ABSTRACT

EXPLORING ASTHMA IN RURAL, WESTERN KENYA

Daniel T. Nassar

Director: Lisa Baker, M.D. Ph.D.

In a pilot study of a convenience sample of eighteen self-identified asthmatic Luo people from the Upper Nyakach Plateau in western Kenya, a cross-sectional study was performed with a sample size of $n = 18$. The purpose of the study was to assess the effect of risk factors on lung function among asthmatics from the Upper Nyakach Plateau. Major predictor variables described the type of dwelling the subject lived in, presence of various animals, and location of cooking fire. The effects of these predictors on lung function were measured using the outcome variable of FEV1/FVC Ratio. Statistically significant protective (higher lung function) results were dirt floors within a dwelling ($r^2 = 0.2380$, $p = 0.04$) and ownership of goats ($r^2 = 0.2651$, $p = 0.0288$). There were no statistically significant negative results for other major predictor variables, but trends of decreased lung function were observed with the ownership of cats, dogs, and chickens. Trends of increased lung function were observed with mud walls, cooking fire located inside of the dwelling, presence of cows or sheep, and keeping animals outdoors only. This pilot study suggests that traditional housing (dirt floors) and ownership of goats were associated with a statistically significant increase in lung function among asthmatic Luo people.

APPROVED BY DIRECTOR OF HONORS THESIS:

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EXPLORING ASTHMA IN RURAL, WESTERN KENYA

A Thesis Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the Requirements for the

Honors Program

By

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PREFACE

This thesis was a collaborative effort between the Kenya Straw to Bread Project, the Kenya Medical Mission Program of Baylor University, and the Luo people of the Upper Nyakach plateau in western Kenya. The data collection took place from May 15-May 29, 2011 in the Upper Nyakach region located at approximately 1660 m of altitude in the Nyando District of Kenya during the annual Straw to Bread visit to the area.

ACKNOWLEDGMENTS

I would like to impart a special thank you to the people of the Upper Nyakach Plateau, Pastor Habil Ogolla, Dr. Lisa Baker, Dr. Troy Abell, those who assisted me in performing home visits to collect data, and Baylor University. This thesis would not have been possible without their efforts.

CHAPTER ONE

Introduction

Background

The term atopy is frequently used to describe an array of related hypersensitivity reactions which include asthma, eczema, and allergic rhinitis. Asthma is a condition that limits airflow by closing the airway through inflammation of the mucus membranes that line them or by contraction of surrounding smooth muscles. Asthma is a common and potentially lethal illness that, according to the World Health Organization (WHO), affects an estimated 235 million people worldwide and spans all age groups, socioeconomic divisions, and ethnicities.

There appears to be an increasing development of asthma in urbanizing regions, though the exact nature of the relationship between urbanization and asthma remains unclear (WHO 2011). While studies have been done to calculate the prevalence of asthma symptoms in some of the main cities and even in some smaller towns in poor countries, the available prevalences provide little information for rural and impoverished areas (Obeng et al. 2008; Yemaneberhan et al. 1997). Although the available evidence indicates some protective benefits of a rural lifestyle, primarily due to desensitization to various allergens, the impact of the disease in these areas may be much greater. Because of the impoverished conditions and lack of available treatment in rural areas of developing countries, it is likely that the asthma that is present results in considerable morbidity and mortality. It is important to begin to identify the particular context of asthma in poor, rural settings and to learn about the relative significance of environmental triggers as a basis for disseminating knowledge and guiding health intervention strategies.

In developed countries, asthma is usually controlled with beta-agonist and anti-inflammatory medications and reduction of environmental triggers in the household or workplace. However, in developing and underdeveloped countries such as those in sub-Saharan Africa, asthma is a more serious threat because these life-saving medications are not available to most asthmatics. Thus, it is even more important to learn more about the contribution of environmental influences that can be modified in rural areas of poor countries.

There are two general categories for factors that influence asthma: genetic and environmental. Though the prevalence of genetic factors for being predisposed or being less inclined to develop asthma is unknown in rural, developing countries, the effect of a family history of atopy at the very least is a variable that should be explored.

Although the disease process is not entirely understood, much research has been done on what triggers asthma. Animal dander, fungi, cockroaches, and other airborne particulates are all documented potential triggers for asthma and will be present in rural areas in different proportions and contexts than in urban settings. Similarly, known and suspected protective agents such as proper nutrition, early desensitization, and longer breastfeeding may also be assumed to be in effect in rural environments, but these factors may combine in different ways than they do in urban homes.

The Need

The prevalences of wheezing and severe asthma symptoms provided by the International Study of Asthma and Allergies in Childhood (ISAAC) Phase III study were for the cities Eldoret and Nairobi. The prevalences of wheezing (13.8% and 18.0%) and severe asthma symptoms (4.0% and 5.5%) for each city, respectively, give an idea of the occurrence of these conditions for two urban locales in Kenya (Ait-Kahled et al. 2007). The prevalence of asthma for rural, impoverished communities in Kenya is largely absent from the literature. Due to the lack of basic medical care in many of these communities, asthma may be underdiagnosed, undiagnosed completely and untreated for many who are afflicted. Compounding matters, the substandard pollution control, widespread poverty and malnutrition, and unsanitary living conditions common in underdeveloped countries are risk factors that are likely to be problematic for those suffering from asthma and for their general health.

Most of the Luo people on the Nyakach plateau in western Kenya live a traditional, tribal life of subsistence farming and animal herding. Very few people have jobs of any kind, and poverty is extreme. Though there are some who live in a home of mud bricks and a concrete floor, many people still live in mud huts with thatched roofs and dirt floors, and they may cook indoors over an open wood fire with little ventilation. They keep cattle, goats, sheep, and chickens in addition to dogs and cats. It is not uncommon for these animals to wander in and out of the house and even to sleep indoors. Often the houses are one room with a small sleeping area partitioned off by a curtain. Multiple family members live and sleep in this small space, so infectious disease easily spreads. This constellation of environmental triggers makes it hard to imagine how anyone could breathe well, and it creates a particularly difficult atmosphere for people with asthma.

Purpose and Plan

The goal of this study was to pilot the methodology for a later study in which environmental triggers for a sample of self-identified asthmatic adults in rural Kenya are described and correlated with lung function. Spirometry was employed to give a quantitative measure of lung function in addition to the patient's reported medical history. Environmental triggers were identified by an observer/interviewer during a visit to the patient's home the same day.

The factors that were measured during home visits included the characteristics of a dwelling (floor, roof, and wall type), the presence of specific animals, the location of animals (indoors and out-of-doors), the location of the cooking fire, number of people living in the dwelling, the occupation of the subject, as well as information on how they were physically feeling that day, how their breathing was that day, and how generally healthy they were. Creating this pilot database was essential to begin to understand the key players in a very enigmatic game. Because the community consists of small villages whose residents have little formal education and virtually no health education, understanding more about the effects of asthma triggers will allow for knowledge to be disseminated to the people through village elders and other efforts. Additionally, due to the lack of regular medical care in the area, there is a great need for additional practical medical knowledge. The information gathered in this study will form the basis for a larger study of the same variables in the future with the goal of aiding those suffering from asthma and preventing additional cases from worsening.

Final Thoughts

A growing focus on healthcare in impoverished rural communities is necessary in a world concerned with health on a global scale. Learning about the intimate household environment of people and the way their communities operate is essential in developing a strategy for asthma prevention and relief. The intent of this study is to participate in such a learning experience with the Luo people from the Upper Nyakach in western Kenya. This venture was undertaken with the intent of discovering how to mitigate the effects of asthma within the community in a way that is culturally and economically feasible for its people. The study was designed to couple quantitative clinical data with a survey of asthma triggers present in Luo households in order to create a picture of the environmental and physiological interactions taking place. The conclusions of this study will be used to understand the epidemiology of asthma in this area of sub-Saharan Africa and to guide future asthma prevention and treatment plans. It is hoped that the information gained from this community-based research can be generalized to other rural, impoverished areas of poor countries, particularly those in sub-Saharan Africa. However, in the end, the most important aspect of this study is that it was conducted for the people of the Upper Nyakach and will be used to allow them to have a better quality of life.

