ABSTRACT

Title of Dissertation: RELATIVE IMPACTS OF DETERMINANTS OF CHILDHOOD STUNTING IN MALAWI

Jasbir Kaur, Doctor of Philosophy, 2019

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Background: High rates of stunting have persisted in Malawi for several decades. There is a need to better understand trends and determinants of childhood stunting in the population to inform effective policies and programmatic interventions.

Objective: To analyze levels, trends, and distribution of stunting in a nationally-representative population of Malawian children under age five, and to analyze determinants and micronutrient levels associated with stunting in subset of children under age two.

Design: The study analyzes data from the Malawi Demographic and Health Surveys in 2000, 2004, 2010 and 2015–16 and the Malawi Micronutrient Survey in 2015–16. Stunting in children is defined as height-for-age index more than two standard deviations below the reference medium. Bivariate and multivariate analyses are used to estimate the change in stunting by socio-demographic variables, and impact of environmental enteropathy, water sanitation and hygiene, access to food, infant and young child feeding practices, women's empowerment, domestic violence, and biomarkers of nutrition, specifically iron- deficiency anemia and vitamin A deficiency controlled for inflammation in children ages 0–59 months, adjusted for sampling design effects.

Setting: Malawi is a landlocked country, divided into three regions: the northern, central, and southern regions.

Subjects: Children ages 0–59 months with data on anthropometric measurements from the MDHS survey in 2000 (n=9,188), 2004 (n=8,090), 2010 (n=4,586), and 2016 (n=5,149), and from the MNS survey in 2015–16 (n=2,018).

Results: The prevalence of stunting decreased in children from 54.3 percent in 2000 to 36.6 percent in 2016. Child's household structure (a finished roof), child's age, gender, birth order and birth interval, household wealth, land ownership, mother's education, mother's stature and BMI, and mother's age appear to be the strongest determinants of childhood stunting. With addition of biomarkers of nutrition, inflammation, and inherited disorders, age of the child, birth order, and mother's report of child's size at birth and household hunger are major determinants of childhood stunting. At the cellular level, serum ferritin, retinol binding protein, and sickle cell disease and alpha-thalassemia are strongly associated with stunting in children.

RELATIVE IMPACTS OF DETERMINANTS OF CHILDHOOD STUNTING IN MALAWI

by

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List of Abbreviations

AGP	alpha-1-acid glycoprotein
AIDS	acquired immunodeficiency syndrome
EA	enumeration area
CDC	Centers for Disease Control and Prevention
CHSU	Community Health Services Unit
CRP	C-reactive protein
DBS	dried blood spots
DHS	Demographic and Health Survey
FISP	farm input subsidy program
G6PD	glucose 6-phosphate dehydrogenase
GOM	Government of Malawi
GPS	Global Positioning System
HAZ	Height-for-age Z-score
HHS	household hunger scale
HIV	human immunodeficiency virus
HPLC	high performance liquid chromatography
IDA	iron deficiency anemia
IRB	Institutional Review Board
LNS	lipid based nutrient supplement
MAM	Moderate acute malnutrition
MDHS	Malawi Demographic and Health Survey
MRDR	modified relative dose response
NCHS	National Center for Health Statistics
NSO	National Statistical Office
RBP	retinol binding protein
SAM	severe acute malnutrition
SD	standard deviation
sTfr	soluble transferrin receptor
sTfR	serum transferrin receptor

UNICEF	United Nations Children’s Fund
USAID	United States Agency for International Development
WAZ	Weight-for-age Z-score
ZOI	Zone of Influence

Chapter 1: Introduction

Stunting, or low height-for-age, develops in the critical first thousand days of life (from conception to 24 months postpartum). This is the critical period for child growth [1]. Children who are stunted not only have short stature; stunting affect’s adult height, and has devastating long-term consequences and suboptimal function, including impaired health, survival, educational and economic performance later in life [2]. Other consequences of stunting include a compromised immune system [3] and impaired cognitive ability [4]. A growing body of research shows that stunting in the first two years increases the risk of obesity due to impaired fat oxidation [5] and elevated blood pressure [6]. In countries with high childhood stunting, prevalence of stunting starts to rise at the age of about three months, and process of stunting slows down at around three years of age. Thereafter, the mean height runs parallel to the reference. For younger children (under 3 years), therefore, height-for-age reflects a process of “failing to grow” or “stunting.”

In Sub-Saharan Africa, stunting rates are as high as 60 percent in children under age 5. Yet in the past 2 decades, there has been minimal impact of nutritional programs on stunting outcomes at the programmatic level, and the overall levels of stunting in Sub-Saharan Africa have not changed much [1]. Earlier interventions in the nutrition field assumed that children were not growing well because they were not eating foods dense in protein and calories [7]. Findings from a review of over 35 efficacy trials and intervention studies showed that children receiving dietary interventions grew an average of 1.7 cm taller by 12–24 months than children who did not receive any nutrition interventions. However, children receiving nutritional interventions did not achieve “normal growth” [8].

Given the recent evolution in thinking about the causes of stunting and undernutrition – i.e., that multiple dietary and non-dietary factors intersect and interact to produce child nutritional outcomes, it is now globally recognized that multi-sectoral nutrition approaches, including both nutrition-specific and nutrition-sensitive interventions are required for accelerated progress.

The nutrition-specific interventions address the immediate determinants of malnutrition such as dietary diversification, breastfeeding, complementary feeding, micronutrient supplementation, feeding and care practice, food safety and food processing among others. Whereas the nutrition-sensitive interventions address the underlying and systemic causes of nutrition such as agriculture and food security, water, sanitation, hygiene (WASH), women’s empowerment, girl’s and women’s education, social safety nets, etc. [9, 10].

Malawi

Malawi has the fifth highest stunting rate in the world, and more than 53 percent of children below the age of five were stunted in 2000 and 2004. The prevalence of stunting decreased to 47 percent in 2010. Although the prevalence of stunting remains high, the recent Demographic and Health Surveys (DHS) survey in 2015-16 in Malawi showed a remarkable decrease in the stunting levels (37 percent) in children under age 5.

Stunting is typically caused by chronic inadequate diet and illness. Malawian diets consist of staple foods, maize, followed by rice and cassava. While maize and other staple crops ae high in carbohydrates, they are low in vitamins and minerals. As a result, meals are often adequate in terms of total calories or quantity. Consequently, in terms of nutrient adequacy at the household level, some of the Malawian children may be getting enough to eat in terms of total calories but consumption of nutrient-rich foods such as meat, fish, eggs, dairy, legumes, fruits and vegetables is low, on a regular basis. Adequate nutrition requires both – sufficient total calories (quantity) and enough total vitamins and minerals per calorie (quality). Studies have shown that without a high-quality diet, even those children who are able to get sufficient food and calories suffer from undernutrition [11].

Demographic and Health Surveys

The MEASURE DHS (Demographic and Health Surveys) project is a United States Agency for International Development (USAID)-funded survey program that is considered the gold standard for population and health data collection in the developing world. The nationally- and regionally- representative household surveys are carefully designed to collect reliable, representative, and cross-nationally comparable data on a wide range of key population and health variables at specific levels of disaggregation, qualified by confidence intervals that show the precision of the survey estimates. The data from these surveys have been critically important both to host country institutions and to donor agencies in planning, monitoring and evaluating population, health, and nutrition programs. Women age 15–49 years and men age 15–54 years are interviewed on a wide range of topics, including their socio-demographic status, fertility levels and desires, contraceptive use, and use of maternal and child health services.

The DHS surveys use model questionnaires and standardized data formats to ensure that data are comparable across countries. Female respondents are asked detailed questions about health and nutrition including, diet of their children born in the last five years. DHS questionnaire includes questions on whether a child ate foods from various food groups in the previous 24 hours. The nutritional status of children and women is determined through anthropometry and anemia testing. Studies have also shown that information available in the DHS datasets can be used effectively to create indices with sufficient variability, are generally normally distributed and are associated with nutritional status of the population [12].

Malawi Micronutrient Survey

The Malawi Micronutrient Survey (MNS) 2015–16 was designed to determine the prevalence of micronutrient deficiencies, specifically, vitamin A, vitamin B12, folate, iron, iodine, and zinc. Other biomarkers tested included markers of inflammation, infection, and inherited blood disorders. In addition to evaluating the prevalence of anemia in children and adults, the survey also estimated the coverage of micronutrient supplementation and fortification. Data collected from preschool children (6–59 months) comprises of the study sample.

Given the very high prevalence of stunting in the country, and need for multi-sectoral nutrition approaches, including both nutrition-specific and nutrition-sensitive interventions, as well as the availability of rich datasets for a very large sample size, data from the Malawi Demographic and Health Surveys (MDHS), 2000, 2004, 2010 and 2015–16 and MNS Survey 2015–16, the study investigates individual and combined effects of proximate determinants of stunting including dietary diversity, water, sanitation and hygiene (WASH), infant and young child feeding (IYCF) practices, environmental enteropathy (EE), and household access to methods of food production (landownership), women's status (participation in decision-making and domestic violence) and their relative impacts in children ages 0-23 months. In addition, the study examines the relationship between stunting and biomarkers of nutrition, specifically iron deficiency anemia and vitamin A deficiency in children ages 0–59 months.

Research Objectives

The objective of the current research is to investigate the individual and combined effects of the proximate determinants of childhood stunting in Malawi using the DHS datasets from four survey cycles between 2000 and 2015, and the data from the MNS Survey (2015–16) . The specific objectives are as follows:

1. To evaluate trends in stunting and provide key insights into specific demographic variables associated with stunting in children ages 0–59 months using data from the MDHS surveys in 2000, 2004, 2010 and 2015–16.
2. To investigate individual and combined effects of proximate and distal determinants of childhood stunting in children ages 0–23 months using data from the MDHS survey 2015-16.
3. To assess the relationship between childhood stunting, proximate and distal determinants of stunting and biomarkers of nutrition, specifically iron deficiency anemia, vitamin A deficiency, zinc deficiency, selenium, markers of infection, and inherited blood disorders in children ages 0–59 months.

The study contributes to the exploration of the various determinants of stunting in children. Finding of the study is expected to have a significant potential programmatic benefit in terms of providing empirical support for re-orientating nutrition programs to include other proximate determinants of food security, more specifically nutrition-specific and nutrition-sensitive factors, as well as biological markers, as contributors to child growth.

Chapter 2: Background and Review of Literature

Malawi is a small land-locked Sub-Saharan African country that is located south of the equator. It borders Tanzania, Mozambique and Zambia. Malawi’s economy is primarily agriculture based providing 85 percent of Malawi’s domestic exports. Agriculture in Malawi is mainly rain-fed and hence makes it vulnerable to climatic shocks. Malawi’s ability to maintain food security and its overall economic development have been stifled due to high rates of undernutrition, human immunodeficiency virus (HIV) and acquired immunodeficiency syndrome (AIDS), malaria, poverty (53 percent of population lives below the poverty line), underdeveloped markets, and low agricultural productivity. Food insecure months are generally January through April, and the annual harvest generally occurs in April-May [13].

Malawi has one of the highest rates of chronic malnutrition in Africa and fifth highest stunting rate in the world, affecting more than half of children under age five. Prevalence of stunting is 47 percent and about 20 percent of children are severely stunted [14]. Stunting results from persistent lack of nutritious food and infectious diseases accompanied by inadequate child and maternal care [1]. The key determinants of child undernutrition are food insecurity, poverty and high rates of illiteracy, especially among women [15]. Other underlying factors have also been identified, including infections and illnesses such as malaria, diarrhea, respiratory infections, and HIV/AIDS. Poor infant and young child feeding practices are also known contributors to child undernutrition. Identification of these variables and the fact that nutrition interventions in past 3 decades have had marginal impact have prompted researchers to investigate other pathways that could lead to child undernutrition, specifically stunting [16, 17].

Life expectancy in Malawi is only 53 years. Approximately 57 percent of children suffer from vitamin A deficiency [14] and 13 percent of infants are born with low birth weight. The prevalence of anemia in children 6–59 months of age is 63 percent and more than 80 percent of children age 6–11 months have hemoglobin levels less than 11 g/dl [14]. Malawi's outlook on food security and nutrition has been shaped by its challenge with hunger and the Government of Mali (GOM) strong commitment to achieve food self-sufficiency and improve nutritional status of children [18].

Malawians generally eat a maize based dish (*nsima*), rice, cassava, and potatoes. *Fufu* made from cassava root, *kandowole* made from cassava flour, sorghum, and *mandasi* (doughnut) are also consumed as the source of energy. *Nsima* in the shape of patties is served with *ndiwo*, a sauce that is made of beans or vegetables. Vegetables generally comprise of cassava leaves, sweet potato leaves, bean leaves, pumpkin leaves, cabbage, mustard leaves, rape leaves, or kale leaves and cabbage. In the wealthier households, *ndiwo* is prepared with vegetables, meat (goat) or fish. In addition, some insects and termites are consumed [19-21].

Maize (corn) is the dominant crop and food consumed in Malawi while fishing in Lake Malawi is practiced as an important source of income and contributes to two-third of the animal protein intake. Livestock ownership and its consumption is low [19]. About half of Malawi's available food supply is comprised of maize and only 15 percent of the population consumes milk, meat, or eggs on a consistent basis [22]. Arimond and Ruel [23], in their analysis of data from 11 DHS countries, found an inverse relationship between dietary diversity and stunting in Malawian children ages 6–23 months.

Infant and young child feeding practices

In the domain of nutrition and food security, information is frequently unavailable at the household level because most routine surveys do not include questions on food insecurity (WFP, 2006). As stated earlier, Malawian diets consist of staple foods, maize, followed by rice and cassava. While maize and other staple crops ae high in carbohydrates, they are low in vitamins and minerals. As a result, meals are often adequate in terms of total calories or quantity. Therefore, in terms of nutrient adequacy at the household level, some of the Malawian children may be getting enough to eat in terms of total calories but consumption of nutrient-rich foods such as meat, fish, eggs, dairy, legumes, fruits and vegetables is low on a regular basis. Adequate nutrition requires both – sufficient total calories (quantity) and enough total vitamins and minerals per calorie (quality). Studies have shown that without a high-quality diet, even those children who are able to get sufficient food and calories suffer from undernutrition [11]. For instance, Uganda is considered the “bread basket” of the region with plenty of local production and access, yet stunting is as high as 47 percent in some regions [24].

