Contemporary Clinical Trials Communications 10 (2018) 154–160

Contents lists available at ScienceDirect

Contemporary Clinical Trials Communications

journal homepage: www.elsevier.com/locate/conctc

Study design for a clinical trial to examine food price elasticity among participants in federal food assistance programs: A laboratory-based grocery store study

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ARTICLE INFO

Keywords:
Price elasticity
Food assistance
Egg
Obesity
Social status
Stress

ABSTRACT

We present a protocol for a study investigating the effect of food price changes on purchasing decisions among individuals participating in federal food assistance programs and among those not participating in these programs. We use a laboratory-based grocery store design, which provides greater control over factors influencing food purchasing than *in situ* experiments in actual grocery stores. We focus primarily, but not exclusively, on eggs because they are highly nutritious, easy to prepare, can be included in many different dishes, and are a part of a wide range of cultural food menus. The primary aim of this study is to compare the own-and cross-price elasticity of eggs between individuals participating in federal food assistance programs and those not participating in these programs. Our secondary aims are to 1) compare the own- and cross-price elasticity of eggs between overweight/obese individuals and non-overweight/obese individuals, 2) examine whether delay discounting moderates the effect of income on own- and cross-price elasticity, 3) examine whether subjective social status moderates the effect of participation in federal food assistance programs on the purchase of high nutrient-dense foods, and 4) examine whether usual psychological stress level moderates the effect of subjective social status on the purchase of high-nutrient dense foods. The results of this study will provide information about the drivers of food demand among low-income adults. A better understanding of these drivers is needed to develop effective nutrition interventions for this large population.

1. Introduction

Evidence from diverse study designs demonstrates that the effect of food price on consumer food demand varies widely across food types [1,2]. This effect can be expressed as a *price elasticity*, which is a metric that represents the change in demand of a given food per unit change in its price (*own-price elasticity*) or per unit change in the price of other foods (*cross-price elasticity*).

For low-income individuals with limited food budgets, the cost of healthy foods may limit their purchase of these items. Individuals from low-income households, even those participating in federal food assistance programs, consume poorer quality diets [3–6] and have higher rates of cardiometabolic mortality [7] compared to their higher income counterparts. Epstein et al. [8] demonstrated that lower-income individuals purchase fewer healthy foods when their price increases compared to higher income individuals, demonstrating that income is an important mediator of price elasticity. Continued efforts are clearly needed to improve diet quality among low-income populations.

Moderate diet and lifestyle changes are more easily adopted and sustained than more dramatic changes, and can lead to meaningful health gains [9–12]. In line with this principle, low-income individuals may benefit from clinical counseling to make gradual dietary improvements, rather than changing their diet patterns all at once. This could take the form of incrementally increasing consumption of targeted healthy foods in place of certain unhealthy foods. Eggs are a good candidate for this targeted approach because they are rich in many important nutrients [13–15] and increase the bioavailability of some co-consumed nutrients like carotenoids [16] and vitamin E [17]. Eggs are also easy to prepare, can be included in many different dishes, and are part of a wide range of cultural food menus [18].

However, egg prices are among the most volatile of all major food groups [19,20]. For example, egg prices increased by 18% in 2015 but

Abbreviations: 24HR, 24-h Recall; BMI, Body Mass Index; NHANES, National Health and Nutrition Examination Survey; NRF, Nutrient-rich Foods Index; USDA, United States Department of Agriculture; SNAP, Supplemental Nutrition Assistance Program; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; WWEIA, What We Eat In America

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https://doi.org/10.1016/j.conctc.2018.05.011
Received 25 January 2018; Received in revised form 1 May 2018; Accepted 4 May 2018
Available online 07 May 2018

decreased by 21% in 2016 [19]. Andreyeva et al. [1] found that the demand for eggs changed by 2.7% for every 10% change in price. More recently, Afshin et al. showed that a 10% decrease in price can increase consumption of healthy foods by 12%, but did not include eggs in their analysis [2]. To the best of our knowledge, no studies have compared the own- and cross-price elasticity of eggs between low-income Americans participating in federal food assistance programs and their higher income counterparts. A better understanding of the price elasticity of eggs, and the individual level factors that drive healthy food purchases, is needed to tailor nutrition interventions for the 55 million low-income individuals who participate in federal food assistance programs like the Supplemental Nutrition Assistance Program (SNAP) and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). The effectiveness of educational interventions, such as SNAP-Ed and WIC counseling, may be enhanced if their curriculums addressed some additional key factors that influence individuals' decisions to purchase healthy foods.

