



## Into the (Food) Desert: A Food Desert Simulation

By Mark J. Bonica & Kerryn L. Story

*University of New Hampshire, United States*

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**Setting:** Conducted as a field experiment utilizing local convenience stores. Subjects: One of the coauthors acted as the subject.

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“All models are wrong, some are useful.” – George E. Box

## I. INTRODUCTION

The term “food desert” came into political discourse and later into academic literature initially in Britain during the 1990’s when a resident of a public housing project made the claim that his health was adversely affected by his inability to conveniently purchase nutritious food (Cummins & Macintyre, 2002). Michelle Obama, in her role as First Lady and her “Let’s Move” campaign, referred to food deserts as “nutritional wastelands that exist across America in both urban and rural communities where parents and children simply do not have access to a supermarket” (the White House, 2010). The term has been invoked to justify policy interventions to subsidize the opening of full-service supermarkets in areas identified as food deserts with tax breaks, grants, and other incentives (Wenger, 2015; Reinvestment Fund, n.d.).

There have been many efforts to define exactly what a food desert is and to define a methodology for identifying geographic areas that qualify as food deserts (Sohi, Bell, Liu, Battersby, & Liese, 2014). The literature

generally agrees that a food desert is a geographic area occupied by low income residents who have limited access to retail sellers of fresh fruit and vegetables (Shaw, 2006) (Dutko, Ver Ploeg, & Farrigan, 2012). Most definitions include the claim that a typical resident of a food desert is condemned to purchase her/his food resources from a convenience store or a fast food restaurant (Walker, Keane, & Burke, 2010).

For purposes of this simulation, we will use the United States Department of Agriculture (USDA) definition of a food desert, which follows:

Food deserts are defined as urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable food. Instead of grocery and supermarket stores, these communities may have no food access or are served only by fast food restaurants and convenience stores that offer few healthy, affordable food options. The lack of access contributes to a poor diet and can lead to higher levels of obesity and other diet-related diseases, such as diabetes and heart disease (USDA Agricultural Marketing Service, 2015).

As noted in the USDA definition, food deserts can exist in both rural and urban environments. The operating assumption is that in either case the residents of an area designated as a food desert have difficulty accessing healthy, affordable food options largely as a result of transportation challenges. The USDA uses Census tracts to identify food deserts and relies on two screening criteria: 1) that the community is “low-income” defined as “a) a poverty rate of 20 percent or greater, OR b) a median family income at or below 80 percent of the area median family income”; and 2) that the community is “low access” defined as more than 1/3 of the community lives at least one mile from a super market or large supermarket store in the case of an urban census tract or ten miles from a super market or large supermarket store in the case of a rural census tract (USDA Agricultural Marketing Service, 2015). Using this definition the USDA provides a food desert locator tool (“USDA USDA-ERS Food Desert Locator”) which allows researchers and policy makers to locate official food deserts in the United States.

Other researchers have used more sophisticated techniques to attempt to identify food deserts, such as geographic information system (GIS) technology which enables route mapping and more accurate measures of travel requirements between

*Author α:* PhD, Assistant Professor, Department of Health Management and Policy, University of New Hampshire, 331 Hewitt Hall, Durham, NH 03824. e-mail: mark.bonica@unh.edu

*Author σ:* MPH, RD, Instructor, Military-Baylor Graduate Program in Nutrition, Academy of Health Sciences, Army Medical Department Center and School, Ft. Sam Houston, TX, 78234. e-mail: kerryn.l.story.mil@mail.mil

residents' homes and supermarkets (Jiao, Moudon, Ulmer, Hurvitz, & Drownowski, 2012) (Leclair & Aksan, 2014) (Liese, Hibbert, Ma, Bell, & Batterbsy, 2014). Regardless of the methodology for actually identifying the presence of food deserts, the operating assumption is the same: individuals residing in food deserts get the majority of their nutrition from convenience stores and fast food restaurants. The fact that they are limited to seeking nutrition in this environment is suggested to lead to poorer quality diets which in turn contribute to diet-related chronic conditions such as obesity, diabetes, and heart disease (Adams, Ulrich, & Coleman, 2010).

The literature on food deserts and health outcomes has correlational research but little by way of experimental evidence. This led the authors of this study to ask the question, holding all other things constant, what are the effects of being exposed to a food desert? Is geography destiny? Does living in a food desert limit an individual to a poor quality diet? Or is it possible with reasonable care and discipline to consume a nutritious, sustainable diet even under the constraints defined by the food desert literature? To expand our knowledge about these questions, we simulated a journey into the food desert.

## II. METHODS

The experiment is a single-case, A-B design (Herson, 1984). A single case, A-B design is limited in its generalizability (AHRQ, 2014), but can serve as a qualitative heuristic case to explore a concept that is not well defined (Kleining & Witt, 2000). Given the uncertainty in the literature about the actual effects of attempting to seek nutritious food when one simply does not have access to a supermarket, but the fact that policy has been built around the assumptions of specific chronic illness, this case study attempts to explore the effects of such conditions separate and in isolation from other confounding factors of poverty.

