ABSTRACT

The Effect of Mother's Health on Children's Hemoglobin and Lead Levels in Rural Western Kenya

Jessica Anne Korona

Director: Lisa Baker MD PhD

The Luo tribe of western Kenya has the highest infant mortality, maternal mortality, and HIV rate in Kenya (Kenya DHS, 2010). This study of 49 mother-child pairs was done in May 2013 in the context of an annual temporary clinic on the Nyakach Plateau of rural western Kenya. Mothers were questioned about their protein and calorie intake during pregnancy, their participation in the cultural practice of eating "soft rocks", their health during pregnancy, and their breastfeeding history with a designated child. The blood hemoglobin and lead levels were measured for each mother-child pair, and the child's height and weight were taken. The child's history of geophagia was also ascertained. 44.9% of mothers reported ingesting the local "soft rocks" during their pregnancy. 55.1% of mothers had no protein in their diet during pregnancy, and 65.3% reported eating less than usual during their pregnancy. Poor health during pregnancy was reported by 40.8% of the mothers. Abnormal lead levels were found in 72.6% of mothers and 86.84% of children. Although no relationship was found between mother's lead level and child's lead level, the data showed that mothers' geophagia was related to their own hemoglobin level (0.0252), and anemic mothers had anemic children (p= 0.0073). Children's hemoglobin levels were also decreased if their mothers reported eating less than usual during their pregnancy, which also correlated with the mother's decreased intake of dietary protein during pregnancy. Overall, mothers with a poorer health status as indicated by a combination of these high-risk variables were more likely to have anemic children. This study shows that high-risk pregnancies are associated with decreased health in their children in this particular rural area of western Kenya. These findings may be due to the multiple insults to the fetus during its development. In addition, it may indicate that the unhealthy environment of poor diet and health that created the high-risk pregnancy becomes the unhealthy environment of the next generation after the child is born. Most likely, both of these mechanisms are at work.

APPROVED BY DIRECTOR OF HONORS THESIS:

____

Dr. Lisa Baker, Biology

APPROVED BY THE HONORS PROGRAM:

____

Dr. Andrew Wisely, Director

DATE:_______________________________

THE EFFECT OF MOTHER'S HEALTH ON CHILDREN'S HEMOGLOBIN AND LEAD LEVELS IN RURAL WESTERN KENYA

A Thesis Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the Requirements for the

Honors Program

By

Jessica Anne Korona

Waco, Texas

May 2014

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to wholeheartedly thank everyone who has made this thesis a reality. This work could have never been completed without the mentorship of Dr. Lisa Baker and Dr. Troy Abell who have given their enduring support and time to my growth as an individual. I am so very grateful for my co-investigator, Anju, Kannappan, who has been a delight to work with throughout the entire process and generously obtained data for both of us during her most recent journey to the Plateau. This thesis would not have been possible without the endless help of Jonathan Tingle who was involved in every analysis of data on the SAS 9.3 software. His involvement has been such a blessing and I am forever thankful. Lastly, I would like to thank my family and friends from the bottom of my heart. They have never failed to give me encouragement and hope when I was in need of it the most.

DEDICATION

To those on the Nyakach Plateau I have yet to meet. I am so very excited to see how you will impact my life.

CHAPTER ONE

Introduction

The Luo tribe of western Kenya has the highest infant mortality, maternal mortality, and HIV rates in Kenya (Kenya Demographic and Health Survey, 2010). In addition, according to the Food and Agricultural Organization country profile on food insecurity, the proportion of Kenyans who are food insecure is above 30% (Hansen et al. 2011). Food shortage is a crucial issue for mothers and their developing children during pregnancy, and these problems are made worse by unpredictable droughts and flooding of many areas of the country. A study done on the Luo tribe showed that at least 20% of the women are underweight (Hansen et al. 2011). Anemia, lead poisoning, and geophagia often accompany hunger and poverty, and these problems have an impact on mothers and children alike.

Globally, anemia affects 1.62 billion people, which corresponds to 24.8% of the world population (de Benoist, 2008). The highest prevalence is in preschool-age children (47.4%), and the next highest group is pregnant women at (41.8%). Within the developing world, anemia is associated with decreased protein intake and lack of food in general. It is a growing problem in impoverished areas in the world, especially for pregnant women and children.

The widespread use of lead has caused extensive environmental contamination and health problems in many parts of the world. Its cumulative toxicant qualities cause it to affect multiple body systems, including the neurologic, hematologic, gastrointestinal, cardiovascular, and renal systems. The neurotoxic effects of lead are particularly harmful to children who possess a vulnerable nervous system during the years of brain development. In some cases of lead poisoning, irreversible neurological damage can be seen. Lead exposure is estimated to account for 0.6% of the global disease burden, with the highest prevalence in developing regions of the world (WHO, 2014). Every year about 600,000 new cases of intellectual disabilities due to childhood lead exposure are reported (WHO, 2014).

Pica is the compulsive intake of non-nutritive substances such as earth, clay, chalk, soap and ice (Lopez 2004). The most common forms of pica are geophagia or the intake of earth and pagophagia or the intake of ice. Its prevalence during pregnancy is generally underestimated. Published data reveal a prevalence of between 8% and 65% worldwide (Woywodt 2002). The causes of pica are not clear, but its occurrence is frequently associated with anemia or iron deficiency during pregnancy. From different viewpoints it has been regarded as a psychiatric disease, a culturally sanctioned practice, or a sequel to poverty and famine (Woywodt, 2002). Geophagia has been reported in many cultures throughout history ranging from Roman physicians to 18th century explorers.

All these factors contribute to the high-risk pregnancies of the Luo tribe, and the later health of a child is drastically impacted by the mother's health during pregnancy. All of the mother's health risks, such as geophagia, poor nutrition, anemia, and high lead levels, directly affect the health of her children, contributing to an endless cycle of poor health. This vulnerable population of mothers and children is an example of the worst circumstances in the rural developing world, and this study seeks to explore the prevalence of risk factors for poor health among Luo mothers and the toll that is taking on their children.

CHAPTER TWO

Review of Literature

The health of a child is drastically impacted by the mother's health during pregnancy. After birth the child's growth and development continue to be determined by the mother's nutrition throughout the period of breastfeeding and then subsequent growth is further impacted by environmental factors. Any activity the mother participates in during her pregnancy can ultimately affect the health of her child.

A fairly common cultural practice in sub-Saharan Africa is geophagia, which can also be characterized as pica. Pica is the act of craving and consuming non-food substances. There are many different forms of it, one of the most common being geophagia, which is the eating of soil or clay. This practice has been observed among people in all parts of the world and was first described by Hippocrates in ancient times (Nijru et al., 2011). It is particularly common in sub-Saharan Africa and is exhibited in pregnant women and young children. In a study conducted in the Bondo District, Nyanza Province in western rural Kenya, 71% of pregnant women reported eating soil and 94% said that their children ate soil as well (Prince et al., 1999). Women in western Kenya have estimated eating 50-60 grams of soil per day, and they believe that their children consumed at least 28 grams daily (Prince et al., 1999). 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). In Kenya, the preferred earth was soft rocks, or odowa, with 54.2% of the pregnant women consuming it (Luoba et al., 2004).

Though there is such a high prevalence of geophagia, the exact etiology is unknown. Community Health Workers have told pregnant women that the practice is harmful, however, women still crave the soft rocks or soil and pick them up from the sides of the road or buy them at the market. The practice has been associated with religion, culture and famine. From a cultural standpoint, femininity is said to be associated with the soil whereas maleness is encompassed by the sky (Geissler et al., 1999). Geophagia is said to strengthen the link between people, fertility, good health, and ancestral blessing (Nijru et al., 2011).

There is also a time-dependent theory suggesting that geophagia has different functions depending on the time of ingestion. If soil is ingested in the first trimester, sickness is avoided. If ingested in the second trimester, geophagia can be used to supplement the nutrient demands of the fetus, and in the third trimester, geophagia is said to soften pelvic bones thus making the birthing process easier (Nijru et al., 2011). These ideas are localized to western Kenya.

This practice is culturally acceptable for women and children. Though it was previously thought that only young children engaged in geophagia, a study showed that a prevalence of 73% existed among school age children in western Kenya (Geissler et al., 1997). When questioning children it was discovered that soil was eaten at break time, after lunch, on the way home from school, after dinner, after greasy food, and when feeling nauseous (Geissler et al., 1997). Soil from ant hills was the most common soil eaten, with soft rocks or odowa being the second most common (Geissler et al., 1997). Children are meant to stop eating soil upon reaching adolescence however, girls may continue again upon reaching childbearing age. Craving soil can be a sign that a woman is pregnant, and many women have likened the feeling to that of craving tobacco, alcohol, or recreational drugs (Nijru et al., 2011).

Sixty-eight percent of women said that they ate the soil because they liked the taste, or it “felt nice” in their mouth (Geissler et al., 1999). Others said that it alleviated nausea. Women also mentioned that they ate the soft rocks to eliminate swelling of the limbs, cheeks, and stomach, as well as, dizziness, palpitations, breathlessness, and weakness. These symptoms can be associated with anemia, and tests of women complaining of these symptoms showed significantly lower hemoglobin levels, confirming the condition (Nijru et al., 2011). In addition, women have said that the ingested soil supplied them with calcium, minerals, and other needed nutrients. Some studies have shown that geophagic soils can contain up to 14% of the recommended dietary allowance (RDA) of iron in pregnancy (Nijru et al., 2011). Though this may be true, the consequences of geophagia may outweigh the benefits.

One study showed that there were numerous cases of tooth surface loss and damage as a result of pica eating disorder. The women complained of pain and had difficulty eating other foods (Barker, 2005). Some women also cited gastrointestinal distress after engaging in the eating of soil (Young et al., 2010). A large number of studies have been conducted to see if geophagia is a risk factor or a risk marker for anemia, and the results are still unclear. The fact that is clear, however, is that there is a strong association between geophagia and low hemoglobin levels (Geissler et al., 1998). Though causation may not be clear, association is well documented.

