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USING POSITIVE DEVIANCE BY MICRONUTRIENT STATUS TO IDENTIFY DIFFERENCES IN FOOD BEHAVIORS IN WOMEN OF REPRODUCTIVE AGE IN GHANA

CARISSA N. HEINE
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Reviewed and approved* by the following:

Alison D. Gernand
Assistant Professor of Nutritional Sciences
Thesis Supervisor, Honors Advisor

Laura E. Murray-Kolb
Associate Professor of Nutritional Sciences
Faculty Reader

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

Micronutrient deficiencies are common in low-income countries. A previous study measured the concentrations of several micronutrients in pre-pregnant women in a low-resource, semi-rural town in Ghana and gathered information from each woman on socio-economic, demographic, and other lifestyle characteristics (n=100). For the current study, we followed the "positive deviance" approach: micronutrient status and other biomarkers from the previous study were used to identify "positive deviants" (excellent nutritional health, n=13), a normal control group (average nutritional health, n=61), and "negative deviants" (lowest nutritional health, n=24). Field staff interviewed women from both positive (n=9) and negative (n=11) deviant groups in their homes and directly observed household resources. Data was analyzed using quantitative and qualitative methods as appropriate. The study found that consumption of turkey berry (a high-iron fruit), ownership of home and agricultural land, exposure to healthcare, living in a larger household with more than two adults, living farther from the town's market and having a consistent schedule for purchasing food were higher among the positive deviants (healthiest women), while consumption of starchy foods and sugary drinks and possession of electric or gas utilities were higher among negative deviants. Future work could explore the ability to promote the factors found to be related to better nutritional health in this community and to explore similar issues in other low-resource communities around the globe.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1

Introduction and Literature Review

Malnutrition is an important health concern in low-income and middle-income countries. In a review of the causes, manifestations, treatments, and interventions of malnutrition in developing countries, poverty was identified as the main underlying cause (1). There are many factors that contribute to poverty and resulting malnutrition, including politics, economics, education, environment, culture, health education, health services, and food production. Two main types of malnutrition are prevalent in developing countries: protein-energy malnutrition and micronutrient deficiencies. Causes of malnutrition are complex, and to be effective, interventions must address the issue from many directions including agriculture, nutrition education, safe drinking water production, quality health services, sex differences, and population vulnerability.

Micronutrient Sources, Metabolism, and Function

Five micronutrients with particular importance before and during pregnancy were included in this study: iron, zinc, copper, vitamin A, and vitamin D. In this section, the metabolism and key functions of each of these micronutrients will be discussed.

Iron is a key essential mineral most widely known for being part of the hemoglobin molecule in red blood cells (2,3). Iron is found in two forms in food – heme and non-heme – and each are metabolized differently. Heme iron, found in the hemoglobin and myoglobin structures of meat, is hydrolyzed from the globin part of the molecule by proteases in the stomach and

small intestine. The free heme is easily transported across the enterocyte brush border, primarily in the duodenum, by heme carrier protein 1. Inside the cell, the ferrous iron (Fe^{2+}) is freed from the heme molecule by heme oxygenase and can be used by the cell itself or transported to other body tissues. Non-heme iron is found in plant foods, especially lentils, kidney beans, sesame seeds, and quinoa, often bound to other compounds. Enzymes and other secretions released by the stomach and small intestine free ferric iron (Fe^{3+}) from the compounds, allowing it to be reduced to ferrous iron in the stomach or on the brush border membrane of enterocytes. The ferrous form can be absorbed into the enterocyte through transporters like the divalent metal transporter 1 (DMT1). Iron's key function is as a component of many proteins. One iron atom sits in the center of each hemoglobin protein, which is responsible for carrying oxygen in the blood. Iron is also part of cytochromes in the electron transport chain, the last set of reactions for energy production from carbohydrates. Other proteins that require iron are monooxygenases, dioxygenases, peroxidases, and oxidoreductases.

Zinc is another mineral that has important functions in many body tissues. Found in a wide variety of foods, such as red meats, seafood, whole grains, and leafy and root vegetables, zinc must also be hydrolyzed from other molecules before absorption (3,4). During digestion, zinc ions are freed from food molecules, allowing zinc to be absorbed in the small intestine, typically the jejunum. A carrier protein transports zinc across the brush border membrane into the enterocyte. High intakes of zinc may cause passive diffusion to occur. Once inside the enterocyte, it may be used by the enterocyte itself, stored in the enterocyte, or transported into plasma for usage by other tissues (5). Zinc is transported by albumin or other proteins, such as transferrin, α-2 macroglobulin and immunoglobulin G, and travels to the liver and other body tissues. The primary role of zinc is as a component to numerous enzymes with wide-ranging

functions. Some enzymes that require zinc are carbonic anhydrase, alkaline phosphatase, alcohol dehydrogenase, and superoxide dismutase (3). Zinc also regulates protein synthesis in tissue growth and participates in transcription regulation by interacting with transcription factor proteins.

Copper is another key essential mineral for humans, and like other minerals, it must be released from organic compounds in foods (3,5). Primary sources are animal foods, such as organ meats and shellfish, though some nuts, seeds, legumes, and dried fruits also are good sources of copper. In the stomach, hydrochloric acid and pepsin release copper from the organic compounds. Copper is mostly absorbed in the small intestine but some may be absorbed in the stomach as well. Copper seems to be absorbed across the brush border membrane through active carrier mediated transporters as well as passive diffusion, but the exact mechanisms are not well understood. Like other minerals, copper may be used by the enterocyte itself, stored in the enterocyte, or transported into plasma for usage by other tissues. In the cell, free copper ions may cause damage, so copper is often bound to proteins for storage or intracellular transport. Copper is thought to be transported into plasma by an active transport mechanism. Albumin also binds copper and transports it to the liver, where it is transformed into ceruloplasmin and released into the blood for delivery to other tissues. A key function of copper, as part of ceruloplasmin, is facilitating mineral oxidation, such as ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}). Copper is also part of superoxide dismutase (with zinc), cytochrome c oxidase, and amine oxidases.

Vitamin A is a term that refers to a group of molecules, including retinol, retinal, retinoic acid, retinyl esters, and provitamin A carotenoids (3,5,6). Retinoids, primarily retinyl esters, are found in animal foods such as liver, dairy products, and fish. Carotenoids, or precursors to vitamin A, are found in a wide variety of brightly colored fruits and vegetables since the

carotenoids are pigments that create the red, orange, and yellow colors. Pepsin in the stomach hydrolyzes bonds between carotenoids and other food compounds. As fat-soluble compounds, the free retinyl esters and carotenoids form fat globules in the stomach that travel to the small intestine, where they are digested further, releasing free retinyl and carotenoid esters. These join micelles and are absorbed across the enterocyte brush border membrane into enterocytes, where retinyl esters are incorporated into chylomicrons and transported to other body tissues via the lymphatic system. Enterocytes metabolize carotenoids to retinoic acid, which is bound to albumin in blood plasma and transported to the liver. The most well-known function of vitamin A is for vision. It is required for rhodopsin formation, which facilitates vision in dim environments. However, vitamin A is also necessary for inducing cellular differentiation, the process of transforming an immature cell to a specific mature cell. It also has functions in gene expression, through interactions with DNA, and growth, by stimulating growth of epithelial cells.

Vitamin D is a steroid derivative that has been long associated with strong bones (5). Vitamin D can be found in reasonable amounts in few foods, mainly fatty fish, liver, egg yolks, and mushrooms. In the U.S., dairy products are fortified with vitamin D. Vitamin D can also be synthesized in the skin from exposure to UVB light (7). Dietary vitamin D is incorporated into micelles in the stomach and intestine before it is absorbed passively into the enterocyte. In the enterocyte, it is incorporated into chylomicrons, transported to the lymphatic system, then to the blood, and finally to the liver. Vitamin D synthesized by the skin is transported by vitamin D-binding protein (DBP) in the blood directly to the liver (5,7). In the liver, all vitamin D is hydroxylated to 25-hydroxyvitamin D, an inactive intermediate metabolite. This is released into the blood, attached to DBP. It is taken up by the kidney for another hydroxylation to form 1,25-dihydroxyvitamin D, the biologically active form. This is released into the blood attached to

DBP, sent to target tissues all over the body, and taken up via the vitamin D receptor (VDR). Vitamin D is intimately linked to calcium and phosphorus homeostasis, directing the absorption of calcium and the mobilization of calcium and phosphorus from bone into blood. Vitamin D also plays a role in regulating cell growth and differentiation.

Micronutrient Deficiencies

As discussed above, each micronutrient has specific roles and functions in the human body, though not all may be known yet. Some minerals, namely iron, zinc and copper, have similarities in food sources and metabolism, but are each necessary for unique functions. Deficiencies of one or multiple micronutrients can have significant impacts on an individual's health and quality of life. Deficiencies can be caused by a variety of factors. Low consumption of nutrient-dense foods often leads to deficiencies, which is particularly common in developing or low-income countries (1). This can occur with or without protein-energy malnutrition. Diseases, infections and parasitic infestations are also common causes of malnutrition and resulting micronutrient deficiencies in low-income countries, creating a vicious cycle in which malnutrition reinforces disease and infections, which reinforces malnutrition (1,8).

Deficiencies can also be impacted by the ease of micronutrient absorption, called bioavailability, which is influenced by many factors. First, micronutrients may compete for absorption if they use the same mechanism. For example, iron and zinc utilize DMT1 for absorption (5). If DMT1 has reached capacity with zinc, it may not be able to facilitate iron absorption, even in a meal that contained good food sources of iron. However, the evidence for this is not conclusive (9). Another factor is other compounds in foods that may inhibit

micronutrient absorption. For example, polyphenols from tea and coffee or oxalic acid in spinach, chard, berries and other foods can inhibit iron absorption up to 60% by binding the atom into an insoluble complex (10). Lastly, many micronutrients interact and have co-dependent function mechanisms. One micronutrient deficiency may cause another; for example, vitamin A deficiency has been shown to correlate with decreased iron incorporation into red blood cells, causing microcytic iron deficiency anemia (11). However, when the vitamin A deficiency is corrected, the iron deficiency anemia is corrected as well (12).

There are specific deficiency cut-off points for many blood biomarkers. Although not universally established for every micronutrient, there are commonly accepted cut-offs or ranges that most likely indicate deficiency. There are several biomarkers for iron status, including hemoglobin, ferritin, total iron binding capacity (TIBC) and transferrin saturation (TSAT). The following cutoffs indicate depleted iron stores and early deficiency in adult women (3): hemoglobin <12.0 g/dL, serum ferritin <12 μg/L, TIBC >400 μg/dL, and TSAT <16%. Fasting serum concentrations of zinc <70 μg/dL suggest deficiency (3), and serum copper concentrations <10 μmol/L likely indicate inadequate status (3). The adequacy range for plasma retinol concentration is 30-86 μg/dL (5) and below 20 μg/dL is considered a sign of deficient or marginal vitamin A status (3). Lastly, vitamin D deficiency is defined as serum 25OHD concentrations less than 30 nmol/L (13).

The consequences of deficiencies in these five micronutrients are diverse. Iron deficiency is the most common cause of anemia, though other micronutrients can cause forms of anemia as well (2,8,14). Anemia is the most well-known sign of iron deficiency. Symptoms of iron deficiency without anemia include pallor, listlessness, behavioral disturbances, impaired cognitive ability, and short attention span. Zinc deficiency in children is evident by growth

retardation, cartilage and bone abnormalities, and delayed sexual maturation. Adults usually experience alopecia (hair loss), poor wound healing, dermatitis and decreased sense of taste (3,4). Copper deficiency has many manifestations as well, including hypochromic anemia (discolored blood cells), leukopenia, hypopigmentation or depigmentation of skin and hair, bone demineralization, and impaired immune function (3).

Vitamin A deficiency is most easily detected through eye problems such as xerophthalmia, Bitot's spots and night blindness, but there are other symptoms as well, such as anorexia, retarded growth, increased susceptibility to infection, and keratinization of mucous cells in the skin (3). The characteristic dry eyes of xerophthalmia are caused by decreased mucus production that accompanies abnormalities and scarring of the conjunctiva and cornea of the eye. Vitamin D deficiency in children is evidenced by rickets when bones fail to mineralize, creating bowed legs when the child starts to walk (15). In adults, vitamin D deficiency is evident by osteomalacia. Due to the relationship between vitamin D and calcium, vitamin D deficiency causes increases in calcium and phosphorus resorption from bone, causing brittle, weak bones.

