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The Importance of Tea in the Correlation between Caffeine and Health

Burhan Başaran

Abstract

This study aims to examine the studies on the correlation between caffeine intake of individuals and health and to emphasize the importance of tea for health. Caffeine is a substance contained in many foods we frequently consume in our daily diets such as tea, coffee, cola, and energy drinks and is generally known for its stimulant nature. That is why consumers take caffeine into their bodies throughout their lives. The European Food Safety Authority states that daily intake of 400 mg (about 5.7 mg/kg bw for 70 kg) caffeine from all sources does not create any concern for adults. There is no complete consensus about whether caffeine consumption causes various ailments in individuals or whether it has a protective effect against contracting various diseases. The literature review has revealed that coffee and tea in adults and tea, soft, and energy drinks in children and adolescents play an important role in caffeine intake. Tea is a plant that is especially rich in phenolic compounds and has many benefits for human health. Therefore, for conscious consumers, tea is different from other drinks due to caffeine and phenolic compounds and is thought to do more good than harm to people.

Keywords: black tea, green tea, white tea, dietary caffeine intake, health

1. Introduction

Tea is produced from *Camellia sinensis* leaves using various methods and is one of the most commonly used beverages throughout history due to its consumption and health properties [1, 2]. Commercial tea is divided into three main groups: full fermented black tea, semi-fermented oolong tea, and non-fermented green tea according to the production method [3]. Besides these groups, there is non-fermented white tea that is produced and consumed mostly in Asia and has a higher price than other types of tea [4]. Black tea and green tea are the most well-known and consumed types. About 78% of all tea consumed in the world is black tea, 20% is green tea and 2% is oolong tea [5]. The physical and chemical properties of fresh tea leaves vary depending on many factors such as geography, climate, soil, leaf age, and cultivation [6, 7]. Fresh tea leaf consists of polyphenol by 36%, carbohydrate by 25%, protein by 15%, lignin by 6.5%, ash by 5%, amino acid 4%, lipid by 2%, organic acid by 51.5%, chlorophyll by 0.5%,

and carotenoid and volatile compounds by less than 0.1% in dry matter [8]. Fresh tea leaf is considered to be one of the plants with the richest amount of phenolic compounds [9]. **Table 1** shows the phenolic compound contents of different types of tea (**Table 1**).

Tea is also an important source of caffeine which is found naturally in coffee, cola, chocolate, cocoa or added as an additive to various energy drinks, medicine and cosmetics [11], is the most consumed drink in the world, whose use is increasing each passing day, and is considered to be a psychoactive substance [12, 13].

Caffeine is a member of a group known as purine alkaloids which also contain 3,7-dimethylxanthine (theobromine), 1,7-dimethylxanthine (paraxanthine), and methyluric acids. Its chemical formula is $C_8H_{10}N_4O_2$ and its systematic name is known as 1,3,7-trimethylxanthine [14].

Caffeine is largely absorbed by the stomach and small intestine after being taken into the body, quickly moves into body cells and reaches the highest level in 15 to 60 minutes after crossing the blood-brain barrier. The half-life of caffeine varies depending on factors such as puberty, pregnancy, and disease, but it is considered to be 5–6 hours in a healthy individual [15, 16]. Metabolites such as paraxanthine, theobromine, and theophylline are released as a result of caffeine metabolism. Only 10% of caffeine is excreted from the body without being metabolized [17].

Caffeine is available at different levels in many foods that we often consume in our daily lives. Therefore, it can be easily said that individuals consume caffeine regularly every day. However, the prediction that caffeine intake into the body for nutrition and short, medium and long-term exposures can lead to various health problems has led the scientific world to do research in this area. This study aims to examine the studies on the correlation between caffeine intake of individuals and health, and to emphasize the importance of tea for health.

	Green tea (mg/g-km)	Black tea (mg/g-km)	Oolong tea (mg/g-km)
Total phenolic substance	208.80–236.78	221.75–248.31	87.70–195.6
Total catechin	221.94–234.71	187.84–279.43	16.64–282.75
Total flavone and flavonoid glycosides	4.53–5.43	3.03–5.01	4.09–4.68
EGCG (epigallocatechin agallate)	53.14–126.20	2.42–81.93	16.53–132.54
GC (catechin gallate)	5.05–10.52	0.20–10.82	7.5–8.93
EGC (epigallocatechin)	4.40–97.79	0.71–78.82	12.96–19.94
ECG (epicatechin gallate)	14.19–27.80	0.42–13.02	2.09–46.28
EC (epicatechin)	0.20–28.30	0.10–3.59	2.68–2.77
GCG (gallocatechin gallate)	2.60–48.02	0.09–58.89	49.54–60.92
Gallic acid	0.59–5.20	0.57–5.80	1.30–1.37
Caffeine	15.66–77.30	3.14–83.20	2.58–40.84
Theophylline	0.60–0.80	0.10–0.20	—
Theobromine	0.27–6.0	0.41–4.70	0.72–0.99

Table 1.
Phenolic compounds of different types of tea [10].