Anemia can be a problem in rural areas of the developing world during pregnancy. In northern Kenya, a study was conducted using Ariaal women to observe maternal hemoglobin levels. Maternal hemoglobin depletion was present in this group of women (Miller, 2010). The women were iron-depleted due to the increased demands of pregnancy, and the iron was not sufficiently replaced during the course of lactation. This group of women continued to have depleted iron levels (and resulting anemia) after the lactation period (Miller, 2010). Although this group of women was not questioned about geophagia, the study shows that anemia is a significant problem during pregnancy.

Anemia seems to be associated with helminthic infections, HIV, and malaria as well as geophagia. It is likely that eggs from the helminths reside on the soil and rocks being ingested. Although this may be the case, it is not clear whether geophagia causes parasite infection, or if the reverse occurs and people eat the rocks because of the depleted nutrients taken by the helminths (Nijru et al., 2011). Helminthic infections deplete the body of nutrients, and in an area where there is already a high incidence of poor nutrition, HIV, and malaria, an added infection that further decreases nutrients is not needed by a pregnant woman (Geissler et al., 1999). Primary school children in Kenya were tested for helminthic infections and asked questions about geophagia. Infection and reinfection rates were much higher among children engaging in geophagia. The relative risk for infection and reinfection from A. *lumbricoides*, A. *trichiura*, and *ascariasis* was 2.28 for children engaging in the practice (Geissler et al., 1998). In addition, the craving for rocks or soil can be a pathway for ingestion of environmental soil contaminants and toxic trace elements that can be a further danger to the pregnant mother and her child.

Women need additional micronutrients when pregnant, and many in developing countries are not getting the nutrients needed. During and before pregnancy, women need additional amounts of the following micronutrients: folic acid, zinc, iodine, calcium, and iron, to name a few (Black, 2001). These micronutrients may not be available in a community for an average person let alone a pregnant woman. According to the Food and Agricultural Organization country profile on food insecurity, the amount of Kenyans that are food insecure is above 30% (Hansen, Christensen, Larsson, et al., 2011). This can be due to the unpredictable droughts and poverty of many areas of the country (Hansen et al., 2011). A study done on the Luo, Kamba, and Maasai tribes showed that 20% of women are underweight (Hansen et al., 2011). After dietary assessment was completed in the tribes, researchers found that the mean protein intake of women was below the World Health Organization standard and that the main source of energy came from grains. The low protein intake can be explained by the low total food intake as well as the variety of food ingested, which is mostly carbohydrates (Hansen et al., 2011). It is suspected that women engage in geophagia in order to consume the micronutrients that are not available to them in their diet. Though it has been shown that some soils contain adequate amounts of iron, zinc, and calcium, the levels in the soil are nowhere close to the amount needed by a pregnant women (Nijru et al., 2011). Additionally, some soils contain toxic elements such as lead that can endanger the pregnant mother and her child.

Though soil analysis has shown that some soil does provide nutrients such as iron, copper, zinc, and calcium, it is impossible to determine if the earth-eater is getting the correct dose from the soil they ingest. Before the industrial revolution, the practice of geophagia may have been a safe way to obtain some of the needed nutrients, however that is not the case in present day. Leaded gasoline has since been used and any leakage on the roads could contaminate the soils with high levels of lead (Nijru et al., 2011). In a previous study done on lead levels in Kenya, high lead levels were reported that were far above the World Health Organization's standard in soil and foodstuffs in 2005 (Njoroge, 2005). If the soft rocks and soil pregnant women and children are eating come from areas with high levels of lead, the lead can cause harmful side affects to the earth-eaters. Overall, geophagia can by a pathway for the ingestion of harmful elements such as lead, cadmium, potassium, mercury, arsenic, aluminum, dioxins, and radionuclide isotopes (Nijru et al., 2011).

Lead is a particularly dangerous contaminant for pregnant women and children. It can be measured in the blood and is considered high when levels go above 10 µg/dL, however detrimental effects have been observed at levels much lower than the above value (Shannon, 2003). Experts now use a reference level of 5 µg/dL to identify children with high-risk blood lead levels in the United States (CDC, 2012)

Lead poisoning, or even higher than normal levels of lead can have detrimental effects on the body (Falcon, 2003). The deficiency of minerals such as iron, zinc, copper, and calcium increases lead absorption by the body. The body is low in nutrients and is unable to absorb what is necessary, however, if lead is readily available for absorption the body will quickly absorb it instead in a competitive mechanism. Adult humans absorb about 10-15% of ingested lead, while children absorb up to 50% of ingested lead (Njoroge, 2005). The absorbed lead is bound to erythrocytes and distributed to soft tissue and bone. Bone marrow encompasses 94% of the lead burden in adults and 74% in children. This is dangerous because the half-life of bone lead is more than twenty years (Njoroge, 2005). Endogenous lead would normally mobilize from the bones during pregnancy due to the high rate of bone turnover; however, if the mother is insufficient in calcium and other elements, a higher demineralization rate is expected, and more lead will be released into the blood (Al-Saleh et al., 2010). This leads to higher blood lead levels in pregnant mothers.

The detrimental effects of increased absorption of lead are as follows. Lead reduces the survival time of erythrocytes leaving the patient fragile, weak, and more susceptible to malaria (Ahamed et al., 2007). If lead levels are the highest out of all the nutrients, lead will trump the others and will be absorbed the most. Even sub-toxic lead levels could endanger the lives of pregnant mothers and their developing children. Lead can increase the incidence of premature deliveries and can indirectly contribute to preeclampsia. It interferes with the structural and functional changes in the vascular wall and contributes to abnormal constrictor and dilator responses leading to hypertension (Chai et al., 1988). In an area that is already genetically susceptible to hypertension, added causes can further make this problem worse, further endangering the health of those with lead toxicity.

High lead levels can also result in intrauterine fetal growth retardation, which can cause increased morbidity and mortality in newborns (Njoroge, 2005). Some epidemiological studies of children show that when exposed to lead even at low levels, the children exhibit a lower IQ, learning disabilities, behavioral abnormalities, and kidney damage. Cognitive and growth defects may also occur (Njoroge, 2005). In 1995, Baranowska found that high concentrations of lead in the placenta were correlated with low values on the Apgar scale (Falcon, 2003). Along the same lines, recent studies have indicated an association between blood lead levels below 10 μg/dL as well as adverse health effects including diminished cognitive function, diminished neurological function, dental carries, and growth retardation (Njoroge, 2005). Lead may be able to take the place of calcium during calmodulin-dependent phosphorylation of brain membranes. Getting lead this close to the brain may be a cause of the effects of lead poisoning (Habermann et al., 1983). During the perinatal period, the susceptibility for neurotoxicity to occur is high because of the immaturity of the blood-brain barrier (Falcon, 2003). This may be the reason why the Center for Disease Control has been thinking about lowering the blood lead action level for children to 2 μg/dL in order to ensure that children are protected from some of the detrimental neurobehavioral effects of lead (Al-Saleh et al., 2010).

Even slightly higher than normal levels of lead can impair the absorption of other needed micronutrients during pregnancy, which can lead to complications. A decrease in iron absorption causes anemia as described above and also increases the risk of death from hemorrhage during delivery. Folic acid deficiency can lead to congenital malformations. Zinc deficiency has been associated with congenital abnormalities and retarded immunological development. Additionally, iodine deficiency can result in hypothyroidism (Black, 2001). Toxic levels of lead can pose dangers to pregnant mothers and their developing fetuses. If pregnant women eat soil or soft rocks contaminated with lead, they are able to pass it on to their children, which could result in high blood lead levels of the children leading to the dangerous consequences described above.

During pregnancy, heavy metals are transferred through the placenta to the developing fetus. The placenta acts as a selective barrier by allowing nutrients and oxygen to pass to the fetus, and preventing toxic compounds from crossing through (Al-

Saleh et al., 2010). Though the placenta is selective for some materials, it is not so for others. In a study conducted by Al-Saleh and colleagues (2010), a significant correlation between maternal and cord blood lead levels was found. Lead levels were either both high or both low. This could indicate that even when the mother has a low blood lead level, the placenta cannot prevent lead transfer from mother to newborn (Al-Saleh et al., 2010). Trans-placental transmission of lead occurs by simple diffusion, with neonatal blood levels approximating those of the mother. In one study done to evaluate lead transfer via the placenta, the lead levels in the cord blood and breast milk increased with the lead level in the maternal blood with coefficients of correlation of 0.714 and 0.353 respectively (Li et al., 2000). This confirms that lead can also be transferred via breast milk after giving birth. Another study has shown that uptake of lead by the fetus is cumulative over time, indicating a net unidirectional flow from mother to child (Shannon, 2003). The same study showed that neonatal lead levels tended to be higher in offspring of women with low calcium intake, which is a common occurrence in western Kenya (Shannon, 2003).

Calcium can be a key factor when dealing with toxic lead levels. Calcium will interact with lead by binding lead in the gut, competing with lead for absorption, altering intestinal cell avidity for lead, or altering the affinity of target tissues to lead (Ettinger et al., 2007). Calcium supplementation has been associated with modest reductions in blood lead levels when administered both during lactation and pregnancy (Ettinger et al., 2007). This indirectly suggests that calcium plays a role in the movement of lead across the placenta. With more calcium present, there will be less lead flow to the fetus. At the cellular level, lead passes through calcium channels in the kidneys, so if there is low calcium, more lead will be able to pass into the bloodstream through the kidneys, whereas if there are high levels of calcium, less lead will be able to pass through to be absorbed by the body (Simons et al., 1987).

In a randomized double-blinded controlled trial comparing calcium supplementation with no supplementation during pregnancy, supplementation was associated with an 11% reduction in blood lead levels while adjusting for confounders and starting with lead levels under the World Health Organization's designated 10 μg/dL (Ettinger et al., 2009). The results of calcium supplementation for high lead levels could be even more beneficial to the mother and her child.

In one hospital case, a mother and newborn pair had toxic levels of lead in their blood. The mother was given a solution with fluid calcium for a time to lower her lead levels. The newborn underwent a double-volume exchange transfusion and the infant's lead level fell from 113.6 μg/dL to 12.8 μg/dL immediately after the exchange transfusion. The infant then received 5 days of chelation therapy with intravenous calcium ethylenediaminetetraacetic acid. It was reported that the infant had some episodes of mild hypotonia and irritability but otherwise the baby recovered and the lead levels lowered quickly with no devastating side effects to the child. This treatment was quite successful in the management of lead poisoning (Hamilton et al., 2001).

