

Effects of caffeine on health and nutrition: A Review

Tsedeke Wolde

Lecturer of Nutrition, Department of Public Health, College of Medical and Health Sciences, Wollega University, Nekemte, Ethiopia

Abstract

This paper reviews the available literatures and research findings on the effect of caffeine on health and nutrition. Caffeine is a mild stimulant found in many of our favorite beverages and some of our foods, such as coffees, teas, colas, and even chocolate. Caffeine can negatively affect our health if it is not consumed in moderation. Caffeine can cause nutrient depletion of important nutrients, like vitamin B6, and interfere with nutrient absorption of essential minerals, including calcium, iron, magnesium and B vitamins. Studies have found caffeine consumption is associated with reduced risk of developing type 2 diabetes, although the mechanisms are unclear. However, sensitive sub-populations, including pregnant women, children and older individuals, and those with a history of heart disease, may experience effects at lower levels of caffeine and should limit their consumption to three cups of coffee per day, or no more than 300 mg/ day, to avoid adverse effects. Thus, the purpose of this paper is to review the effect of caffeine on health and nutrition.

Key words: caffeine, health, diseases and nutrition.

Introduction

Caffeine is a naturally occurring chemical stimulant and an alkaloid belonging to a class of compounds called methylxanthines. Its chemical formula is C₈H₁₀N₄O₂. Caffeine is one of the most comprehensively studied ingredients in the food supply. Yet, despite our considerable knowledge of caffeine and centuries of safe consumption in foods and beverages, questions and misperceptions about the potential health effects associated with caffeine persist (IFIC, 2003).

Caffeine can act as antioxidant to prevent diseases. Antioxidants are substances that help protect cells in the body against damage acting as a defense against oxidative damage. The role of an antioxidant is to help reduce oxidation reactions and thus reduce damage to body tissues. Antioxidants have been linked to a number of potential health benefits, including protection against heart disease and most forms of cancer. Chlorogenic acid, caffeic acid, and melanoidins are all the types of antioxidants found in coffee. Coffee is one of a number of drinks that contain high antioxidant content. Antioxidants are also found in tea, cocoa and red wine. But there are four times more antioxidants in coffee than in tea (Escott-Stump, 2008).

Caffeine rapidly absorbed following oral consumption peak blood (plasma) levels usually within 30 minutes. Then distributes into all body compartments – pass easily into brain, breast milk and crosses placenta. Then metabolized in the liver changed to di and mono- methylxanthines and finally filtered by the kidneys and they exit the body with the urine. How long it takes to leave caffeine from the body? it varies between individuals for example, an average adult – 3-5 hrs, child less than 6 months – 24 hrs, Pregnant – 7-8 hrs, and Smoker – 2-3 hrs (IFIC, 2003).

At present, there is little evidence to show consumption of caffeine increases the risk of cancer. Studies have shown no negative association, and possibly some protective effects, between caffeine consumption and several types of cancer (IFIC, 2003).

Caffeine consumption may help reduce the risk of several chronic diseases, including diabetes, liver disease, and cancer, as well as improve immune function but it has also risk for developing coronary artery disease, osteoporosis, gastritis, iron deficiency anemia, and still births (IFIC, 2003). Caffeine can cause nutrient depletion of important nutrients, like vitamin B6, and interfere with nutrient absorption of essential minerals, including calcium, iron, magnesium, and B vitamins (Escott-Stump, 2008).

Most studies have found that caffeine consumption does not reduce bone mineral density in women who consume adequate calcium. However, positive associations between caffeine consumption and hip fracture risk in three studies imply that limiting coffee consumption to three cups per day (about 300 mg/day of caffeine) may help prevent osteoporosis- related fractures in older adults (IFIC, 2003).

Although epidemiological data on the effects of caffeine during pregnancy are conflicting, the evidence suggests that women who are pregnant or are planning to become pregnant, or who are breastfeeding, can safely consume caffeine, but should limit their consumption to three cups of coffee per day, providing no more than 300 mg/day of caffeine (IFIC, 2003).

