

HYDRATION STATUS WITH CAFFEINATED BEVERAGES VERSUS WATER: DOES HABITUAL CAFFEINE INTAKE MATTER?

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ABSTRACT

The Beverage Hydration Index (BHI) allows comparison of fluid retention profiles for different beverages relative to water. Whether caffeine with or without electrolytes differentially impairs hydration status after 4 h is unclear. **Purpose:** The effects of commercially-available caffeinated beverages were compared to water on hydration measures to understand whether caffeine habitual intake is an influencing factor. **Methods:** Twenty-eight healthy adults participated in a BHI protocol. Beverages were administered in four 250 mL aliquots over 30 min: 500 ml of caffeinated beverage (CAF) with 280 mg, CAF of 280 mg plus electrolytes (CAF+E) or CAF with 100 mg+E and carbohydrates (CAF+CE) along with 500 ml water (1st and 4th aliquot). Urine output was recorded over 4 h. Habitual caffeine intake ranged from 0 to 535 mg/day and groups were stratified by naïve (< 25 mg/day, n = 9) and regular users (> 25 mg/day). **Results:** Caffeine dose relative to body mass (BM) was higher for CAF and CAF+E (4.2 ± 0.7 mg/kg BM) compared to CAF+CE (1.6 ± 0.3 mg/kg BM). At 4 h, BHI for CAF (0.86 ± 0.16) and CAF+E (0.91 ± 0.16) was lower (p < 0.001) versus water (1.0 ± 0.0) and CAF+CE (1.01 ± 0.12). Urine mass with CAF and CAF+E was significantly greater (p < 0.01) by 244 g and 162 g versus CAF+CE. After 4 h, net loss in TBW was greater (p = 0.003) with CAF (-1.2 ± 0.6 kg) and CAF+E (-1.1 ± 0.7 kg) compared to CAF+CE (-0.8 ± 0.4 kg). Caffeine habitual intake of participants had no effect on BHI (p = 0.785) across all drinks between naïve (0.94 ± 0.2) and habitual users (0.95 ± 0.12). The % fluid retained after 4 h (based on BM change) for caffeinated beverages was lower (p < 0.001) for CAF (-71.2 ± 21.5%) and CAF+E (-65.1 ± 26.3%) versus CAF+CE (-46.4 ± 18.8%) and did not differ (p = 0.52) based on caffeine habituation. **Conclusions:** A low carbohydrate-electrolyte beverage with moderate levels of caffeine had similar hydration properties compared to water. This differs from beverages where caffeine doses are higher and contain limited levels and/or no electrolytes. Habitual caffeine intake of participants had no apparent influence on diuresis when ingesting a moderate dose of caffeine along with water in a relatively short time frame.

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INTRODUCTION

It is commonly reported that caffeine acts as a diuretic; however, research suggests this may not apply to individuals habituated to caffeine. The Beverage Hydration Index (BHI) (Maughan et al. 2016) assesses fluid retention as a model to compare hydration potential of different beverages relative to water. Common caffeinated beverages (e.g., tea, coffee, diet soda) had lower BHIs versus water, although not significantly different. In a later study, Maughan et al. (2019) reported 0 to 400 mg of caffeinated coffee did not elicit greater diuresis (or lower BHI) versus water.

PURPOSE

To examine the impact of commercially-available caffeinated energy drink formula (with and without carbohydrate and electrolytes) on hydration properties via the Beverage Hydration Index. We hypothesized caffeine would not adversely influence fluid retention of these beverages over 4 hours.

