Review Article

How bitter taste influences nutrition and health in primary care

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Abstract

Sensitivity to bitter tastes has a genetic basis which is partly mediated by the TAS2R3 gene. Existing research on how this gene influences dietary habits and successful strategies for encouraging the incorporation of additional fruits and vegetables into individuals' diets is discussed. We propose that knowledge of a patient's status TAS2R3 genotype could help physicians develop personalized nutritional strategies using exposure and associative conditioning techniques to encourage optimal nutrition.

Keywords: Bitter taste, chronic diseases prevention, good nutrition

Poor Nutrition is a Problem and is Associated with Chronic Diseases

More than 86% of annual spending on healthcare in the United States is due to chronic illnesses.[1] Stroke, heart disease, cancer, poor bone health, and diabetes mellitus type 2 are among the most common of these conditions, and are all costly to treat and potentially preventable. Additionally, a quarter of adults have two or more chronic health problems.[2] Poor nutrition is a significant contributor to many of these chronic diseases.[3]

Furthermore, in developed countries obesity is associated with poor nutrition (high calories, low nutrition density). About one-third of adults (36%) are obese (body mass index [BMI] $\geq$30 kg/m^2) and nearly one in six youths (17%) between the ages of 2 and 19 years are obese (BMI $\geq$ 95th percentile).[4] Childhood obesity is a serious issue in the United States and places children at risk for poor health. The prevalence of obesity increases with age from 8.9% for 2- to 5-year-olds to 17.5% for 6- to 11-year-olds and 20.5% for 12- to 19-year-olds.[4,5] Studies show that the amounts of fruits and vegetables consumed decrease from the age 2-year-old and onward, as parents serve them less frequently as a response to the reluctance to consume fruits and vegetables. The rate of obesity increases as the fruit and vegetable intake decreases with advancing in age.[6]

Dietary Intake is Associated with Multiple Factors

Food choices are governed by a multitude of complex processes, from social factors over the course of life, to mood, cost, taste, convenience, and health. In general, individuals choose foods primarily based upon flavor, costs, and convenience with flavor being the main criteria for food selection.[7] When we eat or drink something, the perception of flavor is formed mostly from the combination of retronasal smell and taste sensations coming from nose and mouth.[8] The sense of smell plays an important role in the anticipation of eating, while the sense of taste is only in effect while the foods are ingested.[8]

Taste has been described as the body's "nutritional gatekeeper"[7] and is primarily a nutrient sensing system[8] which has a prominent

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role in satiation and food intake.[9] As such, taste preferences and perceptions have a significant effect on eating behaviors. Taste perceptions varies by the individual, often depending on variations in taste receptor genes. Recently, inquiries into the genetic origins of taste and its relationship to health status and the amounts of phytochemicals in the diet has been a subject of interest.[10]

Background and Epidemiology of Tastes

The oropharynx taste system has three main purposes in humans: to determine if food is nutritious, to determine if food is safe to consume, and to prepare the digestive system to process consumed food.[11] There are five essential tastes humans are able to identify: umami, salty, sweet, sour, and bitter. The sensation of taste is mediated by the taste buds, specialized epithelial cells which are located in the oropharynx. However, taste signaling is not exclusive to the taste buds.[12] Taste receptors have also been found in tissues like trachea, bile ducts, stomach, and intestine. Their role is not yet elucidated and researchers are examining the role of the nutrients for the whole body.[12]

TAS2R3 is the most studied gene which mediates the ability to taste different bitter compounds.[13] The receptor associated with this gene responds to two bitter-tasting chemicals, 6-n-propylthiouracil (PROP) and phenylthiocarbamide (PTC).[13] The presence or absence of the TAS2R3 gene allows for the categorization of individuals as either "tasters" or "non-tasters."[13] "Tasters" are people who perceive PTC or PROP as bitter, whereas "non-tasters" perceive these compounds as tasteless.

The prevalence of bitter tasters vs. non-tasters is highly dependent on the population under consideration.[13] Nearly 100% of indigenous Americans (Native Americans and Inuits) are tasters. The prevalence of PTC and PROP tasters is greater than non-tasters.[14] Females express the taster phenotype more often than males.[14,15] It is estimated that approximately 70% of Caucasians are tasters, whereas the Chinese, Japanese, and sub-Saharan African populations have higher rates, varying between 80 and 90%.[16]

Health Implications of Bitter Tastes

PTC and PROP taster status has been found to correlate to dietary intake of several foodstuffs.[17] Earlier studies have demonstrated a positive association between perceived bitterness and PROP taste sensitivity, which is suggested to be the cause of PTC and PROP tasters lower levels of acceptance and intake of bitter fruits and vegetables (e.g., grapefruit juice, cruciferous vegetables).[18-21] The TAS2R38 genotype determines the perception of bitterness for glucosinolate, a compound found in several plants, such as broccoli, turnip, and horseradish.[22] Individuals with this genotype have been found to have a lower vegetable intake,[17,23] as well as a preference for sweet-tasting beverages and foods.[24,25]

One study showed that the non-tasters had significantly higher levels of α-tocopherol in their blood plasma than tasters since the non-tasters were eating more discretionary fats, such as salad dressings and oils, and more dark green, leafy vegetables.[26] Also, the non-tasters were not able to discern a high-fat salad dressing from a low-fat dressing.[18] Tasters tend to consume fewer calories and/or have a lower BMI than non-tasters.[27] In another study, the PROP bitter phenotype was significantly correlated with colon polyp number, after adjusting for the effect of age on the presence of colon polyps. This effect was strongest in men over 66 years of age with the older men more likely to be overweight or obese.[28]