No consent was required as one of the authors (author 1) was the subject. The subject was a male, 68 inches tall, age 44 during the experiment.

### a) *Simulating Food Desert Conditions*

The experimental design was intended to simulate food desert conditions. The design involved the subject eating only food available for purchase at a convenience store for a period of 30 days. The only exception was tap water, which he was allowed to use from any available source. No explicit restrictions were placed on the subject in terms of what he could or could not buy at a convenience store, thus he could have eaten prepared foods such as sandwiches or pizza if it was available. He was allowed to purchase foods which would become ingredients in home prepared meals, such as peanut butter, flour, or tomato sauce as long as he could purchase them in a convenience store.

During the treatment phase, the subject also targeted a daily food resource expenditure of \$7.25. This target was selected because it would represent a single hour's wages at the federal minimum wage. The \$7.25 target was not hard a restriction. The subject could spend more or less, but the subject targeted average food resource expenditures at this amount. The target functioned as a goal to improve the simulation. Food desert conditions imply not only poor access to full service supermarket stores, but also lower household income levels.

The target food resource expenditure was not necessarily an actual daily expenditure. The subject charged himself only for the value of the food consumed during the course of any given day, not the total amount spent. For example, if the subject purchased a jar of peanut butter, and the cost of the jar was \$4.19 but there were 10 servings in the jar, the subject would charge himself \$0.42 each time he consumed a serving of peanut butter. Thus, on the day the peanut butter was purchased, if the subject consumed only one serving of peanut butter, the food diary would reflect an expenditure of \$0.42, not the whole \$4.19.

### b) *Data Collection*

The subject tracked exercise during the treatment phase using a personal activity tracker (a Fitbit Flex™). The subject generally only engaged in walking for intentional exercise in addition to ordinary activities of daily living. Other similar normal activities of daily living such as moving around the kitchen while cooking or walking through a store while shopping were captured by the personal activity tracker, thus the activity tracker is a reasonable estimate of actual exercise.

The subject used a spreadsheet-based food diary to record daily food consumption in terms of cost and caloric value. Calories were derived from a smart phone app (Loseit™). During the 30 day experiment, Lose it™ converted the activity tracker information into calories burned. Following the 30 day period, the subject re-entered the food diary into the US Department of Agriculture's Super Tracker™ web site (<https://www.supertracker.usda.gov/>) in order to produce a more complete nutritional record of intake over the previous 30 day period. Following the experimental period, the authors reconstructed the cost of foods consumed each day by shopping at a local supermarket store to develop a comparison daily cost if the subject had been able to shop outside in normal conditions, rather than only in convenience stores.

Labs were taken immediately prior to and immediately after the conclusion of the treatment period, providing A-B design. Labs were not redrawn 30 days after the end of the treatment period. The following labs were taken: Serum Cholesterol, LDL Cholesterol, HDL Cholesterol, Triglyceride, Glucose, and Hemoglobin A1C.

c) *Defining a “convenience store”*

The National Association of Convenience Stores (NACS) divides convenience stores into six format categories based on size and offerings. During the treatment phase the subject shopped at convenience stores that would generally fit the “limited selection convenience store” or “traditional convenience store” formats (NACS, 2015). These store formats are characterized by limited grocery selections and store sizes of less than 2,500 sq ft. The subject occasionally used a smaller convenience store known as “kiosks” or “mini convenience stores” when traveling, but was largely able to stay within the limited or traditional formats. He purposely avoided anything resembling expanded or hyper-convenience store formats (larger store formats bordering on supermarket stores) so as not to have access to more goods than are suggested to be available in a food desert.

During the treatment period, the subject resided in a medium-sized town in southern New Hampshire and commuted to a smaller town for work at a state university. There were several convenience stores in both towns, as well as several standard supermarket stores owned by regional or national chains. The convenience stores were a mix of independent, “mom

and pop” stores as well as stores that were part of regional or national chains. The subject used a car for transportation and explored as many convenience stores in the area as possible.

Although many convenience stores now include fast food restaurant counters, the subject did not consume restaurant food during this experiment. Fast food restaurants are included in most food desert definitions, however the cost of such food would have been prohibitive under the \$7.25 daily target.

III. FINDINGS

The treatment period began February 2, 2015 and concluded after March 3, 2015. The subject successfully completed the 30 day treatment period, only eating food he could purchase in a convenience store.

a) *Cost results*

The subject consumed a mean of \$8.89 of food per day, with a standard deviation of \$3.12. Comparison supermarket store costs were calculated by finding food prices at a local store of a regional supermarket chain in the subject’s town.

