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Update on the Evaluation of the Anti-Obesity Effect of Green Tea (Camellia sinensis)

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ABSTRACT

Objective: Obesity is a worldwide rising risk factor for numerous incommunicable illnesses. The most common interventions have been ineffective from a public health perspective. Green tea (Camellia sinensis) seems to be an effective well-known alternative but there is a need to see the most updated and reliable information on the matter. The study aimed to verify how effective is green tea as reductor of human body mass index (BMI).

Methods: This meta-analysis reviewed recent controlled randomized trials on the effect of catechin and caffeine in the BMI of adult male and female subjects. The analysis did not include studies including alternative therapies or drugs potentially affecting BMI. The studies presented the quantity of catechin and caffeine (mg). Body mass index and waist circumference were measured before and after the interventions. The trials lasted two to eight months, depending on the study designs.

Results and Conclusion: Five studies met the criteria for the current analysis. In one study, the subjects took oral capsules of green tea extract (379mg). Overall, daily doses of catechin varied from 208-1200mg, and caffeine from undetectable levels to 480mg (the tea products were either enriched, capsules or canned with known levels). All showed reduction in body weight, the average BMI reduction was 0.68 kg/m2, and waist circumference was 1,5cm. There was a direct relationship between the concentration of catechin and reduction of BMI, but the BMI appeared to drop to a certain threshold of "optimal" weight, close to values considered as normal weight by the World Health Organization (WHO). There were few cases suggesting abdominal discomfort, but there they did not require additional treatment or hospitalization. Green tea consistently showed ability to reduce weight to a less risky level for health. Yet, it is now necessary to develop dose-response models for its active compounds and clarify the dynamics of the dosage over time. Furthermore, green tea is perhaps more effective in synergy with well-known methods to maintain or reduce weight, such as balanced diets or physical exercise.

Keywords: Green tea, obesity, catechin, caffeine, body mass index, waist circumference

1. INTRODUCTION

Obesity occurs when calorie intake is higher than energy expenditure, resulting in excessive lipid accumulation in the adipose tissue, and it is well-known as an increasingly prevalent medical condition (1). It is a major risk factor for several cardiovascular diseases, diabetes, pulmonary illnesses, certain types of cancer and osteoarthritis (2). In 2016, the World Health Organization (WHO) estimated that over 1.9 billion adults (> 18-year old) were overweight from which more than 650 million were obese, 39% of men and 40% of women were overweight and 13% of the world population (11% of men and 15% of women) were obese (3). In 2018, Piche *et al.* (4) published more recent estimates as 30% of men and 35% of women obese worldwide. According to them, it has doubled in more than 70 countries since 1980. In Mozambique, the prevalence of obesity in adults is 7,2% (5).

Despite of several interventions to combat reduce the prevalence of obesity through promotion of healthier lifestyle, medication, surgical interventions, physical activity and low-calorie diets, results have not been satisfactory and their effects do not last for long, and sometimes patients face adverse effects of such therapies (2, 6-8). Thus, it is crucial to search for effective, easy to use, tolerable and economic alternatives. Recently, natural phytotherapeutic supplements are drawing attention, and green tea (from *Camellia sinensis*) is the most widely used (9-11).

Green tea's anti-obesity properties is associated to its relatively high content of catechins, antioxidants consisting

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of (–)-epicatechin (EC), (–)-epicatechin-3-gallate (ECG), (–)-epigallo-catechin (EGC), and (–)-epigallocatechin-3-gallate (EGCG) (12). According to Kao *et al.* (13), EGCG was capable of reducing up to 29% of body weight of rats within one week, when injected in the peritoneum. The authors added that such effect is due to EGCG's molecular inhibition of fatty acid synthase. Catechins also inhibit a-amylase and lipase, interfere with emulsification, digestion, and fungal solubilization of lipids (14, 15). Akhlaghi and Kohanmoo (15) summarized the same information and added other possible mechanisms at which catechins can affect weight loss, including: (a) appetite control, perhaps by inhibiting ghrelin, (b) interaction with intestinal bacteria, resulting in its breakdown into bioavailable components with potential anti-obesity effects, and (c) increasing the population of colonic bacteria and selecting species capable of affecting converting lipids into short-chain fatty acids. Though clinical evidence supports green tea's anti-obesity effects, there are some contradictions and inconclusive findings. Furthermore, optimal intake is yet to be understood (16).