METHODS

Table 1. Mean (± SD) physical characteristics (n=14 men, 14 women)

	Age	Height (cm)	Body Mass (kg)	%Body Fat	Total Body Water (L)
Women	21.3 ± 2.4	164.6 ± 6.7	61.0 ± 7.4	21.2 ± 4.3	36.9 ± 4.2
Men	23.9 ± 3.7	181.1 ± 7.6	75.8 ± 9.2	11.4 ± 5.0	50.5 ± 5.9

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

	Water	CAF+CE (Liquid IV 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):

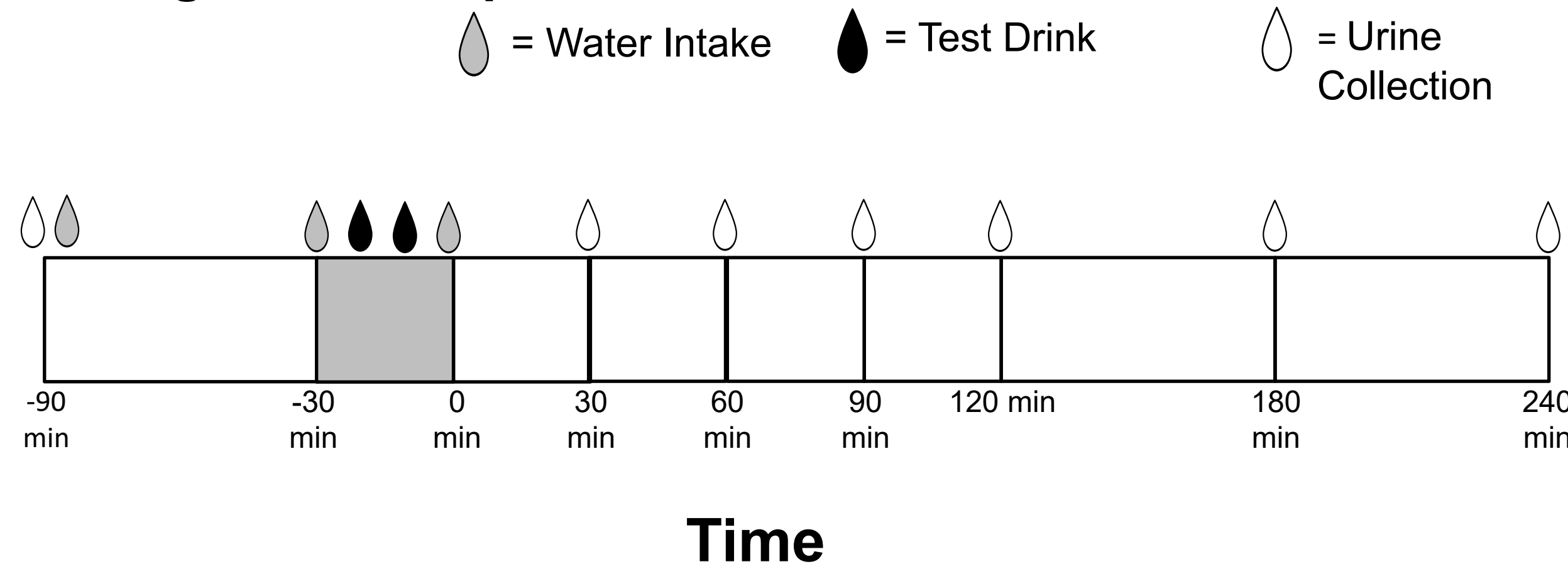
- 1 L beverage ingested in 30 min (4 x 250 ml every 7.5 min)
 - Caffeinated energy drink = 500 ml + 500 ml water

$$BHI = \frac{\text{Cumulative urine output after drinking water}}{\text{Cumulative urine output after drinking test beverage}}$$

