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The influence of oral phenotypic markers and fat perception on fat intake during a breakfast buffet and in a 4-day food record

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ABSTRACT

The ability to discriminate among foods with different fat contents has been associated with preference for high-fat foods and total fat intake. Consequently, oral phenotypic markers that influence fat perception may influence food selection and fat intake. The aim of this study was to investigate how the fungiform papilla (FP) count on the tongue tip, 6-n-propylthiouracil (PROP) bitterness, saliva flow, the increase in salivary flow via oil stimulation and the ability to perceive fat influence fat intake and food selection. A total of 107 subjects (80 female, 27 male) completed a 4-day self-administered food record before they rated the fat contents of different milk–cream mixtures and a high-fat emulsion. Of these subjects, 103 (76 female, 27 male) participated in an ad libitum breakfast buffet that was offered at the university cafeteria. The results show that the perception of the fat content of cream with 30.0% fat was associated with energy intake from fat and discretionary fats over 4 days and during the breakfast buffet. Subjects with lower FP counts ate relatively more high fat milk and spreads and as a consequence more fat during the breakfast buffet than subjects with high FP counts. The increase in salivary flow via oil stimulation was positively correlated with the reported intakes of discretionary and total fat over 4 days. These results support the hypothesis that FP count and the intensity perception of supra-threshold differences in fat content might play an important role in the selection of high-fat foods and fat intake.

1. Introduction

The sensory properties of food, as well as cultural, socioeconomic and biological factors, have been suggested to be a main determinant of food choice (Drewnowski, 1997; Köster, 2009). Therefore, physiological factors influencing the perception of the sensory properties of food might affect nutritional behavior and the development of diet-related diseases (Duffy, 2007; Sørensen, Møller, Flint, Martens, & Raben, 2003). The influence of oral physiology on the perception of fat is of particularly broad interest due to the accumulating evidence showing a relationship between the ability to detect differences in fat content among foods and fat intake (Keller et al., 2012; Stewart et al., 2010). Physiological factors that have been suggested to influence the intake of fat through an influence on the perception of fat are the fungiform papilla (FP) count (Hayes & Duffy, 2008), the perceived intensity of the bitter tasting substance 6-n-propylthiouracil (PROP) (Kamphuis & Westerterp-Plantenga, 2003; Yackinous & Guinard, 2002) and saliva flow (SF) (Neyraud, Palicki, Schwartz, Nicklaus, & Feron, 2012).

Humans have a large variation in FP count, which could possibly explain individual differences in oral sensation (Correa, Hutchinson, Laing, & Jinks, 2013). FP houses taste buds that contain taste receptors and are innervated and surrounded by trigeminal neurons, which are involved in the texture perception of food (Whitehead, Beeman, & Kinsella, 1985; Whitehead & Kachele, 1994). As a result, subjects with a high FP count have a higher trigeminal innervation and perceive tactile stimuli to be more intense than subjects with a low FP count (Essick, Chopra, Guest, & McGlone, 2003). Furthermore, it can be assumed that taste buds contain putative fatty acid receptors involved in fat perception (Galindo et al., 2012). This would lead to the conclusion that the textural attributes of fat are detected through the mechanoreceptors of the trigeminal neurons, and the fatty acids in fats are detected through the fatty acid receptors of the chemosensory system (Galindo et al., 2012; Rolls, 2012); thus, the number of FP may influence fat perception. Recent studies have shown that FP count is positively correlated with ratings of creaminess (Hayes & Duffy, 2007) and perceived fat content (Nachtsheim & Schlich, 2013). A follow-up study by Hayes and Duffy (2008) showed that women with high FP counts had a point of optimal liking for fat, whereas women with low FP counts exhibited a constant level of liking at increasing fat content (Hayes & Duffy, 2008). On this basis, food liking is suggested to determine intake (Tuorila et al., 2008); the

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FP count might influence fat intake. Until now no study has investigated the influence of the FP count on fat intake.

The perceived intensity of the bitter tasting substance 6-n-propylthiouracil (PROP) is the best-studied phenotypic marker of oral physiology and has been used to explain individual differences in fat perception and fat intake (Hayes & Duffy, 2007; Kamphuis & Westerterp-Plantenga, 2003; Tepper, Neilland, Ullrich, Koelliker, & Belzer, 2011; Tepper & Nurse, 1997). Individuals who perceive PROP as only slightly bitter are called PROP nontasters (pNT), whereas individuals who are able to perceive PROP as moderately or extremely bitter are called PROP medium tasters (pMT) and supertasters (pST), respectively (Bartoshuk, Duffy, & Miller, 1994). Several studies have shown that pSTs perceive oral sensations from fat in foods more intensely (Hayes & Duffy, 2007; Tepper & Nurse, 1997) and have a lower acceptance of full fat milk (Keller, Steinmann, Nurse, & Tepper, 2002), high-fat salad dressings (Tepper & Nurse, 1998) and sweet-fat dairy mixtures than do pNTs (Hayes & Duffy, 2008). The postulated mechanism by which the perceived intensity of PROP bitterness influences the perception of fat is caused by a higher trigeminal innervation due to the higher FP count on the tongue tips of pSTs compared to pNTs (Yackinous & Guinard, 2001). However, several studies have found no relationship between PROP bitterness and fat perception or preference (Drewnowski, Henderson, & Barratt-Fornell, 1998; Keller et al., 2002; Lim, Urban, & Green, 2008; Nachtsheim & Schlich, 2013). These results may be contradictory due to the use of saltiness as a standard for the classification of pNT, pMT and pST (Yackinous & Guinard, 2001) and the use of scales that are not generalized outside an oral context (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006). Furthermore, the ranges of fat content tested (Yackinous & Guinard, 2001) and the FP counts between the taster groups differed in each study (Essick et al., 2003).

