

Caffeine Intake and its Effect on Hydration Status Among Workers: A Literature Review

Tria Rosemiarti*, Ray Wagiu Basrowi

Occupational Medicine Master Program, Department of Community Medicine, Faculty of Medicine, University of Indonesia, Jakarta, Indonesia

*Corresponding Author: Tria Rosemiarti

E-mail: dr_tria_rosemiarti@yahoo.co.id

Abstract

Introduction: caffeine is one of a compound that is widely found in coffee, tea, energy drink, and chocolate. Their consumption is high among adults, especially workers during working hours. The diuretic effect from caffeine, caffeinated beverages² density, and drink behavior change due to the consumption of caffeinated beverages might alter the hydration status. Moreover, low hydration status is associated with work performance where heat strain may worsen it. The objective of this study is to review the original studies on the association of caffeine intake and hydration status among workers.

Methods: studies were obtained from 4 electronic databases which are Scopus, PubMed, EBSCO, and google scholar. Inclusion criteria were published in English or Bahasa Indonesia, between January 2000 and February 2023. Only originals studies included with the method of experimental or observational studies.

Results: there were eighteen studies found regarding the association between caffeine intake and hydration status. The indicator of hydration status varied from urine specific gravity, urine or serum osmolality, urine color, glomerular filtration rate, urine pH, urine volume, body water, and rehydration capability. Most of the intervention was caffeine intake, but two studies involved tea consumption instead.

Conclusions: Recent studies suggested inconclusive results between caffeine intake and hydration status in adults where some studies showed insignificant change between intervention and control groups and some others showed the poor quality of hydration status among caffeine consumers. More studies are necessary to conduct, especially among workers since their specifically high consumption of caffeine and the risky environment of working.

Keywords: hydration, urine specific gravity, caffeine, coffee intake, urine

Abstrak

Pendahuluan: Kafein adalah salah satu zat yang banyak ditemukan pada kopi, teh, minuman berenergi, dan coklat. Minuman tersebut banyak dikonsumsi oleh orang dewasa, terutama para pekerja selama jam kerja. Efek diuretik dari minuman tersebut, tingginya densitas, serta pengaruh pada kebiasaan minum memiliki kemungkinan untuk mempengaruhi status hidrasi. Status hidrasi memiliki berhubungan dengan produktivitas kerja, terutama bila muncul heat strain. Tujuan dari studi ini adalah me-reviu penelitian terdahulu terkait hubungan antara asupan kafein dan status hidrasi pada pekerja.

Metode: Penelitian terdahulu diperoleh dari 4 basis data elektronik, yaitu scopus, PubMed, EBSCO, dan google scholar. Kriteria inklusi meliputi dipublikasi dalam bahasa Inggris atau bahasa Indonesia antara Januari 2000 dan Februari 2023. Studi yang dimasukkan hanya yang merupakan studi orisinal dengan metode eksperimental ataupun observasional.

Hasil: Terdapat delapan belas studi yang ditemukan terkait hubungan asupan kafein dan status hidrasi. Indikator status hidrasi meliputi urine specific gravity, serum osmolalitas, osmolalitas urin, warna urin, glomerular filtration rate, pH urine, volume urin, kandungan air tubuh, dan kemampuan rehidrasi tubuh. Penelitian yang paling banyak ditemukan adalah penelitian dengan intervensi berupa asupan kafein, namun ada dua penelitian dengan intervensi konsumsi teh

Kesimpulan: Studi terbaru menunjukkan adanya hasil yang belum konklusif antara hubungan asupan kafein dan status hidrasi pada orang dewasa dimana beberapa studi menunjukkan perubahan yang tidak signifikan antara kelompok intervensi dan kelompok kontrol. Sementara itu, terdapat studi yang menunjukkan adanya kualitas status hidrasi yang menurun pada kelompok yang menerima intervensi berupa asupan kafein yang tinggi serta lingkungan kerja yang berisiko.