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

BHI < 1.0: beverage = greater diuresis vs. water

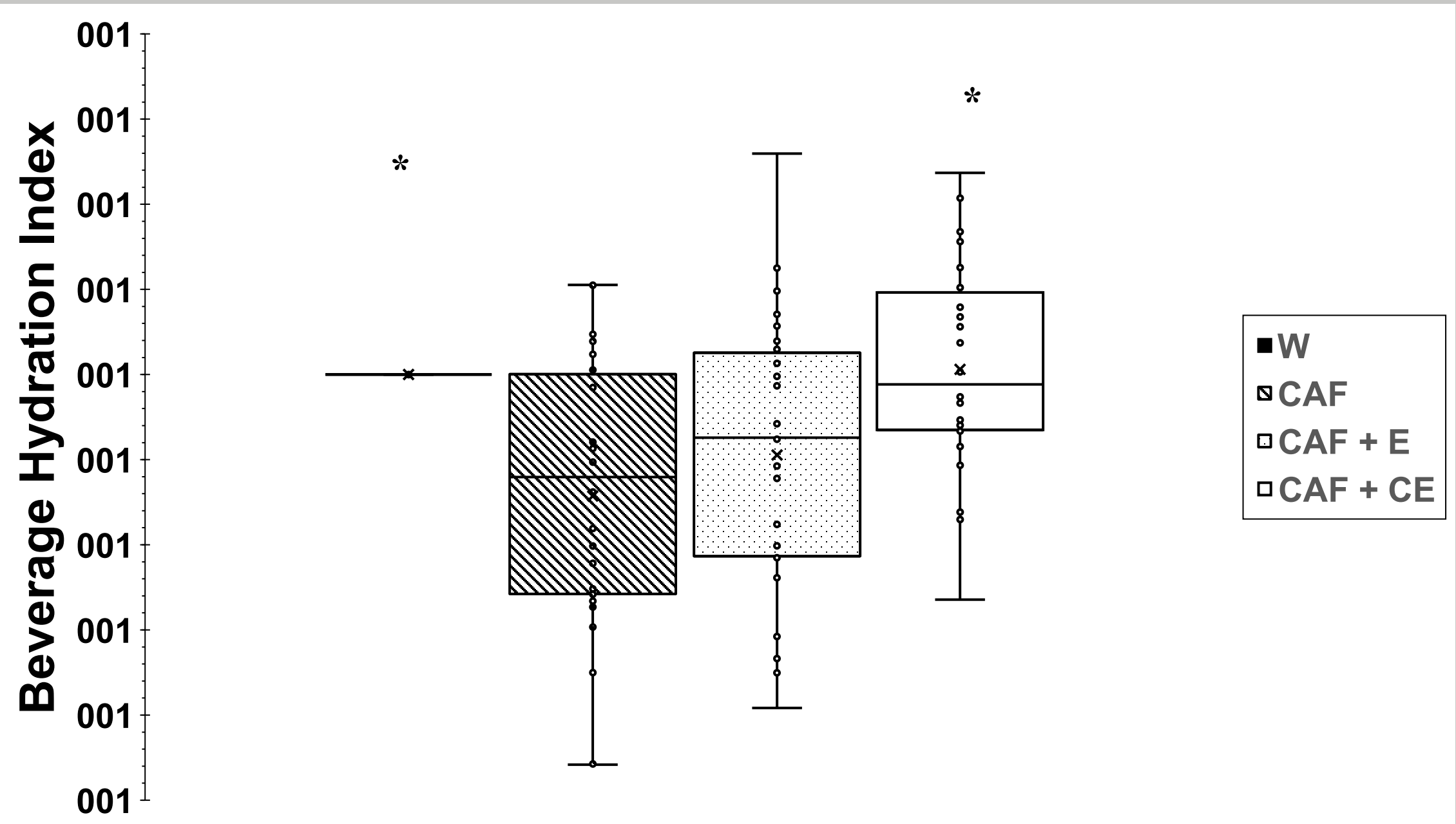
Figure 1. Test protocol schematic