Micronutrients and their Significance Before and During Pregnancy

Overall nutritional status and dietary quality is essential before and during pregnancy – excessive or inadequate energy intake or diseases like diabetes or hypertension negatively impact the health of a pregnancy by increasing the child's risk of birth defects, obesity, or chronic noncommunicable diseases (14). Adequate nutrition, including micronutrient intake, is essential before pregnancy, not only during pregnancy, in order to improve maternal and fetal health and prevent complications during pregnancy and lactation (8). Unfortunately women of reproductive

age are especially susceptible to micronutrient deficiencies, which often accompany energy malnutrition (1,8,16). Of concern, nutrition recommendations for reproductive women globally have some limitations: 1) micronutrient status is rarely viewed as a continuum from the preconception period to pregnancy to lactation (but instead as three separate stages); and 2) a few micronutrients, namely iron and folate, receive the most attention while multiple micronutrient deficiencies often occur simultaneously in populations with a poor diet (16). Vitamin B_{12}, vitamin A, vitamin D, zinc, and iodine are also important for healthy pregnancy outcomes, but they are less often targeted for research and intervention in pregnant women. Many nutritional factors and micronutrients are essential before and during pregnancy to support positive pregnancy outcomes, and deficiencies of individual nutrients can have severe consequences if they are not addressed prior to pregnancy.

Deficiencies in the five micronutrients discussed above, and others not covered in this study, influence the health of a pregnancy. Maternal needs of vitamin A, iron, zinc, and copper increase during pregnancy, while vitamin D requirements remain the same (3,13). Iron deficiency anemia has been associated with maternal mortality, though mechanisms are not fully understood (3). Iron deficiency can also negatively impact fetal growth and the development of the fetal brain (14,17). Zinc and copper are cofactors of enzymes that protect the fetus and placenta from oxidative stress during vascularization of the placenta, thus zinc and copper deficiencies can reduce blood flow to the fetus (14,17). They have also been associated with miscarriage. Zinc deficiency can compromise fetal neurological development due to its involvement in DNA and RNA synthesis in the brain (17). Iron, copper and zinc deficiencies may influence kidney and pancreas development, potentially setting the fetus up for higher risk of cardiometabolic disease (17). Vitamin A is essential for embryonic development and seems to

be important in almost every tissue, so vitamin A deficiency can contribute to problems in organ function (14). Maternal vitamin D deficiency results in newborn vitamin D deficiency, which can lead to the child's development of rickets (17). Other micronutrients that are particularly important in pregnancy are B vitamins, iodine, selenium, and folic acid.

Unfortunately, the highest burden of micronutrient deficiencies falls on populations in low-income countries or low-resource settings. The close relationship between micronutrients and pregnancy outcomes mean that women in these countries are set up for less healthy pregnancies and poorer pregnancy outcomes. Iron deficiency anemia is one of the most well-recognized nutritional deficiencies in the world, with a world-wide prevalence of 15-20% (17). Vitamin A deficiency during pregnancy is also high with an estimated 15% of pregnant women in low-income countries deficient. The global prevalence of other micronutrient deficiencies hasn't been summarized, but the estimated prevalence of zinc deficiency in pregnant women in South Asia reaches 74% (17). In Nepal co-occurring deficiencies are common, causing only 4% of pregnant women to be adequate in all micronutrients (17). The high costs of measuring micronutrient status have limited the study and understanding of the nutritional health of women in low-income countries, yielding less-than-ideal amounts of information about a serious global problem.

Positive Deviance Approach to Health Research

To address these serious micronutrient deficiency issues, many intervention strategies have been developed. Supplementation is one of the most common strategies, especially for women of reproductive age, pregnant women, and young children, based on a summary of

intervention strategies described in a comprehensive review of nutrition interventions (18). Food fortification is also a preferred intervention strategy and is recognized as one of the most cost-effective interventions for large populations (18). By fortifying common foods with micronutrients, multiple deficiencies can be counteracted at the same time in a relatively cheap manner, an advantage over supplementation which often focuses on one or two micronutrients at a time.

The strengths of these strategies – demonstrated by the histories of salt iodization and vitamin A supplementation for children – lie in their demonstrated impact on health in many countries; ability to benefit large numbers of people; practicality and simplicity; strong advocates and supportive governments; philanthropic financial support; and academic engagement (19). In contrast, iron supplementation strategies have not been as successful; the strengths of vitamin A supplementation and salt iodization listed above have been weaker for iron supplementation programs and iron supplementation works best when given in daily or weekly doses instead of large bolus doses every six months (3,17). Just like any intervention, supplementation and food fortification have their weaknesses (19). Supplementation is usually targeted to specific groups of people based on general risk of deficiency, not based on the individual's needs, and neglects people outside of those groups (19). Supplementation also faces the challenge of low compliance (17,19). Fortified foods are effective when eaten in adequate quantities, but often the poorest, most undernourished populations are not purchasing fortified foods due to availability, expense, or preference (19). Fortified foods also may be ignored in favor of staple cultural foods. They can be challenging to produce, may not taste as good as the non-fortified product, and may not contain highly bioavailable nutrients (19).

These weaknesses should not be left unconsidered when developing new interventions for global health concerns like micronutrient deficiencies. Some alternate intervention strategies have been researched and advocated for, such as increased production and consumption of animal source foods, such as meat, milk, eggs and fish (20,21). Many believe that supporting citizens of developing nations in producing and consuming their own animal source foods would be a more sustainable, long-term strategy to improve micronutrient status in these countries. Regardless of differing perspectives on the sustainability and efficiency of this idea in particular, these researchers demonstrate the importance of continuing to develop intervention strategies beyond traditional strategies like supplementation and food fortification. More research, using new research methods and approaches, is needed to find more sustainable, effective, culturally acceptable, long-term ways to increase micronutrient sufficiency in low-resource countries and communities.

Aiming to find such intervention is an approach called Positive Deviance, which has been used in health and community research. This research strategy strives to find individuals in a community who, despite having the same resources and facing similar hardships as the rest of the community, practice behaviors that result in good health. It is based on the assumption that these existing solutions to community problems are "more likely to be effective, affordable, acceptable, and sustainable" (22). Positive Deviance requires the involvement of those who experience the problem regularly, or at least live in the community where it exists, and will be affected by the solution implemented to solve the problem (23). This research usually takes place in resource-poor communities that have high risk for negative outcomes, but it could be applied in any community or group context. This method stands in stark contrast to the traditional intervention strategies described above, which often import solutions by researchers or other

experts from outside the community. Ideally, the Positive Deviance approach involves a mindset shift for both the researcher and the community, and the traditional expert/community member relationship, in which community members have little say over the solutions offered, is reframed by giving the community a central voice in exploring the problem, co-discovering solutions, and teaching others (23). This allows the community to become excited about the implemented solution and even continually work to improve it and hold itself accountable to it.

There are seven steps to carrying out a Positive Deviance study or improvement program (23). The first two steps are to define the problem and desired outcome (whether behavior or results) by engaging the community's leadership and the local group affected by the problem in dialogue. Third, the "Positive Deviants", or those in the community who already exhibit the desired outcome, need to be identified. Then their unique practices and behaviors that set them apart from the rest of the community must be discovered, through dialogue with the positive deviants. The fifth step is to design and implement interventions, based on knowledge gained from these conversations with the community, that allow others in the community to access the knowledge resources or behavior practices of the positive deviants. These interventions must be assessed for effectiveness and altered as needed (step 6) before the last step of disseminating the findings to other communities that experience the same problem.

Just like any strategy, there are advantages and disadvantages to the Positive Deviance approach (24). First, it has the advantage of utilizing the wisdom of members of the community itself and identifying solutions that are applicable to others with the same socioeconomic constraints. Also, it exposes communities to methods of local problem solving, increasing their ability to solve other community problems on a local level. Furthermore, it may reveal partial solutions that can be implemented faster and have more immediate effect than long-term

development of the country or community. A disadvantage of the Positive Deviance approach is the requirement to find rare positive examples, which can be time-consuming and costly. Also, Positive Deviance is impossible to use in settings where there are no positive examples due to lack of services or resources. Positive Deviance research itself can be time-consuming and expensive for the researchers, since it requires active collaboration with a specific community. Lastly, the unique strategies identified in one community may or may not be applicable to other communities in the general population, due to different customs and resources. The lack of generalizability decreases its efficiency in tackling problems shared by a large population.

Applications of Positive Deviance to Nutrition or Pregnancy-Related Research

The Positive Deviance methodology has been applied in the study of health and nutrition and has been shown to be extremely effective and empowering in low-income or low-resource communities (23,24). One literature review compiled examples of the Positive Deviance methodology being applied to infant and child malnutrition and other areas, including pregnancy outcomes (25). The review included Positive Deviance programs addressing various problems that took place in Vietnam, Egypt, Pakistan, Haiti, Guatemala, and Indonesia and summarized similar themes across the programs. The most significant theme across all programs was addressing health and policy change goals with community-specific solutions. The analysis of the programs yielded the conclusion that both the implementation and results of the Positive Deviance methodology are complex and comprehensive and must take into account the larger context and sociological issues of the community. There is great potential for expanding the

application of the Positive Deviance methodology beyond nutrition and maternal-child health issues, but the methodology needs to grow in recognition in other areas of research.

One preliminary Positive Deviance inquiry study explored pregnancy weight gain and infant birth weight in two large rural communities in Al-Minia Governorate, Upper Egypt in order to determine behaviors associated with these two pregnancy outcomes (22). Pregnancy weight gain was measured in the Al-Ghatousha community and birth weight was measured in Etsa-Albalad. In Al-Ghatousha, the 74 women were weighed monthly between 4 and 7 months of pregnancy and in Etsa-Albalad, 66 infants were weighed within 48 hours of birth. The researchers also conducted group interviews with women in both communities to learn about demographics, use of antenatal care, water and sanitation, symptoms of possible urinary or reproductive tract infection, pregnancy workload, exposure to tobacco, and diet. To estimate socio-economic status of the women, the researchers asked a group of senior village officials to categorize the families of the participants based on income level. The researchers also conducted separate focus group discussions in each community with positive deviant women, their husbands, and their mothers-in-law. The researchers used an Arabic translator to talk with the participants and took hand-written notes on the focus group discussions.

In the pregnancy weight gain group, two groups were created based on amount of weight gain (poor-gainers gained < 1 kg/month; good-gainers gained ≥ 1.5 kg/month); 11 of the good-gainers were identified as positive deviants because they were also considered low income. In comparisons between the two weight-gain groups overall, good-gainers reported fewer pregnancies, were less likely to be low income, and were more likely to have some schooling. The positive deviants (low-income good gainers) and good-gainer group as a whole were both more likely to report multiple antenatal care visits, use tap water, rest more during pregnancy,

and eat more meat and vegetables during pregnancy. Women in the poor-gainers group were more likely to have dysuria, report cloudy or reddish urine, and consume more beans during pregnancy.

In the birth weight group, the mothers were split into two groups based on infant birth weight (low birth weight <3 kg; healthy birth weight ≥3 kg). Eighteen of the women with healthy birth weight infants were positive deviant women because they were also considered low-income. In this community, income was not associated with birth weight, although the community (Etsa-Albalad) was more economically advantaged than the other community (Al-Ghatousha). Mothers of infants with higher birth weights, including the low-income positive deviants, were less likely to be in their first pregnancy, reported more antenatal care visits, and reported resting more than usual during pregnancy. Women with lower birth weight infants were more likely to report cloudy or reddish urine. No dietary differences were detected between the groups.

The focus groups with the positive deviants strengthened these results. Positive deviants understood the importance of antenatal care and reported making sacrifices to receive it, such as selling wheat, corn, chickens or jewelry; purchasing medicines on credit; or borrowing money. Positive deviant women also prioritized rest, relying on household members to help with household tasks. Positive deviant women from Al-Ghatousha reported eating more meat despite the extra expense and ate more vegetables.

The data from this study provided background information for a more in-depth pilot Positive Deviance intervention project in two target areas (Ghatousha and Deir-Samalout), using another community from Al-Minia for comparison. The intervention project focused on women

at risk for low-birth weight infants and the key strategies used were upgraded antenatal care and weekly gatherings of pregnant women.