Though calcium supplementation has been proven to be successful in treating lead toxicity, it is not sustainable in rural western Kenya for long periods of time. Mission teams are only available for short spurts throughout the year and sending medication would be unwise with the presence of a corrupt government. A more practical approach to increasing calcium levels would be to optimize the traditional diet of the residents of western Kenya. In a study done to analyze western African foods, calcium concentrations were determined using an inductively coupled plasma atomic emission spectrophotometer. Based on dry weight, the top five foods for calcium are sorrel leaves, amaranth leaves, okra leaves, onion leaves, and baobab leaves (Boukari et al., 2001). If these plants were eaten more often by those in Africa, their calcium levels could increase which would help to even out their increasing blood lead levels. In addition to eating more calcium, people could also drink more calcium. Goat's milk could also contribute to increasing calcium levels. In rural East Africa, it seems more practical to increase calcium levels through diet as opposed to using supplements.

Conclusion

Many things can be transferred from mother to child during pregnancy, creating a risk for the developing fetus and likewise the mother. Harmful practices, and poor health of the mother can greatly impact the health of their children. The prevalence of geophagia in western Kenya is high. The etiology is confusing with many different areas of culture contributing to why pregnant women crave soft rocks and soil. Some people believe this practice is harmful and others helpful. In any case, if women are ingesting high levels of lead from geophagia or any other source, the lead can be transferred from the mother to her child through the placenta and breast milk, which can result in toxic lead levels in mother and child leading to devastating consequences. Calcium supplementation has been shown to treat high levels of lead, but that program may be hard to implement into a rural African village without using their diet. Addressing the impact of high lead levels in the soil being ingesting by pregnant women is important in controlling lead toxicity. There is a gap in the literature concerning pregnant women consuming soft rocks who are breastfeeding and are also pregnant with another child at the same time. Lead is transferred through breast milk and the placenta, but to what degree would that transfer change if a woman is carrying a fetus and is breastfeeding another child? Many things are transferred from mother to child during pregnancy due to their diet and health status. The aim of this study is to explore the effect of lead ingested by mothers in rural western Kenya when they are pregnant and also breastfeeding another child and to evaluate how the health of the mother will affect the health of the child. On a broader level, the goal of this community-based research is to describe the range of the mother's challenges during pregnancy among this group of Luo women and to see to what extent their poor diet, geophagia, and poor health during pregnancy are reflected in indications of her offspring's poor health later in childhood. This portrait of pregnancy on the Nyakach Plateau will hopefully provide guidance about effective interventions in the future.

CHAPTER THREE

Hypothesis

Research Question 1

If women eat soft rocks while pregnant, will their children have high blood lead levels, after controlling for the child's geophagia and the child's age?

Hypothesis 1: Women who eat soft rocks while pregnant will have children with higher blood lead levels than women who did not eat soft rocks while pregnant.

Null Hypothesis: There is no relationship between mothers eating soft rocks while pregnant and lead levels in their children.

Research Question 2

2A.Will mothers' blood lead levels be positively associated with their children's blood lead levels?

Hypothesis 2A: Mothers' blood lead levels will be positively associated with their children's blood lead level, after controlling for children's geophagia and children's age.

Null Hypothesis: There is no relationship between mothers' blood lead level and children's blood lead level.

2B. If breastfeeding does transfer lead to the child, then breastfeeding while pregnant would dilute the effect of lead on the developing fetus. If women eat soft rocks while breastfeeding, will their children have high blood lead levels?

Hypothesis 2B: Women who were breastfeeding while pregnant will have a lower correlation of their lead level with that of the reference child than women who were not breastfeeding while they were pregnant with that child.

Null Hypothesis: There will be no difference in the relationship between mother and child's blood lead levels in mothers who breastfed during pregnancy compared to mothers who did not breastfeed during pregnancy.

Research Question 3

Using hemoglobin as a biomarker for children's health, is the child's hemoglobin level related to the mother's hemoglobin?

Hypothesis 3: Mothers' hemoglobin levels will be positively associated with their children's hemoglobin level.

Null Hypothesis: There is no relationship between mothers' hemoglobin level and children's hemoglobin level.

Research Question 4

Mothers' are considered to have high overall health risk during pregnancy if they ate less than usual, had no/low protein, had no milk, and had poor health (by self-report) during pregnancy. Using hemoglobin as a biomarker for children's health, is the child's hemoglobin level related to the mother's overall health risk during pregnancy?

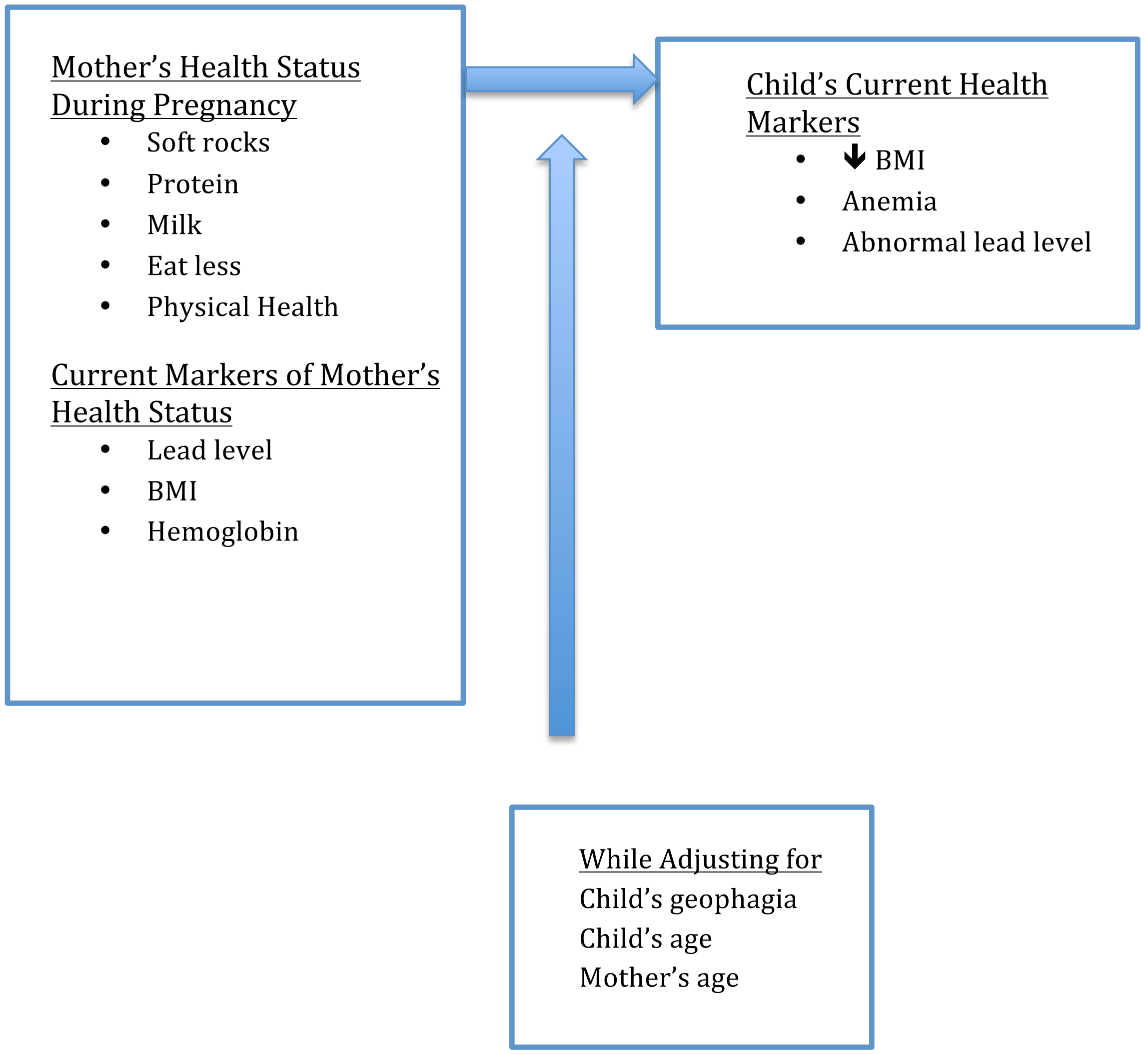
Hypothesis: Mothers' overall health risk during pregnancy will be negatively associated with children's hemoglobin.

Null Hypothesis: There will be no relationship between mothers' overall health risk during pregnancy and children's hemoglobin.

Description of Study

This study investigates the health of the mothers and children on the Nyakach plateau. Specifically the study evaluates mothers' geophagia, diet, lead levels, anemia, and overall health risk, and their effect on child lead and hemoglobin levels. Data were collected in the form of questionnaires and blood tests from patients seeking medical treatment at a temporary clinic in rural western Kenya in May of 2013.

Figure 1: Schematic Representation



CHAPTER FOUR

Methods Chapter

Setting

Straw to Bread is a U.S.-based non-profit organization that sponsors a team that conducts a temporary medical clinic for two weeks each year on the Nyakach Plateau in rural western Kenya among the Luo tribe. This annual activity is part of ongoing development projects and research in this area that encompass health care, food and sustainable agriculture, safe water sources, education, and small business development. This study was conducted in the Straw to Bread clinic in May 2013. Data were collected over the course of ten days, between May 22nd and May 28th 2013.

Sample

The sample was drawn from women who came to the clinic as patients themselves or accompanying patients. The first forty-nine women were invited to participate in the study if they were mothers and if they had at least one child with them. If more than one child was present, the youngest child was designated as the "reference child" for purposes of the study.

Research Design

The study design is cross-sectional. Questionnaires and blood samples were collected when the women were at the clinic waiting to see the doctor.

Measurements

Height was measured in centimeters using a tape measure, and weight was measured in kilograms using a commercial scale purchased locally. Body Mass Index (BMI) was then calculated as the weight divided by the height (in meters squared).