Kata kunci: hidrasi, urine specific gravity, kafein, konsumsi kopi, urin

Introduction

Water is a nutrient that is often overlooked despite its abundant functions for the body to work optimally. Its deficiency in a short time can cause headaches, fatigue, impaired cognitive function, and low concentration.¹ In the long run, low water intake leads to decreased work productivity and lowered kidney function. Around 70% to 80% of water requirement is obtained from drinking, depending on the country and their food culture differences.² Among beverages, plain water was the most consumed, and hot beverages, which include coffee and tea, came second³. Indonesia is the country with the highest coffee consumption in Asia where fresh-brewed consumption made up to 30% of total caffeinated drink consumption.⁴ Among workers, Sunardi et al it was shown that tea and coffee were the second highest consumption after water compared to other beverage groups³.

Bardosono et al displayed the result regarding the hydration status difference between workers with different work environments.⁵ Workers under hot and conveniently cool circumstances did not show contrasting hydration status significantly (1.0178 ± 0.0076 vs. 1.0187 ± 0.0077). Based on the urine color chart, it was indicated that both groups of workers underwent a similar probability to be dehydration. High intake of coffee among workers may decrease water intake which can lead to worsening dehydration.⁵

Solutes in coffee is the background of its higher specific gravity compared to water that a density is 1.000. The density of coffee is 1.280, depending on the type of coffee⁶. Setyarsih et al stated that water intake was correlated to urine specific gravity.⁷ In South Korea, it was shown that students consumed higher sweetened beverages among students who drank coffee often compared to students who drank coffee rarely.⁸ Higher sweetened beverage consumption then could lead to lower water consumption and resulted to worsen hydration status. The aim of the study is to review studies regarding the effect of caffeine intake and hydration status among workers.

Methods

Four electronic databases, Scopus, Google Scholar,

EBSCO, dan PubMed, were used to search the publication. The PICO model is used where population are workers, interventions are caffeine intake where coffee, tea, and chocolate consumption are included, comparisons are non-caffeine drinks or neutral nutrient food, outputs are status hydration that are measured by urine specific gravity, urine color chart, or creatinine serum. Keywords that are searched in the databases were “caffeine intake” OR “coffee consumption” OR “tea consumption” OR “chocolate consumption” OR “energy drink consumption” AND “hydration status” OR “urine specific gravity” OR “urine color” OR “creatinine serum”

The studies included is limited to original studies where their method could be randomized controlled trial, case control, cohort, or cross sectional. The participants were adults or active people. Languages that are used in the studies included are English and Bahasa Indonesia between the year of 2000 until February 2023

Results

After going through the literature process with inclusion and exclusion criteria, we found 15 articles that matched with the eligibility that can be seen in table 1. All the studies were experimental studies but four of them did not comprise a control group they only observed the effect after the intervention. The participants varies from regular healthy adults and five of them were athletes where their performances were also observed. However, adults as participants in the studies which we reviewed represented workers for this paper's objective.

Discussion

There were inconclusive results from this literature review regarding whether caffeine intake, either through direct ingestion or in beverage consumption, could affect hydration status among healthy people. Armstrong et al, Zavvos et al, Ekpenyong et al, and Zhang et al showed an unfavorable outcome from caffeine intervention where the hydration status was lower than the control group.^{9,12,14,21} Meanwhile, Seal et al showed the acute effect of urinary excretion in a significant manner compared to the control group.¹¹