Another Positive Deviance study looked into growth-promoting behaviors and practices of mothers on their children in the largest urban slum in Asia, Dharavi, in Mumbai, India (26). Participants of the study were mothers enrolled in a community management of acute malnutrition (CMAM) program. To determine the study sample and identify potential participants, the researchers used anthropometric data collected through the CMAM program to calculate height/length-for-age and weight-for-age for 4209 lower socio-economic status children under three years living in different geographic areas of Dharavi. Children were excluded from the study if they had no siblings, had ever received medical nutrition therapy, and whose recorded nutrition status was likely to be inaccurate when compared to a household inspection. Children were labeled as potential positive deviants if their height/length-for-age and weight-for-height z-scores were greater than zero and labeled as potential non-positive deviants if their z-scores for the same measurements were less than -2, producing a list of children likely to be either well-nourished or malnourished. Community health workers selected a subset of mothers of the children on the list and interviewed them in their homes. The semi-structured interview covered topics on breastfeeding and complementary feeding practices, food security, childcare practices, social support, and child and maternal health. The community health workers also conducted a 24-hour recall of the child's diet with the mother and filled out an observation checklist of demographics, socioeconomic characteristics, and household observations. The interviews were audio-recorded and later transcribed and translated into English.

Of the 22 interviews conducted, 12 were with mothers of positive deviants and 10 were with mothers of non-positive deviants. The children's 24-hour recalls were analyzed and scored

for dietary diversity using the dietary diversity indicator from Food and Nutrition Technical Assistance and two researchers coded the transcripts independently before finalizing the coding structure and key themes by reaching consensus. Positive deviant mothers demonstrated 5 themes: 1) exhibiting optimal infant and young child feeding practices, such as breastfeeding exclusively for 6 months, 2) seeking advice on child nutrition from social networks, 3) valuing information from the media, 4) acknowledging the importance of maternal health, and 5) relying on social support systems to help in child rearing. The researchers found these outcomes interesting, since these differences emerged even though all women participated in the same education program taught by community health workers.

These two studies demonstrate some of the key nutrition-related topics most often studied using the Positive Deviance method using quantitative and/or qualitative data. Despite the differences between the goals, methods, and application of the Positive Deviance approach in these studies, together they are examples of how the Positive Deviance approach has been applied in nutrition research.

Purpose and Specific Aims

In light of the benefits and advantages of a Positive Deviance approach, and the continued issues of micronutrient deficiencies in women, we conducted a Positive Deviance study in Ghana with women of reproductive age. Our goal was to examine differences between women of healthy and unhealthy micronutrient status. Our specific aims were: 1) to identify women with healthy nutritional status (“positive deviants”) and women with lower nutritional

status (“negative deviants”) based on micronutrient and health status, and 2) identify unique behaviors and characteristics of each group that may influence their nutritional status.

Chapter 2

Methods

This project was completed as a follow-up of women who participated in a cross-sectional study entitled "Micronutrient Deficiencies in Ghanaian Women before Pregnancy". We used existing quantitative data from the parent study as well as new qualitative data collected specifically for this Positive Deviance study. Existing data were used to identify positive deviants (PDs), normal controls, and negative deviants (NDs); both existing data and qualitative data were used to identify differences between the ND and PD populations. Figure 1 illustrates the study design and analytic sample.

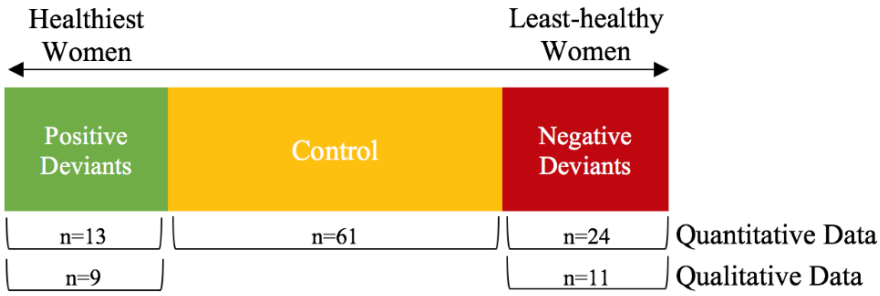

Figure 1. Study Design

Parent Study Methods

In the parent study, Dr. Alison Gernand and Dr. Laura Murray-Kolb (co-Principal Investigators in Nutritional Sciences at Penn State) worked with Dr. Esi Colecraft, a faculty member in the Department of Nutrition and Food Science at the University of Ghana in Accra, Ghana to examine micronutrient deficiencies in women before pregnancy. They conducted a pilot study in Asesewa, a semi-rural town located in the Upper Manya Krobo district in the

Eastern Region of Ghana and enrolled participants from October 20, 2015 until April 14, 2016. Data was collected by Ghanaian staff – research staff at the Department of Nutrition and Food Science in the University of Ghana and local residents with research experience. Staff worked at the Nutrition Research and Training Centre (NRTC) and conducted study visits in the Asesewa Government Hospital. The NRTC was established in 2010 through collaborative efforts between University of Ghana, McGill University in Canada, World Vision, and local resource institutions (27,28). The NRTC serves as the headquarters for nutrition research activities in the area, including a long-term intervention study (contemporaneous to this study) that taught local families the nutritional benefits of eating animal foods; how to keep a vegetable garden; and how to supplement their income by selling chicken eggs. The parent study received ethical approval from ethical review boards at the Noguchi Memorial Institute for Medical Research at the University of Ghana and The Pennsylvania State University.

The primary aim of the parent study was to assess micronutrient status in reproductive-age, non-pregnant Ghanaian women who expected to become pregnant within the next six months. Iron, zinc, copper, vitamin A, and vitamin D were assessed for each participant, as these are among micronutrients particularly important for healthy pregnancy outcomes. The researchers expected to find deficiencies of one or more of the micronutrients in the pre-pregnant women, information which could inform future studies and interventions. The secondary aim of the study was to develop research collaborations and capacity that would facilitate a future longitudinal study that would follow the women into pregnancy and postpartum.

The study enrolled 100 women who met the following eligibility criteria: aged 18 to 35 years, lived in the Upper Manya Krobo District, and were not currently pregnant but were planning to become pregnant in the next six months. Women who were pregnant within the last

12 months were ineligible to participate. Women were recruited through staff visits to local churches and community meetings, and by door-to-door visits. Interested women went to the hospital and completed an eligibility screening questionnaire. Eligible women were invited to enroll by going through the informed consent process and signing a consent form. Data collection was either completed immediately after the consent process or scheduled for the next available date. Since the women self-identified for participation, the sample was a convenience sample and its size was limited due to the pilot nature of the project.

Data and specimen collection consisted of a questionnaire on health and pregnancy history and socioeconomic factors (self-report); weight, height, blood pressure, and hemoglobin concentration (measured); and a blood draw. A list of all questions asked in the questionnaire can be found in Appendix A. All 100 women completed the anthropometric assessment and blood draw, but two women had missing questionnaire data (n=98 for questionnaire data analysis).

About 8 mL of venous blood was collected into two tubes (one for serum, one for plasma) from each participant by a trained phlebotomist during the study visit to the hospital. The blood samples were taken at a convenient time for each participant and were non-fasting. A Hemocue was used to immediately measure the participant's hemoglobin concentration using a drop of the venous blood. Blood tubes were centrifuged at the hospital per standard procedures, then plasma and serum samples were aliquoted into microcentrifuge tubes and stored in a liquid nitrogen tank at the hospital. Every week, new samples were transported back to the University of Ghana and stored in a -80°C freezer. At the completion of the study, all samples were shipped on dry ice to Penn State for micronutrient analysis.

The blood samples were analyzed in laboratories in the Penn State Department of Nutritional Sciences for iron, zinc, copper, and retinol (vitamin A) concentrations; vitamin D was

analyzed by an internationally certified laboratory at the Hospital for Sick Children in Toronto, Canada. Zinc and copper were measured in plasma by Dr. Gernand's laboratory using flame atomic absorption spectroscopy (29). Iron markers were measured by the laboratory of Dr. Murray-Kolb. Serum ferritin was measured using an immunoassay kit (Ramco Laboratories Inc, Houston, Texas), and serum iron and total iron binding capacity (TIBC) were measured using colorimetric methods (30), and transferrin saturation was calculated. In the case of inflammation, as indicated by alpha-1-acid-glycoprotein (AGP) ≥110 mg/dl and/or C-reactive protein (CRP) >1 mg/dl, serum ferritin was adjusted (AGP and CRP were both measured by ELISA). Retinol was measured in plasma in the laboratory of Dr. Catharine Ross using ultra-violet absorption in a Shimadzu UV-1201 Spectrophotometer using ultra performance liquid chromatography. Serum 25-hydroxyvitamin D ($25(OH)D_3$, for vitamin D status) was measured by high-performance liquid chromatography tandem mass spectrometry in Toronto (15).

Positive Deviance Study Methods

This thesis project used all data from the 100 participants of the previous study, and identified PDs and NDs based on micronutrient status, blood pressure, and body mass index (BMI). Then, qualitative data were collected from a representative set of PDs and NDs in the summer of 2017. This study received ethical approval from two ethical review boards: The Ethics Committee for Basic and Applied Sciences at the University of Ghana and The Pennsylvania State University Institutional Review Board. This study was funded in part through the Erickson Discovery Grant, an award for undergraduate students at Penn State to conduct research over the summer.

A priori, we established criteria for the PDs and NDs. PDs were identified as those who met all of eight criteria (n=13); NDs were defined as women who met ≤5 of those criteria (n=24) (see Table 1).

Table 1. Criteria to Classify Positive Deviants

Category	Range
Body mass index (BMI)	18.5-24.9 kg/m^2
Systolic blood pressure	90-120 mmHg
Diastolic blood pressure	60-80 mmHg
Plasma zinc	>70 μg/dL
Plasma copper	10-25 μmol/L
Transferrin saturation	16-45%
Plasma retinol	30-86 μg/dL
Serum 25-hydroxyvitamin D	>50 nmol/L

This study examined PDs and NDs in two parts using quantitative and qualitative data (see Figure 1). The quantitative data comes from the questionnaire administered to women in the previous study, and analysis was conducted on all available data (n=98). The qualitative data was unique to this Positive Deviance study and comes from in-depth interviews and brief household observations that were conducted with PDs and NDs who were able to be contacted and were available for the interviews.

All women identified as PD or ND were eligible for participation in the qualitative assessment. We aimed for 10 interviews in each group and made an initial list of 20 women, made of the first 10 PD and ND women enrolled in the parent study. However, with the larger pool of ND women, we were able to select the women with the lowest nutritional status within that category. This list was then blinded to PD/ND status and given to the field staff to use for recruitment. From the United States, we monitored the study's progress by communicating with

staff over email and WhatsApp. Since several women on the initial participant list were unavailable for an interview, we sent the staff ID numbers of additional women to ask to interview (staff had the full list of participant IDs, names and contact information from the previous study), without indicating if these women were PDs or NDs. This allowed staff to remain blinded to the woman's health classification in the interview process while ensuring a balanced sample size of PDs and NDs. Staff recruited participants by phone and those who were available to participate were interviewed in their home by the study staff after completing the informed consent process. The full interview was conducted in the language of the participant's preference (Dangme, Ewe, Twi, Hausa and English are commonly spoken in the area) and audio was recorded on a digital voice recorder. Later, audio files were transcribed and translated into English by the field staff per standard procedures. In the end, 20 women were interviewed – 9 PDs and 11 NDs.

The interview included questions about the foods the woman regularly ate, her cooking procedures, her food sources, and the social and educational resources she utilized. A household observation was also conducted to take note of equipment and food production methods the woman uses regularly. These were developed with the goal of building on the data from the parent-study questionnaire to learn details about the women's food-related behaviors and resources that may impact their health status. Prompts about specific foods or food groups were included in the interview based on common local foods as well as dietary sources of the micronutrients measured in the parent study. While the interview was self-report, the household observation checklist was completed by study staff based on items they observed in the household. In addition to noting which items they observed, they asked the woman for clarification on the item's usage as necessary and wrote notes on the observation checklist. The

full interview guide and household observation checklist can be found in Appendices B and C, respectively.