Based upon the studies noted above, the PROP phenotype may serve as a general marker for oral sensations and food preference which affect an individual's dietary behavior and nutritionally based health.[15] Tasters have a higher sensitivity to a variety of oral stimuli, including other bitter-tasting compounds found in a diverse range of foods, including dark chocolate, black coffee, caffeine, soy, green tea, sweet substances, chemical irritants (chili or ethanol), and the texture of fats.[19,29]

In contrast to higher caloric foods, taster children consumed fewer bitter vegetables than non-taster children when offered a variety of vegetables.[30] Several studies in adults have also shown that tasters consume fewer vegetables.[23] Many of the bitter-tasting compounds in foods (e.g. flavonoids, phenols, glucosinolates) have anticarcinogenic and antionxidant properties, which could have positive effects on the health of tasters throughout their life. Also, a sensitivity to bitter tastes has been shown to be associated with higher BMI percentiles among children.[31]

Because certain beneficial foods taste bitter and might be unsavory to some patients, individual characteristics according to bitter food consumption patterns may have clinical relevance. Promoting the consumption of vegetables and fruits, particularly by increasing awareness of how perceptions of bitter taste varies for each person may be a potential strategy to promote healthier eating, since chronic disease emerge in large part from poor food choices which are in part dictated by taste preferences. Individual food adventurousness, ethnic background, socioeconomic status, environmental influence are factors that play a good role in influencing food choices and, ultimately, likes and dislikes, further masking the influence of taster status.[24]

Addressing Dietary Issues in the Primary Care Office

Clinical testing for bitter tastes?

The development of simple, office-based screening methods for determining the risk for poor nutrition may be beneficial. Because the sensation of taste is important to dietary behavior and dietary behaviors is an important determinant of good health, PROP bitterness could act as a risk marker for nutrition-related diseases.[32] PTC and PROP taster status may help to identify food preferences and consumption and is thought to be a potential genetic risk marker for some of the major diet-related chronic illnesses.[33]

To perform a bitter taste test, either PTC or PROP strips are relatively inexpensive and can be purchased online. A patient is tested after they have refrained from eating of drinking (except water) for a minimum of 30 min before the test.[16] The patient is instructed to place an edible PTC or PROP taste strip on their tongue and hold it against the roof of their mouth for 5 s before giving a response (sweet, sour, salty, bitter, or no taste).[16] Based upon the results of this test, targeted nutritional guidance may be provided.

Strategies to Improve Nutrition Intake

Childhood eating habits persist into adulthood.[34] The weaning period and young childhood present opportunities for interventions aimed at increasing consumption of fruits and vegetables, which may lower the risk of developing obesity and chronic diseases later on in life.[35] With the knowledge of the taste test status, physicians can implement more effective nutrition strategies for the patients and their families.

Childhood eating habits

Depending upon the age of the child, several strategies could be employed to maintain or enhance the nutritional value of their diet. Breastfeeding confers an advantage in the initial acceptance of specific foods, but only if mothers eat these foods regularly (more fresh dark leafy greens, vegetables and fruit). Once weaned, infants who receive repeated dietary exposure to that food, tend to eat more of it and learn to enjoy its flavor.[36] The duration of breastfeeding also positively impacts flavor preferences and intake of vegetables in childhood.

In preschool children, repeated exposure to a novel food lowers reluctance or avoidance of novel foods, otherwise known as food neophobia.[37] There were eight food exposures which increased liking for a plain vegetable as much as one that was previously paired with a preferred dip. However, for children aged two years and older, associative conditioning seems to be required to improve enjoyment of bitter vegetables since children at this age are at the height of neophobia and require the added benefit of a reinforcer to learn to enjoy bitter tastes. For the PROP tasters specifically, the use of a dip or sauce was found to result in 80% more raw broccoli consumed by preschool aged children compared to when it was served plain.[38]

Changing behaviors in adults

Exposure and associative conditioning are two methods for improving how much of a new type of food adults consume and how much they enjoy it. As with children, adults can learn to like bitter vegetables when eating with a familiar dip or sauce. College students who recalled eating vegetables only occasionally in childhood showed a greater current liking for those foods, as compared to those who never ate them.[39] This effect was present even for vegetables college students recalled disliking as children. As long as they were exposed to the vegetable in childhood, they were more likely to enjoy the vegetable in adulthood compared to those who had never been exposed.

Healthy fats (like avocado, nuts, and olive oil) or spices (and mustard, ketchup) can be used to mask the bitter taste of vegetables which can also enhance bitter vegetable acceptance in adults. Masking can be performed upon first exposure to initiate consumption, then associative conditioning can be used to promote liking and intake of the plain vegetable.

Another method to help tasters accept the vegetables is by cooking through steaming, boiling or broiling them prior to serving, which decreases the bitterness.

Conclusion

In summary, promoting good nutrition by increasing the consumption of all fruits and vegetables in children and adolescents is important. The genetically based taste preferences can be modified with age and exposure and they could help the clinician in better understanding the taste and food preference of their patients directing them toward beneficial dietary options. Patients can be educated on the understanding of their own bitter taste status and guided toward a variety of food preparation options that lead to optimum health. Here we propose a simple clinical bitter taste testing option to be considered by the well rounded family practice physician.

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Conflicts of interest

There are no conflicts of interest.

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