ABSTRACT

Markers of an Unhealthy Pregnancy:
An Assessment of The Ingestion of Soft Rocks During Pregnancy and Blood Lead Levels in Luo Women of Rural Western Kenya

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Geophagia, the consumption of soil or "soft rocks," is a common practice in certain regions of the world. Although the composition of these non-food items varies regionally, multiple studies have found detrimental health effects, specifically lead toxicity. Trace amounts of lead have been found in the soft rocks that are typically consumed by Luo women living on the Nyakach Plateau in rural western Kenya, and a 1999 study conducted in this area found that 54% of the women admitted to consuming soft rocks during pregnancy. The purpose of this study was to determine the extent of soft rocks consumption during pregnancy and a potential correlation with blood lead levels of mothers living on the Plateau in the Nyanza Province. A 30-question survey about nutritional habits during pregnancy was given to 49 Luo mothers, and their anthropometric (height and weight) and blood (hemoglobin and lead) measurements were recorded. Close to half of the women stated that they had eaten soft rocks during pregnancy, and the average blood lead level of this group was 5.89 μg/dL (range= 4.0-16.0, SD= 2.31). A significant relationship was found between the level of exposure (zero, medium, or high level of soft rocks consumption) and blood lead level ($F= 3.76$, $R^2= 0.165054$, $p= 0.0325$). When asked the reason for ingesting the soft rocks, 52% of the women stated their "craving" for the rocks as their primary reason, with the second most-frequent response being a cultural reason. Other alarming findings were that two-thirds stated they ate less during pregnancy, and half of them said they were in poor health during this time. A significant correlation between increased soft rocks consumption and increased lead levels in the bloodstream could indicate that the two are related, or the association may be a marker of general poor health and health behaviors. The findings of this analysis demonstrate high levels of geophagia among the women in this particular region, which may have negative effects on themselves and potentially on their children.

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MARKERS OF AN UNHEALTHY PREGNANCY:

AN ASSESSMENT OF THE INGESTION OF SOFT ROCKS DURING PREGNANCY AND BLOOD LEAD LEVELS IN LUO WOMEN OF RURAL WESTERN KENYA

A Thesis Submitted to the Faculty of

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In Partial Fulfillment of the Requirements for the

Honors Program

By

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DEDICATION

I am extremely grateful to my parents, brother, and roommates for keeping me sane and reassured through all of the highs and lows of this project. This study is dedicated to them as well as to the mothers of the Nyakach Plateau.

CHAPTER ONE

Introduction

Geophagia is a specific form of pica, the abnormal craving and/or consumption of nonfood items, involving soil or soft rocks (Lacey, 1990). Though the etiology of geophagia is unclear, it has been shown that earth-eating is a social practice with high cultural value that is often passed down through generations and mainly practiced by women (Abrahams & Parsons, 1996). Some women reported craving the rocks during pregnancy for their nice taste, while others believe that it will supply them with needed nutrients (Young 2010). Food insecurity could also play a role in a person's decision to partake in geophagia (Rose, Porcerelli & Neale, 2000; Halstead, 1968). Developing regions, particularly Sub-Saharan Africa, have a high prevalence of this practice.

There is concern for potentially harmful effects of geophagia, such as gastrointestinal infections or anemia from iron deficiency (Kutalek et al., 2010; Prince et al., 1999). A particularly notable cause for concern is the potential ingestion of lead through consumption of soil or soft rocks. If ingested in high amounts, lead can cause a wide range of health complications ranging from impaired neurological development to iron-deficiency anemia (Schnaas et al., 2000; Alabdullah et al., 2005; Carvalho et al., 2011). Lead toxicity is especially of interest among pregnant women because fetal transmission may occur following the ingestion of soft rocks (Gardella, 2001). Among the Luo tribe in rural western Kenya, pregnant women have been told that the "soft rock", as it is known, is not good for them to eat. However, a 1999 study found that 54.2% actively engage in the practice (Prince et al., 1999).

The composition of the ingested geophagic materials varies across regions, but on Nyakach Plateau in Kenya, traces of lead have been detected in the soft rocks the women of this area eat (unpublished data, 2012). Additionally, testing done in an annual clinic in this area revealed abnormal blood lead levels among this population (unpublished data, 2010). Through conversing with the Luo mothers of the Nyakach Plateau, this study investigated women's lives during pregnancy including diet, health, and the ingestion of soft rocks. The intent of the study was to explore the conditions under which a woman would eat rocks during her pregnancy and to document the prevalence and degree of anemia and lead toxicity in the population. It was hypothesized that eating soft rocks during a prior pregnancy would correlate with lower hemoglobin and higher lead levels in the present. The measurement of lead toxicity and the extent of geophagia in this population may serve as a retrospective indication of a prior unhealthy pregnancy.

CHAPTER TWO

Review of Literature

Although discrepancies between specific definitions of "pica" exist in the literature, the general term refers to the abnormal craving of nonfood items (Lacey, 1990). Around 400 BC, the first known description of pica was provided by Hippocrates and has then on been established in the literature, though not to a very detailed extent (Young, 2010). A specific form of pica is known as geophagy or geophagia, the deliberate ingestion of soil or soft rocks. Even though it is logical that geophagy would be most common among small children, research has shown that pregnant women are even more likely to engage in geophagy. In fact, during adulthood, geophagy seems to be much more common during pregnancy than it is in other periods of adulthood (Young, 2010). The soil types commonly eaten include the walls of huts, termite mounds, arboreal ant-clay, and soft stone, or *undongo ya mawe* which is sold on the market and frequently craved by pregnant women (Geissler et al., 1999).

Among women who are chronically malnourished in terms of macro- and micronutrients, such as those in sub-Saharan Africa (SSA), the tendency toward geophagy is greater, and serious dangers threaten already compromised pregnancies. In some obstetric populations, such as Dar es Salaam, the prevalence of geophagy exceeds 60% (Nyaruchucha, 2009). Reasons for this relatively high prevalence among pregnant women as opposed to other adult groups range from cultural beliefs to potential curative effects for morning sickness and other pregnancy symptoms, but the reasons vary from region to region (Nyaruchucha, 2009). Rural western Kenya is a setting in which this potentially disastrous set of circumstances is typical. A study published in 1999 found that 71% of pregnant Luo women in the rural Bondo District of Western Kenya ate soil, and 91% said that their children ate soil as well (Prince et al., 1999). In Kenya, the preferred earth was soft rocks, or odowa, with 54.2% of the pregnant women consuming it (Prince et al., 1999). As this has been the most recent published study concerning geophagy practices in this particular region of Kenya, a more current update on the prevalence among these women is needed.

Pica Hypotheses

There are three major hypotheses concerning the practice of pica. The *nutritional deficiency hypothesis* states that the reason behind engaging in pica is due to a deficiency in particular micronutrients (Young et al., 2008). Looking specifically at pregnant women, this hypothesis addresses the fetal demand for growth nutrients and suggests a role in the mother's abnormal cravings as well as the increased demand of nutrients for her own metabolism (Hunter, 1973; Eiley, 1998). For example, there are multiple studies that demonstrate the correlation between pica practice and the individual's need for calcium and zinc supplementation (Eiley, 1998; Prasad, 2013). There are also further studies that show a micronutrient deficiency causing changes in taste sensitivity, suggesting that pica is not an attempt to remedy the nutritional deficiency but is rather a consequence of this internal change in taste perception (Young et al., 2008).

The second physiological hypothesis is known as the *protection hypothesis*, which states that pica plays a protective role in the body by alleviating the harmful effects caused by toxins and microbes (Young et al., 2008). One mechanism by which pica substances may potentially protect the body is through the reduction of the intestinal lining permeability by binding to the mucosal layer, thus decreasing the amount of toxins into the bloodstream (Young et al,, 2010). Another potential mechanism is through the pica substance's ability to bind to a pathogen, rendering them unable to be absorbed by the gut. One study showed that a particular type of geophagic clay has the ability to bind to tannins and glycoalkaloids, secondary compounds in plants that possess toxic effects, and decrease their harmful effects (Johns & Duquette, 1991). However, this conclusion is not inclusive of all type of pica substances. There have also been studies indicating that geophagy is practiced in response to abdominal pain and the presence of gastrointestinal worms. One hypothesis states that pregnant women may have become more sensitive to these GI distresses due to their hormonal changes, but this is mainly speculative (Young et al., 2010).

It is important to note that many of these studies simply found an association between the factors mentioned and the practice of geophagy and cannot prove causation of either point. Also, the protective factors mentioned vary with the form of pica being discussed, as the composition varies with each non-food item in question.

The third hypothesis is known as the *hunger hypothesis* which states that people engage in pica due to the lack of any other source of food (Young et al., 2008). Pica is primarily found in, but not limited to, those of lower socioeconomic status, therefore demonstrating the possible correlation between food security and pica practice (Rose, Porcerelli & Neale, 2000; Halstead, 1968). In a study interviewing Kenyan women about their dietary habits during pregnancy, around 84% of the women interviewed ate soil at least once a day even though they had shown understanding of what constitutes "good food" (milk products, beans, eggs, etc.) due them not being able to afford it (Geissler et al., 1999).