Blood samples were drawn by trained laboratory techinicians. Blood hemoglobin levels were measured using an i-STAT blood analyzer system (Abbott, Princeton) in grams per deciliter. Blood lead level was measured using LeadCare II analyzer system (Magellan Diagnostics). On this particular instrument, meaningful distinctions are made beginning at 3.3 micrograms per deciliter and above. Value whose level appeared on the instrument as < 3.3 were coded as 0.

The questionnaire (see Appendix 1) was administered to women by the investigator or by trained research assistants. Questions were developed by the investigator and included demographic variables for mother and child, questions about child geophagia, and information about the mother during her pregnancy with the reference child, including her diet, health status, and soft rocks consumption.

Statistical Analysis

The data were double-entered into Microsoft Excel and then imported into SAS 9.3, the statistical program that as used for data analysis. Frequencies and other descriptive statistics were calculated for each variable. Bivariate analysis was run using Chi-square and t tests. Multivariate analysis was used to assess interaction effects and the relative contribution of each predictor variable to the outcome variable. Multiple regression, logistic regression, and analysis of variance were used. In some cases, data were stratified and contingency table analysis was done to assess the modification of the relationship between the predictor and the outcome variables.

IRB approval

This study was approved by the Baylor University Institutional Review Board before data collection began. All data from human subjects was anonymous. Informed consent was obtained before a subject provided data for the study.

CHAPTER FIVE

Results

Sample Characteristics

The sample consisted of 49 mother-child pairs. The average age of the children was 4.3 years (SD=3.52) and a range from 1 month to 13 years. The sample was composed of 52% boys and 48% girls. The average age of the mothers was 29 years (SD=6.97) and a range of 16 to 46 years. The data from one mother was excluded from the analyses due to missing data.

Anthropometric Measurements

See Table 1 for summary statistics for mothers and children. The BMI for the mothers is within the normal category according to the CDC, which ranges from 18.5-24.9. For children, BMI percentiles were used to standardize the results for age and gender, and 33% of the sample fell below the fifth percentile, see table 1.

Table 1 Body Size

	Height(cm)	Weight(kg)	BMI (mother) BMI Percentile (child)
Mother	164.05(SD=8.63)	57.9 (SD=9.01)	21.7 (SD=3.41)
Child	99.82(SD=28.9)	15.98(SD=7.11)	27.2 (SD=28.6)

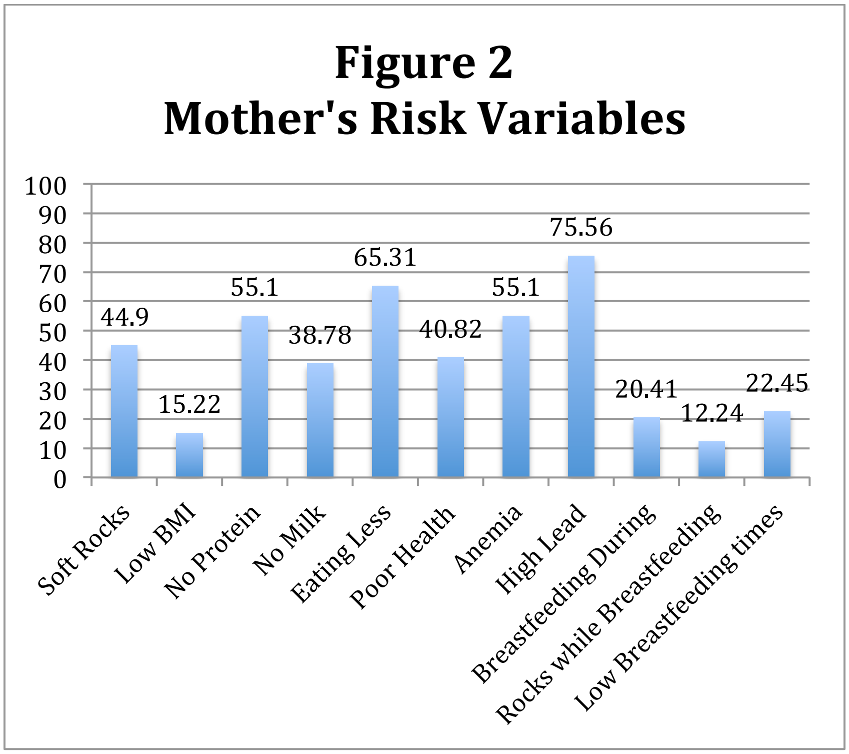
Mother's Health Variables

Mother's Health Risk Variables

Health status or risk information was obtained from the mothers about the time in which they were pregnant with the designated child. Table 2 below shows the presence of numerous risk factors of the mother during pregnancy, and Figure 2 shows the percentages in graph form.

Table 2 Individual Frequencies of Mothers' Risks

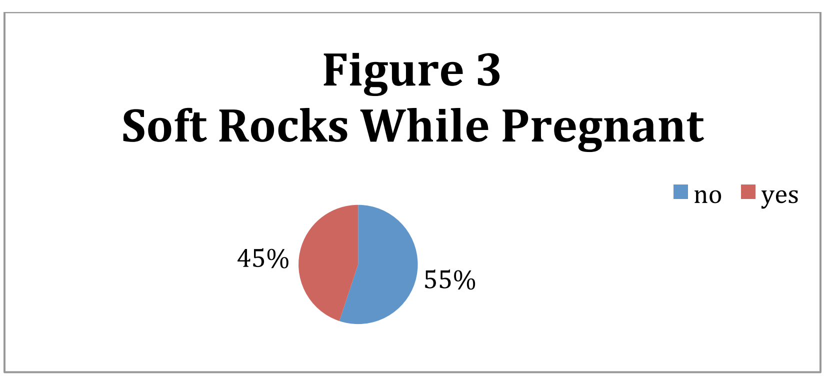
Risk	Percent (n)
Soft Rocks	44.90 (22)
Low BMI<18.5	15.22 (7)
No Protein	55.10 (27)
No Milk	38.78 (19)
Eating Less	65.31(32)
Poor Health	40.82 (20)
Anemia<12.5g/dL	55.10 (27)
High Lead >5µg/dL	75.56 (34)
Breastfeeding During Pregnancy	20.41 (10)
Rocks while breastfeeding	12.24 (6)
Low breastfeeding time	22.45 (11)



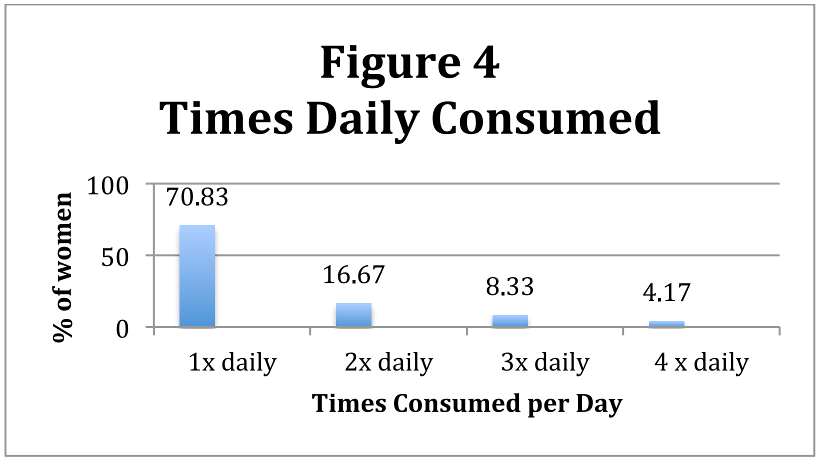
*Y axis shows percent of mothers with the risk variable listed on the x-axis.

Soft Rock Variables

Out of 49 women interviewed, 45% reported eating soft rocks while pregnant (see Figure 3). Of the people who said that they ate the rocks, 65.38% of them said that they obtained the rocks off the side of the road, with the remaining women obtaining them from the local market or a combination of the two.

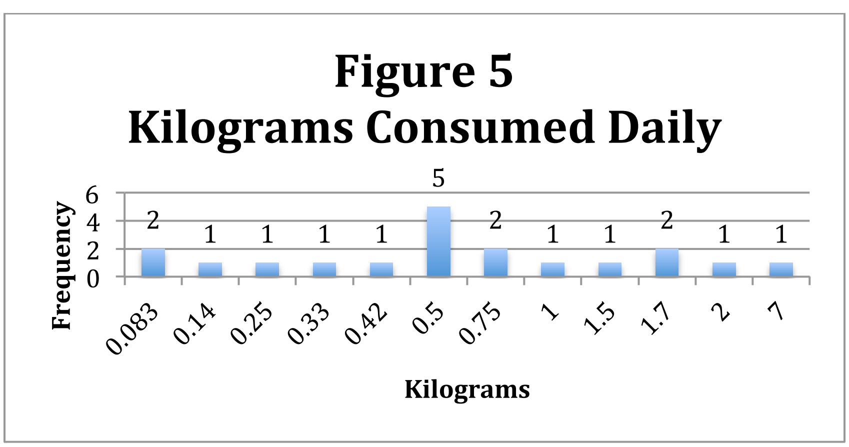


Of the women who consumed soft rocks during pregnancy, almost one-third of the women reported eating soft rocks several times a day (see Figure 4). One woman reported eating the rocks 4 times daily.



*Graph shows percentage of women that consumed the soft rocks different times daily.

Women were also asked to describe the quantity of soft rocks eaten. This was done by using a standard cup as a guide. The lowest quantity consumed was 0.083 kg and the highest quantity was 7 kg. The majority consumed about half a kilogram daily. The mean quantity consumed was 1.06 kg (SD=0.847). The quantities are shown in Figure 5.



*Graph shows frequencies of number of women consuming different quantities daily.

Sometimes the soft rocks are roasted and then eaten. A few of the roasted soft rocks and soft rocks from the Plateau were tested for their lead levels using the aqua regia method and the nitric acid method[1]. 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 a higher lead level (see Table 3). Still, this level is not significant when looking at the composition of the rocks as a whole. According to the US EPA, a significant level would have been above 40 ppm, and the samples shown below contain 6.54 ppm and 2.45 ppm, which are not close enough to be considered a serious source of lead. This does not take into account the large quantities of rocks that many women ate, however, and it is possible that the sheer volume of even trace amounts of lead would be of concern.