Sources of caffeine

Caffeine is a naturally occurring substance found in the leaves, seeds and/or fruits of at least 63 plant species worldwide and is part of a group of compounds known as methylxanthines. The most commonly known sources of caffeine are coffee, cocoa beans, kola nuts and tea leaves [Frary et al., 2005].

The amount of caffeine in food products varies depending upon the serving size, the type of product, and preparation method. With teas and coffees, the plant variety also affects the caffeine content. An eight-ounce cup of drip-brewed coffee typically has 65-120 mg caffeine; an eight-ounce serving of brewed tea has 20-90 mg; and a 12-ounce canned soft drink has 30-60 mg [Knight, et al., 2004]. Energy drinks can contain 50-160 mg or more per eight-ounce serving, plus caffeine from guarana and other added sources not normally declared as caffeine; and one ounce of solid milk chocolate typically has just six mg caffeine [ABA, 2007; Mayo Clinic, 2005].

Other sources of caffeine include over-the-counter pain relievers. Caffeine is an adjuvant—it increases the rate at which the medication is absorbed into the body. It is also present in some stimulant tablets and cold medications. Caffeine can be present in these products ranging from 16-200 mg [Cleveland Clinic, 2006].

Caffeine daily consumption intake

The per capita consumption level of caffeine for all consumers (of all ages) is approximately 120 mg per day, or a mean intake of 1.73 mg/kg body weight/day [Knight et al., 2004].

Children consume significantly less caffeine than adults. As of 2004, the average daily intake of caffeine by young children ages 1-5 and 6-9 years from all caffeinated beverages was 14 and 22 mg/day, or 0.82 and 0.85 mg/kg body weight/day, respectively [Knight et al., 2004]. For children and young adults, the primary sources of caffeine are soft drinks and teas, while for adults ages 25 and older; it is mostly derived from coffee [Knight et al., 2004].

However, a growing beverage category, energy drinks, is a popular choice with several age groups, and is a category to monitor for consumption in the coming years.

Evidence from both scientific reviews and specific studies on consumption of caffeine generally concludes that daily consumption of 300 mg/day, or about three cups of coffee, is safe, even for more sensitive segments of the population, such as young children and pregnant women [Nawrot et al., 2003].

Functions of caffeine

Caffeine is absorbed and passes quickly into the brain. It does not collect in the blood stream or get stored in the body. It leaves the body in the urine many hours after it has been consumed. There is no nutritional need for caffeine. It can be avoided in the diet. Caffeine stimulates, or excites, the brain and nervous system. It will not reduce the effects of alcohol, although many people still believe a cup of coffee will help a person "sober-up." Caffeine may be used for the short-term relief of fatigue or drowsiness (Escott-Stump, 2008).

Side effects of caffeine

Anxiety

- ❖ Depression
- ❖ Difficulty sleeping
- ❖ Nausea
- ❖ Restlessness
- ❖ Tremors
- ❖ A fast heart rate
- ❖ Urinating more often
- ❖ Vomiting
- Stopping caffeine abruptly may cause withdrawal symptoms, such as:-
- ✓ Drowsiness
- ✓ Headaches
- ✓ Irritability
- ✓ Nausea, and

- ✓ Vomiting
 - Reduce caffeine gradually to prevent any symptoms of withdrawal.
 - The effect of caffeine on health has been widely studied.
- Large amounts of caffeine may decrease bone mass density, most likely by interfering with the body's ability to absorb calcium. This may lead to osteoporosis.
- Caffeine may cause or worsen painful, lumpy breasts (fibrocystic disease).
- Caffeine may have a negative effect on a child's nutrition if caffeinated drinks replace healthy drinks, such as milk. A child who consumes caffeine may also eat less, because caffeine reduces the appetite (Escott-Stump, 2008).

Effect of caffeine on health and diseases

Cardiovascular health

The relationship between coffee, caffeine and cardiovascular health markers has been explored, with emphasis on cardiac arrhythmia, heart rate, serum cholesterol and blood pressure. In his review, Nawrot et al. (2003) concluded that moderate caffeine consumption (400 mg or less, or four or fewer cups of coffee per day) does not adversely affect cardiovascular health. Insufficient data exist to be able to draw conclusions about the risk of coronary heart disease (CHD) or mortality associated with consumption of much higher amounts.

