International Journal of Recent Innovation in Food Science & Nutrition
Vol. 1, Issue 1 - 2018

DOES MODERATE CAFFEINE CONSUMPTION CAUSES DIURESIS? - A SYSTEMATIC REVIEW

RIDHIMA BHALLA[*], MEDHA GUPTA[**]

ABSTRACT

Caffeine (1,3,7-trimethylxanthine) is the most consumed psychoactive substance in the world. The main sources in the dietary intake are coffee, tea, cocoa products and beverages. In India, acceptance and consumption of tea and coffee are have increased over the years. More than 90% adults in India use it regularly, and among them, average consumption is more than 200 mg of caffeine per day. There are studies that suggest caffeine consumption can cause diuretic effect in the body. Though it remains unclear that what amount of caffeine can cause diuresis. This Indian review studies the impact of moderate caffeine consumption in various scenarios to understand its impact on hydration status. In this systematic review, characteristic of 27 studies have been included which includes 3 placebo-controlled studies and 8 studies of exercise and sports based environment. Our main finding suggest that: (1) A daily intake of 300 mg of caffeine was shown to be safe in healthy adults with no reports of any fluid electrolyte imbalance. (2) Caffeine ingestion did not lead to excessive fluid loss in healthy adults.

KEYWORDS: Caffeine, Tea, Coffee, Diuresis.

INTRODUCTION

Caffeine (1,3,7-trimethylxanthine) is the most consumed psychoactive substance in the world. Although caffeine is naturally present in many plant-based foods, the main sources in the dietary intake are coffee, tea, cocoa products and beverages[1, 2]. Table 1 provides typical caffeine levels found in standard portions of these. The wide variation in the caffeine content of tea and coffee can be explained by differences in the blend and brewing times (FSA 2004). In India, acceptance and consumption of tea and coffee have increased over the years. By 2008, the internal consumption of tea had risen to about 82% of the total production in India[3]. Also, the proportion of occasional coffee drinkers has increased in the last few years (Coffee Board) but tea is truly the national drink of India. Domestic consumption of coffee has been rising 5 percent annually, while tea has generated only about 2 percent yearly growth. More than 90% adults in India use it regularly, and among them, average consumption is more than 200 mg of caffeine per day[4]. Although consumption of low to moderate doses of caffeine is generally safe, consumption of higher doses by vulnerable individuals can lead to increased risk for negative health consequences, including a mild diuretic effect[5].

[*]Manager, Medical Writing, McCann Health.
[**]Senior Writer, McCann Health. ***Correspondence E-mail Id:*** editor@eurekajournals.com

© Eureka Journals 2018. All Rights Reserved.

Moreover, a number recent studies show that some caffeine users become addicted to or dependent on caffeine[5].

Many of these individuals are unable to reduce consumption despite knowledge of recurrent health problems associated with continued caffeine use[3]. Food Safety and Standards Authority of India (FSSAI) recommends a limit of 320 ppm (mg/l) of caffeine in energy drinks[6]. According to global health authorities, for the healthy adult population, moderate daily caffeine intake at a dose level up to 400 mg day (-1) (equivalent to 6 mg/kg body weight/day in a 65 kg person) is not associated with adverse effects[7, 8]. The U.S Food and Drug Administration states caffeine has diuretic properties when consumed in large doses (≥500 mg) and advises its users to drink extra water to avoid dehydration during exercise in the heat[10].

The underlining mechanism of caffeine induced diuresis is not yet clear. It has been postulated, methylxanthines such as caffeine can inhibit phosphodiesterase in the proximal tubule of the kidneys, which may contribute to the diuretic effect[9]. Because caffeine does not increase the kidneys' glomerular filtration rate[10], the diuretic effect is more likely to berelated to its natriuretic effect following adenosine receptor blockade. Evidence shows that caffeine acts on the kidneys by inhibiting sodium reabsorption in the proximal and distal tubules[11] thus increases the solute excretion and consequently free water excretion.

The Food Standards Agency (FSA 2001) advises pregnant women to limit their caffeine intake to a maximum of 300 mg per day owing to concerns that excessive caffeine may cause miscarriage or low birth weight. There are no official recommendations to limit caffeine consumption in non-pregnant consumers, although this has not prevented the assumption that caffeine can be harmful. Specifically, it is claimed that regular caffeine consumption, even at moderate levels, increases the risk of dehydration, anxiety and sleep disorders. Few studies have also challenged the assertion that caffeine could contribute to a severe fluid deficit[12,13]. The question still remains concerning the magnitude, significance, and moderators of the diuretic effect. Owing to the lack of credible data to establish the link between caffeine induced dehydration, we performed a systematic review of all the available data on the association of caffeine with dehydration.