Table 1. Studies included in the review

No.	Author population	Method	Result
1	Armstrong et al ⁹ 59 healthy and active men, from 18 to 34 years old in USA.	Randomized controlled trial Intervention 1: caffeine intake in a capsule with a dose of 6 mg/kg body weight/day for 5 days Intervention 2: caffeine intake in a capsule with a dose of 3 mg/kg body weight/day for 5 days Control: caffeine intake in a capsule with a dose of 0 mg/kg body weight/day (placebo) for 5 days Output: Urine volume, urine color, urine specific gravity (USG), and urine osmolality	There was a significant difference in USG between a day before intervention and a day after intervention (Int 1: 1.023±0.005 vs 1.026±0.005; Int 2: 1.021±0.005 vs 1.024±0.005) among participants in intervention 1 and 2, but not in control group There was no significant difference in neither urine volume, urine osmolality, or urine color between groups and between times.
2	Mota et al ¹⁰ 26 men and women from 18 – 59 years old in USA	Double-blind randomized cross-over trial with 2 groups of intervention and 1 control group Intervention 1: ~200 mg of caffeine intake Intervention 2: ~ 400 mg of caffeine intake Control: 0 mg of caffeine intake Output: urine volume, total body water (intracellular and extracellular)	There was no significant difference of urine volume and total body water (intracellular and extracellular) between before and after intervention in all groups
3	Seal et al ¹¹ 8 men and 2 women with an average age was 27 years old in Greece	Counterbalanced cross-over trial with 2 groups of intervention and 1 control group Intervention 1: 200 ml of instant coffee with low caffeine (3 mg/kg body weight) Intervention 2: 200 ml of instant coffee with high caffeine (6 mg/kg body weight) Control: 200 ml of water Output: cumulative urinary excretion, cumulative urinary osmotic excretion	Intervention 2 showed higher cumulative urinary excretion and cumulative urinary osmotic excretion significantly 120 and 180 minutes after coffee consumption compared to the control group. Meanwhile, intervention 1 did not show any significant difference of output compared to the control group
4	Zavvos et al ¹² 9 men with average age was 26 years old in Greece	Counterbalanced randomized trial with 1 intervention group and 1 control group Intervention: espresso coffee consumption (171+8.9 mg caffeine) intake during the period of body fluid replacement Control group: only water consumption during the period of body fluid replacement Output: urine specific gravity, urine volume, urine color	Compared to control group, intervention group showed darker color (2±0.9 vs 4±1.66), higher USG (1.014±0.006 vs 1.022±0.004), and higher urine volume (302±151 ml vs 200±71 ml) significantly after the period of body fluid replacement (120 minutes after exercise)

No.	Author population	Method	Result
5	Killer et al ¹³ 50 healthy men with habitual coffee drinkers from 18 – 46 years old in the UK	Counterbalanced cross-over trial with 1 intervention group and 1 control group Intervention: consumption of 4x200 ml per day of coffee containing 4 mg/kg for 3 consecutive days Control: consumption of water 4x200 ml per day Output: total body water, USG, urine volume, urine osmolality, urine creatinine, serum osmolality	There was no significant difference between time and group of total body water, USG, urine volume, urine osmolality, urine creatinine, and serum osmolality
6	Ekpenyong et al ¹⁴ 105 men and women from 18 to 35 years old in Nigeria	Pre and post-experimental with 3 interventions group Intervention 1: 2 g of Cymbopogon citratus (lemongrass tea) Intervention 2: 4 g of lemongrass tea Intervention 3: 8 g of lemongrass tea Lemongrass tea was given in leaves powder and brewed in 150 ml hot water. All interventions last for 30 days Output: estimated glomerular filtration rate (eGFR), serum urea, serum creatinine concentration, urine pH, USG, diuretic indices	There was a significant decrease in serum urea, serum creatinine concentration, eGFR, and urine pH, between before and after intervention in all groups. There was a significant increase in mean 12-h urine volume between before and after intervention in group intervention 3 only and a significant increase in mean 24-h urination frequency between before and after intervention in all groups There was no significant difference found in USG between group and between time
7	Aedma et al ¹⁵ 14 trained wrestlers with the average age was 25.3 years old in Estonia	Double-blind, counterbalanced, cross-over trial with 1 intervention group and control group Intervention: caffeine intake of 5 mg/kg Control: placebo containing glucose Measurement of output was conducted before ingestion and after ingestion that was also after the competition Output: USG, urine osmolality	There was no significant difference found in time interaction and between intervention and control group
8	Munoz et al ¹⁶ 47 cyclists with an average age of 52 years old in the USA	Pre and post-intervention trial with 9 intervention groups where one of them was caffeine intervention and other eight groups were other non-caffeine related nutrient intervention Intervention: Caffeine intake (-64.6 mg) Output: urine color, USG, plasma osmolality, plasma copeptin, body mass change	There was no significant difference between pre and post-intervention in body mass change, USG, urine color, plasma osmolality, and plasma copeptin after cycling 161 km