To address this research gap, we use a laboratory-based grocery store experiment, which has precedent in previous studies [8,21–23]. Compared to *in situ* experiments in grocery stores, laboratory analogues provide greater control over factors that influence purchasing, such as in-store advertising, resulting in enhanced internal validity [24] while providing high external validity based on strong relationships between lab simulation tasks and actual supermarket purchases [25].

2. Study aims and hypotheses

2.1. Primary aim

The primary aim of this study is to compare the own-and cross-price elasticity of eggs between individuals participating in federal food assistance programs (*program participants*) and those not participating in these programs (*non-participants*). We hypothesize that the own- and cross-price elasticity of eggs will be greater among program participants compared to non-participants, meaning that program participants' food demand will be more responsive to changes in price.

2.2. Secondary aim 1

In a laboratory-based grocery store experiment, when the price of less healthy foods increased, leaner mothers increased their purchases of healthier foods to a greater extent than obese mothers [23]. This suggests that obesity status is a moderator of price elasticity, such that obese individuals are more resistant than non-obese individuals to price change schemes that are designed to improve diet quality. We therefore hypothesize that the own- and cross-price elasticity of eggs will be greater among non-overweight/obese individuals compared to overweight/obese individuals.

2.3. Secondary aim 2

A lack of financial resources can shift attention from planning for future demands to attending to immediate concerns resulting in a lack of future time perspective, and can increase the likelihood of meeting more immediate smaller needs at the expense of not meeting larger delayed needs, a concept known as *delay discounting* [26]. For these individuals, a disproportionate focus on current demands at the expense of planning for the future can prevent them from setting and achieving long-term goals such as improving their food security, diet quality, and health status [27]. We hypothesize that the own- and cross-price elasticity of eggs will be greater among program participants who attend to the present and discount the future, compared to those who those who discount the present and attend to the future.

2.4. Secondary aim 3

Subjective social status is defined as an individual's perceived position in the social hierarchy, and can have a greater influence on health behaviors and outcomes compared to more objective measures [28,29]. Cheon and Hong [30] found that individuals with lower subjective social status exhibited greater appetite, consumption of high energy-dense foods, and energy intake compared to individuals with higher subjective social status. In the present study, we hypothesize that, among program participants, high nutrient-dense food purchases will be greater among individuals with high subjective social status compared to individuals with low subjective social status.

2.5. Secondary aim 4

Previous research has demonstrated that the level of psychological stress may moderate the association between subjective social status and negative health outcomes such as obesity [31]. We hypothesize that high nutrient-dense food purchases will be higher among individuals with lower levels of reported usual stress and high subjective social status compared to individuals with higher levels of usual stress and high subjective social status.

3. Materials and methods

3.1. Study design

This study utilizes a three factor design, with one between-subject factor and two within-subject factors (Fig. 1). The between-subject factor is participation in a federal food assistance program. Based on self-reported data collected during the screening phase, subjects are assigned to two groups: food assistance program participants (n = 40) and non-food assistance program participants (n = 40). The within-subject factors are price change condition and price change scenario. In one price change condition, the price of eggs varies while the price of all other foods remains constant (own-price elasticity); and in the second price change condition the price of other foods varies while the price of eggs remains constant (cross-price elasticity). Within each price change condition, subjects complete three price change scenarios in which the price of eggs or other foods (depending on the price change condition) is set at the reference price or varies by −25% and +25% of the reference price (reference prices were collected from a local supermarket). These price change scenarios are based on previous studies which demonstrated that own- and cross-price elasticities can be observed with price changes of this magnitude [8].