2. Nutritional caffeine intake

Today, individuals consume low or high levels of caffeine, often knowingly and sometimes unknowingly. Since the production and consumption of caffeine-containing foods vary by country, society and individual, it is quite difficult to accurately calculate individuals' nutritional intake of caffeine. **Table 2** shows caffeine levels in certain foods which are frequently consumed by the general population and considered to be important in terms of caffeine content.

Caffeine is very common in nature, and coffee, tea, energy drinks, chocolate, and cocoa are accepted as sources of nutritional caffeine intake [22]. Caffeine levels in these foods vary according to content, ratio between tea/coffee and water, brewing time and other consumption characteristics [23, 24]. In general, coffee has a higher caffeine level than other foods. As for tea groups, the caffeine level of black tea is higher than other tea types. Caffeine levels are usually at a certain level in soft drinks such as cola and energy drinks as they have standard prescriptions and production techniques. The caffeine level in chocolate varies according to the amount of cocoa it contains. Coffee is also known as the source of nutritional caffeine of adults throughout Europe, especially in Finland, Denmark, Sweden and Switzerland. In all member states of the European Union, there is a "high levels of caffeine" warning on beverage labels containing more than 150 mg/L of caffeine [25].

Many institutions and researchers try to estimate nutritional caffeine intake by examining dietary habits of individuals. The number of studies conducted in this area is quite large and the findings of some studies are given below.

Food group	Food subgroup	Caffeine level (mg/L or mg/kg)
Chocolate	Chocolate milk or chocolate beverages	7–67
	Chocolate snacks	62–418
	Dark chocolate	340–525
Coffee	Coffee drink	320–690
	Cappuccino	250–315
	Espresso coffee	713–1916
	Decaffeinated and imitations	11–29
	Instant coffee, ready to drink	210–690
	Turkish coffee	620–858
Tea	Black tea	181–220
	Green tea	125–320
	White tea	63
	Tea (unspecified)	158–234
	Instant	47–199
Cola beverages (regular)		79–130
Cola beverages (diet)		109–140
Energy drinks		150–335

Table 2.
Caffeine levels in some foods [11, 18–21].

FDA states that a daily intake of 400 mg of caffeine can be considered safe for healthy adults. On the other hand, it has declared that some individuals may be negatively affected by lower doses of caffeine, and studies will begin to investigate the safety of caffeine added to foods, with particular emphasis on children and adolescents [18]. Health Canada has specified safe daily caffeine intake for healthy adults and pregnant women as ≥400 mg/day and <300 mg/day, respectively. The same institution has reported that daily caffeine intake for children of different age groups is in the range of 45 to 85 mg/day (45 mg/day for 4–6 years, 62.5 mg/day for 7–9 years, and 85 mg/day for 10–12 years) [26].

In a study conducted in America with 24,808 individuals between 2001 and 2010, it was reported that more than 85% of adults (≥19 years of age) regularly consumed caffeine and that their average daily caffeine intake was 180 mg/day. In the same study, highest and lowest intake of caffeine was detected in males between the ages of 31 and 50 and females between the ages of 19 and 30, respectively, the caffeine intake of males (211 mg/day) was more than females (161 mg/day), and 98% of the daily caffeine intake came from beverages. The drinks that cause caffeine intake are as follows: coffee by 64%, carbonated soft drinks by 18%, tea by 16%, and energy drinks by less than 1% [27].

In a study examining the daily caffeine intake of adolescents living in the United States between 1999 and 2011, it was reported that more than half of the children at ages ranging from 2.5 to 5 and about 75% of children over the age of 5 consumed caffeine on a daily basis. The mean daily caffeine intakes of children between the ages of 2 and 11 and adolescents between the ages of 12 and 17 were determined as and 50 mg/day, respectively. It was reported that the source of caffeine was carbonated soft drinks for children under the age of 12 and coffee for children that were 12 and older [28].