- 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

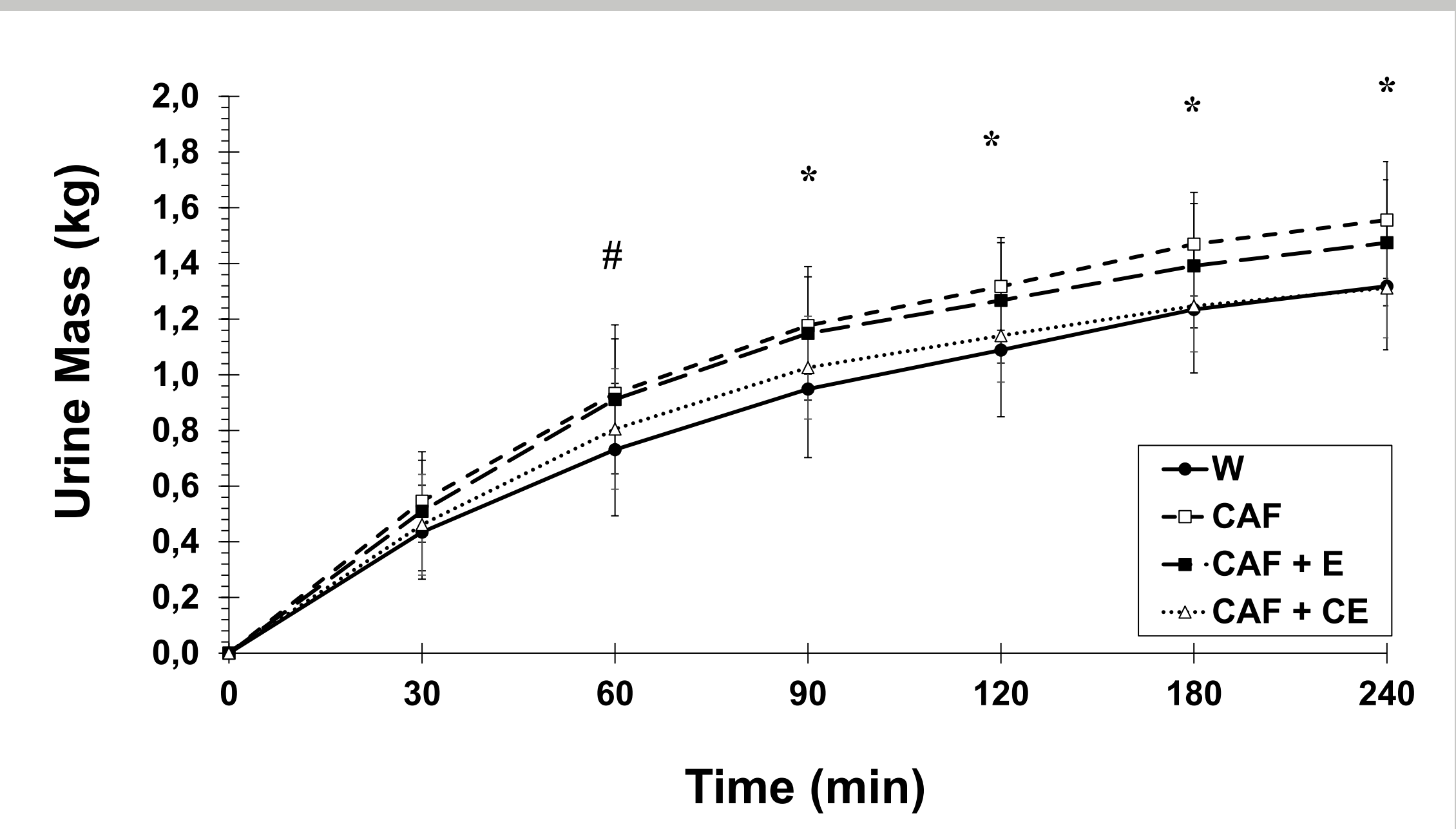
RESULTS:

Figure 2. Boxplot of BHI at 4 h 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