CHAPTER TWO

Review of Literature

Background

Asthma is a respiratory disease that affects all age groups, genders, and ethnicities on a global scale. It is a restrictive and obstructive pulmonary hypersensitivity disease that presents clinically as wheezing, chest tightness, shortness of breath, and coughing (usually at night or in the morning). According to the WHO asthma fact sheet, the highest mortality rates for asthma occur in low and lower-middle income countries (WHO 2011). The prevalence of asthma has been increasing by 50% every ten years (Braman 2010). Disability-adjusted life years (DALYs) are sometimes used to assess the burden of a disease based on factors such as severity of illness, age of onset, age at which death may occur from the disease, and the duration of the illness (Murray 1994). The DALYs lost for asthma are similar to other chronic diseases such as diabetes, schizophrenia, and liver cirrhosis (Bousquet 2005). According to a study published in the American Journal of Industrial Medicine that described the worldwide mortality and morbidity from asthma, chronic obstructive pulmonary disease (COPD), and pneumoconiosis, asthma was estimated to account for 38,000 deaths and over 1.6 million DALYs in the year 2000 (Driscoll 2005).

Prevalence

The prevalence of asthma in developing countries such as Kenya, Ethiopia, Cameroon, and Nigeria in Africa has consistently increased over the past 7-10 years (Obeng et al. 2008). Furthermore, asthma is occurring much more frequently in urban areas as opposed to rural subsistence areas. A 1997 case control study conducted in Ethiopia compared the odds ratios accompanying rural versus urban dwellers, after adjusting for age and gender. The design compared 9844 people from the urban city Jimma against a combined population of 3032 from rural areas. The resulting odds ratios comparing rural against urban lifestyles were as follows: 0.31 (95% CI 0.22–0.43; $p < 0.0001$) for wheeze, 0.35 (0.25–0.49; $p < 0.0001$) for asthma, and 0.48 (0.32–0.73; $p = 0.0006$) for cough (Yemaneberhan et al.1997). Although this data shows that living in a rural community appears to be largely protective, there may be an increase in asthma in these less affected communities as communities grow and develop more "urban" practices. On the contrary, when rural areas are impoverished and do not hold sustainable practices, asthma can become a problem, potentially, due to the stress induced by a life of poverty (Apter 2011).

The prevalence of asthma and asthma-related symptoms among young Africans in two Kenyan cities can be estimated from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase III documentation (Ait-Kahled et al. 2007). ISAAC presented the current symptoms of asthma related diseases, via questionnaires, in those subjects between the ages of 13-14 year olds. The primary outcome of interest for this study was baseline prevalences recordings for the Kenyan towns of Eldoret and Nairobi, as these towns were closest to the proposed study area, although both cities are large urban centers and therefore may not be directly compared to the rural Upper Nyakach. The study gathered data from 72 and 15 schools, with 3289 and 3023 respondents from Eldoret and Nairobi, respectively. The towns featured a moderate prevalence of wheezing (13.8% and 18.0%) and relatively high severe asthmatic symptoms (4.0% and 5.5%). A further breakdown of the asthma symptoms observed was provided based on a video questionnaire. Severity and frequency of wheezing, such as “Wheezing (while at rest)” – “Ever”/ “In the last year,” etc., were recorded for the centers that facilitated the video questionnaire.

Anatomy and Physiology

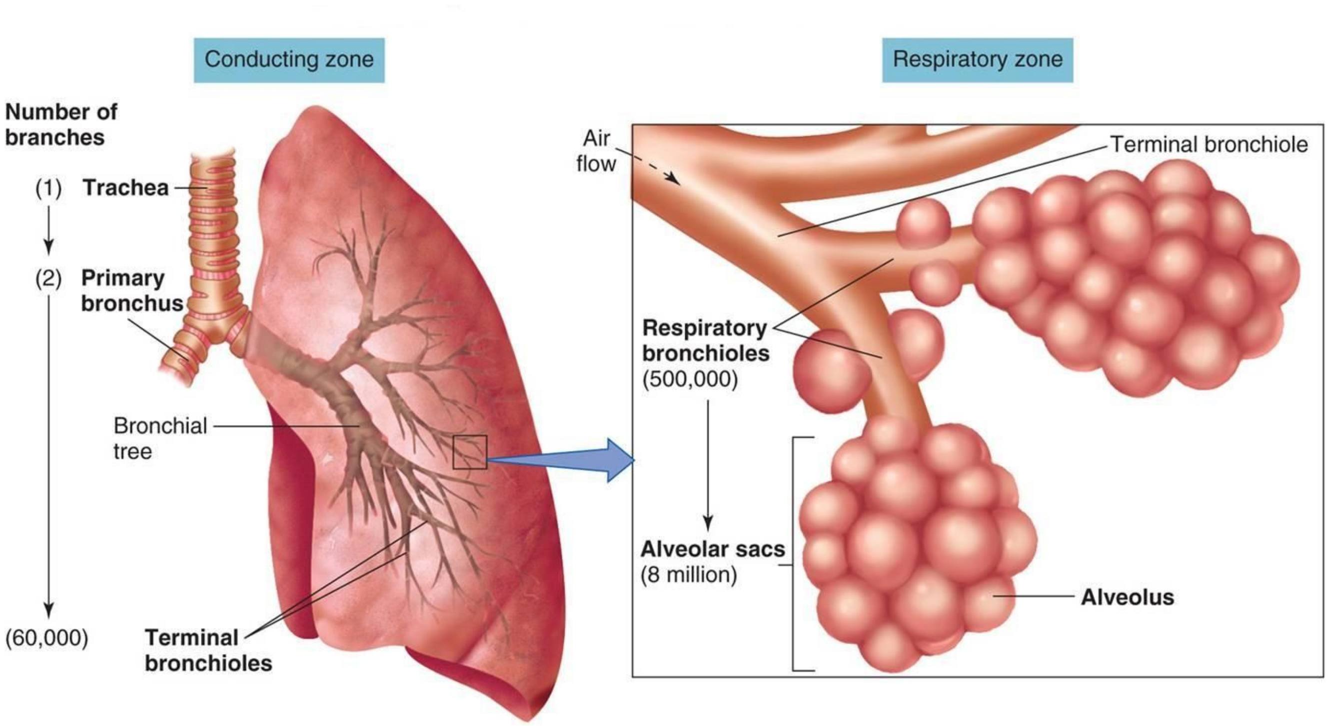


Figure 1 - Anatomy of conducting and respiratory zones of the lungs. (HumanPhysiology2011)

Within the lungs, the anatomy and physiology of the conducting zones provide an important fundament to understanding how asthma works. The small airways prior to the alveoli in the lungs, the small bronchi and bronchioles, are the segments of the lungs that are directly affected and produce the symptoms of asthma (Crowley 2007). These airways are encased in smooth muscle controlled by $ß_2$ adrenergic receptors and are supplied by extensive capillary beds. Distention of the airway vasculature may influence mucosal thickness both through the additional space occupied by the distended vessels and through edema formation. Edema in the mucosa accompanies the exudate formation that is characteristic of asthma, but more work may be needed to quantitate the relationship (Widdicombe 1992). The presence of epinephrine (a.k.a. adrenaline) in the blood causes the smooth muscle enclosing the conducting zones to relax, widening the small bronchi and bronchioles and thereby increasing airflow to the respiratory zones. This physiological function is part of the sympathetic nervous system ("fight or flight" response) which would operate to augment airflow as needed in an "emergency" situation.

