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Impact of caffeine and coffee on our health

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Coffee is the most frequently consumed caffeine-containing beverage. The caffeine in coffee is a bioactive compound with stimulatory effects on the central nervous system and a positive effect on long-term memory. Although coffee consumption has been historically linked to adverse health effects, new research indicates that coffee consumption may be beneficial. Here we discuss the impact of coffee and caffeine on health and bring attention to the changing caffeine landscape that includes new caffeine-containing energy drinks and supplements, often targeting children and adolescents.

Caffeine and coffee consumption

Caffeine is the most routinely ingested bioactive substance throughout the world. It is a natural alkaloid found in more than 60 plants including coffee beans, tea leaves, cola nuts, and cocoa pods. Its concentration varies depending on the type of product, agronomic and environmental factors, and processing. Common beverages containing variable amounts of caffeine include coffee (the major dietary contributor), tea, soft drinks, energy drinks, chocolate products, certain medications (headache treatments and painkillers), dietary supplements, and over-the-counter stimulants. Americans daily drink more than 400 million cups of coffee, which is the major source of caffeine in the adult diet, compared with tea and caffeinated soft drinks in children and adolescents [1].

Caffeine as part of a blend of compounds in coffee

Coffee is a complex beverage containing, besides caffeine, more than 1000 compounds responsible for its pleasant flavor and aroma. The final sensory properties of a freshly prepared cup of coffee are the result of a long chain of chemical transformations that occur from the coffee bean to the coffee cup. Among the many bioactive compounds present in coffee are methylxanthines (caffeine, theobromine, theophylline) diterpene alcohols (cafestol, kahweol), chlorogenic acids (caffeoylquinic acids, feruloylquinic acids, *p*-coumaroylquinic acids), flavonoids (catechins, anthocyanins), hydroxycinnamic acids (ferulic acid, caffeic acid, *p*-coumaric acid), tocopherols, and melanoidins. Caffeine concentration and the biological activity of coffee depend on a blend of factors, such as variations in raw materials (species, origin, and genetic traits), agricultural practices (traditional or organic), post-harvest techniques (wet or dry), duration and conditions of storage, roasting degree (light, medium, or dark), kind of roasting process (standard or torrefacto), type of commercial coffee (roasted ground or instant), and grinding and brewing method (boiled, filtered, or espresso). This means that we never drink two cups of coffee with the same chemical composition, even when the coffee comes from the same outlet [2].

A snapshot of caffeine concentration in foods

Caffeine concentration varies among different food products, with coffee having in general the highest concentration compared with tea, soft drinks, energy drinks, shot drinks, and solid foods. A significant variation in caffeine concentration exists within a beverage category; most energy drinks contain mainly caffeine, due to its desired stimulatory effect on the central nervous system, and taurine because of its physiological function of enhancing endurance performance and to aid in the reduction of lactic acid build-up after exercise [3]. Chocolate and other cocoa-containing foods, sweets, and snacks contribute small amounts of caffeine to the diet. Table 1 outlines selected products that are available in the market and their caffeine concentrations. Box 1 summarizes facts related to caffeinated beverage (CB) consumption and caffeine intake in the USA.

The good, the bad, and the ugly of caffeine and coffee consumption

Debate persists about whether coffee consumption is beneficial or detrimental for human health [4]. Epidemiological data support the view that habitual coffee consumption has several health benefits, including lower risks of Parkinson's and Alzheimer's disease, a favorable effect on liver function, a possible role in weight loss (increased metabolic rate, energy expenditure, lipid oxidation, and lipolytic and thermogenic activities), and a decreased risk of developing certain cancers (endometrial, prostatic, colorectal, liver) [5,6]. Several studies have demonstrated that coffee consumption has a significant association with decreased risk of type 2 diabetes (T2D) and that every additional cup of coffee is associated with a 7% reduction in disease risk. However, other studies have shown that caffeine alone causes deterioration of glucose tolerance. Because similar results are seen for decaffeinated and regular coffee, this means that, although caffeinated coffee may induce an increased glycemic response, other bioactive compounds present in coffee, such as chlorogenic acids, other phenolic compounds, magnesium, and trigonelline, may counteract this effect by altering glucose absorption, liver glucose

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Table 1. Caffeine content of selected beverages and foods

Product	Serving size (fl. oz)	Caffeine in one serving (mg)
Coffee		
Regular drip or percolated	8	95–330
Brewed or percolated, decaffeinated	8	3–12
Instant, prepared from powder	8	30–70
Espresso	1	50–150
Tea		
Black, regular, brewed or tea bag	8	40–74
Black, decaffeinated	8	2–5
Green, brewed or tea bag	8	25–50
Oolong, brewed or tea bag	8	21–64
White, brewed or tea bag	8	15
Instant, prepared from powder	6	33–64
Yerba mate, brewed or tea bag	8	65–130
Iced tea	12	27–42
Beverages		
Carbonated beverages with caffeine added	12	22–69
Alcoholic beverages with caffeine added	1	3–9
Energy drinks with caffeine added	8.2–23.5	33–400
Caffeinated waters	16.9–20.0	42–125
Foods		
Chocolates	8 oz	0–6
Sweets	Various	1–122
Snacks, from US Department of Agriculture database	1 oz or 1 bar	3–41
Snacks, gums, and mints	Various	20–400
Fast foods	Various	1–49

