HHS Public Access
Author manuscript
Psychol Addict Behav. Author manuscript; available in PMC 2017 December 01.

Published in final edited form as:
Psychol Addict Behav. 2016 December ; 30(8): 857–867. doi:10.1037/adb0000223.

The Substitutability of Cigarettes and Food: A Behavioral Economic Comparison in Normal Weight and Overweight or Obese Smokers

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Abstract

Obesity and cigarette smoking contribute to a multitude of preventable deaths in the US and eating and smoking behavior may influence each other. The field of behavioral economics integrates principles from psychology and economics and permits systematic examination of how commodities interrelate with one another. Using this framework, the current study evaluated the effects of rising food and cigarette prices on consumption to investigate their substitutability and their relationship to BMI and associated variables. Behavioral economics categorizes commodities as substitutable when the consumption of one increases as a function of a price increase in the other. Smokers (N = 86) completed a two-part hypothetical task in which money was allocated to purchase cigarettes and fast food-style reinforcers (e.g., hamburgers, ice cream) at various prices. Results indicated that food and cigarettes were not substitutes for one another (cross-price elasticity coefficients > .20). Food purchases were independent of cigarette price, whereas cigarette purchases decreased as food price rose. Cross-price elasticity coefficients were significantly associated with confidence in one's ability to control weight without smoking (rs = −.23 and .29), but not BMI (rs = .04 and .04) or post-cessation weight concerns (rs = −.05 and .12). Perceived ability to manage weight without cigarettes may influence who substitutes food for cigarettes when quitting. In addition, given observed decreases in purchases of both commodities as food prices increased, these findings imply that greater taxation of fast food-style reinforcers could potentially reduce consumption of these foods and also cigarettes among smokers.

Keywords

smoking; weight; behavioral economics; substitution; cross-price elasticity of demand

While obesity and tobacco use are both associated with higher rates of disease, disability, and death, in combination their effects on health are multiplied (Peeters et al., 2003; Freedman et al., 2006). Reducing these risks may be challenging, in part, due to the

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interactive way in which eating and smoking may influence each other such as increased caloric intake contributing to post-cessation weight gain (Klesges, Meyers, Klesges, & La Vasque, 1989; Perkins, 1993; Filozof, Fernandez Pinilla, & Fernandez-Cruz, 2004).

Using Behavioral Economics to Understand Substitution of Goods

Consuming more calories as a function of consuming fewer cigarettes suggests that eating and smoking may be interchangeable for some individuals. The field of behavioral economics (BE) integrates psychology and economics to understand the allocation of finite resources in consumption behavior and is particularly well-suited for characterizing these relationships. The purchase of a commodity is strongly influenced by its price (Hursh 1980; Hursh & Winger, 1995), including cigarettes (e.g., MacKillop et al., 2008; MacKillop et al., 2012). More specifically, own-price elasticity reflects the changes in consumption of a commodity based on how much it costs, with elastic demand referring to purchases decreasing at rates proportionally greater than the price increase and inelastic demand referring to purchases decreasing at rates proportionally less than the price increase (e.g. Hursh, 1980, 1991, 1993; DeGrandpre, Bickel, Higgins, & Hughes, 1994). Elasticity and other facets of the demand curve are measures of the reinforcing properties of the commodity to the individual. In addition to own-price sensitivity, the availability of alternative reinforcers also affects purchasing behavior (Hursh 1984; Bickel, Madden, Petry, 1998). The type of alternative reinforcers available is important because reinforcers can interact in various ways that affect consumption. According to BE theory, commodities can be either *substitute*, *complement*, or *independent* (Hursh, 1984; Bickel, DeGrandpre, & Higgins, 1995). When two commodities are highly interchangeable, they are said to be *substitutes* (Hursh 1984; Bickel et al., 1995).

Substitutes are alternative reinforcers that can partially or wholly replace each other (e.g., coffee and tea). Two commodities are perfect substitutes when they are equally preferred and, thus, interchangeable. In contrast, *complementary* commodities generally go together and the presence of one enhances the reinforcing value (marginal utility) of the other (e.g., chips and salsa). The consumption of *independent* commodities are unrelated and do not affect each other (e.g., tea and salsa). To test the relationship between commodities, the price of one is manipulated while the price of the second remains constant and changes in purchases of both are measured. Creating a system in which two goods are available and individuals must decide how to allocate resources between them under varying conditions of constraint, allows for a direct measure of the substitutability of the two. Previous work has studied the substitutability of illicit substances by calculating cross-price elasticity (Petry & Bickel, 1998; Petry, 2000). Cross-price elasticity adds a second reinforcer to the elasticity of demand equation in order to assess how increasing the constraints on access (i.e., raising the cost) for one good will affect demand for a second reinforcer. In this context, there are three possibilities: purchases of the second item will increase (i.e., a substitute), decrease (i.e., a complement), or will be unaffected (i.e., independent). Higher cross-price elasticity, or a small price increase for one good (e.g., raising the price of chocolate cookies by $.10) producing a notable change in demand for the second good (e.g., buying twice as many oatmeal cookies), is a good indicator that there is equality between alternatives and one can readily be substituted for the other. Notably, cross-price elasticity is not always symmetrical (i.e., proportionately identical) between two commodities (e.g., if increasing the cost of cigarettes does not have the same effect on food consumption as increasing the cost of food would have on cigarette consumption).

In determining the equality between two reinforcers and the extent to which they may have symmetrical vs. asymmetrical substitution, the reinforcing value an individual gets from eating and smoking must be considered. When an individual is addicted to a drug such as nicotine or when an individual is obese, the value of a particular reinforcer (cigarettes and food, respectively) is enhanced at the expense of other reinforcers due to adaptation in neuronal circuits involved in reward, motivation, memory, and control that occur with repeated exposure to the reinforcer over time (Volkow, Wang, Fowler, & Telang, 2008). Given the enhanced value of smoking for nicotine-dependent individuals, alternate reinforcers would likely be less valued leading to few viable substitutes. However, this may not be the case for overweight or obese smokers. Research has suggested that food is a powerful reinforcer for overweight and obese individuals and the greater the severity of obesity, the more food becomes a substitute for alternative reinforcers (Epstein, Salvy, Carr, Dearing, & Bickel, 2010). For many overweight or obese smokers, who have had longstanding, problematic, patterns of use of both cigarettes and food, it may be the case that both commodities serve as similarly powerful reinforcers, facilitating greater ease of substitution between the two.