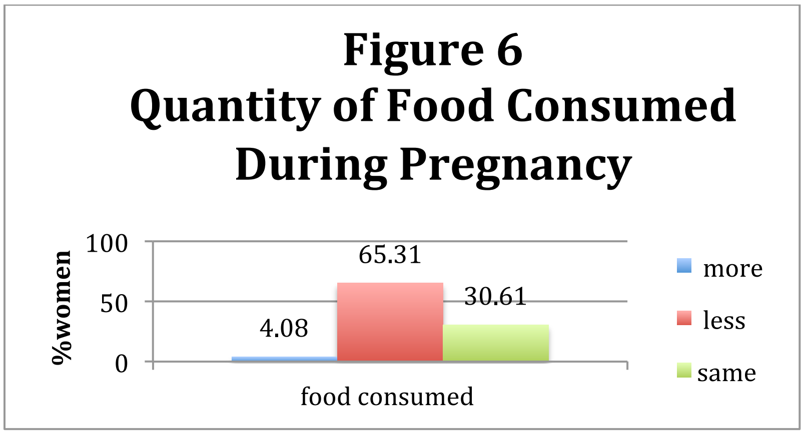
Table 3 Composition of Soft Rocks

	ppm (µg/g)	
	Roasted	**Plateau**
Mg	784.4526158	1159.592636
Ba	525.1978794	687.9189571
Ag	1.124257277	2.409792019
Ti	2874.640872	4412.239865
Ca	388.8117635	319.4015723
Fe	25104.22231	39273.93317
Mn	348.9605282	519.5299035

[1] Special thanks are given to Dr. Erica Bruce of Baylor University for this analysis.

Food Consumption During Pregnancy

Women were questioned about the quantity of food consumed during their pregnancy, and 65.31% reported eating less food while pregnant as shown in Figure 6.



*Graph shows percentage of women consuming each quantity of food.

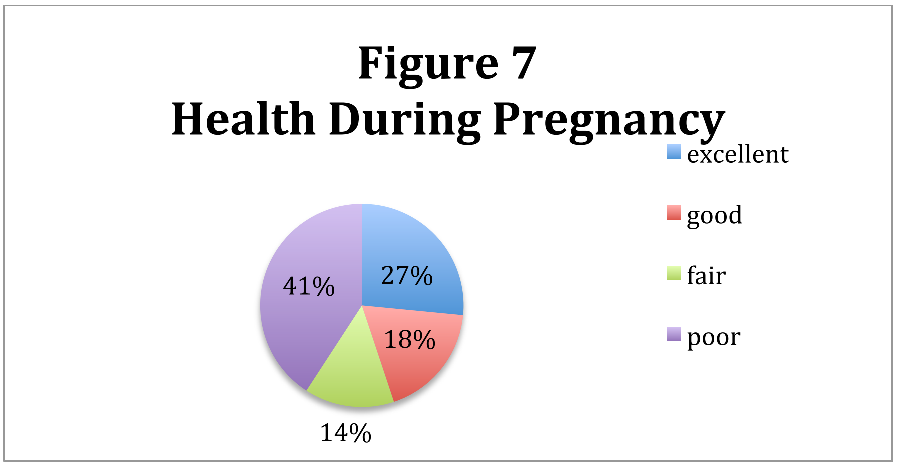
The mothers were asked to list what they ate on a typical day when they were pregnant. The results are summarized in Table 4. Answers were categorized into: animal protein (meat, fish, poultry, and eggs), and non-animal protein (beans, milk), vegetables, fruit, starch, added sugar, and soft drinks. The most striking finding was that over half of the women had no protein-rich food in their diet at all except for the 60% who had a little milk once or, rarely, twice a day in their tea. The solid animal protein that was consumed was virtually always a very small dried fish. The only food that was eaten 3 times daily was starch, with only 32.65% of mothers consuming it at that level. Soft drinks were consumed by only one mother who drank one daily. Starch seems to be the main source of nutrition in this community.

Table 4: Times Per Day Food was Consumed

Type of Food	# Times/Day	Percent (n)
Animal Protein	0	55.10 (27)
	1	22.45 (11)
	2	22.45 (11)
Other Protein	0	93.88 (46)
	1	6.12 (3)
Milk	0	38.78 (19)
	1	53.06 (26)
	2	8.16 (4)
Vegetables	0	14.29 (7)
	1	36.73 (18)
	2	48.98 (24)
Fruit	0	93.88 (46)
	1	4.08 (2)
	2	2.04 (1)
Starch	0	4.08 (2)
	1	18.37 (9)
	2	44.90 (22)
	3	32.65 (16)
Added Sugar	0	36.73 (18)
	1	57.14 (28)
	2	6.12 (3)
Soft Drinks	0	97.96 (48)
	1	2.04 (1)

Health Status During Pregnancy

Of the 49 women in the sample, 41% reported that they had poor health during their pregnancy. The results are summarized in Figure 7.



Breast Feeding Variables

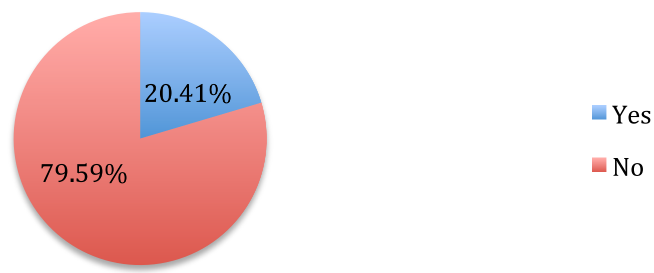
Mothers were asked a number of questions about their practice of breastfeeding (see Table 5). The largest percentage of women (28.57%) breastfed their last child for 24 months. The second highest time periods were 12 months at 10% and 36 months at 10%. The mean was 17.87 months (SD 11.14).

Table 5 Breastfeeding Duration

Time in Months	Percent (n)	Cumulative Frequency
0.46	2.04 (1)	2.04
1	8.16 (4)	10.2
4	2.04 (1)	12.24
5	4.08 (2)	16.32
6	6.12 (3)	22.44
7	2.04 (1)	24.48
8	2.04 (1)	26.52
9	4.08 (2)	30.60
11	2.04 (1)	32.64
12	10.20 (5)	42.84
14	2.04 (1)	44.88
17	2.04 (1)	46.92
18	4.08 (2)	51.00
24	28.57 (14)	79.57
29	2.04 (1)	81.61
30	4.08 (2)	85.69
31	2.04 (1)	87.73
32	2.04 (1)	89.77
36	10.20 (5)	100.00

In certain circumstances mothers must breastfeed a child while they are pregnant with the next one. Out of 47 women who answered the breastfeeding questions, 20.41% reported breastfeeding during their pregnancy with their most recent child (see Figure 7).

Figure 7. Breastfeeding During Pregnancy



Mother's Blood Lead and Hemoglobin Levels

For the mothers, the mean blood lead level was 5.72 micrograms per deciliter with a standard deviation of 2.59 and range of 0-16.3 (n=47). These ranges are very large for blood lead levels. The CDC's toxic lead level for adults is 10 micrograms per deciliter. Only 4.60% of the mothers have a blood lead level higher than 10 micrograms per deciliter; however, 72.34% of the mothers have a blood level above 5 micrograms per deciliter, which could become detrimental during pregnancy when blood is shared. See Table 6 below for statistics.

Table 6 Blood Lead and Hemoglobin

	n	Mean (SD)	Range
Blood Lead (µg/dL)			
Mothers	47	5.72 (2.59)	0.00-16.30
Children	44	5.96 (3.09)	0.00-12.60
***Hemoglobin (g/dL)**			
Mothers	37	12.16 (2.15)	7.10-18.00
Children	36	11.83 (1.66)	7.10-15.6

* Frequencies are lower due to inability to draw venous blood sample.

Hemoglobin was also a major outcome variable. The mean hemoglobin level for the mothers was 12.16 g/dL with a SD of 2.15 and range of 7.1-18.0 (N=37). For women the normal range of hemoglobin is 12.0 to 15.5 grams per deciliter. 37.8% of the mothers had a hemoglobin level under 12.0 g/dL making them anemic or at risk for anemia. The critical hemoglobin levels of 11g/dL and 12 g/dL are highlighted in the Table 7.

Table 7 Mother Hemoglobin Level

Mother Hemoglobin	Percent	Cumulative Percent
7.1	2.7 (1)	2.7
7.8	2.7 (1)	5.4
7.9	2.7 (1)	8.1
9.5	2.7 (1)	10.8
9.9	2.7 (1)	13.5
10.2	10.8 (4)	24.3
10.5	2.7 (1)	27.0
11.6	2.7 (1)	29.7
11.9	8.1 (3)	37.8
12.0	2.7 (1)	40.5
12.2	10.8 (4)	51.4
12.6	5.4 (2)	56.8
12.9	5.4 (2)	62.2
13.3	10.8 (4)	73.0
13.6	8.1 (3)	81.1
13.9	10.8 (4)	91.9
14.6	2.7 (1)	94.6
15.0	2.7 (1)	97.3
18.0	2.7 (1)	100.0

Mother's Risk Score

A composite maternal health risk score was created for the mother based on the presence or absence of a high level of risk for factors during pregnancy and breastfeeding as well as current factors. High-risk pregnancy and breastfeeding variables were: soft rock intake, no protein intake, no milk intake, eating less during pregnancy, perceived poor health during pregnancy, long duration of breastfeeding, and breastfeeding another child while pregnant with the designated child. Current health risk variables were: BMI <18.5, anemia (hemoglobin <12.5 g/dl), and high lead level (>5). Mothers were given a score of 1 for the variable if the high risk was present, and 0 if the risk was low. The frequency of women with the presence of each risk factor is shown in Table 2. The frequencies for the combined risk score are found in Table 8.