Dietary diversity and indices can be used as proxies for measuring overall **dietary quality** in different countries. Various studies have developed scoring systems to explore dietary diversity at the household level [25]. Food variety and dietary diversity scores derived from DHS-type surveys that include qualitative recall of consumed food items have served as simple scoring tools and have been validated to clearly reflect dietary quality [26, 27].

Dietary diversity is defined as the number of different foods or food groups consumed over a given reference period. Consistent associations have been found between dietary diversity and indicators of food consumption and food availability; higher diversity of diets is positively associated with child's anthropometric status and hemoglobin concentrations, and highly correlated with caloric and protein adequacy. There is overwhelming evidence that dietary diversity has a consistent positive association with child's growth and nutritional status [28].

Other studies have shown that dietary diversity is positively associated with anthropometric outcome measures, including stunting [29, 30]. In fact, lack of diversity is a strong predictor of stunting after controlling for breastfeeding status, morbidity, gender, and mother and household characteristics in children under age 5 [30].

The IYCF interventions thus far have proven to be the most preventive health and nutrition intervention with the greatest impact on child survival. The early initiation of breastfeeding impacts neonatal mortality, six months of exclusive breastfeeding has a significant effect in reduction in infant deaths caused by diarrhea and pneumonia, and continued breastfeeding from 6 to 23 months offer protection against illnesses such as diarrhea and respiratory infection [31-33]. Studies have shown that appropriate infant feeding practices are associated with increases in height and weight among children age 0–24 months [34]. Dietary diversity, timely introduction of solid foods and consumption of iron rich foods in children under 24 months of age results in significant reduction in both underweight and stunting [8, 35].

There is strong evidence that young child feeding practices affect the nutritional status of children under 2 years of age [32]. For example, analysis of the National Family Health Survey, 2005-06 data for over 18,000 Indian children revealed that it is not the early initiation or duration of breastfeeding that is associated with nutritional outcomes but the consumption of solid foods or semi-solid foods between 6–9 months that is significantly associated with being underweight. The study also found that having a minimum dietary diversity score, i.e., consumption of 4 or more food groups was significantly associated with stunting and wasting [36]. Similar observations on timely introduction of complementary foods and height-for-age Z-score (HAZ) have been found in other studies [37]. Data from Peru indicate that consumption of milk and milk products are highly correlated with linear growth [38].

A study in Malawi showed that children in the intervention group consumed more diverse diets, had higher proportion of energy, and protein (from animal sources) compared to children receiving habitual rural maize-based diets. The intervention increased the Z-scores for mid-upper arm circumference (MUAC), arm muscle area, and hemoglobin, but the intervention had no impact on height or weight gain of children 30-90 months [39]. Similarly, Malawian children ages 6-18 months that received energy-dense complementary food showed a modest increase in weight gain, but no gains were observed for linear growth [40].

Of the eight core indicators of infant and young child feeding practices, the study will analyze 1) early initiation of breastfeeding, 2) Age appropriate breastfeeding, 3) Minimum Dietary Diversity, 4) Continued breastfeeding at 1 year, 5) Consumption of iron-rich or iron-fortified foods. The indicator on minimum dietary diversity will be analyzed as a separate independent variable. Using the DHS data, it is not possible to calculate the indicators on meal frequency and minimum acceptable diet [33].

IYCF status report in Malawi indicates that the rate of early initiation of breastfeeding is 58 percent, exclusive breastfeeding in children under age6 months is 57 percent and, continued breastfeeding is about 72 percent. About 89 percent of children ages 6–9 months who are breastfed consume complementary foods. Malawi seems to have adequate IYCF health service counseling, but community level actions and comprehensive IYCF monitoring and evaluation remain poor [41].

Breastfeeding is almost universal in Malawi but exclusive breastfeeding for the first six months is low. The main complementary food for infants is a plain porridge, which is low in energy and nutrition content and is offered at low meal frequency. The adult diet is bulky but has a low meal frequency too. Rural diets are generally dominant in maize – Malawians get enough calories to stave off hunger (from grains and cereals), but do not have diverse diets leading to micronutrient deficiencies, often called as "hidden hunger" because it occurs even when the diets include adequate amount of energy (calories) [42].

Most iron comes from vegetable sources and foods from animal sources are rarely eaten. Despite limited dietary diversity, large within-person variation in nutrient intake is observed among pregnant women in rural Malawi. The study suggest that poor individuals may have higher intra-individual variability because of irregular access of locally produced foods. Energy intakes (fat, carbohydrates, protein) and zinc, vitamin A and C are significantly higher during harvest and post-harvest seasons; however, calcium and vitamin C intakes are significantly higher during the pre-harvest season [20].

Arimond and Ruel [23], in their analysis of 11 DHS countries, concluded that dietary diversity may even be more important for children who rely on complementary foods rather than breastmilk for their energy and nutrient requirements. The analysis was based on a 7-day dietary recall as opposed to a 24-hour recall of foods consumed by children –recall bias from 7-day dietary recall has implications for data quality and 24-hour dietary recalls are considered more accurate [43]. The study did not explore other pathways (described below) that are likely determinants of stunting.

Household wealth, Food Access & Hunger

Food access is having sufficient resources, both economic and physical, to obtain appropriate foods for a nutritious diet. Even though food may be available in the market, it may not be accessible to households that cannot afford it. In fact, some of the major famines in the world, including the one in Malawi in 2002 were a result of market shocks resulting in inability of the households to buy food even when food was available in the market. Therefore, purchasing power of the household is exceedingly important in mitigating the effects of food insecurity on nutritional status of children.

About half of children (47.1 percent) in Malawi are undernourished and though wealth is inversely related to stunting levels, stunting is high even in the highest wealth quintile (36 percent) [14]. In addition, 90 percent of population lives in rural areas [19], and 75 percent of rural households in Malawi have no access to markets. A distance of at least 10 km needs to be covered to reach the nearest market. In fact, only 41 percent of rural households’ food consumption is based on purchases, whereas, about half (49 percent) of the rural households in Malawi depend on their own production. However, increasing on-farm diversity is not always the most effective way to improve dietary diversity in smallholder households. In fact, market access has positive effects on dietary diversity, which are larger than those of increased production diversity [44].

Environmental enteropathy and Water Sanitation and Hygiene (WASH)

Researchers believe that there are biologically plausible pathways including enteric infections that may be responsible for continued growth faltering in children despite nutrition interventions [45, 46]. Inadequate or poor nutrition can lead to reduced immunity to infection. Malnutrition and infection interact synergistically to form a vicious cycle of growth faltering. Infections such as diarrhea lead to pathogenic damage to the intestinal lining leading to increased nutrient requirements, maldigestion and malabsorption of food further resulting in less absorption of energy. The damage and inflammation of the mucosal lining also stimulate inflammatory and immune response to repair damaged tissue and fight infection and therefore, leaving less energy available for growth [47, 48]. It is estimated that children with diarrhea in the first 1000 days are likely to have an 8 cm growth shortfall and impaired cognitive development (10 IQ point decrement) by the time they are 7–9 years of age [46]. Weisz et al (2011) found that greater duration of diarrhea was associated with greater reductions in HAZ. [49]. A pooled analysis of 9 studies between 1978 to 1998 from Africa, Asia and Americas showed a cumulative impact of diarrheal episodes on stunting by 2 years of age [16].

With mounting evidence of the role of diarrhea in childhood stunting, there is much focus on diseases or infection control programs such as WASH. Poor WASH practices lead to a sub-clinical disorder called environmental or tropical enteropathy. WASH interventions reduce episodes of diarrhea – with 99 percent coverage –it reduces prevalence of stunting by 2.4 percent (entirely modeled through reductions in diarrhea). Children living in very poor conditions do not recover from the chronic effects of EE, and hence EE may be an important pathway to stunting than diarrhea.

EE is a subclinical condition caused by constant fecal-oral contamination that results in blunting of intestinal villi (decreased villous height) and intestinal inflammation leading to impair intestinal absorptive and immunologic functions [50]. EE is almost universal in developing countries due to chronic exposure to feco-oral bacteria [51]. In addition, EE also leads to ‘leaky gut’ i.e., an increased permeability of the intestinal tract and impaired ability to prevent pathogens from breaching the intestinal barrier. This leads to an elevated immune response, within which nutrients gets further diverted from growth to fighting infection [46].

EE is not found in fetuses or newborns suggesting that it is the unhygienic conditions during early childhood that initiates a chronic intestinal pathology that only resolves when living conditions are improved. The cause of EE is likely to be multifactorial, including microbial contamination of food and poor hygiene practices [52]. EE occurs when young children ingest large quantities of fecal bacteria, which then harbor in the small intestine and induce EE through a T-cell mediated process. The increased permeability of the atrophied villous facilitates translocation of microbes, which in turn triggers the metabolic changes of the immune response. EE is a universal condition among children in developing countries and may mediate stunting [16, 51]. In a recent study in Bangladesh, fecal samples of children were tested monthly from birth to until two years. The study computed microbiota-for-age Z- score that significantly correlated with the chronological age of children with healthy growth phenotypes.

Applying the metrics, it was found that moderate acute malnutrition (MAM) and severe acute malnutrition (SAM) have gut microbiota that are immature, i.e., the representation of the age-discriminatory taxa in their gut communities was more similar to younger instead of age-matched healthy children of the same locale. The degree of immaturity was greater in SAM than MAM [53].

EE is commonly observed in preschool age Malawian children living in poverty and is associated with stunting [52, 54]. By transplanting microbiota from 6- and 18-months healthy and undernourished Malawian children into young germ-free mice fed a Malawian diet, showed that immature microbiota from undernourished children ages 0-3 years, transmitted impaired growth phenotypes. This study provides evidence that microbiota immaturity is causally related to undernutrition [53], and gut microbiome as a causal factor in Kwashiorkor [55, 56]. A similar study in Malawi found that IgA responses to several bacterial taxa correlated with anthropometric measurements of nutritional status in longitudinal studies and hence bacterial targets to IgA responses may have etiologic, diagnostic, and therapeutic implications for childhood undernutrition [57]. It has been estimated that up to 43 percent of growth faltering is attributable to long term intestinal lesions in children ages 2–15 months[45]. EE together with reduced nutrient absorption leads to growth faltering in the first 2 years of life due to high growth demands during this period [58]. In a multi-country analysis of the effects of diarrhea on stunting, it was observed that every episode of diarrhea led to a 1.5 percent increase in the probability of stunting in children at 2 years of age [59]. In addition to malabsorption, inadequate dietary diversity further results in growth faltering and lowered immunity to infections. This is evident by the fact that micronutrients reduces EE in rural children in Malawi [52].

Children with severe acute malnutrition have higher mean stool weight and higher lactic acid content that are consistent with carbohydrate malabsorption. A pH of less than 5.5 and presence of reducing substances in the feces are indicative of carbohydrate intolerance and malabsorption (both monosaccharides and disaccharides) because of villous atrophy[60]. Resistant starch has been shown to decrease intestinal inflammation in some animal and human studies. However, it did not reduce gut inflammation in rural Malawian children [61].

Malawians diets are heavily dominated by staple foods, maize, followed by rice and cassava. Plant based diets consumed by Malawian children are important sources of phytic acid which complexes with divalent cations, forming insoluble compounds in the intestine which inhibit the absorption of certain trace elements, particularly zinc. Dietary studies of Malawian children have documented that high phytate content of the maize diet leads to zinc deficiency [62]. The intestinal permeability is known increase with zinc deficiency, mainly due to lactulose permeation. Abnormal permeability of the intestine also leads to higher obligate endogenous fecal zinc losses [62]. Thus, zinc deficiency and EE are interacting factors that may propagate overt clinical condition in children with overlapping causes of enteropathy [54].

Children with poor quality diets may be exposed to aflatoxin, a fungal metabolite that contaminates inadequately stored crops such as maize and peanuts. Aflatoxin impairs intestinal integrity in animal models and is associated with stunting in children, potentially through the same pathway as EE [16]. On the other hand, micronutrients found in commonly consumed grain legumes such as cowpea and common beans may reduce stunting and EE in high-risk population [63]. From these studies, it is becoming increasingly apparent that childrens diet, environment, gut microbiota, and health are inextricably linked [64].

According to the World Health Organization (WHO), repeated diarrhea or intestinal worm infections caused by unsafe water, inadequate sanitation or insufficient hygiene is associated with about half of malnutrition worldwide. Recent literature suggests that EE may be attributed to the failure of nutritional interventions and oral vaccines in developing countries [65]. More than 43 percent of growth faltering in Gambian children is associated with chronic inflammation of the mucosa of the small intestine caused by EE [66]. Similarly, after adjusting for potential confounders, a study in Bangladesh observed that children from clean households had 22 percent lower stunting prevalence compared with children from contaminated households. These households were examined for water, sanitation, and hygiene conditions. Distinction between clean and contaminated households was based on stool collection and parasite assays [67].

Diarrhea is one of the most important mediators through which poor sanitation affects nutritional status [68]. The high prevalence of common childhood illnesses, especially diarrhea, can have a negative effect on linear growth in children [34]. Even when food consumption is sufficient, unsafe water, poor sanitation and hygiene leads to diarrhea, inhibiting nutrient absorption. If diarrhea does not kill a child, repeated bouts create a vicious cycle of diarrhea and undernutrition (underweight and stunting), reducing a child’s resistance to infections. This phenomenon, which leads to stunting in children, has been observed in Asia, Africa and Latin America [16, 46, 69]. In a pooled analysis of nine community based studies showed that the odds of stunting at 24 months of age increased multiplicatively with each diarrheal episode or day of diarrhea. The proportion of stunting attributed to five previous episodes of diarrhea was 25 percent [70].

WASH interventions include a provision to clean piped drinking water, facilities for excreta disposal, promotion of handwashing with soap after defecation, and disposal of child feces, prior to preparing and handling food and before eating [71]. In Malawi, access to safe water is 74 percent, access to improved sanitation is 47 percent, while access to basic sanitation, including traditional latrines is as high as 88 percent, but good hygiene practices are low with only 37 percent of the population practicing better hygiene [72].

Maternal factors and women's empowerment

Among the non-nutritional factors, gender equality and women's empowerment have a strong impact on children's nutrition. Women's empowerment, mother's emotional and mental health is highly associated with child nutrition and development [73]. The nutrition-sensitive program and approaches highlights the critical importance of female empowerment given the role that women play as mothers, caregivers, farmers and income earners [10].