Food Security

Food security in developing areas is a prominent and thoroughly researched topic in the literature. The World Food Summit of 1996 defined food security as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life," and the WHO describes it as being built on three pillars: food availability, food access, and food use (World Health Organization [WHO], 1996). The causes of food insecurity can be grouped into two categories: inadequate *access* to food and inadequate *production* of food, with the former being a more pressing concern at the household and individual level (Misselhorn, 2005). Food security includes both quantity and quality, so food diversity is an integral component of adequate nutrition (Wahlqvist, 2003). Although there are no significant conclusive data on the relationship with body mass index (BMI), poverty and low income are known to be correlated with food insecurity (Ivers & Cullen, 2011).

Food insecurity is of particular importance to pregnant women because they have a higher demand for nutrients and face a more formidable financial burden if they are the primary income provider for their family (Laraia et al., 2006). Known to be strongly correlated with food insecurity, maternal and child malnutrition contributes to more than a third of child deaths and more than 10% of total global disease burden (Black et al., 2008) . During the time frame between 2010-2012, about 868 million people, approximately 15% of the total population, were undernourished, with about 234 million of those people residing in sub-Saharan Africa (FAO Media Centre, 2012).

Culture and Pica

Aside from the physiological influences on pica behavior, cultural beliefs are believed to play an integral role as well. The study mentioned earlier, in which Kenyan women claimed to not eat "good food" due to insufficient funds, also noted that 32% of those women gave "being pregnant" as the reason for eating soil (Geissler et al., 1999). In the case of the Ewe culture in Ghana, geophagy is believed to be linked to human fertility and femininity (Abrahams & Parsons, 1996). Others believe the cultural reason behind the practice lies in the women's ties with "traditional roles" such as gardeners and potters (Young, 2010). However, because beliefs about pica vary across the world and there are multiple examples of its occurrence throughout the animal kingdom, culture on its own does not provide a general explanation for this practice as a whole (Young, 2010). For example, although a cultural belief may be what a woman states as her reason, she might believe geophagy provides her with something culture-related when in reality she is simply unaware of a particular nutrient deficiency.

Health Complications Connected with Pica

Although a few positive health outcomes associated with pica are possible, as mentioned above, there are also findings that support the notion that this practice has the potential to be detrimental to the health of the person involved. For example, microbial contamination in some geophagic materials collected in sub-Saharan Africa is significantly prevalent, specifically with bacteria from the genus *Bacillus* which is known to cause gastrointestinal complications if ingested (Kutalek et al., 2010). There is also an increased risk for re-infection of worms in pregnant and lactating women who participate in earth-eating, as well as an increase in the risk of dental damage (Luoba et al., 2005;

Barker, 2005). Those who engage in geophagy are most susceptible to harmful pathogens and toxins, especially in pregnant women since they are already immunosuppressed to avoid rejecting the embryo (Young, 2010). Anemia and iron deficiency have both also been shown to be correlated with pica, both as a symptom of geophagy and as a cause (Prince et al., 1999; C. Beyen et al., 2009). Along with all of these risks mentioned, a principle cause of concern regarding pica stems from the potential ingestion of lead, which can result in multiple health complications.

Geophagy and Lead Levels

Diet still remains the most prominent source of high lead levels in the blood, especially in remote regions of SSA where automobiles are rare and house paint is a luxury people cannot afford (Tuakuila et al., 2013). The extent to which gasoline, paint, and contaminated water affect lead exposure varies between regions, but most studies conducted in Africa have continued to focus on the source of lead toxicity being in paint chips rather than from voluntary pica behavior. However, even studies conducted in the United States have provided evidence for a correlation between geophagy and heightened blood lead levels. For example, a 2013 study in New York City found that lead-poisoned pregnant women who reported practicing geophagy were more likely to have higher peak blood lead levels than the lead-poisoned women who did not report any pica practices (Thihalopivan, Candalla & Ehrlich, 2013). Another study in Massachusetts looked into 15 different cases of women admitted to the hospital due to lead poisoning, with a mean blood lead level of 72 μg/dl , and found that 10 (83%) of these women admitted to intentional pica during their pregnancy (Shannon, 2003). Chelation therapy was used in both of these studies as a way to treat the high blood lead levels in the women.

Approximately 95% of lead is stored in bone and mineralized tissues and tends to stay in the body for a time spanning from years to decades, emphasizing the fact that people are at risk for the side effects of high lead levels long after their exposure to it (Barry, 1975; Hu, 1998).

According to the CDC, the current target value for at-risk blood lead levels is 10 µg/dl for adults (Center for Disease Control [CDC], 2012). However, adverse renal effects have been reported at mean blood lead levels <5 µg/dl and have been noted to be more severe in nature if coupled with other conditions such as cardiovascular disease (Ekong, Jaar & Weaver, 2006). A major renal problem caused by lead toxicity is the disruption of the proximal tubule function by the insertion of lead into the structure (Longham-Adham, 1997). Lead nephropathy is considered to play a role in the development of hypertension among those with high lead levels by reducing the rate of glomerular filtration and increasing peripheral vascular resistance (Navas-Acien et al., 2007). Other problems such as poor muscle coordination and nerve damage to sense organs can also be a result of heightened lead levels in the body (U.S. Environmental Protection Agency, 2006). Clearly, all of these complications would take an even greater toll if they occurred in pregnant women, because fetal development would be affected in addition to maternal consequences.

Multiple studies have found that blood lead levels in children are significantly higher than those of adults, and children less than six years of age have an average of 20% higher lead levels than the older groups. This difference may be due to their tendency to ingest lead through hand/mouth contact as well as their digestive absorption rate being higher that adults (Tuakuila et al., 2013).

Related Studies: Lead Effects in Children

Lead in the bloodstream is known to cause a variety of neurological complications in children, including impaired cognitive development, and has also proven to be acquired both in utero and postpartum (Schnaas et al., 2000; Bellinger, 1994; Hackley & Katz-Jacobsen, 2003). Lead's effect on the nervous system is also found to be much more problematic and severe than in adults (Lidsky & Schneider, 2003). In addition to the risk of neurotoxicity in the infant, there is reason to believe that pre-natal lead exposure increases the risk for high blood pressure in children by affecting the intrauterine environment (Cantonwine, Ettinger & Hu, 2012). Skeletal abnormalities, such as delayed skeletal maturation, also have been reported among neonates of women with increased lead levels (Shannon, 2003). There are also many studies that indicate a negative correlation with placental lead level and gestational period, showing that high lead levels in the pregnant mother increases the risk of a stillbirth (Falcón, Viñas & Luna, 2003; Hu, 1991). A few studies have looked into the possible correlation between prenatal lead exposure and low birth weight children, however no conclusive relationship between the two has been found (Ernhart et al., 1986; Greene & Ernhart, 1991; Needleman et al., 1984).

Iron-deficiency anemia has been found to be associated with high blood lead levels in children who are exposed to lead (Alabdullah et al., 2005; Carvalho et al., 2011; Jain et al., 2005). Iron-deficiency anemia is considered the third stage of iron deficiency, with iron depletion being stage I and iron-deficient erythopoiesis being stage II (Suominem et al., 1998). It has been found that blood lead concentrations were significantly increased during stage II and that the administration of iron supplementation had markedly decreased lead concentration in anemic patients (Choi & Kim, 2003). Overall, lead levels greater than 10 µg/dl are associated with an increased risk of mild or severe anemia as well as decreasing iron absorption, with high blood lead levels being associated with low iron and ferritin levels. An increased amount of lead in the body causes it to be taken up by the iron absorption machinery in the small intestine, thus secondarily blocking iron through competitive inhibition as well as interfering with heme biosynthesis (Hegazy et al., 2010). A reciprocal effect also exists with iron-deficiency potentially causing increased lead absorption, with a common iron-lead transporter in the body making an interaction between the two disorders possible (Kwong, Friello & Semba, 2004). Because lead affects multiple body systems and iron is an integral requirement for many cellular processes, the synergistic effects of iron deficiency and lead poisoning likely occur by several pathways have yet to be discovered.

Transmission from Mother to Child

The correlation between maternal and umbilical cord blood lead levels ranges from 0.55 to 0.92 and shows that lead has the ability to move freely across the placenta (Gardella, 2001). Harvill et al. (2005) showed that fetal lead increased as maternal blood pressure and weight gain increased among women over 30 years of age, demonstrating that lead mobilization across the placenta may increase under certain cardiovascular conditions. Also, lead mobilization to bone is known to increase significantly during pregnancy since bone turnover is high during this period (Korrick et al., 2002). This stored lead is then able to travel from the bone storage to the fetus/child during pregnancy and lactation (Manton et al., 2003).