Table 1: Comparison of convenience store to supermarket store costs

	Convenience Store Costs	Grocery Store Costs
total	\$ 262.46	\$ 183.67
mean	\$ 8.89	\$ 6.12
median	\$ 7.58	\$ 4.29
SD	\$ 3.12	\$ 3.05
low	\$ 5.06	\$ 2.72
high	\$ 5.57	\$ 29.23

Supermarket store food prices were calculated by comparing items that were as close as possible to identical to the ones purchased at convenience stores. This involved finding the same size containers of food, (i.e., looking for the same size box of instant rice) rather than seeking out available economies of scale in a larger box. The comparison supermarket store prices represent the most similar food products to the same degree as possible. A larger difference could have been found by allowing for economies of scale in purchasing, therefore the reported difference underestimates the potential difference had the subject had the ability to shop at a supermarket store.

b) *Body Weight change*

The subject had a starting weight of 175.8 pounds and a BMI of 26.7Kg/m<sup>2</sup>.<sup>1</sup> on the morning of

February 2<sup>nd</sup> (day 1 of the 30 day experiment). On the morning of March 4<sup>th</sup> (the morning following the last day of the treatment, and the day the second set of labs were drawn) the subject weighed 163.5 pounds and had a BMI of 24.9Kg/m<sup>2</sup>, for a loss of 12.3 pounds. Chart 1 shows the weight change over the 30 day treatment period.

<sup>1</sup> BMI calculated using National Institute for Health online calculator at [http://www.nhlbi.nih.gov/health/educational/lose\\_wt/BMI/bmicalc.htm](http://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmicalc.htm)

Chart 1: Weight Change



Subject's daily weight in pounds.

Chart 2: Calories consumed and exercise

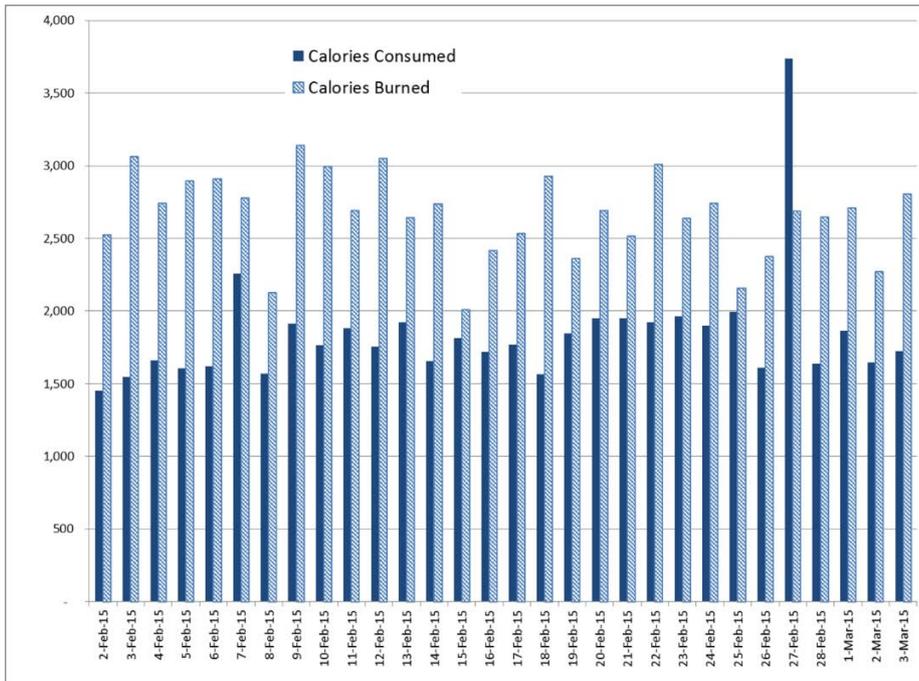


Table 2: Calories consumed

	Calories Consumed	Calories Burned
mean	1,852	2,660
median	1,763	2,693
SD	187	289
low	1,453	2,007
high	3,739	3,139

According to National Institutes of Health BMI standards (National Institutes of Health, 2015), the subject should maintain a weight between 125 (19Kg/m<sup>2</sup> BMI) and 164 pounds (25Kg/m<sup>2</sup> BMI) to be in the normal range. Using the Harris Benedict and Mifflin-St Jeor equations (Amirkalali, Heshmat, & Larijani, 2008) and a mid-point of 144 Paunds, the Harris-Benedict predicted resting energy expenditure (PREE) for the subject was 1,531 calories and 1,518 calories respectively. Caloric intake was well above the PREE throughout the experiment with a mean daily intake of 1,852 kcal. For comparison, a survey of residents from two communities residing in food deserts self-reported a

daily caloric intake of 1,727 and 1,861 kcal (Dubowitz, et al., 2015). The subject was employed in a relatively sedentary job throughout the experiment, however, he engaged in moderate exercise on most days (walking), with an average of 11,890 steps per day, with a daily range from 2,137 to 20,275. The activity tracker application calculates total expenditure to include resting energy expenditure. Calories consumed (as estimated by Loselt ® app) and calories burned (as estimated by the FitBit ® app) are depicted in chart 2 and a summary is given in table 2. Assuming the accuracy of these applications, the subject incurred a daily caloric debt of 808 calories.