Subjects also have their height and weight measured, and complete questionnaires on demography, hunger, delay discounting, time perspective, psychological stress, subjective social status, dietary restraint, and attitudes and knowledge about eggs and health. Details are provided in subsequent sections.

3.2. Subject recruitment

Subjects are recruited from Grand Forks, ND and surrounding communities using various media: brochures, flyers, newspaper and newsletter advertisements, advertising on the research center website, and other media as appropriate. Interested individuals are instructed to complete an online survey to determine eligibility. Recruitment will continue until 40 program participants and 40 non-participants have completed the study.

3.3. Subject eligibility and screening

Eligible subjects include women aged at least 18 years who are the primary food shopper in the household. Exclusion criteria are: 1) no children at least 18 years residing in the household, 2) health

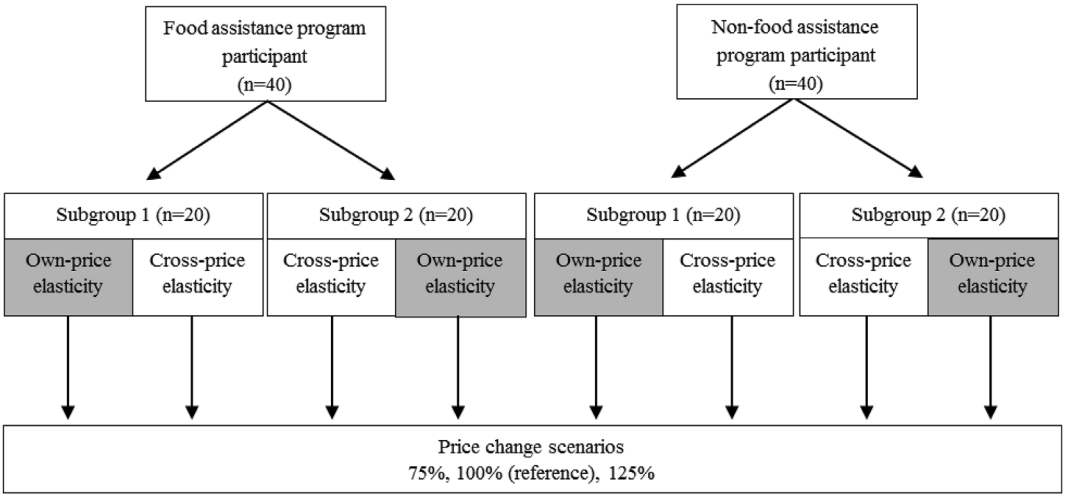

Fig. 1. Study design.

conditions or food practices that substantially limit food choice, 3) currently pregnant, and 4) unwillingness to comply with all study requirements. Accepted subjects are invited for an information meeting during which an investigator describes the study, answers questions, and consents the subject.

3.4. Procedures

All experiments and questionnaires for each subject are conducted during a single visit at the research center lasting approximately 2.5 h. Subjects are asked to refrain from consuming food or beverages, other than water, for 2 h before their visit in order to reduce any influence of recent eating on food purchasing behavior.

3.5. Purchasing trials

Subjects are assigned a weekly food budget based on the USDA Thrifty Food Plan, a tool used in food assistance program administration to estimate the cost of a healthy diet for low-income families [32]. The USDA Thrifty Food Plan takes into account the number of people in the family as well as the age and sex of each of the family members.

For each purchasing trial, a picture of each food and beverage (hereafter, *food*) are laid out on a table, and foods are arranged by food group (dairy and eggs; meat, poultry, and seafood; bread, oats, rice, and pasta; cereal; beverages; condiments; snacks; and fruits and vegetables). Each picture is accompanied by a price description of a given food item and a barcode with embedded information on price and nutritional profile. On the back of each picture is a nutrition facts panel and ingredient list.