Pathophysiology

Asthma is clinically defined as:

"a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role. The chronic inflammation causes an associated increase in airway hyper-responsiveness that leads to recurrent episodes of wheezing, breathlessness, chest tightness and coughing, particularly at night or in the early morning. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment" (Masoli et al. 2004).

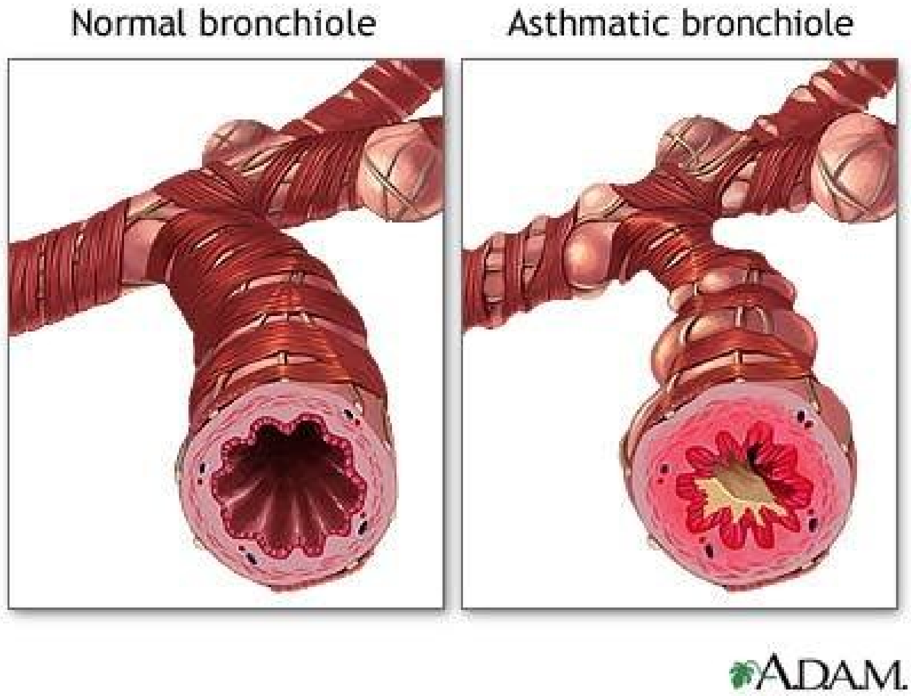


Figure 2 - Depiction of a normal bronchiole and an asthmatic bronchiole that displays both the obstructive (inflammation) and restrictive (muscle contraction) aspects of asthma. When these effects occur in conjunction, they greatly reduce a person's ability to ventilate and lower lung volume. (MedlinePlus)

The symptoms of asthma are caused by obstruction of bronchioles due to inflammation of the airway lining and restriction of the airway space by the contraction of smooth muscles that surround the bronchioles, as seen in **Figure 2**. Clinical treatment of these symptoms comes in two forms due to the double-pronged nature of the pathophysiology. The reduction of airflow caused by muscle contraction is treated with fast-acting, short-term $ß_2$ receptor agonists. Medications such as albuterol (salbutamol) activate the $ß_2$ receptors specific to the smooth muscle of the lungs around the bronchi and cause the muscles to relax, thereby reducing the restrictive effects of asthma (Crowley 2007). As powerful and quick as the effects of these medications are, non-specific ß agonists such as $ß_2$ agonists offer no relief for the inflammation within airways which cause the obstructive effects of the disease. In order to treat the obstructive component of asthma, anti-inflammatory drugs such as corticosteroids are needed to reduce mucosal inflammation over time. Long-term steroid use can cause immunosuppression and, because of this side-effect, steroid use must be limited. Steroids used to treat the obstructive aspect of asthma do not act quickly enough to be effective in emergency situations, leaving emergency asthma relief to bronchodilators containing albuterol, but they are the mainstay of prevention in regions where they are available. Asthma is a chronic disease that can be exacerbated by the presence of certain substances, called triggers, which irritate the lungs and cause hypersensitivity reactions.

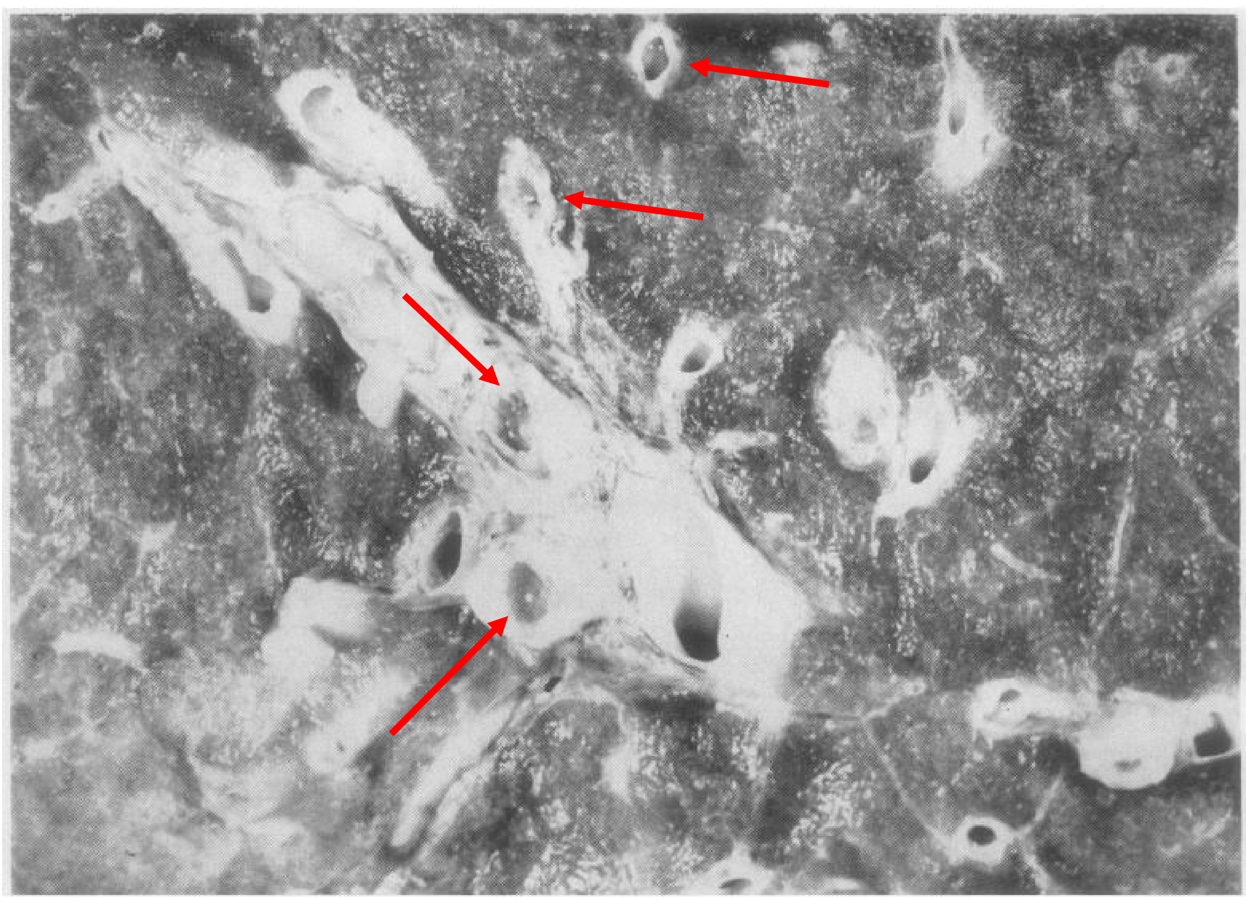


Figure 3 - A cross-section of an asthmatic lung. This person died from her asthma due to the mucus plugs (indicated by the arrows) that formed in the small bronchioles.