No.	Author population	Method	Result
9	Fiala et al ¹⁷ 10 athletes with an average age of 24 years old in the USA	Double-blind, random, cross-over design trial with 2 intervention groups that each intervention lasted for 3 days Intervention 1: rehydrated with water during exercise and coke during all other times Intervention 2: rehydrated with water during exercise and caffeine free coke during all other times Output: USG, urine color, urine osmolality	There was no significant change of USG, urine color, and urine osmolality in time and group interaction
10	Scott et al ¹⁸ 9 male and 4 female climbers in Mt. Everest or Mt. Lhotse	Cross-over experimental study with 1 intervention group and 1 control group Intervention: participants consumed a minimum consumption of was 2 cups with each cup was 400ml Control: participants abstained from tea and other beverages containing caffeine Output: USG and urine color	There was no significant difference found in USG and urine color before and after intervention in all groups
11	Silva et al ¹⁹ 30 healthy men from 20 – 39 years old in Spain	Double blind cross-over experiment with 1 intervention group and 1 control group that lasted for 4 days Intervention: caffeine intake 5 mg/kg body mass/day in capsule consumed twice in a day Control: placebo capsule containing malt-dextrin Output: total body water, extracellular water, intracellular water	There was no significant difference observed in total body water, extracellular water, and intracellular water between time or between group
12	Tucker et al ²⁰ 34 adult males with mean age 23.6 ± 4.7 years; height 178.5 ± 7.2 cm; mass 76.0 ± 12.1 kg; in the USA	Pre and post-experimental with 4 interventions group Intervention I : water Intervention II : water+ caffeinated caloric cola Intervention III : water and caffeinated noncaloric cola Intervention IV : water, caffeinated caloric cola, caffeinated noncaloric cola, and orange juice Beverage intervention involved subjects consuming provided treatment beverages for 24 hours starting on Wednesday morning of each week. They were required to report to the laboratory on Wednesday for pre treatment and Thursday mornings for post treatment each week Output : color, urine specific gravity, urine osmolality, serum osmolality, and total body water	There was no significant difference in total body water between pre and post and post treatment There was a significant decrease in Urine Specific Gravity and osmolality between pre and post treatment in group IV. There was a significant increase in Urine Specific Gravity and osmolality between post treatment o group I and II with post treatment group IV There was no significant difference in creatinine between pre and post treatment There was no significant difference in serum osmolality between pre and post and post treatment

No.	Author population	Method	Result
13	Zhang et al ²¹ 8 male university students with mean age 23 years, height 178 cm, and body weight 77 kg in the USA	Counterbalanced randomized with 4 intervention group Intervention I : exercise with caffeine, no rehydration (C+W-) Intervention II : exercise with no caffeine, rehydration tap water (C-W-) Intervention III : exercise with caffeine, rehydration tap water (C+W+) Intervention IV : exercise with no caffeine, no rehydration (C-W-) For the caffeine trials, 10 minutes prior to the exercise phase participants consumed caffeine capsules equal to 6 mg/kg of baseline body mass. Output : urine-specific gravity, total urine production, change in body mass, hypohydration	There was a significant difference of participants number of hypohydration between group III dan IV There was no significant difference between time and group in urine specific gravity, total urine production, and change in body mass with the intervention
14	Dias et al ²² 59 college-aged men in the USA	Randomized controlled trial with 2 intervention groups and 1 control group that lasted for 6 days. Before the intervention, all groups consumed caffeine with dose of 3 mg/kg body mass/day that lasted for 6 days to balance out all the participants Intervention 1: consumed caffeine with dose of 3 mg/kg body mass/day Intervention 2: consumed caffeine with dose of 6 mg/kg body mass/day Control: consumed 0 caffeine Output: USG, urine osmolality, urine color, and urine volume Measurement of output was conducted after intervention (before and after exercise)	There was no difference in USG, urine osmolality, urine color, and urine volume found in all groups between before and after exercise and between groups interaction