*Lab results*

*Lab results are summarized in Table 3.*

*Table 3: Lab Results*

Test Name	Pre	Post	Reference Range	Units
Cholesterol, Serum	168	169	(</=-200)	mg/dL
HDL	62	62	(40-60)	mg/dL
LDL	97	90	(</=-130)	mg/dL
Triglyceride	45	84	(</=-150)	mg/dL
A1C	5.4	5.6	4.8-5.6	%
Fasting Plasma Glucose	102	89	(70-110)	mg/dL

*“Pre” represent values at the beginning of the experiment.  
 “Post” represent values from the day following the experiment.  
 “Reference range” is the standard range for normal results.*

The LDL cholesterol and fasting plasma glucose decreased between pre and post experiment readings. Fasting plasma glucose readings should be interpreted with caution, however, as readings may vary from day to day, and can be affected by some medications, posture when sample was drawn, sample handling, prolonged fasting, exercise, and acute stress (Sacks, 2011). Thus, a single elevated fasting plasma glucose reading warrants further testing. During the experiment, the subject’s A1C and triglyceride levels rose. Since A1C is a reflection of long term glycemic exposure, it is a more accurate measurement of glycemic control over time. A1C levels are used in the diagnosis of diabetes. In the case of the subject, although A1C levels rose during the experiment, the level remained within the reference range. The increase could be a reflection of the intake of simple sugars throughout the course of the experiment.

*c) Nutritional Analysis*

All nutritional analyses were extracted from reports generated by USDA’s Super Tracker database based on the subject’s entry of foods consumed during the experiment. The subject entered all foods with serving sizes consumed into the database on a daily

basis during the experiment. All food intake was self-reported and based on the subject’s measurement of serving sizes. The subject maintained food logs and entered foods consumed into Super Tracker for a period of 30 days. Nutrient analyses were generated through the database.

With regard to macronutrient intake, the subject exceeded recommended grams of carbohydrate during most of the 30 days tracked. This is likely because many foods consumed were processed and therefore higher in carbohydrate content. Protein target was met on all but five of the days tracked. The third macronutrient, fat, must be categorized as monounsaturated, polyunsaturated, or saturated fat in order to provide meaningful nutritional interpretation of daily intake. During eight of the 30 days, or 26% of the time, the subject’s intake of saturated fat sources exceeded the 2010 Dietary Guidelines for Americans’ recommendations for daily intake (<10% of total fat) (health.gov, 2015). There are no daily targets or limits set by the Dietary Guidelines for Americans for monounsaturated or polyunsaturated fat intake, however, the goal is to eat foods rich in these fats while staying within the total fat allowance for the day. Sixteen



percent of calories consumed by the subject were of monounsaturated fat sources, and 9% were of polyunsaturated fat sources.