Table 8 Mother Risk Score

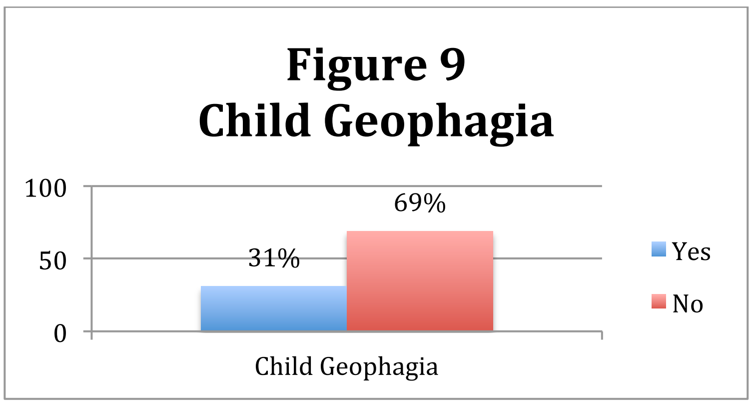
Mom_risk	Frequency	Percent	Cumulative Percent
1	3	6.98	6.98
2	4	9.30	16.28
3	8	18.60	34.88
4	7	16.28	51.16
5	9	20.93	72.09
6	4	9.30	81.40
7	6	13.95	95.35
8	2	4.65	100.00

The highest frequency risk group was a mother having a combination of 5 of the risk variables. The average risk score was 4.42 with a SD of 1.92 and a range of 1 to 8. Each mother reported at least 1 risk factor during her pregnancy, which could lead to deterioration of her child's health.

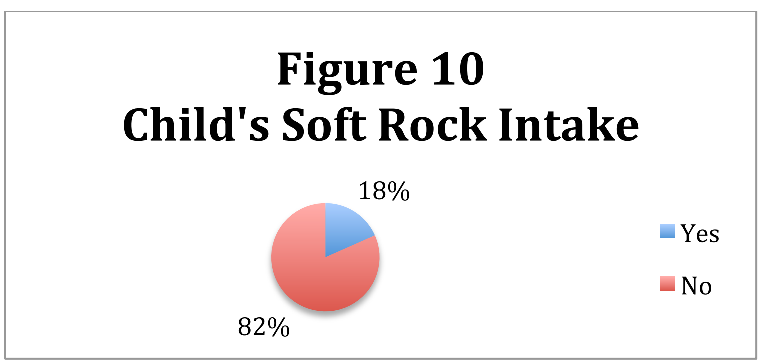
Child's Health Variables

Child Geophagia Variables

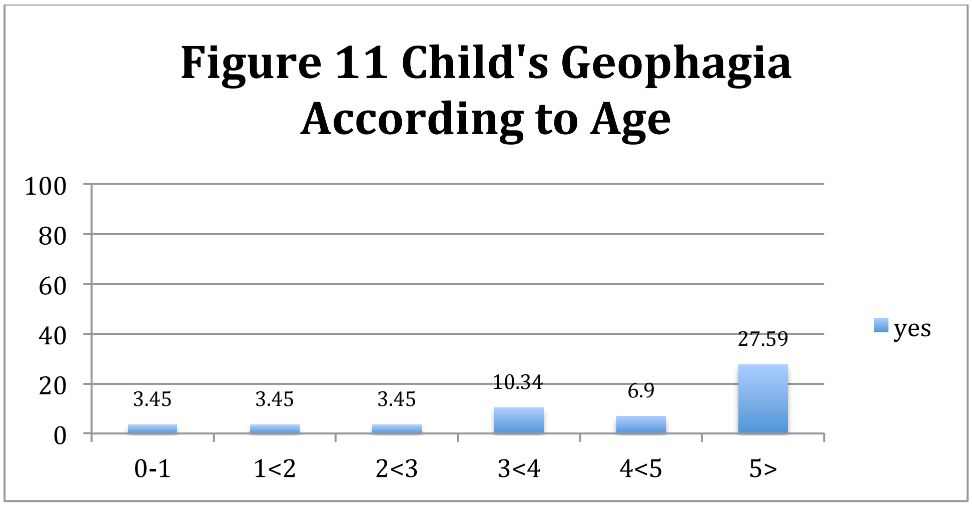
The mothers were asked whether they had ever seen their child eat things other than food such as dirt or soil, and 32% of the women gave a positive response (see Figure 9).



When asked if their child ever ate the soft rocks also only 18% reported a positive response (see Figure 10).



The frequency of geophagia was then analyzed by each year of age for children under 5 (see Figure 11). These children are of particular interest because these mother's pregnancies were the most recent which will more closely reflect any effects of the mother's toxicity from geophagia that were transferred to the child during pregnancy or breastfeeding. Only 27.59% of children under 5 engaged in geophagia. The majority of children who did so were between 1 and 3 years of age. In this age span, children are able to move around and place objects in their mouth.



*Graph shows percentage of children in each age category engaging in geophagia.

Childs Lead and Hemoglobin

The outcome variables in this study were child blood lead and hemoglobin levels as well as mother blood lead and child hemoglobin levels. The mean child lead level was 5.96 micrograms per deciliter with a standard deviation of 3.07 and range of 0-12.6 (n=44). These ranges are very large for blood lead levels. The CDC recommends that at blood levels above 5 micrograms per deciliter for children ages 1-5 that the health system should take action. In our sample only 25% of the children blood lead levels were 5 or lower, meaning that 75% of these children have toxic blood lead levels.

Table 6 Blood Lead and Hemoglobin

	n	Mean (SD)	Range
Blood Lead (µg/dL)			
Mothers	47	5.72 (2.59)	0.00-16.30
Children	44	5.96 (3.09)	0.00-12.60
***Hemoglobin (g/dL)**			
Mothers	37	12.16 (2.15)	7.10-18.00
Children	36	11.83 (1.66)	7.10-15.6

* Frequencies are lower due to inability to draw venous blood sample.

Hemoglobin was also a major outcome variable. The mean child hemoglobin level was 11.84 grams per deciliter with a SD of 1.66 and range of 7.1 to 15.6 (n=36). According to the CDC, Children aged 1 to 2 years are considered anemic if their hemoglobin concentration is less than 11.0 g/dL . Children aged 2 to 5 years are considered anemic if their hemoglobin concentration is less than 11.1 g/dL. 27.8% of the children had hemoglobin levels below 11 g/dL making them anemic or at risk for anemia. The critical hemoglobin levels of 11g/dL and 12 g/dL are highlighted in Table 9.

Table 9 Child Hemoglobin Level

Child Hemoglobin	Percent (n)	Cumulative Percent
7.1	2.8 (1)	2.8
9.2	2.8 (1)	5.6
9.5	5.6 (2)	11.1
10.2	2.8 (1)	13.9
10.5	8.3 (3)	22.2
10.9	5.6 (2)	27.8
11.2	13.9 (5)	41.7
11.6	5.6 (2)	47.2
11.9	5.6 (2)	52.8
12.2	5.6 (3)	61.1
12.6	5.6 (2)	66.7
12.9	11.1 (4)	77.8
13.3	11.1 (4)	88.9
13.6	2.8 (1)	91.7
14.3	5.6 (2)	97.2
15.6	2.8 (1)	100.0

Hypotheses

Research Question 1

If women eat soft rocks while pregnant, will their children have high blood lead levels, after controlling for children's geophagia and child's age?

Hypothesis 1: Women who eat soft rocks while pregnant will have children with higher blood lead levels than women who did not eat soft rocks while pregnant.

An ANOVA procedure on mother's soft rock intake (Exposure 5 variable) and child's lead level controlling for children's geophagia, and child's age, yielded nonsignificant results. The. See results of test in table 10 below. We were not able to reject the null hypothesis.

Table 10 The Relationship Between Mother's Soft Rock Intake and Child Lead

Overall model: F=0.39, p=0.813, R^2=0.045 (n=37)

Dependent Variable: Children's Lead Level

Variable	**F-value**	**p-value**
High Maternal Soft Rock Intake	0.67	0.5171
Geophagia	0.18	0.6782
Age of Child	0.04	0.8374

Research Question 2

2A. Will mothers' blood lead levels be positively associated with their children's blood lead levels?

Hypothesis 2A: Mothers' blood lead levels will be positively associated with their children's blood lead level, after controlling for children's geophagia and children's age.

After running an ANOVA procedure on mother's blood lead level and child's blood lead level, the results showed that there was not a statistically significant relationship between the two variables. 44 mother and child pairs were run in this analysis, which ended with ($F=0.44$, $R^2=0.0103$, $p=0.5118$). Thus our hypothesis must be rejected and our null hypothesis accepted concluding that there is no statistically significant relationship between mother's blood lead level and child's blood lead level (see table 11 below).

Table 11 Relationship Between Mother's Lead and Child's Lead

Overall model: $F=0.18$, $p=0.9098$, $R^2=0.0123$ ($n=43$)

Dependent variable: Child's lead level

Variable	F-Value	p-value
Geophagia	0.13	0.7162
Mother lead	0.37	0.5488
Age child	0.04	0.8455

2B. If breastfeeding does transfer lead to the child, then breastfeeding while pregnant would dilute the effect of lead on the developing fetus. If women eat soft rocks while breastfeeding, will their children have high blood lead levels?

Hypothesis 2B: Women who were breastfeeding while pregnant will have a lower correlation of their lead level with that of the reference child than women who were not breastfeeding while they were pregnant.

After running ANOVA procedure on child blood lead level (making the 0 level equal to 3.3 and only including children under the age of 5), and mother's lead level when mothers were breastfeeding during pregnancy, the results showed that among women who were breastfeeding another child while pregnant, there was not a relationship between mother lead level and child lead level. ($F=0.08$, $p=0.78$, $R^2=0.0119$) The test also showed that among women who were not breastfeeding another child while pregnant with the child in the study, there was also not an association between the mother's lead level and the child's lead level ($F=0.57$, $p=0.4553$, $R^2=0.0187$), although, it was closer to significance than when mothers were breastfeeding during pregnancy, due to the test results we can not say that breastfeeding may dilute the transfer of lead to the developing fetus.

Research Question 3

Using hemoglobin as a biomarker for children's health, is the child's hemoglobin level related to the mother's hemoglobin?

Hypothesis 3: Mothers' hemoglobin levels will be positively associated with their children's hemoglobin level.