Women's empowerment or autonomy is most often measured by women's participation in household decision-making, which is most frequently associated with nutritional outcomes in children under five [74, 75]. Mother's participation in making household decisions is associated with 15 percent less stunting, 16 percent less wasting and 32 percent less underweight children [76]. Women's empowerment is significantly associated with length-for-age, specifically the domains of access to and decisions regarding credit, autonomy in production, and satisfaction with leisure time [77].

On the other hand, domestic violence against women is an indicator of disempowerment [78]. Children's exposure to domestic violence, whether direct prenatal exposure (altered uterine exposure as a result of pregnant mother's experience with domestic violence), and direct or indirect post-natal involvement is significantly associated with higher odds of stunting and severe stunting in Kenyan children ages 6-59 months whose mothers were exposed to any or only physical domestic violence [79]. Data from 42 DHS surveys from 29 countries showed that stunting was positively associated with mothers' exposure to physical violence and sexual intimate partner violence [80]. A longitudinal study of pregnant women in Bangladesh observed lower height and weight at birth, smaller changes in weight-for-age Z-score (WAZ) and HAZ from ages 0–24 months, and lower WAZ and HAZ at 24 months of age with exposure to any domestic violence [79]. Similar observations from other studies [78] underscores the effect of domestic violence on nutrition and growth of young children.

Markers of nutrition, infection and inflammation

Stunting is primarily due to chronic deficiency of energy, protein and micronutrients, especially iodine or zinc. Nutritional biomarkers offer physiological evidence of micronutrient deficiencies and stunting.

The nutritional biomarkers[1] provide a more objective assessment of nutritional status since they are highly correlated with dietary intake and are independent of errors associated with questionnaire data, including the recall bias [81]. A national micronutrient survey in Malawi found that 80 percent of preschool children have anemia and 58 percent have iron deficiency anemia, and 59 percent have iron deficiency anemia (IDA) by Hb and transferrin receptor. Hence, WHO classifies anemia as a public health problem in Malawi. Similarly, vitamin A deficiency is also considered a clinical public health problem as 60 percent of preschool children have serum retinol values of less than20µg/dl.

Findings from epidemiological studies indicate that current infections and micronutrient deficiencies are proximal determinants of stunting [82]. Hemoglobin (Hb) level is the most reliable indicator for diagnosis of anemia. Iron deficiency anemia is the common cause of anemia and stunting [83-85] and impair immunity in children [84] , but the impact of iron supplementation on linear growth has been inconsistent. Likewise, retinol binding protein (RBP) is associated with Hb, and vitamin A deficiency co-exists with iron-deficiency [86]. Clinical vitamin A deficiency is associated with poor growth, but a few studies have reported increase in height when children with severe deficiency of vitamin A were given supplements [22], and most studies have not reported any significant effect on linear growth or weight gain [15].

C-reactive protein (CRP) and alpha-1-acid glycoprotein (AGP) are acute-phase proteins that are significantly lower in non-stunted children compared to stunted children

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[1] *A nutritional biomarker is a biochemical indicator of intake and/or status of a given nutrient or food component.*

[82, 87, 88]. Similarly, vitamin A and zinc are associated with stunting in children [89]. Vitamin A deficiency decreases zinc-binding proteins and impaired absorption of zinc. Further, zinc plays an important role in the metabolism of vitamin A. Zinc supplementation alone, or in combination with iron, and vitamin A has been associated with lower HAZ scores [90]. It has been shown that food insecure children have higher levels of anemia and are on average 2 cm shorter than food secure children [85].

Relationship between consumption of energy dense foods, micronutrients and stunting is complex. Siyame et al [91] found that Malawian women from Zomba and Mikalango had higher zinc deficiency (90 percent) than iron deficiency anemia (6 percent). This was attributed to diets low in zinc (median 5.7 mg/day) with high phytate:zinc molar ratios (20.0) but high in iron (21.0 mg/day) as a form of contaminated (soil) iron. Zinc is Malawian children is also found to be deficient – even after a supplementation of 7 mg Zn/day, the low plasma zinc in children rose from 23 percent at 6 months to 37 percent at 12 months [40]. It has been found that supplementation of zinc with iron and vitamin A, rather than zinc alone increases the linear growth of stunted children with low hemoglobin [92]. Research indicates that pre- and postnatal micronutrient intake results in improvements in length-for-age z-score and reduction in stunting in newborns until three months [93]. A meta-analysis of randomized controlled trials also show that zinc supplementation has a significant effect on the linear growth of children with a gain a 0.37 cm in zinc-supplemented group [70].

A recent study assessed the relationship between dietary energy density and nutritional status in children ages 1–10 years. The study found that stunting, but not other growth problems were associated with higher dietary energy density [94]. For Malawian children, the predominantly consumed corn porridge (as opposed to energy dense corn dough consumed by adults) lacks in micronutrients, particularly zinc, iron, and selenium, and has low-energy density. The addition of peanut andsoy based fortified spread to the corn porridge only increased the weight but not height in the Malawian children [40]. Similarly, in a randomized controlled study, complementing diets of Malawian children with lipid-based nutrient supplements, and supplementing diets of Malawian women during pregnancy and six months postpartum with small quantity lipid-based nutrient did not promote child growth or prevented stunting in children ages 6–18 months[95, 96].

In a randomized controlled trial, a sustained supplementation of lipid-based nutrient supplement, called FS50 containing milk protein from cow’s milk, sugar, and a mixture of micronutrients, embedded in lipid base had a positive impact upon the incidence of severe stunting [97]. Similarly, when micronutrients were added to a fortified porridge spread in Ghana, linear growth was observed among the children [40]. Whereas, Congolese and Burkinabe infants given different quantities of mono- and poly-unsaturated fatty acids showed increases in weight gain but not the length.

In a quasi-experimental design, efficacy of dietary diversification and modification was assessed in Malawian children ages 30-90 months. After a year of intervention, children in the intervention group consumed more diverse diets. They had lower risk of inadequate intakes of all nutrients examined –significant differences were observed for protein, folate, vitamin B 12, calcium and zinc,

Since most of these nutrients have a critical role in immune competence and linear growth, it is not surprising that deficiency of these nutrients has been associated in part with the high prevalence of morbidity and stunting reported in Malawian children (*ibid)*[39].

Zinc is essential for many physiological processes, and severe zinc deficiency leads to dwarfism [12]. Zinc deficiency is common in many populations [13]. Two out of three recent meta- analyses [14– 16] of clinical trials of zinc supplementation in children report a large and significant effect of daily oral zinc supplements on linear growth, especially in stunted children and in developing countries. Imdad and Bhutta [16] reported the greatest impact when zinc was given alone–children under 5 there had a net gain of 0.37 ± 0.25 cm for a dose of 10 mg zinc daily for 24 weeks.

Antenatal zinc supplementation increases fetal long bone growth [17] –this is of particular relevance because nutritional stunting is due to short femur length [18]. A study in Nepal showed a small but significant increase in height among school children whose mothers received antenatal zinc supplements [19], whereas a large study of antenatal zinc supplements had no effect on postnatal growth, but infants had reduced prevalence of diarrhea and other infections [20]. Zinc supplements have been repeatedly shown to prevent respiratory complications and diarrhea in infancy, which is also associated with stunting. A study combining zinc and anti-parasite treatment reported a positive effect of zinc on linear growth that was reduced by the presence of *Giardia lamblia* and *Ascaris lumbricoides* [21]. This indicates that the benefit of zinc may be limited because of continuing infection or by the presence of other nutrient deficiencies.

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In summary, ongoing degradation in the quality of children’s diets leads to malnutrition and micronutrient deficiencies, which are exacerbated by the health consequences of poor water quality and inadequate sanitation. This vicious cycle of malnutrition is compounded by enteric infectious diseases, which alters gut integrity and impair absorption of nutrients, resulting in further malnutrition.

The approach of USAID’s and United Nation’s flagship nutrition and food security initiatives in Malawi is to integrate nutrition into the value chain through nutrition-sensitive agricultural productivity, finance and local capacity development. Programs are targeted at the local level, focusing on increased agricultural productivity, conservation, behavior change, dietary diversification, and improved feeding for pregnant women, young children, and infants [19, 98]. Most of these programs (Feed the Future, Food for Peace, Scaling Up Nutrition, Counting to 2015, World Food Programme, International Fund for Agriculture Development, World Bank Group, Food and Agriculture Organzation’s Green Belt Program etc.), started around 2010-2011 and are currently ongoing [19]. Therefore, data from MDHS 2010 and MDHS 2015, respectively, may provide key insight into variables that are associated with food insecurity before and after implementation of national programs that included interventions, in addition to nutrition, to reduce undernutrition in young children.

Chapter 3: Methods and Procedures

Research Population

DHS surveys use multi-stage cluster sampling. The sampling is in two stages. First, the whole population is divided, on paper, into smaller discrete geographical areas, such as villages, that are called clusters. For each cluster, the population size is known or can be estimated. Clusters are then randomly selected; the chance of being selected is proportional to the cluster's population size. In other words, this is sampling with "probability proportional to population size." In the second stage, a fixed number of households are chosen at random from within each cluster area or village. Thus each household and each person in the whole area have an equal chance of being selected [99].

DHS surveys have large sample size, usually between 5,000 to 30,000 households. The selection of primary sampling units or PSUs and number of households selected is based on the core domains, including anthropometry, anemia and fertility rate. The cluster size is the number of households per women to be selected per PSU or cluster. The DHS uses a cluster size of about 30-40 women in the rural areas, and about 20-25 women in the urban sector [100]. Based on experiences of actual surveys, a study was conducted to investigate the optimal sample sizes in DHS surveys. The findings show that the optimal second-stage sample size is about 20 women per cluster. Hence, for most DHS surveys, the sample sizes meet the optimal standard or are within tolerable limits of relative precision loss [101]. The proposed study will examine the DHS data from Malawi for survey years 2000, 2004, 2010, and 2015-16.

The MNS Survey (2015-16) was conducted jointly with the MDHS 2015-16. The National Statistical Office (NSO), the Community Health Services Unit of the Ministry of Health (CHSU), and the Department of Nutrition, HIV and AIDS (funding from Irish Aid), World Bank, and the Emory Global Health Institute, and United Nations Children’s Fund (UNICEF) implemented the MNS survey. The technical assistance for the survey was provided by the Centers for Disease Control and Prevention (CDC), and Emory University. The MNS Survey 2015-16 was designed to determine the prevalence of micronutrient deficiencies, specifically, vitamin A, vitamin B12, folate, iron, iodine, and zinc. Other biomarkers tested included markers of inflammation, infection, and inherited blood disorders. In addition to evaluating the prevalence of anemia in children and adults, the survey also estimated the coverage of micronutrient supplementation and fortification. Data was collected for preschool children (6–59 months), school-aged children (6–14 years), women of reproductive age (15–49 years), and men (20–54 years).

Using nutrition data from MDHS 2000, 2004, 2010 and 2015-16 , and MNS survey, 2015-16 , the study investigates individual and combined effects of proximate determinants of household-level food security on stunting in children ages 0–23 months. The study also assesses the relationship between food security and biomarkers of nutrition specifically iron deficiency anemia and vitamin A deficiency in children ages 0–59 months.

Variable Definitions

To assess the impact of proximate determinants of food insecurity on child nutritional status (stunting) the following dependent and independent variables were examined:

Dependent Variable The *height-for-age index* provides an indicator of linear growth. Children whose height-for-age are below minus two standard deviations (-2 SD) from the median of the reference population are considered short for their age, or *stunted.* Children who are below minus three standard deviations (-3 SD) from the reference population are considered *severely stunted.* Stunting reflects a failure to receive adequate nutrition over a long period and is also affected by recurrent and chronic illness [102]. Height measurements in MDHS (2000, 2004, 2010 & 2015-16) were carried out in children 0–5 years using a measuring board developed by Shorr productions. Recumbent length was measured for children under two years of age [14].

The WHO Global Database on Child Growth and Malnutrition uses a Z-score cut off point of less than -2SD for low height-for-age and less than -3SD to define severe undernutrition [102]. However, the dependent variable, stunting was defined as moderate-to-severe. If a child’s height-for-age is 2 SD below the reference median (moderate-to-severe), it was coded as ‘1’, otherwise ‘0’.

Independent Variables: Variables that have been shown to be associated with childhood nutritional status in previous research was drawn from the household and woman’s data file [103]. The independent variables included in the analyses, and their definitions are as follows:

The individual **dietary diversity** scores for both women and children are part of DHS surveys. The survey included questions on whether a child ate foods from various food groups in the previous 24 hours. The dietary diversity indicator used for the analysis was created from 24-hour recall of consumption of foods listed in the DHS questionnaire. These food groups emphasize micronutrient intake and not just economic access to food [31-33].

Dietary diversity was calculated as a dichotomous variable reflecting whether a child age 6-23 month has consumed four or more of the seven food group listed below:

1. Grains, roots and tubers
2. Legumes and nuts
3. Dairy products (milk, yogurt, cheese)
4. Flesh foods (meat, fish, poultry and liver/organ meats)
5. Eggs
6. Vitamin-A rich fruits and vegetables
7. Other fruits and vegetables

The variable on consumption of iron-rich food was also dichotomous, reflecting a child's consumption of organ meat, flesh meat, or fish.

To derive the dietary diversity score, each food group was first computed to include all foods eaten in that food group. For example, all foods in the grains, roots and tubers group were identified. In Malawi, children generally eat baby cereal, porridge, breads, and noodles, other foods made from grains, potatoes, cassava, and other tubers. Each food item identified was then computed as '0' for not consumed and '1' for consumed in the past 24 hours. Therefore, a child who consumed any of the foods, i.e., ‘1’ for baby cereal, ‘1’ for porridge, ‘1’ for noodles, ‘1’ for bread, ‘1’ for other grains, ‘1’ for potatoes, ‘1’ for cassava and ‘1’ for other tubers was grouped as ‘yes’ or ‘1’ for grains, roots and tubers. Similarly, foods in other food groups were identified and computed. In all, eight food group variables were computed. The dietary diversity score was created by summing the number of different food groups that were consumed by a child in the 24 hours preceding the survey interview.

