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Genetic and environmental influences on liking and reported intakes of vegetables in Irish children

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ABSTRACT

Variation in the bitterness of 6-*n*-propylthiouracil (PROP) is partially explained by polymorphisms in the TAS2R38 gene. Based on their perception of bitterness from PROP, people may be classified into non-, medium and supertasters. PROP perception has previously been linked to liking for cruciferous vegetables in children in some studies, but only one study to date has examined TAS2R38 genotype and its relationship with vegetable intake in children. Children's vegetable consumption generally does not meet the recommended guidelines, thus the present study aimed to examine the influence of oral sensory measures, genetic variation and social factors on vegetable liking and intake. Vegetable liking in 7–13 year old Irish children ($n = 525$) was measured on a 5-point liking scale, and dietary intakes were assessed via a 3-day diet history. Vegetable intakes were calculated and standardised per kg body weight. A subset of children ($n = 485$) were genotyped for SNPs in TAS2R38, (A49P, V262A, I296V), and fungiform papilla (FP) were counted. The bitterness of PROP and sweetness of sucrose were rated on a generalised labelled magnitude scale (gLMS). PROP and sucrose intensity were significantly correlated ($R^2 = 0.33$, $p = 0.001$), although neither sucrose intensity nor FP density differed across the TAS2R38 genotype groups. Supertasters were less likely than nontasters to have tried/tasted cruciferous vegetables $p < 0.04$). A small, positive correlation was seen in FP density and vegetable intake, but only in the AVI homozygous children, ($R^2 = 0.17$, $p = 0.035$). 174 Nutrient acceptable children reported an intake of one or more of the vegetables of interest in the 3-day period. Liking of cruciferous vegetables and reported intake were significantly correlated. In multiple regression analyses in this subsection of the cohort, socioeconomic status (SES) and gender were more important than PROP bitterness or TAS2R38 genotype in predicting intakes (approximately 15% of liking and 67% of intake was explained by these models). Overall, neither PROP taster status nor TAS2R38 genotype alone had significant impact on bitter vegetable liking or intake. Further research into FP density and vegetable liking and intake may be warranted.

1. Introduction

Children in Ireland, like most children in the UK, Europe and the US, do not eat sufficient fruit and vegetables to meet the recommended 400 g per day (Cockroft, Durkin, Masding, & Cade, 2005; IUNA., 2005; Vereecken, De Henauw, & Maes, 2005). Eating habits formed in childhood can become lifelong (Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2005), therefore a better understanding of the factors affecting food choices in children is vital. Food choice is influenced by multiple factors including socio-cultural, socioeconomic, environmental and physiological (Berg, Jonsson, Conner, & Lissner, 2003; Scheibehenne, Miesler, & Todd, 2007; Webber, Sobal, & Dollahite, 2010). In models of food choice in the Western world, taste is often listed as one the most influential physiological factors, alongside cost and availability (Brug, Tak, te Velde, Bere, & de Bourdeaudhuij, 2008; Glanz, Basil, Maibach, Goldberg, & Snyder, 1998; Scheibehenne et al., 2007). The sense of bitter taste is thought to have arisen to warn against the ingestion of toxic or poisonous substances, which can often taste bitter (Glendinning, 1994). As a result, we have an innate dislike of bitter-tasting foods, and this response is stronger in children than adults (Mennella, Pepino, & Reed, 2005). Bitter taste perception can vary however, depending on genetic variations in bitter receptor genes (Hayes, Feeney, & Allen, 2013). The best-known example of this is the variation in response to the compound 6-*n*-propylthiouracil (PROP). An individual can be classified as a nontaster, medium taster, or supertaster, depending on their perceived intensity of PROP (Bartoshuk, Duffy, & Miller, 1994). Differences in bitter

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perception may lead to differential food preferences and food choices (Brug et al., 2008; Feeney, 2011; Feeney, O' Brien, Markey, Scannell, & Gibney, 2011; Mennella et al., 2005; Tepper, Williams, Burgess, Antalis, & Mattes, 2009). Much of the variation in PROP bitterness is attributable to single nucleotide polymorphisms (SNPs) within the *TAS2R38* gene, which encodes a bitter receptor for thiourea-containing compounds such as PROP and phenylthiocarbamide (PTC) (Kim, Jorgenson, Coon, Leppert, & Risch, 2003). Three common SNPs within *TAS2R38* occur at amino acid positions 49, 262 and 296 (Kim, Wooding, Ricci, Jorde, & Drayna, 2005), resulting in eight possible haplotypes, of which five are observed in the population. The majority of individuals (approximately 95%) exhibit a combination of just two haplotypes (Drayna, Coon, Kim, Elsner, & Cromer, 2003; Kim et al., 2005), designated proline-alanine-valine (PAV) and alanine-valine-isoleucine (AVI). These haplotypes encode bitter receptors with differential responses for thiourea compounds, and are termed the 'taster' and 'nontaster' haplotype, respectively (Kim & Drayna, 2005; Kim et al., 2003; Wooding, Kim, Bamshad, Larsen, & Jorde, 2004). Related thiourea compounds are also found in cruciferous vegetables (Fahey, Zalcmann, & Talalay, 2001; Wooding et al., 2010) and thus PROP perception and/or *TAS2R38* genotype is often hypothesised to affect liking for and intake of cruciferous vegetables, particularly in children; (Anliker, Bartoshuk, Ferris, & Hooks, 1991; Bell & Tepper, 2006; Keller, Steinmann, Nurse, & Tepper, 2002; Lumeng, Cardinal, Sitto, & Kannan, 2008; Turnbull & Matisoo-Smith, 2002).