Chart 3: Macronutrients

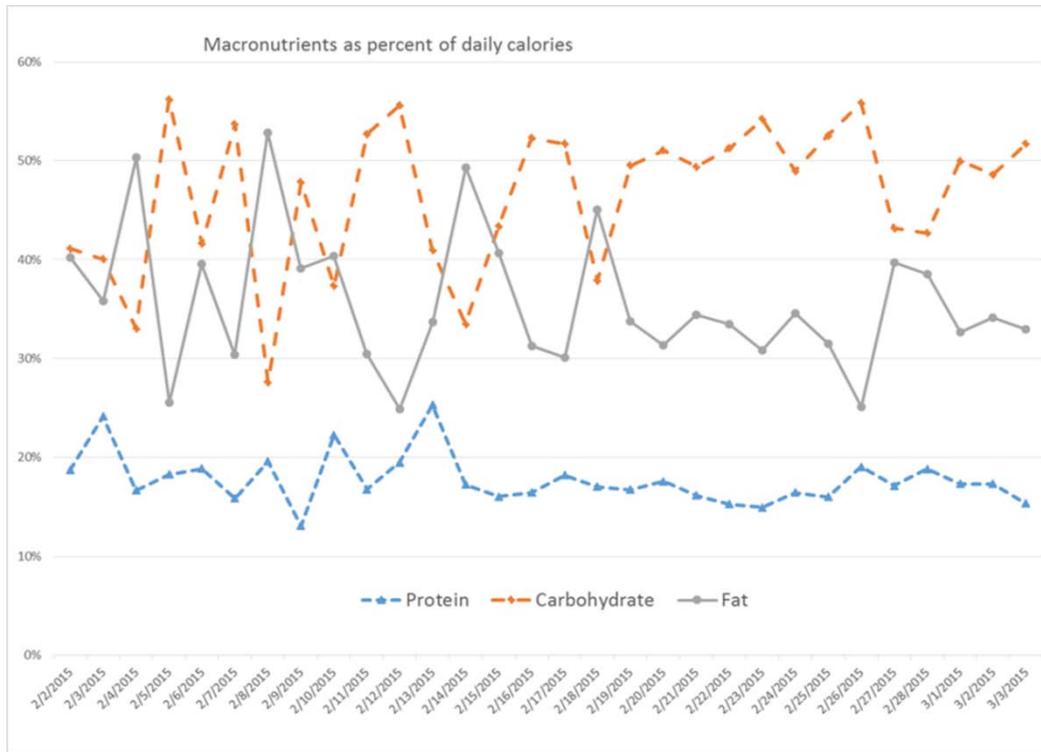


Table 4: Micronutrient Shortfalls

Micronutrient	Percent of Recommended Daily Intake
Calcium	73
Potassium	59
Magnesium	85
Zinc	81
Vitamin A	93
Vitamin C	54
Vitamin D	13
Vitamin E	73
Vitamin K	62
Choline	64
Fiber	63

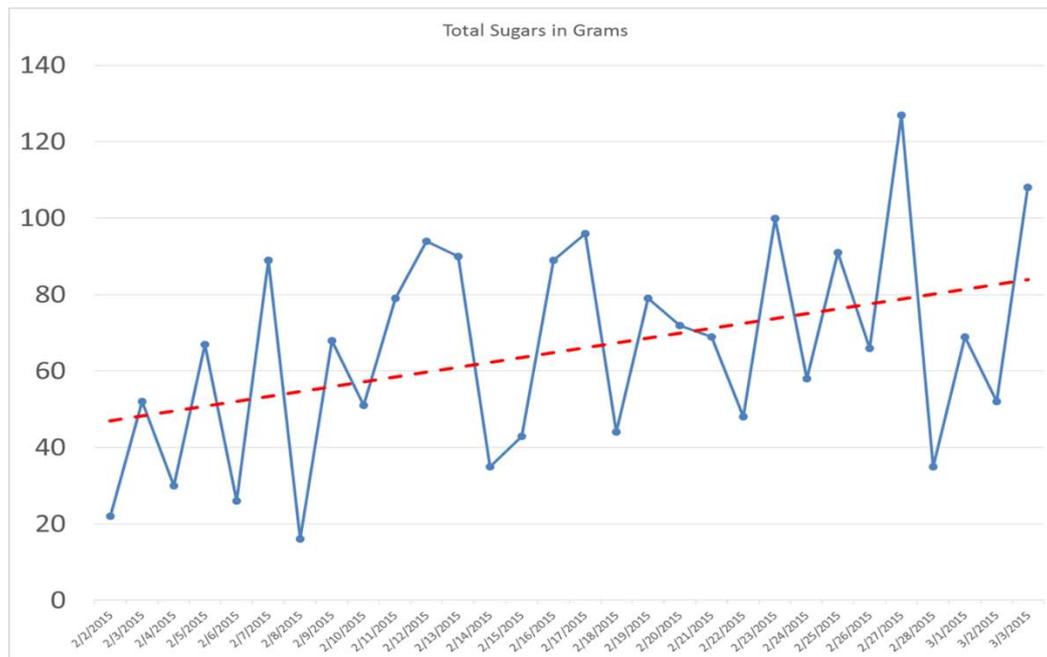
With regard to micronutrient intake, averaged out over the 30 day period, the subject fell short in meeting the recommended daily intakes for some vitamins and minerals:

Fiber intake was also inadequate to meet the recommended intake on all but one day during the 30 day trial. Fiber averaged 24 grams per day, meeting only 63% of daily needs (38 gram target). The diet exceeded the recommended daily intake for sodium and iron.

Over a period of 30 days, the lack of or overconsumption of micro or macronutrients would not be overly concerning. In the case of this experiment, for this subject, there was an end date to the experiment, a time when foods no longer had to be purchased only at a convenience store. However, such is not the case for many individuals who live within a food desert and must survive for years on foods lacking nutrient density. Vitamin and mineral deficiencies or excesses, over time, manifest in clinical symptoms.

Another interesting finding in the nutrient analysis was that the subject's intake of sugars, particularly added sugars, trended upwards from the first day of the diet.

Chart 4: Dietary Sugar



The chart tracks the daily total grams of sugar consumed in the diet. The trend line shows an upward drift in the number of grams consumed each day.

Sugars provide no additional nutrient value but do supply additional calories and account for the sweetened taste of some foods, particularly baked goods. Added sugars include sources such as white sugar, high fructose corn syrup, maple syrup, honey, molasses, or brown sugar, to name a few. The upwards trend could have represented the subject's preference for sweeter foods the longer he consumed the diet, or it could be because foods available at the convenience stores in the food desert contained added sugars to improve their flavor.