Death in asthma can occur due to severe, acute smooth muscle constriction around the airway, or it can occur due to the obstructive effects of the disease, ultimately caused by the formation of a mucus plug (see **Figure 3**) that occludes the airway lumens in the lung. Mucus plugs form when epithelium becomes detached from the bronchial mucosa and mixes with mucus and eosinophils. The interaction of these two mechanisms is seen in that the separation of bronchial epithelium occurs due to mechanical separation caused by spasms in the smooth muscle surrounding bronchi and bronchioles (Barnes et al. 1998). The lung section in **Fig. 3** was taken from a 24 year old female with a family history of asthma who died from her asthma after 21 years of being afflicted with the disease.

Protective Factors

Nutritional:

Proper nutrition may protect against asthma. In a meta-analysis of 62 eligible reports from 11 systematically searched databases, a tentative protective relationship was found for the consumption of vitamins A, D, and E; zinc; and fruits and vegetables (Nurmatov 2011). Related to nutrition, childhood and juvenile asthma were reported to be influenced by the amount of time a child spent breastfeeding. In a prospective cohort study, 150 infants were followed from their first year of life through the age of 17 with checkpoints at three, five, ten and 17 years of age. The study analyzed the amount of atopy found within and between the different categories of breastfeeding time (prolonged (>6 months), intermediate (1-6 months), and short or no (<1 month) breastfeeding). The conclusion was made that breastfeeding protected against atopic disease, including respiratory allergies (Saarinen 1995). This conclusion suggests that there may be beneficial effects from breastfeeding for preventing asthma.

In rural Kenya there is a preponderance of malnutrition and food insecurity, but mothers almost exclusively breastfeed their infants. Because birth intervals are short among impoverished communities with high infant mortality, the length of breastfeeding may not provide a benefit as large as it would in groups with wider birth spacing.

Environmental:

Though animal, plant, and inorganic environmental triggers are known to exacerbate asthma, there is also evidence that exposure to some early endotoxin exposure may actually protect against atopy. A study of differences in the development of atopy among 84 farming and non-farming families in Southern Germany and Switzerland (von Mutius 2000) investigated using the non-farming families as control groups for level of endotoxin exposure. Endotoxins are integral parts of the cell wall of Gram-negative bacteria and are can be found in high quantity where livestock and poultry are present. The results of the study in Southern Germany and Switzerland suggested that desensitization due to early endotoxin exposure may play a role in the development of atopic diseases among children (von Mutius 2000). Several other studies investigating endotoxin exposure more in depth, however, suggest that while early endotoxin exposure may protect against atopic diseases such as eczema, the same protective relationship may not exist for asthma (more information in the Risk Factors section). In a prospective cohort study involving 1884 term and normal-weight neonates, the level of endotoxin exposure from house dust in the mothers' and children's mattresses at neonate age of three months was measured. The neonates were followed from three months to one year of age. At six months, the risk for atopic eczema in the poorest families was significantly reduced (OR = 0.50; 95% CI, 0.28-0.88), whereas the risk of respiratory infections (OR = 1.69; 95% CI, 1.25-2.28), and cough with respiratory infection, bronchitis, or both (OR = 1.73; 95% CI, 1.28-2.33) increased. Most importantly, the risk of wheeze associated with early endotoxin exposure at six months was significantly increased (OR = 2.37; 95% CI, 1.40-4.03). Unlike the risk of the other respiratory illnesses with decreased by the end of the first year or life, the risk of wheezing remained elevated (OR = 1.60; 95% CI, 1.10-2.30) (Gehring et al. 2001). This finding concerning endotoxins may be important in mitigating the overwhelming exposure of rural Kenyans to environmental triggers. Although early endotoxin exposure may play a protective role in the development of some atopic diseases, it is unclear whether the desensitization offered by a rural, agricultural lifestyle outweighs the negative effects of exposure to other allergens and irritants such as animal dander, dust mites, and wood fire exhaust.

Risk Factors

Environmental:

Environmental risk factors in sub-Saharan Africa include: exposure to Kikuyu grass, Makaore cherry, Tanganyika anigré, and Der néré (local flora), as well as helminthic infection by *Trichuris*, S*chistosoma, Ascaris*, and hookworm. Other household risk factors may include house dust mites, cockroaches, and cat and dog dander. Washing soap presents a lesser known, yet plausible, allergen. Along with these potential allergens, pesticides and insecticides, wood or kerosene heating, grass mats, mud and cow dung, smoking, diesel exhaust, and malnutrition are also risk factors (Wjst 2007). Factors such as wood fire exhaust, animal feces, and malnutrition are common in rural lifestyles of impoverished communities, such as the community of interest in this study.

Occupational:

The occupational risk factors for asthma include isocyanate, latex sensitivity, and working as professional poultry workers, hairdressers, gold miners, and wood choppers (Wjst 2007). Annual rainfall may also have an effect on asthma by facilitating an increase in the production of fungal spores, which add a cumulative burden to those employed outdoors (Gargouri 2010). Organic factors that were found to trigger the disease by a study on occupational asthma were flour/grain, wood dust, and fungi/mold (Health and Safety Executive 2009).

Other Risk Factors:

Risk factors such as parental history, female gender, low physical activity, have also been shown to be associated with asthma.

Use of Spirometry

Not only is there a need for more information about triggers, protective factors and risk factors for asthma, but also there is a need to document precisely the presence and degree of compromised lung function. Quantitative measures of lung function (spirometric measures) among a rural community in central or east Africa were found in only two studies. The first was a comparison between rural and urban children in Kenya, and a school in Atlanta, Georgia of similar age. The rural, farming community in the study was just 343 km from the Nyakach region. In this study, subject's previous asthma symptoms were noted and pre- and post-exercise spirometry measurements were taken. The results of this study found that the percent predicted of FEV1 for the rural community was slightly lower than that of the urban school, but both African schools had higher values of percent predicted FEV1 that the school in Atlanta (Perzanowski et al. 2002). The second study took place in the Huye District of Rwanda and was conducted at a university hospital (Musafiri et al. 2011). This study found that of the 1920 participants (age 15-80): 12.5 % reported episodes of wheezing, 14% were classified as having airflow obstruction based on FEV1/FVC Ratio less than the lower limit of normality defined by the American Thoracic Society (ATS), and diagnosed asthma in 8.9 % of individuals (Musafiri et al. 2011). There were no cases found in the literature of spirometry that was conducted in a rural community with such an extremely high level of poverty as the Upper Nyakach plateau in Kenya.

Summary

In summation, as the extensive list of risk factors and potential protective variables increases, no overall hypothesis for asthma causation has been developed. This is especially true for the understudied rural, impoverished regions of Africa. Asthma in these communities may be influenced in a complex way by the largely over-arching effects that poverty imposes upon the human body in conjunction with a rural lifestyle.

In addition to the paucity of knowledge about asthma in rural developing countries, little is known about the effects of environmental triggers on the lung function of asthmatics in such communities. Through producing conclusions on the effect of environmental triggers on lung function in impoverished, rural African households, this study intended to contribute new information to the scientific community as well as provide data to guide community-based health interventions.

CHAPTER THREE

Hypothesis

Research Question

"Which environmental factors have the most influence on the lung function of individuals with asthma in rural Western Kenya?"

With the general objectives of investigating the influence of environmental irritants on lung function in rural Western Kenya, this study proposes to record the environmental factors present in households (type of floor, type of walls, location of cooking fire, and the presence of animals) and evaluate the effects of these potential household irritants in relation to lung function. The analyses will test various hypotheses that irritants have varying effects on lung function as noted in the hypotheses below.

For all major hypotheses, the outcome variable FEV1/FVC Ratio (RATIO) will be used to asses lung function.