Hypertension (high blood pressure) is a recognized risk factor for CHD and stroke. Caffeine can acutely raise heart rate and blood pressure immediately after consumption, although regular caffeine consumers can build up a tolerance to these effects. Although the impact of coffee on blood pressure was first debated nearly thirty years ago, extensive epidemiological studies have confirmed that there is no link between coffee consumption and hypertension, hyperlipidemia, and coronary artery disease (CAD) (Nawrot et al., 2003). One study has linked caffeine intake to abnormal heart rhythms, particularly premature atrial and ventricular contractions of the heart. In this study, caffeine taken in tablet form resulted in blood pressure elevations four times greater than for caffeinated coffee. Thus, although there appears to be no clear evidence for a strong causal relationship between caffeinated coffee and abnormal heart rhythms, it is not as clear when considering caffeine alone or in beverages other than coffee [Frishman and Sonnenblick, 2002].

Although scientific review author James (2004) suggested there is strong experimental evidence that blood pressure remains reactive to caffeine in the diet, and that overall epidemiological evidence implicates caffeine as a risk factor for hypertension, more recent studies on women have not supported this. According to the American Heart Association (AHA)'s policy on caffeine, "Whether high caffeine intake increases the risk of coronary heart disease is still under study" [AHA, 2007].

In the study by Lopez-Garcia et al. (2006), researchers found that coffee consumption was not associated with an increased risk of CHD. In the Nurses' Health Studies I and II, coffee consumption, even at high levels, appeared to have no effect on blood pressure; however, both regular and diet colas caused a modest increase in blood pressure. This apparent contradiction was thought to be due either to an ingredient other than caffeine or by a protective effect of another component of coffee. People already suffering from high blood pressure should consult a physician about their caffeine intake, as they may be more sensitive to the effects of caffeine on blood pressure [Winkelmeyer et al., 2005].

Reproductive health

There are several comprehensive review papers that examine the relationship between caffeine and reproductive health. A review by Leviton and Cowan [2002] specifically examined outcomes such as delayed conception, miscarriage (both chromosomally normal and aberrant), birth defects, premature birth, and low birth weight and found that caffeine does not cause any of these outcomes. The authors concluded that the associations found in the less rigorously analyzed studies could possibly be due to other factors, such as smoking.

Christian and Brent (2001) conducted a very systematic review on the relationship between caffeine consumption by both pregnant women and women of child-bearing age and the occurrence of congenital malformations, fetal growth retardation, small-for-date babies, miscarriages, behavioral effects, maternal infertility and genetic effects.

The only statistically significant results were teratogenic (birth defect) effects in rats administered extremely high levels of caffeine intravenously, which do not necessarily translate to humans and also could never be attained merely by drinking beverages containing caffeine.

Fertility

Nawrot et al. (2003) noted in their review of caffeine that most epidemiological studies on caffeine and fertility were affected by methodological issues, including inadequate measurement of caffeine intake, inadequate

control for possible confounding factors, recall bias in retrospective studies, lack of data on frequency of unprotected intercourse and, in some studies, inadequate sample size. Despite these limitations, the epidemiological studies generally indicate that consumption of caffeine at levels at or below 300 mg per day, or approximately three cups of coffee per day, did not reduce fertility in otherwise fertile women.

A study on the effects of alcohol and caffeine on fertility demonstrated a significant risk when alcohol and caffeine were consumed together; however no effects were observed when caffeine was consumed alone [Nawrot et al., 2003].

Miscarriage

There have been numerous epidemiological studies examining the relationship between coffee or caffeine intake by pregnant women and the risk of miscarriage. Some studies have observed significant associations between caffeine intakes greater than 300 mg/day, particularly from coffee, and the risk of miscarriage, whereas other studies have not [Higdon and Frei, 2006]. While individual epidemiological studies cannot prove cause and effect, they can contribute to the wealth of information on potential observed effects. However, they must be taken within the context of the entire body of data [Nawrot et al., 2003].