Considering the importance of obesity and the lack of effective, safe and long-lasting strategies to control it, the current study was performed on green tea, since it is inexpensive and easy to use, with minimal collateral effects. Thus, it aims to investigate how green tea affects weight loss in overweight and obese subjects.

2. METHODS

The study comprised a meta-review of randomized controlled clinical studies about the impact of green tea on weight loss in overweight and obese patients. The participants were healthy male and female subjects, at least 18 years old. They were overweight (> 25 kg/m^2) or obese (> 30 kg/m^2) according to standards by the WHO standards for BMI and waist circumference (which ideally should be within 85-95cm in healthy individuals) (17, 18). The current analysis did not include studies in which participants used other medicines potentially affecting body weight. They used exclusively green tea or its extract. Were excluded studies in which the chemical composition of the tea was not specified or it was mixed with other ingredients.

All studies considered provided, to their control groups, a placebo or a smaller dose of great tea in relation to the experimental group. Studies where patients performed physical exercise were excluded. All experiments lasted at least two months and the studies were all performed during the last ten years.

Initially, 30 studies seemed potentially relevant. However, 11 were excluded because they were *per si* literature reviews. Then, 9 were excluded because they had been performed over 10 years before. Three were excluded because they used other types of intervention together with green tea, and 2 more were excluded because they did not presented measurements of both BMI and waist circumference. Finally, 5 articles matched all criteria for this study and they were analyzed (Table 1). It was also necessary to perform an analysis of covariance (ANOVA, a = 0.05) in Jamovi (Version 0.9.5.13, Jamovi, Project, Amsterdam, Netherlands) (19) to determine if the weight loss in female and male subjects were significantly different and linear regression to visualize the relationship between catechin consumption and body loss. The latter analysis was not performed for waist circumference and caffeine because of some inconsistencies.

Table 1. *Demographic characteristics of the subjects analyzed.*

Authors	Intervention and control	Sample size	Number of randomized participants	Number of participants in the end of the study	Participants in the end of the study (%)	Female/male ratio	Average age (sd)
Suliburska *et al.* (26)	I1: green tea C1: placebo	I1: 23 C1: 23	I1: 23 C1: 23	I1: 23 C1: 23	I1: 100% C1: 100%	I1: 1:1 C1: 1:1	I1: 49 (9) C1: 52 (8)
Wang *et al.* (21)	I2: green tea C2: placebo	I2: 205 C2: 205	I2: 192 C2: 192	I2: 182 C2: 182	I2: 95% C2: 95%	I2: 3:1 C2: 3:1	I2: 37 (9) C2: 37 (9)
Brown *et al.* (23)	I3: green tea C3: placebo	I3:67 C3:70	I3: 64 C3: 64	I3: 64 C3: 64	I3: 100% C3: 100%	I3: 0:1 C3: 0:1	I3: 50 (5.5) C3: 49 (5.5)
Nabi *et al.* (20)	I4: green tea C4: placebo	I4: 41 C4: 41	I4: 29 C4: 29	I4: 29 C4: 29	I4: 100% C4: 100%	I4: 2:1 C4: 2:1	I4: 46 (6.4) C4: 48 (7.58)
Sone *et al.* (27)	I5: green tea C5: placebo	I5: 30 C5: 30	I5: 25 C5: 26	I5: 25 C5: 26	I5: 100% C5: 100%	I5: 2:1 C5: 2:1	I5: 43 (14.8) C5: 48 (12.4)

C: control; I: intervention; sd: standard deviation

3. RESULTS and DISCUSSION

All authors consulted presented reduction of the average BMI, particularly Nabi *et al.* (20), likely because they used higher daily levels of catechins (1200mg) and caffeine (480mg; see Table 2), resulting in an average IMC reduction of 3.1 kg/m2 (Table 3). The overall average BMI reduction was 0.68 kg/m2. It is worthwhile mentioning Wang *et al.* (21), who divided the intervention group in three subgroups, IG1, IG2 and IG3, the order representing an increased concentration of catechin and caffeine. The subgroup IG3 did not present significant weight reduction, and the average BMI actually appeared to increase slightly. This might have been due to well-known limitations of BMI itself as a measure of BMI, as it for instance misrepresents the state of body fat content in several circumstances, especially because of the muscular mass (22). For instance, the same individuals showed final values of waist circumference value inversely proportional to the amount of catechin consumed daily, though waist circumference is still to be discussed in detail. In all studies, the placebo did not present considerable BMI decline. Three studies presented considerable differences between the intervention groups and the placebos, especially the study by Brown *et al.* (23) where intervention took longer (8 months) if compared to the others (≤ 3 months). Thus, it seems safe to assume that consumption of green tea affected BMI. Auvichayapat *et al.* (9) found similar results in Thailand, Matsuyama *et al.* (24) in Japanese children, and Jurgens *et al.* (16) in another meta-analysis.