Regressing child's hemoglobin on mother's hemoglobin showed a significant relationship (F=8.15, p=0.0073, R^2=0.1933). These results indicate that mother's hemoglobin is related to child's hemoglobin and that the mother's health is associated with the health of her child.

Research Question 4

Mothers' with high overall health risk during pregnancy ate less than usual, had no/low protein, had no milk, and had poor health (by self-report) during pregnancy. Using hemoglobin as a biomarker for children's health, is the child's hemoglobin level related to the mother's overall health risk during pregnancy?

Hypothesis: Mothers' overall health risk during pregnancy will be negatively associated with children's hemoglobin.

A health risk variable was created for the health of the mother during her pregnancy. 40.82% of women reported having poor health during their pregnancy. This variable was run against child's hemoglobin level alone and while adjusting for lack of protein, and milk intake, and eating less than usual during pregnancy. The bivariate relationship between mother's health and child's hemoglobin was significant (p=0.0211). When the variables are all run together using analysis of variance, the results are nonsignificant (F=2.09, p=0.1055, R^2=0.213) (see Table 12 below). The graph (Figure 12) on the following page illustrates the relationship between the two variables.

Figure 12 Distribution of Child Hemoglobin and Mother's Health

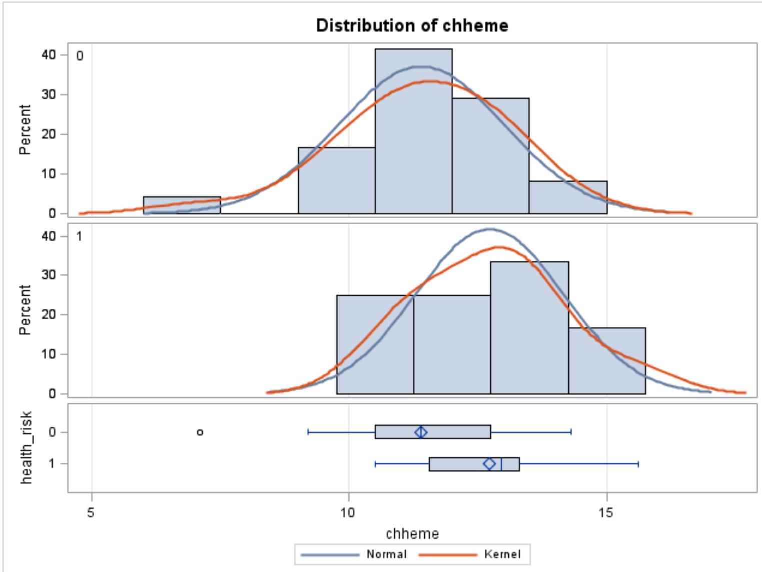


Table 12 The Relationship Between Child Hemoglobin and Mother's Health

Overall Model: F=2.09, p=0.813, R^2=0.045 (n=37)

Dependent Variable: Child's hemoglobin level

Variable	F-value	p-value
No protein	1.95	0.1733
No milk	0.06	0.8024
Eating less	0.57	0.4651
Poor health	6.05	0.0199

Additional Findings

Soft Rocks and Anemia Risk

Almost half (44.90%) of the women reported eating soft rocks during their pregnancy. A risk score was created for anemia using the hemoglobin levels of the mother with 12.5 g/dL being the cutoff level for anemia risk. 55.10% of the mothers were at risk for anemia. A chi-square test was run on these two variables (p=0.0252) showing a statistically significant relationship between the consumption of soft rocks during pregnancy and the presence of anemia in the mother. Seventy-one percent of those who ate soft rocks were anemic compared with 41% of those who did not eat soft rocks (see table 13 below).

Table 13 Relationship between Soft Rocks and Anemia Risk

	Mother ate soft rocks during pregnancy	Presence of anemia in mother		
		Not Anemic	Anemic	Total
	No			
Frequency		16	11	27
Percent		32.65	22.45	55.10
Row percent		59.26	40.74	
Column percent		72.73	40.74	
	Yes			
Frequency		6	16	22
Percent		12.24	32.65	44.90
Row percent		27.27	72.73	
Column percent		27.27	59.26	
Total		22	27	49
		44.90	55.10	100.00
DF=1; X^2=5.0134; p=0.0252				

Eating Less and No Protein

There was a significant relationship between the mothers who ate less during their pregnancy and mothers who ate no protein during their pregnancy (X^2=4.13, p=0.0422). Mothers who ate less protein were more likely to report having eaten less than usual overall during their pregnancy. Seventy-eight percent of women who ate no protein also ate less than usual during pregnancy compared to 50% of those who did eat protein (see Table 14).

Table 14 Relationship Between Protein Risk and Eating Less

	Ate no protein during pregnancy	Ate less during pregnancy		
		No	Yes	Total
	No			
Frequency		11	11	22
Percent		22.45	22/45	44.90
Row percent		50.00	50.00	
Column percent		64.71	34.38	
	Yes			
Frequency		6	21	27
Percent		12.24	42.86	55.10
Row percent		22.22	77.78	
Column percent		35.29	65.63	
Total		17	32	49
		34.69	65.31	100.00
DF=1; X^2=4.1284; p=0.0422				

CHAPTER SIX

Discussion

The relationship between mother and child during pregnancy is a major influence in the future health of the child. This population of Luo women has a number of vulnerable children being born to unhealthy mothers. As a developing fetus, the child has so many factors already affecting its health such as the poor health status of the mother, mother's lead level, mother's anemia, mother's soft rock intake, low protein intake, low milk intake, eating less in general during pregnancy, and the mother breastfeeding while pregnant with the child. Access to health care is an enormous problem in rural western Kenya, and mothers need to give birth to healthy children to give them a fighting chance at survival.

This study demonstrated relationships between mothers' health and children's health, although it did have the limitations of sample size, self-reported data, generalizability, and the inherent limits of a cross-sectional study. The sample size of this study was only 49 mother and child pairs. Had this number been higher, more analysis may have been completed that could answer questions between gaps in the results. We were unable to break the sample into smaller categories in some cases due to the limited sample size. In addition, our survey questionnaire relied on self-reported data. There is no way to know if the data about diet or soft rocks is completely accurate. Some of the questions we asked were culturally sensitive, and there is no way for us to know whether or not the responses are the truth. Some data were excluded from the study for this reason. For example we asked the mothers what their child's weight was at birth.

All of the mothers gave numbers for their child's birth weight, but we learned later that the mothers most likely simply reported numbers that they had heard were healthy weights for babies. This is the only self-reported data excluded. In addition, there are some respects in which this study may not be generalizable to outside populations. It is extremely helpful to the community on the Nyakach plateau, but this extremely poor, traditional Luo group may be different than other women, particularly in their practice of geophagia. The other data are likely to be typical of the health and dietary concerns of poor women in sub-Saharan Africa. Data were collected at only one point in time, and it would be optimal to collect blood on the baby and mother just after birth and then sequentially over time. This could possibly be done in future research to see if there is a major event that triggers the high lead levels in this population.

Hypothesis: *Women who eat soft rocks while pregnant will have children with higher blood lead levels than women who did not eat soft rocks while pregnant.*

The results obtained from comparing the mothers' blood lead levels to their children's blood lead level did not show a relationship between the two variables. The difference could be due to the fact that the children were of variable age, so it could have been years since the mother's pregnancy. This would allow ample time for the lead level to decrease in the mother's blood, since the half-life of lead in the blood is from 28 to 36 days (CDC). The half-life of lead could explain why the blood tests that we compared showed no association. It is true that lead has the potential to cross the placenta during pregnancy, so an association between mother and child blood lead levels could have occurred if blood samples were compared shortly after birth. In any case, the mothers and children both had abnormally high levels of blood lead, and the source is from something in the environment in which they live. Although we previously thought that there was an association between soft rocks and high lead level, since more recent analysis of the composition of the rocks has been completed it has been found that the lead is not unusually high in the rocks. Analysis showed that the rocks only contained 6.54 ppm for roasted and 7.74 ppm for normal rocks from the plateau. According to the EPA, less than 40ppm is normal, so there is no way that the simple consumption of these rocks is causing lead levels as high as they are in the mothers and children. There is most likely an outside source of lead in the environment that is causing these dangerously high levels.

Hypothesis: *Women who were breastfeeding while pregnant will have a lower correlation of their lead level with that of the reference child than women who were not breastfeeding while they were pregnant.*

Breastfeeding a child while pregnant with another child is a common occurrence in rural western Kenya due to very short birth intervals. As stated in the literature, it is possible for lead to cross over into the breast milk. In theory, this was thought to decrease the blood lead level that would be transferred to the developing fetus. The results of this study did not support this hypothesis. This could be due to the fact that the sample size for this study was small, but since no significant relationship was found between mother and child's blood lead level, there is no reason why there would be a significant relationship here. These fluctuations in blood lead level for both mother and child are intriguing and leave more questions open for further study. Breastfeeding for a long period of time or short period of time is a trade-off between the well-being of the fetus and the infant. Both children need the added nutrients. Another trade-off is that the child gains nutrition during breastfeeding or while the mother is pregnant, but the child also suffers the consequences of geophagia and poor maternal nutrition. In the case of lead, more is being transferred to the child from the mother over the course of breastfeeding. If the mother is breastfeeding this child while pregnant with another one, the fetus might be protected from added lead exposure, but the breastfed child would have additional lead exposure. Also, since the health of the mother is so poor before birth, there is a question of whether or not she will have enough energy to breastfeed and care for her additional children. The question of breastfeeding is a difficult one to answer, and all the problems go back to the poor health of the mother and lack of food in this population, which creates the mother's poor nutritional status during the course of the pregnancy.

Hypothesis: *Mothers who ate soft rocks during pregnancy will have significantly lower current hemoglobin levels than mothers who did not eat soft rocks during pregnancy.*

It was recently shown in another thesis that there is a relationship between the quantity of soft rocks mothers eat while pregnant and their blood lead level. Though we know that the rocks are not causing the blood lead levels, there may be something else associated with these two variables that is related to the relationship. This study shows that mothers who are anemic ate soft rocks while they were pregnant. Perhaps the women eat the soft rocks because they are anemic and are lacking in energy due to the contrasting affects of lead and calcium in the body. The women could also be eating the soft rocks because they were eating less during their pregnancy. This is a question in the literature as well. No study has been able to show what comes first, anemia or soft rock ingestion. No matter the reason the mothers are eating the rocks, the mothers have many risk factors associated with their health and it is a wonder that they are having children as healthy as they are despite the high lead levels and anemia.