Fieldwork

The funding for this study allowed Dr. Gernand and me to spend a week in Ghana, in both Asesewa and Accra. The two main purposes of the trip were 1) to train the field staff on study procedures and activities and 2) to expose me to the environment and culture in Ghana so that I could better manage the study and analyze and interpret the data. During our time in Accra, we stayed at the University of Ghana and visited the Department of Nutrition and Food Science. We spent our time working out details for our time in Asesewa and gathering materials from the previous study to return to Penn State. We then traveled to Asesewa and spent Monday through Friday at the Nutrition Research and Training Centre (NRTC). Two field staff had already been hired (one worked for the parent study and knew all the participants). We trained them on interviewing and transcription procedures and worked with them to translate the consent form and interview questions into the local languages. We conducted two practice interviews and were able to conduct the first study interview during our time there. Over meals of authentic Ghanaian food in a small restaurant down the road from NRTC, we asked the staff questions about Ghanaian food and culture that might come up in answers to interview questions. See Appendix D for more information on and pictures of local foods.

In total, data collection occurred from August 10, 2017 until September 9, 2017. Each interview lasted approximately 50-75 minutes and produced between 8 and 16 pages of transcription. Study staff were provided with a computer and enough cell phone data to create a

wifi hotspot for uploading audio files and interview transcripts to Penn State's secure cloud service via Box.com. As transcripts were uploaded, they were reviewed in real time and the staff were asked clarification questions to ensure the meaning of the translated and transcribed interviews was understood. In addition, the staff sent pictures of the completed observation checklists using WhatsApp (facilitating immediate review). The hard copies of the signed consent forms, interview guides, and observation checklists were stored at the University of Ghana in Accra until the end of the study when they were transferred to the U.S. Now all documents are stored in a locked laboratory at Penn State.

Quantitative Data Analysis

The analysis of the questionnaire data – the quantitative portion of the study – was completed using Stata 14 (Stata Corp, College Station, TX). Characteristics of the participants of the parent study (n=98) were analyzed across the three groups (PD, control, and ND), as shown in Table 1 (see also Figure 1). Data for most variables were classified into two or three categories in order to analyze all data using chi-square tests. For example, the household size – the combined number of adults and children indicated as living in the household with the participant – is a discrete variable but was separated into categories of 1-2, 3-5, and 6+ people. Height and hemoglobin concentration were normally-distributed continuous variables and were analyzed using ANOVA to compare means across the three groups.

Two variables used from the questionnaire originally had many categories: drinking water source and toilet facilities. The categories for these variables were combined to consolidate similar responses into two or three categories, guided by Sixtus Aguree, a Ghanaian and PhD

student working under Dr. Gernand who worked on the previous study. Categories for these variables were combined based on drinking water treatment and cost (for drinking water) and infrastructure (for toilet facility).

Two variables used were composite variables formulated by doctoral students working on the parent project. We obtained a socio-economic status (SES) index from Sixtus Aguree (doctoral student working under Dr. Gernand). He developed the index with the multivariate principal component analysis approach (in lieu of specific income data) and used information about household assets collected in the questionnaire, such as whether or not they owned livestock, a bike, a refrigerator, a radio, and agricultural land. He used 12 assets in total. Using the SES scores calculated through this method, the SES scores were split into the top 20%, middle 40%, and lowest 40%, similar to other research (31,32). We obtained a food security index from Ruth Pobee (doctoral student working under Dr. Murray-Kolb). She used eight questions from the questionnaire that were about the woman and her household (33). Data from the questions focused on children's food insecurity were not included. If a woman answered 'Yes' to any of the household food insecurity questions, she was marked as food insecure in the overall variable. She also created a categorical variable that summed the woman's responses to all eight questions to show the scale of food insecurity, so that 0 indicated food secure and 8 indicated most food insecure.

Data were cleaned for random missing responses and when possible, responses were entered by hand based on the participant's responses to other questions that informed the answer for the missing variable. One participant was missing a serum copper measurement, which could have prevented her from being defined as a PD, control, or ND. However, her values for the other criteria showed that she did not meet the PD cutoff for exactly one other variable, meaning

that she would be in the 'control' group (meeting 6-7 of the PD criteria) with or without the copper value, and was classified as such.

Qualitative Data Analysis

Transcript analysis – the qualitative portion of the study – was completed in three phases. First, the women's responses in the transcripts were coded using Dedoose, an online qualitative analysis software. Before coding, another staff member generated a new ID number for each transcript, blinding me to PD and ND interview transcripts. We made seven code "families" based on the interview topics: 1. Foods Consumption, 2. Food Sources, 3. Food Storage, 4. Food Preparation, 5. Diet Influencers, 6. Social Groups, and 7. Other Unique Behaviors. Codes were created based on interview questions as well as patterns in the women's responses, yielding 39 codes in total. When coding was complete, I was unblinded to the PD and ND women and created two categories of transcripts in Dedoose. This allowed me to separate the coded excerpts into separate documents based on PD or ND status, preparing for the next step.

In phase two, I downloaded word documents of excerpts from each code and compared them between ND and PD women to look for differences in responses between the groups. I read the documents in pairs and recorded themes from the PD and ND trends in an excel sheet. To distinguish each participant's excerpts and clarify the themes, I made every set of excerpts a different text color and highlighted themes in different colors. This prevented me from double-counting themes that were mentioned several times by only one participant. I also recorded the number of PD and ND responses in each code. When I finished comparing the code documents for trends, I summarized the differences in trends between PDs and NDs.

In the third phase, I studied the data from the household observation checklists. Sometimes this data was able to clarify women's interview responses, such as the type of agricultural land they owned. I performed chi square tests on Stata for each variable to look for differences in household possessions or resources between NDs and PDs who were interviewed.

Chapter 3

Results

Results from the parent study questionnaire were separated into two topics: socio-demographics and health and pregnancy history. These results give an overview of the population of 100 women as well as comparisons between the three groups – PDs, controls, and NDs. Responses from the qualitative data collected in the Positive Deviance study were separated into themes, based on the topics covered by the interview questions. Similarities and differences between the interviewed PDs and NDs are presented for each theme.

Quantitative Data

Socio-Demographic Comparisons

Table 2 summarizes the key socio-demographic characteristics of all 98 women who had complete data in the parent study. Overall, 63% of participants were between the age of 23 and 30 years. Almost all had experienced some education, but only 46% had been educated to primary school or beyond. None had a university education. The majority of women responded that they were in a committed relationship, but only 38% responded that they were married through the official government process. The majority responded that a male was the head of their household; interestingly, 13% responded that they themselves were the head. Most women reported living in a household of three or more people while 23% reported living in a household of one or two people. Almost all women reported having two or more adults living in the household and almost 70% reported one or more children living in their household. Essentially

all women had health insurance and 69% reported having an income-generating activity. About a quarter of the women were identified as food insecure. Most drank sachet water (equivalent of bottled water, see Appendix D) or water piped into their compound, yard or plot. The majority used toilet facilities outside of their home, and most shared it with people outside of their household. Only 17% used a flush toilet in the household or had a place dedicated to hand-washing. Eighty-three percent reported owning at least one mosquito net, but only 64% reported sleeping with it the night before the study visit. The majority reported using charcoal for cooking fuel and about a quarter reported using gas. A third indicated owning livestock and/or agricultural land. Almost all women reported having electricity (97%); not treating water in any way before using it (98%); and obtaining household water (not for drinking) from a public tap or piped into the dwelling area (96%).

We compared these characteristics between the PD, control, and ND groups and most characteristics either appeared similar, or attributing the differences to chance could not be ruled out. Owning agricultural land and home ownership were the only variables that were statistically significantly different ($p=0.025$ and 0.005, respectively). Fifty-four percent of PDs, 36% of controls, and 13% of NDs reported owning agricultural land while 85% of PDs, 44% of controls and 54% of NDs reported owning their own home (versus renting or squatting). PDs reported a wider range of acres owned and reported a higher median number of acres than the NDs. Variables that approached statistical significance for differences were: the sex of the household head, toilet facilities, and possession of a mosquito net. No PD women were the head of their household, compared to 18% of the control group and 8.3% of NDs. A higher percentage of PD women, compared to both the control and ND groups, indicated using either flush toilet system (23% PDs vs. 16% of both control group and NDs), or free, public toilet facilities (62% PDs vs.

49% control and 29% NDs). A higher percentage of NDs reported using a ventilated improved pit latrine (54% NDs vs. 34% control and 15% PDs). Lastly, 92% of PDs reported owning mosquito nets compared to 85% of the control group and 71% of NDs, but the rate of *using* the nets was relatively similar between all three groups.

A few other trends emerged from comparing the groups that are worth noting although not statistically significant. PDs tended to be older and to report larger households: 7.7% of PDs reported having one or two members of the household and 54% reported having between three and five members, while around 25% of the control and ND groups reported having one or two members and about 41% of the two groups reported having between three and five household members. All PDs reported at least two adults in the household, and the majority (62%) reported having three or more. Compared to NDs, a lower percentage of PDs were in the lowest SES category (23% PD vs. 46% ND) and a higher percentage were in the highest SES category (39% PD vs. 8% ND). A lower percentage of PDs (8%) reported using liquefied petroleum gas as cooking fuel compared to control and ND groups (26% and 21% respectively). Lastly, a higher percentage of PDs reported owning livestock (46% PDs vs. 33% control and 25% NDs).

Table 2. Socio-Demographic Comparisons

	Total n=98	**PD n=13**	**Control n=61**	**ND n=24**	
Variable	n (%)				**P Value[a]**
Age (years)[b]					0.401
18-22	12 (12.4)	2 (16.7)	16 (26.2)	6 (25.0)	
23-30	61 (62.9)	5 (41.7)	35 (57.4)	12 (50.0)	
30-35	24 (24.7)	5 (41.7)	10 (16.4)	6 (25.0)	
Education level					0.337
No schooling	6 (6.12)	0 (0.0)	5 (8.2)	1 (4.2)	
Less than primary/middle/JSS[c]	47 (48.0)	9 (69.2)	24 (39.3)	14 (58.3)	
Primary/middle/JSS	34 (34.7)	4 (30.8)	23 (37.7)	7 (29.2)	
SSS[c]/vocational	11 (11.2)	0 (0.0)	9 (14.8)	2 (8.3)	

In a committed relationship	96 (98.0)	13 (100)	59 (96.7)	24 (100)	0.538
Married	38 (38.8)	5 (38.5)	22 (36.1)	11 (45.8)	0.707
Participant is head of household	13 (13.3)	0 (0.0)	11 (18.0)	2 (8.3)	0.157
Male head of household[b]	79 (92.9)	12 (92.3)	46 (92.0)	21 (95.5)	0.866
Household size (adults and children)					0.712
1-2	23 (23.5)	1 (7.7)	16 (26.2)	6 (25.0)	
3-5	42 (42.9)	7 (53.9)	25 (41.0)	10 (41.7)	
6+	33 (33.7)	5 (38.5)	20 (32.8)	8 (33.7)	
Number of adults in household					0.523
1	7 (7.1)	0 (0.0)	6 (9.8)	1 (4.2)	
2	47 (48.0)	5 (38.5)	29 (47.5)	13 (54.2)	
3+	44 (44.9)	8 (61.5)	26 (42.6)	10 (41.7)	
Number of children in household					0.970
0	29 (29.6)	3 (23.1)	19 (31.2)	7 (29.2)	
1-3	52 (53.1)	7 (53.8)	32 (52.5)	13 (54.2)	
4+	17 (17.4)	3 (23.1)	10 (16.4)	4 (16.7)	
Have health insurance	92 (93.9)	13 (100)	56 (91.8)	23 (95.8)	0.481
Generate income	69 (70.4)	9 (69.2)	41 (67.2)	19 (79.2)	0.551
SES index					0.233
1 – lowest	40 (40.8)	3 (23.1)	26 (42.6)	11 (45.8)	
2 – middle	40 (40.8)	5 (38.5)	24 (39.3)	11 (45.8)	
3 – highest	18 (18.4)	5 (38.5)	11 (45.8)	2 (8.3)	
Food insecurity	24 (24.5)	4 (30.8)	14 (22.9)	6 (25.0)	0.836
Drinking water source					0.531
Piped or purchased	62 (63.3)	9 (69.2)	36 (59.0)	17 (70.8)	
Free, shared, and treated	36 (36.7)	4 (30.8)	25 (41.0)	7 (29.2)	
Toilet facilities					0.180
Flush toilet system in household	17 (17.4)	3 (23.1)	10 (16.4)	4 (16.7)	
Ventilated Improved Pit latrine	36 (37.7)	2 (15.4)	21 (34.4)	13 (54.2)	
Pit latrine, composting toilet, hanging toilet	45 (45.9)	8 (61.5)	30 (49.2)	7 (29.2)	
Have a hand-washing place	17 (17.4)	1 (7.7)	12 (19.7)	4 (16.7)	0.582
Have mosquito net[b]	81 (82.7)	12 (92.3)	52 (85.3)	17 (70.8)	0.176
Slept with net last night	64 (79.0)	12 (83.3)	39 (75.0)	15 (88.2)	0.470
Cooking fuel					0.261
Charcoal	69 (70.4)	10 (76.9)	40 (65.6)	19 (79.2)	
Wood	7 (7.1)	2 (15.4)	5 (8.2)	0 (0.0)	
Liquefied Petroleum Gas	22 (22.5)	1 (7.7)	16 (26.2)	5 (20.8)	
Have agricultural land	32 (32.7)	7 (53.9)	22 (36.1)	3 (12.5)	0.025
Acres of agricultural land[d]	10 (4,24)	10 (4,36)	13 (3,23)	3 (2,4)	

Own their home	51 (52.0)	11 (84.6)	27 (44.3)	13 (54.2)	0.005
Have livestock	32 (32.7)	6 (46.2)	20 (32.8)	6 (25.0)	0.424

[a] chi-square unless otherwise noted
[b] Age: total n = 97 (PD n=12) (missing screening data for 1 participant); Male household head: total n = 85 (control n=50, ND n=22) (women who answered not being the head of their household); Slept with mosquito net: total n = 81 (PD n=12, control n=52, ND n=17)
[c] JSS – Junior Secondary School (comparable to U.S. middle school); SSS – Senior Secondary School (comparable to U.S. high school)
[d] median (interquartile range). Due to very small sample size, statistical difference in median was not tested.