To-date, no studies have directly examined the substitutability of cigarettes and food using cross-price elasticity of demand, nor have any studies examined the extent to which substitution may vary between normal weight and obese or overweight smokers. Ultimately, examination of the substitutability of cigarettes and food may help us to understand the overconsumption of both commodities and could potentially lead to the development of more comprehensive and effective interventions. In the area of multiple behavior change, if cigarettes and food are truly substitutable for certain individuals, helping an overweight smoker increase engagement with an alternate reinforcer or activity (e.g., replacing mindless eating and smoking with something healthy or pleasurable) that is a substitute for both may result in complementary reductions in two unhealthy behaviors simultaneously. In behavioral smoking cessation treatment, suggesting substitution to an individual who finds smoking and eating similarly reinforcing, who reports willingness to tolerate post-cessation weight gain, and for whom post-cessation weight gain would likely pose little risk, may facilitate smoking cessation resulting in numerous health benefits. For other smokers, particularly those who are overweight and/or weight-concerned, identifying foods that they find highly reinforcing that could be substituted without resulting in considerable weight gain (e.g., particular fruits and vegetables, low-calorie and portion-controlled snacks) may clinically useful to facilitate cessation while reducing the likelihood of relapse due to post-cessation weight gain. Finally, individuals that report food to be a particularly poor replacement for smoking may be more likely to benefit from strategies other than substitution. In addition to clinical applications, characterizing the substitutability of cigarettes and food could be beneficial for public policy as it may inform potential consequences of food and tobacco taxation and regulatory policies.

Toward these ends, the goal of the current study was to quantify the substitutability of food and cigarettes systematically using cross-price elasticity analysis among a population of community smokers with a range of BMIs. The study had four aims: 1) to examine the cross-price elasticity of cigarettes at escalating food prices (i.e., the substitutability of cigarettes for food); 2) to examine the cross-price elasticity of food at escalating cigarette prices (i.e., the substitutability of food for cigarettes); 3) to determine whether or not there was an asymmetrical substitution effect between the two; and 4) to evaluate the extent to which substitutability was associated with BMI and weight-related variables including smoking-related weight concerns and weight efficacy after quitting smoking. Thus, the first three aims measured substitutability generally among a population of community smokers whereas the final aim sought to understand how these relationships were influenced by weight.

Method

Participants and Procedures

Cigarette smokers ($N = 86$) were recruited from the community for a smoking study. Individuals who responded to advertisements were screened by telephone. Inclusion criteria were being 18–65 years old, currently smoking 5 or more cigarettes/day, having at least an 8th grade education, and not having used illicit substances on a weekly or more frequent basis over the past 90 days. Qualifying participants were invited for an in-person assessment in which procedures were reviewed with participants and informed consent was obtained. Information was collected via self-report measures and semi-structured interviews with trained research staff. Participant characteristics are displayed in Table 1. Approximately half of the sample was characterized as overweight or obese. Participants, on average, smoked approximately a pack of cigarettes a day. Mean Fagerström Test of Nicotine Dependence (FTND) scores suggested a low to moderate level of nicotine dependence.

Assessments

Food and Cigarette Substitutability Task (FCST)—Substitutability of food and cigarettes was assessed using a two-part, hypothetical purchasing task adapted from the cigarette purchase task (Jacobs & Bickel, 1999; MacKillop et al., 2008) and the food purchasing questionnaire task (Epstein, Dearing, & Roba, 2010). Both parts of the purchasing task included both commodities and the elasticity of cigarettes and food were not assessed when each was available alone. Food and cigarettes were assigned reference prices at 100% of local market value including $1.00 per food item and $0.25 per cigarette. In order to equate prices across a variety of foods, the food items selected were all comparably priced offerings (mode = $1.00; range = $0.99 to $1.99) at local fast food restaurants. As cigarette and food prices were based on market value, the price of a single food item and a single cigarette were not equivalent; assigning both the same price would result in greater artificiality due to the large discrepancy from market value that would be required for one of the commodities. An assortment of food items (24) were selected to give participants an adequate variety of breakfast (e.g., oatmeal, French toast sticks, sausage biscuit, hash browns), lunch and dinner (e.g., cheeseburgers, chicken wrap, garden salad, chili, chicken nuggets, fries), and snack items (e.g., apple pie, chocolate chip cookies, ice cream cone) with similar caloric values (mean calories/item = 289) to mimic eating over the course of a day. The food items were presented on a paper menu which included the name and image of each food item but did not include any nutritional information. Imitation money was exchanged for pieces of paper depicting the requested number of food items and cigarettes on each trial.

The FCST had eight trials in total: four in which the price of cigarettes was held constant while the price of food items increased to 200%, 300%, and 400% of the reference price and four trials in which the price of food was held constant while the price of cigarettes increased by the same percentages. Similar paradigms have been used in the past to examine preference for and substitutability of drugs of abuse (Petry & Bickel, 1998) and healthy and unhealthy foods (Epstein et al., 2006). Participants were given the following instructions:

> *Imagine a typical day during which you are smoking and eating the amounts you usually do. Assume you have a $16 tab to spend but no cigarettes or food for the day.* [Participants given $16 in experimental cash]. *Imagine that the foods on this menu are the ones that are available for you to purchase and that the cigarettes available for purchase are your preferred brand (i.e., the brand that you usually smoke). Assume that you have access to water but NO ACCESS to any other foods than those offered on the menu at these prices. Assume you have NO ACCESS to any cigarettes or nicotine products other than those offered at these prices. Therefore, assume you have no snacks or cigarettes stashed away and that you cannot get food or cigarettes through any other source. Also, assume that the cigarettes and food you are about to purchase are for your consumption only. In other words, you can't sell them or give them to anyone else. You also can't save or stockpile food or cigarettes for another day. Everything you buy is, therefore, for your own personal consumption within a 24-hr period. I will ask you to indicate the NUMBER OF CIGARETTES AND THE NUMBER OF FOOD ITEMS you would purchase at various prices. Be sure to consider each price increment carefully and respond to the questions honestly. Remember, the total amount you spend for your daily food and cigarettes cannot exceed $16.*

Before being shown the items on the food menu, participants were assessed on motivational state variables which could influence decision-making including hunger and cigarette craving (Food: 0 (not hungry at all) – 10 (extremely hungry); Cigarettes: I crave a cigarette right now: 0 (not at all) – 10 (the strongest feeling possible)). Frequency of eating fast food (# of days: 0–30) and appeal of the menu items (Likable: 0 (extreme dislike) – 10 (like extremely); Appetizing: 0 (not at all pleasant) – 10 (extremely pleasant)) were also assessed to verify task relevance. Finally, participants were asked to indicate them menu items that they would be *most* and *least* likely to purchase. To ensure understanding, participants first completed a modified practice version of the task.