No.	Author population	Method	Result
15	Grandjean et al ²³ 18 healthy men from the age of 24 – 39 years old in the USA	Counter-balanced, cross-over trial with 4 intervention groups and 1 control group which lasted for 7 days in each intervention Intervention 1: equal amounts of water and caffeinated-carbonated coke Intervention 2: equal amounts of water and caffeinated-carbonated non-caloric coke Intervention 3: equal amounts of water, caffeinated-carbonated coke, caffeinated-carbonated non-caloric coke, and instant coffee Intervention 4: half water and half carbonated citrus non-caffeinated soft drink Control: water only Output: Urinary creatinine, urine osmolality, USG	There was no significant difference in urinary creatinine, urine osmolality, and USG found in time interaction and group interaction
16	Ruxton et al ²⁴ 19 healthy men in UK	Counter-balanced randomized controlled cross-over trial with 2 intervention groups and 1 control group Intervention 1: 4 cups of tea during 12 h session Intervention 2: 6 cups of tea during 12 h session Control: 4 and 6 cups of water intake Output: Blood urea nitrogen (BUN), urine volume, urine creatinine, urine osmolality, urine color	There was no significant in BUN, urine volume, urine creatinine, urine osmolality, and urine color between the consumption of tea and water with the same amount.
17	Carmo et al ²⁵ 10 judo athletes with an average age were 21.6 years old in Brazil	Double-blind cross-over trial with 1 intervention group and 1 control group Intervention: caffeine intake in a supplement form containing 5 mg/kg body mass Control: placebo Output: serum creatinine and body water	There was no significant difference in serum creatinine and body water between groups or between before and after intervention
18	Williamson et al ²⁶ 20 healthy males with the average age was 26.6 years old in the USA	Randomized Double-blind cross over designed with 1 intervention group and 1 control group Intervention: 200 mg of caffeine in capsule form Control: placebo of 200 mg of dextrose BIA Measurement were conducted before and after intervention ((15-min, 30-min, 45-min, 60-min, 75-min, 90-min) Output: Total Body Water, Extracellular water, and Intracellular water	There was no significant difference in Total Body Water, Extracellular water, and Intracellular water between the consumption of caffeine and the placebo

Good hydration status is an important factor that supports the body to optimally function and actively perform. Benton et al reviewed studies regarding water intake, mood, and mental performance and it was found that among adults, lower hydration status led to the decrease of vigilance and alertness, along with worsened mood.²⁷ The same results were also displayed by Masento et al where increased fatigue, difficulty concentrating and task working were presented as well.²⁸ All these outcomes are prominent for workers considering mood, mental performance, and brain function are significant for productivity.

Different usage of caffeine or beverage types might be the background of different results of the study. Tea and coffee contained different caffeine amounts where coffee contains 212 mg/L and tea contains 179 mg/L.²⁹ Furthermore, different types of coffee consumed also showed different effects on the body and health.³⁰ Different types of coffee contained different caffeine per serving size ranging from 235 mg, 150 mg, and 63 mg which can be found in 350 ml brewed coffee in coffee shops, 350 ml americano in coffee shops, and 30 ml of espresso.³¹

Among the studies found in this review, half of them used whole coffee, instead of caffeine ingestion, for the experimental study. Tea, cola, espresso, and instant coffee were applied for the intervention period. Espresso which contains the highest caffeine among other caffeinated beverages was used in the study by Zavvos et al and might explain why its effect on hydration status was significant.¹²

Higher solute in coffee lead to higher specific gravity compared to water with 1.000 specific gravity. The specific gravity of coffee is 1.280, depending on the type of coffee.⁶ It was shown that total fluid consumption was associated with urine specific gravity.⁷ In South Korea, it was presented that students with higher coffee consumption consumed higher sugar-sweetened beverages along with more sugar and oil intake.^{8,32} This low-quality consumption habit induced low water consumption that resulted in poor hydration status.^{33,34}

Caffeine is an alkaloid that is found naturally in coffee.¹⁹ It is the most consumed substance, that has antagonist effects on adenosine receptors. Caffeine can bind to adenosine receptors located in the central and peripheral nervous system.³⁵ Caffeine is soluble in water and lipids. It easily crosses the blood-brain barrier and in all body fluids.³⁵

After consumption, caffeine can be absorbed with

bioavailability 99-100 %.³⁶ Caffeine is absorbed by small intestine within 45 minutes.³⁷ Peak concentration of caffeine in serum is about 2 hours.³⁵ The half-life of caffeine is 3-7 hours in adults.³⁵ Moreover, it is also supported by Thor that half-life of caffeine was 4-5 hour.³⁸