Major Hypotheses

Hypothesis 1: The lung function of asthmatics living in dwellings with dirt or clay-coated dirt floors will be lower than the lung function of asthmatics living in dwellings with concrete floors.

Hypothesis 2: The lung function of asthmatics living in dwellings with mud or clay-coated mud walls will be lower than the lung function of asthmatics living in dwellings with brick or concrete walls.

Hypothesis 3: The lung function of asthmatics living a household with a cooking fire inside the dwelling will be lower than the lung function of asthmatics living a household with a cooking fire located in a separate building or outside of the dwelling.

Hypothesis 4: The lung function of asthmatics living a household that includes the presence of cats will be lower than the lung function of asthmatics living in a household that does not have cats.

Hypothesis 5: The lung function of asthmatics living a household that includes the presence of dogs will be lower than the lung function of asthmatics living in a household that does not have dogs.

Hypothesis 6: The lung function of asthmatics living a household that includes the presence of cows will be lower than the lung function of asthmatics living in a household that does not have cows.

Hypothesis 7: The lung function of asthmatics living a household that includes the presence of goats will be lower than the lung function of asthmatics living in a household that does not have goats.

Hypothesis 8: The lung function of asthmatics living a household that includes the presence of sheep will be lower than the lung function of asthmatics living in a household that does not have sheep.

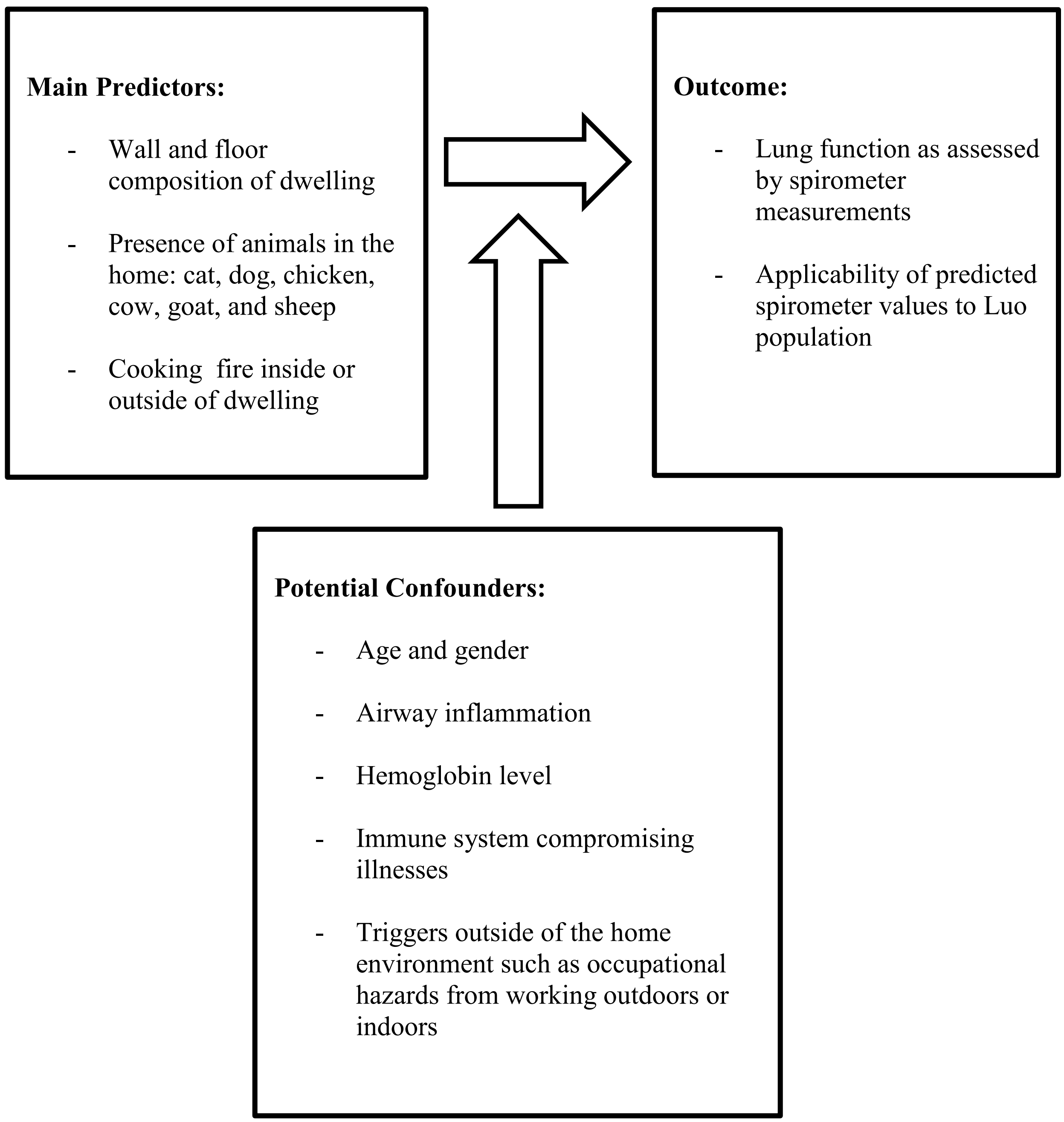
Hypothesis 9: The lung function of asthmatics living a household that includes the presence of chickens will be lower than the lung function of asthmatics living in a household that does not have chickens.

Hypothesis 10: The lung function of asthmatics living a household that reported animals living both inside and outside the dwelling will be lower than the lung function of asthmatics living in a household that reported animals living outdoors only.

Hypothesis 11: Working under the assumption that the National Health and Nutrition Examination Survey (NHANES) III spirometric predictions for African Americans are applicable to Luo people from the Upper Nyakach Plateau in Western Kenya, a high positive correlation will be observed between individual lung function measurements (FEV1, FVC, Ratio) and the percent of predicted values (FEV1%, FVC%, Ratio%) for each measurement.

In the schematic representation below, the exposure variables, potential confounders, and outcome variable are displayed.

Schematic Representation of Hypothesis



CHAPTER FOUR

Methods

The study was performed on a convenience sample of Luo people from the Upper Nyakach Plateau who: a.) had been clinically identified to have asthma, b.) were indicated as asthmatics by a local informant, or c.) had a history of asthma. Approval from Baylor University's Institutional Review Board was received for the study design and questionnaire form prior to data collection. Using additional clinical data from the 2011 clinic (15-29 May), a cross-sectional study was performed. Because this was a study of asthma, individuals who were not classified as being asthmatic were excluded from the study. Exclusions also were made for persons under the age of seven due to difficulty in collecting spirometer data with young children. Asthma was classified using physician diagnosis from the 2011 clinic data, which included spirometer measurements, as well as a previous diagnosis of asthma which was recorded at the time of patient intake.

All subjects were visited in their homes or surveyed in the clinic and asked to fill out the Asthma Health and Home Environment Data sheet with the assistance of a translator, when needed. Upon arriving at the house of a subject, the researcher noted the presence of potential triggers. In general, the notation "0" was used to indicate absence and "1" to indicate presence of a trigger for applicable fields. For example, if animals were not observed then the value "0" was ascribed in order to indicate the absence of a potential trigger. A list of the variables and their respective values is included below (see Appendix B). Variables included: age and gender of the subject; composition of a dwelling's walls (mud, brick, metal); roof type (thatched, metal, tile); location of the cooking fire for a dwelling (inside or outside); number of individuals living in the home; location of the household's source of water; location where the subject sleeps (bare dirt floor, dirt floor with blanket, concrete floor, bed); presence of animals (none, outdoor only, indoor/outdoor); and the occupational environment of the individual if applicable. Other notes were made regarding the patient's general health, how the patient was feeling on the day of his or her visit, chronic and current diseases, and how his or her breathing was on that day. Hemoglobin and CRP levels had been recorded for clinical purposes.