There is reason to believe that the rate of lead mobilization in the body varies depending on the stage of pregnancy when there is no additional exposure. Hertz-Picciotto et al. (2000) analyzed the patterns of blood lead during pregnancy and supported the conclusion of blood lead levels rising in late pregnancy, demonstrating their results with a U-shaped curve with maternal blood lead level as a function with weeks of pregnancy. Another study noted the plasma lead levels in the mother were most significant during the first trimester, and although their results were not statistically significant they correspond with this curve (Hu et al., 2006). It is also known that blood pressure naturally increases during the third trimester, therefore it is possible that this may be responsible for the increase in blood lead concentration (Rothenberg et al., 2002). Transmission of lead from the mother to the child is still possible after birth through breastfeeding; however, this transfer has been shown to be a cause for concern only if the mother's blood lead level is significantly greater than 10 µg/dl since lead faces a high mammary gland barrier when compared to the low placental barrier (Weitzman & Kursmark, 2009; Dorea & Donangelo, 2006). Several studies have addressed this issue with interesting and complex results, however they did not account for additional lead exposure during pregnancy, which may have played an integral role in overall lead burden.

There is a debate in the literature as to the extent of calcium's protective nature against high lead absorption. Calcium is assumed to aid in lowering lead toxicity in a variety of ways, such as binding to lead in the gut to decrease absorption, decreasing the affinity of lead in tissues, or altering the cell processes associated with lead absorption (Barltrop & Khoo, 2006). Increased calcium intake is strongly advised for women during time of pregnancy and lactation, as it is highly important for fetal growth and development (Prentice, 2000). A 2004 study (Gulson et al., 2004) looking into blood lead changes with calcium supplementation during pregnancy and postpartum showed a significant increase in lead mobilization during late pregnancy (mean increase of about 25% in blood lead concentration), but this did not correlate with calcium intake. There was also a very weak relationship between calcium intake and changes in the isotopic composition of blood lead during postpartum. However, another study conducted by Gulson et al. (1998) that focused on lead transmission after pregnancy demonstrated that increased lead mobilization during lactation is a possible phenomenon because of increased calcium intake requirements that are not met by the mother. Likewise, cross-sectional studies of children and the association of blood lead concentration and calcium intake are equally divided between those showing no correlation and those showing an inverse relationship between the two factors (Ballew & Bowman, 2001). Overall, lead absorption is a multifactorial condition.

Measuring Lead in the Body

The two principal biomarkers of lead dosage that are measured are blood lead and bone lead. Concerning blood lead measurements, maternal plasma blood lead is believed to produce a more accurate measurement of lead dosage in the fetus than whole blood, as seen by a study carried out by Chuang et al. (2001). One explanation for this is the fact that fetal lead exposure stems from lead that has the ability to cross the placenta and therefore must be derived from the plasma (1% of lead concentration in whole blood) rather than the red cells (99% of lead concentration in whole blood) (Chuang et al., 2001). However plasma blood samples are not completely reflective of internal lead pregnancy, especially at low concentrations (Sommar et al., 2013). Reasons for this may be due to ineffective collection methods, such as the use of low-specificity equipment or error in swift serum/plasma separation after drawing blood that can result in unexpectedly high plasma-lead levels (Barbosa et al., 2005). Bone lead on the other hand is considered a much more accurate way of analyzing overall lead concentration in a person, as more than 90% of lead resides in bone stores in adults (70% in children) (Oflaherty, 1995). Bone lead also has a longer half-life of up to 25 years compared to that of blood lead, which is around 35 days (Rabinowitz, Wetherill & Kopple, 1976). However as alluded to earlier, bone turnover increases during pregnancy, and it has been found that this increases the association between plasma lead and bone lead and thus increases the accuracy of plasma blood analysis as an indicator of overall lead burden (Téllez-Rojo et al., 2004).

The Current Study

This community-based research focuses on women on the Nyakach plateau in the Nyanza province of rural western Kenya, with the goal of developing interventions to improve maternal and child health. The Nyakach Plateau is roughly 36 km (22. 4 miles) southeast of Kisumu, Kenya and 12 km (7.5 miles) southeast of Lake Victoria. The dominant tribe of this area is Luo and speaks Dholuo as the primary language. The vast majority of residents have no mode of transportation other than walking. This very poor population has the highest HIV rate in Kenya and struggles to survive by subsistence farming.

Some baseline testing in an annual temporary clinic indicated high levels of blood lead, anemia, and hypertension among this population (unpublished data, 2010), but the source of the lead exposure is unknown. Buildings in the area are traditional mud huts with thatched or metal roofs, or they are brick structures with concrete floors. Thus, lead-based paint is not the source, and unleaded gasoline is also an unlikely cause. On this high, rocky plateau, almost no one can afford a car, and transportation is limited to walking, bicycles, and the occasional motorcycle taxi. A far cry from polluted, urban environments, this area is relatively low-risk for those exposures. Polluted ground water is often used in this area, but preliminary water testing conducted on the Plateau has produced no definitive results to show that lead is a significant problem in any of the water sources (unpublished data, 2012). Pesticides are another potential source of lead, but this community is too poor to afford to use them.

The most likely lead exposure in this community is from the soil, specifically from what is locally known as "soft rocks". An initial analysis of these rocks indicates that the content contains some of lead. Aqua regia testing showed a lead composition of 7.74 μg/g in the Plateau soft rocks (unpublished data, 2012). Though this amount of lead is below the EPA amount considered acceptable in soil for plants (US EPA) and is presumed to be safe for humans, the sheer amount of soft rocks ingested by pregnant women on the plateau appears to be as much as one kilogram daily. It is speculated that even trace amounts in this huge quantity might accumulate to produce a damaging blood lead level. Alternatively, if there is an association between soft rock consumption and lead levels, it may suggest that both variables are associated with a third factor, i.e. soft rock consumption is a marker for some other unhealthy exposure that also causes high lead levels. Establishing the prevalence of soft rock consumption (especially during pregnancy and breastfeeding), abnormal blood lead levels, anemia, poor diet, and other health threats is needed to begin to sort out these complex relationships. In addition, it is important to understand the meaning of this activity among these women for there to be success in any future efforts to change the behavior. Concerning the Luo women on the Plateau, there is no written record of their cultural perceptions of pica, but anecdotal information suggests that this pica among adults is mostly limited to pregnancy and is talked about in terms of a “craving” for soft rocks.

In conclusion, this study proposes to evaluate the prevalence and extent of geophagia during pregnancy and abnormal blood lead levels in a sample of women on the Nyakach plateau. With this knowledge and other information about women’s perceptions and behaviors, there is a better foundation from which to establish future interventions to try to change the practice of geophagy and to determine the extent of the problem of high lead levels among women.

CHAPTER THREE

Hypothesis

Research Questions

Primary Research Question: Is there a relationship between the ingestion of soft rocks by the mother and maternal blood lead level?

Hypothesis 1: The ingestion of soft rocks during pregnancy is associated with higher current blood lead level in mothers.

Null Hypothesis: There is no relationship between the ingestion of soft rocks and blood lead level.

Secondary Research Question: What is the primary reason as to why the Luo mothers eat soft rocks during pregnancy?

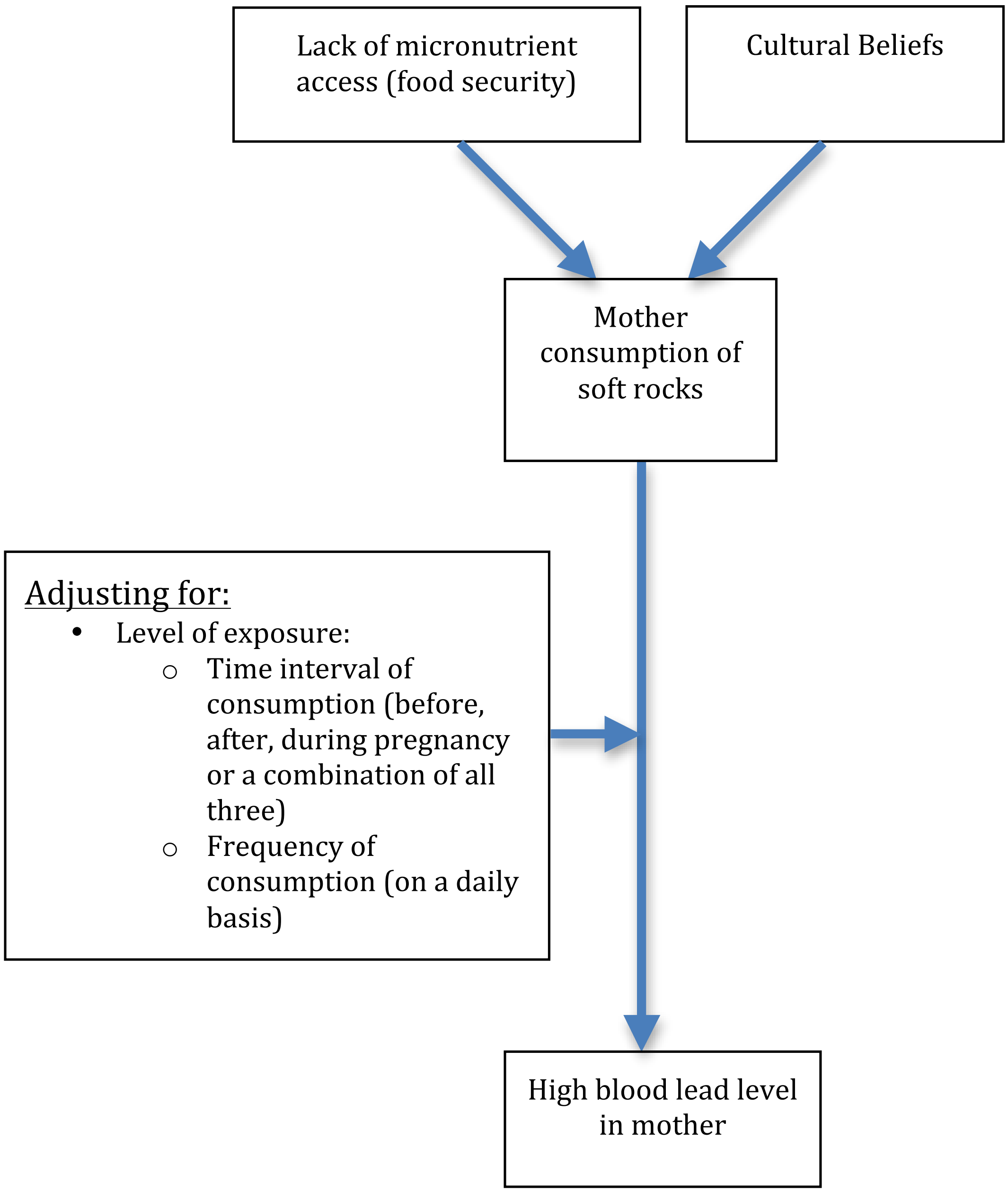
Hypothesis 2A: Luo mothers report that the primary reason they eat soft rocks during their pregnancy is due to lack of necessary nutrients from other sources.