Birth defects (teratology)

The majority of epidemiological studies have found that maternal caffeine consumption is not associated with increased risk of congenital malformations, or birth defects, in fetuses [Higdon and Frei, 2006]. At present, there is no convincing evidence from epidemiological studies that moderate caffeine consumption by pregnant women ranging from 300–1,000 mg per day throughout the entire pregnancy increases the risk of birth defects [Nawrot et al., 2003]. However, in light of other women's health issues, such as fertility and miscarriage, pregnant women are advised to keep caffeine consumption at or below 300 mg/day (or approximately three cups of coffee).

Bone health (osteoporosis)

Given the increased awareness of the incidence of osteoporosis in post-menopausal women, research on the relationship between caffeine intake and bone health has been a particular area of focus. Consumption of large amounts of caffeine (more than 744 mg/day) has been shown to increase urinary excretion of calcium and magnesium [Tucker, 2003]. However, calcium excretion is complex and is affected by many other dietary constituents such as calcium, potassium, phosphorus, isoflavones, antioxidants, salt, oxalate, phytates, and protein [Massey, 2003; Atkinson and Ward, 2001]. Studies on caffeine and calcium metabolism and bone deterioration show that, as caffeinated coffee consumption increases, milk consumption decreases. Bone deterioration becomes more pronounced when dietary calcium is inadequate, and less pronounced when dietary calcium intake is adequate.

Nawrot et al. (2003) concluded that caffeine's potential to adversely affect calcium balance and bone metabolism is dependent on lifetime caffeine and calcium intakes, and is critical for women. Based on the data reviewed, the authors suggested that caffeine intake of less than 400 mg/day does not have significant effects on bone density, nor on calcium balance in individuals consuming at least 800 mg calcium per day. Higdon and Frei (2006) also suggested that, although most studies have not found coffee or caffeine consumption to reduce bone mineral density in women who consume adequate calcium, positive associations between caffeine consumption and hip fracture risk in three prospective cohort studies suggest that limiting coffee consumption to three cups of coffee per day (about 300 mg of caffeine per day) may help prevent hip-bone fractures in older adults.

Cancer

Most of the research on possible links between cancer and caffeine has been conducted on coffee and tea. Therefore, it is extremely difficult to isolate the effects of caffeine unless the research specifically focuses on caffeine. Consequently, research on caffeine and its effects on cancer, if any, is sparse. There are however, references in coffee and tea research relating to caffeine that are generally positive.

Nawrot et al. (2003) concluded in his review of the research that caffeine is unlikely to be a human carcinogen at levels below five cups of coffee per day (or less than 500 mg caffeine per day). Furthermore, the overall evidence indicates that caffeine, as present in coffee, does not cause breast or bowel cancer. Moreover, although early case control studies appeared to link caffeine intake to pancreatic, bladder and ovarian cancers, more recent, better designed studies have not supported these conclusions [Tavani and La Vecchia, 2004; Zeegers et al., 2004]. A number of case control studies have demonstrated reduced risk of colorectal cancer with coffee consumption [Tavani and La Vecchia, 2004; Higdon and Frei, 2006]. In a review, Tavani and La Vecchia (2004) showed that not only was there no risk of colon or colorectal cancer with caffeinated beverages, but there may even be a protective effect. A study by Michels et al. (2005) confirmed that there is no association between rectal cancer and consumption of caffeinated beverages.

Reduced risk of diabetes

In both cohorts, higher caffeine intakes were associated with significant reductions in diabetes risk. In contrast, tea consumption did not affect type 2 diabetes risks in either study [Salazar-Martinez, et al., 2004]. Van Dam and Hu [2005] conducted a systematic review of nine cohort studies, including more than 193,000 men and women, and found a 35% lower risk of type 2 diabetes in those who consumed at least six cups of coffee per day, and a 28% lower risk in those who consumed between four and six cups per day, compared to those who consumed less than two cups per day. In another long-term study of the relationship between caffeinated beverage consumption and incidence of type 2 diabetes, the authors followed more than 41,000 participants over ten years, assessing coffee consumption every two to four years. The results suggest that caffeine intake from coffee and other source is associated with a significantly lower risk for type 2 diabetes [Salazar-Martinez, et al., 2004].