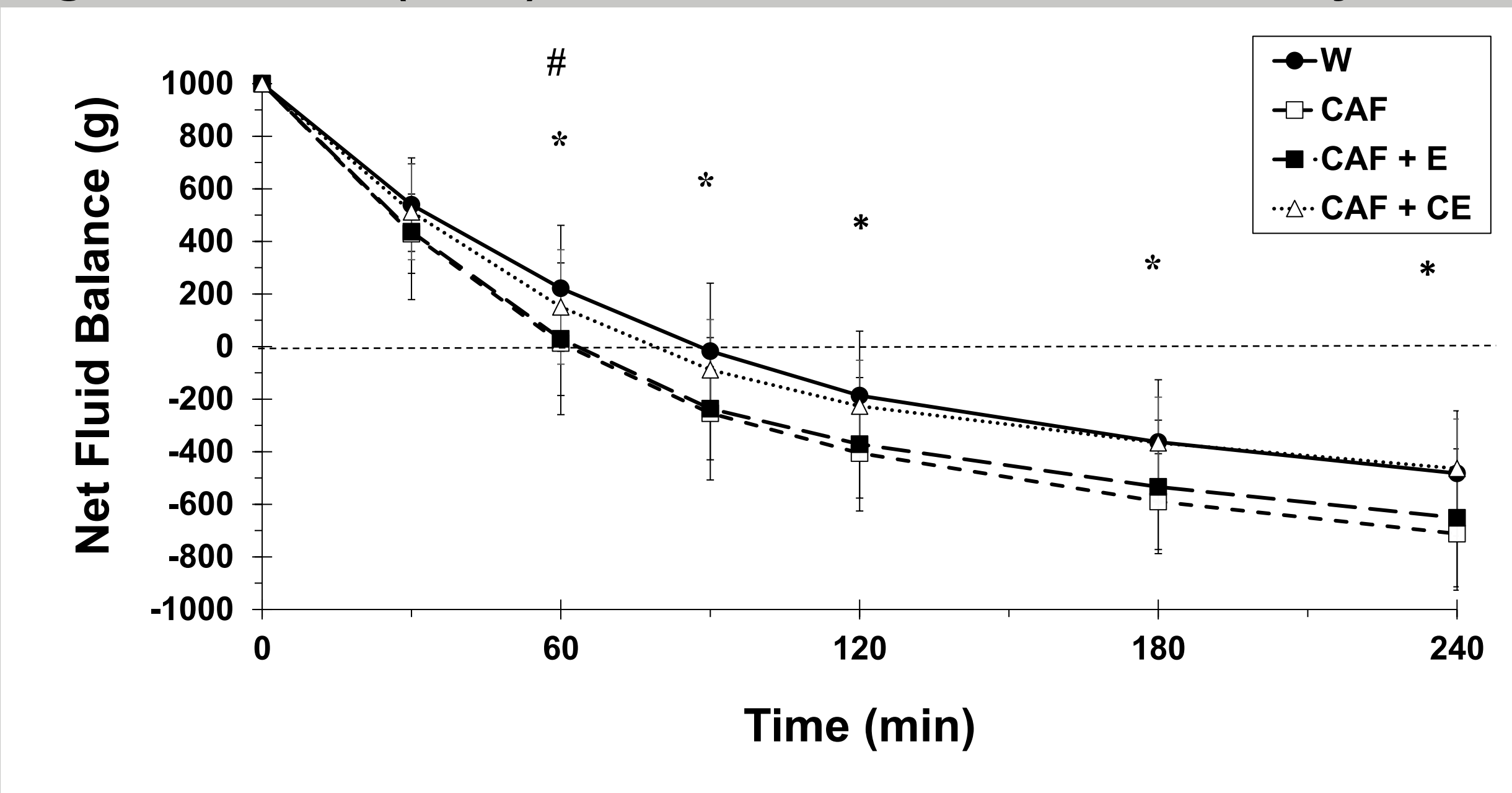
Table 3. Mean (± SD) % fluid retained over time

