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DETERMINANTS OF CHILD HEALTH IN RURAL SOUTH AFRICA

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Defended March 11, 2016

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Abstract

This study examines the correlation between household characteristics—namely household head education, sex of household head, assets, livestock ownership, and field usage—and children's nutritional status, quantified by growth stunting, underweight status, and wasting, in rural South Africa. Children aged 1-5 years old in the Agincourt Health and Demographic Surveillance Site of South Africa were sampled in 2010 and 2011. The proportion of children who were growth stunted was 16% in 2010 and 26% in 2011. In 2010 and 2011, 3% and 6% of the children sampled were underweight, respectively. The percent of children considered to have wasting syndrome was 0.7% in 2010 and 2% in 2011. These data provide evidence supporting previous studies showing that childhood malnutrition is a continuing problem in rural South Africa. Further, childhood undernutrition was correlated with all five household characteristics, but most significantly with household head education, field usage, and assets. Results from this study suggest that investing in education may be an effective tool for reducing childhood undernutrition.
Introduction

Adequate childhood nutrition, through which a child’s energy and nutrient needs are met, is central in determining long-term physical health, cognitive function, economic productivity, and susceptibility to disease (Richards et. al., 2013; Remans, et. al. 2011; Kimani-Murage, et. al., 2010; Hong, 2006; Haidar et. al., 2005; Duflo, 2000; FAO, 1990). Children who are underweight, malnourished, or have stunted growth are more susceptible to infectious diseases, have delayed physical and cognitive development, and are less productive learners (Guerrant, et al., 2009; Glewwe, et al., 2001).

Worldwide, approximately 165 million children under five years old are growth stunted, 101 million are underweight, and 52 million are experiencing wasting syndrome (hereafter referred to as wasting) (Das, Salam, & Bhutta, 2016). Growth stunting, defined as a height-for-age z-score below -2, is used as a long term indicator of childhood undernutrition (Tzioumis & Aidar, 2014). Growth stunting early in life is correlated to poor cognitive and educational performance, low productivity, and excessive weight-gain later in childhood (de Onis, et. al., 2011; Kimani-Murage et al., 2010). In contrast to growth stunting as a long term indicator of health, underweight status (a weight-for-age z-score at or below -2) is an indicator of acute undernutrition (Tzioumis & Aidar, 2014). Children who are underweight are less likely to be receiving adequate micronutrients, which can lead to adverse health effects in both the short and long term (Tzioumis & Aidar, 2014; de Onis, et. al., 2011; Kimani-Murage et al., 2010). The measurement of wasting (a height-for-weight z-score below -2) offers both a short term and long term indication of nutrition. Similar to growth stunting and underweight status, wasting is correlated with lower levels of both physical and cognitive development (Duflo, 2000).
Ironically, while developing nations struggle with a high prevalence of undernutrition, there is an increasing prevalence of overweight and obese children in those same nations. Overweight status and obesity are defined as a BMI over 25 and over 30 respectively, or as a height-for-weight z-score above +2 and +3 respectively (Obesity and Overweight, 2016; Yang, et. al., 2015). This “Dual Burden” of undernutrition and over-nutrition in developing nations presents a novel public health challenge. Without much financial support, public health professionals must simultaneously allocate resources to preventing over- and under-nutrition.

As the wealth of developing nations increases, there is a transition in the composition of diets (Kimani-Murage et al., 2010). People move from traditional diets low in fat and high in fiber, to more “Western” diets—what is eaten in the US and Australia—which tends to be high in fats and sugars (Tzioumis & Aidar, 2014; Kimani-Murage et al., 2010). This is a sign of increasing affluence because as people become less dependent on natural resources and are more able to buy food, they often begin to eat more Western diets. Additionally, as people accrue more wealth, they adopt more sedentary lifestyles and move away from labor intensive jobs (Tzioumis & Aidar, 2014). Together, more Western diets and less physical activity are leading to increasing levels of overweight status and obesity in developing nations.

Interestingly, a combination of undernourished and over-nourished individuals exist even within a single household. This may be because children are receiving different nutrients than their parents, different aged individuals have different activity levels, or different people have varying susceptibility to over- and under-nutrition (Tzioumis & Aidar, 2014). Overweight status and obesity are significant problems because children who are overweight or obese are significantly more likely to have numerous chronic diseases, and they often are not receiving the nutrients necessary for healthy development (Tzioumis & Adair, 2014). Though over-nutrition
suggests that children are receiving more than adequate amounts of food, in fact, many times obese children are receiving too many calories but too few micronutrients. In developing nations, inadequate micronutrient intake is widespread, and this is correlated to obesity in children (Troesch, et. al., 2015). In sum, finding ways to reduce both childhood undernutrition and over-nutrition at the same time is challenging within the context of limited resources available in developing nations.

In 2000, the UN developed eight Millennium Development Goals to work toward by 2015. They set out to work with nations to eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality and empower women, reduce child mortality, improve maternal health, combat HIV/AIDS and malaria, ensure environmental sustainability, and develop a global partnership for development. Significant strides have been made toward achieving these goals, which together have improved child health worldwide. Today, the percent of undernourished people in developing nations is 12.9%--almost half of what it was in 1990 (The Millennium…, 2015). Unfortunately, levels of child undernourishment remain high—there are still 90 million children under 5 years old who are undernourished (The Millennium…, 2015). Furthermore, every day in 2015, 16,000 children under five years old died—a figure that has declined by more than half between 1990 and 2015 (The Millennium…, 2015). Though the Millennium Development Goals have helped to motivate progress, there is still a lot of work needed to ensure child health on a global scale. The UN updated the Millennium Development Goals to now reflect the Sustainable Development Goals, in effect from 2015 to 2030. The Sustainable Development Goals further aim to end poverty, improve food security and nutrition, and ensure healthy lives, in addition to 14 other goals (Draft
Outcome..., 2015). With the entire UN collaborating to achieve these new goals, hopefully rates of childhood undernutrition and mortality will decrease substantially in the decades to come.

Globally, research indicates that increasing women’s autonomy and power leads to improved child health (Cunningham, et. al., 2015). Empowerment is assessed based on a woman’s level of agency, control, and authority in decision-making (Cunningham, et. al., 2015). Decision-making is evaluated in relation to healthcare, eating habits, and other household matters. Similarly, levels of autotomy are defined by the ability to purchase and control resources, and make decisions about health care for both the woman and her children. Autonomy is also reflected by a women's experience of domestic violence (Carlson, Kordas, & Murray-Kolb, 2015). Though the impact of women’s empowerment on child nutrition may be influenced by the child’s age, women’s empowerment has been shown to be an important determinant of child nutrition overall (Cunningham, et. al., 2015). Lack of maternal autotomy, and specifically health care autotomy, has been significantly associated with childhood growth stunting (Carlson, Kordas, & Murray-Kolb, 2015). This may be because when women have more autonomy, they are able to allocate resources to more nutrient rich foods, and children are more likely to see a medical professional if they are sick (Carlson, Kordas, & Murray-Kolb, 2015). Additionally, research around the world has demonstrated that children born to women with some formal education had fewer incidences of growth stunting (Ickes, Hurst, & Flax, 2015; Haidar et. al., 2005). Finally, women’s access to media was protective against childhood wasting in Uganda (Ickes, Hurst, & Flax, 2015). Bringing these research findings together with a policy focus, improving the lives of women has been recommended by USAID and UNICEF as an important pathway to improving child health (Gender Equality..., 2013; Working for..., 2010).
On a more macro level, childhood nutrition is also dependent on global prosperity, as seen by the decline in nutrition during the 2008 Global Recession (Rajmil, et. al., 2015). In both developed and developing nations, the Global Recession was associated with more infant and child mortality (Rajmil, et. al., 2015). One study estimated that the Global Recession resulted in an excess of 28,000 to 50,000 infant deaths during 2009 in sub-Saharan Africa alone (Rajmil, et. al., 2015). Specifically in Greece, infant mortality increased by 20% to 30% between 2008 and 2010 (Rajmil, et. al., 2015). The Global Recession also correlated with increased underweight status in children in Bangladesh (Rajmil, et. al., 2015). This is likely because the price of food increased during the Global Recession, and people tended to eat cheaper, more calorie-dense foods that contained fewer micronutrients (Griffith, O'Connell, & Smith, 2015). Additionally, aid from the US, UN, and Global Fund decreased during the Global Recession (Leach-Kemon, et. al., 2012). In fact, the Global Fund experienced such a decrease in donations that they were not able to give any grants in 2014 (Leach-Kemon, et. al., 2012). The increase in food prices in conjunction with decreases in international aid funding had a negative impact on infant and child health.