It is important to know if green tea had a similar effect in both female and male subjects, because the demographic differences between the studies might have affected the results. The ANOVA test in Table 4 does not show significant differences between the results assuming the different ratios between male and female subjects (p = 0.472).

Table 2. *Description of the interventions used in the selected studies.*

Authors	Intervention group (s) (delivery method, frequency, total doses/ day)	Catechin content per intervention group	Caffeine content per intervention group	Control group (delivery method, frequency, total doses/day)	Duration	Other interventions for weight loss	Co-medication	Co-morbidity
Suliburska *et al.* (26)	1 oral capsule (379mg) of green tea extract, daily (morning)	208mg (daily)	No caffeine detected	1 oral capsule (379mg) of placebo extract, daily (morning)	I1: 3 months C1: 3 months	No	No	No
Wang *et al.* (21) **	1 cup (250 ml) green tea daily in 3 intervention groups (GI*)	GI1 – 458mg GI2 – 468mg GI3 – 886mg	GI1 – 104mg GI2 – 126mg GT3 – 198mg	1 cup of placebo with 30mg of catechin and 10mg of caffeine	I2: 3 months C2: 3 months	No	No	No
Brown *et al.* (23)	1 oral capsule (530mg) of green tea, 2x/day	404mg per capsule	<1%	1 placebo capsule 2x/ day	I3: 8 months C3: 8 months	No	No	No
Nabi *et al.* (20)*	1 glass (150ml) of green tea 2x/day	1200mg	480mg	1 glass (150ml) of placebo 2x/day	I4: 3 months C4: 3 months	No	No	No
Sone *et al.* (27) **	1 glass (500ml) of green tea daily	400mg	105mg	1 glass (500ml) of placebo containing 100mg of catechins daily	I5: 2 months C5: 2 months	No	No	No

*GI – intervention group; * Catechin and caffeine information from the label; ** Tea with catechin and caffeine extracted, and then enriched with these compounds.*

Table 3. *Results of the analyzes.*

Authors	BMI (kg/m2)		Waist circumference (cm)		% of patients with adverse effects
	Baseline	Results after intervention	Baseline	Results after intervention	
Suliburska *et al.* (26)	I1: 32.07 ± 2.41 C1: 33.45 ± 2.65	I1: 31.71 ± 2.29 ↓ C1: 33.36 ± 2.66 ↓	I1: 101.78 ± 6.42 C1: 104.98 ± 6.53	I1: 101.15 ± 6.42 ↓ C1: 105.02 ± 6.10 ↑	No
Wang *et al.* (21)	GI1 – 27.1 ± 2 GI2 – 27.2 ± 3 GI3 – 26.8 ± 2 C2 – 26.8 ± 2	GI1 – 26.8 ± 2.0 ↓ GI2 – 26.8 ± 2.4 ↓ GI3 – 26.9 ± 2.5 ↑ C2 – 26.3 ± 2.2 ↓	GI1 – 96.1 ± 5.8 GI2 – 95.9 ± 7.0 GI3 – 95.5 ± 6.0 C2 – 94.5 ± 6.0	GI1 – 95.0 ± 6.2 ↓ GI2 – 94.6 ± 7.0 ↓ GI3 – 93.6 ± 7.0 ↓ C2 – 94.3 ± 5.8↓	No
Brown *et al.* (23)	I3: 31.7 C3: 31.4	I3: 31.5 ↓ C3: 31.6 ↑	N/A	N/A	I3: 58% C3: 66%
Nabi *et al.* (20)	I4: 29.95 ± 1.79 C4: 29.69 ± 2.01	I4: 26.86 ± 2.59 ↓ C4: 27.07 ± 2.22 ↓	I4: 87.77 ± 6.06 C4: 86.94 ± 8.8	I4: 83.91 ± 6.13 ↓ C4: 85.23 ± 7.8 ↓	Non-specified (there were few cases of abdominal discomfort)
Sone *et al.* (27)	I5: 24.6 ± 4.3 C5: 24.5 ± 4.2	I5: 24.0 ± 4.1 ↓ C5: 24.1 ± 3.9 ↓	I5: 85.0 ± 12.7 C5: 85.7 ± 4.2	I5: 82.7 ± 12.2 ↓ C5: 83.9 ± 11.4 ↓	No