Table 1.Caffeine Content of Foods and Beverages

Food and Beverages	Milligrams of Caffeine (Average)
Coffee (8 oz)	
Brewed, drip	137
Instant	76
Tea (8 oz)	
Brewed	48
Instant	26–36
Caffeinated soft drinks (12 oz)	37
Hot cocoa (12 oz)	8–12
Chocolate milk (8 oz)	5–8
Candy	
Dark chocolate (1.45 oz)	30
Milk chocolate (1.55 oz)	11
Semi-sweet chocolate (1/4 cup)	26–28
Chocolate syrup (1 tbsp)	3
Coffee ice cream or frozen yogurt (1/2 cup)	2

Adapted from: Committee on Obstetric Practice. Moderate caffeine consumption during pregnancy. Obstet Gynecol 2010; 116:467-8.

© Eureka Journals 2018. All Rights Reserved.

METHODS

IDENTIFICATION OF STUDIES

This systematic review conforms to the guidelines outlined by the Meta-Analysis of Observational Studies in Epidemiology recommendations[14]. As a first step, a broad (free text) search string was used in PubMed and Embase databases. The search included key words “caffeine”, ‘coffee’, “tea”, and “cola” in conjunction with “fluid balance”, “diuresis, “diuretic”, “hydration”, “rehydration”, “dehydration”, and “urine volume”. Potentially relevant papers (were accessed in order to review the full text. The references cited by each potentially relevant paper, review, and book chapter were scrutinized in order to locate additional potential papers.

STUDY SELECTION

We included studies that reported relationship between caffeine and dehydration. No publication date was imposed. Only studies published in English and conducted in healthy adults were included. The sources of caffeine included pills, tea, coffee and aerated beverages and carbohydrate electrolyte drinks. Studies were excluded if they were cross-sectional in design and involved minimum of 5 healthy adults. The initial search identified 1065 potentially relevant citations. After screening titles and abstracts, we identified a total of 45 studies for further evaluation (Fig. 1). We excluded studies that were cross sectional in design; eight that were abstracts of conference posters and seven studies that were repeated in the same cohort. The results of the remaining studies that comprised a total of 194 healthy adults have been included in this systematic review.

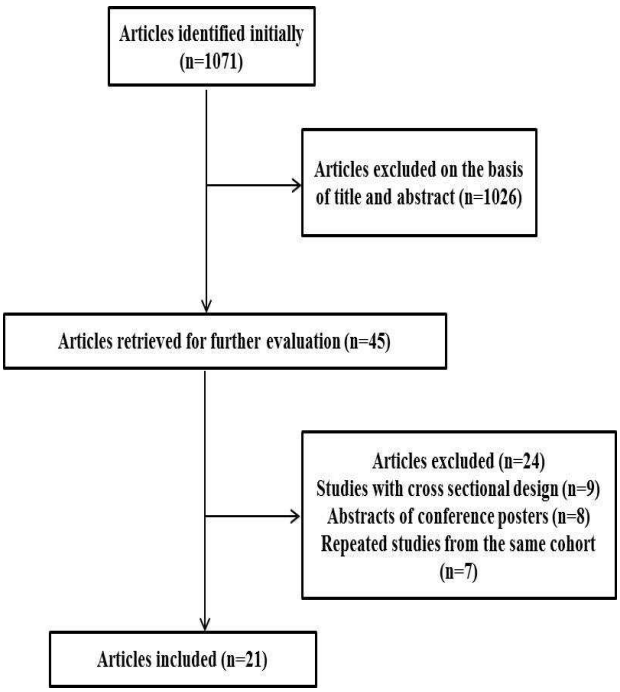

Figure 1.Study selection process of identified articles

RESULTS

PLACEBO CONTROLLED STUDIES

The focus on placebo-controlled studies was important as regular caffeine consumers may be conditioned to anticipate effects on hydration from caffeinated products[15].

Three placebo controlled studies comparing the effects of caffeine vs. placebo on hydration status

© Eureka Journals 2018. All Rights Reserved.

in healthy adults were included in this analysis and summarized in Table 2.

In a study by Tucker et al[16], the hydration status of thirty four adult males under combinations of different beverage types was found to be similar in the caffeine vs. placebo groups. Urine volume and total body water were found to be consistent in the two groups.