Hypothesis 2B: Luo mothers report that the secondary reason they eat soft rocks during their pregnancy is due to cultural beliefs pertaining to these specific rocks.

Null Hypothesis: The reason behind the ingestion of soft rocks by Luo mothers is not significantly associated with the lack of nutrient accessibility or with cultural beliefs.

Description of Study

This cross-sectional study investigated the context and extent of maternal ingestion of soft rocks and lead levels of the mother. Additionally, this study investigated the potential reasoning of the mothers behind the decision to practice geophagy through a detailed questionnaire. Data for this study were collected in May 2013 from patients seeking medical treatment in a temporary clinic run by the U.S.-based nonprofit organization, Straw to Bread. The participants in the study were asked to answer a brief questionnaire about their nutritional habits during their pregnancy as well as have blood drawn for testing.


Lack of micronutrient access (food security)
Cultural Beliefs
Mother consumption of soft rocks
Adjusting for:
Level of exposure:
Time interval of consumption (before, after, during pregnancy or a combination of all three)
Frequency of consumption (on a daily basis)
High blood lead level in mother

CHAPTER FOUR

Methods

Setting

This study was conducted in the Straw to Bread annual temporary clinic held from May 22nd to May 28th, 2013. Straw to Bread is a U.S.-based non-profit organization that sponsors a team that works for two weeks each year on the Nyakach Plateau in rural western Kenya. This annual activity is part of a comprehensive development project in this area that encompasses health care, food and sustainable agriculture, safe water sources, education, and small business development. The 2013 team consisted of about 40 students, physicians, and other volunteers, and over 800 patients were seen over the course of 9 days. The clinic was located within a stone church building in the Upper Nyakach Division of the Nyanza District.

Study Type and Sample

This cross-sectional study used a convenience sample drawn from women who attended the clinic for any reason, including those who were not patients themselves, but who brought their children to see the doctor. The first 49 mothers who came to the clinic were included in the study if they were accompanied by at least one of their children and if they gave informed consent to participate in the study. Women would have been excluded if they showed signs of being ill or weak, but no one fell into this category.

The interviews were carried out either by the study's primary investigator or trained interviewers with the aid of a translator. Before beginning the interview, the interviewer obtained the patient's informed consent and brought the patient to a quiet area of the clinic to ensure the individual's privacy. The interviews were conducted either in the clinic or in the lab adjacent to the clinic. After the interview, blood samples were collected in the lab by trained technicians, and height and weight measurements were recorded.

Measurements

Nutrition/ Soft Rocks Consumption

Each participant was asked a series of 26 questions regarding their nutritional habits during pregnancy and their views on soft rocks consumption (See Appendix A). Questions included asking about what type of food they consumed during breakfast, lunch, and dinner during their pregnancy and whether or not they ate the soft rocks. If the participant answered yes to eating soft rocks, she was then asked to provide more detail concerning the time interval and frequency of her consumption. Questions regarding the reason for consuming soft rocks and any perceived benefits or risks were also asked to the participants.

Body Mass Index (BMI)

Height was measured by having the patients stand with their backs against a wall with a measuring tape attached to it, and the data were recorded in centimeters (cm). Weight was measured in kilograms (kg) using a locally purchased scale. Body Mass Index (BMI) was then calculated using the formula: **Weight *(kg)/ Height (m)*** ^{2}.

Blood Measurements

After blood had been drawn on the patient, a Chem-8 analysis was run on the sample using an i-STAT analyzer (Abbott, Princeton). The resulting hemoglobin level was recorded for this study. The lead level in the blood sample was calculated using a LeadCare II analyzer system (Magellan Diagnostics). Controls were run on both diagnostics machines at the beginning of each day before patients were seen.

Statistical Analysis

The data were double-entered into Microsoft Excel and checked for discrepancies. The final data set was then imported into SAS 9.3, the statistical program used for data analysis. Univariate frequencies for all of the variables were calculated, followed by multivariate analysis to assess interaction effects and the relative contribution of each of the variables in accounting for variance in blood lead level. Analysis of variance (ANOVA) was used to determine the relationship between magnitude of exposure to soft rocks and blood lead level.

IRB approval

This study was approved by the Baylor University Institutional Review Board before data collection began. All data from human subjects was anonymous, and informed consent was obtained before the participants provided data for the study.

CHAPTER FIVE

Results

Sample

Description of Sample

Over the course of ten days, between May 22nd to 28th, 2013, 49 women were interviewed about their soft rocks consumption during pregnancy. The average age of the participants was 29 (range=16-46, SD= 6.97) and the average number of living children each mother had was 3.85 (range=7, SD=1.74). The average number of pregnancies a woman had was 4.24 (range=1-11, SD= 2.21), indicating that on average, women experience a miscarriage or child death. Another indication of the stress associated with motherhood is that 20.41% breast-fed another child while they were pregnant.

Anthropometric Measurements

The average BMI of the participants was 21.07 (range=16.37-33.38, SD=3.42), which lies within the "normal range" classification according to WHO standards (see Table 1). It is notable that only one person was in the obese range, a remarkable difference from the U.S.

Table 1: Body Mass Index (WHO)

	Underweight (<18.5)	Normal (18.5-24.9)	Pre-Obese (25.0-29.9)	Obese (>29.9)
Percentage (n)	15.21% (7)	67.39% (31)	15.21% (7)	2.27% (1)

Blood Lead and Hemoglobin Levels

The outcome variable of interest for this study was the blood lead level (see Table 2), which was measured using a LeadCare II analyzer system (Magellan Diagnostics). The average blood lead value was 5.72 /dL, with a range of 0.00-16.30 μg/dL and a standard deviation of 2.59. On this particular instrument, meaningful distinctions are made beginning at 3.3 μg/dl and above. Values below that level appear on the instrument as <3.3 and were coded as zero. Given that bad health effects can be seen at levels as low as 5 μg/dL, it is very concerning that 72.6% of the sample had results that were > 5 μg/dL (see Figure 1). Only 6.2% of the sample had no lead in their blood. Since the half-life of lead in the blood is only a few weeks, and most of the lead is stored in the bones, these results imply that the situation may be much worse than we think.

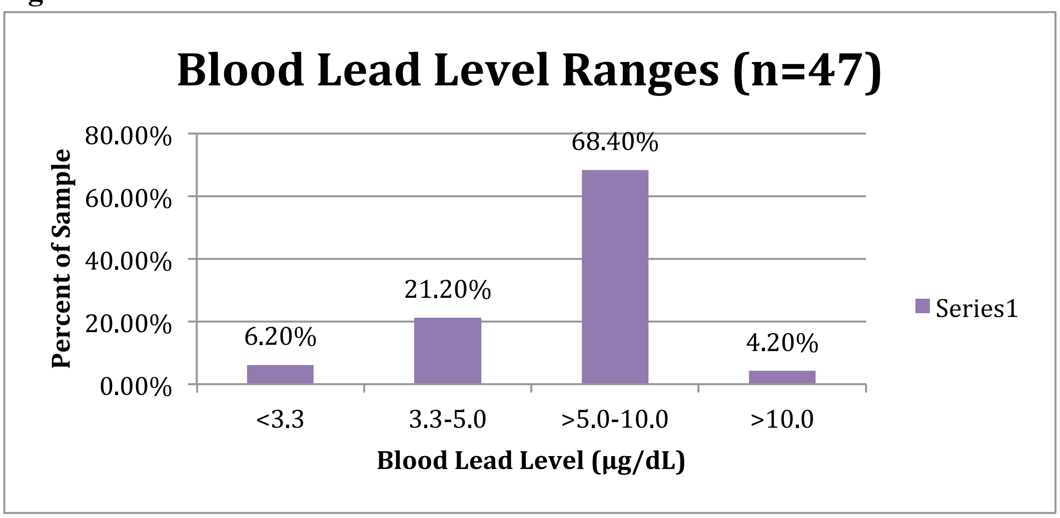
Blood hemoglobin levels were measured using an i-STAT blood analyzer system (Abbott, Princeton) (see Table 2). The average hemoglobin level was normal (12. 16 g/dL) according to WHO standards, but showed a wide dispersion, ranging from 7.10 g/dL (severely anemic) to 18.00 g/dL (non-anemic) with a SD of 2.15.