Fagerström Test of Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991)—The FTND is a 6-item measure of nicotine dependence that evaluates quantity of cigarette consumption, urges to smoke, and level of physical dependence. Scores range from 0–10 with 10 indicating a very high level of dependence. It has been shown to be both reliable and valid (Pomerleau, Carton, Lutzke, Flessland, & Pomerleau, 1994) and exhibited adequate internal reliability in this sample ($\alpha = .66$).

Body Mass Index (BMI)—Participants' height and weight were measured and recorded by the research staff. BMI was calculated using the standard formula: BMI = (weight in pounds / height in inches^2) × 703.

Post-cessation Weight Concern Scale (Borrelli & Mermelstein, 1998)—This is a 6-item scale to measure concern about post-cessation weight gain. Items range from 1 (not at all) to 10 (very) with higher scores reflecting greater anxiety regarding gaining weight after quitting smoking. It exhibited good internal reliability in this sample ($\alpha = .88$).

Weight Efficacy After Quitting (WEAQ; Borrelli & Mermelstein, 1998)—This is a 6-item scale that measures degree of confidence in preventing weight gain after quitting smoking. Items are scored from 1 (not at all) to 10 (very) with higher scores reflecting greater confidence in controlling appetite and eating post-cessation. It exhibited good internal reliability ($\alpha = .89$).

Data Analysis

Power analysis—An a priori power analysis was conducted using GPower 3 (Faul, Erdfelder, Lang, & Buchner, 2007) for repeated measures ANOVA, determining a sample size of $N = 62$, based on a within-subject effect size of $f = 0.15$ across the four price increases for each commodity, $\alpha = 0.05$ (i.e., the probability of rejecting a true null hypothesis), and power = $1 - \beta = 0.8$ (i.e., 1 – the probability of accepting a false null hypothesis).

Primary analyses—To determine demand for food and cigarettes as their prices rose, own-price elasticity (E_{own}) was calculated as previously described (e.g., Petry & Bickel, 1998; Petry, 2001). When price and consumption data for the same commodity are plotted on log-log coordinates, the slope between any two adjacent points represents E_{own}. If the slope is < −1, demand is said to be elastic, and an increase in price quickly results in a decrease in consumption. Alternatively, if the slope is > − 1, demand is said to be inelastic, and any decrease in consumption is proportionately smaller than was the increases in price. Additionally, non-linear regression was used to the examine proportion of variance accounted for (R^2) and proportionate price sensitivity (α) for the commodity whose price was being manipulated in each part of the FCST using the exponential demand equation, $\log_{10} Q = \log_{10} Q_0 + k(e^{-\alpha Q_0 C} - 1)$ (Hursh & Silberberg, 2008). In this equation, Q = consumption at a given price; Q_0 = maximum consumption (consumption at $.00); k = 1, a constant that denotes the range of consumption values in $\log_{10}$ across individuals; C = price; and α = the derived elasticity parameter which reflects the rate of decline in consumption across price.

E_{cross} (i.e., cross-price elasticity) was calculated as a quantitative index of substitutability used to determine whether increasing the price of cigarettes would result in increased consumption of food and whether increasing the price of food would result in increased consumption of cigarettes using the following equation (Petry & Bickel, 1998, Petry, 2001):

$$E_{cross}=[\log(QA2)-\log(QA1)]/[\log(PB2)-\log(PB1)]$$

In this equation QA2 is the quantity (Q) consumed of commodity A at the second of two successive prices of commodity B, QA1 is the quantity consumed of commodity A at the first of two successive prices of commodity B, PB2 is the price (P) of commodity B at the second of two successive prices, and PB1 is the price of commodity B at the first of two successive prices. Logarithm scaling was used so that when price and consumption data were plotted on log-log coordinates, the E_{cross} value was equivalent to the slope of the line between the two price points. Positive slopes (≥ 0.2) indicate that commodity A is a substitute for commodity B and negative slopes (≤ −0.2) indicate that commodity A is a complement for commodity B (Bickel et al., 1995; Petry, 2001). Slopes near zero (between −0.2 and 0.2) indicate that commodity A is independent of commodity B. Slopes ≥ 0.20 detected for E_{cross} of cigarettes at escalating food prices (E_{cross} Cig) indicate that cigarettes are a substitute for food and slopes ≥ 0.20 detected for E_{cross} of food at escalating cigarette prices (E_{cross} Food) indicate that food is a substitute for cigarettes.

Own-price and cross-price elasticities were calculated for each successive increase in cigarette or food price. Thus, three own-price (E_{own} Food) and three cross-price (E_{cross} Cig) elasticities were calculated as food prices increased in $1 increments from $1 to $4. Similarly, three own-price (E_{own} Cig) and three cross-price (E_{cross} Food) elasticities were calculated as cigarette prices increased in $0.25 increments from $0.25 to $1.

Ordinary least squares regression was used to determine the slopes of the lines that best fit the data as a measure of overall own-price and cross-price elasticities of demand. These analyses were conducted for each participant so that all participants had their own, individual-level, measure of own-price and cross-price elasticities for food and for cigarettes. When calculating slopes for individual participants, a value of 0.3 was added to all purchases so that data points of 0 could be included in analyses (DeGrandpre et al., 1993; Petry, 2000). Analyses were repeated utilizing other values (e.g. 0.01) with similar results obtained. In addition to individual-level data, the slope of the best-fitting regression line for the sample as a whole was calculated using the mean number of cigarettes and food items purchased at each price.