A further study (Ruxton CH et al[21]) evaluated the effects of caffeine containing black tea on hydration status in healthy adults to find out no significant differences in the urine volume and blood parameters in the black tea vs. placebo groups with the caffeine intake raining from 2.07 mg per kg bodyweight to 3.11 mg per kg bodyweight. Caffeinated tea was further assessed for its effects on hydration in another randomized, cross-over study by Ruxton CH et al[21]. Total urine volume of 1.062L was reported for the tea consuming group as compared to the 1.357L in the water (placebo) group; suggesting that tea is equally hydrating to water at a daily caffeine intake of about 200 mg.

Killer et al.[10] compared the effects of coffee consumption against water ingestion across a range of validated hydration assessment techniques in a crossover counter-balanced study. The mean coffee intake of 4 mg per kg bodyweight did not have an adverse effect on hydration in the aforementioned study. Total body water (TBW), urine volume and all other hematological markers were found to be similar in the caffeine vs. placebo groups.

STUDIES IN SPORT/ EXTREME TEMPERATURE SETTING

Our search revealed there were studies that were conducted in either a sport or extreme temperature setting to assess the effect of caffeinated drinks on hydration status of healthy trained adults. The key findings from these studies are analyzed and summarized in Table 2.

Most of the studies conducted in a sport setting were also subject to extreme temperature conditions during exercise. In a study by Del coso et al[19], seven endurance trained cyclists peddled in a hot-dry environment and later consumed either caffeinated beverages or placebo for rehydration. The study did not reveal any dehydrating effects in caffeine group even after exercising for 120 min in a hot environment. In a similar study by Millard-Stafford et al[13], caffeinated beverages were shown to maintain hydration and thermoregulatory function during exercise in a warm, humid environment.

Table 2.Basic characteristics of the included studies

Reference	Country	Subjects	Caffeine intake	Caffeine source	Key findings
Placebo-controlled studies					
Tucker et al[16]2012	USA	34 healthy adult males	4 mg/kg BM	Coffee	• No difference in providing adequate hydration over a 24-h period in free-living, healthy adult males
Killer et al.[10] 2010	UK	52 healthy subjects aged 18-46 years	4 mg/kg BM	Coffee	• Coffee, when consumed in moderation by caffeine habituated males provides similar hydrating qualities to water.
Ruxton et al[21] 2009	UK	21 healthy males	168/252 mg	Black tea	• No significant differences between tea (containing

© Eureka Journals 2018. All Rights Reserved.

					caffeine) and water for any of the mean blood or urine measurements
Studies in sports and extreme temperature setting					
Wemple et al.[11] 2010	USA	6 healthy subjects	25 mg/dl	Carbohydrate electrolyte drink	• Caffeine consumed in carbohydrate electrolyte during moderate endurance exercise apparently does not compromise bodily hydration status.
Zhang et al.[12] 2011	USA	8 healthy male subjects; mean age 23 years	6 mg/kg BM	Carbohydrate electrolyte drink	• Moderate caffeine ingestion (mean 460 mg) did not alter urine production during and after exercise.
Millard Stanford et al.[13] 2009	USA	16 healthy male subjects	195 mg/L	caffeinated sports drink	• Caffeine+carbohydrate electrolyte (CE) appears as rapidly in blood as and maintains hydration and sustains cardiovascular and thermoregulatory function as well as CE during exercise in a warm, humid environment
Grandjean et al.[17] 2010	USA	18 healthy male adults aged 24 to 39	253 mg/L	Carbonated, caffeinated caloric and non-caloric drinks and coffee	• No significant differences in the effect of various combinations of beverages on hydration status of healthy adult males
Falk et al.[18] 2008	USA	7 healthy male subjects	5 mg/kg BM followed by 2.5 mg/kg	Coffee	• No significant differences were observed in total water loss, sweat rate, rise in rectal temperature, nor in the calculated rate of heat storage during exercise in the caffeine vs. placebo groups
Del Coso et al[19] 2007	USA	7 endurance-trained cyclists	5 mg/kg BM	Carbohydrate electrolyte drink	• Caffeine increased urine flow and sweat electrolyte excretion, but these effects are not enough to affect dehydration or blood electrolyte levels when

© Eureka Journals 2018. All Rights Reserved.

					exercising for 120 min in a hot environment
Armstrong et al[20] 2011	USA	49 Healthy males; mean age-21.6 years	5 mg/kg BM	Caffeine capsules	• Findings question the widely accepted notion that caffeine consumption acts chronically as a diuretic.
Fiala KS et al[22] 2011	USA	10 healthy adults; mean age-24 years	-	Caffeinated beverages	• Little evidence to suggest that the use of beverages containing caffeine during non-exercise might hinder hydration status.