#### IV. DISCUSSION

The literature on food deserts includes a variety of methods for identifying food deserts in practice, but nearly all of the literature on the subject of identifying food deserts includes the assumption that what researchers are looking for is an environment where financially constrained (poor) residents are limited to consuming a diet that comes from convenience stores and fast food restaurants, as identified by the USDA. It is important to remember that the definition is two part: access limitations and financial limitations.

The experimental results do not support the broader claim that the access portion of food deserts cause obesity, high cholesterol, or diabetes. Even within the very restrictive definition used in this experiment, there were still choices that could be made that allowed

the subject to maintain a healthy weight, and showed no major changes in indicators for heart disease. The slight elevation of A1C reflects an increase in the consumption of carbohydrates, as does the increase in triglycerides. Both of these measures were within normal ranges as of the end of the experiment, but it would be interesting to see how long term exposure to this diet would affect those measures. A longer term exposure could answer whether A1C and triglyceride levels would continue to rise or level out.

Based on these results, it does not appear eating in a food desert is unambiguously harmful with regard to the primary conditions typically associated with food deserts (obesity, heart disease, and diabetes). Much can be done to mitigate the influence of the environment by adhering to some simple rules. The subject employed relatively simple rules of thumb throughout the experiment, such as avoiding chips, candy, and sweetened beverages when possible. He sought to have at least one vegetable and one fruit each day. After an initial purchase of a kielbasa sausage, for example, he tried to avoid meats of higher fat content (hot dogs, sausages) that were available in most stores where meat was sold. None of the stores the subject shopped in sold fresh meats; only packaged and canned meats were available. These simple rules combined with careful tracking of total calories consumed and a conscientious effort to exercise, even if exercise was limited to walking, ensured that the subject did not gain weight and actually progressed towards a healthier weight. The subject engaged in this experiment with intentions of losing weight to reach a healthier goal

weight. He averaged a caloric deficit of approximately 808 calories per day, after calculating calories burned from exercise. If the experiment had continued beyond the 30 days and once the subject reached his goal weight, he would need to add additional calories to his diet to prevent continued weight loss, assuming exercise levels remained the same. Increasing calories to reach a maintenance weight would have resulted in higher daily expenditures and would potentially alter the nutritional composition of the diet. Relatively inexpensive increases could be made to the diet by increasing calories from fats (butter, peanut butter) or carbohydrates (pasta and bread), but both of those may have led to increased negative health outcomes.

As noted, the subject did, over time, increase dietary sugar intake, despite careful tracking of food intake. For example, he started making peanut butter and jelly sandwiches instead of peanut butter and banana sandwiches on day sixteen and beyond. He also purchased and consumed several packages of honey roasted peanuts toward the end of the 30 day period. These rules do not require extensive knowledge of nutrition and functioned reasonably well for the subject. The unintentional drift toward added sugar demonstrates how easy it is to allow a diet to deteriorate, even when one is keeping careful track of foods consumed. Nevertheless, given the other options that were available, these were relatively small slips.

In addition to subtle drifts towards a less nutritious diet, daily stresses could lead to failures of discipline that violated both nutrition and cost goals. The limitations imposed by the food desert required continuous planning and preparation to both achieve the twin goals of reasonable nutrition at a low cost. Day 12 is evidence of the fact that a failure to plan, combined with the normal stresses of life, can cause costs to escalate rapidly. The subject failed to plan properly for an out of town trip, and as a result he spent \$19.88, nearly three times his daily target. The failure to plan included two factors: first, he did not pack sufficient food for the trip, requiring him to purchase food on the go; and second, he did not know his route well enough and became lost (twice) when looking for fuel. The psychology literature on self-control shows that self-control is weaker when we are tired, hungry, or mentally exhausted (Kahneman, 2011). Sustaining both nutrition and cost is a balancing act that wealthier individuals do not have to consider, as food costs are a small fraction of the average household's budget<sup>2</sup>. This simulation forced the subject to have to think about two things at the same time, as well as deal with the ordinary stresses of daily life. Having to think about two things rather than simply focus on one or the other is inherently more stressful and therefore more likely to fail when other

distractions are experienced by the subject. In this case, the subject experienced a high degree of frustration and violated his standing rule of not purchasing chips or sugary drinks and did both.

Successfully navigating the challenges of the food desert required the subject to exert continuous effort. Despite success in preventing weight gain and increases in measures such as cholesterol, the subject was not able to create a diet that met all of the recommended micronutrient levels. The lack of a variety of micronutrients could lead to long term deficiencies and therefore lead to other types of diet-related illness. A longer term study would need to be conducted to make stronger claims on either the macro or micronutrient influence. The food desert literature has largely focused on issues such as obesity, diabetes, and heart disease, but has not discussed the issue of micronutrients. This would be something to consider for longer-term studies.