Immediately prior to the purchasing trials, subjects are given a hand-held barcode scanner and instructed as follows: “Please imagine that there is no food in your home and you need to buy food at the supermarket for you and your household for a one week period. Imagine that this is the only opportunity that you will have to purchase that food. Also imagine that the food cards laid out on the table in front of you collectively represent a supermarket, and that these are the only foods available in that supermarket. You don't have to spend all of your food budget, but you can't go over that limit.” Because only one brand is used for each food, subjects are instructed to imagine that a given brand is their favorite. To indicate a purchase, subjects are instructed to scan the barcode on a given food card, and each purchase is recorded automatically (via barcode) by a computer with an interface designed to replicate a checkout counter at a grocery store (Fig. 2). Food prices are based on information collected from a local supermarket. Subsequent sections describe the protocol for identifying foods to be included in the purchasing trials.

3.6. Food list

Subjects are able to choose from 42 different foods, including 21 high nutrient-dense foods and 21 low nutrient-dense foods. Nutrient density is a measure of food quality based on nutrient content. In this study, nutrient density is estimated using the Nutrient Rich Foods index version 9.3 (NRF 9.3), which uses an algorithm to derive a nutrient density score from the amount of 13 nutrients (vitamins A, C, and E; calcium, iron, magnesium, vitamin K, sodium, saturated fat, and added sugar) in a given food. A low score represents low quality, a high score represents high quality, and a score of zero is the mid-point; there is no limit on the minimum and maximum possible score. NRF 9.3 has been validated against the Healthy Eating Index-2005, an independent measure of diet quality [33,34].

The decision framework we used to develop the list of high nutrient-dense foods and low nutrient-dense foods used in this study was as follows. First, it was decided that the high nutrient-dense food list should represent each of the major food groups recommended by the 2015–2020 Dietary Guidelines for Americans: fruits, vegetables, dairy, whole grains, and high-quality sources of protein [35]. Accordingly, it was decided that the low nutrient-dense food list should contain foods that Americans are encouraged to limit: foods high in added sugar, saturated fat, refined grains, and sodium [35]. We used NRF 9.3 to estimate the nutrient density score of all foods, and then grouped these foods according to the food group categorization scheme used by the What We Eat In America (WWEIA) survey [36], which assigns each food to a primary food group.

Second, it was decided that the foods used in this study should represent those that are commonly consumed by US adults on the basis of weight. To estimate per capita consumption amounts of each food, we analyzed data from the most recent iteration of WWEIA (2013–2014), the dietary component of the National Health and Nutrition Examination Survey (NHANES) [36]. NHANES is a continuous, cross-sectional survey that collects data on demography and health behaviors from a sample of ~5000 individuals per year, and data are released in two-year cycles. Individuals complete a 24-h recall (24HR) administered by a trained interviewer using United States Department of Agriculture's (USDA) Automated Multiple Pass Method [37].

Finally, we compared the list of foods ranked by nutrient density to the list of foods ranked by consumption amount, and assigned foods that were high nutrient-density and commonly consumed to the nutrient-dense foods list, and assigned foods that were low-nutrient density and commonly consumed to the low-nutrient dense foods group

