Disruption in the Relationship between Blood Pressure and Salty Taste Thresholds among Overweight and Obese Children

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ABSTRACT

Background Prevalence of high blood pressure among American children has increased over the past 2 decades, due in part to increasing rates of obesity and excessive dietary salt intake.

Objective We tested the hypothesis that the relationships among blood pressure, salty taste sensitivity, and salt intake differ between normal-weight and overweight/obese children.

Design In an observational study, sodium chloride (NaCl) and monosodium glutamate (MSG) taste detection thresholds were measured using the Monell two-alternative, forced-choice, paired-comparison tracking method. Weight and blood pressure were measured, and salt intake was determined by 24-hour dietary recall.

Participants/setting Children aged 8 to 14 years (N=97; 52% overweight or obese) from the Philadelphia, PA, area completed anthropometric and blood pressure measurements; 97% completed one or both thresholds. Seventy-six percent provided valid dietary recall data. Testing was completed between December 2011 and August 2012.

Main outcome measures NaCl and MSG detection thresholds, blood pressure, and dietary salt intake.

Statistical analyses Outcome measures were compared between normal-weight and overweight/obese children with *t* tests. Relationships among outcome measures within groups were examined with Pearson correlations, and multiple regression analysis was used to examine the relationship between blood pressure and thresholds, controlling for age, body mass index *z* score, and dietary salt intake.

Results NaCl and MSG thresholds were positively correlated ($r[71]=0.30$; $P=0.01$) and did not differ between body weight groups ($P>0.20$). Controlling for age, body mass index *z* score, and salt intake, systolic blood pressure was associated with NaCl thresholds among normal-weight children ($P=0.01$), but not among overweight/obese children. All children consumed excess salt (>8 g/day). Grain and meat products were the primary source of dietary sodium.

Conclusions The apparent disruption in the relationship between salty taste response and blood pressure among overweight/obese children suggests the relationship may be influenced by body weight. Further research is warranted to explore this relationship as a potential measure to prevent development of hypertension.
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CHARACTERIZING AN ASSOCIATION BETWEEN TASTE perception and blood pressure is an ongoing area of research based on the premise that taste function may be reflective of physiologic processes elsewhere in the body, and as such, serve as a marker for an individual's health status.[1] Because of the well-established link between high dietary salt intake and blood pressure,[2] salty taste has long been an area of focus in examining differences between people with hypertension and normotension in terms of hedonic appeal of salt,[3-5] perceived salty taste intensity,[6,7] and sensitivity to salty taste,[5,8-14] because any differences between these groups may allow for diagnosing or managing hypertension.[7,15] To date, findings from research of this nature have been largely equivocal.

No definitive association between blood pressure and either salt preference[3-5] or perceived salty taste intensity[6,7] has been published thus far. Examinations of the link

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between blood pressure and salty taste sensitivity, measured via detection thresholds (defined as the lowest concentration of a stimulus needed by a subject to detect its presence relative to water[16]) or recognition thresholds (defined as the lowest concentration of a stimulus correctly identified by name by a subject based on its characteristic taste[16]), have produced mixed results. Systolic blood pressure (SBP) was positively correlated with salty taste recognition thresholds among normal- and underweight 10- to 17-year-old Nigerian children[9] and was positively correlated with salty taste detection thresholds among normal-weight but not obese Spanish children (age was not reported).[8] No relationship between blood pressure and salty taste detection thresholds was found among 11- to 16-year-old American children who ranged from normal weight to obese.[3] Among adults, people with hypertension had higher recognition thresholds than those with normotension in several studies,[6,10-12] and in one study people with hypertension had higher detection thresholds.[13] Others found no difference in detection thresholds between adults with and without hypertension,[11] and two studies found no difference in either detection or recognition thresholds between these groups.[5,14]