In another study, daily caffeine intake was calculated as 15, 26, 61, 213, and 135 mg/day for the general population who were 4–8, 9–13, 14–19, and 51–70 years old and those who were 4 years old or younger, respectively. The daily caffeine intake is higher in males (196 mg/day) than females (151 mg/day). Although the distribution of the drinks that cause daily caffeine intake varies by age, the largest contribution is from coffee (64%) and tea (18%) [29].

In another study conducted in the United States, daily caffeine intake was calculated as 120 mg/day (1.73 mg/kg body weight/day) for all age groups. The highest caffeine intake was in individuals in the 35–49 age range (170 mg/day). Daily caffeine intake in pregnant women was estimated to be 58 mg/day. According to the other findings of the study, the daily caffeine intake was calculated as 14 mg/day (0.82 mg/kg body weight/day), 22 mg/day (0.85 mg/kg body weight/day), and 106 mg/day (1.54 mg/kg body weight/day) for ages ranging from 1 to 5, 6 to 9, and 20 to 24, respectively. It was pointed out that the main source of caffeine was coffee in adults and soft drinks in young people. Tea ranked second in both groups [30].

Australian Children's Nutrition and Physical Activity Survey determined the general daily caffeine intake as 18 mg/day in a study on caffeine consumption of 4487 children and adolescents between the ages of 2 and 16 in 2007. The mean daily caffeine intake by age groups was determined as 3, 8, 19, and 42 mg/day for ages ranging from 2 to 3, 4 to 8, 9 to 13, and 14 to 16, respectively. It was stated that the main source of caffeine was drinks (81%) and that the highest contribution was made by soft drinks (31%), coffee (21%) and tea (17%), respectively [31].

In a study conducted in Italy on 1213 adolescents (12–19 years), it was found that 76% of individuals consumed caffeine on a daily basis and the daily caffeine intake was approximately 125 mg/day (2.1 mg/kg body weight/day) [32] while the daily caffeine intake was calculated as 79 mg/day and coffee, tea, and soft drinks were

listed as the beverages with the highest contribution to the daily caffeine intake in a study conducted in England on 2008 individuals of varying ages [33].

3. Caffeine and health

Since foods and beverages containing caffeine are common and easy to reach, a very large segment of society regularly consumes caffeine from childhood to old age. Just this information once again reveals the importance of caffeine in our lives. Therefore, systematic and comprehensive studies should be carried out on the effects of nutritional caffeine intake on the health of individuals in the short, medium and long term. A lot of research been conducted in this area.

The fatal dose of caffeine in adults is estimated to be 170 mg/kg body weight/day [34] and there have been reports of some deaths due to caffeine overdose [35]. There is no complete consensus about whether caffeine consumption causes various ailments in individuals or whether it has a protective effect against contracting various diseases [36].

One of the areas in which caffeine's effects on health are most commonly investigated is the cardiovascular system. There are studies showing that caffeine intake by less than 400 mg/day does not have any negative impacts on the cardiovascular system [35], high levels of caffeine consumption leads to an increase in morbidity and mortality in the cardiovascular system by increasing blood pressure and heart rate [37–39], but, despite all this, caffeine has a protective effect [40–42].

Caffeine intake over 300 mg/day has been reported to cause second trimester miscarriages, low birth weight, and an increase in the likelihood of stillbirth [43–45]. Furthermore, the risk of developing childhood obesity increases by 87% in fetuses exposed to caffeine in the womb compared to those not exposed to caffeine [46]. However, there are also studies indicating that there is no correlation between caffeine intake in pregnancy and premature birth and fertility [47–49].

Positive impacts of caffeine consumed at low or medium levels on health such as relieving the airways leading to the lungs of individuals, reducing asthma attacks [50], making people feel healthy, reducing the risk of having type 2 diabetes or Parkinson's disease, and healing liver diseases etc. are also mentioned [51–56].

There is not enough evidence in current studies to prove that caffeine consumption is associated with any type of cancer in the short, medium and long term, it causes an increase in the number of cancer cases, or that it has a protective effect [57]. It has been reported that caffeine intake by less than 400 mg/day does not cause an increase in the cancer risk [11, 58, 59].

One of the most important features of caffeine is that it is a psychoactive compound. While caffeine less than 400 mg/day is generally considered safe, high doses of caffeine taken for a long time lead to caffeine withdrawal syndromes (caffeinism) such as headache, low concentration, restlessness, insomnia, irritability, decreased learning ability and palpitation [60–64].

The prevailing view in the literature is that caffeine consumption has a detrimental effect on an individual's sleep quality. According to current studies, caffeine consumption causes sleep delay, shortening of total sleep time, decreased sleep quality, and, as a result, daytime insomnia. It has also been stated that continued insomnia leads to more caffeine consumption by people [65–67].

