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Keywords: Diuresis; Hydration; Ergogenic

Abbreviations: NT: No Treatment; PL: Placebo Treatment; Caf: Ca eine Treatment; Na: Sodium Treatment; CafNa: Ca ene+Sodium Treatment; USG: Urine Speci c Gravity

Introduction

Endurance athletes may use a wide variety of supplements and nutritional strategies to improve exercise performance. Ca eine use among endurance athletes is common [1] and numerous investigations have supported its e cacy as an ergogenic aid [2]. Likewise, pre-exercise hyperhydration has been shown to decrease rates of dehydration and improve physiological responses to, and performance of, exercise in hot environments [3-6]. Because both acute ca eine consumption and pre-exercise hyperhydration have been shown to improve exercise performance, endurance athletes may want to simultaneously utilize these procedures. However, ca eine may have acute diuretic e ects in euhydrated individuals, which may cause some athletes to forgo its use prior to exercise in the heat.

Previous investigations have indicated that hypohydration can reduce exercise performance in the heat and lead to serious heat-related illnesses [7,8]. While consumption of uid during exercise can e ectively reduce rates of dehydration, some individuals such as soldiers or endurance athletes participating in unsupported training sessions, may not have access to adequate uid supplies and/or may have sweat rates that exceed the maximum rate of gastric emptying for water [9,10]. ese individuals are especially at risk for developing hypohydration. In such cases, the development of hypohydration during exercise can be curtailed by employing pre-exercise hyperhydration [4,6]. Previous investigations have revealed that when euhydrated subjects attempt to attain pre-exercise hyperhydration by consuming pure water or dilute uid, most of the consumed uids are not retained and no signi cant level of hyperhydration is achieved [4,11]. However, consuming a concentrated sodium beverage (164 mmol/L) has been shown to promote signi cant pre-exercise hyperhydration [4] and plasma volume expansion [12], resulting in improved physiological responses and performance during subsequent endurance exercise.

Ca eine has been shown to increase performance when taken prior to endurance exercise [13], with e ective doses ranging from 3 to 9 mg/kg bm [2]. While the diuretic e ect of ca eine appears to be in uenced by hydration status and activity level [14], ca eine has been shown to promote diuresis when consumed in ergogenic amounts with large volumes of dilute, low-sodium uids in resting, euhydrated individuals [15]. e observed diuretic e ect of ca eine under these circumstances could hinder or prevent pre-exercise hyperhydration. However, it is unknown what level of diuresis may occur when ca eine is consumed in conjunction with a sodium-aided hyperhydration strategy. It is believed that ca eine promotes diuresis by increasing sodium excretion in the nephron [16], making it conceivable that consumption of an acute dose of sodium may reduce ca eine-induced diuresis in individuals who are attempting to become hyperhydrated. us, we sought to determine the e ects of an acute, ergogenic dose of ca eine on urine production during hyperhydration strategies when uids are consumed with and without sodium.

Methods

Prior to subject recruitment, the procedures of this investigation were reviewed and approved by the institutional review board of the University of Texas – Permian Basin. Pilot work suggested that 12–15 subjects would be required to achieve suitable statistical power (0.80). Fi een active male subjects (21 2 years, 176 6 cm, 80.2 10.1 kg) with no known digestive, vascular, or renal diseases signi ed their willingness

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that hyperhydration can be achieved when an acute caffeine dose is consumed in conjun

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and sodium are consumed without caffeine.

bm. e Na strategy resulted in signi cantly lower urine excretion level compared to all other strategies ($p<0.001$ *vs.* NT, PL, Caf, $p=0.005$ *vs.* CafNa) and urine excretion level during Na indicated that this strategy promoted a net uid retention of 6.4 mL/kg bm. Urine excretion level during the CafNa strategy was signi cantly di erent from all other strategies ($p=0.004$ *vs.* NT, $p=0.005$ *vs.* PL, $p<0.001$ *vs.* Caf, $p=0.005$ *vs.* Na). Urine excretion level indicated that the CafNa strategy promoted a net uid retention of 3.0 mL/kg bm. Urine excretion analyses revealed a statistical power of 1.00 with a partial η^2 of 0.73.

Discussion

To our knowledge, this is the rst published investigation that evaluated the e ects of an ergogenic dose of ca eine on urine production during pre-exercise hyperhydration strategies. e urine production data suggested that hydration status would be negatively a ected if an ergogenic dose of ca eine and large bolus of water were taken 2 h prior to the start of exercise. Conversely, if the same amount of ca eine and water were co-consumed with 110 mg NaCl/kg bm, hyperhydration would be present at the advent of exercise. However, the level of hyperhydration achieved from CafNa strategy would be signi cantly less than what is achieved when an identical sodium-aided hyperhydration strategy is performed without ca eine.

Previous works have demonstrated that co-consumption of sodium with water in the hours before exercise decreases urine production and increases uid retention and plasma volume when compared to the consumption of equal volumes of dilute uid [4,12]. In these investigations, subjects consumed 10 mL/kg bm of a high-sodium beverage (164 mmol Na+/L). Total resting urine production during the high-sodium trial of Sims et al. [4] was approximately 5.5 mL/kg bm, or about 55% of the total volume consumed, meaning that subjects retained approximately 4.5 mL of uid/kg bm (if uid loss due to sweating and insensible means are ignored). In comparison, during the Na trial of the current investigation, subjects consumed 20 mL/ H_2O kg bm with 110 mg NaCl/kg bm. e NaCl was provided in capsules to blind the subjects to the various treatments, but if it were mixed with the water, the sodium concentration of the resulting beverage would have been 186 mmol Na+/kg bm. Under this hyperhydration strategy, urine production was 65% of the uid consumed and subjects retained approximately 6.4 mL uid/kg bm. Di erences in the hyperhydration protocols of the current study and that of Sims et al. [4] may account for the greater absolute uid retention levels in the current investigation. Sims et al. [4] administered a total of 10 mL uid/kg bm to subjects in seven equal doses over the course of a 60 min hyperhydration period. Urine excretion was measured throughout the hyperhydration period and for an additional 45 min a er the nal uid dose was consumed. In contrast, subjects from the current study consumed a bolus of 20 mL uid/kg bm, 110 mg NaCl/kg bm and a small, low-sodium snack followed by a 120 min urine collection period. e sodium to water ratios were similar between the two investigations but the volumes of water, the temporal aspects of its consumption, and the consumption of a snack all could have contributed to the di erence in uid retention.

e di erences in uid retention between the Na strategy of the current study and that of Sims et al. [4], illustrates the need for systematic investigations of the e ects of di erent uid doses and the timing of the consumption of uids on sodium-aided hyperhydration. Such studies could help to identify and standardize optimal uid dosing strategies for individuals who work in hot environments.

e current results also suggested that hyperhydration can be

an equal dose of water and sodium are consumed without ca eine. While it does appear that ca eine consumption and sodium-aided hyperhydration can be utilized simultaneously, athletes should consider their speci c situation before deciding if the ergogenic e ects of ca eine are worth the compromises that ca eine consumption will have on a sodium-aided hyperhydration strategy. Finally, the current data, and those of previous investigators, suggest that further research should be performed into the ergogenic and diuretic e ects of ca eine so that optimal, combined ca eine consumption and hyperhydration strategies can be developed.

Acknowledgements

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