Hypothesis: Women with lower overall health status during pregnancy will have children whose current hemoglobin level is lower than children of mothers with a higher overall health status during pregnancy.

Close to the majority of women in this study reported having poor health during their pregnancy. It makes sense that the health of the mother would affect the health of their developing child during pregnancy in general. In this community, the vulnerable developing fetus has so many risk factors to overcome that it is amazing that the children are born healthy for the most part. The fetus must combat the mother's high lead level, anemia, poor health, poor diet, ingestion of soft rocks, and the breastfeeding of an additional child. This study found relationships between the poor health status of the mother and the child's low hemoglobin levels, when these two variables were adjusted for not having protein or milk, and eating less during pregnancy in general. Also, anemic mothers give birth to children who become anemic. In addition, it was found that mothers who do not have protein in their diet eat less in general during their pregnancy. This is a huge disadvantage to the child and could be one of the reasons these children are born with low hemoglobin levels. Diet is such a crucial part of pregnancy and by not having food to eat, these mothers are already giving their children a disadvantage in an area where health is poor. After birth the child's growth and development continues to be undermined by the mother's nutrition throughout the period of breast-feeding, and then subsequent growth is influenced by the family's diet and risk of disease exposure.

CHAPTER SEVEN

Conclusion

This study illuminates the poor health status of mothers and the risks to their children in the community on the Nyakach Plateau. The health of a child is drastically impacted by the mother's health during pregnancy. The Luo tribe of western Kenya has many cultural practices, a damaging one being the ingestion of soft rocks during pregnancy and breastfeeding. Though the soft rocks are not high in lead themselves, they could be causing physiological issues that may be leading to the mother's anemia and potentiating high blood lead levels, during pregnancy and long after. Many of the mothers are anemic, and in turn give birth to children who become anemic. Associated with anemia, the majority of mothers reported eating less during pregnancy as well as having poor health during their pregnancy.

In addition to these factors, mothers are breastfeeding one child while being pregnant with another and do not drink milk or eat protein on a regular basis. All of the risk factors that a mother possesses during pregnancy can be related to the health of their children. Mothers with a poorer health status as indicated by the combination of high-risk variables were more likely to have anemic children. This study sheds light on the poor health of mothers and how their poor health is transmitted to their children.

The Luo tribe of western Kenya is a culturally unique group of individuals who are stuck living in poverty and are constantly battling hunger. Though some developments have been made through community health workers and reproductive health education efforts, this population has a long way to go before everyone can be considered healthy. A major goal needs to be improving the health of mothers and their children. Nutrition is a major factor in health. Efforts toward sustainable agriculture and cooperative gardening should be able to make improvements in the health, specifically low hemoglobin levels of the mothers and children. In addition, the source of lead in the community has yet to be determined. This could be a great area for future research in this community. Lowering lead levels could improve the overall health of everyone on the Plateau.

APPENDIX

2013 Maternal Nutritional Questionaire

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 (1st,2nd,3rd 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

CHILD

BIBLIOGRAPHY

Ahamed M, Singh S, Behari JR, Kumar A, Siddiqui MKJ. Interaction of lead with some essential trace metals in the blood of anemic children from Lucknow, India. *Clinica Chimica Acta*. 2007;377(1-2):92–97. doi:10.1016/j.cca.2006.08.032.

Al-Saleh I, Shinwari N, Mashhour A, Mohamed GED, Rabah A. Heavy metals (lead, cadmium and mercury) in maternal, cord blood and placenta of healthy women. *Int. J. Hyg. Environ. Health.* 2011;214(2):79–101. doi:10.1016/j.ijheh.2010.10.001.

Barker D. Tooth wear as a result of pica. *British Dental Journal*. 2005;199(5):271–273. doi:10.1038/sj.bdj.4812651.

Black RE. Micronutrients in pregnancy. *Br. J. Nutr.* 2001;85 Suppl 2:S193–197.

Boukari I, Shier NW, Fernandez R. XE, et al. Calcium Analysis of Selected Western African Foods. *Journal of Food Composition and Analysis*. 2001;14(1):37–42. doi:10.1006/jfca.2000.0967.

CDC. Blood Levels in Children. Centers for Disease Control and Prevention/National Center for Environmental Health. 2012.

Chai S, Webb RC. Effects of Lead on Vascular Reactivity. *Environmental Health Perspectives*. 1988;78:85. doi:10.2307/3430506.

Ed Benoist B et al., eds Worldwide prevalence of anemia 1993-2005. WHO Global Database on Anemia. Geneva, World Health Organization, 2008.

Ettinger AS, Lamadrid-Figueroa H, Tellez-Rojo MM, et al. Effect of Calcium Supplementation on Blood Lead Levels in Pregnancy: A Randomized Placebo-Controlled Trial. *Environ. Health Perspect.* 2009;117(1):26–31. doi:10.1289/ehp.11868

Ettinger A, Hu H, Hernandezavila M. Dietary calcium supplementation to lower blood lead levels in pregnancy and lactation☆. *The Journal of Nutritional Biochemistry*. 2007;18(3):172–178. doi:10.1016/j.jnutbio.2006.12.007.

Falcón M. Placental lead and outcome of pregnancy. *Toxicology*. 2003;185(1-2):59–66. doi:10.1016/S0300-483X(02)00589-9.

Geissler PW, Mwaniki DL, Thiongo F, Friis H. Geophagy among school children in Western Kenya. *Trop. Med. Int. Health*. 1997;2(7):624–630. doi:10.1046/j.1365-3156.1997.d01-345.x.

Geissler PW, Mwaniki D, Thiong'o F, Friis H. Geophagy as a risk factor for geohelminth infections: a longitudinal study of Kenyan primary schoolchildren. *Trans. Roy. Soc. Trop. Med. Hyg.* 1998;92(1):7–11. doi:10.1016/S0035-9203(98)90934-8.

Geissler PW, Prince RJ, Levene M, et al. Perceptions of soil-eating and anaemia among pregnant women on the Kenyan coast. *Soc Sci Med*. 1999;48(8):1069–1079.

Geissler PW, Shulman CE, Prince RJ, et al. Geophagy, iron status and anaemia among pregnant women on the coast of Kenya. *Trans. Roy. Soc. Trop. Med. Hyg.* 1998;92(5):549–553. doi:10.1016/S0035-9203(98)90910-5.

Habermann E, Crowell K, Janicki P. Lead and other metals can substitute for Ca2+ in calmodulin. *Archives of Toxicology*. 1983;54(1):61–70. doi:10.1007/BF00277816.

Hamilton S, Rothenberg SJ, Khan FA, Manalo M, Norris KC. Neonatal lead poisoning from maternal pica behavior during pregnancy. *J. Natl. Med. Assoc.* 2001;93(9):317–319.

Hansen AW, Christensen DL, Larsson MW, et al. Dietary patterns, food and macronutrient intakes among adults in three ethnic groups in rural Kenya. *Public Health Nutr.* 2011;14(9):1671–1679. doi:10.1017/S1368980010003782

Kenya Demographic and Health Survey, 2008-2009 (2010). Kenya National Bureau of Statistics.

Lead. *World Health Organization*. 2014

Li PJ, Sheng YZ, Wang QY, Gu LY, Wang YL. Transfer of lead via placenta and breast milk in human. *Biomed. Environ. Sci.* 2000;13(2):85–89.

Lopez L, Soler, C, de Portela, M. Pica during pregnancy:a frequently underestimated problem. *Archivos Latino Americanos de Nutricion*. Mar 2004; 54(1):17-24.

Luoba AI, Geissler PW, Estambale B, et al. Geophagy among pregnant and lactating women in Bondo District, western Kenya. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 2004;98(12):734–741. doi:10.1016/j.trstmh.2004.01.009.

Miller, E. Maternal Hemoglobin Depletion in a Settled Northern Kenyan Pastoral Population. American Journal of Human Biology. 2010;22(6)768-774.

Njiru H, Elchalal U, Paltiel O. Geophagy During Pregnancy in Africa: A Literature Review. *Obstet. Gynecol. Surv.* 2011;66(7):452–459. doi:10.1097/OGX.0b013e318232a034.

Njoroge K. Blood lead levels in Kenya: a case study for children and adolescents in selected areas of Nairobi and Olkalou districts. *United Nations Environment Programe*, 2005.

Prince RJ, Luoba AI, Adhiambo P, Ng'uono J, Geissler PW. Geophagy is common among Luo women in western Kenya. *Trans. Roy. Soc. Trop. Med. Hyg.* 1999;93(5):515–516. doi:10.1016/S0035-9203(99)90355-3.

Young SL, Khalfan SS, Farag TH, et al. Association of Pica with Anemia and Gastrointestinal Distress among Pregnant Women in Zanzibar, Tanzania. *Am. J. Trop. Med. Hyg.* 2010;83(1):144–151. doi:10.4269/ajtmh.2010.09-0442.

Shannon M. Severe lead poisoning in pregnancy. *Ambul. Pediatr.* 2003;3(1):37–39. doi:10.1367/1539-4409(2003)003<0037:SLPIP>2.0.CO;2.

Simons TJB, Pocock G. Lead Enters Bovine Adrenal Medullary Cells Through Calcium Channels. *Journal of Neurochemistry*. 1987;48(2):383–389. doi:10.1111/j.1471-4159.1987.tb04105.x.

Woywodt A, Kiss A. Geophagia: the history of earth-eating. *JR Soc Med*. Mar 2002; 95(3): 143-146.

Young SL, Khalfan SS, Farag TH, et al. Association of Pica with Anemia and Gastrointestinal Distress among Pregnant Women in Zanzibar, Tanzania. *Am. J. Trop. Med. Hyg.* 2010;83(1):144–151. doi:10.4269/ajtmh.2010.09-0442.