Two repeated measures ANOVAs were conducted to determine the effects of cigarette price on food purchases and the effects of food price on cigarette purchases. One ANOVA measured within-subject changes in food purchases across the four cigarette prices. The other ANOVA measured within-subject changes in cigarette purchases across the four food prices. Statistically significant differences in purchases along with slopes of ≥ 0.20 were required in order for cigarettes or food to be labeled a substitute (Aims 1 & 2). Significant results of repeated measures ANOVAs were followed with post hoc tests to compare differences between means at the various prices. The extent to which substitution of the two commodities was symmetrical or asymmetrical (Aim 3) was determined by comparing the slopes of the overall best-fitting cross-price elasticity of demand lines for mean number of cigarettes purchased over increasing food prices and mean number of food items purchased over increasing cigarette prices. Symmetry was indicated if the slopes of both lines were ≥

0.20 (similarly substitutable), if the slopes of both lines were ≤ −0.20 (similarly complementary), or if the slopes of both lines were between −0.2 and 0.2 (both independent of one another). Asymmetry was indicated if none of the above conditions were met, reflecting different relationships between the commodities as a function of which reinforcer price was manipulated. Finally, the degree to which BMI and weight-related variables were related to substitutability (Aim 4) was explored using Pearson's *r*.

Results

Preliminary Analyses

Participant characteristic and cross-price elasticity variables were examined for assumptions of normality. Outliers defined as Z >3.29 were Winsorized to one unit above the next highest value. There were no missing or inconsistent data on the FCST (i.e., a preference reversal in which a participant indicated wanting more rather than less of a commodity as the price increased). On average, participants reported liking the items on the food menu (*M* = 6.19, *SD* = 2.54), finding the menu items pleasant or appetizing (*M* = 6.38, *SD* = 2.63), and consuming meals or snacks from fast food restaurants on 7.92 days (*SD* = 6.96) in a typical month. The menu items that participants reported being most likely to purchase were a double cheeseburger and a bacon cheeseburger (bimodal) and the item reported as least likely to be purchased was fruit & maple oatmeal (modal) with the cheeseburgers having an average of 385 calories, 180 fat calories, and a calorie density (i.e., calorie/gram) of 2.58 compared to the oatmeal having 290 calories, 35 calories from fat, and a calorie density of 1.16. Participants' overall cross-price elasticities for food and cigarettes were neither associated with state levels of hunger (*r*s = −.01–.15, *p*s = ns), nor cigarette craving (*r*s = −.07–.14, *p*s = ns), suggesting limited influence of motivational states on hypothetical purchases on the FCST.

Behavioral Economic Analyses of Cigarette-Food Substitutability

Own-price elasticity—Figure 1 shows changes in cigarette purchases as a function of cigarette price (left panel) and changes in food purchases as a function of food price (right panel). Table 2 shows own-price elasticity of demand for cigarettes and food based on mean units purchased in the sample. For both commodities, demand was found to be inelastic (slopes > −1), with increases in price associated with proportionately smaller changes in purchases. The exponential equation (Hursh & Silberberg, 2008) to assess demand for cigarettes based on average number of cigarettes purchased at each price, indicated that $R^2 >$ 0.99, $\alpha = 0.03$. Similarly, demand for food based on average number of food items purchased at each price indicated that $R^2 > 0.99$, $\alpha = 0.02$. The price sensitivity parameter (α) was suggestive of inelasticity for both commodities and R^2 suggested goodness of fit based on accounted for variance.

Substitution of food for cigarettes—The left panel of Figure 1 shows food purchases at each cigarette price. A repeated measures ANOVA with a Huynh-Feldt correction determined that, on average, as cigarette prices rose, food purchases decreased with a medium effect size ($F(2.37, 201.82) = 8.63$, $p < .01$, $\eta^2 = .09$). Post hoc tests using a Bonferroni correction revealed that the number of food items purchased in the $.50, $.75, and $1 cigarette price conditions differed significantly from the number purchased in the $.25 reference price condition (*p*s ≤ .01). Forty-three participants (50%) substituted food for cigarettes at one of the three cigarette price increases based on cross-price elasticities calculated for each participant at successive prices. The percentage of participants whose E_{cross} values suggested substitution at each price increase is shown in the right column of Table 2. The number of participants substituting food for cigarettes increased as cigarette prices escalated, with nearly a third of participants substituting food for cigarettes when cigarette price rose to $1.

When considering cross-price elasticities for the sample determined by mean number of food items purchased at each cigarette price (Table 2), the relationship between cigarette price and food purchases was categorized as marginally complementary at one of the price increases and considered independent at the other two. At the final price increase to $1 per cigarette, the positive cross-price elasticity coefficient reflected a tendency to consume more food items when the cost of cigarettes was very high. The slope of the best-fitting line based on mean food items purchased suggested that the number of food items purchased was predominantly independent of cigarette price.

Substitution of cigarettes for food—The right panel of Figure 1 shows cigarette purchases as a function of food price. Examination of cross-price elasticity for cigarette purchases as food price increased using repeated measures ANOVA with a Huynh-Feldt correction suggested that, on average, as food prices rose, cigarette purchases decreased with a medium-to-large effect size, (F(2.54, 215.97) = 26.04, $p < .01$, $\eta^2 = .23$). Post hoc tests using a Bonferroni correction revealed that the $2, $3, and $4 food price conditions differed significantly from the $1 reference price condition (*p*s ≤ .04). Cross-price elasticities for individual participants' purchases at adjacent price points indicated that 31% of the participants substituted cigarettes for food at one of the three food price increases. The percentage of participants whose E_{cross} value suggested substitution at each price increase is shown in the right column of Table 2. The number of participants substituting food for cigarettes remained fairly consistent across price increases.

When considering cross-price elasticity based on mean number of cigarettes purchased at the four food prices, the relationships varied across price conditions. At low food prices, the relationship between food price and cigarette consumption was found to be independent (Table 2). However, at the subsequent price increases, cigarettes were found to be a complement to food items, with the number of cigarettes purchased decreasing along with the number of food items purchased. The slope of the best-fitting line determined by mean number of cigarettes purchased at each price, suggested that cigarettes were a complement to food rather than a substitute for it.