Adapted from the 2012 USFDA report on caffeinated food and CBs [Somogyi, L.P. (2012) *Caffeine Intake in the U.S. Population* (http://www.fda.gov/downloads/AboutFDA/CentersOffices/OfficeofFoods/CFSAN/CFSANFOIAElectronicReadingRoom/UCM333191.pdf)].

Box 1. Coffee history and consumption

A taste of history

The name coffee was derived from the Arabic word *quahweh* and, in Latin, *coffea* for the botanical genus [12]. The history of coffee begins in Ethiopia, where it was discovered in about 850 AD. Cultivation of coffee bushes was dominated by Yemen and there is evidence of coffee drinking by the middle of the 15th century. It disseminated into India, Northern Africa, Turkey, and Balkans. Coffee was introduced from Mocha (Yemen) to Europe by Venetian merchants in early 1615. By the end of the 17th century, the use of coffee in Europe was common and from there it was subsequently introduced to America [13]. Among the 103 species of coffee identified, only two, *Coffea arabica* (arabica) and *Coffea canephora* (robusta), produce 99% of the coffee consumed. Coffee is now grown in 60 tropical and subtropical countries. About 60% of the coffee produced worldwide comes from the American continent, where arabica coffee (low bitterness and low caffeine content) is predominant.

CB consumption and caffeine intake in the USA [11]

- 85% of Americans consume at least one CB per day.
- Among all consumers of CBs, the mean caffeine intake is 165 mg/day.
- The highest caffeine intake occurs in consumers aged 50–64 years (226 mg/day).
- Coffee is the primary source of caffeine in all age groups.
- Carbonated soft drinks and tea are the major contributors to caffeine intake in <18-year-olds.
- Consumers of energy drinks represent ≤10% across all age groups.

metabolism, incretin release, and insulin sensitivity [5,6]. Moreover, the effect of coffee on cardiovascular health is an ongoing controversy; coffee consumption was shown to have adverse effects on serum cholesterol, blood pressure, and plasma homocysteine. However, the effects of coffee on epinephrine concentrations, hyperglycemia, and blood pressure all appear to be weaker than the effects of the same amount of caffeine used in isolation. The harmful cardiovascular effects of caffeine may be offset by the beneficial effects of other compounds in coffee on the biological pathways involved in the development of coronary heart disease [5,6]. The available evidence on T2D and cardiovascular effects related to habitual coffee consumption is largely reassuring.

In addition, there is no significant relationship between coffee consumption and gastric ulcer, duodenal ulcer, reflux esophagitis, or non-erosive reflux disease. Coffee intake has been inversely associated with mortality, with the lowest risk among individuals who chronically consume about two to four cups per day. Among healthy adults a moderate daily caffeine intake of ≤400 mg is not associated with adverse effects [5–8].

By contrast, coffee intake has been associated with bone loss, lower bone density or fractures (heavy coffee consumers), and increased blood pressure. Available evidence suggests that pregnant women must restrict their caffeine intake due to an increased risk of poor fetal growth and spontaneous abortion with daily ingestion of 300 mg [5,8].

Excessive caffeine intake has been associated with headaches, nausea, anxiety, hypertension, and restlessness. The amount of caffeine required to produce adverse effects varies from person to person depending on weight, sex, age, and differences in susceptibility. Most consumers experience, and enjoy, increased alertness, improved mood and focus, and the capacity to remain awake. For others, caffeine can have disagreeable symptoms; some people metabolize caffeine more slowly than others due to variability in the enzymatic activity of the metabolizing enzyme CYP1A2 (Figure 1). Caffeine also has addictive properties, with persistent desire to consume caffeine-containing foods or drinks and withdrawal symptoms (headache, lethargy, and irritability) when caffeine ingestion is abruptly discontinued [6]. Caffeine also enhances memory consolidation [9].

Caffeine's impact on children and adolescents

Children (2–12 years) and adolescents (13–17 years) metabolize caffeine more rapidly than adults. Children in general consume less caffeine (24–37 mg/day) than adults [10,11]. Children and adolescents, including those diagnosed as hyperactive, are no more sensitive to the effects of caffeine than adults. The more caffeine youngsters consume, the less sleep they get, which plays a critical role in learning; this may eventually lead to other health problems [10]. Children ingest caffeine mostly in the form of tea and carbonated soft drinks [11], which should be avoided, particularly because it is unknown how excessive caffeine intake impacts the developing brain. Among adolescents the consumption of sweetened coffee and energy drinks has increased; these are the principal sources of