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6-n-Propylthiouracil sensitivity and obesity status among ethnically diverse children

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Abstract

Objective: To examine the relationship of 6-n-propylthiouracil (PROP) sensitivity to BMI while statistically controlling for demographic characteristics in two age groups of children: 9–10 years and 17–18 years (*n* 1551).
Design: Cross-sectional design with a multi-ethnic (White, African-American, Hispanic, Other) sample of 813 children aged 9–10 years and 738 children aged 17–18 years. Children were recruited from local elementary and high schools with at least 30 % minority ethnic enrolment. Children's height, weight and waist circumference were measured along with their PROP taster status. PROP was measured using two paper discs, one impregnated with NaCl (1·0 mol/l) and the other with PROP solution (0·50 mmol/l).
Results: A significant PROP sensitivity by socio-economic status (SES) interaction term ($P = 0·010$) was detected wherein supertasters had the largest BMI percentile and *Z*-score, but only among the group with highest SES.
Conclusions: The results suggest that other factors overwhelmed the influence of PROP sensitivity on adiposity in lower-SES groups. The percentage of variance accounted for by the interaction term was about 1 %. Thus, PROP supertasters had the largest BMI percentile and *Z*-score, but only among the highest-SES group.

Keywords
6-n-Propylthiouracil
Taste sensitivity
Obesity
Children
African-American
Hispanic

Obesity has become a major health problem among US children over the last 30 years(1). There is a need to examine possible causes of obesity in the hope of guiding interventions(2). Sensitivity to the bitter taste of 6-n-propylthiouracil (PROP) predicted obesity status in middle-aged women(3). PROP is chemically similar to the glucosinolates, which provide the bitter taste in cruciferous vegetables. Whether one can taste PROP is genetically influenced with some people finding the bitter taste aversive (called supertasters), others being able to taste it but not finding it aversive (medium tasters), and others not able to taste it (non-tasters)(4,5). PROP taste sensitivity has been demonstrated to relate to preference for foods(6). The findings of the relationship to adiposity, however, are contradictory. Among adult white women with mostly middle to high socio-economic status (SES), non-tasters and medium tasters were 4 to 6 BMI units heavier than the supertasters(3,7). Alternatively, no relationships were detected between PROP taster status and obesity in other mostly white samples(8). Among children of mostly higher-SES white mothers, male PROP non-tasters had a higher BMI percentile than supertasters with the opposite relationship among girls(9); while in another sample of pre-school children higher BMI *Z*-scores were found among PROP tasters than non-tasters with no gender differences(10). It is possible that the phenotypic expression of the PROP sensitivity gene may vary with age(11) or other demographic characteristics, thereby possibly explaining discrepant findings.

The present study attempted to clarify the inconsistencies in the literature, by assessing the relationships among PROP sensitivity, BMI, gender and other demographic characteristics in a large sample of ethnically diverse children at two different ages (9–10 years, 17–18 years).

Methods

Design

The study was a cross-sectional design with a multi-ethnic (White, African-American, Hispanic, Other) sample of 813 children aged 9–10 years and 738 children aged 17–18 years

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in the Houston, Texas area. A priori power analysis was based on a three-way ANOVA balanced design, with PROP sensitivity (non-tasters, medium tasters, supertasters), race/ethnicity (White, African American, Hispanic, Other) and annual household income (<\$US 30 000, \$US 30 000–59 000, ≥\$US 60 000) as factors. Given an α level of significance of 0·05, forty-seven participants in each cell (*n* 1692) and very small standardized effect sizes for main effects (0·08) and interactions (0·09), there was adequate power (≥80 %) to detect significance for all effects(12). The addition of two dichotomous factors (gender, school) had a negligible effect on the power of the sample to detect very small effects. The study was approved by the Baylor College of Medicine Institutional Review Board. The parents of all children completed informed consent and all children provided assent.

Study sample

All 9- and 10-year-old children were recruited from elementary schools and 17- and 18-year-olds from high schools with greater than 30 % ethnic minority representation from the Houston Independent School District in Houston, Texas. Children were excluded from participating for any of the following reasons: (i) no informed consent from parent(s); (ii) no informed assent from the child; (iii) medical conditions or medications that interfered with taste, diet or physical activity; or (iv) developmental limitations that affected the child's ability to understand or provide age-appropriate responses to the questions posed during phase 2 testing. The recruitment was conducted in three annual waves to efficiently use staff.