Symmetry of substitutability—Overall, the price of cigarettes significantly affected the purchase of food and the price of food significantly affected the purchase of cigarettes. As price of food increased, both cigarette and food purchases decreased significantly. Cigarettes were a complement to food, with the overall number of cigarettes purchases decreasing by 7.31 cigarettes over the course of three food price increases and an overall E_{cross} value of −0.25. In contrast, as the price of cigarettes rose, food purchases decreased only slightly, by

1.08 food items, over the course of three cigarette price increases. The overall E_{cross} value of −0.14 indicated that, as cigarette prices increased, food purchases were independent rather than substitutes or complements. Thus, there was an asymmetrical effect detected between cigarettes and food. Cigarette consumption decreased as food became more expensive but food consumption was unrelated to cigarette price.

Associations with BMI and Weight-Related Variables

While substitutability analyses were conducted across the entire sample, subsequent analyses were conducted to determine the extent to which BMI or other weight-related variables may influence results. Associations between BMI, concern about post-cessation weight gain, and weight efficacy after quitting smoking with cross-price elasticity are shown in Table 3.

BMI—BMI was significantly associated with post-cessation weight concerns but was unrelated to cross-price elasticity, nicotine dependence, daily cigarette consumption, and weight efficacy after quitting. Individuals with greater BMIs were more likely to endorse using cigarettes to control their weight and being concerned about gaining weight as a result of quitting. BMI was not associated with cross-price elasticity at any price increase for cigarettes or food, nor was it associated with the overall slopes of the best-fitting E_{cross} lines (rs = −.18 - .14, ps = ns).

Post-cessation weight concern—In addition to individuals with higher BMIs endorsing greater concern regarding gaining weight after quitting smoking, increased cessation-related weight concern was also associated with having lower perceived ability to manage one's weight without cigarettes post-cessation. Smoking cessation-related weight concern was not significantly associated with tendency to substitute or other baseline smoking behaviors.

Weight efficacy after quitting—Weight efficacy after quitting smoking was significantly associated with cross-price elasticities for both cigarettes and food. Specifically, individuals who reported greater confidence in their ability to quit smoking without gaining weight or eating more than usual had higher E_{cross} values for food (i.e., more likely to increase food purchases as the cost of smoking rose) and lower E_{cross} values for cigarettes (i.e., less likely to increase cigarette purchases as the cost of food rose). Finally, those who reported having the lowest self-efficacy in their ability to manage their weight and appetite without cigarettes were the individuals who smoked the most heavily and were the most dependent on nicotine.

Discussion

The goal of the current study was to explore the cross-price elasticity of demand for cigarettes and food in order to determine the extent to which the two goods were substitutable for each other in a sample of community cigarette smokers. In addition, this study also sought to understand the extent to which these relationships varied based on BMI and related variables including level of concern about post-cessation weight gain and confidence in one's ability to prevent weight gain after quitting smoking. Findings did not suggest substitution of either commodity. Relationships varied based on self-efficacy in controlling weight without cigarettes but not BMI or weight concerns.

Own-Price Elasticity of Demand

The results of the study showed own-price elasticity of demand was inelastic for both food and cigarettes. Demand for necessities such as food and water tends to be inelastic (i.e., less sensitive to price increases) whereas demand for non-essential goods and luxuries tends to be more elastic (i.e., more sensitive to price increases). Despite this, it is likely that many smokers perceive cigarettes as more of a necessity than a luxury, resulting in inelastic demand. Indeed, estimates of elasticity of demand for tobacco in the United States suggest inelasticity with a 10% cigarette price increase resulting in only a 2.5–5% decrease in smoking (Chaloupka, Hu, Warner, Jacobs, & Yurekli, 2000). The largely inelastic nature of demand for both cigarettes and food suggests persistence in purchasing both commodities despite escalating costs.

Substitution of Food for Cigarettes

Despite statistically significant differences in food purchases at rising cigarette prices, food was not determined to be a complement or a substitute for cigarettes, overall. While there were slight decreases in the number of food items purchased during the first two cigarette price increases, following the third price increase there was a slight increase in the number of food items purchased. It is possible that the change in the left-most digit of the cigarette price (i.e., the digit in the furthest position to the left of the price changing from “0” to “1” at the $0.75 to $1.00 price increase) may have contributed to this difference given previous research suggesting that the left-most digit of cigarette price may wield disproportionate influence on purchasing behavior (MacKillop et al., 2012; MacKillop et al., 2014; MacKillop et al., 2015). As such, the increase in food purchases observed at the $1 cigarette price may represent a cross-over point at which a preference for food rather than cigarettes begins to emerge. Nonetheless, since there were no further price increases on the FCST, it is impossible to determine the extent to which this initial shift toward increased food purchases would have persisted to result in a positive slope for food purchases and eventual substitution.

Another related possibility for the lack of substitution of food for cigarettes observed in the present study is that individuals will not substitute food for cigarettes until they have reached their breakpoint (i.e., the point at which cigarette purchases are reduced to zero). It is possible that as individuals decide that the cost of smoking is too great to purchase even one cigarette, they would elect to buy additional food items instead. Past research on substitutability has demonstrated that reducing heroin purchases to zero by pricing bags of heroin to exceed available experimental income, resulted in increased purchases of available alternative drugs (Petry & Bickel, 1998). As the current study did not force consumption of cigarettes to zero by design, the majority of participants did not reach their breakpoints and they continued to purchase cigarettes even when priced at $1 each. It is possible that the tendency for substitution may reflect a breakpoint-specific phenomenon, but it is equally possible that many individuals would report purchasing approximately the same number of food items, even after they have decided to forgo smoking. Due to the small proportion of individuals whose consumption was suppressed to zero, it is not possible to draw any conclusions at this time and further research is needed to explore whether higher cigarette prices, and cigarette prices surrounding one's breakpoint, would result in increased food purchased. Alternatively, it is possible that the tendency for increased food consumption while quitting smoking is predominantly a function of other factors that motivate acquisition and consumption (e.g., craving, emotion) rather than BE factors.