ASTHMA HEALTH AND HOME ENVIRONMENT DATA

Patient ID #: ___________________

Clinic Patient? (circle one) 0=No 1=Yes in 2010 2=Yes in 2011

<table>
<tr><td>Age:</td><td>Roof:
1= thatched
2=metal
3=tile</td><td rowspan="2"># people living in home:</td><td rowspan="2">Cooking fire:
1=inside
2=outside</td></tr>
<tr><td>Gender :
0 =male
1=female)</td><td>Wall:
1=-mud
2=brick
3=metal</td></tr>
<tr><td colspan="2">Floor/Sleeping:
0=Bare dirt floor
1=Dirt floor with blanket
2-Concrete floor
3-Bed</td><td colspan="2">Main water source:</td></tr>
<tr><td colspan="4">Animals: (specify)
0=none
1 = outdoor only
What animals?
2 = indoor/outdoor
What animals?</td></tr>
<tr><td>Job?
If so, what kind of environment?
0=no job
1=works outdoors
2=mud bldg
3=brick bldg
4=other (specify):</td><td colspan="3">How many hours a week?
______________________</td></tr>
</table>

HEALTH DATA		
Chronic diseases:		
Current symptoms of any kind? (list) **Pregnant? (circle)** 0=No 1=Yes		
In general, how are you feeling physically today? 1--Very good 2—Good 3—Fair 4--Poor 5--Very Bad	**Specifically, how is your breathing today?** 1—Very good 2—Good 3—Fair 4—Poor 5—Very Bad	**How would you describe your health in general?** 1—Very good 2—Good 3—Fair 4—Poor 5—Very bad
Lab results: Hemoglobin: ________________ CRP: ________________		

The primary measurements used to detect lung disease were a reduced forced expiratory volume in 1 second to forced vital capacity ratio (FEV1/FVC %; variable name "RATIO"). The CardiacDirect CardioTech GT-105 Spirometer (Ventura, CA) with flow sensor detection and built-in thermal printer was used in the clinic to gather respiratory data. The spirometer measured: a.) forced vital capacity (FVC) in liters, b.) forced expiratory volume in 1 second (FEV1) in liters per second, c.) forced expiratory volume in 6 seconds (FEV6) in *L/s*, and d.) ratio of FEV1 to FVC (FEV1/FVC) in percent form. Predicted values for FEV1, FVC, and FEV1/FVC were automatically calculated using NHANES III predictions for African Americans parameters that were built in to the spirometer software. Patients were instructed to breathe in as deeply as possible and to exhale as quickly, fully, and forcefully as possible while in a standing position without the use of a nose clip. A minimum of three trials were performed in order to obtain a "best" measurement (highest value of FEV1/FVC Ratio). This best trial was saved, printed, and later used in the clinic as well as for all data analysis. An unopened, pre-packaged disposable mouthpiece was used for each new subject and all used mouthpieces were discarded. All instructions on how to properly perform the maneuver were given through a translator in the local Luo language.

All data were entered into a Microsoft Office Excel 2010 (Redmond, Washington) spreadsheet upon returning to the United States. Statistical analysis was performed using SAS 9.2 (Cary, NC). Variables were imported into SAS 9.2 and univariate frequency procedures were used to observe age range, gender frequencies, as well as frequencies for various predictor variables. Analysis of Variance (ANOVA) was performed on the major predictor variables for wall and floor type, number of cats, dogs, chickens, cows, goats, and sheep, and location of cooking fire using RATIO as the dependent variable. In the ANOVA procedure, a dichotomous variable for each animal was used to indicate presence (e.g. cat = 1) or absence (cat = 0) of each animal. Multivariate analysis also was performed using multiple regression to assess the potential modification and confounding of various factors. Potential confounders used in this analysis were airway inflammation (presence of allergic rhinitis, bronchitis, pneumonia, pharyngitis, sinusitis, tonsillitis, or upper respiratory infection), additional occupational exposure, age, gender, and hemoglobin level – as measured by an Abbott i-STAT Portable Handheld (Abbott Park, Illinois).

A correlation procedure using spirometer measurements and their predicted values (FEV1, FEV1 %; FVC, FVC %; etc.) was performed in order to observe the effectiveness and applicability of the NHANES III predictions for African Americans within the sample population. For all statistical analyses, alpha was set at 0.05.

CHAPTER FIVE

Results

After exclusions, the resultant sample size was *n* = 18 for subjects having complete clinical data, questionnaire information, and spirometer measurements. **Table 1** is a case table that displays pertinent information on all study participants.

Univariate Analysis

Personal and Home Environment:

The age of participants ranged from thirteen (13) to 65 with an average age of 32 years. There were six (6) male and twelve (12) female subjects. The average height and weight was 175.9 centimeters and 60.9 kilograms for males and 161.6 *cm* and 59 *kg* for females. The number of people living in each house ranged from two (2) to fourteen (14) with an average of seven (7) people per household. Five (5) of the subjects had their cooking fire outside of the house and the remaining thirteen (13) cooked inside of their house. All subjects had sheet metal roofs on their house, six (6) had dirt or clay-coated dirt floors, while the remaining twelve (12) had concrete flooring. Six (6) subjects had mud or clay-coated mud walls and twelve (12) had brick or concrete walled homes. Only one subject reported sleeping on the floor and the remaining seventeen (17) subjects reported sleeping on a bed. One (1) subject had no animals, two (2) subjects had animals that stayed outdoors only, and the remaining fourteen (14) subjects had animals inside and outside of their home.

Spirometry:

The average FEV1 was 1.93 *L/s* and the average FVC was 2.53 *L*. The average FEV1/FVC Ratio was 76.09%. Average percent of predicted values were 82.21%, 91.83%, and 89.88% for FEV1, FVC, and FEV1/FVC Ratio, respectively.

Table 1 - Displays age, gender, major predictors, outcome measurement, and reported chronic illnesses for all subjects. The rows with dashed borders indicate subjects who lived in the same dwelling.

Case	Age	Gender	Large Animals	Small Animals	Cooking	House	FEV1 /FVC	Chronic Illness
1	28	Male	1 cow	1 dog, 4 chickens	Inside	Dirt floor and clay coated mud walls	68.86	None
2	65	Female	1 cow, 2 goats	1 cat, 1 dog,	Separate Building	Dirt floor and mud walls	79.13	Hypertension, Vision impairment
3	15	Female	1 cow	1 dog, 1 chicken	Inside	Concrete floor and brick wall	81.52	Malaria
4	23	Female	None	None	Separate Building	**(Dorm room)** Concrete floor and walls	79.15	Prior malaria
5	30	Male	7 cows, 3 goats	1 cat, 2 dogs	Separate Building	Concrete floor and walls	83.20	Farsighted and reduced hearing
6	15	Male	2 cows	1 cat, 1 dog, 2 chickens	Inside	Dirt floor and mud walls	68.17	None
7	33	Female	2 sheep	1 cat, 1 dog, 1 chicken	Outside	Dirt floor and mud walls	71.48	None
8	21	Male	1 cow, 1 goat, 1 sheep	1 dog, 1 chicken	Inside	Concrete floor and brick walls	90.03	Ear infection and vision difficulties
9	60	Female	2 cows	1 cat, 2 dogs, 2 chickens	Outside	Concrete floor and Brick walls	72.36	Hypertension
10	23	Female	2 cows, 1 goat, 1 sheep	None	Inside	Dirt floor and clay-coated mud walls	73.77	None
11	13	Female	1 cow	1 cat	Inside	Dirt floor and clay-coated mud walls	82.31	None
12	31	Female	1 cow	1 cat	Inside	Dirt floor and clay-coated mud walls	80.15	Ulcer
13	44	Female	2 cows, 4 goats	1 cat, 1 dog, 3 chickens	Inside	Concrete floor and brick walls	87.84	None
14	17	Female	4 sheep	1 cat, 4 chickens	Inside	Dirt floor and mud walls	85.04	None
15	26	Male	1 goat, 1 sheep	1 cat, 1 dog, 4 chickens	Inside	Clay-coated dirt floor and clay-coated mud walls	82.21	Eye problems and rashes
16	52	Female	None	1 cat, 4 chickens	Inside	Dirt floor and clay-coated mud walls	58.52	**HIV**
17	39	Female	2 cows	2 cats, 2 dogs, 2 chickens	Outside	Concrete floor and brick walls	57.09	Back pain
18	32	Female	None	1 cat, 1 dog, 15 chickens	Inside	Dirt floor and clay-coated mud walls	68.75	None

Bivariate Analysis

The relationships between the hypothesized exposures and lung function were explored using analysis of variance (ANOVA) and displayed in **Tables 2-12**. The shading of the Effect on Lung Function (FEV1/FVC) column in **Table 13** (summary table) will be explained in relation to each variable in the discussion.

