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Research report

Does salt increase thirst? ☆

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ABSTRACT

Our diet is believed to be overly rich in sodium, and it is commonly believed that sodium intake increases drinking. Hence the concern of a possible contribution of dietary sodium to beverage intake which in turn may contribute to obesity and ill health. Here we examine whether voluntary, acute intake of a sodium load, as occurs in routine eating and snacking, increases thirst and drinking. We find that after ingesting 3.5 or 4.4 g NaCl (men) and 1.9 or 3.7 g (women) on nuts during 15 minutes, there is no increase in thirst or drinking of freely available water in the following 2 h compared with eating similar amounts of sugared or unflavored nuts. This suggests that routine ingestion of boluses of salt (~30–40% of daily intake for men, ~ 20–40% for women) does not increase drinking. Methodological concerns such as about nuts as vehicle for sodium suggest further research to establish the generalizability of this unexpected result.

Introduction

A commonly held belief is that salt intake arouses thirst to redress hydromineral balance. In so doing, dietary sodium may increase beverage drinking and its associated caloric content, and contribute to obesity during growth and adulthood (Alexy, Cheng, Libuda, Hilbig, & Kersting, 2011; Cassady, Considine, & Mattes, 2012; Grimes, Riddell, Campbell, & Nowson, 2013; He, Markandu, & MacGregor, 2008; He, Markandu, Sagnella, & MacGregor, 2001; Larsen, Angquist, Sørensen, & Heitmann, 2013), although in other studies dietary sodium has little influence on total water intake (Goldstein & Leshem, 2014; Kant & Graubard, 2010; Kant, Graubard, & Atchison, 2009).

In contrast, little is known about the possible contribution of acute salt intake to thirst, drinking, and prandial drinking, particularly the effect of food with high sodium content such as some fast foods and salty snacks. While it is generally accepted that acute intake of salt (NaCl) is dipsogenic, the experimental evidence for this is not robust, the evidence derived from dehydrated more often than euhydrated people or rodents, often in boluses modeling extreme hypernatremia, by intravenous infusion (IV) of hypertonic saline rather than its ingestion, and when ingested, in solution rather than food (Denton et al., 1999; Obika, Amabebe, Ozoene, & Inneh, 2013; Rolls, Phillips, Ledingham, Forsling, & Morton, 1985; Stachenfeld, 2008).

In dehydration, oral or IV saline can either extend drinking, or reduce thirst, and oral saline may reduce thirst more effectively than IV saline (Barney, 1997; Kenefick, O'Moore, Mahood, & Castellani, 2006; Millard-Stafford, Wendland, O'Dea, & Norman, 2012; Obika, Idu, George, Ajayi, & Mowoe, 2009; Obika et al., 2013; Riebe et al., 1997). However, there are more strategies than dilution with water to reestablish euhydration, physiological, such as absorbing the excess sodium into the vast extracellular space, or excreting it, or behavioral accommodation (Drummer, Norsk, & Heer, 2001; Heer, Baisch, Kropp, Gerzer, & Drummer, 1999; Millard-Stafford et al., 2012; Rolls et al., 1980).

For wild animals, of necessity in many ecologies, drinking is often and substantially delayed, and animals are endowed with appropriate physiological systems to withstand or even reverse persisting hydromineral imbalance – the camel is a case in point. In humans, behavioral accommodation and circumstances that de-prioritize euhydration are common: ignoring or overcoming thirst, not drinking, diversion, restraining urination, inaccessibility of drink or toilet, hedonics relating to the type and quality of the drink (taste, temperature), cognitive, perceptual, cultural and social factors (Bar-Or & Wilk, 1996; Burdon, Johnson, Chapman, & O'Connor, 2012; Cassady et al., 2012; Engell, Kramer, Malafi, Salomon, & Lesher, 1996; Greenleaf, 1992; Kenney & Chiu, 2001; Millard-Stafford et al., 2012; Szlyk, Sils, Francesconi, Hubbard, & Armstrong, 1989). Further, humans will maintain voluntary dehydration, even extreme dehydration, despite water being available to drink (Bar-Or & Wilk, 1996; Greenleaf & Sargent, 1965; Maresh et al., 2004; Szlyk et al., 1989).

Such adjustments carry costs, energetic or other (e.g. social), raising the question of whether a salt load in humans as occurs quite routinely (fast food, bar/pub tidbits, hamburger, ketchup and chips/

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fries, cured meats and sausages, salty snacks, etc.) necessarily engenders drinking as occurs when a salt-load is tested in dehydrated people or animals in the lab (Engell et al., 1996). Moreover, salt taken with food probably has a different post-ingestive disposition than salt in aqueous solution, oral or IV (Cassady et al., 2012; Shi & Passe, 2010).

Because one of the strategies to maintain euhydration might be to reduce the intake of salt in anticipation of the consequent thirst and imposition of drinking, it is important to note that in most experiments, human or animal, intake of sodium is forced. In addition, voluntary, rather than forced intake of sodium, is more likely to enlist non-physiological considerations into the response configuration.

