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Salt appetite is not increased in summer heat

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ABSTRACT

We tested the hypothesis that salt appetite increases in summer heat due to increased sodium loss due to increased drinking and perspiration. A test battery in the same sample of healthy young people tested in summer and winter revealed no seasonal differences in salt appetite (or fluid intake) despite a 10 °C rise in mean environmental temperature. Unexpectedly, sweet preference is reduced in summer.

1. Background

The current concern about how much sodium intake and for whom is based on epidemiological studies correlating sodium intake and pathology and the extant notion that sodium infiltrates our bodies unbeknownst via commercially prepared food (He, Pombo-Rodrigues, & MacGregor, 2014). This notion is somewhat belied by similar sodium intake in less industrialized societies, that taste is an important determinant of choice, and the suggestion that low-salt food is less bought whereas salted is sought (He et al., 2014; International Food Information Council Foundation, 2011; McCarron, Geerling, Kazaks, & Stern, 2009; Weeks, 2011).

Almost no research addresses the fundamental reasons for why salt is ingested in excess although it stands to reason that unravelling the causes of salt intake could improve its regulation. Some determinants of sodium intake are known. Maternal vomiting during pregnancy increases salt preference in offspring (Crystal & Bernstein, 1995), neonatal sodium loss or furosemide increase dietary sodium intake in children (Leshem, Maroun, & Weintraub, 1998; Shirazki, Weintraub, Reich, Gershon, & Leshem, 2007), putative electrolyte loss or deficiency in infancy (vomiting, diarrhea, low chloride feeding formula) increase sodium intake in adolescence (Kochli, Rakover, & Leshem, 2005; Leshem, 1998; Stein et al., 1996), growing adolescents diet is proportionally richer in sodium than other electrolytes and calories (Goldstein & Leshem, 2014), and severe dehydration and repeated hemorrhage may increase long-term salt appetite in adults, although the evidence is currently weak (Leshem, 2009).

In addition, despite its long-term contribution to pathology in some (Singer, Cohen, & Alderman, 2015), salt may have short-term benefits that may increase its attractiveness by Pavlovian conditioning (Wald & Leshem, 2003): it facilitates euhydration after exertion (Casa et al., 2012), may alleviate stress (Leshem, 2011; Smith et al., 2014), possibly depression - particularly in women (Goldstein & Leshem, 2014) and may influence immune function (Jantsch et al., 2015).

We have previously shown that salt appetite is high in a desert population, possibly to assist hydration, and becomes preferred after exertion in proportion to perspiration, possibly related to the sodium loss therein (Leshem, Saadi, Alem, & Hendi, 2008; Wald & Leshem, 2003). Hence, salt appetite might increase in summer heat as a consequence of increased perspiration, thirst-increased water turnover, and their attendant sodium losses (Bates & Miller, 2008; Ji, Kandala, & Cappuccio, 2013). Moreover, if sodium intake in summer benefits hydration, it may condition sodium preference, thereby further contributing to global sodium intake (Wald & Leshem, 2003). Indeed, while the effect of climate on salt intake has been addressed in intake recommendations it has been in the absence of comparative data on the effects of climate or season (Bates & Miller, 2008; Ji et al., 2013; Maughan, Watson, & Shirreffs,

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There is some evidence for increased salt intake in the cold, greater winter intake of sodium in a North Korean study is cited, and acutely chilled rats increase sodium intake (eg Yoshida, Okuno, Kawabata, & Morimoto, 1994).

It is clearly important to know whether sodium intake varies with season or climate. If it does, then, for example, dietary advice and analyses need be adjusted and interpreted accordingly.

Sodium intake is difficult to assess reliably for many reasons (Birukov et al., 2016; Mercado et al., 2015), may be physiologically bound, untasted, habitual, voluntary, ingrained and encultured. It is distinct from animal sodium appetite because humans only seek sodium chloride (salt), whereas animals seek the sodium ion *per se*, paired to a variety of anions, and we do not respond to sodium deficit or hormonal treatments that arouse sodium appetite in animals. However, early sodium loss enduringly enhances salt intake as it does in animals. Hence, salt consumption in humans is not a unitary phenomenon, and therefore here the term 'salt appetite' encompasses the variety of states contributing to intake and the variety of forms in which it is expressed, and which also distinguish it from other taste preferences (Leshem, 2009). We here define it operationally as a compendium of dietary intake, salting, modelled salting and snacking, and by the psychophysics of its taste hedonics and intensity (Kochli et al, 2005; Leshem, 2009). We suggest that both this dissection and the analysis are useful to properly understand why we ingest salt as we do.

Here we examine another potential contributor to salt appetite - seasonal variation. We tested the hypothesis that salt appetite increases in summer using a salt appetite test battery in the same group of young people in summer and winter. Confirmation would suggest studies comparing salt appetite across climatic regions and seasons, and contribute to awareness of this source of increased salt appetite.