N/A: Not applicable

Table 4. *ANOVA of average BMI reduction between the groups with distinct ratios female/male*

	Sum of Squares	*df*	Mean Square	*F*	*p*
Ratio female/male	3.57	3	1.19	1.09	0.472
Residuals	3.27	3	1.09		

df: degrees of freedom

Figure 1 shows a direct relationship between daily catechin intake and reduction of BMI (Pearson's coefficient = 0.67). However, it is important to bear in mind that these interventions had different duration and that might have impacted the final outcome. Yet, since the Pearson's coefficient shows an acceptable correlation between the daily intake and BMI loss, it is possible that green tea induces weight loss to a certain threshold at which BMI maintains steady. Brown *et al.* (23) conducted their study through eight months but there is no information on the gradual weight loss during this period and it makes difficult to know if such threshold exists through their observations. Since the impact of green tea on BMI has already been demonstrated, further analysis should be longitudinal to clarify the dynamics of weight loss over time.

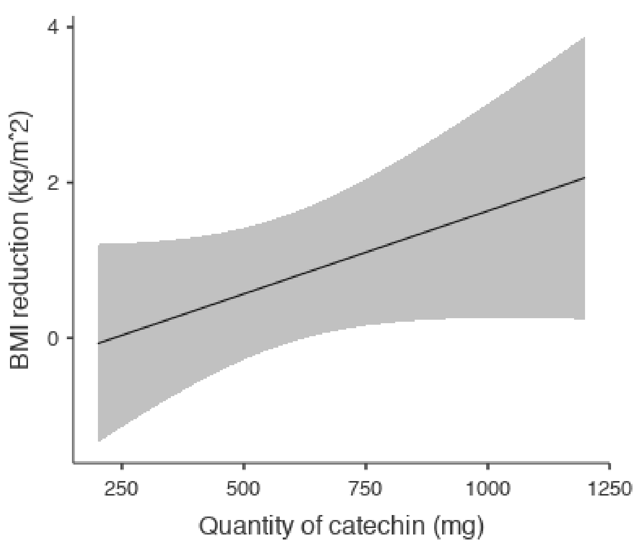

Figure 1. *Relationship between daily intake of catechin and BMI loss. The shade represents 95% confidence interval. The negative values of the vertical axis represent weight gain.*

Results were not considerably different regarding waist circumference. Nabi *et al.* (20) again indicated the most pronounced reduction (3.86cm), certainly because the patients received higher daily doses of catechins and caffeine. The average reduction for all studies (in which it was measured) was 1,5cm. Wang *et al.* (21) did not find increased concentration of green tea to be directly proportional to reduction of waist circumference, but, the final outcome (the final size) was proportional to the concentration. It sustains the previous conclusion that there is a threshold at which green tea exerts its weight reducing effects, depending on particular variables still to be considered (possibly genetic, physiological or morphological, lifestyle, environmental, etc.). It is equally important to observe that most subjects Wang *et al.* (21) studied were not obese but rather overweight, and considering the standard deviations, very few were likely obese in comparison to the entire sample. Thus, perhaps tea only reduced the body fat into an "optimal" range. There is no agreement about such value, as it depends on several factors, but WHO Expert Consultation (18) showed that risk for cardiovascular disease increases considerably when the circumference is within the range 85-95cm. Thus, the results show that the mixture of catechins and caffeine in green tea is beneficial for the reduction of waist circumference. Hursel *et al.* (25) made similar observations through another meta-analysis and this reinforces the idea of green tea as regulator of human BMI.

Regarding adverse effects, Brown *et al.* (23) and Nabi *et al.* (20) reported few cases in which patients reported slight abdominal discomfort. However, such effects did not require hospitalization or any special treatment. Furthermore, there is no evidence indicating that green was the sole cause, or the cause at all, of the adverse effects.

4. CONCLUSION

The current study suggests that green tea can be a reliable alternative to treating overweight or obese patients, since it was effective, well-tolerated, with no significant adverse effects. However, there is a need to expand the study, explore it for longer periods and longitudinally, to find out how green tea extract functions over time and determine the doses or adequate posology for the treatment of obesity. The method can be coupled with other treatments such as diets and physical exercise. Larger samples might further improve the results.

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