No relationship between blood lead levels and hemoglobin levels was found through a multiple regression analysis ($F= 0.56$, $R^2= 0.0158$, $p=0.4586$). However, there was a significant correlation between anemia and the consumption of soft rocks during pregnancy ($p=0.0252$). It is important to note that there are multiple factors that could account for anemia in these women such as diet, malaria, HIV status, chronic blood loss, and helminthic infections.

Table 2: Descriptive Statistics for Blood Lead and Hemoglobin Levels

	n	Mean (SD)	Range
Age (years)	48	29 (6.97)	16-46
BMI	46	21.69 (3.42)	16.37-33.38
Blood Lead (µg/dL)	47	5.72 (2.59)	0.00-16.30
Hemoglobin (g/dL)	37	12.16 (2.15)	7.10-18.00

Figure 1



Health and Nutrition During Pregnancy

As described in the Chapter 4, questions about pregnancy referred to the youngest child accompanying the mother in clinic (referred to as the "reference child") when she was interviewed. When asked specifically about that pregnancy, 50.82% of the women stated that their health was poor during that time (see Figure 2), and 65.31% stated that they ate less than usual during their pregnancy (see Figure 3). About half of the women said that they did not eat anything that was classified by the researchers as animal protein during their pregnancy, and over three-fourths of the women said they included starch in their diet at least twice a day during their pregnancy (see Table 3). Vegetables were a part of their diet once or twice a day for 86%, but only 6% said that fruit was included in their diet during pregnancy. Overall, only a third of the participants said they ate three times a day, and those who had a third meal ate only starch (maize).