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

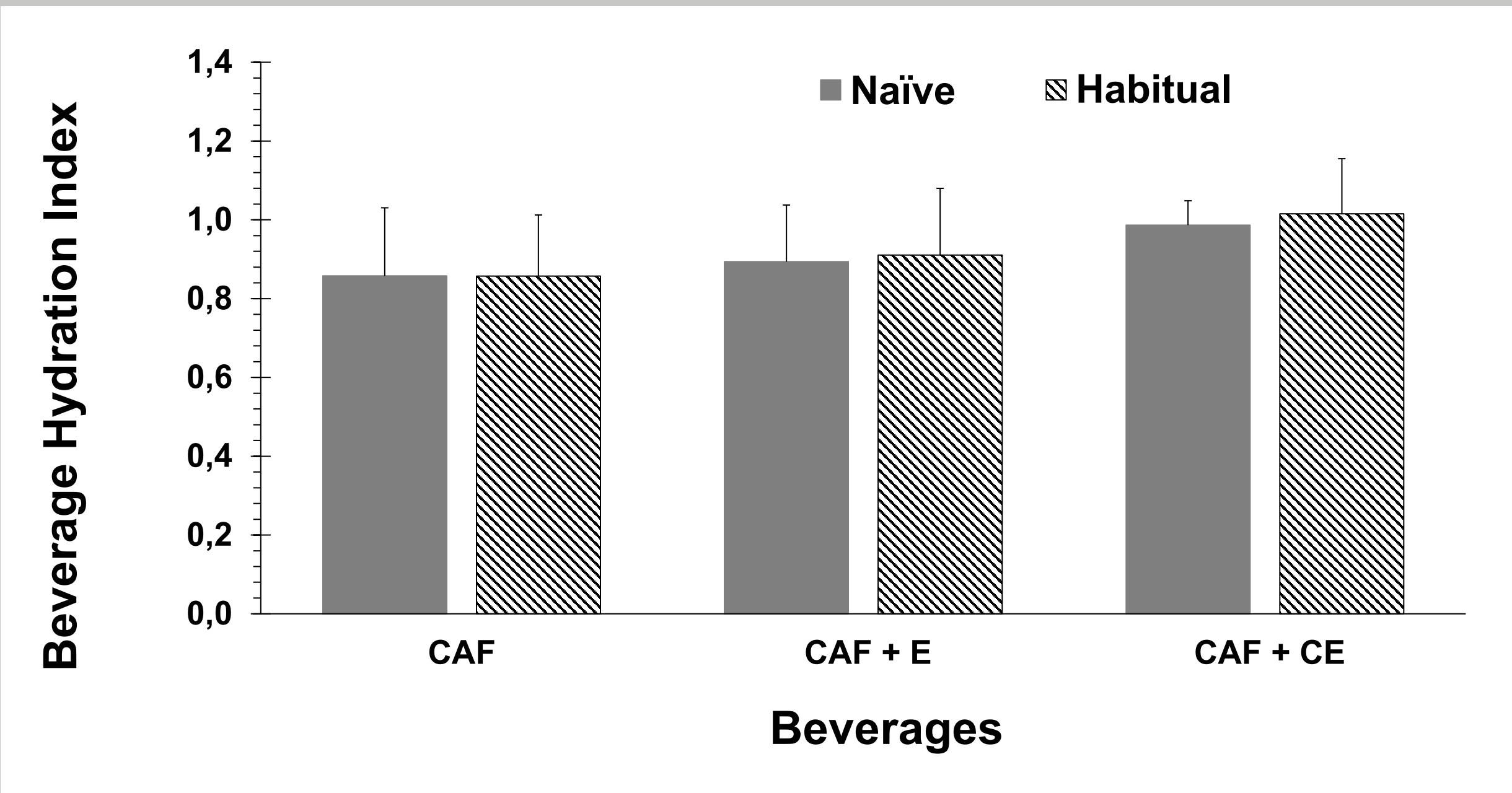
Figure 4. Mean (± SD) net fluid balance based on body mass



*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. Beverage Hydration Index @ 240 min is similar between habitual and naïve caffeine users



CONCLUSIONS

Based on the Beverage Hydration Index:

- A low carbohydrate-electrolyte beverage with ~100 mg caffeine had similar hydration properties compared to water.
- In contrast, caffeinated drinks of 280 mg with limited glucose and/or electrolytes had lower hydration properties compared to water
- Habitual caffeine status had no impact on diuresis when consuming up to 280 mg caffeine

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