Based on the consumption, children were dichotomized into the following categories:

- Low dietary diversity (≤ 3 food groups), coded ‘0’
- High dietary diversity (≥ 4 food groups), coded ‘1’.

The household interview asked respondents about the source of drinking water, and sanitation. From the Malawi datasets (MDHS 2000, 2004, 2010, and 2015-16), the following **WASH** variables were calculated:

a) Whether the household used an improved drinking water source: Improved drinking water sources are piped water into dwelling, plot, or yard; public tap/standpipe, tube well/borehole, protected dug well, protected spring and rainwater collection.
b) Whether the household had access to an improved sanitation facility: Improved sanitation is defined as having flush or pour/flush, facilities connected to a piped

sewer system, septic system, or a pit latrine; pit latrines with a slab, composting toilets or ventilated improved pit latrines.

The following variables on infant and **young child feeding practices** was calculated for these analyses:

a) Early initiation of breastfeeding: Whether the child was put to the breast within one hour of birth.

b) Age appropriate breastfeeding: Whether infants 0–5 months of age received only breast milk during the previous day and whether children 6–23 months of age received breastmilk, as well as solid, semi-solid or soft foods during the previous day.

c) Minimum Dietary Diversity: Whether children received foods from ≥4 food groups (calculated as separate independent variable).

d) Continued breastfeeding at 1 year: Proportion of children 12–15 months of age who are fed breast milk.

e) Consumption of iron-rich or iron-fortified foods: Proportion of children 6–23 months of age who receive an iron-rich food or iron-fortified food that is specially designed for infants and children, or that is fortified in the home.

Escherichia Coli (*E.coli*) are widely distributed among poultry and are primarily related to poor hygienic conditions. Farm animals can also carry *Salmonella* and *Cryptosporidium,* a protozoan, is more virulent than *E.coli* in causing diarrhea in children = under two years of age. It is commonly found in cattle, poultry and other farm animals [104]. These organisms are transmitted to children and infants either through animal feces, contaminated water and food or even by direct person-to-person contact [105].

Therefore, the proposed study will analyze ownership of animals, especially poultry and cattle, and its association with stunting in children.

Ownership of animals was used as a proxy for **environmental enteropathy** since in the rural landscape of Malawi, households with livestock share close proximity of animals and children. Animals often share the area where children play or where food is being cooked and eaten. Ownership of livestock was computed as ‘1’ if the household had goats; ‘1’ if the household had pigs; ‘1’ if the household had cattle; ‘1’ if the household had sheep; ‘1’ if the household had poultry (chickens, ducks, pigeons).

A composite indicator of the above variables was computed as ‘1’ if the household had goats, pigs, cattle, sheep or poultry; else 0.

Since data on income and expenditures are not available from DHS surveys, data on ownership of assets was used as a proxy for market access and purchasing power. The DHS **wealth index** measures household wealth using an index derived from asset variables using principal component’s analysis (PCA) by placing individual households on a continuous scale of relative wealth. Studies have found that these indices are robust and provide similar poverty rankings of households as income or consumption expenditure measures [42].

The DHS Wealth Index was used as a proxy for household economic status. It is a composite measure of household’s cumulative living standard. The wealth index quintiles include: lowest, second, middle, fourth and highest [106]. As a measure of economic status, the wealth index was validated against the consumption expenditures using the World Bank’s Living Standard Measurement Surveys. The results from the validation concluded that the wealth index, in fact, performed better than the traditional consumption expenditure index for key survey variables [106].

Household assets are good predictors of child nutritional status. The index is based on whether the household owns common items such as radio, television, bicycle, motorcycle, car, refrigerator, toilet, and has access to piped water, etc.

The DHS has two sets of **women's empowerment** indicators: (a) Women's participation in household decisionmaking either alone or jointly with husband or partner. The index is constructed based on woman's response to her say in large household purchases, her own healthcare, the spending of money she earned, and visits to relatives. The index ranges from 0 to 3. (b) Women's attitudes towards wife beating are the number of reasons for which a woman thinks it is justified to beat wife. The index ranges from 0 to 5; a lower score reflects a higher status of women.

The MDHS survey 2015-16 also included the domestic violence module in one-third of the sampled households. Physical, sexual, and emotional violence was measured by asking a series of questions to all ever-married women. The variables were coded as '0' for No and '1' for Yes for each type of violence.

Micronutrient testing and sample collection

The MNS Survey (2015-16) collected information on food accessibility and the experience of food deprivation using the **Household Hunger Scale** (HHS). The HHS scale developed by Food and Nutrition Technical Assistance II project was used to calculate the prevalence of households with moderate or severe hunger. It has been validated for cross-cultural equivalence. The recall period is 30 days or four weeks for the questions that are used to create the HHS indicator [107].

Two types of indicators – a categorical HHS indicator and a median HHS score for the households were calculated. For occurrence questions, for example, *“Was there ever no food to eat of any kind in your house because of lack of resources to get food?”*, “0” was coded for households that answered “No” and “1” was coded for households that answered “Yes”. Similarly, frequency-to-occurrence questions, “rarely” =1; “sometimes” = 2; “often” = 3 were recoded to as “rarely” =0; “rarely or sometimes” = 1; “often” = 2 (new recoded value). Values were summed for each household to calculate the HHS score. Each household received a HHS score between 0 and 6.

- Households scoring 0–1 were classified as households experiencing little to no hunger.
- Households scoring 2–3 were classified as households experiencing moderate hunger.
- Households scoring 4–6 were classified as households experiencing severe hunger [108].

Using the above classification, a binary HHS indicator was computed and coded as “0” (little to none), and “1” (moderate-to-severe).

In each of the clusters selected for the MNS survey, nurses and laboratory technicians in a temporary field laboratory collected blood samples through venipuncture. Approximately 7 ml of blood was collected into a trace element free (blue top), and an EDTA (purple top) vacutainer tube per child. Whole blood collected in the EDTA vacutainer tube was used for hemoglobin and malaria testing. Dried blood spots (DBS) were made from 100 µl of whole blood. The DBS cards were dried, stored, and transferred to the central laboratory for inherited blood disorder testing. The remaining blood from the vacutainer tube was centrifuged, and plasma was aliquoted and stored at CHSU of the Ministry of Health, and serum was harvested from the blue top vacutainer tube and was used for various micronutrient biochemical analyses. In a subset of eligible sample, an additional 3 ml of blood sample was collected in a third EDTA vacutainer tube for modified relative dose response (MRDR) and retinol laboratory testing using high performance liquid chromatography (HPLC). Venous blood was collected after the child had consumed a small challenge dose of retinol analog and a fatty snack in the form of a granola bar. The sample was centrifuged for plasma, which was aliquoted into two sterile cryovials.

The processed serum and plasma specimens were labeled, stored in portable freezers in the field, and transported along with the specimen tracking forms to the nearest district laboratory for temporary storage at -20° C to the district laboratory and finally to the central laboratory at CHSU, where the samples were stored at -70° C until their transfer for further analysis.

Approximately 10 ml of urine was collected in sterile collection cups from all eligible children. The urine samples were tested for the presence of hematuria as a proxy for diagnosis for urinary schistosomiasis using a urine dipstick.

Anemia

Anemia is characterized by low levels of hemoglobin in the blood. Likewise, iron status is assessed by measuring serum ferritin. Serum ferritin is an acute phase protein and increases as part of the inflammatory response. Adjusting for inflammation leads to an increase in the estimated prevalence of iron deficiency using ferritin concentrations. Therefore, prevalence estimates of inflammation-corrected iron deficiency are more accurate and presented in this research.

- Hemoglobin concentrations were adjusted based on altitude of the cluster in all children.
    - ≥11 g/dl coded as “0” (not anemic), and
    - <11 g/dl coded as “1” (anemic)
- Serum ferritin results were adjusted for CRP and AGP concentrations using the Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia internal country-specific regression correction approach. Serum ferritin values are reported as both unadjusted and adjusted for inflammation.
    - ≥12 µg/L coded as “0” (No, Iron deficiency), and
    - <12 µg/L coded as “1” (Yes, Iron deficiency).
- Iron deficiency anemia or IDA (inflammation corrected iron deficiency and anemia).
    - ≥11 g/dl coded as “0” (No, IDA), and
    - <11 g/dl coded as “1” (Yes, IDA)

Vitamin A Deficiency

Vitamin A status was assessed using RBP as a surrogate measure for serum retinol. Since the molar ration of RBP and retinol is not always 1:1, a sub-sample of serum was also analyzed for serum retinol to adjust the RBP cut-points. Although it is well known that inflammation affects vitamin status, there are no global recommendations on how to account for inflammation and hence the RBP and retinol concentrations were not adjusted for inflammation.

- Retinol Binding Protein (RBP):
    - ≥0.46 µmol/L coded as "0" (Not VA deficient), and
    - <0.46 µmol/L coded as "1" (VA deficient).

Zinc Deficiency

Since serum zinc concentrations may be affected by physiologic factors, including fasting status, time of blood collection, and inflammation, the zinc concentrations were corrected for fasting and time of collection. No corrections or adjustments were made for inflammation, as there are no current recommendations for adjustment.

- Serum zinc corrected for fasting and time of collection:
    - Morning, non-fasting <65 µg/dL coded "1" (Zn deficient), otherwise not deficient.
    - Afternoon, non-fasting <57 µg/dL coded as "1" (Zn deficient), otherwise not deficient in Zinc.

Markers of inflammation/infection

Markers of inflammation, malaria, and schistosomiasis were assessed to evaluate common causes of infection and subclinical inflammation that may be associated with nutritional status and influence the interpretation of biomarkers. Inflammation was assessed using CRP, which measures acute inflammation, and AGP which measures chronic inflammation.

- C-reactive protein (CRP): ≤ 5 mg/L coded “0” (normal), and > 5mg/L coded as “1” (abnormal)
- Alpha-1-acid glycoprotein (AGP): ≤ 1 g/L coded “0” (normal), and >1 g/L coded as “1” (abnormal)
- Any inflammation: CRP or AGP coded as “0” (no inflammation), and CRP or AGP coded as “1” (any inflammation).

Plasmodium falciparum is the most common cause of malaria infection in Malawi that contributes to high morbidity and mortality, hence data was assessed to determine the presence of malaria in children. Similarly, urinary schistosomiasis is common in Malawi due to Lake Malawi’s water infested with snails.

Markers of inflammation/infection

Inherited blood disorders, such as alpha-thalassemia, sickle cell disease, and glucose 6-phosphate dehydrogenase (G6PD) deficiencies are common among children in Africa, including Malawi. The prevalence of these disorders and their relationship with stunting has not been explored.

Confounding Variables

The analysis controlled for other independent variables, including mother’s education, which is significantly ($p<0.001$) associated with higher probability of reduction in both underweight and stunting in children who received timely introduction of solid foods, and improved dietary diversity [35]. Mother’s education was categorized as no schooling, primary or less and secondary or more. Studies have shown that after controlling for other confounding factors, maternal height is associated with stunting in children [109-111]. In fact, maternal height is a composite indicator that represents genetic and environmental effects on the child's growth [70] and maternal short stature and underweight is associated with fetal growth restriction [70]. In addition, child's height is also associated with birthweight [112, 113]. Therefore, the study controlled for mother's height and BMI.

The other covariates included child's age, previous birth interval and sex. In addition, since dietary diversity and other determinants of food security are highly correlated with income and may be confounded by socio-economic factors [114], analysis was controlled for household wealth, and land ownership.

Statistical Analysis

The study incorporated cross-sectional analysis of secondary data using the women's dataset from the MDHS Survey (2000, 2004, 2010 & 2015-16), and Malawi MNS (2015-16). The data was analyzed using STATA 15.0 (STATA Corp, College Station, TX USA). Independent and control variables were derived from the standard recode data.

Diagnostics

Since some predictors in the model may give redundant information, collinearity statistics were tested to examine multicollinearity. Moderate collinearity is common since any correlation among the independent variables is an indication of collinearity. If multicollinearity increases, the regression model estimates of the coefficients become unstable, and the standard errors of the coefficients may be large (inflated). As part of the collinearity statistics, ‘tolerance’ and ‘Variance Inflation Factor’ (VIF) tests are performed to indicate variables that contain redundant information. Tolerance ($1-R^2$), an indicator of how much collinearity that a regression analysis can tolerate and VIF (1/tolerance), an indicator of how much of the inflation of the standard error could be caused by collinearity were tested.

Descriptive statistics included analysis of socio-demographic characteristics, stunting and other covariates. Bivariate analysis (Chi-square tests) was performed to study the relationship between proximate determinants of food security (dietary diversity, WASH, IYCF practices, EE, wealth index etc.) and stunting. Separate multiple logistic regression models examined the association between the determinants of food security and stunting while controlling for the confounding factors. Cases with missing values on any of the dependent or independent variables were excluded from the logistic regression analysis. Results of the multivariate analysis are presented as the odds ratios. The outcome variables for nutritional status was defined as binary variables taking the value one if the child was stunted and zero if the child was not stunted.

Since DHS surveys are conducted using a cluster sample design, observations within a cluster are expected to be more alike than observations in different clusters. Since proposed determinates of food security may vary with other variables such as mother’s education, models were constructed to test interactions between determinates of stunting and other factors such as mother’s education and child’s age, etc. These were included in the final model if they were significant at the 5 percent level. All of the significant variables (potential confounders) from the bivariate analysis were introduced in the multivariate model.

Sampling, Weighting, and Stratification

MDHS data were collected using two-stage stratified cluster sample and not simple random sampling. First, enumeration areas (EAs)from the census were randomly selected from a list of all such areas. These are also called ‘clusters’ or ‘primary sampling units’. These were town or villages, or census tracts in cities. Next, all the households in the cluster were counted and labeled. Then, a random-selection was used to select households within each cluster. These households were visited for data collection.

While cluster sampling as done for MDHS surveys is much more practical, it also means that the selected households are not statistically independent. Instead, the characteristics of a given household (and its household members) are more like those of other households in the same cluster, and are less like households in other clusters. This effect of a non-independent sampling process, called the "sample survey design effect," shows up in the standard error of estimation statistics (means, regression coefficients). Clustering tends to decrease the size of standard errors, leading to a greater likelihood of rejecting the null hypothesis. In other words, it is more conservative to correct statistically for the design effect.