Finally, HIV/AIDS has a huge impact on child health. Currently there are 36.9 million people in the world living with HIV/AIDS, and 2.6 million of these people are children (Global Statistics, 2015). Children are most often infected with HIV via vertical transmission during birth or breastfeeding, though this risk is lessoning as new technology and pharmaceuticals become available. Vertical transmission is when the virus is passed from the mother to the child during birth. Though the risk of vertical transmission can be reduced with antivirals, these medications are not widely available in poor rural areas, and as a result, many children are born with HIV (Sherr, et. al., 2014). As of 2011, the prevalence of HIV in the Mpumalanga Province (the
location of the present study site) was 24%--one of the highest rates in world (Mpumalanga Provincial…., 2013). Furthermore, 29.4% of pregnant women in the Mpumalanga Province were living with HIV as of 2009 (Mpumalanga Provincial AIDS Spending Assessment Brief, 2013). HIV/AIDS effects children if they contract the disease from their mother, if a family member is chronically ill, if their household is impoverished by HIV/AIDS, or if they are orphaned. Even if a child does not contract HIV from their mother, they may face risks to their health by living in a household effected by HIV as a result of these indirect impacts. Living with an HIV/AIDS positive adult is correlated to low birth weight, slower early growth, and decreased food security (Sherr, et. al., 2014). These children are also more likely to be underweight and wasting, and they are more likely to experience respiratory infections and diarrhea (Kidman, et. al., 2010). In cases where children are orphaned by HIV, they are more vulnerable to dropping out of school, experiencing developmental problems due to lack of food, having social problems, and to contracting HIV themselves (Andrews, Skinner, & Zuma, 2006). These children also report going to bed hungry and not eating dinner more frequently than non-orphaned children (Sherr, et. al., 2014). Given that sub-Saharan Africa has a high prevalence of HIV/AIDS, and that this disease has substantial impact on child health, children living in sub-Saharan Africa are at elevated risk for health deficiencies resultant of the HIV/AIDS pandemic.

Globally children face substantial health risks as a result of malnutrition. International, national, and local factors such as the Global Recession, HIV/AIDS prevalence, and women’s empowerment influence child health. The UN has set goals to improve child health and target each of the above factors, but childhood undernutrition continues to affect millions of children globally.


**Background**

This study focuses on children aged 1-5 years old in the Agincourt Health and Demographic Surveillance Site (AHDSS) in rural South Africa. The study site is located in a rural northeast region of South Africa, and is characterized by high population density, low food security, and high dependence on natural resources (Twine & Hunter, 2011). Sanitation is poor, access to healthcare is limited, and there is a high prevalence of HIV/AIDS (Kimani-Murage, et al., 2010). To provide necessary information on children’s nutritional status in the AHDSS, this research answers the following question: Are household head education level, sex of household head, assets, livestock ownership, and field usage determinants of underweight status, growth stunting, and wasting in children aged 1-5 years old in rural South Africa?

In rural South Africa, food security—access to sufficient, safe, and nutritious food to meet dietary needs—is a common challenge (FAO, 1996). For example, in the South African province of Mpumalanga, the AHDSS location, more than 80% of households have less than adequate intake of energy, protein, and fat (Leroy et al., 2001; WHO, 1990). Formal employment is limited and most land plots are too small to support subsistence agriculture. Households rely heavily on natural resources such as bushmeat, edible insects, or wild fruits and vegetables to supplement their diet (Hunter, et. al., 2007). Many families in the region depend on wages from migrant labor and there is also a high dependence on both child care grants and old age pensions provided by the South African government. At 64%, the Mpumalanga Province has one of the highest poverty rates in South Africa (Kimani et. al., 2010). Given that poverty is one of the strongest indicators of child mortality, it is clear that children in this region are at risk (Akter, et. al., 2015; Richards, et. al., 2013; Kimani et. al., 2010). In fact, about 1 in 5 children between the
ages of 1 and 4 years old have stunted growth and are underweight, which may be due to the extreme poverty and lack of fertile land in the area (Kimani-Murage, et al., 2010).

The Mpumalanga province is especially poor because most of the residents settled in the region during forced relocation to this former homeland in the early 1960s (King, 2005). When apartheid became South African law in 1948, a series of laws separating black and white people were established. Black and white people were not allowed to be married, non-whites had to carry documents allowing them to be in certain areas, blacks were not permitted to participate in government, and the government forcibly removed over 3.5 million black people from rural areas designated “white”, to new “homelands” (Masoka, 2014). These homelands typically had poor soil quality, were in very rural areas, and had little infrastructure. With no power in the South African government, the residents of these homelands were condemned to poverty. The apartheid government fell in 1994, but poverty continues to plague Mpumalanga Province (Greenburg, 2004).

Figure 1: An average home in the AHDSS. Few homes have running water or can afford electricity.
Neves and DuToit (2013) propose that household livelihoods in rural South Africa are comprised of four primary domains: land-based and agrarian activities (e.g. subsistence agriculture), informal economic activities (e.g. selling marula beer), state cash transfers (old age pensions and child support grants), and social reciprocity (e.g. giving and receiving assistance from friends and family). The dependency on each of these categories is variable between households; for example, some households may rely on farming and natural resources exclusively, while others may be completely dependent on seasonal employment and remittances. The diversity of livelihood characteristics in rural South Africa likely has implications for childhood nutrition because different livelihood strategies result in households having varying available resources to feed their children. In fact, studies worldwide have found both positive and negative correlations between particular livelihood characteristics and childhood nutrition (Remans, 2011; Haidar & Kogi-Makau, 2009; Haidar et. al., 2005; Duflo, 2000). This connection between household characteristics and child health in rural South Africa is the focus of this research.

This study examines the association between child health and household head education, sex of household head, assets, livestock ownership, and field usage. Similar studies throughout sub-Saharan Africa have identified household characteristics that make children more susceptible to underweight status, growth stunting, and wasting (Remans, 2011; Haidar & Kogi-Makau, 2009; Haidar et. al., 2005; Duflo, 2000), but an analysis of the correlation between child health and these household characteristics has not previously been undertaken within the AHDSS.

