IMPACT OF CAFFEINE AND ELECTROLYTE LEVELS ON MEASURES OF HYDRATION OVER A 4HR PERIOD IN HEALTHY MEN AND WOMEN

Michael Lelko[1], Dana Ryan[1], Sai Chaluvadi[1], Evan Berk[2]
[1]Liquid I.V., El Segundo, CA
[2]Unilever, Englewood Cliffs, NJ

ABSTRACT

PURPOSE: The Beverage Hydration Index (BHI) allows comparison of fluid retention profiles for different beverages relative to water. The impact of caffeine with and without electrolytes on hydration status over 4 hours is not well characterized. The effects of commercially available caffeinated beverages were compared to water (W) on hydration measures to understand the impact of various formulations on hydration status over 4hrs in a sedentary & euhydrated state. This study aimed to provide more clarity on the impact of different caffeinated products and their ability to promote fluid retention or diuresis. **METHODS:** 28 healthy adults (14M/14F; age 22.6±3 y) participated in a BHI protocol. Participants arrived to the lab in a euhydrated state which was confirmed by urine specific gravity. Beverages were administered in a randomized order of four 250mL aliquots over 30min: 500ml of caffeinated beverage (CAF) with 280mg, CAF of 280mg plus electrolytes (CAF+E) or CAF with 100mg+E & carbohydrates (CAF+CE) along with 500ml W. Urine output was recorded over 4hr. **RESULTS:** W & CAF+CE averaged a more positive net fluid balance (NFB) (p<0.001, 0.001) compared to CAF & CAF+E, ranging from 120 to 175ml greater overall fluid balance. From 60–240min, CAF+CE exhibited significantly higher NFB when compared to CAF & CAF+E (p<0.05). From 120-240min, CAF+CE had significantly higher BHI (1.01±0.12) when compared to CAF (0.86±0.16) & CAF+E (0.91±0.16) (p<0.05). CAF+CE had significantly lower urine output when compared to CAF & CAF+E from 90-240min (p<0.05). **CONCLUSION:** A low carbohydrate-electrolyte beverage with moderate levels of caffeine (CAF+CE) had similar hydration properties compared to W and both were significantly greater than CAF and CAF+E. Based on BHI, CAF+CE retained ~10 and 15% more fluid when compared to CAF+E and CAF, respectively, which has practical implications for caffeine containing products. This data suggests that a low carbohydrate-electrolyte beverage with added caffeine may attenuate diuresis in a hydrating energy drink solution.

INTRODUCTION

Caffeine is commonly reported to act as a diuretic, potentially impairing hydration. However, emerging evidence suggests that this effect may be mitigated by the presence of electrolytes. The Beverage Hydration Index (BHI), introduced by Maughan et al. (2016), provides a standardized method to assess fluid retention and compare the hydration potential of various beverages relative to water. In their study, common caffeinated beverages such as tea, coffee, and diet soda exhibited lower BHIs than water, though differences were not statistically significant. Future research is warranted to further investigate the role of electrolytes in modulating the hydration effects of caffeinated beverages, using BHI as a comparative framework.

PURPOSE

This study aims to evaluate the combined impact of caffeine and electrolyte content on beverage-induced hydration. By comparing the BHIs of various commercially available beverages, we seek to quantify how these components influence fluid retention and overall hydration potential.

METHODS

Table 1. Mean (±SD) subject physical characteristics

	Men	Women
N	14	14
Age	23.9 ± 3.7	21.3 ± 2.4
Height (cm)	181.1 ± 7,6	164.6 ± 6.7
Body Mass (kg)	75.8 ± 9.2	61.0 ± 7.4
Total Body Water (L)	50.5 ± 5.9	36.0 ± 4.2

Table 2. Measured osmolality, Na+, K+ in test beverages

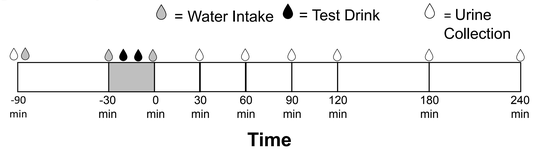
	Water	CAF+CE (Liquid I.V. Energy)	CAF+E (Prime Energy)	CAF (Celsius)
Osmolality (mOsm/kg)	3 ± 1	225 ± 4	140 ± 4	98 ± 4
Sodium (mM)	0.6 ± 0.0	44.7 ± 2.5	8.1 ± 0.8	0.6 ± 0.1
Potassium (mM)	0.1 ± 0.0	18 ± 1.2	10.4 ± 1.0	0.6 ± 0.1
Carbohydrate (gm/500 ml)	0	11.6	4.2	0
Caffeine (mg/500 ml)	0	106	280	280

Beverage Hydration Index (BHI) (Maughan et al. 2016):

- 1 L beverage ingested in 30 min (4 x 250 ml every 7.5 min)
  - Caffeinated energy drink = 500 ml + 500 ml water

BHI > 1.0: beverage= greater fluid retention vs. water
BHI < 1.0: beverage = greater diuresis vs. water

Figure 1. Test protocol schematic



- Net fluid balance calculated based on loss in body mass
- BHI calculated relative to urine output from water trial
- Two factor (drink by time) repeated measures using Friedman test (for BHI) and ANOVA (urine mass, net fluid balance) with Bonferroni post-hoc tests