Health and Pregnancy History Comparisons

Table 3 summarizes the health information and pregnancy history of the participants and also provides a comparison between groups. The mean height of the women was approximately 5 feet 3 inches. The mean plasma hemoglobin concentration was 12.3 g/dL, and almost 40% of women were anemic. This measured outcome is much higher than the self-reported "diagnosed with anemia" variable in the table, in which only 14% of women self-report being diagnosed as anemic by a doctor. Almost 60% of women had been pregnant at least once. The majority of women who had been pregnant (n=58) had experienced no miscarriages, stillbirths, or abortions. The majority of those women had experienced 1 or 2 live births (74%). A low percentage of women reported being diagnosed with heart problems (9%), while more than half (55%) had been diagnosed with malaria. Some results were not included in Table 2. Only one woman reported being diagnosed with diabetes and no one reported being diagnosed with cancer. Most of the women (97%) reported that they did not take any micronutrient supplements. BMI was part of the criteria for identifying PDs and NDs, but of the 24 ND women, 7 were overweight (25.0-29.9 kg/m^2) and 8 were obese (> 30 kg/m^2); none were underweight. All PDs were within the healthy BMI range (18.5-24.9 kg/m^2), by definition.

When these characteristics were compared between the PD, control and ND groups, two factors were clearly different between the groups. First, 92% of PD women indicated

experiencing at least one or more pregnancies. In the control and ND groups, only 59% and 42% had experienced one or more pregnancies, respectively. Secondly, when comparing number of abortions between the groups, more PD women had experienced an abortion than control group or NDs. In fact, half of the PD women who reported being pregnant before also reported having an abortion. Other factors appeared different between groups but were not statistically significant: hemoglobin concentration was higher for PDs vs controls and NDs; rates of anemia from measured hemoglobin were lowest for PDs, while self-reported diagnoses of anemia were highest for PDs and lowest for NDs; and self-reported heart problems diagnoses were highest for PDs and lowest for NDs.

Table 3. Health and Pregnancy History

	total n=98[a]	**PD n=13**	**Control n=61**	**ND n=24**	
Variable	n (%)				**P value**[b]
Height (cm)[c]	160.2 (6.2)	162.1 (6.4)	160.2 (6.0)	159.2 (6.7)	0.395[c]
Hemoglobin (g/dL)[c]	12.3 (1.3)	12.9 (0.9)	12.2 (1.4)	12.2 (1.2)	0.180[c]
Anemia[d]	39 (39.0)	3 (23.1)	25 (39.7)	11 (45.8)	0.393
Gravidity					0.055
0	40 (40.8)	1 (7.7)	25 (41.0)	14 (58.3)	
1	22 (22.5)	5 (38.5)	14 (23.0)	3 (12.5)	
2+	36 (36.7)	7 (53.9)	22 (36.1)	7 (29.2)	
Live births					0.736
0	7 (12.1)	2 (16.7)	5 (13.9)	0 (0.0)	
1	29 (50.0)	6 (50.0)	18 (50.0)	5 (50.0)	
2+	22 (37.9)	4 (33.3)	13 (36.1)	5 (50.0)	
Miscarriage (1 or more)	11 (19.0)	3 (25.0)	6 (16.7)	2 (20.0)	0.813
Stillbirth (1 or more)	5 (8.6)	0 (0.0)	4 (11.1)	1 (10.0)	0.487
Abortion (1 or more)	14 (24.1)	6 (50.0)	8 (22.2)	0 (0.0)	0.022
Diagnosed with anemia	14 (14.3)	3 (23.1)	9 (14.8)	2 (8.3)	0.079
Diagnosed with malaria	54 (55.1)	9 (69.2)	35 (57.4)	10 (41.7)	0.231
Diagnosed with heart problems	9 (9.2)	3 (23.1)	5 (8.2)	1 (4.2)	0.149

[a] Height, Hemoglobin, and Anemia: total n=100 (all 100 women enrolled in study have these measurements); Live births/miscarriages/stillborn births/abortions: total n=58 (PD n=12, control n=36, ND n=10) (women who reported having been pregnant)
[b] Chi-square test, unless otherwise noted
[c] Mean (standard deviation), used ANOVA to obtain p value
[d] Hemoglobin <12.0 g/dL

Qualitative Data

We aimed to get the same number of women interviewed from PD and ND groups, however there was a smaller pool of PD women to contact. We recruited and interviewed a total of 20 women: 9 PDs and 11 NDs. The length of time for the 15-question interview ranged from 27 to 73 minutes long. We incorporated the data from the direct household observation here, along with self-reported interview results. The most clearly identifiable themes came from the ND responses, possibly because more NDs were interviewed than PDs. To summarize the interview trends, more NDs reported having refrigerators and using them to store leftover food; cooking with gas, propane or electric stoves; eating more types of starchy foods, fruits, and meat regularly; drinking sugary drinks; eating prepared or processed foods; getting food from several sources including as gifts from others; burying cocoyam, yam and cassava in the ground for storage; and washing maize after soaking before milling. More PDs reported having gardens and/or farms, being part of a women's financial group, traveling 30 or more minutes to market, going to market on Fridays, fermenting maize in water after milling, and eating “turkey berry” (local fruit). Descriptions of local foods and preparation methods are provided in Appendix D.

Diet

Similarities

When asked to discuss the foods and drinks consumed regularly (once a week or more), all interviewed women mentioned eating banku (a fermented maize and cassava dough, often served beside a thin soup) and fish, whether fresh or dried, every day. About half of the women from each group mentioned eating vegetable oil while more than half of each group mentioned

eating palm oil. About half of each group mentioned three or more vegetables that they eat in a normal week. About two thirds of each group mentioned drinking 'tea' (which in this context is most likely a reference to a powdered coffee drink, not leaf tea steeped in water) and about a third of each group mentioned drinking Sprite.

> *Interviewer: I want you to mention all the foods you eat for me.*
> *ND (#1010): Mention all? Ok. I eat banku, yam, fufu, cocoyam, potato, white yam.*
>
> *Interviewer: What about dry fish?*
> *PD (#1361): As for the dry fish, I eat anytime. Something like salmon, herrings, and tuna I eat every day.*

Differences

Almost all NDs reported four or more starchy foods that they eat regularly, such as fufu, waakye, kenkey, porridge, rice, plantain, potato, cocoyam, and yam (see Appendix D), compared to about half of the PDs. More NDs also mentioned pre-prepared foods that they buy, including kenkey, banku, waakye, ice cream, biscuits, rice, and beans, whereas PDs rarely mentioned these. More than half of the NDs mentioned eating meat and/or poultry several times a week. All NDs mentioned three or more sugary drinks that they drink regularly, and overall, NDs mentioned a wider variety of sugary drinks, including malt drinks, coke, "lip" tea, Fanta, powdered coffee drinks, and fruit juices. In contrast, less than half of PDs mentioned consuming three or more sugary drinks regularly. Lastly, as a group, NDs mentioned a wider variety of fruits compared to PDs and about half reported eating mangos and/or pineapple, while more PDs mentioned eating oranges, bananas, and/or pawpaw.

> *ND (#1441): Oh, I eat different foods but it is like those foods are not my favorite.*
> *Interviewer: What are those foods?*
> *ND (#1441): Oh, tuozaafi, yam, waakye.*
> *Interviewer: Ok. But the fufu, rice?*
> *ND (#1441): And banku is the one I like.*

Interviewer: What are the foods that you eat that you don't cook yourself but gets from somewhere else?
ND (#1028): Eh, sometimes if I travel, I buy kenkey which I don't cook myself sometimes banku. Mm, ice kenkey and sobolo.

ND (#1437): Mostly with the fresh meat I eat it on Fridays. But with the dry fish, if I buy kenkey, then I buy fish to add up.

About half of the PDs reported eating turkey berry (see Appendix D), while no NDs mentioned turkey berry. Most PDs mentioned eating different types of vegetable soups or stews multiple times a week. As a group, PDs mentioned eating meat, poultry, rice, and other fruits (including pears, mangos, and apples) irregularly (less than once a week).

PD (#1384): Fish…is a regular, this thing that we used to take.
Interviewer: …What about the meat?
PD (#1384): The meat once a while.

Interviewer: So what fruits do you eat?
PD (#1020): But for banana and apple, before the almighty God if I have the money I buy.
Interviewer: Ok. And what about pawpaw and mango?
PD (#1020): Oh as for mango I don't get it here but when I go to the village and I get it anytime I am coming from the village I bring some.

Food Preparation and Storage

Similarities

Regarding food storage, all women mentioned storing uncooked foodstuffs indoors. About half of women in both groups reported storing foodstuffs in a cupboard or container until using it to cook, and about a third of women in both groups reported storing uncooked foods for up to 3 days before using it. Another third reported storing foodstuffs for only one day. Regarding food preparation, more than half of women in both groups reported cooking with a coalpot (see Appendix D). About half from each group reported washing their cooking

containers before using them. About a third of each group reported owning three or more pots and/or pans to use. About two thirds of both group were observed to be cooking over an open fire during the household observation.

> *Interviewer: How do you keep your leftover food that you will use the next day so it does not get spoiled?*
> *PD (#1419): I heat the leftover and keep it in the kitchen cupboard. We have a separate place in the kitchen where we keep a burner so I put it on the burner.*
> *Interviewer: Is that all you do to keep your food safe?*
> *PD (#1419): Yes that is all. I don't have a refrigerator.*

> *ND (#1417): If I will cook banku, I wash the cooking pot, add some water and sieve it, then I add the corn dough and mix. Then I cook it on a coalpot. I cook the banku on a coalpot. If I see that it is hard, I add some water to it on fire and allow the water to boil and turn it.*

Differences

Only NDs, although a low percentage, reported burying cocoyam, yam, and/or cassava in the ground for storage before cooking. More NDs reported storing cooked food leftovers in a refrigerator, a trend supported by our household observation, which demonstrated that more NDs had refrigerators than PDs. More NDs reported cooking with a saucepan and/or cooking pot and using charcoal as a heat source. A low but higher percentage of NDs also reported using "switch" stove with a gas cylinder to cook, a trend emphasized by direct observation data, which found that more NDs had gas, propane or electric stoves. In addition, more NDs reported adding salt to food while cooking, washing, peeling and cutting fruit before eating, and letting maize soak in water for three days before milling it. Only NDs – and more than half – reported straining water from maize and washing it again before milling it. In contrast, only PDs – and more than half – reported soaking maize in water for fermentation after milling it and fewer PDs soaked maize for strictly three days before milling it.

Interviewer: Please describe the things or measures you use to store your food so that lasts for you.
ND (#1383): If it is yam, and I went to store, I dig the ground and bury it inside. Cocoyam too, the same, so that it does not get dried and looks fresh.