Every village in the AHDSS has a primary school and most have a secondary school, but the quality of education remains poor (Overview, 2015). In South Africa, primary school corresponds to seven years of schooling, and this is mandatory for all children. There is a fee to
attend school, but if a child’s family makes below a certain income, then the cost of school is either reduced or free. As of 2004, 60.7% of the population in the Mpumalanga Province was literate although 23.1% had never attended school (Lehohla, 2006). Secondary school comprises five additional years of schooling after primary school, but children must pass an exam to be admitted to secondary school. Secondary schools are not available in every village, and students may have to travel to attend school. Tertiary school, or what would be known as university in the US, is available to students who can pass an entrance exam. Few residents of the AHDSS pursue post-secondary education (Overview, 2015).

Under-five year old mortality, growth stunting, and underweight status are significantly lower when a child’s parents are educated (Akter, et. al., 2015; Richards, et. al., 2013; Gribble, Murray, & Menotti, 2009; Hong, 2006). Improvements specifically in women’s education has been correlated with a 43% reduction in child malnutrition in sub-Saharan Africa between 1970 and 1995 (Bain, et. al., 2014). In El Salvador, almost 30% of children have stunted growth when

Figure 2: Children in a primary school in the AHDSS.
their mothers have three or fewer years of schooling, but more educated mothers have significantly fewer underweight or growth stunted children (Gribble, Murray, & Menotti, 2009). Levels of child growth stunting in Kenya were found to be 29% higher for mothers with either no education or lower than secondary education, as compared to mothers that had at least secondary education (Bain, et. al., 2014). In a study examining childhood nutrition in the UK, Sweden, and rural China, more educated mothers were more likely to have children with height, weight, and BMI closer to the WHO standard for optimal growth (Lakshman, et. al., 2013). This suggests that higher parental education provides protection against children being overweight and obese in addition to having low height, weight, and BMI.

Beyond nutritional status, parental education is strongly correlated with infant and child mortality worldwide (Ezeh, et. al., 2015; Fang, et. al., 2015; Shapiro & Tenikue, 2015; Wang, et. al., 2014; Gakidou, et. al., 2010). In Bangladesh, child mortality was 38% lower among children whose mother had a secondary education, as compared to children of less educated mothers, and 16% lower if the father had a secondary education (Akter, et. al., 2015). Similarly, in Nigeria and Taiwan, children between 1 and 5 years old had a significantly higher risk of child mortality if either of their parents had either no formal education or only primary education (Ezeh, et. al., 2015; Fang, et. al., 2015). Fang et. al. (2015) found that low education and rural residence compounded the risk of child mortality. A study across 26 nations in sub-Saharan Africa found that recent improvements in women’s education accounted for a 37% decrease in child mortality (Shapiro & Tenikue, 2015). This association between maternal education and child mortality became stronger between 1995 and 2007, and Akter, et. al. (2015) recommend investing in girls’ education as an important tool in combating childhood mortality due to poor nutrition.
Low levels of household assets are also strongly associated with chronic childhood under-nutrition and growth stunting around the world (Richards, et. al., 2013; Gribble, et. al., 2009; Hong, 2006). Globally, children who live in the poorest 60% of households are more than two times as likely to be chronically undernourished (Hong, 2006). In Africa, 40% of children aged 0-5 years old have stunted growth in the poorest 20% of households, while 14% of children between 0 and 5 years old have stunted growth in the richest 20% of households (Hong, 2006). Richards, et. al. (2013) found that mothers with more assets were more likely to use preventive health measures, and their children had better health and nutritional status. Similarly in Latin America, children living in the poorest 20% of the population are two times more likely to be underweight than their counterparts in the middle 20% of the population (Gribble, et. al., 2009). Additionally, almost 33% of children living in the poorest 40% of households are growth stunted in El Salvador (Gribble, et. al., 2009).

Dietary diversity—the number of different food groups consumed over a given period—is significantly correlated with household expenditure and assets (Thorne-Lyman, et. al., 2009); and increased dietary diversity has been significantly associated with increased height-for-age z-scores around the world (Arimond & Ruel, 2004). Specifically in Cambodia, increased consumption of a diverse diet decreased the levels of growth stunting in children aged 0-5 years old (Darapheak, et. al., 2013). In low and middle-income countries worldwide, cash income is strongly associated with better childhood nutrition because of increased access to expensive proteins such as meat, fish, and poultry (Richards, et. al., 2013). A study in Cambodia found that increased consumption of animal source food, decreased levels of both growth stunting and underweight status in children aged 0-5 years old (Darapheak, et. al., 2013). Overall, higher
levels of household assets are associated with greater dietary diversity and are preventive of childhood undernutrition.

Gender roles in rural South Africa are evolving but men still hold most of the decision making power. According to a female teacher interviewed about gender inequalities, “inequality is visible” between men and women, which negatively effects women’s abilities in work, school, and at home (de Lange, Mitchell, & Bhana, 2012). There are now laws that criminalize both child abuse and sexual violence, but many men still believe it is permissible to force a woman to have sex (Dworking, 2013). In rural South Africa, the cultural norm is for men to be dominant and women submissive. Many men are resistant to changes in women’s rights and have negative opinions concerning the treating women as equals (Dworking, 2013). The head of the household is typically male unless he is physically absent, in which case a woman may be considered the household head.

Figure 3: A market in the AHDSS on the day that grants are distributed. Cash from these grants allows residents to purchase a wider variety of food than they are able to grow on their own.
As to the association between child health and the sex of household head, female-headed households are more likely to have malnourished, growth stunted, and underweight children (Haidar & Kogi-Makau, 2009; Haidar, et. al., 2005). Children in male-headed households have better nutritional intake than those in female-headed households, and the proportion of stunted and underweight preschoolers is significantly higher in female-headed households (Haidar & Kogi-Makau, 2009). For example, in Ethiopia 55.6% of children in female-headed households are growth stunted, while 43.2% of children are stunted in male-headed households (Haidar, et. al., 2005). Although mothers in female-headed households have more earning power and more control over how money is spent, these households tend to be poorer, own fewer assets, and have less access to formal employment and government services (Richards, et. al., 2013; Haidar & Kogi-Makau, 2009). Paradoxically, female empowerment improves child health, but having a
female-household-head impairs child health likely because it is more difficult for women to provide enough income to support their families.

Finally, the shortage of farmland is associated with growth stunting and underweight status of children, and lack of livestock negatively influences the nutritional status of children (Haidar, et. al., 2005). The absence of livestock is a prominent risk factor for growth stunting and underweight status (Haidar, et. al., 2005). In Ethiopia, growth stunting is negatively correlated to cow/donkey ownership (50.6% versus 35.6%), and 58.1% of children living on less than 0.5 hectares of land are growth stunted, versus 28.8% of children who are living on more than 1 hectare of land (Haidar, et. al., 2005). The proportion of underweight children was higher among the landless as well (Haidar, et. al., 2005).

Figure 5: A woman and her child sitting in a typical garden plot within one of the villages of the AHDSS. This is the amount of land each household has for food production unless they acquire access to land outside the village for additional farming.

