for coronary heart disease. A 2013 narrative review supports these findings [115]. Mechanisms by which green tea may reduce the risk of cardiovascular disease are: polyphenols may exert antioxidant effects on the cardiovascular system [116], highest concentration of (−) EGCG [117], regulation of intermediary outcomes such as blood pressure, body fat [118], lipids [119], and improve glycemic control [120] which may improve cardiovascular health. Caffeine may contribute to regulating blood vessel homeostasis [121, 122].

Most studies on green tea and type 2 diabetes-related outcomes are RCTs. Previous reviews including meta-analyses on tea and diabetes did not always report results separately for green compared to other teas partially due to limited original papers [123]. The findings for green tea and diabetes-related health outcomes in this review were inconclusive with some studies suggesting reduced fasting blood glucose though this may largely vary depending on varies factors related to the exposure such as dose and duration as well as individual characteristics such as age, BMI and physical activity as well as other known risk factors of type 2 diabetes.

The findings of this review suggest a weak association between green tea and BMI and weight loss, though further studies are needed to confirm green's potential therapeutic use for obesity [124]. BMI-related studies emphasize weight loss through via the following mechanisms. First, catechins inhibiting catechol-O-methyltransferase which stimulate the lipolytic route; second, modulation of gut microbiota, and third act on white adipose tissue, elevated in obesity, stores fatty acids [124, 125] (Fig. 1).

The current review provides a broad scope of integrated evidence from meta-analyses including original studies using various study designs such as cohort, case-controls studies and RCTs and reports. The main limitation is the lack of quantitative summary effects due to the large variety of data informing the study: study design, health outcomes, and exposure categories. In addition, data were scarce on certain health outcomes of interest such as cognitive and oral health.

The evidence on green tea consumption and health outcomes presented in this review suggests green tea may be favorable for cardiovascular disease, particularly stroke, and certain cancers such as endometrial, esophageal, lung, non-Hodgkins lymphoma, oral, and ovarian cancer. More evidence is needed to assess the impact of green tea on breast, gastric, and liver cancer risk. Additional studies could also help clarify the suggested null association with certain cancer sites: colorectal, pancreatic, and prostate cancer. Possible minor adverse events on health from green tea consumption were reported in one study, however these must be interpreted cautiously within the study context and possible finer dose-response implications. The findings for green tea and diabetes risk were inconclusive. For BMI the current evidence suggests a possible weak association, while the evidence is stronger supporting a decrease in blood pressure from green tea. More studies investigating a possible association between green tea consumption and other health outcomes such as cognition, injuries, respiratory disease would be informative to more completely assess the impact of green tea on human health.

In conclusion, our review suggests green tea may have health benefits especially for cardiovascular disease and certain cancer sites.

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Author contributions SKA designed the research, compiled the findings and drafted the manuscript. MI checked the manuscript for intellectual content.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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