ND (#1408): If I will cook rice like this, I will wash the saucepan. I have a cylinder and stove, so with that I set the fire and put the saucepan on the fire. I then put some amount of water in the saucepan and add some salt. After adding the salt, if the water becomes hot then I put the rice in it…. If yam, then I will peel the yam, wash it and wash the saucepan, then put the yam in it and cook.

Interviewer: How do you ferment your foods?
ND (#1401): If I remove the chaff from the maize, and put it in water for some 3 days. I will remove it from the water after the 3 days, wash it again and send it to mill it. Then I will mix it with water and allow it to sit for 3 or 2 days.

Food Sources and Weather Influences

Similarities

All women reported purchasing food at the local market in Asesewa, which is centrally located, and about a fifth of women in both groups reported buying food at the market in Akateng, a nearby town. Less than half of both groups reported going to market on Mondays or going twice a week, but more PDs reported shopping on Mondays than NDs. About half of women in each group reported preferring to buy food at Asesewa market because they can get everything they need there. Most women mentioned there was more fruit and vegetable variety in the rainy season. About one third of women in each group mentioned that food becomes more expensive during the dry season.

PD (#1384): …when it is raining like this, you will get more fresh vegetables something like carrot, cabbage, lettuce and those/those kind of vegetables, they are always fresh and plantain too like this season, you can have plenty as compared to the dry season and it is even expensive at the market.

Interviewer: So what is the main reason why you buy from where you buy it?
ND (#1425): Because that is the place here. I get whatever I need, anytime I need it.

Differences

More NDs reported receiving food as gifts from others and generally reported multiple food sources. The majority of NDs reported traveling 20 minutes or less to the Asesewa market, while more than half of the PDs reported traveling more than 30 minutes to the Asesewa market. More NDs reported going to market when they need specific foods, while the majority of PDs reported going to market every Friday. In addition, more PDs reported going to market once or twice a week (less than NDs). The majority of NDs reported going to the Asesewa market because it is not expensive, the food is fresh, and it is the only place they can buy food. Regarding weather influences on the foods available to them, more NDs reported eating less quantity and variety of foods in the dry season compared to the rainy season. More NDs also mentioned starchy foods, fruits, and/or vegetables they eat more in the rainy season than the dry season.

> *Interviewer: So which days do you go and buy?*
> *PD (#1416): Fridays and Mondays*
> *Interviewer: Fridays and Mondays? Please what is the distance from your house to the market where you buy your things which is Asesewa market? Like if you calculate, it will be how many minutes?*
> ...
> *PD (#1416): I need about 40 minutes to the market.*

> *ND (#1417): The reason why I go to Asesewa market and buy there is because, that place is not far. And they always bring fresh foods there always that you will get and cook. And the foods are less expensive. They bring more foods that are good.*

Interview responses regarding growing food themselves were contradictory. A third of NDs mentioned not growing any food at home, but more PDs reported going to Asesewa market because they do not produce food at home. In addition, about half of women in each group mentioned three or more foods that they grow themselves, whether in a farm or garden.

Women's responses in the interview also did not always line up with outcomes of our direct observation data: most PDs that actually owned a garden or farm did not self-report those food sources in the interview. Two NDs did not mention whether or not they grow food in the interview, and one ND said that she did not grow food in the interview but indicated owning a farm in the household observation. Combining responses from the interviews and the household observation, all but one PDs indicated having growing space either at their home or at a farm outside of town, while four NDs did not. The NDs that did report growing food at home mostly reported growing cassava and plantain while PDs reported growing cassava and maize.

Nutrition Education and Social Groups

Similarities

About a third of both groups reported learning about food from health professionals, such as the nutrition research project (the outreach effort by the University of Ghana), visits to the hospital, friends who are nurses, and presentations by health professionals. The majority of women in both groups mentioned foods they were told to eat more of, such as bananas, oranges, pineapple, turkey berry, kontomire, and dry fish. Around a third of women in both groups said they were part of two different social groups, and the majority of both groups were part of a church group.

> *Interviewer: So, what are some of the foods that you were taught at the hospital that when you eat, it will make you strong?*
> *ND (#1432): Foods like kontomire, soya beans and dry fish. If you use them to prepare stew, you will stay healthy.*

> *Interviewer: …What are some of the foods they [women's fellowship] mentioned to you?*
> *PD (#1368): They mentioned that fruits like orange, banana, plantain and others. We should always eat these foods to make us healthy.*

Differences

Only NDs, although a low percentage, reported being part of no social groups. Two thirds of the PDs and less than half of the NDs were part of one group and more PDs reported being part of women's financial groups. More PDs mentioned foods they were told *not* to eat, including sugar, meat, eggs, and vegetable oil, while more NDs reported learning food-related skills, such as how to cook, personal hygiene, and how to clean the home. More PDs reported learning about food in their church groups than NDs.

> *Interviewer: So, what are some of the things you learn if you go for meetings in this group? What have you been taught? Were you taught something about healthy foods?*
> *ND (#1383): Yes. We were told that if we will eat foods like fruits, you need to wash it before eating. And how to cook good and delicious foods.*

> *PD (#1415): Yes. Sometimes if your condition is worse, then they [the hospital] will ask you not to consume sugar, fresh meat. But you should rather eat dry fish…We should eat banana in addition. Orange, apple, water melon and pineapple…*
> *Interviewer: So these are the things that you learn when you go to the hospital?*
> *PD (#1415): Yes. We were told to eat kontomire and turkey berry. That if you don't get them to eat, you will not gain the blood.*

Chapter 4

Discussion

Context and Interpretation of Findings

This study was conducted in the semi-rural town of Asesewa, Ghana, which is home to the only hospital for the district – the Asesewa Government Hospital. This hospital is respected and used by the surrounding community and is where study visits were conducted for the parent study. The parent study included 100 women between the ages of 18 and 35 years who expected to become pregnant in the next year and blood analysis and anthropometric data showed that the population was reasonably healthy, albeit with 39% of women being overweight or obese. About half of women were deficient in at least one micronutrient: 7% were deficient in vitamin A, 9% were deficient in copper, 10% were iron deficient, and 15% were zinc deficient. Only 10% exhibited at least two deficiencies; none were vitamin D deficient and almost none were hypertensive. In this context, we conducted a Positive Deviance study to identify food behaviors and characteristics of PDs (healthiest women) compared to NDs (the least healthy women), mainly based on micronutrient status and other health markers.

Taking into account all data, several key themes emerged. Because not much comparable research has been done, there is limited potential for comparing results from this study to others. Most PD research related to nutrition focuses on pregnancy and childhood, not preconception. The most comparable study is the PD study on pregnancy outcomes in upper Egypt described earlier (22).

First, more PDs reported owning agricultural land and owned more acres of agricultural land than NDs. This finding can be interpreted different ways. Considered in light of home

ownership trends – most PDs owned their home while almost half of NDs rent – this could be an indication of security in the community. PDs may be more established in the community and therefore have the comfort of a sense of permanency in their household. More agricultural land might also indicate that PDs have a stronger attachment to or appreciation of their food. Since they work hard to produce it and rely on their farm or garden as a major food source, they might take greater care to not let it go to waste. They also might eat more plant foods, as opposed to meat, which was reported more by NDs when asked about their regular diet, because they are more convenient. Agricultural land might also allow PDs the opportunity to grow more foods they like, including a wider variety of fruits and vegetables. The women were not asked in the interview what foods they produce at home, but some women did mention a few foods they grew at home. The agricultural land may also be a source of income from cash crops, not food, for the women. In this situation, the woman's household may not even be operating the farm themselves; they may rent it to others to farm.

In contrast, those who did not mention owning agricultural land might still obtain food from local farms: they could work on a farm and get free produce during harvest; they could obtain food from family members with farms; or they could live close enough to the market that they do not feel the need to grow food in a garden or farm. These details were not assessed in the current study. As demonstrated by the variety and apparent inconsistencies in the women's responses about their ability to grow food at home, the questions asked in the questionnaire and interview may not have been specific enough to assess the significance of the nuances of land ownership and farming in the community.

Another theme is the lower prevalence of anemia among PD women. While more PD women self-reported being diagnosed with anemia by a doctor, measured hemoglobin values

from the blood samples taken in the parent study show that more NDs actually had anemia. While iron status (estimated by transferrin saturation) was used in the PD criteria, hemoglobin was not, making this finding a unique difference between the groups. Anemia can be an indication of several micronutrient deficiencies other than iron, such as folate or vitamin B12, which were not assessed in this study. Interestingly, about half of the PDs mentioned eating turkey berries, a plant widely recognized in the area for its ability to 'give blood' (using the phrasing from the interviews). The botanical name of turkey berry is *Solanum turvum*, which has in fact been studied and measured for its nutritional content: one study found that they contain 77 mg iron per kg of the fruit (approximately 9.6 mg/cup) (34). For comparison, the RDA for women between the ages of 19 and 50 years in the United States is 18 mg/day (3). Turkey berry consumption seems to be a significant source of iron for PD women, potentially making it an influential factor in the iron status and anemia differences between PD and ND women. More ND women did mention regularly eating meat, but chicken seemed to be eaten more frequently than red meats like beef and goat.

Several factors that were not particularly significant in and of themselves do point to a potential trend in PD women having a greater exposure to the healthcare system. A higher percentage of PD women self-reported diagnoses of anemia, malaria, and heart problems from a doctor. As demonstrated by the discussion about anemia earlier, these reports may not accurately indicate prevalence of these health conditions in both populations. More than half of ND women were overweight or obese, increasing the chance that they may exhibit undiagnosed heart problems and other health issues. So, the difference between the groups may not be their actual health but the fact that they went to a doctor at all. In support of this potential trend, a higher percentage of PD women reported owning at least one mosquito net, and most obtained them at a

government health center, hospital, or clinic. Another supporting trend is that almost all PDs reported having been pregnant at least once before – several even more than four times – while more than half of NDs reported never being pregnant before. Since the hospital in Asesewa is trusted and respected by the community, women with more pregnancies may have been to the hospital more often for prenatal care. This suspicion goes along with the finding from the PD study done in Egypt on successful pregnancy outcomes, which found that PD mothers had more prenatal care visits and made personal sacrifices in order to receive prenatal care than non-PD mothers (22). Pulling these three trends together points to the possibility that more PD women in this study have used and benefitted from the healthcare system than ND women, enabling them to learn more about healthy diets and lifestyle behaviors.

The interviews also seem to point to dietary differences between the groups: most NDs reported eating starchy foods (e.g. banku, fufu, porridge, plantain, yam), processed foods, and/or sugary drinks regularly, and adding salt to food while cooking – characteristics of a more 'Western' diet. These foods have little nutritional value; the high sugar and starch contents mean that they contain more empty calories than other foods and offer little micronutrient value. However, some of the sugary drinks consumed by NDs, such as 'lip' tea and other powdered coffee or chocolate drinks, are fortified with micronutrients like iron, calcium, and vitamins A, C, D, E and K (35). In contrast, PDs rarely mentioned processed foods and mentioned fewer starchy foods and sugary drinks that they consume regularly. While there was not an apparent difference in reports of vegetable and fruit consumption – in fact, NDs as a group reported a wider variety of fruits – PDs may be eating a more traditional Ghanaian diet and potentially other foods that support their nutritional health, including turkey berry. Overall a diet higher in starch and sugar may be contributing to higher rates of obesity and lower micronutrient status for NDs.

There also appears to be aligning trends between household size, age, and sex of household head that may point to other lifestyle differences for PDs. PDs reported more adults and children in their households – while the trend of having more children mirrors the trend of more pregnancies for PD women, more adults in the household may mean that the woman has more support in raising the children and taking care of the household. In addition, not being the head of the household may mean the woman has fewer responsibilities for the household and more time to take care of herself. Being slightly older, as well as having more pregnancies, may indicate that PD women are more mature and have more experience in self-care and child-rearing. The PD study in Egypt found similar findings – PD mothers indicated resting more during pregnancy and having more help with chores, contributing to healthier birth outcomes (22).

Another theme that arose through the interviews were closer proximity to the Asesewa market among NDs. While this can seem counterintuitive – one might expect PDs to live closer to the market and therefore have more direct access to food – this may indicate a difference in amount of exercise ND and PD women get. While most NDs reported taking 20 minutes or less to get from home to the market, the majority of PDs reported that it took 30 minutes or more to get to the market. However, most women did not clearly indicate their mode of transportation to the Asesewa market. This trend may be related to higher rates of overweight and obesity among NDs – since they do not have to walk as far for food, they may be getting less exercise.