Caffeine is metabolized in the liver by the hepatic isozyme CYP1A2. Caffeine has three major metabolites by demethylation: theobromine, paraxanthine, and theophylline.³⁹ By blockade of adenosine receptors, theophylline can inhibit renal reabsorption and causes diuretic effect.⁴⁰

Among athletes, the main output was mostly their performance since caffeine was classified as an ergogenic aid that helped boost their physical performance.⁴¹ In those studies, hydration status was measured by body weight or total body water change before and after exercise or training. The rehydration ability of caffeine and water was also observed in Fiala et al and Zhang et al which showed contrasting results.^{17,21} Hydration status after training or rehydration capability among athletes becomes essential since their performance depends on their hydration condition.⁴²

Caffeine is a potential ergogenic aid for enhancing their performance during training, exercise, or competition⁴³ Its benefit for athletes' neurocognitive and alertness performance along with endurance, high-intensity, and strength-power performance is highly gained.^{43,44} This code, however, appeared to be contradictive with the results of some studies found in this review where hydration status worsened after caffeine intervention, especially among athletes.¹²

As the authors acknowledge, there was not any study found that involved workers as specific participants. On the other hand, workers are the group who consumed a high amount of coffee and tea during work hours which might change their hydration status. Moreover, low hydration status is associated with work performance where heat strain in a hot workplace may worsen it.^{45,46}

Conclusion

This review summarizes the relevant literature regarding the association of caffeine intake and hydration status, either caffeine in individual components or in beverages in coffee, tea, chocolate, or energy drink. There are eighteen studies found and three of them showed significant results of hydration status between the

group who received caffeine intake compared to the control group. However, studies that did not show significant results were also detected. Thus, the result of the association between caffeine intake and hydration status remains inconclusive more studies in the future are encouraged. Among workers, the relationship is needed to be observed further since caffeine consumers are high among them and hydration status might lead to advance consequences like work performance and non-communicable diseases.