In summary, this study contributes to the understanding of patterns of child health in rural South Africa. Grounded in research from a variety of settings, my analytical focus is on the
association of child health with sex of household head, household head education, assets, livestock ownership, and field usage. I predict that child health will be positively correlated with higher levels of household head education, assets, livestock, field usage, and a male household head. As standard measures, child health is reflected by growth stunting, underweight status, and wasting. Together, these three values indicate both a child’s long-term and short-term nutritional status (Remans, et. al., 2011; Kimani et. al., 2010; Gribble, Murray, & Menotti, 2009; Haidar & Kogi-Makau, 2009; Hong, 2006; Haidar, et. al., 2005; Duflo, 2000). These quantifiable parameters of health allow us to understand which household attributes are associated with nutritional adequacy for children and, in this way, this study fills a crucial gap in the understanding of determinants of child health in rural South Africa. In addition to broadening the research base, these analyses offer quantifiable evidence about patterns in childhood undernutrition, and the findings can support requests for needed resources from various governmental programs and aid organizations.

**Materials and Methods**

**Study Setting:**

The Agincourt Health and Demographic Surveillance Site (AHDSS) is located within the Mpumalanga Province, a former homeland characterized by widespread poverty and lack of basic infrastructure (Twine & Hunter, 2011). The AHDSS is operated by the University of Witwatersrand School of Public Health (Wits) and South Africa’s Medical Research Council (MRC). Since 1992, the AHDSS has conducted an annual census focused predominantly on household demographics and adult health.
Today, the 400 km² area encompasses 31 villages, including approximately 110,000 residents within about 21,000 households. Approximately one quarter of the population are former Mozambicans who settled in the 1980s as a result of the Mozambique Civil War. Residents in the region obtain health care at nine small clinics and one larger health center outside of the study site, but overall access to health care is limited. Household land plots are generally too small to support subsistence agriculture, so residents also use communal land around the villages for collecting natural resources, grazing livestock, and cultivating crops. Formal employment is limited, and dependence on migrant labor and remittances is common. Remittances are money sent to households from friends or family working in another area. There is a high reliance on child support grants and old age pensions provided by the South African government. The child support grant offers qualifying families with children under 18 about $20
per month per child, and the pension entitles qualifying adults over 60 to approximately $30 per month. Oftentimes, these grants are the only liquid source of cash income for residents of the AHDSS, and as of 2010 the monthly pension was nearly twice the median per capita income for black residents (Ralston, et. al., 2015).

To obtain more detailed information on household livelihood strategies, the "Sustainability in Communal Socio-Ecological Systems" (SUCSES) project was implemented beginning in 2010. SUCSES has collected household livelihood data from households across nine villages in the AHDSS. The study households were randomly sampled and are typical of households in the AHDSS as a whole.

**Data:**

Household livelihood data were collected using a detailed questionnaire written by Dr. Wayne Twine (The University of the Witwatersrand, South Africa). The questionnaire was administered to 557 households across nine villages in the AHDSS as part of the SUCSES project. In each village, 8% of households were randomly sampled from the Agincourt database using a database query. Few households (43) were not surveyed because the residents weren’t home or refused to complete the questionnaire. An extremely low number of households refused to take the survey, and therefore it should not affect the analysis. The questionnaire was administered to respondents by trained field workers from the community and in the local language of Shangaan/Tsonga. The responses were then translated back into English by experienced translators. Field workers were given extra training to ensure that responses were recorded consistently and accurately. Quantitative and qualitative data regarding livelihood income sources, expenditures, assets, livestock ownership, involvement in agriculture, and use of natural resources were collected for each household.
Height and weight data were collected for 142 children aged 1-5 years old in 2010, and 218 children in 2011. Height was measured using a stadiometer, and the average of two measurements was used. Weight was determined using a bathroom scale accurate to 0.1kg. All children between the ages of 1-5 years old in the 550 households present at the time of data collection were included in the study. These measurements were collected in the home also by trained fieldworkers speaking the native language of Shangaan/Tsonga. In the survey, age was measured by the number of completed years; for example a 14-month-old child would be considered 1 year old and a 35-month-old child would be 2 years old. To determine z-scores, age in years was transformed back into months as follows: one year corresponded to 18 months, two years corresponded to 30 months, three years corresponded to 42 months, four years corresponded to 54 months, and five years corresponded to 66 months.

Figure 7: A woman’s height being measured using a stadiometer in the AHDSS. This photo was retrieved with permission from http://www.agincourt.co.za/index.php/about/pictures/.
Statistical Analysis:

This study focused on key aspects of livelihoods that were associated with health. In particular, child health was examined as it related to household head education, sex of household head, assets, livestock ownership, and field usage. For measurement, household head education was rounded to the nearest year, livestock ownership was measured by the number of types of livestock owned (e.g. cows and chickens), and field usage was measured as the number of fields a household had permission from the local chief to farm. Assets were evaluated using an asset index ranging from 1 (least assets) to 13 (most assets) based on the presence of 13 different assets, including ownership of appliances (e.g. stove) and ownership of equipment (e.g. plow).

Height and weight data were transformed into height-for-age z-scores, weight-for-age z-scores, and height-for-weight z-scores, which correspond to growth stunting, underweight status, and wasting, respectively. This was done using the WHO/CDC/NCH reference values contained in the ANTHRO software (version 3.22) (de Onis, et. al., 2006). Children with height-for-age, weight-for-age, and height-for-weight z-scores equal to or below -2 were considered growth stunted, experiencing wasting syndrome, or underweight, respectively (Remans, et. al., 2011; Haidar and Kogi-Makau, 2009; Gribble, et. al., 2009; Hong, 2006; Haidar, et. al., 2005). Children with height-for-weight z-scores between +2 and +3 were considered overweight, and those at or above +3 were considered to be obese (Yang, 2015). For children measured in both 2010 and 2011, the height-for-weight, weight-for-age, and height-for-age z-scores were each compared between years, using a dependent t-test to determine if there was evidence of change (evaluated at the p<0.05 level).

Using STATA statistical software, pair-wise correlations and an independent t-test were used to determinate the association between height-for-age z-scores (growth stunting), weight-
for-age z-scores (underweight status), and height-for-weight z-scores (wasting) as correlated with each of the five household characteristics (household head education, livestock ownership, field usage, sex of household head, and assets). Statistical significance was evaluated at the p<0.1, p<0.05, and p<0.01 levels. Additionally, children with z-scores below -2 and above +2 were separated for analyses of the correlation with each of the household characteristics to see if height-for-age, weight-for-age, and height-for-weight z-scores over +2 (overweight and obese) were correlated with different household characteristics than growth stunting, underweight status, and wasting, respectively.

Growth stunting, underweight status, and wasting, as a group, provide a quantitative understanding of child health in the region. These parameters’ associations with the five identified household characteristics provides meaningful information regarding susceptibilities to childhood health deficits in rural South Africa.

Results

Distribution of Household Characteristics

This section describes the distributions of education of household heads, assets owned, sex of the household heads, categories of livestock owned, and number of fields used.

Household heads had, on average, 4.46 years of education in 2010 and 4.52 years in 2011 (p=0.88). Assets, indicating ownership of possessions such as carts and refrigerators, (measured from 0-13) increased slightly between 2010 and 2011 from 5.32 to 5.63, respectively (p=0.09). In 2010, 62% of the households were male-headed, and in 2011, 59% of households were male-headed. The change between years was not statistically significant for the sex of household heads (p=.60). Livestock ownership, evaluated by the ownership of up to 6 categories of livestock, averaged 0.78 categories owned in 2010 and 0.89 categories owned in 201 (p=0.23). Land usage
was measured as the number of fields farmed outside the homestead. The mean number of fields used in 2010 was 0.67, and in 2011 the mean was 0.73. This change between years was not significant (p=0.54).