Our understanding of potential shared mechanisms underlying salty taste sensitivity and blood pressure thus far may be limited by several confounding factors across studies, including differences in subject age, body weight, and dietary salt intake as well as wide variation in methodologies used to measure taste sensitivity. In light of an increased prevalence of high blood pressure among pediatric populations over the past 2 decades,[17,18] and a known association between weight, dietary salt intake, and blood pressure,[18,19] we examined the relationship between blood pressure and salty taste detection thresholds among normal-weight vs overweight and obese children using a rigorous validated methodology,[20] and we explored whether differences in dietary salt intake influenced this relationship. To determine whether findings were specific to salty taste sensitivity, detection thresholds were also measured for monosodium glutamate (MSG) because of demonstrated differences in MSG taste sensitivity between obese and nonobese women[21] and because MSG is also a sodium-containing taste stimulus. If blood pressure and salty taste sensitivity share a common link, taste measures could provide new insight into our current understanding of the development of high blood pressure in children.

MATERIALS AND METHODS

Participants

Mothers of healthy children aged 8 to 14 years were recruited for a taste study from local advertisements in the Philadelphia, PA, area and from a list of past subjects who asked to be notified of future studies at the Monell Chemical Senses Center. Children with allergies were excluded from participation. All procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania. Written informed consent was obtained from each mother, and written informed assent from each child.

Procedures

Testing took place in a private, comfortable room specifically designed for sensory testing that was illuminated with red light to mask any visual differences among samples. Subjects consumed no food or drink other than water for at least 1 hour before the task and acclimated to the testing room and to the researcher for approximately 15 minutes. Before testing, all children were trained to become familiar with the method and to assess whether they understood the detection threshold task (modified from pediatric assessment of sucrose preference).[20] Children were presented with a pair of plastic medicine cups: one containing distilled water and the other containing either 0.056 mmol/L or 0.018 mol/L sucrose solution. Children were asked to taste both solutions in the order presented and to point to the solution that had a taste (Figure 1). This method eliminated the need for a verbal response and is effective for assessing both taste and olfaction in children. The two pairs (water vs 0.056 mmol/L and water vs 0.018 mol/L sucrose) provided the children with the experience of tasting a pair of solutions in which they could not detect a difference and a pair in which the difference between solutions was easily discernible, both of which are conditions encountered during threshold testing. Training was repeated with children who did not understand the task after one training session.

Taste Detection Thresholds

Detection thresholds for sodium chloride (NaCl) and MSG in solution were measured separately and in randomized order via a two-alternative forced choice staircase procedure developed at the Monell Center and later adapted for use among pediatric populations.[20] As shown in Figure 1, solutions used for testing ranged in concentration from 0.056 mmol/L to 1,000 mmol/L for both NaCl and MSG. Solutions for both stimuli were made through a quarter-log serial dilution of a 1,000 mmol/L solution to make a series of 18 concentrations. Solutions were randomized for order across subjects.[22] For the first trial and each subsequent trial, subjects were presented with pairs of solutions; within each pair, one solution was distilled water and the other was the taste stimulus. Subjects were instructed to taste the first solution presented within a pair, swish the solution in his or her mouth for 5 seconds, and expectorate. Subjects tasted the second solution within a pair using the same protocol, rinsing his or her mouth with water once between solutions within a pair and twice between successive pairs. After tasting both solutions within a pair, subjects were asked to point to the solution that had a taste, as in the training task. The concentration of the tastant in the solution presented in the subsequent pair was increased after a single incorrect response and decreased after two consecutive correct responses. A reversal occurred when the concentration sequence changed direction (ie, an incorrect response followed by a correct response or vice versa). A tracking grid (Figure 1) was used to record subjects' responses. The testing procedure was terminated after four reversals occurred, provided the following criteria were met, to ensure a stable measure of the detection threshold: there were no more than two dilution steps between two consecutive reversals, and the reversals did not form an ascending pattern such that positive and negative reversals were achieved at successively higher concentrations.[23] A subject's threshold for a tastant was calculated as the mean of the log values of the last four reversals. Threshold testing for each child always began at Step 12 (Figure 1), a stimulus concentration that ensured an adequate number of steps on either side of the starting point to determine an accurate threshold. Although only a narrow