Reference

1. Pross N. Effects of dehydration on brain functioning: a life-span perspective. *Ann Nutr Metab* 2017;70:30-6.
2. Laksmi PW, Morin C, Gandy J, Moreno LA, Kavouras SA, Martinez H, et al. Fluid intake of children, adolescents and adults in Indonesia: results of the 2016 Liq.In7 national cross-sectional survey. *Eur J Nutr* [Internet]. 2018;57(3):89-100. Available from: <http://dx.doi.org/10.1007/s00394-018-1740-z>
3. Sunardi D, Chandra DN, Medise BE, Manikam NRM, Friska D, Lestari W, et al. Water and Beverages intake among workers amid the COVID-19 pandemic in Indonesia. *Front Nutr* 2022;9.
4. Reyes CM, Cornelis MC. Caffeine in the diet: country-level consumption and guidelines. *Nutrients* 2018;10.
5. Bardosono S, Ilyas E. Health, nutrition and hydration status of Indonesian workers: A preliminary study in two different environmental settings. *Med J Indones* 2014;23:112-6.
6. Food Standards Australia New Zealand. Specific Gravities [Internet]. Food standards Australia New Zealand. 2020 [cited 2023 Jan 23]. Available from: <https://www.foodstandards.gov.au/industry/npc/Pages/specific-gravities.aspx>.
7. Setyarsih L, Ardriaria M, Fitranti DY. Hubungan densitas energi dan asupan cairan dengan berat jenis urin pada remaja. *J Nutr Coll* 2017;6:326-32.
8. Kim SH. Coffee consumption behaviors, dietary habits, and dietary nutrient intakes according to coffee intake amount among university students. *J Nutr and Health* 2017;50:270-83.
9. Armstrong LE, Pumerantz AC, Roti MW, Judelson DA, Watson C, Dias JC, et al. Fluid, electrolyte, and renal indices of hydration during 11 days of controlled caffeine consumption. *Int J Sport Nutr Exerc Metab* 2005;15:252-65.
10. Mota JF, Gonzalez MC, Lukaski H, Oto GL, Trotter CF, Tibaes JRB, et al. The influence of coffee consumption on bioelectrical impedance parameters: a randomized, double-blind, cross-over trial. *Eur J Clin Nutr* [Internet]. 2022;76:212-9. Available from: <http://dx.doi.org/10.1038/s41430-021-00932-3>
11. Seal AD, Bardis CN, Gavrieli A, Grigorakis P, Adams JD, Arnaoutis G, et al. Coffee with high but not low caffeine content augments fluid and electrolyte excretion at rest *Front Nutr* 2017;4:1-6.
12. Zavvos A, Miliotis P, Stergiopoulos D, Koskolou M, Geladas N. The Effect of caffeine intake on body fluids replacement after exercise-induced dehydration. *Nutr Today* 2020;55:288-93.
13. Killer SC, Blannin AK, Jeukendrup AE. No evidence of dehydration with moderate daily coffee intake: a counterbalanced cross-over study in a free-living population. *PLoS One* 2014;9.
14. Ekpenyong CE, Daniel NE, Antai AB. Effect of lemongrass tea consumption on estimated glomerular filtration rate and creatinine clearance rate. *J Renal Nutr* 2015;25:57-66.
15. Aedma M, Timpmann S, Ööpik V. Effect of Caffeine on upper-body anaerobic performance in wrestlers in simulated competition-day conditions [Internet]. Vol. 23, IJSNEM-Journal.com ORIGINAL RESEARCH International Journal of Sport Nutrition and Exercise Metabolism. 2013. Available from: www.IJSNEM-Journal.com.
16. Muñoz CX, Johnson EC, Kunces LJ, McKenzie AL, Winger M, Butts CL, et al. Impact of nutrient intake on hydration biomarkers following exercise and rehydration using a clustering-based approach. *Nutrients* 2020;12(5).
17. Fiala KA, Casa DJ, Roti MW. Rehydration with a caffeinated beverage during the nonexercise periods of 3 consecutive days of 2-a-day practices. *Int J Sport Nutr Exerc Metab* 2004;14:419-29.
18. Scott D, Rycroft JA, Aspen J, Chapman C, Brown B. The effect of drinking tea at high altitude on hydration status and mood. *Eur J Appl Physiol* 2004;91:493-8.
19. Silva AM, Júdice PB, Matias CN, Santos DA, Magalhães JP, Gonçalves EM, et al. Moderate dose of caffeine in healthy young adult males. *NRC Research* 2013;632:626-32.
20. Tucker MA, Ganio MS, Adams JD, Brown LA, Ridings CB, Burchfield JM, et al. Hydration status over 24-H is not affected by ingested beverage composition. *J Am Coll Nutr* 2015;34:318-27.
21. Zhang Y, Carter SJ, Schumacker RE, Negggers YH, Curtner-Smith, MD, Richardson MT, et al. Effect of caffeine ingestion on fluid balance during exercise in the heat and during recovery. *South Afr J Sports Med* 2014;26:43-7.
22. Dias JC, Roti MW, Pumerantz AC, Watson G, Judelson DA, Casa DJ, et al. Rehydration after exercise dehydration in heat: effects of caffeine intake. *J Sport Rehabil* 2005;14.
23. Grandjean AC, Grandjean NR. Dehydration and cognitive performance. *J Am Coll Nutr* 2007;26:549S-54S.
24. Ruxton CH, Hart VA. Black tea is not significantly different from water in the maintenance of normal hydration in human subjects: Results from a randomised controlled trial. Vol. 106, *Brit J Nutr* 2011.p.588-95.
25. Carmo KEO, Pérez DIV, Valido CN, dos Santos JL, Miarka B, Mendes-Netto RS, et al. Caffeine improves biochemical and specific performance after judo training: a double-blind crossover study in a real judo training situation. *Nutr Metab (Lond)* 2021;18(1).
26. Williamson CM, Nickerson BS, Bechke EE, McLester CN, Kliszczewicz BM. Influence of acute consumption of caffeine vs. placebo over Bia-derived measurements of body