Recovery from liver injury

The study conducted a prospective study to examine the relationship between coffee and tea consumption and incidence of chronic liver disease [Ruhl and Everhart, 2005a]. The results showed that individuals who consume more than two cups of coffee or tea per day have less than half the risk of developing chronic liver disease as those who drink less than one cup of coffee per day.

Effect of caffeine on nutrition

The effect of caffeine on vitamin and minerals absorption

Caffeine is a mild stimulant found in many of our favorite beverages and some of our foods, such as coffees, teas, colas, and even chocolate. Because caffeine can negatively affect our absorption of nutrients, it's important to pay attention to the amount we consume. Moderate caffeine intake (300 mg or less per day) is probably not harmful to most healthy adults; however, regular large amounts (over 350 mg per day) may cause dependency, nutrient depletion, and interference with nutrient absorption. Many also take a multivitamin supplement daily as a part of their morning routine. Not many people are aware that taking vitamins at the same time as a cup of coffee or tea can interfere with the body's absorption of many necessary nutrients (Escott-Stump, 2008).

Calcium

Caffeine causes calcium to be excreted in the urine and feces. For every 150 mg of caffeine ingested, about the amount in one cup of coffee, 5 mg of calcium is lost. This effect occurs even hours after the consumption of caffeine. One study of postmenopausal women found that those who consumed more than 300 mg of caffeine lost more bone in the spine than women who consumed less.

Caffeine also inhibits the amount of calcium that is absorbed through the intestinal tract and depletes the amount retained by the bones. Studies have shown that women with high caffeine intake suffer more hip fractures than those who avoid caffeine or drink in moderation (1 to 2 cups per day) (Escott-Stump, 2008).

Vitamin D

Caffeine inhibits vitamin D receptors, which limit the amount that will be absorbed. Because vitamin D is important in the absorption and use of calcium in building bone, this could also decrease bone mineral density, resulting in an increased risk for osteoporosis (Escott-Stump, 2008).

Iron

Caffeine interferes with the body's absorption of iron, which is necessary for red blood cell production. Drinking caffeine at the same time as an iron source can reduce absorption by up to 80%, according to the Nutrition Desk Reference. Any beverage containing caffeine should be separated from iron-containing foods or supplements by at least one hour (Escott-Stump, 2008).

B Vitamins

Caffeine has a mild diuretic effect, which increases urination. Water soluble vitamins, such as the B-vitamins, can be depleted as a result of the fluid loss. In addition, it interferes with the metabolism of some B-vitamins, such as thiamine (vitamin B1). The one exception to this rule appears to be vitamin B12. Caffeine stimulates the production of stomach acid, which actually helps the body absorb B12 (Escott-Stump, 2008).

Other Vitamins and Minerals

Caffeine may reduce the absorption of manganese, zinc and copper. It also increases the excretion of the minerals magnesium, potassium, sodium and phosphate. There is also evidence that caffeine interferes with the action of vitamin A (Escott-Stump, 2008).

Conclusion

As clearly discussed in the above review, there is evident that caffeine consumption at varying levels may help reduce the risk of several chronic diseases. Sensitive sub-populations, including pregnant women, children and older individuals, and those with a history of heart disease, may experience effects at lower levels of caffeine and should limit their consumption to three cups of coffee per day, or no more than 300 mg/ day, to avoid adverse

effects. Caffeine can cause nutrient deficiencies that can affect both health and quality of life. As with most dietary factors, moderation and balance are keys in optimal nutrition intake.

Acknowledgment

The author would like to thanks Wollega University for the facilities available for literature search and technical support.