RESULT

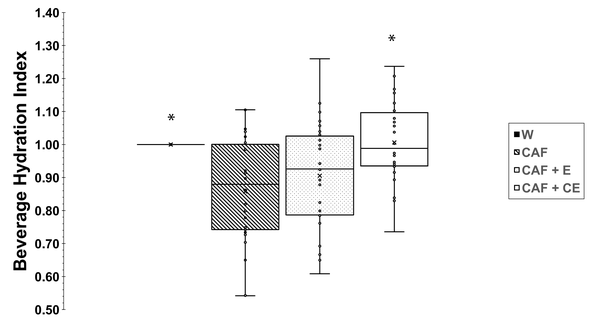
Table 1. Mean (± SD) % fluid retained over time

Time (min)	W	CAF+CE	CAF	CAF+E
60	22.2 ± 23.9 †	15.1 ± 21.8	1.4 ± 20.0	3.0 ± 28.9
90	-1.8 ± 25.9 *	-8.9 ± 19.1 *	-25.4 ± 17.7	-23.7 ± 27.1
120	-18.7 ± 24.5 *	-22.6 ± 17.5 *	-40.5 ± 17.1	-37.2 ± 25.4
180	-36.3 ± 23.7 *	-36.6 ± 17.3 *	-59.0 ± 18.2	-53.4 ± 25.4
240	-48.2 ± 23.8 *	-46.4 ± 18.8 *	-71.2 ± 21.5	-65.1 ± 26.3

*Greater (p<0.05) than CAF and CAF+E
†Greater (p<0.05) than CAF+CE, CAF, and CAF+E

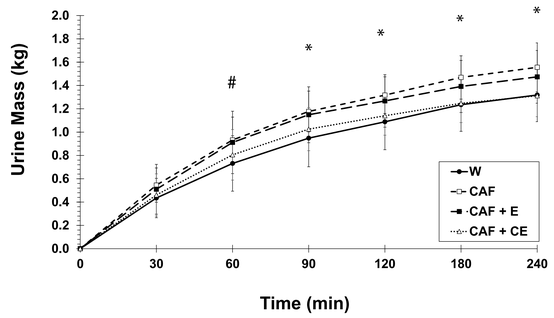
RESULTS

Figure 2. Boxplot of BHI at 4hr by beverage



*Greater (p<0.05) than CAF and CAF+E

Figure 3. Mean (±SD) cumulative urine mass

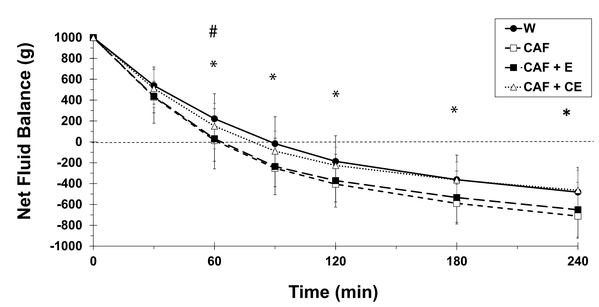


* Greater (p<0.05) mass with CAF, CAF+E vs. W and CAF+CE
# Water lower (p<0.05) than all beverages

CONCLUSIONS

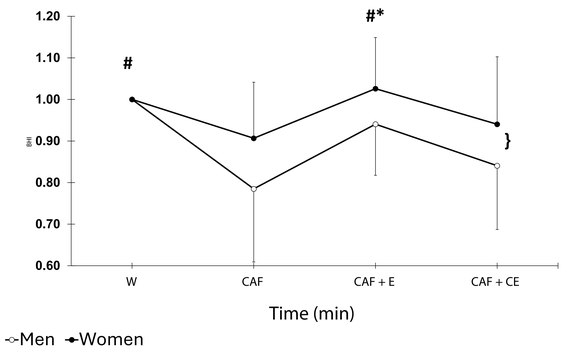
This study demonstrates that a caffeinated beverage containing both carbohydrates and electrolytes (CAF+CE) significantly enhances fluid retention and hydration status compared to caffeine alone (CAF) or caffeine with electrolytes (CAF+E). CAF+CE achieved a Beverage Hydration Index (BHI) comparable to water and outperformed the other caffeinated formulations in net fluid balance and reduced urine output over a 4-hour period. These findings underscore the importance of beverage composition—specifically the inclusion of optimized levels of carbohydrates and electrolytes—in mitigating the diuretic effects of caffeine and promoting hydration. In real-world scenarios such as prolonged travel, shift work, or athletic performance, where both alertness and hydration are critical, a well-formulated caffeinated beverage like CAF+CE may offer a practical advantage. Interestingly, women in this study retained more fluid than men across all beverage conditions, suggesting a potential sex-based physiological difference in hydration response. This observation warrants further investigation to better understand sex-specific hydration strategies.

Figure 4. Mean (±SD) net fluid balance based on body mass



*Greater (p<0.05) loss with CAF, CAF+E vs. W and CAF+CE
Water greater (p<0.05) than CAF+CE, CAF, and CAF+E

Figure 5. Sex differences of BHI



* Women > Men (p=0.043)
# For Men, W & CAF+CE > CAF and CAF+E (p<0.05)
† For Women, CAF+CE > CAF and CAF+E (p<0.05)

REFERENCES

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