Though the household characteristics changed slightly between years, this change was not significant for any of the measured characteristics. These differences may be due to random chance, and they were insignificant because there was high variability between households. The relatively high standard deviations for each characteristic supports that there was large variation across these household characteristics (Table 1).

<table>
<thead>
<tr>
<th>Household Characteristic</th>
<th>2010 Mean</th>
<th>2010 SD</th>
<th>2011 Mean</th>
<th>2011 SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Head Education (Years 0-15)</td>
<td>4.46</td>
<td>4.74</td>
<td>4.52</td>
<td>4.33</td>
</tr>
<tr>
<td>Assets (Scale 0-13)</td>
<td>5.32</td>
<td>1.70</td>
<td>5.63</td>
<td>1.78</td>
</tr>
<tr>
<td>Sex of Household Head (0 = female, 1 = male)</td>
<td>0.62</td>
<td>0.49</td>
<td>0.59</td>
<td>0.49</td>
</tr>
<tr>
<td>Livestock Ownership (Number of categories owned 0-6)</td>
<td>0.78</td>
<td>0.84</td>
<td>0.89</td>
<td>0.92</td>
</tr>
<tr>
<td>Land Usage (Number of fields used 0-6)</td>
<td>0.67</td>
<td>0.80</td>
<td>0.73</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table 1: The distribution of household characteristics measured in the AHDSS in 2010 and 2011. There was no statistically significant change between any household characteristics between 2010 and 2011.

In each household, the education of the identified household head was recorded. Most of the household heads had no education, with 41% never attending school. In our sample, 6% had completed primary school (corresponding to 7 years of education), and 25% reported completing more than primary school. Approximately 7% had completed secondary school (corresponding to 12 years of education) and less than 3% of the people sampled completed any education after secondary school (Figure 8).
Assets were normally distributed in households for 2010 and 2011. Ownership of up to 13 assets was recorded but the maximum was 11. Approximately 50% of people surveyed had five or fewer assets, and 3% of the sample population had eight or more assets (Figure 9).

In each household, a household head was identified as either male or female. Generally, if a male is present he is the household head, and only when a male isn’t present is a female determined the household head. In our sample, 60% of the household heads were male during
2010 and 2011 (Figure 10). The 40% of households with female-heads most likely lacked males in the household either because of mortality or migrant labor.

Livestock ownership was determined by the number of categories of livestock owned including cows, chickens, sheep, donkeys, goats, and pigs. During 2010 and 2011, 40% of the sample owned no livestock, and 43% owned one category of livestock. The proportion of the sample owning four or more categories of livestock was 0.5% (Figure 11).
In the AHDSS, households may tend field plots on communal land surrounding the village. Most of the households sampled did not farm a separate field (50%). During 2010 and 2011, 37% of those sampled had one field outside the homestead. Less than 3% of households in the sample farmed three or more plots (Figure 12).

![Graph showing distribution of fields used outside the homestead](image)

Figure 12: The distribution of fields used outside of the homestead in the AHDSS during 2010 and 2011. These are fields around the perimeter of the village and can be used by households to grow extra crops.

In sum, most households have little education, five or fewer assets, own one or fewer categories of livestock, and do not use fields outside of the homestead. With the exception of assets and sex of household head, all household characteristics were skewed right (Figures 8, 11, and 12). Household characteristics vary substantially between different households as seen by the relatively high standard deviations (Table 1).

**Distribution of Growth Stunting, Underweight Status, and Wasting**

Below is a description of the nutritional indicators measured for children aged 1-5 years old in the AHDSS. For children measured in both 2010 and 2011, there were no significant changes between years for height-for-age z-scores, weight-for-age z-scores, or height-for-weight z-scores using a 95% confidence interval.
The average height-for-age z-score in 2010 was -0.86 with a standard deviation of 1.2. In 2011 the average was -1.2 with a standard deviation of 1.4. There was no statistically significant difference between years for children measured in both 2010 and 2011 (p=0.52). Height-for-age z-scores were normally distributed both years (Figure 13).

![Figure 13: The distribution of the height-for-age z-scores for children aged 1-5 years old in the AHDSS. A height-for-age z-score at or below -2 is considered growth stunted.](image)

The average weight-for-age z-score in 2010 was -0.18 with a standard deviation of 0.92, and the average in 2011 was -0.34 with a standard deviation of 1.1. For children measured in both 2010 and 2011, there was no statistical significance in height-for-age z-scores between years (p=0.62). Weight-for-age z-scores were normally distributed in both 2010 and 2011 (Figure 14).
Finally, in 2010, the average height-for-weight z-score was 0.43 with a standard deviation of 0.91. In 2011, the average was 0.44 with a standard deviation of 1.2. There was no significant change in height-for-weight z-scores between 2010 and 2011 for children measured in both years (p=0.37). Height-for-weight z-scores were normally distributed in both 2010 and 2011 (Figure 15).

Figure 14: The distribution of the weight-for-age z-scores for children aged 1-5 years old in the AHDSS. A weight-for-age z-score at or below -2 is considered underweight.

Figure 15: The distribution of the weight-for-height z-scores for children aged 1-5 years old in the AHDSS. A weight-for-height z-score at or below -2 is considered wasting.
The most common indicator of undernutrition was growth stunting, defined as a height-for-age z-score below -2. In 2010, 16% of the sample was growth stunted, and that increased to 26% in 2011 (Figure 16). For children measured in both 2010 and 2011 there was no significant change in growth stunting. The second most common indicator of undernutrition was underweight status, which was indicated by a weight-for-age z-score below -2. Between 2010 and 2011, the percent of children underweight increased from 2.82% to 5.83%; though this was not a significant increase for children measured in both 2010 and 2011 (Figure 16). Lastly, there was a smaller proportion of the sample that was wasting (having a height-for-weight z-score below -2). In 2010, 0.71% were two or more standard deviations below the mean, and in 2011 this increased to 1.83% (Figure 16). These changes were not statistically significant for children measured in both 2010 and 2011 with a 95% confidence interval.

![Figure 16: The percent of the sample with indicated nutritional deficiencies in 2010 and 2011. Sampled from children aged 1-5 years in the AHDSS. Growth stunting, underweight status, and wasting correspond to a z-score less than or equal to -2 for height-for-age, weight-for-age, and height-for-weight respectively. There was no significant change between years at p<0.05.](image-url)

Few of the children were two or more standard deviations above the mean in height-for-age z-scores (2% in 2010 and 0.4% in 2011). For weight-for-age z-scores, the percent of children two or more standard deviations above the mean was very small, with 0.70% in 2010 and 0.45%
in 2011. In contrast to height-for-age z-scores and weight-for-age z-scores, there was a larger proportion of the population two or more standard deviations above the mean for height-for-weight z-scores. In 2010, 2.1% of the sample was overweight (between two and three standard deviations above the mean), and in 2011 this increased to 6.91% (Figure 17). There were no obese children (having a height-for weight z-score above +3) in 2010, but in 2011, almost 2% of the sample was obese (Figure 17). The changes in z-scores between 2010 and 2011 were not significant for children measured in both 2010 and 2011 at p<0.05 for any of the nutritional indicators measured.