Measures

Parent-completed child information

Parents completed a family demographic questionnaire, which included information on their child's status on medical conditions or medications that interfere with taste, diet or physical activity or influence the child's ability to understand or provide responses (exclusionary criterion), household membership, and household SES status.

Anthropometrics

All child anthropometric measures were conducted at school at times arranged with school administrators (during non-academic class time for elementary school-aged children and before school hours for the high-school students). Trained and certified research staff collected all measurements using standardized protocols. Weight was measured twice using a SECA Alpha 882 scale from SECA Corporation (Hanover, MD, USA) and the two measurements averaged. Height was measured twice using a PE-AIM-101 Stadiometer from Perspective Enterprises (Portage, MI, USA) and the two measurements were averaged. BMI percentile and *Z*-scores were calculated with the computerized program from the Centers for Disease Control and Prevention (http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm) using the averaged height and weight measurements. The 85th percentile was the cut-off point for 'overweight' and the 95th percentile was the cut-off point for 'obese'.

Measurement of 6-n-propylthiouracil taster status

PROP taster status was determined using the paper screening test(4,5). This method uses two paper discs, one impregnated with NaCl (1·0 mol/l) and the other with PROP solution (0·50 mmol/l). The children were first asked to rinse their mouth with bottled water. They were then instructed to place the control disc (NaCl) on the tip of their tongue for 30 s or until the disc was completely wet with their saliva, and then spit it out. They were asked to rate the intensity of the taste using a Labelled Magnitude Scale (LMS) with ratings from 0 to 100, with descriptors of 'barely detectable' to 'weak' to 'moderate' to 'strong' to 'very strong' and 'strongest imaginable'. After they finished this first taste test and rating, they rinsed their mouth with bottled water. After 60 s they were asked to taste a second disc (PROP) and rate its taste using the same procedure and scale. Staff measured each child's markings on the LMS using a metric ruler and recorded the number for each disc. If the child rated the PROP disk ≤16·5 mm, they were classified as a 'non-taster'. Those who rated the PROP disk at ≥51 mm were classified as 'supertasters'. 'Medium tasters' fell in between. If their PROP rating was borderline at ~15 mm and they rated the NaCl disc much higher (at least a 30 mm difference on the LMS), they were classified as non-tasters; if they rated the PROP at ~67 mm and gave a much lower rating to the NaCl, they were classified as supertasters(4). Test–retest PROP assessment was performed on fifty-six participants. The test–retest correlations were 0·79 and 0·85 for NaCl and PROP, respectively. The kappa statistic measuring agreement between the time 1 and time 2 PROP categories was good ($\kappa = 0{\cdot}52$). Most (70 %) participants were classified into the same category at time 2. The remaining participants' (30 %) PROP assessment differed by one category only.

Statistical analyses

Frequencies and percentages were used to describe participants' characteristics. The χ^2 test of independence was used to investigate differences between participants included *v.* excluded from the analyses. Multifactor ANOVA were used to investigate differences in adiposity (BMI percentile, BMI *Z*-score) among the taster status groups. Since there has been some controversy about which indicator is most appropriate(13), we conducted the analyses with BMI percentiles and BMI *Z*-scores. The factors included in the model were taster status (non-taster, medium taster, supertaster), gender (male, female), age (elementary school or 9–10 years old, high school or 17–18 years old), race/ethnicity (White, African-American, Hispanic, Other) and annual household income

(<$US 30 000, $US 30 000–59 000, ≥$US 60 000). The first model (Model 1) contained the factorial main effects only. Because previous studies have shown differences in PROP taster status by gender, Model 2 investigated whether the demographic characteristics moderated any association between PROP taster status and adiposity (PROP taster status by demographic characteristic interactions). Although the main effects were forced in Model 2, a stepwise procedure with backward deletion of non-significant ($P > 0\cdot05$) PROP taster status by demographic characteristic interactions was used. Model 2 contained the main effects plus any significant PROP taster status by characteristic interactions. A third model (Model 3) explored PROP by income by gender (three-way) interaction to assess a possible gender by taster status interaction in the highest income group. Follow-up tests of simple effects were used to investigate significant interactions. The tests involved stratification by each level of the characteristic and subsequently calculating the ANOVA (minus the characteristic under investigation). Significant PROP status main effects were identified and traditional *post hoc* tests followed. Bonferroni's correction (0·05/number of tests) was used to adjust the level of significance in an attempt to control for inflated type I error in follow-up tests and *post hoc* analyses.