The MNS Survey 2015-16 sample clusters were randomly selected from the MDHS Survey 2015-16 sample clusters, which were selected according to a non-proportional allocation of sample to different districts to their urban and rural areas, and due to the possible differences in response rates. Thus, household level sampling weights were used in the analyses presented for micronutrients to ensure that the results are representative at the national and regional levels. Standard errors were calculated taking into account clustering within and between households.

For data analyses, the cluster or primary sampling unit is v021 in women and children's files. STATA command pweight (probability weight) will be used for robust standard errors: [pweight=weight]. Since separate samples were selected from each stratum (regions in Malawi, urban/rural residence, education level, etc.), like clustering, the observations within strata are not statistically independent, and adjusting for stratification is required for more conservative inferences about statistical significance. The stratification used to design the sample is based on the variable v023. It will be computed using STATA is: strata(strata).

Each observation in the MDHS sample is chosen using a method of random selection. Using this method, the probability of selection may not be equal for all members of the population. Therefore, sampling weight for each observation is computed as the inverse of the selection probability. Additional adjustments (such as household non-response) is also made to the sampling weights and hence sampling weights is used to estimate the characteristics of the target population from the reports of the sample. Therefore, DHS sample weights were used in all analyses to make sample data representative of the entire population and for computing both the population estimates (such as means and regression coefficients) and their standard errors. There are different weights for different sample selections or unit of analysis. For MDHS, sample weights for women or child variable is "v005". For analysis, the sampling weight were divided by 1,000,000. A global command, a single line of code at the start of analysis was used to specify the complex survey design of the MDHS dataset: `svyset` [pweight=weight], psu(v021) strata(strata).

All subsequent analyses, descriptive and bivariate analyses, accounted for survey design to produce unbiased mean and accurate variance estimates by using `svy:` before the rest of the command.

Ethical Approval

All procedures and questionnaires for MDHS surveys were reviewed and approved by the Macro International and ICF International's Institutional Review Boards (IRB). The ICF International IRB ensured that the survey complied with the U.S. Department of Health and Human Services regulations for the protection of human subjects (45 CFR 46), while the Malawi IRB ensured that the survey complied with laws and norms of the country. A joint proposal for MDHS and MNS surveys was submitted and approved by the National Health Sciences Research Committee, Malawi. As part of MDHS surveys, an informed consent was administered to all respondents before implementing the survey questionnaire, anthropometric measurements or anemia testing. For the MNS survey, consent for both paper questionnaire, food collection, anthropometry, and biological testing was asked from parents or guardians of children 0–5 years. The MDHS and MNS surveys ensure confidentiality of the survey respondents by removing any personal identifiers from the survey data.

This study is based on secondary analysis of existing data from MDHS surveys from 2000 to 2015-16, and MNS survey 2015-16. Ethical approval from the IRB of University of Maryland, College Park was sought before data analysis was conducted.

Chapter 4: Results

This chapter presents the results of the study in the form of three research papers.

Paper I: Trends in childhood stunting: findings from Malawi, 2000-2016

Abstract

Objective: High rates of stunting have persisted in Malawi for several decades. This study examined trends in stunting among pre-school children in Malawi.

Design: The study examined the data for trend analysis using the cross-sectional population-based surveys in Malawi from 2000 to 2016. Stunting in children was defined as height-for-age index more than two standard deviations below the reference median. Bivariate and multivariate analyses are used to estimate the change in stunting by socio-demographic variables, adjusted for sampling design effects.

Setting: Malawi Demographic and Health Surveys (MDHS) data collected in 2000, 2004-05, 2010, and 2015-16.

Subjects: Children ages 0–59 months with data on anthropometric measurements from the Malawi Demographic and Health Surveys in 2000 (n=18,685), 2004 (n=15,751), 2010 (n=9,119), and 2016 (n=5,159).

Results: The prevalence of stunting decreased in children from 54.3 percent in 2000 to 36.6 percent in 2016. The change in the levels of stunting from 2000 to 2004 was not highly statistically significant (t=2.09, p=0.037), compared to decreases in the levels of stunting from 2004 to 2010 (t=4.51, p=0.000), and 2010 to 2016 (t=6.13, p=0.000).

Compared to 2000, the odds of stunting in children ages 0–59 months decreased by 14 percent in 2004, and by a remarkable 46 percent in 2016.

Conclusion: Stunting decreased linearly among children in Malawi from 2000 to 2016. Age, sex, birth interval, wealth, region, residence, and mothers educational and nutritional status are independently associated with stunting among children. Trends were statistically significant for all variables and sub-groups examined. The prevalence of childhood stunting remains a significant public health issue in Malawi.

Keywords

Stunting, trends, Malawi, pre-school children

Introduction

Stunting is a marker of multiple pathological conditions and is associated with severe physical and cognitive damage. It is one of the most significant impediments to human development, affecting approximately 162 million children under age 5 [115]. The global trend in stunting prevalence and the number of stunted children is decreasing, but in Africa, although there has been some progress the number of stunted children is rising [116]. In Sub-Saharan Africa Burundi (57.7 percent) has the highest rate of stunting followed by Malawi (47.1 percent). However, unlike Burundi and other countries under conflict, Malawi has benefited from decades of peace and political stability [117]. Despite this stability, Malawi has one of the highest prevalence rates of stunting among children under age 5. The stunting levels have largely remained unchanged in the past two decades [118].

Among sub-Saharan countries, landlocked countries such as Malawi have higher rates of stunting than coastal, central, or southern African countries. Research indicates that there are hotspots within countries, and different populations have varying levels of stunting within countries [115, 119, 120]. To implement targeted interventions to reduce stunting, there is a need to identify the prevalence and trends in stunting regionally and by socio-demographic groups. The national level of stunting may not reflect the trends among socio-demographic groups over the years. Therefore, this study examined the trends in stunting as they relate to nutrition, socio-demographic and socio-economic factors, which may help design public policies and interventions to reduce childhood undernutrition in Malawi.

Previous studies have shown that demographic characteristics, including age, sex, birth interval, mother's education, nutritional status, improved sources of drinking water and sanitation facilities, and household wealth has been associated with stunting in children [116, 121, 122]. To understand sub-group differences in Malawi, this study disaggregates the national-level data to socio-demographic sub-groups and presents changes in stunting among children ages 0–59 months over time from 2000 to 2016.

Methods

The study conducted a secondary analysis of four Malawi Demographic and Health Surveys (MDHS) from 2000 to 2016. The surveys were conducted by the NSO of Malawi with technical assistance from Macro International/ICF and funded by the United States Agency for International Development. The surveys used a two-stage cluster sampling design with EAs as primary sampling units and households as secondary sampling units. The sample for the MDHS surveys was large enough for robust national prevalence estimates. In total, the four survey datasets comprised 48,714 children with anthropometry data. The weighted sample sizes of children ages 0–59 months were 18,685 in 2000, 15,751 in 2004, 9,119 in 2010, and 5,159 in 2016. For MDHS 2000, anthropometry data were collected from all children if their mothers were eligible for the interview, for the subsequent years, all children who slept in a household the night before the interview were eligible regardless of the mother's eligibility or interview status.

Anthropometric measurements**:** Height-for-age/length-for-age is defined as height or length of a child relative to the height or length of a child of the same age in a reference population, expressed either as a Z-score or as a percentage relative to the median of the reference population. A child who has low height-for-age is described as being "stunted." Standing height measurements in all four surveys were carried out in children ages 0–59 months using a measuring board developed by Shorr productions. Recumbent length was measured for children less than 24 months of age. The 2000 and 2004 MDHS datasets for height-for-age with previously used National Center for Health Statistics/World Health Organization (WHO) reference population were made comparable to the WHO Child Growth Standards, released in 2006. Subsequently, the height-for-age Z-scores were calculated based on WHO growth standards for all four surveys [123]. The datasets were cleaned and extreme values (<-6 standard deviation [SD] or >+6SD) that were likely to represent measurement or data entry errors, or biologically implausible values were eliminated. Stunting was defined as height-for-age Z-score <-2SD from the WHO Child Growth Standards.

Socio-demographic variables**:** Common household, child, and maternal variables were included in the trend analysis. Some of the variables were recoded into categories for a meaningful comparison. The household variables included residence (urban, rural), region (northern, central, and southern), wealth index (asset-based index grouped into five categories—poorest, poorer, middle, richer, and richest), and source of drinking water (improved and unimproved sources of drinking water) and sanitation facility (availability of improved and unimproved toilet facility). Child characteristics included in the study were age in months (<6, 6–9, 10–11, 12–15, 16–23, 24–35, 36–47, and 48–59 months), sex (male, female), birth order (1, 2–3, 4–5, 6+), and birth interval (first birth, <24 months, 24–35 months, 36–47 months, and 48+ months). Whereas the maternal variables included in the analysis were mother's education (no education, primary, secondary or higher), and body mass index (BMI) (weight in kilograms divided by square of height in meters). Based on the BMI cutoff, women were defined as underweight (BMI <18.5 kg/m^2), normal weight (BMI =18.5 – 24.9 kg/m^2), and overweight or obese (BMI ≥25 kg/m^2).

***Data analysis*:** Data were analyzed using STATA version 14.0 (StataCorp., TX). Datasets for the last four DHS surveys were combined by merging the data, and sample weights were used to account for unequal probability of sampling for non-response. In addition to exploring the height-for-age Z scores in children ages 0_59 months, children were also classified as stunted (<-2SD) or not stunted (>-2SD) for comparison across surveys and across various socio-demographic groups. We performed bivariate analysis using chi-square to find out the association between pairs of variables, that is, between stunting and select explanatory and background variables. We performed the chi-square test for homogeneity and calculated the standard errors and confidence intervals for the prevalence estimates. We also performed a multivariate logistic regression of stunting trends over time among socio-demographic groups, including sex, age, residence, region, maternal characteristics, and household wealth, adjusted for sampling design effects (i.e., strata, clusters, and sampling weights using the survey commands in Stata). The chi–square statistic was used to test the significance of trends at $p<0.001$. After fitting the model and obtaining the estimates, the odds ratio was calculated for survey years 2000 compared to 2004, 2004 compared to 2010, and 2010 compared to 2015-16, for each set of explanatory variables.

***Ethical approval*:** The study is based on the secondary analysis of the publicly available data that have had all identifying information removed. The MDHS surveys acquired informed consent from caretakers of the children before data was collected on anthropometric measurements. The National Statistical Office in Malawi and the Macro International/ICF Institutional Review Board approved the questionnaire and the survey protocol.

Results

The study examined trends in stunting using data from the MDHS conducted from 2000 to 2015-16. Overall, 54,760 children ages 0–59 months were eligible for the four surveys from 2000 to 2015-16. The study, however, included 48,714 children ages 0–59 months who had valid anthropometry measurements. There are multiple reasons for having a lower number of children with anthropometry measurements. These include refusal by the caretaker, children being away from home during household data collection, data entry errors, etc. In terms of the breakdown by survey year, the study included 18,685 children from the 2000 MDHS, 15,751 children from the 2004 MDHS, 9,119 children from the 2010 MDHS, and 5,159 children from the 2015-16 MDHS.

Table 1.1 shows that slightly more than half of the children were females (50.8 percent) and more than 86 percent of children resided in rural areas. The similar percentage of children belonged to the central and southern region and had a birth order of six or more. More than half of the households (58.5 percent) had improved source of drinking water, and 70 percent of households had an improved toilet facility. Although stunting is high among all wealth quintiles, it is highest in the poorest quintile across all survey years. In 2015-16, children living in the poorest households were twice at risk of being stunted, compared to children living in the richest households. The majority of mother's (approximately 64 percent) had primary education, and about a quarter had no education. Seventy-nine percent of mother's were normal weight. The prevalence of stunting across the survey years by the key socio-demographic variables among children ages 0–59 months are also presented in Table 1.1. The proportion of children with stunting decreased from 54.3 percent in 2000 to 36.6 percent in 2016, a decrease of 17.7

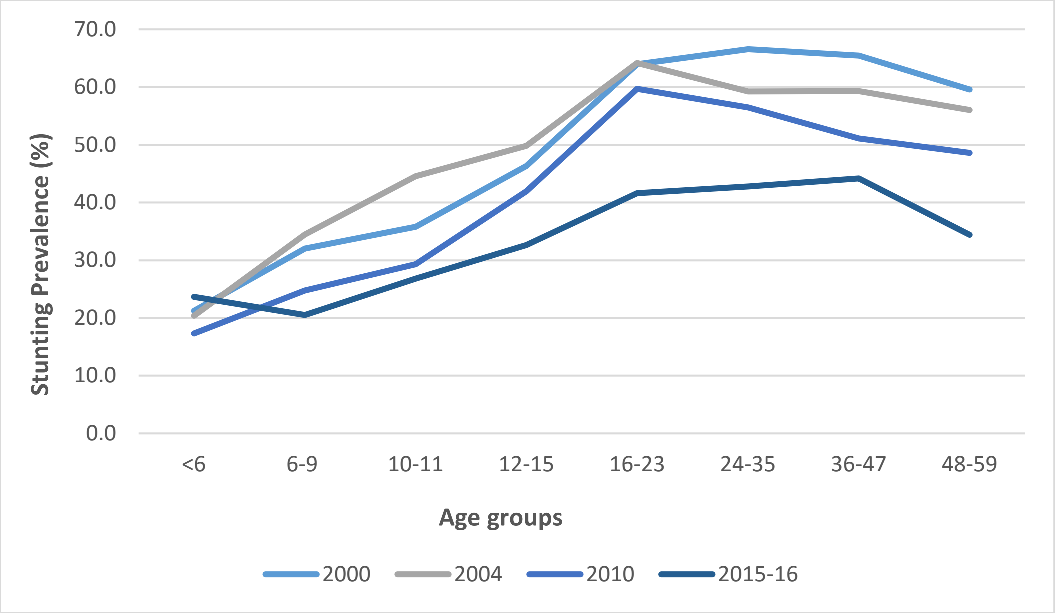

Figure 1.1 Stunting in children 0-59 months by age groups, MDHS 2000-16

percentage points. Age-specific data on stunting (Table 1.1 and Figure 1.1) show a steady increase in the prevalence of stunting by age group. For all surveys combined, the stunting rates reach a peak for the age group of 16–23 months, and then plateau and increase again for the age group 36–47 months with the exception of survey year 2010.

Although for all survey years, as expected, the prevalence of stunting in low in children under six months of age, it is perplexing to note that stunting is higher among this age group for the 2015–16 survey year, and the levels reach a nadir at ages 6–9 months.