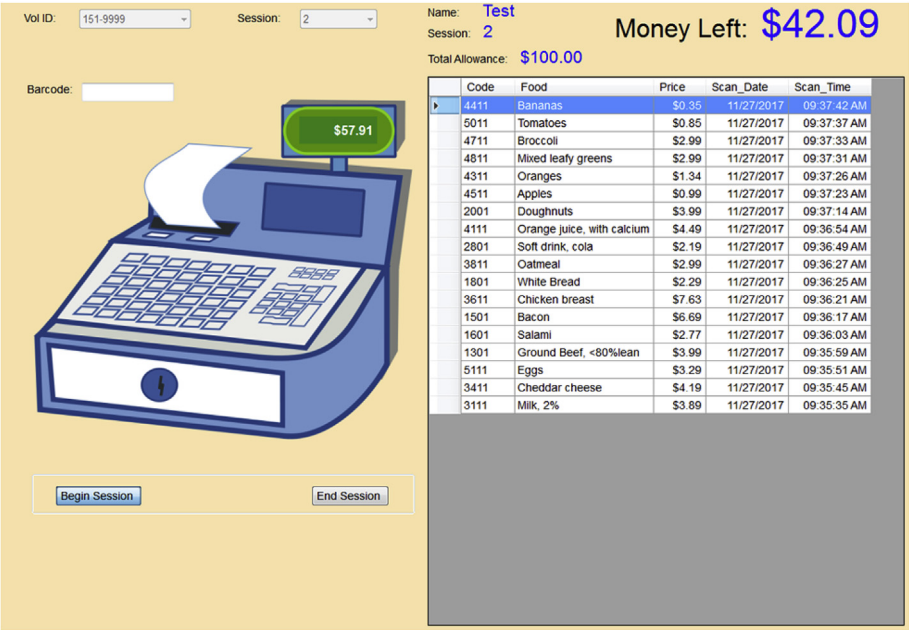

Fig. 2. Computer interface for food purchasing trials.

Table 1
High nutrient-dense foods used in purchasing trials.

Food	NRF 9.3
Red bell peppers	776
Broccoli	516
Mixed leafy greens	423
Oranges	225
Carrots	220
Tomatoes	214
Orange juice, with calcium	161
Kashi GoLean cereal	66
Grape juice	66
Canned tuna	60
Oatmeal	57
Bananas	41
Chicken breast	38
Milk, 2%	36
Low-fat yogurt, with fruit	34
Whole wheat bread	32
Apples	31
Whole wheat noodles	30
Eggs	29
American cheese	28
Cheddar cheese	20

NRF 9.3, Nutrient Rich Foods Index version 9.3.

Table 2
Low nutrient-dense foods used in purchasing trials.

Food	NRF 9.3
White bread	17
Cap'N Crunch cereal	17
Ground beef, < 80% lean	12
Cocoa Pebbles cereal	12
Chocolate milk, 2%	12
Mozzarella sticks, fried	7
Frozen yogurt	6
White rice	6
Soft drink, fruit flavored	0
Corn puffs	0
Cookies	−1
Pork sausage	−4
Bacon	−6
Doughnuts	−8
Popsicles	−9
M&M's candy	−12
Salami	−16
Hot dogs	−17
Soft drink, cola	−18
Catsup	−22
Barbecue sauce	−24

NRF 9.3, Nutrient Rich Foods Index version 9.3.

(beverages were included in each of the lists). The nutrient-density scores for the 21 foods in the high nutrient-dense group ranged from 20 to 776 (Table 1), and the nutrient density score the 21 foods in the low nutrient-dense group ranged from −24 to 17 (Table 2).

3.7. Hunger questionnaire

Subjects complete a one question hunger questionnaire (ten point Likert scale) prior to completing all other testing procedures.

3.8. Psychological stress questionnaire

Usual psychological stress is assessed with the Perceived Stress Scale [38], which asks ten questions about subjects' feelings and thoughts during the past month. Each question is scored on a five point Likert scale, and total stress scores are obtained by reverse scoring the four positively stated questions and then summing the responses to all questions.

3.9. Demographic questionnaire

After completing the first set of purchasing trials (either own- or cross-price elasticity trials, depending on which subgroup the subject is in), subjects complete a brief demographic questionnaire that garners information on race, ethnicity, number of people in the household, family structure, income, and status of participation in federal food assistance programs.

3.10. Time perspective

A key driver of individual decision making is time perspective, which is an unconscious process in which personal and social

experiences are interpreted based on time frames (past, present, future), which helps to provide meaning to those experiences.[39] In other words, some individuals may interpret their experiences based on what they learned from previous occasions; some may view their current experiences based on anticipations and expectations of the future; and others may base their decisions on current sensory, biological, and social aspects of their present situation. To collect information on subjects' time perspective, subjects are asked to complete the Zimbardo Time Perspective Inventory. This questionnaire asks 56 questions ("How characteristic or true is this of you?"), and each question is scored on a five point Likert scale.[39] Each question is used to asses one of five time perspective characteristics: past negative, present hedonic, future, past positive, and present fatalistic. To obtain total scores for each characteristic, the scores for the questions relevant to a given characteristic are summed and divided by the number of questions.[40]