Substitution of Cigarettes for Food

Overall, participants did not increase their cigarette smoking as food became more expensive. There was a statistically significant decrease in cigarette purchases as food prices rose and cigarette consumption fell by more than 40% as food prices increased. The majority of participants continued to buy food items from the FCST menu despite high costs. Rather than increasing their smoking as an alternative to eating or to curb their appetite, participants decreased their cigarette purchases considerably. In fact, at the final price of $4 per food item, 14 participants (16%) elected to spend their entire tab on food with the consequence of cigarette consumption being reduced to zero. This suggests that over a 24-hour period in which there are limited resources to allocate to food and cigarettes, smokers may be more inclined to satisfy their hunger and food cravings rather than their cravings for cigarettes. This is consistent with research that suggested that female smokers deprived of both food and cigarettes in an experimental context showed an initial preference to work for food reinforcers (Epstein et al., 1991). Results of past experimental research have also suggested that individuals who were deprived of both nicotine and food for several hours were more likely to smoke during a self-administration period in a laboratory than were individuals who had been deprived of nicotine alone (Leeman, O'Malley, White, & McKee, 2010). In this study, participants were given the choice to smoke or to receive monetary reinforcement rather than the choice to smoke or eat. Finally, in a study involving overnight abstinence from food and smoking or from food alone, participants were given the choice of working to earn food or monetary reinforcers. There was no overall main effect of smoking on the reinforcing value of food; participants chose food reinforcers over monetary ones to a similar extent regardless of whether they had recently smoked (Perkins, Epstein, Fonte, Mitchell, & Grobe, 1995). Therefore, abstaining from food appears to have increased the value of cigarettes whereas abstaining from cigarettes did not affect the reinforcing value of food. This may speak to the largely inelastic nature of demand for food (i.e., relatively insensitive to price changes) given its necessity for survival and its potency as a primary reinforcer with innate biological value. Results of the current study suggest the persistence of food purchases despite escalating costs and at the consequence of cigarette smoking, with no influence of self-reported hunger or cigarette craving on FCST performance.

Influences of BMI and Weight-Related Variables

Contrary to prediction, BMI was not significantly associated with cross-price elasticities. Overweight and obese smokers' performance on the FCST did not differ significantly from that of normal weight smokers. Although research has suggested that overweight and obese smokers may gain more weight than average upon quitting smoking (Lycett, Munafò, Johnstone, Murphy, & Aveyard, 2011), results of the current study do not support the substitution of food for cigarettes as contributing to this weight gain. Instead, it may be that a cluster of unhealthy behaviors and problematic traits are exacerbated by the quitting process and lead to weight gain. While overweight and obese smokers did not differ from normal weight smokers with regard to nicotine dependence, they did report greater concern about post-cessation weight gain including endorsing a greater likelihood of going back to smoking after quitting if they gained too much weight, as has been reported previously (Pomerleau & Sales, 2007; Levine, Bush, Magnusson, Cheng, & Chen, 2013). Given that the excess weight gain typically experienced by overweight and obese smokers can reduce the health benefits gained from smoking cessation (Chinn et al., 2005), strategies to assist this population are crucial. Surprisingly, despite heavier individuals reporting more concern about managing weight without cigarettes, there was no association between BMI and weight self-efficacy after quitting. Thus, while overweight and obese smokers were more anxious about gaining weight, their perceived weight management abilities without cigarettes were similar to those of smokers without weight problems. Since it appears that many overweight and obese individuals may, in fact, have greater difficulty managing their weight after quitting smoking, helping to keep self-efficacy high and working with individuals to combat weight gain directly is likely to be beneficial. Augmentation of smoking cessation treatment with combined pharmacotherapy may be beneficial such as naltrexone plus bupropion which has been shown to have some promising effects on weight loss (Greenway et al., 2010) and to decrease nicotine use without significant cessation-related weight gain (Wilcox et al., 2010).

Weight efficacy after quitting smoking was associated with a multitude of other study variables including smoking and nicotine dependence and overall cross-price elasticity of demand for both cigarettes and food. First, it is notable that those who tended to smoke more cigarettes and who were more dependent on nicotine had lower perceived efficacy in managing their weight, although they did not report being more concerned about weight gain per se. One possibility for this is that those who are more dependent on cigarettes have greater difficulty quitting smoking, and are more likely to believe that they will need to use food as crutch to do so. As a result, they are not very confident they could quit smoking without eating more and gaining weight. Another possibility is that those who smoke more heavily and are more dependent on nicotine have greater insight into the likelihood of gaining weight after quitting. There is some evidence to support that insight into one’s ability to prevent cessation-related weight gain is incredibly important as research has indicated that, in a clinic-based smoking cessation program, weight efficacy prospectively predicted weight gain even after controlling for BMI, baseline smoking, and other relevant variables (Borrelli & Mermelstein, 1998).

Self-efficacy at controlling weight without cigarettes was also shown to be associated with elasticity of demand on the FCST. Those with higher post-cessation weight self-efficacy also had higher cross-price elasticity of demand as cigarette prices rose (e.g., more likely to substitute food). If individuals feel confident that they will be able to manage their weight, there may be less of a barrier to substituting food when the cost of smoking becomes too great. In contrast, individuals with less confidence in their ability to manage their weight without cigarettes may be hesitant to substitute food, for fear of weight gain. Weight-concerned women report being highly intolerant of cessation-related weight gain (Levine, Perkins, & Marcus; 2001) and, therefore, may logically reject substituting food. Finally, individuals with less confidence in their ability to effectively manage their weight, appetite, and eating without cigarettes, were more likely to increase their cigarette purchases as the cost of food rose during the FCST. Logically, if individuals who are not confident that they could control their appetites or eating without cigarettes report purchasing fewer food items as costs increase, they may perceive a greater need to purchase more cigarettes to replace the food items and manage their appetites and cravings.