Children in the sample studied were more likely to have nutritional indicators two or more standard deviations below the mean, than two or more standard deviations above the mean. Growth stunting had the largest percentage of children with z-scores under -2, and height-for-weight most commonly had z-scores over +2. Though not all children were measured in both
2010 and 2011, those that were measured both years showed no statistically significant change in nutritional status.

**Correlations between Household Characteristics and Nutritional Status**

This section examines how the five household characteristics identified (household head education, assets, sex of household head, livestock ownership, and field usage) were correlated with height-for-age z-scores (growth stunting), weight-for-age z-scores (underweight status), and height-for-weight z-scores (wasting).

Each of the five household characteristics investigated correlated with childhood nutritional status. Household head education was positively correlated with all three indicators of childhood nutrition (Table 2). This indicates that higher levels of education correlate with increased child nutrition. Conversely, assets negatively correlated with weight-for-age and height-for-weight z-scores (Table 2). In contrast to literature on this subject, this suggests that an increased number of assets was associated with decreased child nutrition. This correlation was only significant in 2011. Field usage was also negatively correlated with weight-for-age and height-for-weight z-scores only in 2011 (Table 2). This opposes most literature on the topic, and suggests that an increased number of fields owned was linked to decreased childhood nutrition. Livestock ownership was weakly correlated with height-for-weight z-scores in 2011 (Table 2). This was also a negative association, suggesting that higher levels of livestock ownership were associated with decreased child nutrition. Lastly, children living in female-headed households had increased height-for-age and weight-for-age z-scores (Table 3). The difference between male- and female-headed households was significant in height-for-weight z-scores only in 2010, and in weight-for-age z-scores only in 2011.
Correlation Coefficients

<table>
<thead>
<tr>
<th></th>
<th>Height-for-Age z-score 2010</th>
<th>Height-for-Age z-score 2011</th>
<th>Weight-for-Age z-score 2010</th>
<th>Weight-for-Age z-score 2011</th>
<th>Height-for-Weight z-score 2010</th>
<th>Height-for-Weight z-score 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Head Education</td>
<td>-0.02</td>
<td>0.13 **</td>
<td>0.10</td>
<td>0.14 **</td>
<td>0.16 *</td>
<td>0.09</td>
</tr>
<tr>
<td>Assets</td>
<td>-0.10</td>
<td>0.09</td>
<td>-0.12</td>
<td>-0.14 **</td>
<td>-0.10</td>
<td>-0.18 ***</td>
</tr>
<tr>
<td>Livestock Ownership</td>
<td>-0.07</td>
<td>0.06</td>
<td>-0.10</td>
<td>-0.11</td>
<td>-0.06</td>
<td>-0.12 *</td>
</tr>
<tr>
<td>Field Usage</td>
<td>0.06</td>
<td>0.04</td>
<td>-0.06</td>
<td>-0.13 *</td>
<td>-0.14</td>
<td>-0.15 **</td>
</tr>
</tbody>
</table>

Table 2: Correlations between household characteristics and nutritional indicator for children aged 1-5 years in the AHDSS during 2010 and 2011. A pairwise correlation was used for household head education, assets, livestock ownership, and field usage. Significance is indicated at: * p<0.1, ** p<0.05, *** p<0.01.

Mean z-score

<table>
<thead>
<tr>
<th></th>
<th>Height-for-Age 2010</th>
<th>Height-for-Age 2011</th>
<th>Weight-for-Age 2010</th>
<th>Weight-for-Age 2011</th>
<th>Height-for-Weight 2010</th>
<th>Height-for-Weight 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male-Headed</td>
<td>-1.01 *</td>
<td>-1.13</td>
<td>-0.19</td>
<td>-0.45 *</td>
<td>0.51</td>
<td>0.40</td>
</tr>
<tr>
<td>Female-Headed</td>
<td>-0.60 *</td>
<td>-1.13</td>
<td>-0.16</td>
<td>-0.18 *</td>
<td>0.28</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Table 3: The mean z-score for each nutritional indicator by male- and female-headed household in 2010 and 2011. An independent t-test was used to determine if there was a significant difference in the nutritional status of children in male- and female-headed households. Statistical significance between male- and female-headed households is indicated by * at p<0.1.

Weight-for-age and height-for-weight in 2011 were well determined by the five identified household characteristics. Conversely, none of the nutritional indicators were well predicted by the identified household characteristics in 2010. Additionally, height-for-age was not well predicted by the household characteristics in either 2010 or 2011.

When children with weight-for-age z-scores below -2 and above +2 were separately correlated with the five household characteristics, household head education was significant only in children who had a z-score above +2 in 2011. Additionally, field usage was only significant in children with height-for-age z-scores above +2 and not for children with z-scores below -2. This suggests that higher household head education and a fewer number of fields enables children to exceed nutritional standards.
Discussion

This study examined how five household characteristics, namely household head education, sex of household head, assets, livestock ownership, and field usage, were correlated with childhood nutritional status in rural South Africa. Indicators of childhood nutrition were height-for-age z-scores, weight-for-age z-scores, and height-for-weight z-scores, which as a group provide a quantitative measurement of both long-term and acute child health. These data provide evidence supporting previous studies showing that childhood malnutrition is a continuing problem in rural South Africa. It further provides insight on household characteristics that correlate with higher levels of childhood nutrition, which may inform policies and programs to improve child health in the context of limited resources.

Analysis of Childhood Nutritional Status:

The data from this study, in the AHDSS of rural South Africa, are consistent with previous studies in sub-Saharan Africa demonstrating that child malnutrition still exists at significant proportions (The Millennium…, 2015). When quantifying childhood nutrition, height-for-age, weight-for-age, and height-for-weight z-scores below -2 corresponded to growth stunting, underweight status, and wasting, respectively. Millions of children in sub-Saharan Africa are growth stunted, underweight, and wasting, and though the UN has set goals to improve child health, it continues to be a serious problem (Das, Salam, & Bhutta, 2016). This study examined the proportions of childhood growth stunted, underweight, and wasting in the AHDSS, and how these proportions compare to studies throughout rural South Africa over the last 20 years.

2010, and 2011, the percent of children with growth stunting in rural South Africa was 27%,
27%, 28%, 18%, 16%, and 26%, respectively (Kimani-Murage, et. al., 2010). Though there are
ongoing efforts to improve childhood nutritional status in developing nations, in rural South
Africa there has only been a 1% decrease in childhood growth stunting between 1994 and 2011.
Growth stunting is an indicator of long term nutritional deficiencies, so these data suggest that
the children sampled lacked proper nutrition early in life. Changes in infant feeding practices is
the aim of several education programs in rural South Africa, which may improve the levels of
growth stunting in years to come. Unfortunately, people in this region continue to live in extreme
poverty, and children continue to receive inadequate nutrient intake.

There was similarly little change between these data collected in 2010 and 2011, as
compared to previous studies in rural South Africa for children’s underweight status. In 1994,
1999, 2003, 2007, 2010, and 2011, the percent of children that were underweight was 11%, 10%,
11%, 10%, 3%, and 6%, respectively (Kimani-Murage, et. al., 2010). There has been
approximately 5% change in the proportion of underweight children within the range of the past
17 years. As opposed to growth stunting, underweight status is a measure of more acute child
undernutrition. The proportion of underweight children remains high, suggesting that children
are not receiving adequate nutrition more recently. Though there has been some progress in
reducing the amount of underweight children in rural South Africa, this change is small and
illustrates the need for improved strategies for reducing child undernutrition.