3.11. Delay discounting

To collect information on subjects' preference for meeting more immediate smaller needs at the expense of not meeting larger delayed needs (i.e., delay discounting), subjects are asked to complete the Monetary Choice Questionnaire.[41] This questionnaire asks 27 questions about whether an individual would prefer a relatively less valuable reward at the present time or a relatively more valuable reward in the future. Individuals are categorized into one of ten categories. Scoring is based on matching actual responses to predicted responses, where the predicted responses are estimated based on a hyperbolic function that incorporates information on the value of the reward and the time delay of receiving that award. All scoring is completed using a publically available automated scoring tool.[42]

3.12. Dietary restraint

The Three-factor Eating Questionnaire is used to measure dietary restraint, which is the ability to restrict food intake in order to control body weight.[43] All 21 questions are scored on a binary basis.

3.13. Attitudes and knowledge about eggs and health

Subjects may have pre-conceived perceptions about negative and positive aspects of eggs, such as health risks due to cholesterol that may affect their food purchasing decisions. Therefore, we control for potential confounding by administering a post-trial questionnaire to assess explicit attitudes and knowledge about eggs and health. The questionnaire uses 29 questions to assess four distinct characteristics: social support and acceptability to eating eggs, barriers to eating eggs, facilitators to eating eggs, and knowledge of nutrition recommendations. Each question is scored on a five point scale with lower and upper anchors of strongly disagree and strongly agree, respectively. The negatively stated questions are reverse scored. The scores for the questions relevant to a given characteristic are summed and divided by the number of questions.

3.14. Subjective social status

Subjective social status is measured with The MacArthur Scale of Subjective Social Status.[44] This tool uses a picture of a ladder with ten rungs, and subjects are given the following prompt: "Think of this ladder as representing where people stand in your community. At the top of the ladder are the people who are the best off – those who have the most money, the most education, and the most respected jobs. At the bottom are the people who are the worst off – who have the least money, least education, and the least respected jobs or no job. Please place a large 'X' on the run where you think you stand relative to other people in your community."

3.15. Height and weight measurements

Subjects have their height measured without shoes (Seca stadiometer), and body weight is measured to the nearest 0.1 kg using a digital scale (Health-*O*-Meter Professional digital scale) without shoes and wearing light street clothing; results are converted to Body Mass Index (BMI; kg/m^2).

4. Statistical analysis plan

4.1. Power analysis

Based on price elasticity coefficients from Epstein et al. [23], standardized formulas from PS Power and Sample Size Calculations software version 2.1.30 estimated that 80 subjects will provide 90% power to detect an elasticity coefficient of 0.4, with a between-group difference of 0.54, assuming a standard error of 0.15 and $\alpha = 0.05$. Subjects will be recruited until 80 subjects have provided complete data for all covariates.

4.2. Counterbalancing and randomization of subjects

The order of the price change conditions (own-price elasticity trials and cross-price elasticity trials) are counterbalanced (Fig. 1). For example, within the program participant group, 20 subjects complete own-price elasticity trials prior to cross-price elasticity trials (Subgroup 1), and 20 subjects complete cross-price elasticity trials prior to own-price elasticity trials (Subgroup 2). The same structure is used for the non-participant group. For each subject, the order of price change scenarios within each price change condition is randomized.

4.3. Covariates

Model covariates that will be considered for inclusion include age (continuous), annual household income (categorical), hunger level (continuous), psychological stress level (continuous), household size (continuous), household structure (categorical), time perspective (categorical), delay discounting (categorical), dietary restraint (categorical), attitudes and knowledge about eggs and health (categorical), subjective social status (categorical), and BMI (continuous). Models will be tested for multi-collinearity and developed to provide a hypothesis-driven and parsimonious set of predictor variables.

4.4. Primary aim

Differences in own- and cross-price elasticity of eggs between program participants and non-participants will be tested using a mixed linear model with participation in a federal food assistance program as the between-subject factor, price change condition and price change scenario as within-subject factors, and subject as a random effect. Own-price elasticity will be measured as the percentage change in the amount of eggs purchased for every one percentage change in the price of eggs, and cross-price elasticity will be measured as the percentage change in the amount of eggs purchased for every one percentage change in the price of a given food.

