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Research report

Sociodemographic profiles regarding bitter food consumption. Cross-sectional evidence from a general French population ☆

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ABSTRACT

Certain beneficial foods taste bitter (e.g., cruciferous vegetables) and might be aversive to consumers. Here, individual characteristics according to bitter food consumption patterns were assessed. The study included 2327 participants in the SU.VI.MAX antioxidant-based randomized controlled trial (1994–2002). The sample was drawn from the general French population. Dietary data were obtained from a minimum of twelve 24-h dietary records provided during the first 2 years of follow-up. Two bitter food consumption scores were computed – one assessing the variety of items consumed (unweighted score) and the other reflecting exposure to bitterness estimated via complementary sensory panel data from the EpiPref project (weighted score). Associations with sociodemographic, health, and lifestyle factors were analyzed with multiple linear regression. Among men, the variety of bitter foods consumed was positively associated with educational level and alcohol intake and inversely associated with physical activity and rural area of residence. Among women, the same outcome was positively associated with alcohol intake and inversely associated with diabetes. In turn, Body Mass Index displayed a significant inverse association with the bitterness-weighted score across sex, whereas educational level was supported only in women. This study adds to the presently scant knowledge about non-genetic determinants or moderators of actual bitter food intake. Future studies should elucidate the impact of diabetes and body size on bitter food intake patterns.

Introduction

Background

Nutrition has a lifelong impact on health and has been drawing attention as a critical modifiable factor in chronic disease prevention (Drewnowski & Gomez-Carneros, 2000; World Health Organization, 2003). However, certain foods with an arguably strong potential to ward off disease, due to high contents of beneficial micro- and macro-nutrients as well as bioactive phytochemicals, tend to taste bitter and might be aversive to individuals (Drewnowski & Gomez-Carneros, 2000; Higdon, Delage, Williams, & Dashwood, 2007; Shahidi, 2004). This pertains to cruciferous vegetables (broccoli, cabbage, cauliflower, kale, collard greens, Brussels sprouts), spinach, cucumber (Drewnowski & Gomez-Carneros, 2000; Higdon et al., 2007), grapefruit (Steevens, Schouten, Goldbohm, & van den Brandt, 2011), cocoa (Corti, Flammer, Hollenberg, & Luscher, 2009; Grassi, Desideri, & Ferri, 2010), and cheese (Mozaffarian et al., 2010). In the United States, for example, one of the *Healthy People 2020* nutrition objectives pertains specifically to an increase in the contribution of dark green vegetables, orange vegetables, and legumes to the diets of the population (Department of Health and Human Services & Office of Disease Prevention and Health Promotion, 2010). However, reviews of the research evidence indicate marked individual-level

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orosensory variation, which has been linked to variation in food preferences and dietary behaviors which, in turn, have been associated with risk of various chronic diseases (Duffy, 2007; Tepper, 2008). Epidemiological findings reveal protective associations between cruciferous vegetable intake and risk of cancer (Steevens et al., 2011; Verhoeven, Goldbohm, van Poppel, Verhagen, & van den Brandt, 1996), myocardial infarction (Cornelis, El-Sohemy, & Campos, 2007), and cognitive decline (Morris, Evans, Tangney, Bienias, & Wilson, 2006). Observational and experimental studies have reported beneficial cardiovascular and cognitive effects of cocoa intake (Ding, Hutfless, Ding, & Girotra, 2006; Scholey et al., 2010; Taubert, Roesen, & Schomig, 2007). Finally, cheese intake was positively associated with trans-palmitoleate levels which, in turn, were linked with lower rates of insulin resistance and incident diabetes (Mozaffarian et al., 2010).

Bitter taste rejection is innate, representing a basic defense mechanism against ingesting harmful substances (Bartoshuk, 1989; Meyerhof, Behrens, Brockhoff, Bufe, & Kuhn, 2005). However, it has been shown that bitter taste thresholds vary independently of toxicity thresholds, and that a bitter taste rejection response could be elicited by both toxic and edible dietary components (Glendinning, 1994). Evidence in mammals indicates that a number of structurally diverse compounds can elicit bitter taste, which is perceived via approximately 30, broadly-tuned taste receptors type 2 (TAS2R) (Meyerhof, 2005). For example, a recent laboratory-based study suggested that a number of TAS2R polymorphisms were likely implicated in the sensation, liking, and/or intake of commonly consumed beverages (Hayes et al., 2011). Individual-level variation in perceptions of bitterness intensity (along with oral somatosensation and retronasal olfaction) could be determined via sensitivity to phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP) (Bufe et al., 2005) – which are chemically related to the bitter constituents in cruciferous vegetables (Tepper, 1998), as well as via the number of fungiform papillae on the anterior tongue, perceptions of bitterness of quinine, irritant bitter tasting, thermal tasting, receptor genotypes, and gene-environment interactions (Duffy, 2007; Hayes & Keast, 2011). For example, PROP tasters report increased dislike of certain bitter vegetables and strong-tasting fruits (broccoli, Brussels sprouts, cabbage, kale, asparagus, spinach, grapefruit, grapefruit juice) (Tepper et al., 2009). Epidemiological evidence has revealed an inverse association between perceived bitterness and fruit/vegetable consumption, with PROP tasters deriving a greater portion of their total energy from fat compared to non-tasters (Basson et al., 2005; Yackinous & Guinard, 2002). It has also been demonstrated that bitterness nontasters possessing more fungiform papillae report greater vegetable consumption overall compared with nontasters with fewer papillae (Duffy et al., 2010). A possible link between taste genetics and cancer risk has also been suggested, given a significant, age-independent correlation between perceived bitterness and number of polyps in the colon (Basson et al., 2005).