BM, body mass.

DISCUSSION

It is a common perception that caffeine-containing drinks cause a net loss in fluid and may lead to dehydration thus, adversely affecting the normal hydration. If this were the case, large numbers of population would be at risk from dehydration because 70-97% are regular consumers of caffeinated beverages[23]. According to the National Drinks Survey[24], average intakes of tea and coffee in adults are 2.1 and 1.1 cups per day, respectively. Any risk of dehydration would be higher in elderly people, who, on average, consume 85% of daily nonfood fluid from tea[25]. However, the view that typical intake of caffeine can impair hydration is not supported by this review. Reasons to support this were that the modest amounts of caffeine found in tea and coffee were too low to cause dehydration, and consumers of caffeinated beverages develop tolerance to caffeine over time.

In theory, caffeine could have an adverse effect on hydration as it increases blood flow to the kidneys and inhibits the re-absorption of sodium, calcium and magnesium, thus expelling more water[26].There is also epidemiological evidence that caffeine consumption provokes the need to urinate by stimulating the bladder's detrusor muscles[27]. However, the theory may not translate into practice because much of the research used high caffeine intakes in the form of capsules, rather than caffeinated beverages, and mechanistic studies were performed in rats.

It is also imperative to bring out the differences between the rest and exercise setting studies that have been included in this systematic review.

The following points should be considered when evaluating the literature examining the effects of caffeine-induced diuresis (i) Are the results reported based on resting data? If so, the findings may not represent what is expected to be seen in an exercise setting; (ii) Are the subjects exercising in a thermo neutral environment, or under hot and/or humid conditions? It is possible that the diuretic effect of caffeine may be different in these two environments. Our findings do not show any significant diuretic effects via sweat loss or fluid imbalance at either rest or exercise setting. Thus, restricting dietary intake of caffeine is not scientifically and physiologically supported.

Finally, a few limitations of this review should be noted. Many of the studies had small sample sizes, although the body of the evidence was considerable to assess the effect of hydration. Also most of these studies are short term studies with minimal or no follow-ups, thus making it difficult to comment whether the outcomes were reversible. Finally, it may be difficult to translate any caffeine ranges from experimental evidence to real life owing to differences in how a

© Eureka Journals 2018. All Rights Reserved.

particular caffeine containing beverage is prepared.

Given the sparse data in this area, future investigations should include assessing the impact on habitual caffeine users. Furthermore, the initial hydration status of the individual may be important when addressing the potential caffeine induced diuresis and the impact this may have on heat tolerance and subsequent exercise performance or any other activity.

CONCLUSION

The literature reviewed in this article shows that caffeine ingestion did not lead to excessive fluid loss in healthy adults. A daily intake of 300 mg of caffeine was shown to be safe in healthy adults with no reports of any fluid electrolyte imbalance. Further research in Indian perspective is needed to clarify whether a large dose of caffeine (>300 mg) results in a diuretic effect.

ACKNOWLEDGEMENT

We would like to thank our colleagues Dr. Harshit Jain (McCann Health, London) and Daleep Manhas (McCann Health, Delhi) for providing us all the support and guidance that helped in completing this research.

REFERENCES

[1]. Anderson BL, Juliano LM, et al. Caffeine's Implications for Women's Health and Survey of Obstetrician-Gynecologists' Caffeine Knowledge and Assessment Practices. *J Womens Health (Larchmt)*. 2009 Sep; 18(9):1457-66.

[2]. Anderson K, Nisenblat V, et al. Lifestyle factors in people seeking infertility treatment-A review. *Aust N Z J ObstetGynaecol* 2010; 50: 8-20.

[3]. Griffin M. 2006. "Coffee history." Coffee Research Institute. Available from: http://www.coffeeresearch.org/coffee/history.htm. Accessed 2008 Nov 15.

[4]. Pradip Baruah. Tea Drinking: Origin, Perceptions, Habits with special reference to Assam, its tribes and Role of Tocklai. *Science and culture* 2011;77:9-10

[5]. Food Standards Agency. Healthy, happy eating for exams and the summer. Available at: http://food.gov.uk/scotland/newsupdates/news/pressreleases/2009/apr/healthyeatingexamssummer. Accessed 25 February 2015.

[6]. U.S. Food and Drug Administration. Medicines in my home: caffeine and your body. Available at: http://www.fda.gov/downloads/drugs/resourcesforyou/consumers/buyingusingmedicinesafely/understandingover-the-countermedicines/ucm205286.pdf. Accessed 20 September 2013.