The proportion of children demonstrating wasting syndrome is the lowest indicator of
undernutrition, but in 2011 almost 2% of the children in the AHDSS were still wasting. Wasting
has decreased in rural South Africa from 3%, to 7%, to 5%, to 5%, to 0.7%, to 2% in 1994, 1999,
2003, 2007, 2010, and 2011, respectively (Kimani-Murage, et. al., 2010). Wasting is a measure
of both acute and long-term undernutrition, so these data further suggest that children are receiving inadequate nutrition throughout their childhood. Wasting has only decreased by 1% between 1994 and 2011, but the fluctuation between years suggests that there is variability in the nutritional status of children throughout rural South Africa. The above data were sampled from various areas of rural South Africa, so the variability may be due to differences in nutritional status in different regions. The non-linear change in wasting also suggests that efforts to reduce child undernutrition are not consistently successful. Data on livelihood characteristics and child health over longer periods of time are needed to further explore the inconsistent change in childhood wasting.

Though undernutrition continues to be a problem in rural South Africa, unlike other countries in sub-Saharan Africa, over-nutrition is becoming less prevalent. In 1999, 12% of rural South African children were overweight, and this was reduced to 10% in 2005, 2% in 2010, and 7% in 2011. The low proportion of overweight children in 2010 is likely due to the small sample size, given that it increased 5% during one year in the same area. Obesity effected 4% of children in 1999 and 2005, and this was reduced to 2% in 2011. Over-nutrition typically increases as areas become more affluent, but this area’s decrease in over-nutrition suggests that families are not choosing to eat foods high in calories and low in micronutrients, even as their income grows. An alternate explanation is that over-nutrition has decreased as a result of the Global Recession, and children have had less to eat because of increased poverty. The dual burden of over- and under-nutrition appears to be lessening in the AHDSS. Undernutrition remains a problem in rural South Africa—effecting 26% of children—but overweight status and obesity are becoming less prevalent, effecting 7% and 2% respectively. The AHDSS should be further studied to determine
which factors have caused the decrease in this dual burden, so that these findings can be applied to other areas of sub-Saharan Africa experiencing the dual burden of over- and under-nutrition.

For children measured in the AHDSS in both 2010 and 2011, there was no significant change in nutritional indicators between years. Because anthropometric data were only available for two consecutive years, change over time data in the AHDSS was insignificant. Interestingly, 10% more of the children studied were growth stunted in 2011 than in 2010. Conversely, 5% more of the sample was overweight in 2011 than in 2010. Given that such a short period of time passed between collection of these data and that no significant political change happened in South Africa between those times, this may be due to chance. Further, this variability may not be representative of rural South Africa as a whole because the intragroup variation specifically at AHDSS does not capture intergroup variation throughout the whole of South Africa. As mentioned above, the change in undernutrition in this region has not changed significantly since 1994, so the change seen in these data is most likely due to the small sample size. A decade long study is needed to assess how child health is changing with time in the AHDSS.

**Analysis of Household Characteristics:**

The five household characteristics examined—household head education, sex of household head, assets, field usage, and livestock ownership—were chosen based on current literature supporting their connection to child health in areas around the globe. The livelihood characteristics that most frequently correlated with childhood nutrition, were household head education, assets, and land usage. Sex of household head and livestock ownership were weakly correlated with measures of child health. Further, household head education was positively correlated to childhood nutrition, but sex of household head, assets, field usage, and livestock ownership were all negatively correlated to childhood nutrition.
Increased parental education has been widely documented to improve child health (Richards, et. al., 2013). When parents, and especially mothers, are more educated, they are more likely to take their child to a physician, breastfeed exclusively in the first six months, and feed their children a more diverse diet (Ezeh, et. al., 2015; Gribble, Murray, & Menotti, 2009). Through mechanisms such as these, children grow up less malnourished in more educated households. These data support previous studies, and suggest that increased household head education is associated with increased childhood nutrition. Household head education was positively correlated with height-for-age, weight-for-age, and height-for-weight z-scores. Furthermore, the level of household head education was correlated to a height-for-age z-score over +2 but was not correlated to a height-for-age z-score below -2. This suggests that education is a key factor in determining childhood nutrition.

Maternal education and female empowerment have been correlated with improved child health, and the data from this study support that children have increased nutrition in female-headed households. Although there are often fewer jobs available to women than men, and female-headed households are, on average, poorer than male-headed households, this study found that children in female-headed households were less undernourished (Richards, et. al., 2013; Haidar & Kogi-Makau, 2009). This contradicts previous literature throughout sub-Saharan Africa suggesting that children in male-headed households are more adequately nourished (Richards, et. al., 2013; Haidar & Kogi-Makau, 2009; Haidar, et. al., 2005). This may be because females are more empowered when they are the head of the household, and they have more power over what their children eat and how often they visit a health clinic. Further, this may be because many female-headed households in the AHDSS receive remittances from migrant workers, which gives the female-head more autonomy without decreasing her ability to
financially provide for her family. These data support that female autonomy and empowerment foster adequate childhood nutrition, and therefore programs that support females should be encouraged.

The number of assets a household owns has been associated with childhood undernutrition in developing nations around the world. In Latin America, Africa, and Asia, studies have found that children living in poor households with fewer assets were more likely to be undernourished (Richards, et. al., 2013; Gribble, et. al., 2009; Thorne-Lyman, et. al., 2009; Hong, 2006). Assets serve as a measure of income and affluence, and as households rise from poverty, they accumulate more resources to buy foods rich in micronutrients, which results in children being less undernourished (Thorne-Lyman, et. al., 2009). This study is unique because it found that child nutritional status was increased with decreased assets. This is an anomaly within the literature, and further analysis of these data is needed to identify how this population differs from others studied around the globe. Identifying which assets were most associated with childhood undernutrition may offer insights to why increasing affluence was not associated with improved child health. Additionally, recording household income—from remittances, grants, and employment—may give a better picture of how poverty is related to childhood nutrition. Moving forward, further analysis exploring how poverty correlates to childhood nutrition may offer explanations to why these data are an abnormality among the literature on this subject.

Children who eat more diverse, micronutrient rich foods are less likely to suffer from undernutrition, and this is aided by families having more farmland. Children growing up with less available farmland are more likely to be malnourished (Haidar, et. al., 2005). Access to farmland is unique in the AHDSS because plots of land near people’s homes are very small and cannot produce enough food to support a family. In addition, households can be given more land
by the chief in areas surrounding the village, so they can grow enough food to support
themselves. Contrary to previous studies, these data support that increased access to farmland
does not improve child nutrition. Although households with more farmland have the ability to
grow more food, farming may be an indicator of poverty. For families who cannot afford to
purchase food, farming may be a last resort to feed their family. The negative correlation
between field ownership and childhood nutrition suggests that farming is not a livelihood
strategy that can produce enough assets to adequately nourish children. Other than household
head education, land use was the only other characteristic that was significant for children with
height-for-age z-scores above +2 but not below -2, suggesting that it is an important indicator of
childhood nutrition. Programs that teach people to grow more micronutrient rich foods, and
support farming practices that increase yields, may improve the nutrition of children in
households that farm. Additionally, expanding employment opportunities outside of agriculture
may improve childhood nutrition.