Whereas molecular and genetic research has shed light on sensitivity-based aspects of consumption (Duffy et al., 2010; Riso et al., 2010; Tepper et al., 2009), the sociodemographic and lifestyle correlates of bitter food intake in a public health context remain poorly understood despite a long-standing interest in the relationship among taste, intake, and health (Bartoshuk, 2000; Drewnowski, 1997). Given that fruit and vegetable intake is below established dietary guidelines across different countries (Ervin, 2011; Kesse-Guyot et al., 2011; Vandevijvere et al., 2009), and particularly that cruciferous vegetable intake – in France and abroad – is low (Brat et al., 2006; Johnston, Taylor, & Hampl, 2000), the identification of population subgroups according to their vegetable and other bitter food consumption patterns may help in refining public health recommendations. The aim of the present study was to investigate in a novel manner individual, non-genetic characteristics as correlates of unweighted and weighted measures of bitter food consumption in a general French population.

Methods

Study design and participants

SU.VI.MAX («SUpplémentation en Vitamines et Minéraux AntioXydants»; 1994–2002, $N = 13017$; trial registration: http://clinicaltrials.gov/show/NCT00272428) was a randomized, double-blind, placebo-controlled primary prevention trial assessing the effect of daily low-dose antioxidant supplementation (a combination of 120 mg of ascorbic acid, 30 mg of vitamin E, 6 mg of beta-carotene, 100 μg of selenium, and 20 mg of zinc) on the incidence of cardiovascular disease and cancer over a median of 7.5 years (Hercberg et al., 2004). All participants were free of any diseases that could threaten their 5-year survival and all reported no regular vitamin/mineral dietary supplement use. Group randomization was carried out via block-sequence generation stratified by sex and age (Hercberg et al., 2004). All procedures involving human participants were approved by the ethics committee of Paris-Cochin Hospital and by the French National Information and Citizen Freedom Committee. Written informed consent was obtained from all participants. Further details about the design, implementation, and principal findings of the SU.VI.MAX trial are available elsewhere (Hercberg et al., 2004). Whereas at baseline female participants were aged 35–60 years and male participants – 45–60 years, for comparison purposes, only individuals aged 45–60 years at baseline with complete sociodemographic and dietary data were selected for the present analysis.

Assessment of bitter food consumption

Data on dietary practices were collected via the *Minitel Telematic Network* which was a prototype of the Internet and consisted of a small terminal that was widely used in France as an adjunct to the telephone. Upon enrollment in the trial, participants received a small central processing unit containing study-specific software. It permitted the offline completion of detailed dietary records, which were then transmitted during brief telephone connections. Every 2 months, participants were asked to complete a 24-h dietary record on a randomly assigned weekend or week day, thus accounting for individual and seasonal intake variability.

All participants received a detailed instruction manual with validated photographs of 250 different food and beverage groups comprising over 990 generic items, presented in seven different portion sizes (Le Moullec et al., 1996). Consistent with the trial's steering committee decision and prior SU.VI.MAX reports (Kesse-Guyot et al., 2011), dietary records with <100 kcal/d or >6000 kcal/d were excluded; further, men reporting <800 kcal/d and women reporting <500 kcal/d across $\geqslant 1/3$ of their dietary records were also excluded. A French food composition table was used to calculate nutrient values (Hercberg, 2005).

Using at least twelve 24-h dietary records per participant, collected during the first 2 years of follow-up (1994–1996, reflecting baseline dietary habits), we assessed consumption of individual bitter foods, excluding items that were part of composite dishes, alcohol and coffee. The selection of these items was guided by prior research conducted as part of the EpiPref sensory perception project where the bitterness intensity of 592 different food items (commercially available and home-cooked) was evaluated by a trained panel (Epipref., 2012) using Spectrum™ scales (Munoz & Civille, 1992). From this set of items, only those that had been rated at least three times and that had fallen into the top tertile of bitterness intensity were selected. This verification step was necessary,