2. Method

2.1. Participants

Ethics approval was provided by the University of Haifa (# 245/14). From winter 2013 until summer 2016 140 students at the university of Haifa volunteered for the study for credit or a small sum of money (~$10). Some 40% of participants did not complete their 2nd session ~6 months later which skewed the sample as described. The final sample was n = 68–129 (due to participant-omitted responses, table), aged 24.2 ± 0.6, BMI 23.8 ± 0.5, and ~78% women. Participants were tested in both winter and summer, either first in winter (64%) or first in summer (36%). In each season participants completed questionnaires querying demographic, health, dietary and seasoning, sweetened tea and salted tomato soup to determine preferred level of salting and sweetening real foods, evaluated 6 concentrations of saline and sugar solution by oral spray to compare taste hedonics and intensity, and ate salty and sweet tidbits to reveal preference. From these, "salt appetite", and "sweet preference" as taste control, were derived and compared across seasons (Kochli et al., 2005).

Winter and summer temperatures in the testing lab were 20.6 ± 0.3 °C and 24.0 ± 0.1 (Δ3.4) and outside 17.0 ± 0.4 and 27.5 ± 0.3 (Δ10.1), p's < 0.001. Room humidity differed slightly, 28.5 ± 0.8% and 31.9 ± 1.4 ($p < 0.05$) while outside humidity was similar at 57.6 ± 1.4% and 59.2 ± 1.3 (Israel Meteorological Service).

2.2. Procedure

Participants were asked to avoid eating and drinking beverages other than water for two hours before the test sessions. The session commenced with signing the informed consent form including a brief explanation in general terms that participants would be required to evaluate the taste of various common food items and complete a food frequency questionnaire (FFQ). They then started, with the help of the experimenters, on-screen questionnaires about demographics, smoking, dieting, health, exercise, etc, and the FFQ. At the same time, they were tested for preferred concentration of salt in soup and sugar in tea, followed by the tests with oral sprays of NaCl and sucrose solutions, both with order counterbalanced across participants, so that the questionnaires served to separate the taste tests. After finishing the taste tests, while still completing the questionnaires, the participants were invited to eat freely from salty and sweet tidbits served on separate plates with a cup of water.

The test session for a participant lasted 40–60 min. Participants were tested at various times during the day.

2.3. Behavioral tests (Kochli et al., 2005)

The battery of tests is designed to model different forms of salt intake. Unweighted scores are also combined to provide an operational definition of salt appetite, with a similar procedure for sweet, the control tastant (Leshem, 2009).

2.3.1. Preferred concentration of NaCl in soup and sugar in tea

Tomato soup was prepared by diluting 1 part of pure, unsalted tomato paste concentrate (22BX) with nine parts of boiled water. Tea was prepared with a 3 g tea bag in 1 l boiled water. The soup and tea were prepared freshly before each test session and kept in vacuum flasks at ~45 °C.

Participants were presented with two 200 ml cups of tomato soup, one unsalted and one with 3.3% (w/w) NaCl. They were asked to taste the soup in both cups using a 5 ml teaspoon and were provided with a third cup into which the experimenter then poured one-half of the unsalted soup. Then, using the teaspoon, they were asked to add salted soup to the third cup and taste it until they deemed the mixture most "tasty". The salt concentration of the mixture was determined by weighing the cups, a validated measure of concentration (Kochli et al., 2005). Preference for sucrose in tea was similarly determined, using tea with 20% (w/w) sucrose.

2.3.2. Psychophysical ratings of taste solutions in oral sprays using visual analogue scales (VAS)

This is employed to rate intensity and preference for taste solutions with minimal swallowing. Solutions are diluted to 6 concentrations with bottled water (9 mg/l sodium). NaCl is diluted from 2.56 M by 1/3 steps down to a concentration of 2.5 mM, sucrose from 135 g/l by 1/2 steps dilution to 0.55 g/l. Using perfume bottles, the experimenter sprays 0.29 ml of each taste concentration in fixed and counterbalanced semi-randomized orders (excluding sequential concentrations) onto the participant's tongue. Using VAS, participants rate (horizontal on-screen slider scoring 0–100) each concentration for taste intensity ("how strong is the taste?" – in Hebrew) anchored by "don't feel anything" and "very strong", and for hedonics ("how tasty is it?") anchored by "bad taste" and "very tasty".

2.3.3. Sweet and salty tidbits

While completing the questionnaires, 2 familiar commercial salty (890 and 780 mg/100 g Na^+) and sweet snack items (120.5 and 146 mg/100 g Na^+) in unwrapped bite-size tidbits on separate saucers were placed by the participants who were invited to freely eat of them. The number of tidbits eaten was recorded discreetly.