Limitations and Considerations

The lack of substitution observed overall in the current study was somewhat surprising given the well-established phenomenon of post-cessation weight gain (Klesges et al., 1989). In general, the FCST suggested that food and cigarettes were not viable substitutes for each other given price constraints. Consistent with previous BE studies that developed substitutability tasks to answer specific empirical questions among drug abusers (Petry & Bickel, 1998; Petry, 2000; Petry, 2001), the substitutability task in the present study was designed for the purpose of the present investigation rather than widespread use and, thus, has not been extensively validated like the Monetary Choice Questionnaire (Kirby, Petry, Bickel, 1999) and many other BE measures. The hypothetical nature of the assessment is another limitation. While previous research has demonstrated close correspondence between hypothetical and actual behavior using purchases tasks (Amlung, Acker, Stojek, Murphy, & MacKillop, 2012), the FCST used a similar but distinct BE paradigm. The extent to which preferences reported would have matched actual behavior has not been tested. Similarly, it should be noted that individuals were given only one option on the FCST regarding the type of cigarettes available to purchase (i.e., their preferred brand) but a variety of options for the types of foods available to purchase (i.e, a menu of items). Thus, while each cigarette purchased reflected an identical commodity, this was unlikely to be the case with food purchases. The task was designed in this manner to maximize external validity as, over the course of 24 hr, smokers are unlikely to consume a variety of brands of cigarettes but are likely to consume a variety of food items (rather than eating the same food at every meal). While the variety of food options available was meant to be similar to the many enticing, low-cost, and easily accessible food options available to consumers, it is possible that the heterogeneity of food options in comparison to the one cigarette option (i.e., “preferred brand”) resulted in increased preference for food items over cigarettes. As this study was the first to directly assess cross-price elasticities of food and cigarettes, testing the reliability of these findings using other amounts of experimental income, as experimental income has been shown to influence elasticity (DeGrandpre et al., 1993; Koffarnus, Wilson, Bickel, 2015), other food alternatives, and in other populations of smokers (e.g., adolescents, smokers with eating pathology) are important next steps. While recency of smoking and eating was not associated with substitutability in this investigation, under greater conditions of deprivation, it is possible that these relationships would have varied. This is an important future direction to test as consumption patterns for food and cigarettes can vary widely in response to craving and affective changes that may accompany a period of deprivation. Thus, the conclusions here should be understood to reflect only the effects of *price* on purchases of the commodities given limited income and the desire to allocate resources toward both cigarettes and food.

Public Policy Implications

The finding that cigarettes tended to be a complement to food may be an important discovery given the relative harm caused by both smoking and poor diet. Research has suggested that poor diet/physical inactivity may soon overtake tobacco as the leading cause of preventable death in the Unites States (Mokdad, Marks, Stroup, & Gerberding, 2004). As a result, there has been a call to use methods shown to be beneficial in reducing smoking in the United States, such as taxation, to reduce escalating rates of national overweight and obesity (Garson & Engelhard, 2007). All items available for purchase on the FCST were those available at local fast food restaurants at relatively low cost (i.e., market value $0.99–$1.99) and the two most popular items contained many calories, grams of fat, and had high energy densities. The rationale for taxation on soft drinks, snack foods, and/or fast-food is based on a variety of factors including the economic costs of obesity to society, evidence linking the consumption of these foods to the obesity epidemic, and studies on price elasticity of snack foods suggesting the tax could raise a considerable amount of funds for obesity prevention programs (Kim & Kawachi, 2006). Nonetheless, it has been suggested that "the direct health benefits from reduced consumption of junk foods though taxes might be offset by the substitution of these foods with… harmful non–dietary health behaviors, such as smoking" (Kim & Kawachi, 2006, pg. 434). The current study did not support this potential consequence. In fact, there was a 42% decrease in cigarette consumption reported, on average, when comparing the number of cigarettes purchased when food was $1 to when it was $4, despite the price of cigarettes remaining constant. Interestingly, more participants discontinued smoking completely when food was 400% of market value ($4/item) than when cigarettes were 400% of market value ($1/each), 16% versus 6%, respectively. While the menu items were rated to be appetizing and consumption of these items may have hedonic value, it must be noted that food is primary reinforce necessary for survival, which likely contributed to its inelasticity. While research on the economic feasibility and cost-to-benefit ratio of taxation on foods thought to contribute to the obesity epidemic is needed before any policy implementation, the results of the present study suggest that such a tax could reduce the consumption of both fast-food-style reinforcers and cigarettes among community smokers.

Conclusions

Contrary to prediction, this study found that cigarettes and food were not substitutable for each other. Instead, cigarette consumption decreased as food prices went up and food purchases remained similar regardless of cigarette price. Relationships did not vary based on BMI. Instead, self-efficacy for managing one's weight without cigarettes was found to be associated with baseline smoking behavior and task performance. Individuals who reported higher weight efficacy after quitting smoking smoked fewer cigarettes and were less dependent on nicotine. In addition, those who believed they could control their weight without smoking were less likely to substitute cigarettes for food and more likely to substitute food for cigarettes. Future research exploring whether various approaches (e.g., motivational interviewing, teaching effective weight control strategies prior to smoking cessation) can increase self-efficacy to manage one's weight without cigarettes, whether increasing weight self-efficacy after quitting can facilitate the successful replacement of cigarettes with food substitutes, and whether this would promote higher rates of cessation are important future directions.

Acknowledgments

This research was supported in part by NIH grants R21 DA031269, P30 DA027827, and T32 DA016184, and by the Peter Boris Chair in Addictions Research.