Figure 2

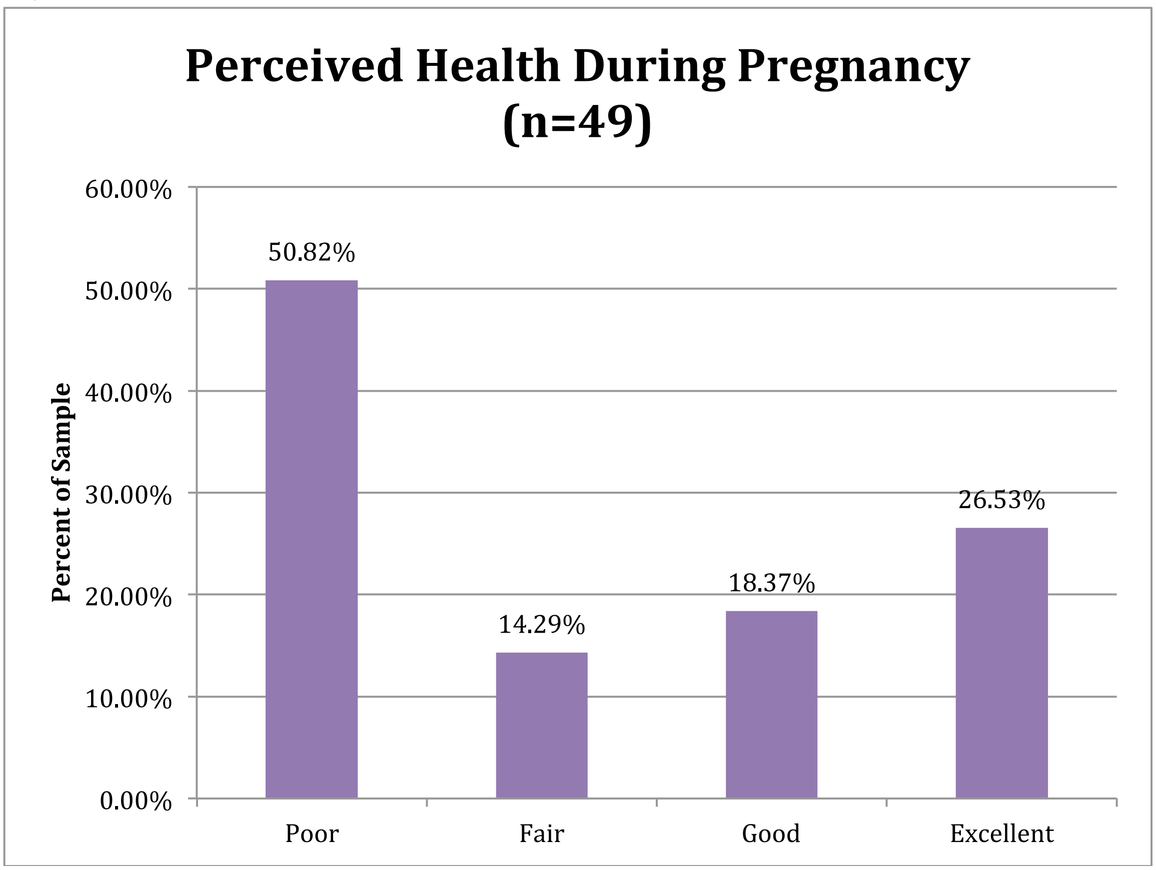


Figure 3

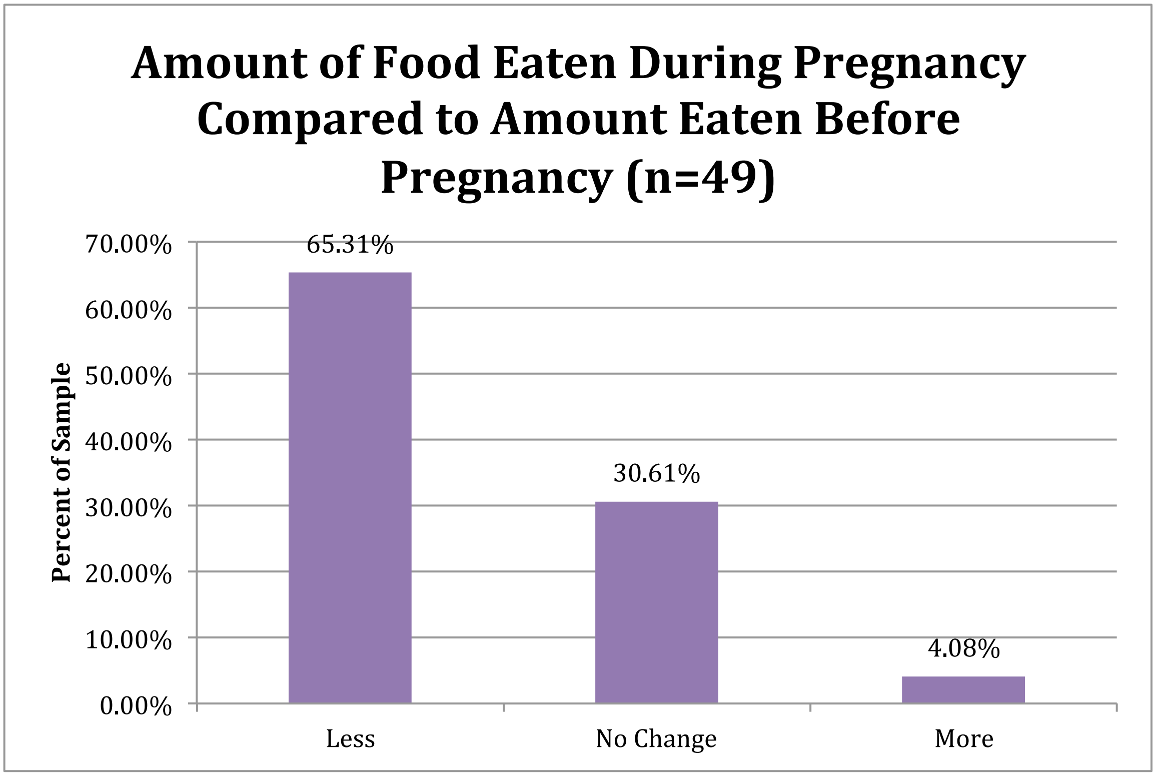


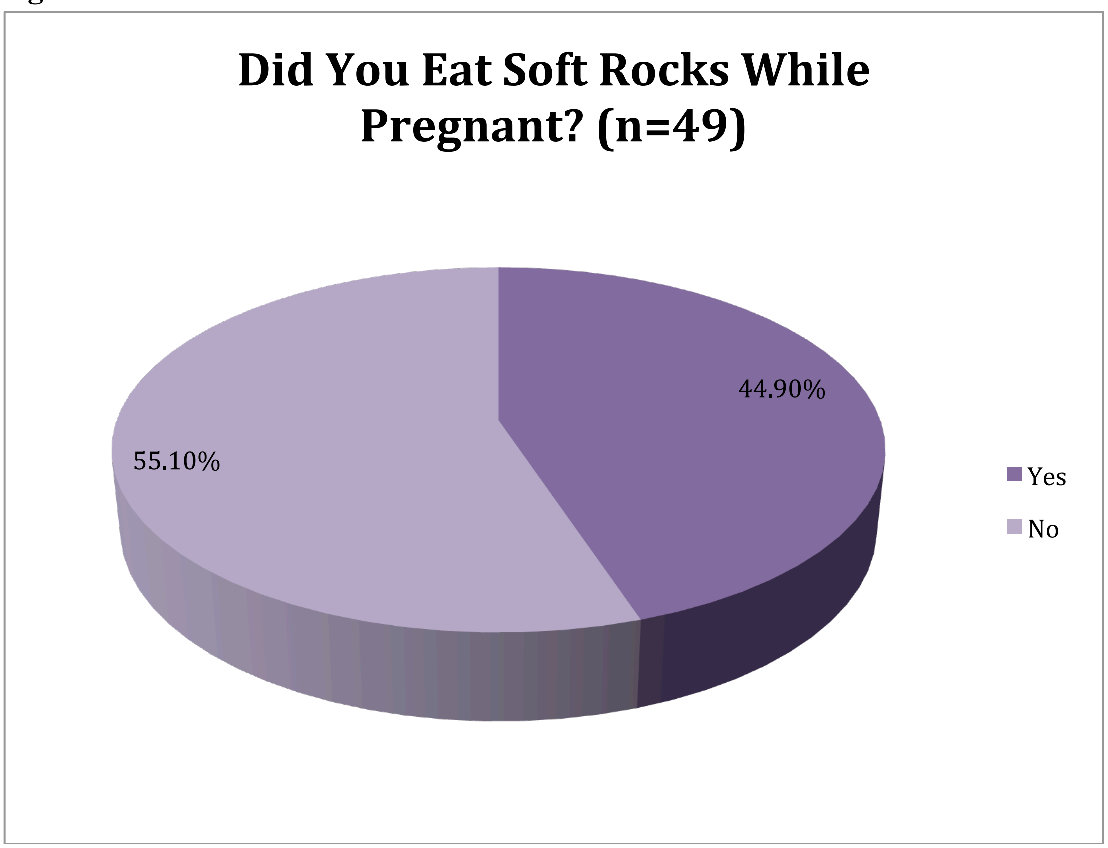
Table 3: Food Intake Frequency During Pregnancy

	Never	Once a Day	Twice a Day	Three Times a Day
Animal Protein (Not Milk)	55.10% (n=27)	22.45% (n=11)	22.45% (n=11)	0.00% (n=0)
Milk	38.78% (n=19)	53.06% (n=26)	8.16% (n=4)	0.00% (n=0)
Starch	4.08% (n=2)	18.37% (n=9)	44.90% (n=22)	32.65 (n=16)
Fruits	93.88% (n=46)	4.08% (n=2)	2.04% (n=1)	0.00% (n=0)
Vegetables	14.29% (n=7)	36.73% (n=18)	48.98% (n=24)	0.00% (n=0)

Consumption of Soft Rocks During Pregnancy

Out of all 49 women interviewed, 44.90% stated that they ate soft rocks during their pregnancy (see Figure 4). Only 4.1% of the women ate soft rocks before and after their pregnancy but not during it (see Table 5A). Of the people who said they ate the rocks, 65.38% of them said they obtained the rocks off the side of the road, with the remaining women buying them from the local market (30.78% of sample) or a combination of the two (3.84% of sample).

Figure 4



Soft Rocks Composition

As indicated in Chapter 2, a few samples of roasted soft rocks and soft rocks from the Plateau were tested for their lead levels through an ICP-MS (Inductively-Coupled Plasma Mass Spectroscopy) using the aqua regia method and the nitric acid controls (see Table 4). The aqua regia testing showed the rocks from the Plateau to have a higher concentration of lead than the roasted rocks, while the nitric acid test showed the roasted rocks to have the higher lead level. According to the EPA, regular soil should contain less than 40 μg/g, and both of the samples did not exceed this limit. However, this standard does not presume that people will eat the soil directly; rather, it is a level that would be acceptable as the soil for plants that would later be ingested and does not take into account the quantity of soft rocks the women consume on a daily basis. The acceptable lead standard for human ingestion is taken from this standard for plants (US EPA).

Table 4: ICP-MS Analysis of Soft Rocks

	Control 1	**Control 2**
Sample	Aqua Regia	Nitric Acid
Roasted	2.53 μg/g	6.54 μg/g
Plateau	7.74 μg/g	2.45 μg/g

Soft Rocks Exposure and Blood Lead Level

The women were asked about the time frame in which they ate the soft rocks as well as the frequency of their consumption on a weekly basis. The results are summarized in Tables 5A and 5B below.

Table 5A: Time Frame of Consumption (n=25)

Time Frame	Percentage (n)
Before Pregnancy Only	4% (1)
During Pregnancy Only	60% (15)
After Pregnancy Only	0% (0)
Before and During Pregnancy	8% (2)
Before and After Pregnancy	8% (2)
Before, During, And After Pregnancy	20% (5)

Table 5B: Frequency of Consumption (n=24)

Frequency	Percentage (n)
Less Than Once a Day	0% (0)
Daily	70.83% (17)
Twice a Day	16.67% (4)
Three Times a Day	8.33% (2)
Four Times a Day	4.17% (1)

A variable was created to indicate both the frequency (daily or more than daily) and the duration of soft rocks ingested (before, during, and/or after pregnancy). All possible combinations were then rank-ordered and summarized as an ordinal "soft rock exposure" variable. Given the small sample size of the study, there were some levels that contained no one or only one or two people. For the purpose of the analysis, these levels were not considered, and the remaining levels were collapsed to: no exposure, medium exposure, and high exposure (see Table 6). Our findings have shown that the women interviewed either did not eat the soft rocks during pregnancy at all or they ate the rocks at least once a day during their pregnancy, with no middle ground as far as frequency of consumption.

Table 6: Levels of Soft Rocks Exposure (n=43)

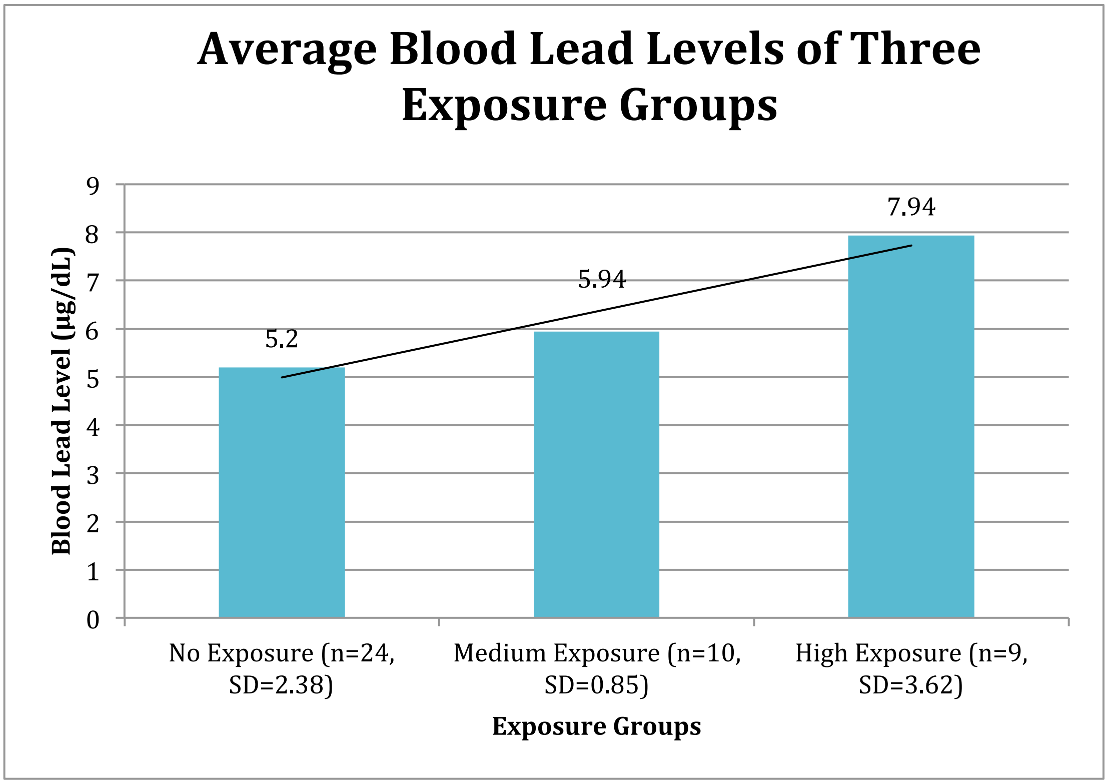
	n	Percentage % (n)
No Exposure	24	48.9% (24)
Medium Exposure (daily during pregnancy)	10	20.4% (10)
High Exposure (daily before, during, and after pregnancy or more than daily during pregnancy)	9	18.4%* (9)

*Percentages do not add up to 100% because levels with 0-2 people were omitted.