A major issue the subject dealt with was the problem of scale. Food desert conditions do not allow for economies of scale. Even when healthier options are available, they are often only available in more expensive, smaller size packages. For example, when the subject first purchased flour, he initially only found a two pound bag for \$2.99 (\$1.50/pound). By comparison, a five pound bag of flour can be purchased in a nearby supermarket store for \$1.75 (\$0.35/pound). The subject was pleased to eventually find frozen peas for \$1.79 (9 oz bag, \$0.20/oz). Canned peas were available in convenience stores ranging for as little as \$0.10 per ounce (though the price of a can of peas varied between stores), therefore frozen peas were less affordable than canned. A two pound bag of frozen peas could have been purchased at a nearby supermarket store for \$1.98 (32 oz, \$0.06/oz), which would have made the frozen peas less expensive than the canned peas from the convenience store, but still slightly more expensive than canned peas from the supermarket store at \$0.04 per ounce. Convenience stores typically did not offer multiple sizes of the same product – such as a nine ounce and two pound bag – with a commensurately lower cost per unit, thus a shopper in a food desert cannot scale up and generate savings by buying in bulk. Had the subject included his family in this experiment, his cost to provide for the family would have simply been a multiple of what he spent on himself.

Frozen vegetables were not available in most of the convenience stores the subject visited, but frozen vegetables, as with peas, offer nutritional values very close to their fresh counterparts at a fraction of the cost. Frozen peas (because this was the one vegetable the subject purchased frozen during the experiment) deliver 90% of the potassium on a per gram basis that fresh peas do, while canned (drained and rinsed) peas deliver only 44% (USDA, 2015). Potassium was one of the

<sup>2</sup> The average US family spent 9.8% of their disposable income on food in 2013 (USDA Economic Research Service).

micronutrients the subject failed to consume sufficient volumes of during the experiment. Frozen peas also minimize added sodium, with only 25% more sodium per gram than fresh, while canned carried more than 56 times more sodium per gram. A fresh green pepper costed \$1.29 in a convenience store, \$0.90 in the local supermarket store (at the time of the experiment), but a fourteen ounce bag of frozen sliced peppers only costed \$1.94. If we assume a medium green pepper weighs 4.4 ounces, a fourteen ounce bag would contain 3.2 peppers, for a cost of \$0.61/pepper. Supermarket stores commonly stock a variety of frozen vegetables, some in large quantities giving significant scale. A five pound bag of mixed vegetables (peas, carrots, corn, green beans) was available in the local supermarket store for \$5.98 (\$0.07/ounce). Had the subject been able to purchase a large bag of frozen mixed vegetables at such a price he could have added more vegetables to his diet without significant cost. Frozen vegetables also have the advantage of being long lasting for both the grocer and consumer. Much of the food desert literature has focused on a lack of fresh vegetables, but it would seem that from both the consumer's and retailer's perspectives, frozen would be more economical.

One could argue that people who are impoverished enough to live in an official food desert might not have access to a freezer large enough to maintain a five pound bag of mixed vegetables in order to capture the benefits of scale. Dried legumes and grains also have lengthy shelf lives. Dried legumes sell for a fraction of the cost of canned legumes in a standard supermarket store, and tend to be healthier because salt has not been added, which is ordinarily done during the canning process. The subject was able to locate a few cans of legumes, but in none of the convenience stores he visited was he able to locate and purchase dried legumes such as dried pinto beans (peanuts, also a legume, were available everywhere). The subject was also only able to find dehydrated, precooked white rice (minute rice) in the convenience stores he visited. Rice and dried beans are traditional staples that could provide a nutritional base to a low cost diet. The precooked rice and canned beans were not low cost in the stores included in the simulation and were less healthy than the traditional alternatives.

Fresh foods were predictably expensive when available, though the comparative costs were not as high as some of the non-fresh items, such as flour. As mentioned, a green pepper costed \$1.29 (at one of the few convenience stores that actually carried green peppers) and \$0.90 at a nearby supermarket store, for a cost ratio of 1.43. Likewise, flour had a cost ratio of 4.29. Instant oatmeal had a cost ratio of almost four times, and jelly was more than five times as expensive. Thus, some of the most expensive items relative to their counterparts in supermarket stores were actually not the fresh items.

Ironically, it was possible to buy a variety of gourmet ice creams, craft beer, and even lobster (if one happens to live in coastal New Hampshire), but fresh fruit and vegetables were extremely limited or non-existent. As the food desert literature has documented, there are abundant cheap, empty calories in every store included in the simulation.

The problems the subject faced, particularly when he had days of failure, were a result of the interaction between poverty and access, rather than simply access. It seems also likely that the subject had deeply ingrained preferences that he fell back on either immediately during times of stress, and gradually and subtly over time. The overwhelming presence of unhealthy food and drink in the stores the subject frequented presented a continuous temptation to revert to unhealthy preferences.