References

- ABA (American Beverage Association). 2007. All-about-beverage products- manufacturing-marketing-consumption/americas-beverage-products/energy-drink/whats inside/index.aspx. (<http://www.ameribev.org>). (Accessed on November 28, 2014).
- AHA (American Heart Association). 2007. Statement on Caffeine, (<http://www.americanheart.org/presenter.jhtml>). (Accessed on November 28, 2014).
- Andersen, L.F., Jacobs, D.R, Jr, Carlsen, M.H., Blomhoff, Rune. 2006. Consumption of coffee is associated with reduced risk of death attributed to inflammatory and cardiovascular diseases in the Iowa Women's Health Study. *Am. J. Clinical Nutrition*. 83: 1039 –1046.
- Atkinson, S.A., Ward, W.E. 2001. Clinical nutrition: The role of nutrition in the prevention and treatment of adult osteoporosis. *CMAJ*.165 (11):1511-1514.
- Christian, M.S., Brent, R.L. 2001. Teratogen update: evaluation of the reproductive and developmental risks of caffeine. *Teratology*. 64(1):51-78.
- Cleveland-Clinic.2006. /health/health-info/ docs/2500/2547.asp?index=9645. (<http://www.clevelandclinic.org>). (Accessed on November 29, 2014).
- Escott-Stump S. 2008. Nutrition and Diagnosis-Related Care. 6th ed. Philadelphia, Pa: Lippincott Williams & Wilkins.
- Frary, C.D., Johnson, R., Wang, M.Q. 2005. Food sources and intakes of caffeine in the diets of persons in the United States. *JADA*. 105(1):110-113.
- Frishman, W.H., Sonnenblick, E. 2002. Cardiovascular Pharmacotherapeutics. ISBN: 0070224811. McGraw Hill.
- Greenberg, J.A., Dunbar, C., Schnoll, R., Kokolis, R., Kokolis, S., Kassotis, J. 2007. Caffeinated beverage intake and the risk of heart disease mortality in the elderly: a prospective analysis. *Am. J. Clinical Nutrition*. 85: 392-398.
- Higdon, J.V., Frei, B. 2006. Coffee and health: a review of recent human research. *Crit Rev Food Sci Nutr*. 46(2):101-123.
- IFIC (International Food Information Council Foundation). 2003. Caffeine & Health: Clarifying the Controversies: 1100 Connecticut Avenue, N.W., Suite 430. Washington. (<http://www.ific.org> 03/08). (Accessed on November 30, 2014).
- James, J. E. 2004. Critical Review of Dietary Caffeine and Blood Pressure: A Relationship That Should Be Taken More Seriously. *Psychosom Med*. 66:63–71.
- Knight, C.A., Knight, I., Mitchell, D.C., and Zepp, J.E. 2004. Beverage caffeine intake in US consumers and subpopulations of interest: Estimates from the Share of Intake Panel survey. *Food Chem. Toxicol*. 42(12):1923-1930.
- Leviton, A., Cowan, L. 2002. A review of the literature relating caffeine consumption by women to their risk of reproductive hazards. *Food Chem Toxicol*. 40(9): 1271–1310.
- Lopez-Garcia, E., van Dam, R.M., Willett, W.C., Rimm, E.B., Manson, J.E., Stampfer, M.J., Rexrode, K.M., Hu, F.B. 2006. Coffee consumption and coronary heart disease in men and women: a prospective cohort study. *Circulation*. 113(17):2045–53.
- Massey, L.K. 2003. Dietary animal and plant protein and human bone health: a whole foods approach. *J Nutr*. 133(3): 862S-865S.
- Mayo Clinic. 2005. Health/caffeine/AN01211. (<http://www.mayoclinic.com>). (Accessed on November 30, 2014).
- Michels, K.B., Willett, W.C., Fuchs, C.S., Giovannucci, E. 2005. Coffee, tea, and caffeine consumption and incidence of colon and rectal cancer. *J Natl Cancer Inst*. 97(4):282-292.
- Nawrot, P., Jordan, S., Eastwood, J., Rotstein, J., Hugenholtz, A., Feeley, M. 2003. Effects of caffeine on human health. *Food Addit Contam*. 20(1):1-30.
- Ruhl, C.E., Everhart, J.E. 2005a. Coffee and tea consumption are associated with a lower incidence of chronic liver disease in the United States. *Gastroenterology*. 129(6):1928-1936.