Hypothesis 1: The ingestion of soft rocks during pregnancy is associated with higher current blood lead level in mothers.

After running an analysis of variance (ANOVA) procedure on soft rocks exposure based on the three categories listed above and the blood lead levels of these 43 women (mean= 5.89 µg/dL), the results showed that there was indeed a statistically significant relationship between the two variables in the predicted direction ($F= 3.76$, $R^2= 0.165054$, $p= 0.0325$) (see Figure 5). The fact that the group with no soft rock exposure still has a mean level of 5.2 indicates that, even if soft rocks are contributing to abnormal blood lead levels, there is still at least one additional sources of environmental lead exposure in this community. For example, one woman who claimed not to have eaten soft rocks during pregnancy had a blood lead level of 14.3 µg/dL, while another woman who had answered "yes" to consuming soft rocks during pregnancy had a blood lead level of 0 µg/dL

Figure 5



Soft Rocks Beliefs

Hypothesis 2A: Luo mothers report that the primary reason they eat soft rocks during their pregnancy is due to lack of necessary nutrients from other sources.

Hypothesis 2B: Luo mothers report that the secondary reason they eat soft rocks during their pregnancy is due to cultural beliefs pertaining to these specific rocks.

When asked for the reason as to why they eat the rocks, about half of the women said they "craved" the rocks themselves, with the next most popular answer being that eating the rocks was a part of their culture (see Table 7). The hypothesized reason for soft rocks ingestion being lack of nutrients was only mentioned by one of the women who answered the question. However, 28% of the women stated that cultural beliefs were the reason for their soft rocks consumption. Thus, hypothesis 2A was not supported in this sample, but hypothesis 2B was partially supported. The much more common response, that they craved the soft rocks, might be an indication that the woman is responding to some nutritional deficiency, but the women themselves do not necessarily make that link.

Table 7: Reasons for Soft Rocks Consumption

Reason	Percentage % (n)
Baby craves the rocks	0% (0)
I crave the rocks	52% (13)
I need the nutrients from the rocks	4% (1)
It is part of my culture	28% (7)
It relieves general sickness	4% (1)
It relieves nausea	8% (2)
I crave the rocks AND it is part of my culture	4% (1)

Other Findings

The most common perceived risk of eating the soft rocks was stomach/abdominal pain (see Figure 6), and over half of the 23 women who were asked about any potential benefits to eating soft rocks claimed that they did not believe there was any particular advantage to it (see Figure 7).

Figure 6

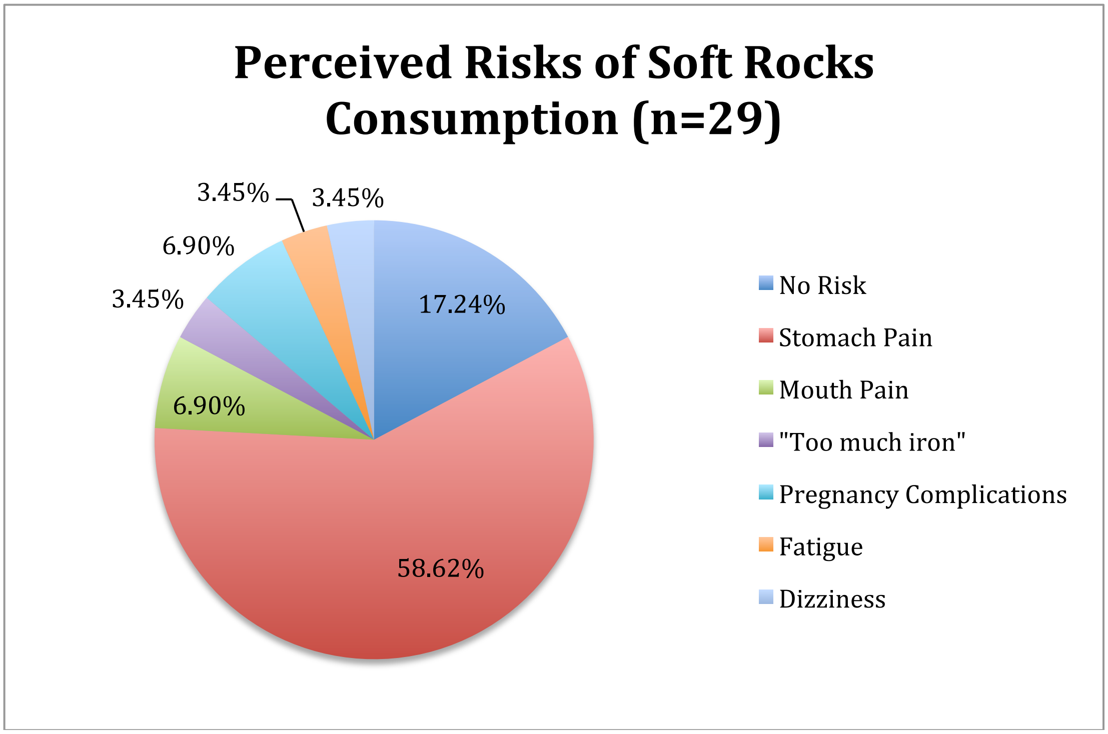
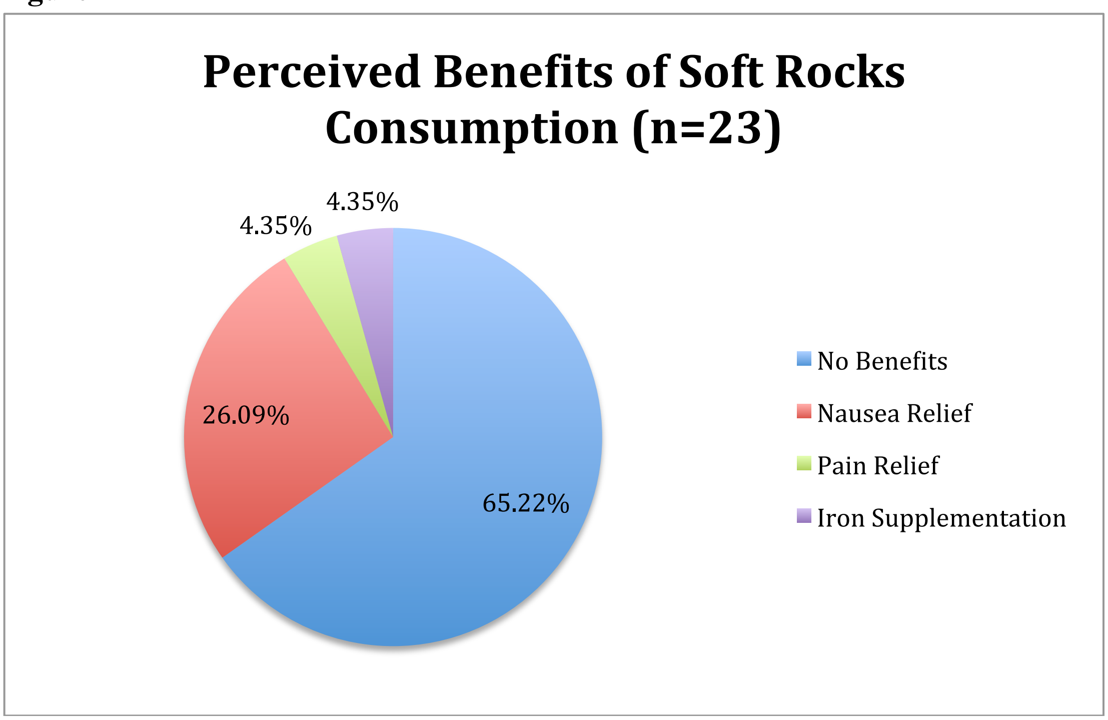


Figure 7



CHAPTER SIX

Discussion

In this study of 49 women, 44.9% said that they had eaten the local "soft rocks" of the Nyakach Plateau at least daily during pregnancy. The very similar finding (54%) fourteen years earlier (Prince et al., 1999) among rural Luo women indicates that this practice is deeply entrenched and has not significantly decreased with increased publicity about the dangers of geophagia. The data also support the primary hypothesis that abnormal blood lead levels in this region (average lead level of all the women in this particular analysis was 5.89) would be associated with soft rock consumption.