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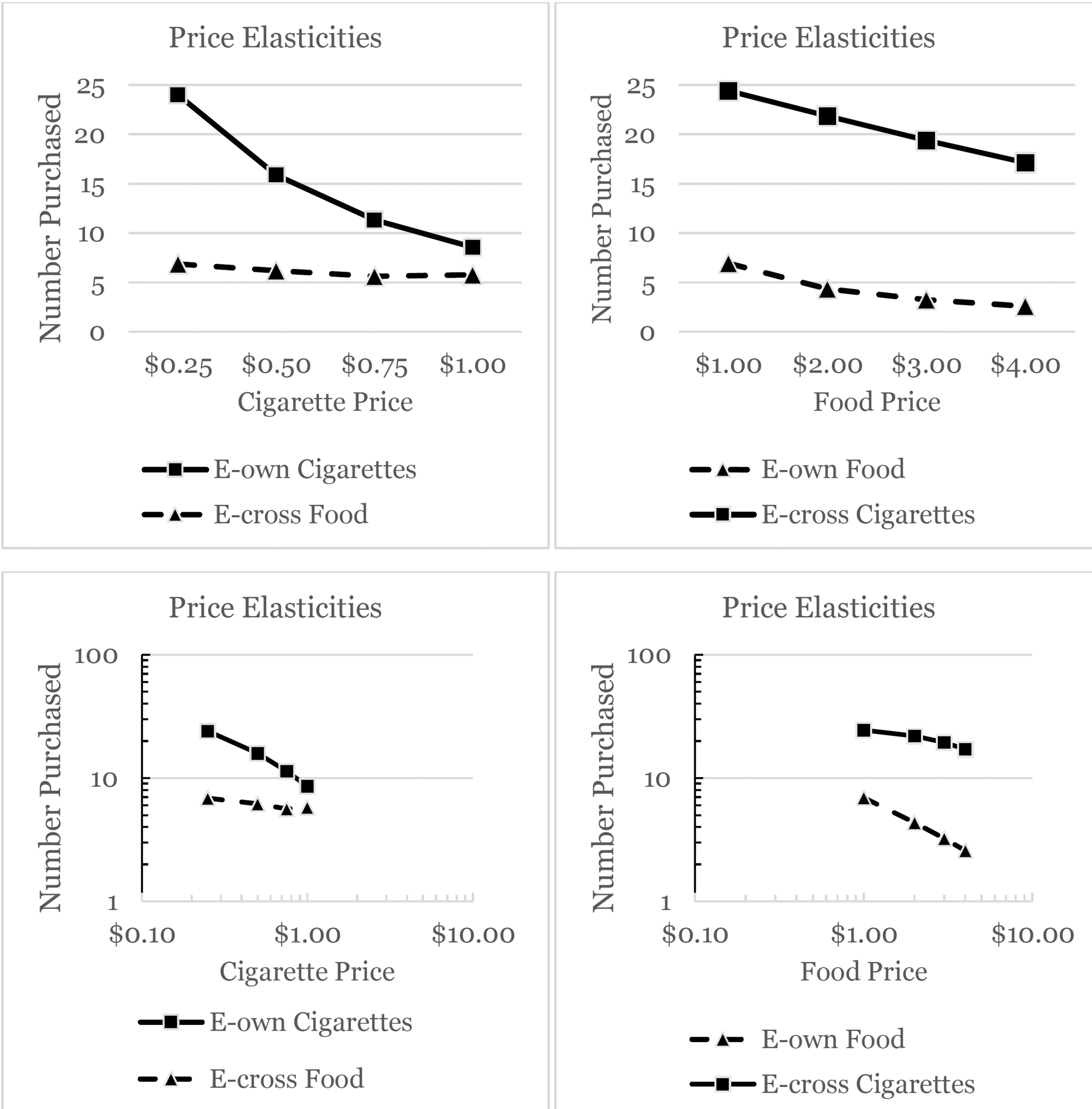

Figure 1.

(Left panel) Mean units of cigarettes and food items purchased as cigarettes increase in price from $0.25 to $1 per cigarette. (Right panel) Mean units of cigarettes and food items purchased as food increases in price from $1 to $4 per food item. *Note.* Prices on x-axes reflect reference prices of cigarettes ($0.25) and menu items ($1.00) based on local market values of both commodities and subsequent increases of 200%, 300%, & 400% across trials. E-own reflects elasticity of demand for the commodity for which price is being manipulation. E-cross reflects cross-price elasticity of demand for the second commodity whose price has not been altered. Bottom two figures plotted on log-log axes.

Table 1

Baseline Participant Characteristics

Characteristic	Mean *(SD)* or Percentage
Male	62%
Race	
White/Caucasian	62%
Black/African American	33%
Asian/Pacific Islander	1%
Multi-racial	2%
Other race	2%
Annual household income	
$0–$14,999	50%
$15,000–$29,999	29%
$30,000–$44,999	11%
$45,000 +	11%
Age	39.2 (12.2)
Years education	13.0 (2.1)
Cigarettes/day	18.0 (9.3)
Fagerström Test of Nicotine Dependence total	4.8 (2.5)
Body Mass Index	27.6 (6.7)
Underweight (BMI < 18.5)	1%
Normal weight (BMI 18.5–24.9)	48%
Overweight (BMI 25.0–29.9)	20%
Obese (BMI ≥ 30)	31%
Post-cessation weight concern total	25.8 (15.0)
Weight efficacy after quitting smoking total	35.4 (13.3)

Note. Combined percentages differ from 100% in some instances as a result of rounding.

Table 2

Own-price and cross-price elasticity coefficients for mean units purchased as price increases and percentage of participants found to substitute at each price increase

Food Price	Cigarette Price	Own-price elasticity	Cross-price elasticity	% Substituting
$1.00	$0.25		-	-
$2.00	$0.25	−0.67	−0.16	13%
$3.00	$0.25	−0.72	−0.30	10%
$4.00	$0.25	−0.79	−0.43	16%
Slope of the best-fitting line		−0.71, $p < .01$	−0.25, $p = .02$	-
$1.00	$0.25		-	-
$1.00	$0.50	−0.60	−0.15	10%
$1.00	$0.75	−0.83	−0.23	19%
$1.00	$1.00	−0.97	0.10	31%
Slope of the best-fitting line		−0.73, $p < .01$	−0.14, $p = .05$	-

Table 3

Correlations between smoking and weight variables with cross-price elasticity of demand for cigarettes and food

	FTND	BMI	Cigs/Day	Concern	Efficacy
E_{cross} Food BFL	−.08	.04	−.12	−.05	**.29**
E_{cross} Cig BFL	.04	.04	.10	.12	**−.23**
FTND	-	.09	**.66**	.17	**−.33**
BMI	-	-	.13	**.37**	−.01
Cigs/Day	-	-	-	.18	**−.44**
Concern	-	-	-	-	**−.30**

Notes. E_{cross} = Cross-price elasticity of demand; BFL = slope of best-fitting line; BMI = Body Mass Index; FTND = Fagerström Test of Nicotine Dependence total score; Concern = Post-cessation weight concern total score; Efficacy = Weight efficacy after quitting smoking total score;

Bolded correlations significant $p < .05$.