Although genetic variation may play a role, the liking of cruciferous vegetables might also be influenced by other factors such as the density of fungiform papillae (FP) on the tongue. FP are mushroom-shaped structures which house the taste buds, which in turn contain taste receptor cells and trigeminal (touch) fibres. PROP perception was positively correlated with FP density in a number of reports (Bartoshuk et al., 1994; Delwiche, Buletic, & Breslin, 2001; Duffy et al., 2010; Essick, Chopra, Guest, & McGlone, 2003; Tepper & Nurse, 1997; Yackinous & Guinard, 2002). This relation is thought to be independent of *TAS2R38* genotype (Hayes, Bartoshuk, Kidd, & Duffy, 2008). FP density is also associated with greater lingual tactile acuity (Essick et al., 2003). Therefore, increased FP density may enhance an individual's sensitivity not only to the taste, but also to the textural qualities of foods. In studies on consumer liking of wholegrain bread, there is an interaction with PROP taster status and FP density, whereby in the nontasters (in whom bitterness perception from whole grains would be minimized), greater FP density is associated with increased liking (Bakke & Vickers, 2011). This also appears true for vegetables, which are complex stimuli in terms of both texture and taste (Duffy et al., 2010). In a group of 55 college students, FP density was correlated with vegetable intake (Duffy et al., 2010), only in the PROP nontasters, and separately in the AVI/AVI individuals. In both of these groups of individuals, bitterness perception would be low, while other oral sensations, like sweetness, may be heightened as FP density increases. This is of interest for cruciferous vegetable liking, since the impression of sweetness from *Brassica* vegetables depends on both the sugar content and the bitter glucosinolate content (Schonhof, Krumbein, & Bruckner, 2004), presumably via mixture suppression of bitterness by sweetness (Lawless, 1979). Vegetables with lower bitterness and greater sweetness were the most liked (Schonhof et al., 2004), and greater sweetness and lower bitterness associate with greater intake (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006). Together, this suggests that variation in FP and PROP phenotype could be particularly relevant in liking of cruciferous vegetables; nontasters with higher FP numbers may have greater liking due to an altered perception.

Few studies have examined current dietary intakes in children with regard to PROP taster status and *TAS2R38* genotype. To date, no study has examined the influence of PROP taster status, *TAS2R38* genetics, FP density, and sweetness perception on vegetable preference and vegetable intake simultaneously in a single cohort of children. The results presented here are from a large study of 525 children aged 7–13 carried out in Ireland between 2007 and 2010 to examine the role of *TAS2R38* genotype and oral sensory phenotype in dietary intakes.

A recent publication from our group examining the drivers of different dietary patterns in Irish children showed no difference between either PROP taster groups or *TAS2R38* genotype groups in terms of their vitamin and mineral intake, or in overall intakes of fruit or vegetable-containing food groups (O'Brien, Feeney, Scannell, Markey, & Gibney, 2013). However, since intake of cruciferous vegetables as a group was not captured separately in those analyses, and in light of the work showing an interaction in terms of FP density and liking, we wondered whether FP density might also predict vegetable liking or intake. Therefore the present analyses aimed to examine genotypic and various phenotypic measures, in addition to SES, on cruciferous vegetable liking and intake in children.

2. Methods

2.1. Participants

A total of 525 children (225 males; mean age 10.39 years ± 1.84 and 300 females; mean age 10.07 years ± 1.43) aged 7–13 years from a range of different social and educational backgrounds were recruited to the study. Recruitment was carried out through schools; via an introductory letter outlining the study was which was sent to the school principal of a random selection of schools on the Department of Education and Science's database. In total, 125 schools were contacted initially via letter. 8 schools declined to participate, 20 agreed to take part and the others did not respond. Information leaflets were distributed to the participating schools, together with consent forms for the children ($n = 592$) to bring home to their parents to read and sign. Written, informed consent was obtained from a parent or guardian before participation. Approximately 89% of children were permitted by their parents to take part. Children were assigned to one of six levels of increasing SES, on a per-school basis, based on information from the Department of Education on social inclusion, class size, urban or rural, and whether or not parents paid school fees. Ethical approval for this study was granted from the UCD Human Research Ethics Committee. When these SES levels were collapsed into low, medium and high, children were relatively evenly represented from all three groups (38%, 37% and 26%, respectively). The full cohort of 525 was unavailable for all variables, for various reasons, shown in Table 1.

2.2. Anthropometry

Weight was measured in duplicate using a Seca 770 digital personal weighing scale (Chasmores Ltd., UK), to the nearest 0.1 kg. Respondents were weighed whilst wearing light clothing and without shoes. Height was measured to the nearest 0.1 cm, using the Leicester portable height measure (Chasmores Ltd., UK), with the respondent's head positioned in the Frankfurt Plane. Body Mass Index (BMI) was used to indirectly assess adiposity and was calculated by weight (kg) divided by height squared (m^2). As age-and-sex specific BMI charts for an Irish reference population were not available, the UK 1990 BMI reference curves for boys and girls (UK90) were used to calculate *z*-scores (Cole, Freeman, & Preece, 1995).