[7]. http://www.fssai.gov.in/portals/0/standards_of_energy_drinks_pdf.

[8]. Coulson R, Scheinman SJ. Xanthine effects on renal proximal tubular functionand cyclic AMP metabolism. *J Pharmacol Exp Ther* 1989; 248(2): 589-595.10.

[9]. Shirley DG, Walter SJ, Noormohamed FH. Natriuretic effect of caffeine: assessment of segmental sodium reabsorption in humans. *Clin Sci (Lond)* 2002; 103(5): 461-466.12.

[10]. Killer SC, Blannin AK, Jeukendrup AE et al. No evidence of dehydration with moderate daily coffee intake: a counterbalanced cross-over study. *PLoS One*. 2014 Jan 9; 9(1): e84154.

[11]. Wemple RD, Lamb DR, et al. Caffeine vs Caffeine-Free Sports Drinks: Effects on Urine Production at Rest and During Prolonged Exercise. *Int J Sports Med.* 1997 Jan; 18(1): 40-6.

[12]. Zhang Y, Carter SJ, et al. Effect of caffeine ingestion on fluid balance during exercise in the heat and during recovery. *S Afr J SM* 2014; 26(2):43-47.

[13]. Millard-Stafford ML, Cureton KJ, et al. Hydration during exercise in warm, humid conditions: effect of a caffeinated sports

© Eureka Journals 2018. All Rights Reserved.

drink. *Int J Sport Nutr ExercMetab.* 2007 Apr; 17(2):163-77.

[14]. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, et al. (2000) Meta-analysis of observational studies in epidemiology: A proposal for reporting. Meta-analysis of Observational Studies in Epidemiology (MOOSE) group. JAMA 283: 2008-2012.

[15]. Smit HJ, Grady ML, Finnegan YE et al. (2006) Role of familiarity on effects of caffeine-and glucose-containing soft drinks. Physiology and Behaviour 87: 287-97.

[16]. Tucker MA, Ganio MS et al. Hydration Status over 24-H Is Not Affected by Ingested Beverage Composition.*J Am Coll Nutr.* 2015 Mar 19: 1-10.

[17]. Grandjean AC, Reimers KJ et al. The Effect of Caffeinated, Non-Caffeinated, Caloric and Non-Caloric Beverages on Hydration. *J Am Coll Nutr*. 2000 Oct; 19(5):591-600.

[18]. Falk B, Burstein R et al. Effects of caffeine ingestion on body fluid balance and thermoregulation during exercise. *Can J PhysiolPharmacol.* 1990 Jul; 68(7): 889-92.

[19]. Del Coso J, Estevez E, et al. Caffeine during exercise in the heat: thermoregulation and fluid-electrolyte balance. *Med Sci Sports Exerc.* 2009 Jan; 41(1): 164-73.

[20]. Armstrong LE1, Pumerantz AC. et al. Fluid, electrolyte, and renal indices of hydration during 11 days of controlled caffeine consumption. *Int J Sport Nutr ExercMetab*. 2005 Jun; 15(3): 252-65

[21]. Ruxton CH, Hart VA. Black tea is not significantly different from water in the maintenance of normal hydration in human subjects: results from the randomized controlled trial. *Br J Nutr.* 2011 Aug; 106(4): 588-95.

[22]. Fiala KA, Casa DJ, et al. Rehydration with a caffeinated beverage during the nonexercise periods of 3 consecutive days of 2-a-day practices. *Int J Sport Nutr ExercMetab*. 2004 Aug; 14(4):419-29.

[23]. Henderson L, Gregory J & Swan G (2002) National Diet and Nutrition Survey: adults aged 19 to 64 years. Volume 1: Types and quantities of foods consumed. *The Stationery Office: London.*

[24]. Taylor Nelson Sofres (2007), The National Drinks Survey. *Taylor Nelson Sofres Ltd: London.*

[25]. Taylor Nelson Sofres (2003), The National Drinks Survey. *Taylor Nelson Sofres Ltd: London.*

[26]. Birkner E, Grucka-Mamczar E, Zwirska-Korczala K et al. (2006) Influence of sodium fluoride and caffeine on the kidney function and free-radical processes in that organ in adult rats. *Biological Trace Element Research* 109: 35-48.

[27]. Arya LA, Myers DL & Jackson ND (2000) Dietary caffeine intake and the risk for detrusor instability: a case-control study. *Obstetrics and Gynecology* 96: 85-9.

© Eureka Journals 2018. All Rights Reserved.