- composition: a randomized, double-blind, crossover design. *J Int Soc Sports Nutr* 2018;15(1).
27. Benton D, Young HA. Do small differences in hydration status affect mood and mental performance? *Nutr Rev* 2015;73:83-96.
 28. Masento NA, Golightly M, Field DT, Butler LT, van Reekum CM. Effects of hydration status on cognitive performance and mood. *Brit J Nutr* 2014;111:1841-52.
 29. Maughan RJ, Watson P, Cordery PAA, Walsh NP, Oliver SJ, Dolci A, et al. A randomized trial to assess the potential of different beverages to affect hydration status : development of a beverage hydration index 1. 2016;717-23.
 30. Gökçen BB, Şanlıer N. Coffee consumption and disease correlations. *Crit Rev Food Sci Nutr* 2019;59:336-48.
 31. van Dam RM, Hu FB, Willett WC. Coffee, caffeine, and health. *NEJM* 2020;383:369-78.
 32. Song F, Oh JE, Lee KW, Cho MS. The effect of coffee consumption on food group intake, nutrition intake, and metabolic syndrome of Korean adults-2010 KNHANES (V-1). *NFS Journal* [Internet]. 2016;4:9-14. Available from: <http://dx.doi.org/10.1016/j.nfs.2016.04.002>
 33. James SA, White AH, Paulson SW, Beebe LA. Factors associated with sugar-sweetened beverage consumption in adults with children in the home after a statewide health communications program. *BMC Nutr* 2020;6:1-11.
 34. Johnson RJ, García-Arroyo FE, Gonzaga-Sánchez G, Vélez-Orozco KA, Álvarez-álvarez YQ, Aparicio-Trejo OE, et al. Current hydration habits: the disregarded factor for the development of renal and cardiometabolic diseases. *Nutrients* 2022;14:1-14.
 35. Temple JL, Bernard C, Lipshultz SE, Czachor JD, Westphal JA, Mestre MA. The safety of ingested caffeine: a comprehensive review. *Front Psychiatry* 2017;8:1-19.
 36. Echeverri D, Montes FR, Cabrera M, Galán A, Prieto A. Caffeine's vascular mechanisms of action. *Int J Vasc Med* 2010;2010.
 37. Barcelos RP, Lima FD, Carvalho NR, Bresciani G, Royes LF. Caffeine effects on systemic metabolism, oxidative-inflammatory pathways, and exercise performance. *Nutrition Research* [Internet]. 2020;80:1-17. Available from: <https://doi.org/10.1016/j.nutres.2020.05.005>
 38. Thorn CF, Aklillu E, McDonagh EM, Klein TE, Altman RB. PharmGKB summary: Caffeine pathway. *Pharmacogenet Genomics* 2012;22:389-95.
 39. Gracia-Lor E, Rousis NI, Zuccato E, Bade R, Baz-Lomba JA, Castrignanò E, et al. Estimation of caffeine intake from analysis of caffeine metabolites in wastewater. *Science of the total environment* [Internet]. 2017;609(July):1582-8. Available from: <http://dx.doi.org/10.1016/j.scitotenv.2017.07.258>.
 40. Fenton RA, Poulsen SB, de la Mora Chavez S, Soleimani M, Busslinger M, Rieg JAD, et al. Caffeine - induced diuresis and natriuresis is independent of renal tubular NHE3. *Am J Physiol Renal Physiol* 2015;308:F1409-20.
 41. Pickering C, Grgic J. Is coffee a useful source of caffeine preexercise? *Int J Sport Nutr Exerc Metab* 2023;30:69-82.
 42. Murray B. Hydration and physical performance. *J Am Coll Nutr* 2007;26:542S-548S.
 43. Goldstein ER, Ziegenfuss T, Kalman D, Kreider R, Campbell B, Wilborn C, et al. International society of sports nutrition position stand: caffeine and exercise performance. *J Int Soc Sports Nutr* 2010;7:1-15.
 44. Keisler BD, Armsey TD. Caffeine as an ergogenic aid. 2006.
 45. Kenefick RW, Sawka MN. Hydration at the work site. *J Am Coll Nutr* 2007;26:597S-603S.
 46. Mutiara A, Basrowi RW, Bardosono S. An overview of hydration status and its relation to occupational heat stress among workers. *World Nutr J* 2019;3:17-23.