It is stated in a study examining the dose-related effects of caffeine that 85–250 mg caffeine per day increases the feeling of alertness and contributes to increased motivation by decreasing fatigue, higher doses between 250 and 500 mg per day may cause restlessness, irritability, insomnia, and anxiety while 15–30 mg/kg

body weight/day caffeine may lead to muscle spasms and severe toxic effects on the cardiovascular and central nervous system in healthy adults [68].

It has been found that caffeine accelerates metabolism by causing thermogenesis and lipid oxidation along with other compounds in food and causes weight loss by enabling people to spend more energy [69–72].

Another important feature of caffeine is its negative impact on bone health due to its diuretic effect. Excretion of elements such as calcium, magnesium, sodium and potassium from the body with urine increases due to high levels of caffeine intake. This results in decreased bone mineral density especially in females as well as increasing the risk of osteoporosis [73, 74].

4. Decaffeinated foods

Since caffeine is present in foods such as tea, coffee, and chocolate included in our daily diet, it is not surprising that the daily caffeine intake recommended for both the general society and specific groups is exceeded. Increased caffeine intake is known to cause various health problems. This is why caffeine free or decaffeinated foods are needed. Significant reduction of caffeine content or removal of caffeine is called decaffeination [75]. The first decaffeination process was carried out in 1903 on coffee beans (coffee beans were moistened with salty water and caffeine was removed with benzene) [76]. There are many different methods of caffeine removal that differ depending on the type of food. These are:

Caffeine removal by traditional methods: The main traditional methods for caffeine removal are the removal of caffeine from food by water, organic solvents and supercritical fluids [77].

Caffeine removal by microbial methods: *Pseudomonas, Serratia, Stemphylium, Penicillium,* and *Aspergillus* species are grown on leaf surfaces, and these microorganisms reduce the caffeine level of the food by decomposing the caffeine [78, 79].

5. Conclusion

Caffeine is a compound that is legal, easy to obtain for the general society, socially acceptable to consume, found in many foods in our daily diet, and generally known for its stimulant properties. Caffeine, whose consumption has increased especially due to the changes in dietary habits in recent years, is a compound that still remains popular today. In this sense, both nutritional caffeine intake and the correlation between caffeine and health have been studied from many different angles. The effects of caffeine consumption on health are still a matter of debate. Although caffeine is generally considered safe except for excessive use in adults, studies on this subject are still insufficient for children and adolescents.

Individuals' daily caffeine intake varies depending on many factors such as the source of caffeine, age of the individual, breed, dietary habits and culture. In general, it can be said that the level of caffeine intake increases in proportion to age, and males consume more caffeine than females. It is understood that coffee and tea in adults and tea, soft and energy drinks in children and adolescents play an important role in caffeine intake.

In the light of the data given in **Table 2** and considering the changes in the consumption patterns regarding foods in recent years, it can be easily said that individuals' daily caffeine consumption is much more than 400 mg/day which is usually considered to be safe. But it should be noted that caffeine intolerance can vary from person to person. Even very small amounts of caffeine can negatively

affect pregnant women, children, the elderly and individuals who are caffeine intolerant. This is why caffeine intake of these individuals should be limited. For this purpose, popularizing caffeine-reduced products on the market can be considered as a strategy for limiting caffeine intake through nutrition. The literature review reveals that tea ranks second in caffeine intake in adults, children and adolescents. Therefore, tea plays a significant role in caffeine intake. But tea has significant differences distinguishing it from coffee, soft drinks and energy drinks that are other sources of caffeine.

Coffee is a drink that is generally perceived as healthy. However, it is also rich in acrylamide that was found out to be contained in food in 2002 and identified by the International Agency for Research on Cancer (IARC) as a possible carcinogen for humans. Carbonated soft drinks and chocolate foods contain many additives in addition to high levels of sugar. Many researchers and institutions approach energy drinks with suspicion due to very high caffeine content. Early acquaintance of individuals with carbonated soft drinks and energy drinks also increases the likelihood of addiction. In general, it can be said that the dietary quality of individuals who consume this type of drink frequently decreases.

Tea is a plant rich in phenolic compounds, especially catechins, and has many benefits on human health due to its antioxidant, antibacterial, anticarcinogen, antimutagenic, and antiallergic effects. Therefore, for conscious consumers, tea is positively different from other foods and drinks due to caffeine and phenolic compounds and is thought to do more good than harm to people. Green tea stands out among tea types with the lowest content of caffeine and high phenolic content.

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