Table 2 - Association of lung function (FEV1/FVC Ratio) and dwelling floor type based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Floor	Dirt floors: $\bar{x}$ = 82.35 sd = 6.33 n = 6	Concrete floors: $\bar{x}$ = 72.96 sd = 9.19 n = 12	5.00	0.0400	0.2380

Table 3 - Association of lung function (FEV1/FVC Ratio) and dwelling wall type based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Wall	Mud walls: $\bar{x}$ = 78.67 sd = 12.23 n = 6	Concrete/Brick walls: $\bar{x}$ = 74.80 sd = 7.84 n = 12	0.68	0.4228	0.0406

Table 4 - Association of lung function (FEV1/FVC Ratio) and location of cooking fire of household based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Cooking Location	Outside: $\bar{x}$ = 72.65 sd = 9.96 n = 5	Inside: $\bar{x}$ = 77.41 sd = 9.15 n = 13	0.93	0.3484	0.0551

Table 5 - Association of lung function (FEV1/FVC Ratio) and presence of cats based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Cat	Cats: $\bar{x}$ = 75.10 sd = 9.91 n = 13	No Cats: $\bar{x}$ = 78.67 sd = 8.03 n = 5	0.51	0.4844	0.0310

Table 6 - Association of lung function (FEV1/FVC Ratio) and presence of dogs based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Dog	Dogs: $\bar{x}$ = 75.89 sd = 9.65 n = 12	No Dogs: $\bar{x}$ = 76.49 sd = 9.57 n = 6	0.02	0.9018	0.0010

Table 7 - Association of lung function (FEV1/FVC Ratio) and presence of chickens based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Chicken	Chickens: $\bar{x}$ = 74.32 sd = 10.94 n = 12	No Chickens: $\bar{x}$ = 79.62 sd = 3.32 n = 6	1.31	0.2693	0.0756

Table 8 - Association of lung function (FEV1/FVC Ratio) and presence of cows based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Cow	Cows: $\bar{x}$ = 77.04 sd = 9.35 n = 12	No Cows: $\bar{x}$ = 74.19 sd = 9.89 n = 6	0.36	0.5586	0.0218

Table 9 - Association of lung function (FEV1/FVC Ratio) and presence of goats based on ANOVA.

Variable	Means		*F*	*p*	Adjusted r^2
Goat	Goats: $\bar{x}$ = 82.70 sd = 5.88 n = 6	No Goats: $\bar{x}$ = 72.78 sd = 9.13 n = 12	5.77	0.0288	0.2651

Table 10 - Association of lung function (FEV1/FVC Ratio) and presence of sheep based on ANOVA.

Variable	Means		F	p	Adjusted r^2
Sheep	Sheep: $\bar{x}$ = 80.51 sd = 7.76 n = 5	No Sheep: $\bar{x}$ =74.39 sd = 9.60 n = 13	1.60	0.2234	0.0911

Table 11 - Association of lung function (FEV1/FVC Ratio) and the location of animals based on ANOVA.

Variable	Means		F	p	Adjusted r^2
Location of Animals	Inside and Outside: $\bar{x}$ = 74.59 sd = 9.32 n = 15	None or Outside only: $\bar{x}$ = 83.57 sd = 5.72 n = 3	2.51	0.1324	0.1360

Table 12 - Association of lung function (FEV1/FVC Ratio) and the type of job held by the subject based on ANOVA.

Variable	Means			F	p	Adjusted r^2
Job	Outdoor Job: $\bar{x}$ = 84.58 sd = 7.71 n = 2	Indoor Job: $\bar{x}$ = 74.12 sd = 10.25 n = 6	No Job: $\bar{x}$ = 75.57 sd = 9.00 n = 10	0.97	0.410	0.1147

Table 13 - A summary of the major predictor variables are shown with r^2 and p-values. Statistically significant results are indicated by the double line border. Red fill cells indicate a decrease in lung function and green fill cells indicate an increase in lung function with the respective variable.

Variable	*F*	*p*	Adjusted r^2	Effect on Lung Function (FEV1/FVC)
Floor	5.00	0.0400	0.2380	Dirt or clay-coated dirt floors were associated with a ~10% increase
Wall	0.68	0.4228	0.0406	Mud or clay-coated mud walls were associated with a ~4% increase
Cooking	0.93	0.3484	0.0551	Cooking fires inside were associated with a ~5% increase
Cat (Yes/No)	0.51	0.4844	0.0310	Presence of cats was associated with a ~3% decrease
Dog (Y/N)	0.02	0.9018	0.0010	Presence of dogs was associated with a <1% decrease
Chicken (Y/N)	1.31	0.2693	0.0756	Presence of chickens was associated with a ~5% decrease
Cow (Y/N)	0.36	0.5586	0.0218	Presence of cows was associated with a ~3% increase
Goat (Y/N)	5.77	0.0288	0.2651	Presence of goats was associated with a ~10% increase
Sheep (Y/N)	1.60	0.2234	0.0911	Presence of sheep was associated with a ~6% increase
Location of Animals	2.51	0.1324	0.1360	Having either no animals (one individual) or only outdoor animals was associated with a ~9% increase
Job	0.97	0.410	0.1147	Working outdoors was associated with a ~10% increase

The original spirometric measurements from subjects were analyzed with the percent of predicted for each spirometric measurement to observe the correlation between the measurements. This was done in order to observe the potential applicability of NHANES III predictions for African Americans to the Luo people of the Upper Nyakach as hypothesized in **Hypothesis 11**. The correlation of lung function measurements are shown below in tabular form.

As can be seen in **Tables 2-12** and summarized in **Table 13**, only two exposures manifested an association with lung function that was statistically significant. (1) Those persons living in a dwelling with a dirt floor or clay-coated dirt floor had higher FEV1/FVC Ratio than persons living in a dwelling with concrete floors. (2) Those persons who owned goats manifested a higher FEV1/FVC Ratio than those persons who did not own goats.

All other hypothesized exposures were statistically insignificant.

Table 14 - A table of outcome variable correlations. This table may be used to compare the amount of overlap in what is measured versus the predicted value for that measure. For example, with Ratio and Ratio % there is a 0.9647 (96.47 %) overlap, meaning that these two values are measuring almost the same quantity. Bolded values will be analyzed in the Discussion chapter.

	Ratio	Ratio %	FEV1	FEV1 %	FVC	FVC %
Ratio	1.00					
Ratio %	**0.9647**	1.00				
FEV1	0.3841	0.3164	1.00			
FEV1 %	0.3249	0.2732	**0.8130**	1.00		
FVC	0.0713	0.0061	0.9436	0.7783	1.00	
FVC %	(-) 0.1648	(-) 0.2391	0.6303	0.8631	**0.7603**	1.00

Multivariate Analysis

Age, Gender, and Hemoglobin:

Adjusting for age and gender provided no marked differences in estimates of the relationship between the hypothesized exposures (floor type, wall type, cooking fire location, etc.) and lung function (FEV1/FVC Ratio) of the asthmatics who participated in this study. Hemoglobin level, similarly, did not appear to modify or confound the estimate recorded in Tables 2-12 (data not shown).