It is particularly striking that, when comparing the average blood lead level for varying amounts of soft rocks consumption, a significant positive association between the two variables was seen (see Figure 5). In the three exposure groups, the data showed that the higher the soft rocks exposure, the higher the lead level. The association holds regardless of the fact that the time since pregnancy (i.e. exposure) varied among the women. Daily exposure over many months produces a high blood lead level in the present compared to lower exposure even after a number of years have elapsed. This being the case, if the blood lead level of the women at the time of exposure (during or right after pregnancy) were known, presumably the blood lead level would have been even higher.

Although the findings show a strong relationship to indicate that soft rocks are indeed associated with abnormal lead levels in this population, the study did not indicate that soft rocks are the sole source, as seen by the "no exposure" group still having an average lead level of 5.20 μg/dL. One strong possibility is that the women underreported their geophagia, thinking that it was a response for which they would be criticized. Given the persistence of geophagia among pregnant women since at least 1999, it is possible that some of the exposure for these women occurred when they themselves were babies in utero and their mothers were eating soft rocks. They may be perpetuating the cycle and giving their own children a double insult. As noted earlier, high lead levels in a mother's body may be causing damage to the fetus as well as producing long-term health complications years later for both mother and child, ranging from renal function impairment to neurologic problems. Limiting the long-lasting effects of lead toxicity during the formative period of pregnancy and childhood are strong reasons why limiting lead exposure in mothers is crucial. Clearly, the search for other sources of lead needs to continue. Therefore, soft rocks consumption may serve more as a potential marker for some other factor that is exposing people to lead than as the sole source of lead toxicity in these women. Whatever the source, it is astonishing that 72.6% of the women had levels that are associated with bad health effects.

This study has provided several other findings descriptive of the overall health context of Luo mothers in which the soft rock consumption occurs. Half of the women reported that they did not have any protein in their diet, and about 15% said that vegetables were not a part of their diet. About 65% said that they ate <u>less</u> food during their pregnancy than normal, and 40% stated that they felt their health was poor during pregnancy. This study indicates that maternal health, particularly nutrition, among the women of the Nyakach region is a topic of great concern. The fact that all of these deficiencies are occurring at the same time that these mothers are eating soft rocks makes the plausibility of a synergistic effect especially serious.

The data obtained through this study also provide evidence of the beliefs held by the Luo women on the Nyakach Plateau about why they eat the soft rocks. Although reasons for geophagia in general vary between regions, it is important to understand the intent of the mothers when they practice it in this particular community with the hopes of creating a successful intervention in the future. Clearly there is a cultural pattern dependent on socialization by the prior generation. However, most of the women did not identify cultural beliefs as the main reason they ate the rocks. Instead, over half said that their behavior was primarily due to unexplainable physical cravings. So, at least on the Nyakach Plateau, the reason for soft rocks consumption seems to the majority of women to be thought of as more of a personal choice than a result of cultural pressure. Future efforts to end geophagia will be challenging given that the majority of women, even those who ate soft rocks, said that they did not perceive there to be any significant benefits to eating them.

Limitations of the Study

Systematic Error

Because the interview portion of this study relied solely on the personal account of each participant, the accuracy of the responses is questionable. Since geophagia holds a certain amount of social stigma in many cultures, not all women would have felt comfortable admitting to this practice, resulting in reporting bias and an underestimation of the prevalence of soft rocks consumption. Likewise, since questions were being asked about a pregnancy that happened from a few moths ago to years ago, the accuracy may vary due to lapses in memory by the participant. Also, since the women who claimed to not have eaten any soft rocks still had an average lead level of above 5μg/dL, there could be other factors not tested that influenced the results. However, with a p value of 0.032, it is safe to conclude that these soft rocks are associated with some of the poor health of the Luo women in this region of Kenya.

Random Error

The sample size of this study is the primary limiting factor in analyzing the results. Because only 49 women participated in the study, not every type of Luo woman in this region may have been sampled. Additionally, the sample sizes of the three levels of exposure set to determine the role of soft rocks ingestion on blood lead level were relatively small as well. However, because a significant association with this specific type of geophagia and high blood lead levels was observed even in a small number of women, it is more likely that there is not enough statistical power to identify real associations than that the significant findings in this study are due to chance. Another limiting factor in this study is the sample of the soft rocks that were tested. Because only a few rocks were obtained from the same general area on the Plateau, the lead concentrations found in them may or may not be representative of all of the rocks in the area. This could lead to a possible overestimation or underestimation of the overall lead burden in the people who consume these rocks.

Generalizability

Since the soft rocks of the Nyakach Plateau are specific to this particular region in Kenya, it is difficult to generalize the particular findings of this study regarding lead to all types of geophagia in all regions.

Conclusion

This study provides insight into the prevalence of soft rocks consumption and blood lead levels among the Luo mothers on the Nyakach Plateau in western Kenya. By using data collected through an orally administered questionnaire and data about lead levels in the blood, this study describes a high proportion of unhealthy women. A significant correlation between increased soft rocks consumption and increased lead levels in the bloodstream could indicate that the two are related, or the association may be a marker of general poor health and other high-risk behaviors. The findings of this analysis demonstrate high levels of geophagia among the women in this particular region, which may have negative effects on themselves and potentially on their children. Although the results of this study are not completely generalizable to other regions due to the specificity of the soft rocks in question, this study adds support for further research regarding geophagia in other parts of the world.

Further studies dealing with the soft rocks consumption on the Nyakach Plateau can look into other potential health effects that are caused by this practice. As opposed to testing only women's blood, testing men's blood as well could prove to be helpful in determining the prevalence and source of abnormal lead levels. If the men's lead levels prove to be abnormal in the absence of geophagia, then the soft rocks are unlikely to be contributing to lead transmission. Other research could focus more on analyzing the knowledge the Luo people have about the soft rocks with the goal of creating a successful intervention. If more data about the detrimental effects can be found, and if the reasons why women eat the rocks are better understood, then a successful intervention can be carried out.

APPENDIX

2013 Maternal Nutrition Questionnaire

1. Date________ (mo/dy/yr) 2. Interviewer: ______________ 3. Patient ID: __________

4. Patient birthday:_____________ (mon/dy/year)
5. Age ______________
6. Can you list what you ate on a typical day when pregnant?

	Morning	Mid-day	Evening
a. protein (meat/fish/poultry/Dagaa/Omena/Eggs)			
b. other protein (beans)			
c. milk			
d. Green Vegetables, Tomato, Onion, Sweet Potato			
e. fruit			
f. Starch (bread/porridge, ugali, maize, rice, chapatti, pots, sweet pots, cassava, beans)			
g. Added Sugar?			
h. Soft Drinks			

7.How was your health during your pregnancy?
_____ excellent (0) _____good(1) _____fair(2) _____poor(4)

8.Did you eat more or less than usual during your pregnancy?
_____more(1) _____less(2) _____no change (3)

9. Did you eat soft rocks while pregnant?
_______ yes (1) __________No (0)

10. Did you eat them only when pregnant?
________Yes (1) __________No (0) _______ N/A

11. When did you start eating them?
______ before pregnancy ________during pregnancy (1^{st},2^{nd},3^{rd} trimester)
______ after pregnancy ________ N/A

12. How often did you eat the soft rocks?
_____ per day _______per week ______N/A

13. How much do you think you ate in a day?
______ kilo
14. What made you want to eat the rocks?
____(0) I don't eat soft rocks

____(1) The baby craves the rocks
____(2) I crave the rocks
____(3) I need the nutrients from the rocks
____(4) It is part of my culture
____(5)Other:_____________________

15.Do you think it helped you?
_______No (0) ______Yes (1) ______N/A(3)
15a. What specific benefits do you think there are to eating it?
____

16. Do you think it hurt you?
_______No (0) ______Yes (1) ______N/A(3)
16a. What specific risks do you think there are to eating it?
____

17. Where did you get the soft rocks?
_____ The ground/side of the road (1)
_____The market (2)
_____ Other:_____________________
_____N/A

18. Did your teeth get sore from eating the soft rocks?
______Yes(1) ______No(0) ______N/A(3)

19. How long did you breast-feed this child?
_________ weeks _________Months ______N/A
19a. Did you eat the rocks while breast-feeding?
_____ yes (1) ________No (0)

20. Have you seen this child eat soft rocks?
______Yes(1) ______No(0)

21. Have you seen this child eat things other than food, such as dirt/soil?
______Yes(1) ______No(0)

22. Was this child born earlier than he/she was due to be born?
______ Yes(1) ______No(0)

23. How much did this child weigh at birth? _________

24. Did this child have any problems at birth or within the first month of life? Explain.

25. Does this child have any health problems now? Explain.

26. Does this child have any learning problems now? Explain.

24. Were you breastfeeding another child while you were pregnant with this child?
_______Yes(1) ________No (0)
24a. If yes, how long were you breastfeeding that child?
________ months

25. How many living children do you have? _______

26. How many times have you been pregnant? _____

MOTHER'S BLOOD PRESSURE ____ sys / _____ dia

BLOOD MEASUREMENTS

_________________Calcium Hemoglobin Lead____________

MOTHER

____

CHILD

____

ANTHROPOMETRIC MEASUREMENTS

____________Height Weight Skinfolds—waist triceps subscapular

MOTHER

____

CHIL

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