#### *a) Limitations of the study*

The first limitation of the study was the fact that where the subject was living and shopping was not an actual food desert. In most cases a full supermarket store was only a few minutes down the road, therefore it would not have been rational for the convenience store managers to have stocked bulky, low margin items such as dried beans and rice. The lack of nutritious foods in the convenience stores frequented by the subject could simply represent a specialization by the stores in foods that people (especially college students) would want for a late night snack or a quick bite to eat. People residing in the subject's locale had ready access to several full supermarket stores, and were not reliant on the convenience stores he shopped in for all of their shopping. In a real food desert, convenience stores may have stocked more items that are more useful in maintaining a normal diet because there would be more potential demand from reliant customers. If the assumption that convenience stores in the subject's area actually intentionally stocked fewer nutritious options is true, it would have made the effort more difficult than if the subject had actually shopped in a real food desert. Thus the negative results could be overstated.

A second important limitation of the study is the fact that poverty is a multi-dimensional challenge for those who live with it. A food desert as defined by the USDA includes the resident being poor; there are wealthy people who live in urban and rural environments who are farther than one or ten miles (respectively) from a supermarket, but the presumption is the non-poor can afford transportation, and therefore the simple geographic distance does not constitute food desert conditions since their wealth allows them to overcome the geographic limitations. A study by Dubowitz, et al., found that 86% of the residents who lived in a food desert community shopped at full-service supermarkets

or supercenters (2015), which implies access is more complex than simply not having a supermarket nearby.

Being poor does not just present the challenge of constructing a nutritious diet with few financial resources and poor access to nutritious food, it also potentially includes uncertainty about physical safety, shelter, child care, health care, and so forth. The authors acknowledge that this experiment isolated the effects of food desert conditions from all of the rest of the challenges of actually being poor. However, many policies being proposed based on food desert research, such as trying to bring farmers' markets into areas identified as food deserts (USDA Food and Nutrition Service, 2015), are similarly one-dimensional and do not address the full impact of poverty. The fact that the subject did not face all of the dimensions of poverty simultaneously does allow the effects of food desert conditions to be isolated, which is an advantage over conducting the same analysis with all of the factors of poverty operating on the subject simultaneously. In this sense, the fact that the subject only faced the nutrition challenges of poverty allows the study to more precisely identify the effects of food desert conditions.

A third limitation is that the study is a single case (N of 1). The same diet and exercise combination may have had different impacts on other subjects in terms of laboratory outcomes and weight gain/loss. Furthermore, some of the lab tests are very sensitive to the timing of consumption (glucose, triglycerides). Thus, foods consumed closer to the end of the experiment might have dominated the outcome of the labs. Had the same food been eaten, but in different order, such that for example days 1-3 had been days 28-30, different lab results might have been found.

Other limitations include some of the rules by which the simulation was set up. Commenters have offered that only charging what is used on a given day is unrealistic, and that a fixed dollar amount should have been used for the entire experiment, such as  $\$7.25 \times 30 = \$217.50$ . There are many ways that the rules of the simulation could be adjusted. We recommend other interested parties run their own simulations with rule variations to see what the respective effects are.

## V. IMPACT AND CONCLUSIONS

All simulations are imperfect; we hope this one was useful. This experiment simulated a food desert with regard to nutrition while holding all other factors constant, allowing us to see the effects of living in a food desert on an otherwise healthy person's health, at least in the short term. Some of the common assumptions about the harms of food deserts, such as weight gain, high cholesterol, and dangerous sugar consumption were controlled by carefully monitoring caloric intake, applying a few simple rules while shopping, and engaging in regular moderate exercise. Laboratory

evidence showed some modest improvements and some modest decreases in health status. However, a detailed analysis of the nutritional content of the diet indicates that some micronutrients were underrepresented in the diet. This could lead to other long term health issues and chronic illnesses, but these are not the illnesses typically associated with food deserts. This experiment suggests that further research might be warranted to look at the effects of micronutrient deprivation in food desert conditions.

The experiment showed that despite planning and reasonable effort, the subject was unable to develop significant economies of scale, supporting the operating assumptions that eating relatively healthily in a food desert is significantly more expensive than eating where larger scale Supermarket retailers are accessible. The relatively high value of frozen and dried foods (higher nutritional value and relatively lower cost) discussed in this paper suggest that further consideration be given to emphasizing policies that encourage the greater availability of frozen and dried foods over fresh. Policies that might result in greater availability of these foods in areas designated as food deserts may be worth further exploration.

This simulation helped to show that food deserts, as defined by the USDA, would contribute to less nutritious diets, however, not in the way typically suggested. Problems of obesity, heart disease, and diabetes require an interaction between the diet available in the food desert, and the broader challenges of poverty that make it difficult to sustain the healthy behaviors that mitigated the effects of the food desert during this simulation. While a relatively balanced macronutrient diet was possible, this simulation showed that there would be a significant problem achieving adequate micronutrients in the diet.

On a personal level, the experiment is a taste of someone else's life. Eating this way, even for a short period of time shifts the way one looks at food and nutrition. As noted in the limitations, there were many other variations on this experiment that could be performed. We would encourage others to try them both to test the value of the simulation and to experience what it is like to live the theory we are discussing.

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