Also, NDs seemed to use the Asesewa market on more irregular schedules than PDs while also getting food regularly from other food sources. PDs tended to report more established schedules for going to market: more than half of the PDs reported shopping at the Asesewa market twice a week on specific days, and almost all reported shopping on Fridays. Almost half

reported shopping on both Mondays and Fridays. In contrast, ND responses were not as consistent: a few NDs went twice a week, a few went as needed (when they need specific foods to cook), and a few went every day. Less than a third of NDs reported shopping on both Mondays and Fridays. Almost all NDs reported receiving food as gifts from friends and family as a regular food source, compared to half of the PDs. These trends may mean that NDs depend on others more for their food than PDs. They also may indicate that NDs have less established schedules for food purchasing and even cooking and do not buy food to have on hand to cook throughout the week. These trends may be related to the groups' proximity to the market – NDs may be able to go to the market as needed, on a less strict schedule, since they live closer to the market. This allows them to have more convenient, regular access to food while PDs have a longer commute to the market and have to plan when to buy food. The Asesewa market also has "convenience" foods, such as ready-to-eat fried foods, that might have been purchased more often by NDs with frequent trips to the market.

Lastly, NDs consistently demonstrated owning and using electric or gas utilities for cooking or food storage, such as refrigerators, freezers, or stoves. Questionnaire data shows that NDs use gas as a cooking fuel more than PDs and the interviews and household observations show that more NDs own refrigerators, electric stoves, or gas/propane stoves. These trends themselves may point to differences in cooking habits and methods between the groups. NDs may be cooking using more 'Western' methods as opposed to traditional methods. They may also store food for longer periods of time by using refrigeration. However, the possession and usage of these items does not seem to support their nutritional health.

Strengths and Limitations

A key strength of this research is implementing the Positive Deviance method, allowing us to explore characteristics and food behaviors of the study population, while valuing local resources and traditions rather than devising intervention strategies from outside the community. Also, the study used both quantitative and qualitative data, benefitting from the strengths of both. Quantitative data allowed the researchers to use traditional, robust methods of data analysis to identify trends in the data while qualitative data allowed participants to share their experiences freely, yielding more nuances than possible in a questionnaire. Information was gathered in a variety of ways, yielding a diverse array of data to analyze and compare results. Data collection and analysis for the Positive Deviance study was blinded on all sides – field staff were blinded to PD and ND participants, participants were not told which group they belonged to, and researchers were blinded when coding and analyzing interview transcripts. Additionally, micronutrient status was directly measured from blood draws rather than dietary intake. The research also used local staff who lived in Asesewa to carry out field activities, giving the staff members more research experience and expanding their research skills. Ghanaian researchers were also readily available at Penn State to aid and add context to data interpretation. Lastly, this research is filling a gap in nutrition and PD research by studying women during preconception.

However, there were several challenges and limitations to this research. First, the sample sizes for both the parent study (n=100) and Positive Deviance study (n=20) were small. Also, the interview transcripts were difficult to understand and interpret, mainly due to the challenge of translation to English; ambiguities were hard to clarify and any mistranslations were difficult to identify. Communication logistics across cultures and time zones also made the study challenging to conduct, preventing the primary researchers from interacting directly with field

staff during data collection and transcription as questions and problems arose. Lastly, there are few studies applying the PD approach to nutrition-specific problems, and none appear to be conducted on women during preconception, making comparison of findings to results from other studies difficult.

Conclusion and Future Directions for Nutrition Research

Micronutrient status is important for healthy pregnancy outcomes, but malnutrition and micronutrient deficiencies remain common in women in low-income communities and developing countries. In order to improve the nutritional status of women around the world, effective, sustainable, and culturally acceptable nutrition strategies are needed. The Positive Deviance method has been shown to be an effective but underutilized approach to nutrition research. Here, we used Positive Deviance to identify women in a low-resource, semi-rural town in Ghana with positive health outcomes based on eight nutrition markers and compare their socio-demographic characteristics, general health and pregnancy history, and food-related behaviors and resources. This study found that owning agricultural land and a home, consumption of turkey berries (a high-iron fruit), exposure to healthcare, living in a larger household with more than two adults, living farther away from the town's market and having a consistent schedule for purchasing food at market were trends among women with the best nutritional status in the studied population. Consumption of starchy or sweet foods or drinks and using electric or gas utilities to cook or store food were trends among women with the poorest nutritional status.

However, there is sparse research in this area. To further develop the body of research on micronutrient status and women's health, more studies should be done on women during preconception to assess their status in micronutrients important for pregnancy. Some of these studies should be done using the Positive Deviance method, so that solutions that already exist within communities can be identified and shared with other community members. In the specific context of this study, future nutrition research should learn more about women who own agricultural land, what they use it for, and what they grow to eat for themselves. It should also explore in more detail the healthcare available to the women, how much they use it, what they think about it, and how they benefit from it, especially regarding nutrition and health before pregnancy. Future research should strive to determine the strength of the association between healthcare exposure and usage and nutritional health. Lastly, future research should do a more rigorous dietary assessment of the women to get a clearer and more consistent picture of the foods these women eat regularly, as well as the impact that their food source and cooking methods have on their health. More research into preconception nutritional health that involves the community in the research and identifies, builds on and shares strategies already employed by community members that demonstrate positive outcomes will help develop effective, sustainable and culturally acceptable interventions to improve the nutritional status of women around the world before they become pregnant.

Appendix A

Factors Studied in Parent Study Questionnaire

1. Have you ever been to school? (if no, skip to question 4)
2. If yes, what is your highest level of education completed?
3. How many years did you complete in school?
4. Are you in a committed relationship?*
5. Are you currently married?*
6. Do you live with your partner/husband?*
7. Are you the head of your household? (if yes, skip to question 9)
8. If not, what is the sex of the head of your household?
9. How many adults aged 18 years and older live in your household?
10. How many children aged 17 years and younger live in your household?
11. Has a health professional ever told you that you have any of the following conditions?
    a. Anemia
    b. Malaria
    c. Diabetes
    d. High blood pressure
    e. Other heart problems
    f. Cancer
12. Have you ever experienced night blindness?
13. How many times (total) have you been pregnant? (if 0, skip to question 19)
14. How many times have you had a miscarriage (spontaneous)?
15. How many times have you had an abortion (induced)?
16. How many times have you given birth to a live-born child?
17. How many times have you given birth to a stillborn child?
18. How many children do you have living today?
19. What is the date of the first day of your last menstrual period?
20. Are you currently taking any vitamin or mineral supplements?
21. What is the main source of drinking water for members of your household?
22. What is the main source of water used by your household for other purposes such as cooking and hand washing?
23. Do you do anything to the water to make it safer to drink?
24. What do you usually do to make the water safer to drink?
25. What kind of toilet facility do members of you household usually use?
26. Do you share this facility with others who are not members of your household?
27. Do you have a specific place for washing hands?
28. Do you have any soap or detergent in your household for washing hands?
29. How many rooms in your household are used for sleeping?
30. What is the main material of the dwelling floor?
31. What is the main material of the roof?
32. What is the main material of the exterior walls?
33. What type of fuel does your household mainly use for cooking?
34. Does your house have:

   a. Electricity
   b. Radio
   c. Television
   d. Refrigerator/freezer
   e. Washing machine
   f. Laptop computer
   g. Desktop computer
   h. Video deck
   i. DVD/VCD player
   j. Sewing machine
35. Does any member of your household own:
   a. Watch
   b. Mobile telephone
   c. Bicycle
   d. Motorcycle or scooter
   e. Animal drawn cart
   f. Car/truck
   g. Canoe/boat with motor
   h. Canoe/boat without motor
36. What is the occupancy status of your household in the dwelling?
37. Does any member of your household own any piece of land that can be used for agriculture?
38. How many hectares/poles/acres/plots of agricultural land do members of this household own?
39. Does your household own any land or buildings that are rented to others for a residential or business purpose?
40. Does your household own any livestock, herds, other farm animals, or poultry?
41. Does your household have any mosquito nets that can be used while sleeping?
42. How many mosquito nets does your household have?
43. Where did you get the net(s)?
44. Did you sleep under a mosquito net last night?
45. Do you have health insurance?
46. What type of health insurance do you have?
47. Do you currently have a valid 2015/2016 national health insurance scheme or NHIS card?
48. Do you have an income generating activity?
49. How much money did you earn over the last week form your income generating activities?
50. Is this income usual?
51. In relation to other women in your community do you think you are:
   a. Better off?
   b. The same?
   c. Less well off?
52. During the last month, were you worried that your household would run out of food because of lack of money or other resource to get food?

53. During the last month, did your household run out of food because of lack of money or other resource to get food?
54. During the last month, did your household lack enough money or other resource to get healthy and nutritious food?
55. During the last month, did you or any adult in your household have to consume a diet based on only a few kinds of foods because of lack of money or other resources to get food?
56. During the last month, did you or any adult in your household not eat breakfast, lunch or dinner [or skip a meal] because of lack of money or other resources to get food?
57. During the last month, did you or any adult in your household eat less than you thought you should because of lack of money or other resources to get food?
58. During the last month, did you or any adult in your household feel hungry but did not eat because of lack of money or other resources to get food?
59. During the last month, did you or any adult in your household eat only one meal a day or go without eating for a whole day because of lack of money or other resources to get food?
60. During the last month, did any child, aged 5 or younger, in your household not eat healthy foods because of lack of money or other resources to get healthy and nutritious food?
61. During the last month, did any child, aged 5 or younger, in your household have to consume a diet based on only a few kinds of foods because of lack of money or other resources to get food?
62. During the last month, did any child, aged 5 or younger, in your household not eat breakfast, lunch or dinner because of lack of money or other resources to get food?
63. During the last month, did any child, aged 5 or younger, in your household eat less than you thought he/she should because of lack of money or other resources to get food?
64. During the last month, did you have to serve less food to any child aged 5 or younger in your household because of lack of money or other resources to get food?
65. During the last month, did any child, aged 5 or younger, in your household feel hungry but did not eat because of lack of money or other resources to get food?
66. During the last month, did any child, aged 5 or younger, in your household eat only one meal in a day or go without eating for a whole day because of lack of money or other resources to get food?

*Cultural note: in Ghana, ‘marriage’ is official legal term; many couples are ‘engaged’ with cultural practices and live together like married couples but never get legally married

Appendix B

Positive Deviance Study Interview Guide

Form 1: Interview Guide

Lifestyle factors related to nutritional status of pre-pregnant Ghanaian women in Asesewa

Study staff name:	_____
Location of interview:	_____
Date of interview:	___ ___ - ___ ___ - ___ ___ ___ ___ (dd – mm – yyyy)
Time interview began:	___ ___ : ___ ___ am/pm (hh:mm)
Time interview ended:	___ ___ : ___ ___ am/pm (hh:mm)

SECTION A: Identification

1. Participant ID Number: ___ ___ ___ ___

SECTION B: Interview

Thank you for agreeing to participate in this study. The purpose of this interview is to learn about the foods you eat, resources available to you, and your daily tasks and activities. Although you may eat the same foods as most of your family members, we are specifically interested in what you eat.

First, I would like to ask you for some information on the foods you eat regularly.

1. **What foods or drinks do you consume on a regular basis? Please describe the foods and drinks and how often you eat/drink them.**

   Probe for (if not mentioned):
   a. Animal foods (dairy, red meat, poultry, organ meats, or fish)
   b. Fruits and vegetables, and the specific parts of them (for example: seeds, stem, leaves, root, peel)
   c. Tea, coffee, cocoa, other drinks
   d. Red palm oil or other oils

2. **Do you know of any foods, or any parts of plants or animals, that you eat but are uncommon for others in this area to eat?** For example, whole fish including small bones, or the leaves of sweet potato plants. Please describe foods you eat that are not common for others to eat, even if you only eat them occasionally.

3. **Please describe why you eat the foods you have discussed so far.**

Now I'd like to know where you get the food you eat.

4. **Where you currently buy food? Please describe all locations, how far they are from your home, and what and how much you typically buy there.**

5. **What food, if any, do you grow, raise, or gather at and around your household? Please elaborate if you eat this food yourself, or if you sell or share it with others.**

6. **Please describe any other food you eat that is not produced at your household or purchased elsewhere. How is it obtained?**

7. **Why do you get food from these places? Are there other places you would like to buy food or other ways you would like get food? Please describe why you get food from the current sources and why you do not get food from other desired sources.**

Now I'd like to ask you about where you keep your food before you cook it and after a meal, if you have leftovers.