Similar to field ownership, livestock ownership was negatively correlated with childhood
nutrition. Livestock have been shown to be protective against childhood undernutrition in other
areas sub-Saharan Africa, but these data are inconsistent with previous studies (Haidar, et. al.,
2005). Livestock provide food, assist with farming, and can be sold as a strategy for coping with
the loss of a wage-earning adult, which protects children from undernutrition in other areas of
sub-Saharan Africa (Nicholoson, et. al., 2003). These data may differ from previous studies
because like farming, livelihood strategies involving livestock ownership may be pursued only
when other options aren’t viable. Identifying which categories of livestock are best correlated
with childhood undernutrition may provide insight into how the AHDSS differs from other
studies throughout sub-Saharan Africa.
Interestingly, all of the household characteristics studied were more correlated with childhood nutrition in 2011 than in 2010. Given the short duration of this study and that none of the nutritional indicators changed between years, it is unlikely that anything changed within the AHDSS to make 2011 more significant. About 80 more children were measured in 2011 than in 2010, and this increased significance with increased sample size highlights the need for more data. Randomly sampling more children will ensure that the sample is representative of the population as a whole and increase the significance of results. For a more comprehensive view of child health and household characteristics, the same children should be measured over the course of several years.

**Implications of Results:**

Childhood undernutrition remained highly prevalent in 2010 and 2011, and this is important because undernutrition in childhood can lead to significant physical and cognitive problems in adulthood (Glewwe, et. al., 2001). Studies have shown that children who receive less than adequate nutrient intake have delayed cognitive development and are less productive learners in school (Ampaabeng & Tan, 2013; Alderman, Hoddinott, & Kinsey, 2006). Specifically, when iron and iodine intake are deficient in infancy, cognitive development is delayed (Hynes, et. al., 2013; Pasricha, et. al., 3013; Tran, et. al., 2013). When children’s physical and cognitive development are impaired, their subsequent educational attainment is inhibited (Peet, et. al., 2015). If these children cannot perform well on entrance exams because of early childhood malnutrition, they have fewer opportunities for secondary and post-secondary education. Without higher levels of education, their opportunities to be employed become more limited. The long term childhood malnutrition in South Africa is resulting in adults with less education and decreased cognitive development. This has obvious consequences for the
development of South Africa as a nation, given that a large part of its working population has learning deficits due to childhood nutritional deficiencies.

What serves as a further detriment is that childhood undernutrition can have impacts throughout a person’s life, and undernutrition can be passed on through generations. When mothers who were undernourished as children become pregnant, their babies are significantly more likely to be undernourished, leading to a cycle of malnutrition (Black, et. al., 2013). Pregnant women who are undernourished have higher maternal mortality rates and are more likely to give birth to undernourished babies. These undernourished infants face increased mortality rates and impaired physical and cognitive development. They are also more prone to infections as children and chronic diseases once they reach adulthood (Guerrant, et. al., 2009). As these infants grow into undernourished children, they become growth stunted, have poor motor development, and have decreased mental capacity. All of these issues, stemming from malnutrition, continue into adulthood and impair their ability to be productive members of society. Once adolescents, the decreased mental capacity continues which decreases their capacity to work. There is further growth stunting and low strength development (Tzioumis & Adair, 2014). This results in undernourished women who have physical and cognitive deficiencies, and who produce undernourished infants. Undernutrition is truly a cyclic problem, and will propagate into new generations unless there is a significant intervention.

Undernutrition has been a problem in rural South Africa since at least 1994, meaning that there are now two generations of undernourished children (Kimani-Murange, et. al., 2010). For South Africa to maintain its workforce and avoid long term physical and cognitive disabilities within its population due to childhood undernutrition, policies and programs need to address childhood malnutrition in rural areas.
In South Africa, 75,000 children do not make it to their fifth birthday each year, and there continues to be substantial problems with childhood undernutrition (Child and Maternal Health, 2016). There have been focused efforts by the UN, UNICEF, and the South African government to lessen childhood undernutrition, but it is a continuing problem. To combat malnutrition, key vitamins and minerals have been added to flour and sugar sold in South Africa in order to reduce diseases from nutrient deficiencies. These minerals include iron and zinc, and vitamins such as riboflavin, folic acid, and vitamin B12. As a group, these vitamins and minerals prevent iron deficiency anemia and protect against delays in cognitive development (Why Fortify…., 2016). Unfortunately, this does not benefit a significant proportion of South Africa’s rural population who grow their own food and cannot afford to buy commodities such as flour and sugar. Another effort to reduce childhood malnutrition has been to educate women about breastfeeding (Child and Maternal Health, 2016). When educating women on breastfeeding, the focus has been on breastfeeding exclusively for the first six months of their child’s life. However, even with educational initiatives such as the Tshwane declaration, there have been no significant changes in childhood malnutrition since 1994 (The Tshwane declaration…., 2011; World Health Organization, 2010). Lastly, there have been some efforts to expand access to primary healthcare in rural areas, such as the National Public Health Institute of South Africa Bill and the National Health Insurance (Minister of Health, 2015; WHO, 2010). Unfortunately, these programs haven’t been on a large enough scale to produce actual change in children’s nutritional status. In sum, there have been various efforts to reduce child malnutrition, but none of them have been sufficient to actually improve the nutritional status of children in rural South Africa as a whole.

To more effectively reduce childhood undernutrition, this study’s findings support investing in education and providing households with information about more productive
farming techniques. Similar to numerous studies throughout the world, data from this study indicate that investing in education is one of the most effective ways to reduce childhood undernutrition. Programs that encourage early enrollment in school, and support students applying for secondary school may improve child health. Further, there is a need for more adult education about nutrition and which foods foster child health. Additionally, in this area, farming is not protective of childhood nutrition. These data suggest that increased ability to farm correlates with decreased child nutrition. Encouraging residents to grow foods higher in micronutrients and engage in practices for improved crop yield may improve childhood nutrition. In all, these findings suggest ways to reduce childhood undernutrition, particularly through education and growth of more nutrient rich foods.

**Conclusion**

This study provides a quantitative assessment of childhood nutrition in the AHDSS. Undernutrition, indicated by growth stunting, underweight status, and wasting syndrome, continue to effect a significant proportion of rural South African children. Data from 2011 indicate that the proportion of children growth stunted, underweight, and experiencing wasting syndrome was 26%, 6%, and 2% respectively. This means that approximately one in four children in the AHDSS was experiencing long-term undernutrition in 2011, and more than one in twenty children was experiencing acute undernutrition. These data are unique because this quantitative measurement of childhood undernutrition can be tracked over time to assess how well various interventions and policies are decreasing childhood undernutrition. Unfortunately, there has been very little change in undernutrition in rural South Africa since 1994. These findings indicate that education is positively correlated with child nutrition, and a commitment to
programs and policies that elevate the education in this population will likely improve childhood nutrition.

Acknowledgements

This study received funding from the Undergraduate Research Opportunities Fund at the University of Colorado Boulder. I am grateful to Dr. Lori Hunter and Dr. Suzanne Nelson for their considerable time spent editing this thesis. I am also thankful for Dr. David Sherwood for his administrative help. Dr. Wayne Twine at the University of Witwatersrand, South Africa is appreciated for his role in data collection. I am grateful if Philip Pendergast for his assistance with the statistical analysis. All photos were taken by Dr. Lori Hunter.

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