Results

A total of 1690 students were recruited into the study. Due to missing data for annual household income, 139 (8·2 %) students were excluded from these analyses. Participant characteristics are shown in Table 1. Results from χ^2 tests of independence yielded significant associations between inclusion/exclusion status and age group and race/ethnicity. More high school students and more Hispanic students were missing annual household income. The sample used for analyses (*n* 1551) consisted of slightly more females (58·9 %) and was nearly evenly split between elementary-school students (9–10 years old; 52·4 %) and high-school students (17–18 years old; 47·6 %). One-quarter of the sample self-identified as White (25·7 %) and nearly one-third self-identified as African-American (32·2 %) and Hispanic (30·9 %). The Other group (10·8 %) comprised children mostly of Asian or multi-ethnic heritage. Nearly two-thirds (62·0 %) of the sample came from homes with annual incomes less than $US 60 000 and nearly one-third of the students were overweight or obese (33·7 %). Almost half of the students were medium tasters (46·6 %) and one-third were supertasters (33·9 %).

Results from the multifactor ANOVA investigating differences in BMI percentile (Table 2) with main effects only

Table 1 Participants' characteristics stratified by inclusion/exclusion and BMI status: multi-ethnic sample of children aged 9–10 years and 17–18 years, Houston, Texas, USA

	Total		Included		Excluded†		Underweight/normal		Overweight/obese	
Characteristic	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Total‡	1690	100·0	1551	91·8	139	8·2	1115	66·0	575	34·0
Gender**										
Female	994	58·8	914	58·9	80	57·6	679	60·9	315	54·8
Male	696	41·2	637	41·1	59	42·4	436	39·1	260	45·2
Age group (years)*,**										
9	552	32·7	526	33·9	26	18·7	346	31·0	206	35·8
10	311	18·4	287	18·5	24	17·3	175	15·7	136	23·7
17	636	37·6	575	37·1	61	43·9	455	40·8	181	31·5
18	191	11·3	163	10·5	28	20·1	139	12·5	52	9·0
Race/ethnicity*,**										
White	429	25·4	399	25·7	30	21·6	334	30·0	95	16·5
African-American	538	31·8	499	32·2	39	28·1	342	30·7	196	34·1
Hispanic	541	32·0	480	30·9	61	43·9	297	26·6	244	42·4
Other	182	10·8	173	11·2	9	6·5	142	12·7	40	7·0
Annual household income**										
<$US 30 000	520	30·8	520	33·5	0	0·0	317	28·4	203	35·3
$US 30 000–59 000	442	26·2	442	28·5	0	0·0	278	24·9	164	28·5
≥$US 60 000	589	34·9	589	38·0	0	0·0	433	38·8	156	27·1
Missing	139	8·2	0	0·0	139	100·0	87	7·8	52	9·0
BMI status										
Underweight	27	1·6	26	1·7	1	0·7	27	2·4	0	0·0
Normal	1088	64·4	1002	64·6	86	61·9	1088	97·6	0	0·0
Overweight	275	16·3	247	15·9	28	20·1	0	0·0	275	47·8
Obese	300	17·8	276	17·8	24	17·3	0	0·0	300	52·2
Taster status										
Non-taster	331	19·6	304	19·6	27	19·4	225	20·2	106	18·4
Taster	786	46·5	723	46·6	63	45·3	531	47·6	255	44·3
Supertaster	573	33·9	524	33·8	49	35·3	359	32·2	214	37·2

*Significant ($P < 0\cdot05$) demographic differences between included and excluded participants.

**Significant ($P < 0\cdot5$) demographic differences between underweight/normal and overweight/obese participants.

†Excluded due to missing annual household income; thus income not tested.

‡Total displays row percentages whereas remaining variables display column percentages.