As a result of the reduced preference for high fat foods (Hayes & Duffy, 2008; Keller et al., 2002; Tepper & Nurse, 1998), pST might have a lower dietary fat intake. Studies that have investigated the effect of PROP bitterness on dietary fat intake have reported contradictory results. Yackinous and Guinard (2002) showed that pST and pMT women consumed a greater percentage of their dietary energy from fat than pNT women, whereas Drewnowski, Henderson, and Cockroft (2007); Borazon, Villarino, Magbuhat, and Sabandal (2012) found no relationship between PROP bitterness and fat intake. Studies in children showed that PROP bitterness is negatively correlated with the intake of energy and discretionary fats, especially in girls (Goldstein, Daun, & Tepper, 2007; Keller et al., 2002). However, these results could not be confirmed by a recent study (O'Brien, Feeney, Scannell, Markey, & Gibney, 2013). Differences in the methods used to determine the PROP status and the indirect methods used to assess fat intake, such as food frequency questionnaires (Keller et al., 2002; Yackinous & Guinard, 2002), diet history (O'Brien et al., 2013) and dietary intake records (Borazon et al., 2012; Goldstein et al., 2007), might explain some of the inconsistencies in the reported effects of PROP bitterness on fat intake. Studies using indirect measures to determine nutritional behavior are especially prone to underreporting of foods with a high fat content and thus total fat intake (Brunner, Stallone, Juneja, Bingham, & Marmot, 2001; Carlsen et al., 2010; Westerterp & Goris, 2002), which may lead to an underestimation of the effect of PROP bitterness on fat intake. However, studies that measured actual intake during lunch buffets also showed discrepancies in their results. Kamphuis and Westerterp-Plantenga (2003) showed that PROP tasters consumed more energy from fat in a mixed lunch buffet than pNTs. In contrast, Tepper et al. (2011) could not find an influence of PROP status on macronutrient selection, but showed that pNT consumed more energy from taco, pizza or sandwich lunches compared to the control lunch with fixed food items than PROP tasters (pMTs and pSTs). Differences in the methods used to determine the PROP status and the lunch items may explain the contradictory results (Tepper et al., 2011). To date, no study has investigated the influence of PROP bitterness on dietary intake during a breakfast buffet. A breakfast buffet might be a more appropriate meal situation because the subjects can alter their fat intake directly by choosing foods with different fat contents (e.g., spreads or dairy products).

Another physiological factor that might influence fat intake by influencing fat perception is SF. The diluting and lubricating properties of the saliva may influence the perception of the fat related texture attributes (Engelen, de Wijk, Prinz, van der Bilt, & Bosman, 2003; Neyraud et al., 2012). Furthermore, SF can be increased through oil stimulation (SFI), which has been suggested to influence fat perception (Nachtsheim & Schlich, 2013). Until now, no study has investigated the influence of SF or SFI on fat intake.

The objective of this research was to further investigate the influence of PROP bitterness, fungiform papilla count, saliva flow and fat perception on fat intake. Previous research on the same cohort showed that FP count and SFI had a significant influence on the perception of fat (Nachtsheim & Schlich, 2013). The hypotheses tested in this study were that (1) PROP bitterness influences fat intake, (2) fungiform papilla count influences fat intake, (3) saliva flow influences fat intake, and (4) fat perception influences fat intake. For hypothesis (3), two sub-hypotheses were defined: (3.1) unstimulated saliva flow influences fat intake, and (3.2) the absolute amount of SFI influences fat intake. To the best of our knowledge, this is the first study to investigate the influence of oral physiology and the ability to perceive fat on dietary intake during a breakfast buffet.

2. Materials and methods

2.1. Subjects and study procedure

A total of 121 subjects were recruited into a larger observational study to test the relationship between oral physiology, fat perception and food selection. The selected volunteers were between the ages of 19–39 years, healthy, not pregnant, not lactating, not dieting and free from deficits in taste or smell. The subjects provided written consent and were paid for their participation. The health status and breakfast behavior of each subject were assessed via questionnaire. A detailed description of the sensory and physiological measurements (fungiform papilla count, PROP bitterness, saliva flow and saliva flow increase through oil stimulation) can be found in Nachtsheim and Schlich (2013). Overall, 116 subjects participated in the physiological tests and were divided into two groups according to FP count, saliva flow and saliva flow increase using the statistical method median split. A total of 107 subjects (80 female, 27 male) completed a food record and participated in all physiological and fat perception tests. In this group, the mean age was 23.5 (range of 19–39 years), the mean weight was 66.7 kg (range of 44.0–100.0 kg), and the mean body mass index was 22.5 kg/m^2 (range of 14.9–35.1 kg/m^2). A total of 103 subjects (76 female, 27 male) participated in the ad libitum breakfast buffet and the physiological and fat perception tests. In this group, the mean age was 23.5 (range of 19–39 years), the mean weight was 66.4 kg (range of 44.0–100.0 kg), and the mean body mass index was 22.4 kg/m^2 (range of 14.9–31.6 kg/m^2).

Sensory and physiological tests were performed in five sessions. In the first session (30 min), the sensory tests, physiological tests and food record were explained. The subjects completed the food record in the two weeks following the first session. In the second session, PROP bitterness and FP count on the tongue tip were measured (45 min). In sessions three, four and five (60 min each), unstimulated and stimulated SF were determined prior to the