4.5. Secondary aim 1

Differences in own- and cross-price elasticity of eggs between program overweight/obese subjects and non-overweight/obese subjects will be tested using a mixed linear model with participation in a federal food assistance program as the between-subject factor, price change condition and price change scenario as within-subject factors, and subject as a random effect. Own-price elasticity will be measured as the percentage change in the amount of eggs purchased for every one percentage change in the price of eggs, and cross-price elasticity will be

measured as the percentage change in the amount of eggs purchased for every one percentage change in the price of a given food. We will use an unstructured covariance matrix to allow us to test whether random intercepts and/or random slopes are needed.

4.6. Secondary aim 2

The moderating effect of delay discounting on the relationship between participation in federal food assistance programs and own- and cross-price elasticity will be tested using a mixed linear model with participation in a federal food assistance program as the between-subject factor, price change condition and price change scenario as the within-subject factors, and subject as a random effect. An interaction term will be used to examine the synergistic effects of participation in federal food assistance programs and delay discounting on price elasticities. Own-price elasticity will be measured as the percent change in the amount of eggs purchased for every one percent change in the price of eggs, and cross-price elasticity will be measured as the percent change in the amount of eggs purchased for every one percent change in the price of a given food. We will use an unstructured covariance matrix to allow us to test whether random intercepts and/or random slopes are needed.

4.7. Secondary aim 3

The moderating effect of subjective social status on the relationship between participation in federal food assistance programs and the purchase of high nutrient-dense foods will be tested using a mixed linear model with participation in a federal food assistance program as the between-subject factor, price change condition and price change scenario as the within-subject factors, and subject as a random effect. An interaction term will be used to examine the synergistic effects of status of participation in federal food assistance programs and subjective social status. Purchases of high nutrient-dense foods will be measured as the ratio of low energy-dense food purchases to high nutrient-dense food purchases (in dollars). We will use an unstructured covariance matrix to allow us to test whether random intercepts and/or random slopes are needed.

4.8. Secondary aim 4

The moderating effect of usual psychological stress on the relationship between subjective social status and the purchase of high nutrient-dense foods will be tested using a mixed linear model with participation in a federal food assistance program as the between-subject factor, price change condition and price change scenario as the within-subject factors, and subject as a random effect. An interaction term will be used to examine the synergistic effects of subjective social status and usual stress level. Purchases of high nutrient-dense foods will be measured as the ratio of low energy-dense food purchases to high nutrient-dense food purchases (in dollars). We will use an unstructured covariance matrix to allow us to test whether random intercepts and/or random slopes are needed.

5. Implications

We anticipate that changes in food prices will elicit greater changes in demand (i.e. have higher price elasticities) among federal food assistance program participants compared to non-participants; that changes in food prices will elicit greater changes in demand among non-overweight/obese individuals compared to overweight/obese individuals; and that delay discounting will moderate the effect of income on price elasticities. We also anticipate that subjective social status will moderate the effect of status of participation in federal food assistance programs on the purchase of high nutrient-dense foods, and that usual psychological stress will moderate the effect of subjective social status on the purchase of nutrient-dense foods. The results of this study will provide information about the drivers of food demand among low-income adults, and a better understanding of these drivers is needed to develop effective nutrition interventions for this large population. As a result of addressing these hypotheses, existing educational interventions that target low-income individuals may be enhanced by expanding their scope to address psychosocial barriers to purchasing more healthy foods. Potential interventions could include education on selecting healthy foods on a limited budget, and low-cost methods to prepare these foods in the household.

Financial support

This research was funded by the Egg Nutrition Center/American Egg Board and USDA-ARS 3062-51000-051-00D.

Conflicts of interest

The authors do not have any conflicts of interest to declare.

Acknowledgements

We thank Mr. Wayne Riveland for his assistance with developing the computer program and interface we used for the purchasing trials. We also thank Ms. Calah Mershon for her assistance with designing the food cards we used for the purchasing trials, and for providing her constructive comments on the study design.

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