Table 2 Results from multifactorial ANOVA of adiposity by participant characteristics: multi-ethnic sample of children aged 9–10 years and 17–18 years, Houston, Texas, USA

	Model 1		Model 2	
	Main effects only	Multivariate effect size (η^2)	Main effects + significant interactions	Multivariate effect size (η^2)
BMI percentile	Adjusted $R^2 = 0{\cdot}07$		Adjusted $R^2 = 0{\cdot}07$	
Taster status	*F*(2,1541) = 0·33, *P* = 0·720	0·00	*F*(2,1531) = 0·29, *P* = 0·749	0·00
School	*F*(1,1541) = 6·36, *P* = 0·012	0·00	*F*(1,1531) = 6·00, *P* = 0·014	0·00
Race/ethnicity	*F*(3,1541) = 18·58, *P* = 0·000	0·03	*F*(3,1531) = 16·06, *P* = 0·000	0·03
Gender	*F*(1,1541) = 4·24, *P* = 0·040	0·00	*F*(1,1531) = 4·35, *P* = 0·037	0·00
Income	*F*(2,1541) = 3·14, *P* = 0·044	0·00	*F*(2,1531) = 5·45, *P* = 0·004	0·01
Taster by race/ ethnicity			*F*(6,1531) = 2·15, *P* = 0·045	0·01
Taster by income			*F*(4,1531) = 3·74, *P* = 0·005	0·01
BMI *Z*-score	Adjusted $R^2 = 0{\cdot}07$		Adjusted $R^2 = 0{\cdot}08$	
Taster status	*F*(2,1541) = 0·43, *P* = 0·652	0·00	*F*(2,1531) = 0·12, *P* = 0·885	0·00
School	*F*(1,1541) = 9·28, *P* = 0·002	0·01	*F*(1,1531) = 8·27, *P* = 0·004	0·00
Race/ethnicity	*F*(3,1541) = 20·04, *P* = 0·000	0·04	*F*(3,1531) = 19·78, *P* = 0·000	0·04
Gender	*F*(1,1541) = 4·78, *P* = 0·029	0·00	*F*(1,1531) = 4·74, *P* = 0·030	0·00
Income	*F*(2,1541) = 2·91, *P* = 0·055	0·00	*F*(2,1531) = 4·82, *P* = 0·008	0·01
Taster by income			*F*(4,1531) = 3·31, *P* = 0·010	0·01

Model 1: main effects only.
Model 2: main effects and significant two-way interactions; only two-way interactions of taster status by remaining characteristics tested.
Multivariate effect size (η^2): small (0·02), moderate (0·15), large (0·35)[18].
Follow-up tests for interaction effects: (i) no significant differences in BMI percentile by taster status when stratified by race; (ii) significant difference in BMI percentile between non-taster and taster (*P* = 0·06) and non-taster and supertaster (*P* = 0·008) for highest annual household income (≥$US 60 000) group only; (iii) significant difference in BMI *Z*-score between non-taster and taster (*P* = 0·002) and non-taster and supertaster (*P* = 0·002) for highest annual household income (≥$US 60 000) group only.

Table 3 Means, standard errors and effect sizes for taster status by annual household income: multi-ethnic sample of children aged 9–10 years and 17–18 years, Houston, Texas, USA

	Non-taster (NT)			Taster (T)			Supertaster (ST)			Effect size (comparisons)†		
	n	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	NT *v.* T	NT *v.* ST	T *v.* ST
BMI percentile												
<$US 30 000	93	68·8	3·17	260	66·8	1·95	167	64·4	2·37	0·06	0·14	0·08
$US 30 000–59 000	77	67·1	3·21	203	62·8	1·99	162	62·2	2·28	0·15	0·17	0·02
≥$US 60 000	134	52·1	2·78	260	63·2	1·84	195	64·7	2·06	0·36	0·42	0·05
BMI *Z*-score												
<$US 30 000	93	0·65	0·11	260	0·59	0·07	167	0·58	0·08	0·06	0·06	0·01
$US 30 000–59 000	77	0·70	0·12	203	0·43	0·07	162	0·52	0·08	0·26	0·18	0·08
≥$US 60 000	134	0·17	0·09	260	0·48	0·07	195	0·49	0·07	0·29	0·31	0.01

†Effect sizes for pairwise comparisons at each level of annual household income: small (0·20), moderate (0·50), large (0·80)[18].