There is also a gender difference in thirst and drinking. Men concentrate urine more and their thirst/vasopressin system has higher thresholds, so they might drink less than women (Perucca, Nadine Bouby, Valeix, & Bankir, 2006), girls drink more than boys (Sichert-Hellert & Kersting, 2004), older women drink more than men after exercise (Baker, Munce, & Kenney, 2005), and women, the elderly in particular, are thirstier than men (Hendi & Leshem, 2014).

Accordingly, here we examine thirst and drinking responses to an acute, voluntary, sodium load ingested as food in men and women.

Method

Participants

The study was approved by the University of Haifa Psychology Department Review Board. Participants signed an informed consent form. The form explained what the participants would be expected to do, but did not explain the aim of the study, although it was explained that the results of the study would be available after its completion for interested participants. Fifty-eight psychology students, 43 women and 15 men, participated for study credits. Men and women BMI was respectively 23.3 ± 0.6 kg/m^2 and 21.9 ± 0.6, age 23.7 ± 0.7y and 21.5 ± 0.4, and smokers 3 and 5, the differences not significant. However, weight and height differed, respectively 75.0 ± 3.1 *vs.* 59.8 ± 1.6 kg and 179 ± 2 *vs.* 165 ± 1 cm, p's < 0.001.

Procedure

Table 1 summarizes the experimental procedure. Participants were directed to avoid eating, smoking, or drinking fluids except water (unrestricted) for 2 h before the experiment, nor smoke, or consume anything except that provided in the lab during the break in the experiment when they remained in the lab, except for a toilet break. Each participant participated in three experimental sessions; in each one they were asked to evaluate one of 3 flavors of roasted nuts, either salted, sweetened, or unflavored. Sweetened nuts were included as an additional tastants control enabling comparisons across our studies (Leshem, 2008, 2009, 2013). To extend the evaluation time and thereby increase intake, there were the same four types of nut (walnut, pecan, cashew, almond) in each flavor. Following the evaluation participants completed either a demographic or a gustatory questionnaire (taste preferences, dieting, drinking habits), and a third of an elaborated dietary questionnaire (below), after which they were allowed 90 minutes free time at a desk in the lab with bottled water and computer access. They then again rated each nut type briefly on a single scale without tasting, as justification for the free time spent in the lab. Weight and height were always recorded at the end of the last session to minimize possible effects on eating. Sessions were separated by at least 2 days and each participant was tested at the same time of day in each session.

Nuts

Nuts were divided randomly into three batches before roasting – one batch was salted, 7.5 g NaCl/100 g nuts, added in solution that evaporated during roasting, a second was similarly prepared with sucrose, 15 g/100 g, and the third batch was not flavored. Concentrations were adjusted for salt and sugar remaining in the roasting pan, and batch-averaged salt concentration used in the analyses per 100 g nuts was 5.16 g in walnuts, 4.03 g in pecan, 3.15 g in cashew, 2.89 g in almond, and for sucrose 10.42 g in walnut, 10.03 g in pecan, 9.63 g in cashew, and 5.90 g in almond.

These concentrations produced similar nut intakes for all three flavors in pilot studies.

Nuts were stored refrigerated in airtight containers.

Nut evaluation

Participants were presented with a single flavor on different days, counterbalanced across participants. For the evaluation, each of the four different nut types were presented weighed on separate plates in front of the participant, who was requested to taste them, and carefully respond to 16 on-screen questions on each type of nut, scoring its qualities such as how salty, sweet, bitter, sour, fat, crisp, fresh, damp, crunchy, tasty, marketable it was, as well as free comments. This took about 15 minutes.

The aim of this part of the test was to encourage the participants to eat the nuts, and thereby ingest a salt load, and approximately equivalent amounts of the non-salted nuts. Participants were encouraged to complete the evaluation in 15 minutes, so as to constrain sodium intake to roughly equivalent time over the participants.

The amount of each type of nut eaten was recorded after the session.

At the end of the experiment, participants were asked for a brief recall of the tastiness of the 4 nut types (scale 1–5), so as to provide a rationale for the 120 min sojourn in the lab.

Thirst

After completing the nut evaluation, participants rated their thirst, hunger and satiety on a 5-point scale (Hendi & Leshem, 2014) at 15 minute intervals commencing 30 min after the session began so as not to interrupt the evaluations, and by which time all participants had completed the initial nut evaluation and part of the dietary questionnaire. The thirst scale was anchored by "not" (1) and "very much" (5) to be marked in response to "How thirsty am I now" (in Hebrew). Only the thirst estimates are presented; hunger and satiety were included to avoid sole focus on thirst by the participants.

Table 1
Experimental procedure, repeated for each of 3 flavors on different days.

Timeline (min)	−120	Lab: 0–30	30–120	118–120
Procedure	Only water	Flavored nut evaluation, demographic and partial dietary questionnaire. Drinking monitored.	Free time in lab. Drinking and thirst monitored at 15 min intervals.	Brief recall nut evaluation