Figure 1.2 shows the distribution of mean height-for-age Z-scores for the pooled data from 2000 to 2016 in children ages 0–59 months in Malawi. It shows that during that 16-year period, half the children in Malawi are stunted. Although stunting remains high in 2016, the mean height-for-age Z–scores significantly decreased from -205.811 in 2000 to -152.916 in 2016 (Figure 1.3).

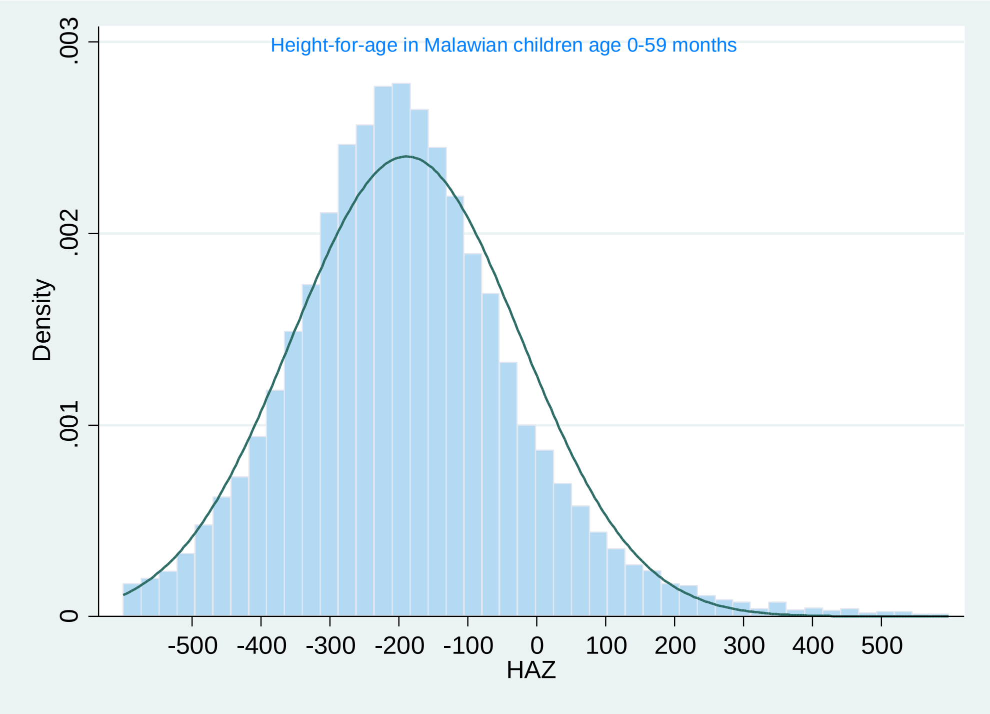

Figure 1.2 Normal distribution curve for HAZ scores, MDHS 2000-16

The decrease in height-for-age Z–scores is statistically significant at p=0.000 for all survey years except between years 2000 and 2004 (Figure 1.3). Table 1.2 also shows a statistically significant (p=0.000) decrease in the mean height-for-age Z–scores across all survey years except between the first two survey periods (p=0.03, 2000 compared to 2004). The most significant decrease in the mean height-for-age Z–scores of 52.894 occurred from 2000 to 2016 (t=12.36, p=0.000).

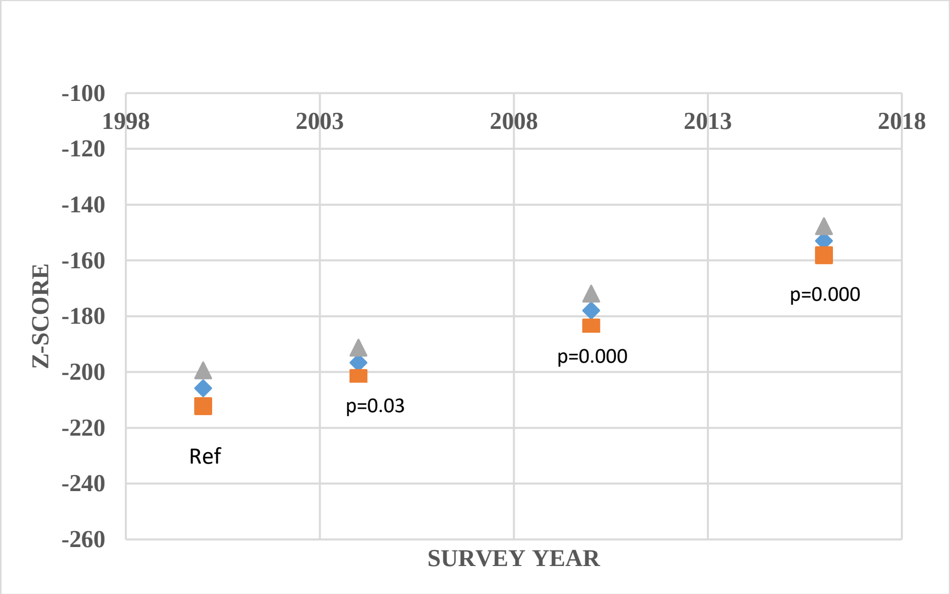

Figure 1.3 Mean HAZ score by survey year, MDHS 2000-16

Table 1.3 shows the odds of stunting against the selected key variables. The test of homogeneity was statistically significant at p=0.001 (not shown) for all variables examined indicating the odds of stunting differed by levels in each sub-group, that is, indicating a linear trend in stunting. The score test for trend of odds in Table 1.3 is highly significant at p=0.000 for all variables, indicating that there is a trend in stunting across all variables except for region (p=0.015). It should be noted that a highly significant score test for trend indicates a linear trend in stunting across variables, but it does not indicate the form of the relationship.

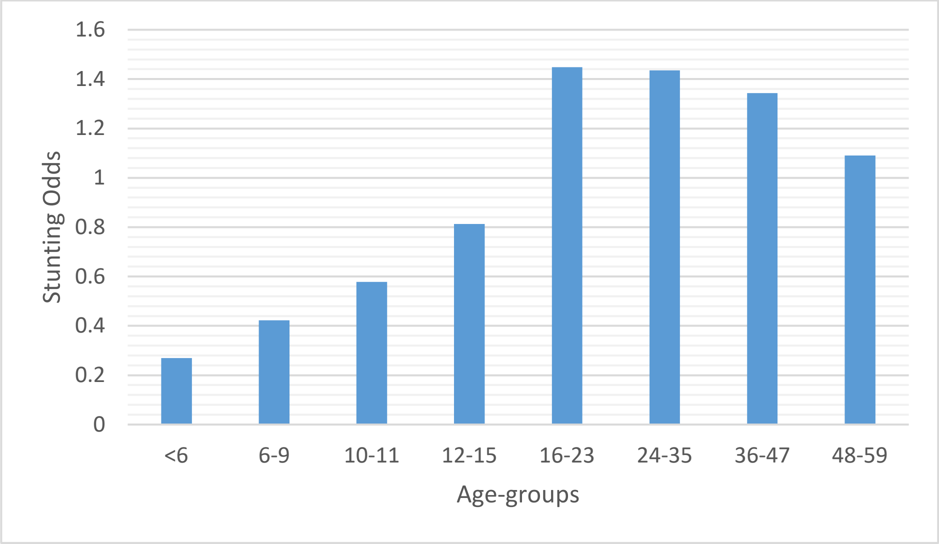

Figure 1.4 Trend of odds being stunted by age-groups, MDHS 2000-16

Figure 1.4 illustrates the trend in the odds of being stunted by age group, and Figure 1.5 illustrates the trend by wealth index, respectively. The odds of stunting are significantly higher in the 16–23 months age group (OR=1.45, 95% CI 1.38-1.51). The odds of stunting is significantly higher in the lowest wealth quintile (OR=1.28, 95% CI 1.23-1.33).

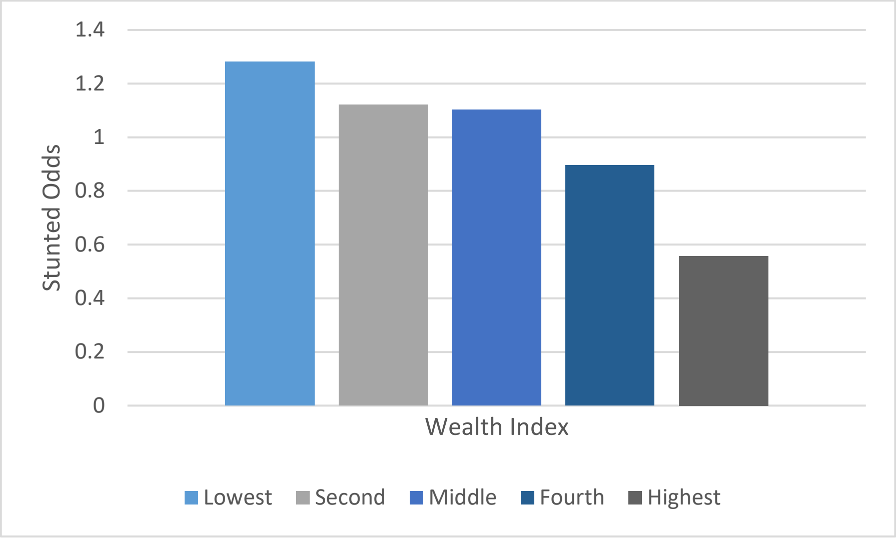

Figure 1.5 Stunting in children by wealth index, MDHS 2000-16

In addition to the changes across survey years, Table 1.4 shows the trend of the odds of being stunted over time by socio-demographic variables. The Hosmer-Lemeshow goodness-of-fit test shows that the model is adequate at F= 1.73, p=0.0775. The odds of stunting decreases with survey year. Compared to children under 6 months of age, the odds of stunting increases with age and is highest in ages 16–23 months. The odds of stunting are 22.8 percent less in girls compared to boys. There is a 78 percent decrease in the odds of stunting in children from households in the highest wealth quintile, compared to the households in the lowest wealth quintile. The odds of stunting are significantly lower in children living in urban areas and central region of the country. Compared to the first birth, the odds of stunting are increased for higher birth order. The source of sanitation facility had a minimal impact on stunting, and the odds of stunting was 11 percent higher in children from households with an improved source of water.

Decomposing the analysis by maternal variables, the study finds that mother's education (secondary or higher) is significantly associated with decreased stunting in children. The odds of stunting is about 39 percent lower for children with mothers who have secondary or higher education compared to mothers who have no education. The odds of stunting in children is 41 percent lower if the mother is overweight and 11 percent lower if the mother has a normal weight. It should be noted, however, that only 5 percent of mothers were underweight (the reference category).

Table 1.5 shows changes in stunting across one survey year relative to another. The MDHS surveys are cross-sectional surveys, so the study compared the changes in stunting from the survey year 2000 to 2004, from the survey years 2004 to 2010, and from the survey years 2010 to 2015–16. From 2000 to 2004, there was a slight decrease in stunting from 54.3 percent to 52.2 percent. Similar decreases were also observed for girls, children living in rural areas, and specific age categories (10–11, 24–35, and 36–47 months). These were significant at $P<0.05$. No significant changes were observed for other selected variables or sub-groups. Although stunting remained high at 47.1 percent in 2004, it was significantly ($P<0.000$) reduced for a number of variables and sub-groups from 2004 to 2010. These include girls, children living in rural areas, children living in the central region, children with a birth interval of +48, and children with households that had an improved water source and children from households that fell in the middle wealth quintile, and children with mother's who had a primary education. A slightly significant ($P<0.05$) decrease in stunting was also observed for a majority of variables and subgroups (see Table 1.5). The most significant ($P\leq0.000$) decrease for most all variables and sub-groups occurred from 2010 to 2016. Except for the age groups less than 6, 6–9 months, 10–11 months, birth interval of +48 months, and children with mothers who were underweight all other variables and sub-groups showed a significant ($P<0.05$) decrease in stunting from 2010 to 2016.

Discussion

Results of the study show that there is a linear trend in the reduction of stunting across survey years, and this trend exists for all variables and sub-groups within each variable. Stunting in children decreased from 54.3 percent in 2000 to 36.6 percent in 2015-16. An impressive 10.5 percentage points decrease in stunting occurred between 2010 and 2016. This aligns with the United States Agency for International Development/Malawi's goals for 2017 to reduce the prevalence of stunting in children under age 5 [98]. This also follows the period when Malawi experienced a food surplus during the 2008–2009 growing season due to favorable weather and the Farm Input Subsidy Programme initiated by Government of Malawi [124].

Compared to children under 6 months of age, the odds of stunting increase by more than 50 percent in children ages 6–9 months. This coincides with the period when protection from mothers antibodies have started to wane, and children become more mobile and hence exposed to infections [125, 126]. The odds of stunting are highest in the children ages 16–23 months (Figure 1.4), which is consistent in the literature from Malawi [126].

The current study shows an interesting finding that although the rates of stunting decrease significantly in 2016 compared to the preceding survey years, stunting in children under 6 months of age was higher in 2016 compared to the previous years. This is contrary to the literature that suggests that growth faltering starts at six months of age. However, a cohort study in rural Malawi found that stunting incidence was highest during the first six months of age [127], and recent research shows that malnutrition in children under 6 months of age is on the rise, and they are vulnerable to malnutrition irrespective of their breastfeeding status [128]. Some research also indicates that in some settings, prevalence of stunting start to rise at about 3 months of age [129]. This is an important and concerning departure from age-specific trends in stunting nationally and globally. Although most infant and young child feeding indicators are collected for children ages 6–24 months, future studies should also focus on children under 6 months, because stunting is a long-term process that results from multiple insults that often starts as early as in utero and continues through the first three years of child’s life [88, 130]. Newborns in Lungwena, Malawi are on average 2.5 cm shorter at birth compared to the 2000

Centers for Disease Control and Prevention reference population [127]. In fact, it has been estimated that compared to the reference population, in Malawi, approximately 20 percent of 10-cm deficit in height at three years of age is already present at birth [127, 131], and the intra-uterine growth retardation-low birth weight is estimated to be around 15 percent [126].