(Model 1) yielded significant effects for age group (*P* = 0·012), race/ethnicity (*P* < 0·001), gender (*P* = 0·040) and income (*P* = 0·044). The unadjusted mean BMI percentile was 67·5 (SD 28·4) for the 9–10-year-olds and 62·6 (SD 28·0) for the 17–18-year-olds, with a small effect size (Cohen's *d* = 0·17) for the difference. Males had significantly higher BMI percentiles. African-American and Hispanic students had significantly (*P* < 0·001) higher BMI percentiles than White and Other students. A negative linear trend in income was observed: as income increased, BMI percentile significantly (*P* < 0·013) decreased. Similar patterns were observed for BMI *Z*-score.

Results from the multifactor ANOVA investigating differences in BMI percentile with significant PROP taster status by characteristic interactions (Model 2; Table 2) yielded a significant PROP status by race/ethnicity interaction (*P* = 0·044) and a PROP status by income interaction (*P* = 0·005). Follow-up tests of simple effects stratified by each race/ethnicity did not yield any significant PROP taster status effects. However, follow-up tests stratified by income level yielded a significant PROP taster status main effect (*P* = 0·002) for the highest income group (≥$US 60 000) only. *Post hoc* tests for PROP taster status among the highest income group yielded a significant difference between (i) non-tasters and medium tasters (*P* = 0·006) and (ii) non-tasters and supertasters (*P* = 0·008). Among students from the highest-income households, the BMI percentile of non-tasters (52·1) was significantly lower than that of medium tasters (63·2) and supertasters (64·7; Table 3). Similar results were observed when investigating differences in BMI *Z*-score. Results from Model 3 (not shown) did not yield significant PROP by income by gender (three-way) interactions for BMI percentile or BMI *Z*-score. No other significant PROP taster status main effects or effects moderated by characteristics were observed.

Discussion

There was a significant taster status by income interaction effect when either BMI percentile or BMI *Z*-score was used. This significant PROP taster status by family income interaction may explain differences in earlier findings by showing that the influence of PROP sensitivity on BMI percentile emerged only among higher-income individuals. We know of no other study that tested or found this effect. The studies demonstrating a PROP taste sensitivity to BMI relationship appeared to be mostly among higher-SES populations(3,7). This PROP taste sensitivity by income relationship suggests that other factors in the lives of the lower-income individuals overwhelmed the influence of PROP taster status on BMI percentile. The analyses indicate these other factors were not related to gender or age group, but might include food insecurity(14) or dietary restraint(15), which were not assessed here. The moderate effect sizes indicate that PROP sensitivity should be included in future research as a possible contributor to adiposity in middle- and upper-income populations, but can be omitted in research with lower-income populations.

The direction of relationship, with higher BMI percentile among medium tasters and supertasters, is opposite to that found in some studies(3,16), but congruent with the relationship shown in others(10) and different from those showing no relationship(8). Why upper-income medium tasters and supertasters would have larger BMI percentiles is not clear. A recent review of the literature on the relationship of PROP sensitivity to dietary intake and preference (JC Baranowski, T Baranowski, R Jago *et al.*, unpublished results) indicated there were no consistently empirically documented relationships which might account for dietary intake differences by PROP status. The factors accounting for this interaction term deserve more attention among upper-income samples. However, the taster status by income interaction term contributed approximately 1 % to the variance accounted for in the model, suggesting an overall weak effect.

The taster status by ethnicity group interaction term was barely significant when using BMI percentile scores, but not with BMI *Z*-scores. *Post hoc* analyses did not identify significant differences between subgroups. The main effect for ethnic group revealed the common higher BMI percentile among ethnic minority groups. The lack of an age by taster status interaction term suggests that the phenotypic expression of PROP sensitivity does not vary by age in this age range.

The substantial test–retest reliability indicates that unreliablity in PROP status assessment would not account for the different findings in our study.

The strengths of the current research include the large sample of children assessing PROP sensitivity and BMI status, with diverse multi-ethnic (African-American, Hispanic and White) and SES levels, and documentation of acceptable reliability in the field assessment of PROP status. The limitations were that the sample was from a south-western US urban population alone, used a PROP measurement protocol appropriate for field research (e.g. not the five solution protocol), and BMI was the only measure of adiposity(13,17). The significant PROP status by SES interaction term could be a chance finding, but it appears to account for differences across studies.

In conclusion, the present study documented a PROP taster status by income interaction in relationship to both BMI percentile and BMI *Z*-scores. Adiposity among PROP medium tasters and supertasters was substantially higher than in non-tasters primarily among upper-income participants. Further research needs to clarify the factors accounting for this relationship.

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