8. **How do you store food before it is cooked, prepared, or eaten? Please mention how long food is stored and anything you do to preserve foods for an extended period of time.**

9. **How do you store food after it has been cooked or prepared, such as leftovers from meals?** Please mention where you store food and how long.

Now I'd like to know about how you cook and prepare food.

10. **How do you cook your food? Please describe your heat source(s) and cookware (for example, iron pots).**

11. **How do you prepare foods that are not cooked? What foods do you consume without cooking them?**

12. **How do you ferment foods? Please describe your fermenting process, the foods you ferment, and how you prepare them for eating.**

Now I would like to ask you about factors that may interrupt your diet.

13. **How do the weather conditions and seasons impact your diet? Do you eat more or less of different foods in different seasons or weather conditions?** Please describe any changes to your food sources and preparation techniques that occur due to changes in weather conditions or seasons.

Lastly, I'd like to know about any social, financial or educational resources you have available to you.

14. **What programs, community groups, financial services, and/or educational resources do you participate in or utilize?** For example: a women's financial group, program for raising chickens for eggs, church group, resources from a health clinic. Please describe the type of activities you participate in or benefit from and the frequency of your participation.

15. **Is there anything more you would like to add, in particular, anything that makes you unique in regards to food habits or resources?**

Thank you for participating in this interview! Your responses will help us get to know the resources available in your community that may impact your health.

Appendix C

Positive Deviance Study Household Observation

Form 2: Observation Checklist

Lifestyle factors related to the nutritional status of pre-pregnant Ghanaian women in Asesewa

Study staff name:	_____
Date of form completion:	___ ___ - ___ ___ - ___ ___ ___ ___ (dd – mm – yyyy)
Time of form completion:	___ ___ : ___ ___ am/pm (hh:mm)

SECTION A: Identification

2. ID Number: ___ ___ ___ ___

SECTION B: Observation Checklist

Item	**Observed? Yes/No**	**Location**	**Notes**
Food refrigeration unit			
Enclosed, non refrigerated space for food storage			

Open-air area for food storage			
Open fire for cooking			
Gas/propane stove for cooking			
Electric stove for cooking			
Vegetable Garden			
Food-producing trees			
Other crop production			
Raising own livestock/ chickens			

Appendix D

Foods, Drinks, Utensils and Cooking Techniques in Asesewa

Starchy Foods

Food Item	Description	Picture (if available)
Banku	Fermented maize flour (cornmeal) cooked in water and often stored in thin plastic bags. It is often served with soup and eaten with the fingers.	
Fufu	Thick dough made of yam, plantain and cassava pounded together in a mortar and pestle. Fufu is always served with a soup or stew poured over it.	
Porridge	Cooked grains, usually millet, maize or a mixture of grains.	
Ga Kenkey	Fermented balls of maize flour (cornmeal) dough wrapped and steamed in corn husks.	
Fante Kenkey	Fermented balls of maize flour (cornmeal) dough wrapped and steamed in plantain leaves.	
Ice Kenkey	Kenkey dough mashed with milk and sugar. It is eaten as a dessert and served cold.	
Jollof Rice	Rice cooked with spices, oil, tomatoes, tomato paste and sometimes vegetables and/or meat/fish.	
Waakye	Rice and beans cooked together with millet leaves, garnished with pasta, and served with tomato sauce.	
Mpompoto	Overcooked yam or cocoyam served with meat or fish and palm oil.	
Apapransa	A one-pot dish made from maize flour, palm oil, fish, and beans.	

Yam	Root vegetables similar to potatoes. Often boiled and served alongside stews.	
Cocoyam	A root plant with edible leaves (called ‘kontomire’). Known as ‘taro’ in other parts of the world.	
Cassava	A tuber plant with edible leaves. Known as ‘yucca’ or ‘manioc’ in other parts of the world.	
Plantain	Starchy fruits that resemble bananas. Often sliced thin and fried until crunchy (plantain chips) or fried in bigger chunks until soft.	

Cooked Foods

Food Item	**Description**	**Picture (if available)**
Light Soup	A peppery, thin tomato-based soup that often contains bits of meat, fish or vegetables (e.g. eggplant)	

Okra Stew	A thin tomato-based soup with dried, ground okra added.	
Groundnut Soup	A creamy soup made with ground peanuts, tomato sauce, spices, and sometimes a meat.	
RedRed Stew	Black-eyed peas cooked with smoked fish, tomato sauce, palm oil, and spices. It is often served with gari (see below)or fried plantains.	
Kontomire Stew	Leaves of the cocoyam plant cooked with smoked fish, tomatoes, and vegetable oil.	

Vegetables

Food Item	**Description**	**Picture**
Turkey Berry	Small berries grown in bushes known for their high iron content.	

Kontomire	Tough leaves of the cocoyam plant (similar to collard greens).	
Garden Egg	Small eggplants (about the size of an egg), usually white, yellow or orange in color.	
Okra	Short, tough green vegetables that create star-shaped slices and become slimy when cooked.	

Other Foods

Food Item	**Description**	**Picture (if available)**
Gari	A course, dry meal made from fermented cassava.	
Palm oil	A red-colored oil that is high in saturated fat made from red palm nuts.	

Snails	Large snails often cooked in stews.	
Palm Nuts	Nuts grown on the red palm tree that contain palm oil.	

Drinks

Food Item	Description
Generic Drinks	
Sachet Water	Water packaged in small plastic bags. The corner of the bag is ripped off with the teeth to drink the water.
Brukina	A drink made from cow milk and millet
Sobolo	Sugar added to bissap leaves with water and ginger
Lip Tea	Powdered coffee drink. Two common brands are Milo and Cowbell Coffee.
Malt	A non-alcoholic soft drink produced by Guinness.
Country Milk	A refrigerated drink made with milk, wheat, and sometimes beans.
Brand-Name Drinks	
Incolac	Milk powder fortified with vitamins A and D.
Alvaro	A drink made from barley, lactose, and malt extract.
Don Simon	A mixed fruit drink
Vitamilk	Soy milk with added vitamins and minerals that comes in many flavors.
Rush	An energy drink

Utensils

Item	Description	Picture
Coalpot	A metal structure that holds a pot over hot coals for cooking.	
Cooking pot	Pots used for cooking.	
Containers for food storage	Various containers for storing food.	

Food Preparation

Action	Description	Picture
Pounding Plantain for Fufu	Plantain is pounded and mashed using a wooden mortar and pestle.	

Milling Cassava	Cassava and other grains are milled to make dough.	
Soaking Maize	Soaking maize in water to make banku.	

Photos are the author's.
Sources of information included personal experience in Ghana and *The Ghana Cookbook* by Fran Osseo-Asare & Barbara Baëta (Published in 2015 by Hippocrene Books, Inc.)

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ACADEMIC VITA

Academic Vita of Carissa Heine
carissaheine@gmail.com

EDUCATION

The Pennsylvania State University, *University Park, PA* — *Graduation:* **May 2018**
Bachelor of Science in Nutritional Sciences, Dietetics Option
Honors in Nutritional Sciences, Schreyer Honors College
Minors: Spanish; Civic and Community Engagement
Student Marshall for the Department of Nutritional Sciences
Dean's List: 6 semesters

La Universidad Pontificia de Salamanca, *Salamanca, Spain* — **Fall 2016**
Psychology course (*Aprendizaje Humano* - Human Learning) taught in Spanish

NUTRITION-RELATED EXPERIENCE

Community Engagement Intern — *Penn State Center Philadelphia; Awbury Arboretum* — **Philadelphia, PA**
- Taught nutrition concepts in creative and interactive ways to teens in Teen Leadership Corps program — *Summer 2016*
- Managed teen staff at weekly farmers' market stand
- Developed instructional card prototypes on selection, preparation, and storage of vegetables targeted to a low-literate audience for presentation at Nutrition Links conference (Sept. 2016)

Dietary Services Intern — *Foxdale Village Retirement Community* — **State College, PA**
- Worked with dietitian and head chef to develop new cycle menu and improved display boards — *Summer 2017*
- Provided dietary services to residents in coordination with complete care plan

Pediatric Nutrition Assistant — *Family Food LLC* — **Virtual**
- Wrote summary reports and growth charts for children in various nutrition programs — *September 2016 – August 2017*

Farm Intern — *Student Farm at Penn State* — **University Park, PA**
- Collaborate with other interns to operate a diversified, 1-acre vegetable farm and 25-member Campus Supported Agriculture (CSA) program — *March 2017 – November 2017*

Short Order / Prep Cook — *Kling House Restaurant at Kitchen Kettle Village* — **Intercourse, PA**
- Prepared meals to order and food for next day service — *Spring 2012 – Summer 2015*
- Promoted positive attitude, team spirit and cooperative atmosphere during fast-paced service

RESEARCH EXPERIENCE

Honors Thesis: *Using Positive Deviance by Micronutrient Status to Identify Differences in Food Behaviors in Women of Reproductive Age in Ghana* — **University Park, PA** — *October 2015 – Present*
- Responsibilities include: writing interview questions, planning travel to Ghana, applying for grants, receiving ethical approval from two IRBs, writing standard operating procedures (SOPs), overseeing data collection from abroad, cross-cultural communication, analyzing data, writing thesis paper

LEADERSHIP EXPERIENCE

Penn State Student Farm Club (SFC) — **University Park, PA**
Director of Advocacy and Outreach — *Summer 2017 – Present*
- Meet and communicate with administrators, student leaders of other clubs, and potential donors to determine a long-term site for the Student Farm and develop a collective vision for the program
- Manage and support club project teams
- Applied for and received $5,000 community service award for SFC
- Presented about SFC at Pennsylvania Association of Sustainable Agriculture conference 2018

Project Team Lead *Spring 2017*

- Planned two evenings of cooking instruction, collaborative cooking, and community dining for 12 people
- Planned overnight trip to Philadelphia to tour urban farms and attend 2017 Philly Farm & Food Fest

Co-Founder & Treasurer *Fall 2015 – Spring 2016*

- Coordinated events and fundraisers to engage student members and increase awareness of SFC
- Managed club finances and applications for external funds for large club events
- Presented about SFC at the University of Vermont Food Systems Summit 2015

Active Member (Student Farm Initiative) *Fall 2014 – Spring 2015*

- Compiled a list of courses at Penn State that could count for a new Food Systems minor
- Participated in planning community visioning sessions for the Student Farm at Penn State

Penn State InterVarsity Christian Fellowship **University Park, PA**

Leadership Team Member

- Worked with leadership team of 10 people to develop leadership skills, grow our vision for ministering to campus, and plan weekly activities *Fall 2015 – Spring 2017*

Small Group Leader *Spring 2015*

- Led a weekly small group student Bible study
- Met regularly with a younger student for discipleship and to train her to be a small group leader
- Attended Urbana15 youth missions conference in St. Louis, Missouri in December 2015

Active Member *Fall 2014*

- Attended weekly small group Bible studies and large group worship and activities

ACTIVITIES

Student Member — *Academy of Nutrition and Dietetics* ***Fall 2015 – Present***
Student Protégé — *College of Health & Human Development Alumni Mentoring Program* ***Spring 2017 – Present***
Student Mentor — *The Schreyer Honors College Career Development Program* ***Fall 2017 – Present***
Student Protégé — *The Schreyer Honors College Mentoring with Honors Program* ***Fall 2015 – Spring 2016***
Semester Study Abroad in Salamanca, Spain — *IES Abroad Salamanca* ***Fall 2016***
Food Committee Lead — *Penn State Student Sustainability Advisory Council* ***Fall 2015***

AWARDS, CERTIFICATIONS AND SKILLS

Awards: Alumni Recognition for Student Excellence Award; Erickson Discovery Grant; Schreyer Travel Grant
Language: Proficient in speaking, reading, and writing in Spanish
Certification: National Restaurant Association ServSafe Certified (until Oct. 2020)
Computer Program Skills: SuperTracker, CulinarE Companion™ Recipe Management, Stata, Dedoose, Microsoft Office, MiniTab, Photoshop, Canva, GoogleDrive, Dropbox, Box
Other Skills: CITI IRB trained, laboratory safety trained