Stunting is negatively correlated with household wealth in all four surveys. From 2000 to 2015–16, the prevalence of stunting has decreased in each wealth quintile. This could be because income poverty appears to have decreased between 2004–2005 and 2010–2011. Although stunting is higher among the poorest households, like many other sub-Saharan countries, rates of stunting also remain relatively high among the non-poor households [119]. In addition, the reason stunting is high in all wealth quintiles could be because more than half of the population (50.7 percent) lives below the poverty line [132]. These observations are similar to other studies in the literature [126, 133, 134].

In the first two surveys, between 2000 and 2004, there is virtually no difference in stunting with respect to the source of drinking water. The trends, however, changes in 2010 and 2016 with reduced stunting among children with households that reported an improved source of drinking water. For all four surveys reduced stunting is observed among children from households that had improved source of toilet/sanitation facilities. Various studies have found a negative correlation between the source of toilet/sanitation facilities and stunting among children [133]. These findings align with other studies that suggest that improving water, sanitation, and hygiene improves linear growth in children [58].

With respect to the region, the central region of Malawi has the highest stunting rate, followed by the southern region. This has been documented in previous studies [126]. Children from the rural areas have higher stunting than children from the urban areas. Other studies suggest the trend has not changed since the 1990s [126, 134].

Preceding birth interval is also a predictor of stunting in children. The study found that stunting is lower when the birth interval is more than 48 months. In general, except for the first birth, there is an inverse relationship between the length of the preceding birth interval and the proportion of children who are stunted. Likewise, for all four surveys, stunting was highest when the birth interval was less than 24 months.

Similar to other studies, sex inequalities in this study are substantially smaller than economic inequalities [135]. Our study also observed slightly higher rates of stunting in boys compared to girls for all survey years. Although stunting decreased in both girls and boys by 17.6 percentage points from 2000 to 2016, boys had higher rates of stunting for all survey periods. A number of studies have found that in sub-Saharan countries, among children under 5, boys have slightly higher rates of stunting compared to girls [119, 136].

This study demonstrates the importance of maternal factors. Mother’s education was consistently and significantly associated with stunting in all four surveys. Study findings show that attainment of higher education (i.e., secondary or higher education) was associated with lower the odds of childhood stunting. This is consistent with other studies that have shown that mother’s education is a major determinant of whether a child becomes malnourished [126, 133]. Maternal undernutrition is also a determinant of child undernutrition. Children whose mothers were underweight (BMI <18.5) were more likely to be stunted, compared to children whose mothers were a normal weight or overweight. This is an expected finding as mothers who have higher education are more empowered to be able to take decisions regarding nutrition and care of their children.

Comparison of stunting between survey periods and trends in stunting for each of the covariates shows a significant reduction in stunting from 2010 to 2015-16. This reduction can be attributed to several programs and Government of Malawi initiatives that aim to reduce stunting and poverty in Malawi. These include Feed the Future, Food for Peace, Counting to 2015, Scaling Up Nutrition which all started around 2010-2011 [19].

The levels of stunting are on the decline in Malawi, however, more than one in three children remain stunted and stunting remains high across all sub-groups, which indicates the need fortargeted interventions in accelerating reductions in stunting among children in Malawi. Despite a strong government commitment, strong agricultural productivity, and economic growth in recent years, the severity of malnutrition in Malawi remains persistent, even in the upper wealth quintile [137]. This accentuates the importance of factors not related to income but associated with knowledge, attitudes and practices with regard to food production, preparation, and consumption; breastfeeding and other young child feeding practices; and disease prevention. Future studies need to explore the relationship between these factors and stunting in children in Malawi.

Conclusion

At the national level, stunting among children in Malawi decreased, from 54.3 percent to 36.6 percent between 2000 and 2016. Despite the remarkable decrease in stunting, it remains of high public health significance in Malawi. According to the Global Nutrition Report, Malawi has made some progress in reducing stunting among children, but the progress remains off course [138]. Findings from our study indicate that child's age is an important factor in the prevalence of stunting. Higher stunting in children under 6 months of age in 2016 compared to previous years, in general, does not align with the existing research; however, studies in rural Malawi have found highest incidence of stunting in children under 6 months. Our findings suggest that stunting during intrauterine period and first 6 months needs to be examined in future studies.

There is evidence that proximate and distal determinants such as child feeding practices, inadequate care and complementary feeding, water sanitation and hygiene practices, infections, and environmental enteropathy play an important role in stunting [130]. Future studies should explore the proximate and distal determinants of stunting in Malawi, which may better inform effective policies and programmatic interventions.

Paper II: Determinants of Childhood Stunting in Malawi – an analysis of the data from the Malawi Demographic and Health Survey, 2015-16

Abstract

Background: Despite recent reductions, stunting in Malawi is among the highest in the world. The complex determinants of stunting include poverty, gender, low rates of exclusive breastfeeding, inadequate care and complementary feeding, limited access to sanitation facilities, environmental enteropathy and recurrent infections. How these factors impact stunting and their relative contribution remains to be investigated. The aim of this study is to explore key determinants of stunting in Malawi.

Methods: The study uses the data from Malawi Demographic and Health Surveys, 2015-16 to explore the proximate and distal determinants of childhood stunting in 2,018 children 0–23 months with anthropometric measurements. The association between stunting and socio-demographic, maternal and child factors was assessed using step-wise logistic regression.

Results: In separate models, prevalence of stunting is significantly higher in boys than girls, in children living in rural areas than urban, and in children that have experienced diarrhea in the past 2 weeks. Stunting is also higher among children from poorest or poorer households. Paradoxically, stunting is higher in children from households that own land and have higher land area. Mother’s BMI and children’s dietary diversity was negatively associated with stunting. In the final model, gender, age, birth interval, and ownership of land remains the strongest determinants of childhood stunting.

Conclusion: Childhood stunting is widespread in Malawi. The study identifies factors that are associated with stunting in children, including socio-economic disparities that may be critical in designing policies and interventions to reduce stunting Malawian children.

Introduction

Prevalence of stunting in Malawi is one of the highest in Sub-Saharan Africa. Data from the Demographic and Health Surveys and recent research show that Malawi has made impressive gains in reduction of stunting from 54.3 percent in 2000 36.6 in 2016 (Kaur et al, *transcript in preparation*). The prevalence of childhood stunting remains high.

Prendergast and Humphrey[120] in their seminal paper, " Stunting syndrome in developing countries" and de Onis and Branca [115] on "Childhood stunting: A global perspective," emphasize the importance of pathological changes that are due to linear growth faltering, which includes increased morbidity, mortality, reduced physical, neurodevelopmental, and economic capacity, and elevated risk of metabolic disease in adulthood and not just short stature.

Children who are malnourished during the first 1,000 days of life have weaker immune system predisposing them at risk for severe infectious diseases, including diarrhea and pneumonia. The interaction between infections and malnutrition have been recognized as early as 1960s showing that repeated diarrhea and other childhood illness's results in altered growth trajectories in children [45]. It has been shown that impoverished children start off on a fairly good growth trajectory which is comparable to healthy children. It is only after repeated diarrheal diseases and other infections that the growth faltering starts to happen in children less than 2 years of age [46]. The prevalence of stunting increases very rapidly between 12 to 24 months, and continues to increase until 36 months, and remains fairly stable until five years [139]. Therefore, the first two years of the child's life is extremely important for optimal growth.

Since stunting is result of a complex interaction of household, environmental, and socio-economic influences, a multi-sector approach consisting of improving food security, dietary diversity, childcare, and disease-control interventions have the potential to reduce childhood stunting [1, 115]. Multi-sectoral approaches to nutrition have shown to accelerate progress in reducing childhood stunting – these include both nutrition-specific and nutrition-sensitive interventions. The nutrition-specific factors examine the immediate causes of inadequate dietary intake and underlying causes inadequate feeding and care practices, household food insecurity, access to food, and inadequate financial and human resources[78]. On the other hand, the nutrition-sensitive factors explore the underlying and basic causes of malnutrition by including nutrition goals and actions from a wide range of sectors, including environment, WASH, agriculture, health services, girl's and women's education, socio-cultural interventions, including focus on women's nutrition and empowerment [78].

Studies have examined the complex determinants of stunting–these include poverty, gender, low rates of exclusive breastfeeding, inadequate care and complementary feeding, limited access to sanitation facilities, environmental enteropathy and recurrent infections [3, 23, 115, 120, 122, 135, 140]. The recent development initiatives in Malawi have promoted smallholder diversification through introducing additional crop and livestock species with the intention to improve household nutrition.

However, the link between ownership of land and land area and stunting has not been explored. Therefore, this paper contributes to the literature in exploring the proximate and distal determinants of childhood stunting in children 0-23 months that may be critical in designing policies and interventions to reduce stunting in children in Malawi. The study selects children age 0–23 months because most of the intervention programs are focused towards the crucial period of pregnancy and the first two years of life – the 1000 days from conception to the child's second birthday, and the infant and child feeding guidelines are designed for children 0–23 months.

Research in context

Evidence before the study: Programmatically, there is evidence that a multi-sector approach consisting of improving food security, dietary diversity, childcare, and disease-control interventions have the potential to reduce childhood stunting.

Added value of this study: The study contributes to the exploration of the various household-level pathways leading to stunting in children.

Implications of all the available evidence: The findings from the study are expected to be relevant for informing food security policy and program implementation. Findings of the study may have a significant potential programmatic benefit in terms of providing empirical support for re-orientating nutrition programs to include other proximate determinants of food security, more specifically nutrition-specific and nutrition-sensitive factors as contributors to child growth.

Methods

Data source and design

The study analysed data from the 2015-16 Malawi DHS survey to determine the proximate and distal determinants of childhood stunting in Malawi. The survey was conducted by the National Statistical Office (NSO) with technical assistance from ICF International and funded by the United States Agency for International Development. The surveys utilized a two-stage cluster sampling design with EAs as primary sampling units and households as secondary sampling units. The weighted sample sizes of children age 0–23 months was 6,225, but the height and weight information were collected only in one-third of the households, and therefore, the study sample consisted of 2,018 children with valid height and weight measurements. For MDHS 2015-16, anthropometry data was collected from all children who slept in the household a night before the interview regardless of the mother's eligibility or interview status.

The effects of various socio-demographic and health factors on stunting will be estimated using bivariate and multivariate logistic regression procedures in Stata 15.0 (Stata Corp., College Station, TX). A number of logistic regression models were estimated to assess the relative significance of confounding factors included in the analysis.

Outcome Variable

Height-for-age or length-for-age is defined as height or length of a child relative to the height or length of a child of the same age in a reference population, expressed either as a Z-score or as a percentage relative to the median of the reference population. A child who has low height-for-age is described as being "stunted." Standing height measurements in all four surveys were carried out in children ages 0–59 months using a measuring board developed by Shorr productions. Recumbent length was measured for children less than 24 months of age. The MDHS survey 2000 and 2004 datasets for height-for-age with previously used NCHS/WHO reference population were made comparable to the WHO Child Growth Standards, released in 2006. Subsequently, the height-for-age Z-scores were calculated based on WHO growth standards for all four surveys [123]. The datasets were cleaned and extreme values (<-6SD or >+6SD) that are likely to represent measurement or data-entry errors, and biologically implausible were eliminated. Stunting was defined as height-for-age Z–score <-2SD from the WHO Child Growth Standards.

Explanatory Variables

Socio-demographic variables: Common household, child, and maternal variables were included in the trend analysis. Some of the variables were recoded into categories for a meaningful comparison. The household variables included residence (urban, rural), region (northern, central, and southern), wealth index (asset-based index grouped into five categories - poorest, poorer, middle, richer, and richest), and source of drinking water (improved and unimproved sources of drinking water) and sanitation facility (availability of improved and unimproved toilet facility). Child characteristics included in the study were age in months (<6, 6–9, 10–11, 12–15, 16–23, 24–35, 36–47, and 48–59 months), sex (male, female), and birth interval (first birth, <24 months, 24–35, 36–47, and 48+ months).

Household wealth and land ownership: The DHS Wealth Index serves as a proxy for household economic status. It is a composite measure of household’s cumulative living standard. The wealth index quintiles include: lowest, second, middle, fourth and highest [106]. The index is based on whether the household owns common items such as radio, television, bicycle, motorcycle, car, refrigerator, toilet, and has access to piped water, etc., and measures household wealth using an index derived from asset variables using principal components analysis (PCA) by placing individual households on a continuous scale of relative wealth. In addition, ownership of animals was used as a proxy for environmental enteropathy since in the rural landscape of Malawi, households with livestock share close proximity of animals and children. Animals often share the area where children play or where food is being cooked and eaten. Ownership of agricultural land was used as a proxy for access to food. The reported agricultural land area in hectares by the farming households was further categorized as small-scale farm (<5 hectares); medium-scale farm (≥5 and <50 hectares); and large-scale farm (≥50 hectares).

WASH practices and ownership of livestock: Whether the household uses an improved drinking water source: improved drinking water sources are piped water into dwelling, plot, or yard; public tap/standpipe, tube well/borehole, protected dug well, protected spring and rainwater collection. Whether the household has access to an improved sanitation facility: improved sanitation is defined as having flush or pour/flush, facilities connected to a piped sewer system, septic system, or a pit latrine; pit latrines with a slab, composting toilets or ventilated improved pit latrines. Households with livestock share close proximity of animals and children. Hence, ownership of livestock was used as a proxy for environmental enteropathy. The dummy variables were created for each livestock and assigned a value of 1 for presence of livestock. Similarly, a composite indicator of the above variables was computed and assigned a value of 1 the household has goats, pigs, chicken, poultry, cows and cattle.

IYCF variables: IYCF practices during the first two years of life are important in growth and development of child. Poor infant and young child feeding practices are also known contributors to child undernutrition. Exclusive breastfeeding includes children aged 0–5 months who have received breast milk including expressed breast milk or breast milk from a wet nurse. Early initiation of breastfeeding includes proportion of children born in the past 24 hours preceding the survey that were put to breast within one hour of birth, and continued breastfeeding of children age 12–15 months. The study explored age-appropriate breastfeeding, i.e., whether infants age 0-5 months received only breast milk during the previous day and whether children 6–23 months of age received breastmilk, as well as solid, semi-solid or soft foods during the previous day. In addition to computing the dietary diversity from seven food groups, the study also examined the consumption of animal source foods that are considered good sources of iron, zinc, vitamin A, and vitamin B12. Consumption of animal source foods provides highly bioavailable micronutrients, protein and improves bioavailability of other micronutrients [42].