Airway Inflammation:

None of the participants in the study were diagnosed with current conditions that potentially could cause them to have airway inflammation (sinusitis, pneumonia, etc.); this precluded any further testing of airway inflammation as a potential confounder.

Occupational Exposure:

Occupational exposure was shown to have no statistically significant impact on the variance of FEV1/FVC Ratio. An ANOVA procedure, however, showed that those who worked inside (brick building) had a statistically non-significant lower lung function ($\bar{x}$ = 74.12%) compared to those who worked outdoors ($\bar{x}$ = 84.58%) ($p = 0.4010$). A similar relationship was observed for those who had no job.

CHAPTER SIX

Discussion

Major Hypotheses 1-2

Both housing hypotheses were shown to be unsupported in the analysis. The relationship between mud and clay-coated mud walls and lung function was not statistically significant; it unexpectedly did show an increase in lung function for those living in dwellings with mud walls, as opposed to the hypothesized decrease. Future testing of this variable would be needed to understand more about the effect on types of walls in a dwelling in relation to lung function. Of the statistically significant results, the finding that subjects with dirt floor dwelling had increased lung function ($p = 0.04$) was supported by a previous study which suggested a decreased prevalence of clinically diagnosed asthma in rural environments (Musafiri et al. 2011).

Major Hypothesis 3

The hypothesis that cooking location would have an impact on lung function was unsupported in this study. Because the results of this analysis were not statistically significant ($p = 0.3484$) and the association was contrary to well documented effects of smoke as an irritant, further research would be needed to understand more about the effect of cooking fire location on lung function in the target population.

Major Hypotheses 4-9

The presence of cats or dogs was associated with the second (~3 %) and third (~1 %) largest decrease in lung function, respectively. The associations observed for the presence of these two groups of animals support the hypothesis, but the null-hypothesis failed to be rejected due to lack of statistical significance. While dogs and cats were well known risk factors for asthma in the United States and many other countries, the particularly low explained variance produced by dogs may be due to cultural attitudes towards dogs that were observed among the Luo people. Dogs were kept almost exclusively outside and were not seen to be household pets at the same level as cats. This difference may account for the reduced effect of dog allergens on lung function compared to that of cat allergens.

Cow ownership produced a small estimate of effect ($r^2 = 0.0218$) on lung function; the presence of cows was associated with a 3% increase in lung function, although the results of this analysis did not reach statistical significance ($p = 0.5586$). As the largest animals found on the plateau, cows were least likely to be inside a dwelling and therefore may have been of less consequence to lung function. The availability of milk, a valuable source of vitamins, may also have been detected by these results, although cow milk has the lowest amount of vitamin A and the second lowest amount of vitamin D when compared to goat and sheep milk (Barłowska et al. 2011).

The large amount of variance ($r^2 = 0.2651$) and low p-value (0.0280) that presence of goats appeared to have in relation to lung function was not immediately explainable. There is a possibility that those who had goats were consuming goat milk regularly enough for them to benefit from the high level of vitamin A and D found in goat milk which may have a protective effect against asthma, thereby producing an increase in lung function (Nurmatov 2011; Pandya and Ghodke 2007; Parkash 1968).

The ownership of sheep explained 9.11 % of the variance in lung function and was associated with a 6 % increase in lung function ($p = 0.2234$). This association may have been observed for the reason similar to that of goats. Sheep milk contains higher levels of vitamin A (although lower than that of goat milk) than cow milk, so it was possible that the ownership of sheep allowed for sheep milk consumption which could have had a positive effect on lung function (Barłowska et al. 2011).

The presence of chickens was associated with the single largest amount of variance (7.65%) in the reduction of lung function (5% lower lung function). This high association may be due to chickens carrying various mites that would have a harmful effect on the lung function of asthmatics. Another possible explanation for chickens producing a greater negative effect on lung function may have been that chickens are more likely to deposit fecal matter within the house if they were allowed inside. Additionally, the documented effect of being exposed to poultry as an occupational risk factor for asthma supported the observed decline in lung function for those who owned chickens (Wjst 2007).

Major Hypothesis 10

Analysis on the location of animals (outdoor only v. indoor and outdoor) yielded an explained variance of 13.58 %; and having only animals that lived exclusively outdoors or no animals at all was associated with a 9 % increase in lung function ($p = 0.1324$). This observation aligns well with the reduced lung function seen with small animal ownership (cats, dogs, chickens), as these animals (particularly cats and chickens) were more likely to have or gain access to the interior of the dwelling.

Hypothesis 11(Minor)

A minor goal of the study was to observe the applicability of NHANES III predictions for African Americans to the population of Luo people. When the measured values and the percent of predicted for each spirometric measurement were compared in **Table 3**, correlations between Ratio and Ratio%, FEV1 and FEV1%, and FVC and FVC% were found to be relatively high (>75%). This indicates that the spirometry measurements, when compared to the prediction values, have a high positive correlation. Most importantly, the value of FEV1/FVC Ratio, the best single value used for assessing lung function, was positively correlated with the percent of predicted values of Ratio 96.47% of the time.

Limitations

The largest limitation of this study was the small sample size. An unknown software error resulted in the failure to save many early spirometric measurements. Additionally, the thermal printing paper on which spirometer results were printed faded easily, resulting in the illegibility of some early printouts. The initial number of subjects that were included in the study was 31, nearly double the final number of 18 subjects. This limitation greatly hindered this study.

Conclusions

Despite the limitations of this pilot study, statistically significant, protective relationships between lung function and traditional housing practices, as well as the ownership of goats were observed. A similar relationship to that of goat ownership may have been detected with ownership of sheep and, to a lesser degree, cows, but neither of these explained as much variance and did not reach statistical significance. These data will be used in future assessment of asthma in the area and may be used to advise clinic patients suffering from asthma in ways to mitigate their symptoms and improve their lung function. It appeared that only small animals such as cats, dogs, and chickens had notable negative effects on lung function, with chickens producing the greatest decrease in lung function, although it was not statistically significant. The Minor Hypothesis which tested the applicability of NHANES III spirometric predictions for African Americans to the Luo people of the Nyakach plateau showed that individual values of spirometry were closely correlated with the percent of predicted values derived from the NHANES III predictions, suggesting that these predictions were applicable to the target population.

APPENDICES

APPENDIX A

Glossary of Terms

FEV1/FVC: ratio of FEV1 to FVC in percent

FEV1: forced expiratory volume in 1 second

FEV6: forced expiratory volume in 6 seconds

FIVC: forced inspiratory vital capacity

FVC: forced vital capacity

APPENDIX B

Glossary of Variables

Animals:
- 0 = None
- 1 = Outdoor only
- 2 = Indoor/outdoor

Cooking fire:
- 1 = Inside
- 2 = Outside

Floor/Sleeping:
- 0 = Bare dirt floor
- 1 = Dirt floor with blanket
- 2 = Concrete floor

Occupation:
- 0 = No job
- 1 = Works outdoors
- 2 = Mud building
- 3 = Brick building
- 4 = Other (specify)

Roof:

1 = thatched
2 = metal
3 = tile

Wall:

1 = mud
2 = brick
3 = metal

"How are you feeling physically today?"

Ranked from 1-5, "Very good," "Good," "Fair", "Poor," and "Very bad"

"Specifically, how is your breathing today?":

Ranked from 1-5, "Very good," "Good," "Fair", "Poor," and "Very bad"

"How would you describe your health in general?":

Ranked from 1-5, "Very good," "Good," "Fair", "Poor," and "Very bad"

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