Maternal factors: The maternal variables included in the analysis were mother's education (no education, primary, secondary or higher), and BMI (weight in kilograms divided by square of height in meters). Based on the BMI cut-off, women were defined as underweight (BMI <18.5 kg/m^2), normal weight (BMI $=18.5 – 24.9$ kg/m^2), and overweight/obese (BMI ≥ 25 kg/m^2). Mother's anemia status was defined as mild anemia (<11.0 g/dl), moderate anemia (7.0-9.9 g/dl), and severe anemia (<7.0 g/dl). Stunting in mothers was defined as HAZ score<-2SD, and mother's education as having no education, primary, and secondary or higher education.

The study computed the women's participation in household decision-making either alone or jointly with husband or partner. The index is constructed based on woman’s response to her say in large household purchases, her own healthcare, the spending of money she earned, and visits to relatives. The index ranges from 0 to 3. Women’s attitudes towards wife beating are the number of reasons for which a woman thinks it is justified to beat wife. The index ranges from 0 to 5; a lower score reflects a higher status of women. The MDHS survey 2015-16 also included the domestic violence module in one-third of the sampled households. Physical, sexual, and emotional violence was measured by asking a series of questions to all ever-married women.

Statistical analysis

To examine the independent and the combined effects of each of the predictors on stunting, models were run separately and in the step-wise manner. Separate models were created for socio-demographic and background predictors, household wealth and ownership of land, child’s environment, and WASH practices, IYCF practices, and maternal factors. Each of the models constructed were full models. The predictors that did not fit reasonably well were dropped out of the model. Collinearity and goodness of fit tests were also used to remove predictors that were not helping the model. After individual models were created, predictors from each model were added to the original model in a stepwise manner. Afterwards, a post-estimation method was used to store results of the estimation commands to generate the final model.

Results

The MDHS survey 2015-16 consisted of 6,225 children age 0-23 months with almost equal proportion of male (50.3 percent) and female (49.7 percent) children, with anthropometry measurements collected in one-third of the households. After taking into account the missing and flagged cases, and observations with height out of plausible limits, the measurements were available for 2,018 children. Hence, the study sample comprised of 2,018 children ages 0–23 months. The prevalence of stunting in children age 0–23 months is 29.7 percent (Table 2.1) which is lower than the prevalence of 36.6 percent found in the previous study.

Bivariate results

This paper reports the study findings by socio-demographic variables, children's household environment and WASH, wealth and ownership of land, infant and young child feeding practices, and maternal factors, including decision-making and empowerment.

Socio-demographic factors: Table 2.2 shows prevalence of stunting in children 0–23 months by socio-demographic characteristics. Prevalence of stunting is approximately 20 percent in children less than eight months, thereafter, more than one in four children 9–12 months are stunted. One year after birth, the prevalence of stunting continues to increase steadily to reach 40 percent in children 18–23 months. The linear increase in stunting is positively and statistically significant with an increase in age ($p=0.0000$). Similar significant differences are observed for differences in stunting between males (34.5 percent) and females (24.8 percent). Children in rural households have significantly ($p=0.0297$) higher prevalence of stunting compared to children residing in the urban areas (30.9 percent and 21.9 percent, respectively). Other background variables such as region and birth interval, and stunting are not statistically significant at $p<0.05$.

Household environment and WASH: The prevalence of stunting in children varies by the type of floor, wall, and roof of the dwelling. Children residing in households with finished floors and roof have significantly ($p=0.002$) lower prevalence of stunting compared to children from households that have natural or rudimentary floor and roof. (Table 2.3). The bivariate analyses show no significant differences in stunting among children with respect to the WASH variables, but the prevalence of stunting was higher (32.9 percent) in children who were reported to have diarrhea compared to children who did not have diarrhea (28.2 percent) in the preceding two weeks before the survey. The association between stunting and diarrhea in children was statistically significant at $p=0.05$. The relationship between stunting in children and household ownership of livestock (cows, cattle, goats, pigs, chicken, and poultry) was not statistically significant at $p<0.05$.

Household wealth and ownership of land: Table 2.3 shows a dramatic and linear decrease in the prevalence of stunting by household wealth. The difference in prevalence of stunting by wealth quintiles is statistically significant at $p=0.003$. Three quarters of the households own some form of agricultural land, but children from these households have higher prevalence of stunting compared to households that do not have own any land. The size of the land is not associated with stunting.

Infant and young child feeding practices: The proportion of women who continue to breastfeed is high (86.6 percent), but exclusive breastfeeding is relatively low (15.4 percent). Infants that are exclusively breastfed have lower prevalence of stunting (24.3 percent) compared to infants who are not being fed breastmilk (30 percent), receiving breastmilk and solids (31.5 percent), or being fed other milk or liquids in addition to breastmilk (36.6 and 38 percent, respectively). These differences are statistically significant at p=0.05. About 77 percent of women initiated breastfeeding within one hour of birth and less than 5 percent of women continued breastfeeding for at least one year, its impact on stunting, however, is marginal and not statistically significant (Table 2.4).

About 13 percent of infants are introduced complementary feeding at ages 6–8 months. These infants have significantly lower prevalence of stunting at (20.9 percent; p=0.01) compared to stunting in infants who did not consume solid or semi-solid foods at age 6–8 months (31 percent).

Prevalence of stunting varies by dietary diversity score and is statistically significant at p=0.03. Less than 2 percent of infants received diverse diets with 6+ food groups. The recoded dietary diversity index did not show an impact of diverse diets in reducing stunting among children in this study. Similarly, consumption of flesh foods such as meat, flesh and poultry were not associated with reducing stunting.

Maternal factors, empowerment and decisionmaking: Mother’s BMI, short height, and education have a strong association with stunting in children. Children with stunted mothers have significantly higher prevalence of stunting (44.8 percent) compared to children with mothers who are not stunted (25.7 percent) at p=0.0000. Similarly, children with underweight mothers have higher prevalence of stunting (44.5 percent) compared to children with mothers who are either normal weight (30.5 percent) or even overweight (21.3 percent). Mother’s BMI and stunting in children were statistically significant at p=0.001.

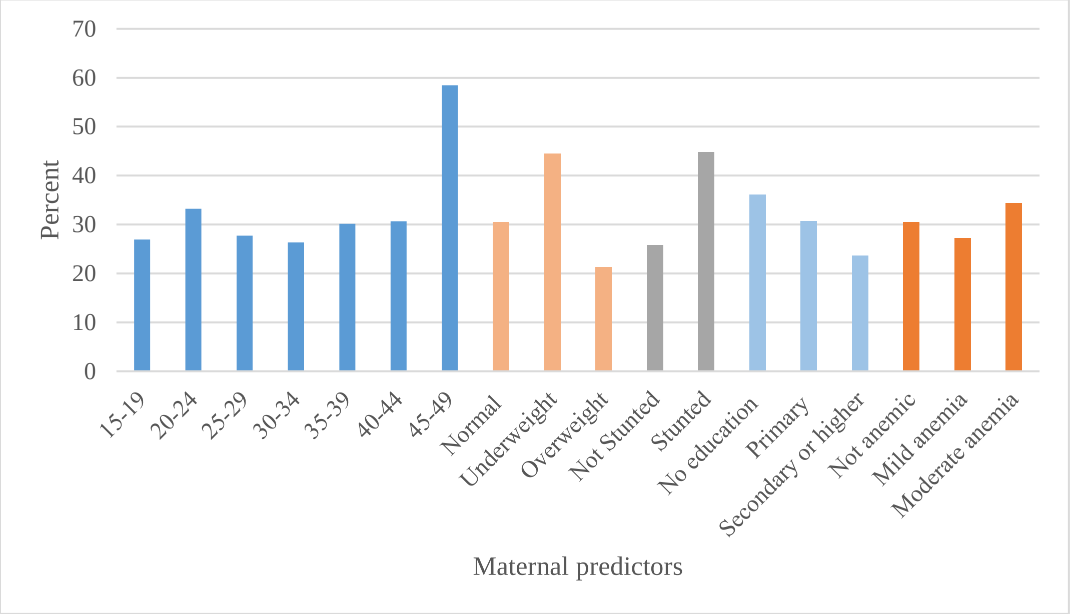

Figure 2.1 Stunting in children by maternal factors, MDHS 2015-16

Mother's education has a protective and statistically significant effect in reducing stunting in children (p=0.02). There is a negative association between mother's education and stunting in children. Prevalence of stunting is 36.1 percent among children with mothers who have no education to 30.7 percent among children with mothers who have primary education and 23.7 percent among children with mothers who have secondary or higher education. Anemia levels in children or mother did not show a significant association with stunting in children (Table 2.5).

There is no statistically significant association between children of women who make decisions with her husband or partner (health care, large household purchases, and visiting family or friends) or who children of women who make their own decisions and stunting in children. (Table 2.6). The study did not find a significant association between mother's marital status and stunting in children.

Women's attitude towards wife beating has a significant association with stunting among children especially when she feels it is not justified to beat wife if she goes out (p=0.007).

The results failed to find an association between stunting among children and mother's experience of physical or sexual violence. However, women's experience of emotional violence is marginally associated with stunting in children (p=0.05). Children of mothers who experience emotional violence have higher prevalence of stunting (34.9 percent) compared to children of mothers who do not experience emotional violence (29.3 percent).

Multivariate results

To examine the independent and the combined effects of each of the predictors on stunting, models were run separately (Tables 2.7, 2.8a, 2.9a, 2.10a, and 2.11a) for association of stunting and socio-demographic variables (model I), children's household environment and WASH (model II), wealth and ownership of land (model III), infant and young child feeding practices (model IV), and maternal factors, including decisionmaking and empowerment (model V). Afterwards, stepwise models (Tables 2.7, 2.8b, 2.9b, 2.10b, and 2.11b) were run to create the final model (Table 2.12).

Model I: The first model examined the relationship between stunting and socio-demographic variables (Table 27). Compared to children 0–5 months, the odds of being stunted in children 13–17 months and 18–23 months increases by a factor of 1.76 and 2.39, respectively. The odds of females being stunted is 40 percent lower than males and is statistically significant at p=0.000. Similarly, the odds of stunting is lower with increase in the birth interval. The risk of stunting increases by a factor of 1.5 for children living in rural areas compared with urban areas (p=0.04).

Model II: Table 2.8a presents the odds of stunting by wealth and ownership of land. The odds of stunting in children from wealthier households were lower compared to poorest households, the odds of stunting in children is statistically lower at p<0.05 and p<0.001 for richer and richest households, respectively. Paradoxically, ownership of land including ownership of a large-scale farm (≥ 50 hectares) was associated with higher risk of stunting in children at p<0.05.

Model III: The model examines the relationship between stunting in children and their environment and WASH practices (Table 2.9a). The study did not find a statistically significant association between stunting in children and households that have safe drinking water and improved sanitation. Similarly, household’s ownership of livestock or prevalence of diarrhea in children in the past two weeks was not significantly associated with stunting in children.

Model IV: Stunting was not associated with exclusive breastfeeding in children. The odds of stunting were approximately 40 percent lower for children who received complimentary food at age 6–8 months (p=0.005). Dietary diversity, i.e., consumption of four or more foods groups did not have an association with stunting (Table 2.10a).

Model V: Table 2.11a presents the likelihood of stunting in children by maternal factors. Having a stunted mother and an underweight mother significantly doubles the odds of stunting in children (p=0.000 and p<0.05). There is 40 percent decrease in the odds of stunting among children born to overweight mothers compared to children born to normal weight women. violence against women did not result in statistically significant association with stunting in children.

Final Model

Results of the stepwise regression models are reported in Tables 2.7, 2.8b, 2.9b, 2.10b 2.11b). In order to perform cross-model comparison of the stepwise regression analysis, the final model was created that contained estimates for the five models (Table 2.12). The results of the multiple regression analyses confirm that the odds of stunting are highly statistically significant ($p<0.001$) and lower among female children ($p<0.001$) and children with adequate birth intervals.

The odds of stunting are significantly higher at $p<0.001$ among children age 18–23 months, Higher birth interval, 36–47 months, reduces the risk of stunting significantly ($p<0.05$).

In the stepwise regression analysis, wealth based on household asset failed to show a significant association with stunting. The study did not find an association with WASH, ownership of livestock, exclusive breastfeeding, and dietary diversity. Due to multicollinearity, complimentary feeding was omitted from the final model The ownership of land and households that have larger-scale farms have higher prevalence of stunted children compared to households that does not own land and have small- or medium-scale farms ($p<0.05$).

Among the maternal factors, mother's stature and BMI very significantly associated with stunting at $p<0.001$ and $p<0.01$, respectively. The odds of stunting are significantly higher among children with a stunted mother ($p<0.001$). Having an underweight mother also puts a child at a higher risk for stunting ($p<0.01$). Mother's education and stunting in children did not show a significant association.

Discussion

Socio-demographic factors: The prevalence of stunting in children age 0–23 months is 29.7 percent, which is lower than the prevalence of 36.6 percent in children ages 0—59 months found in the previous study. The difference in the prevalence of stunting is due to the age of the sample children. Stunting in children two years and older increases rapidly and continues to rise until 3-4 years. Our findings indicated that the risk of stunting increases with age, consistent across several studies that have well documented an increase in prevalence of stunting with age [120, 135, 141, 142]. Gender and urban/rural differences with respect to stunting have been observed in Africa and in Malawi. The results of this study are supportive of the wider literature that posits boys are more stunted than girls, Many studies in sub-Saharan Africa have reported higher prevalence of stunting in boys compared to girls [136]. In an assessment of stunting rates for children age 6–36 months in 28 African countries during the period 1987 to 2002, the average difference in stunting rate between boys and girls was 2.6 percentage points, with stunting rates being higher among boys in all but four of these countries. [119, 136, 141, 143]. In the multivariate analysis, the findings confirm that gender, age, birth control, and birth intervals are strong predictors of stunting in children.

Household environment and WASH: In the bivariate analysis, although the stunting was lower in children with improved and safe access to water, but the study did not find a statistical association between safe drinking water and stunting. The type of sanitation facility did not have an impact on stunting. Despite mounting evidence of importance of safe drinking water, sanitation and hygiene some studies have shown that WASH interventions do not independently affect stunting in children. A recent cluster randomized controlled trial in Bangladesh found that children by two years were taller only in the combined group with WASH and nutrition, and the WASH group without combination with nutrition or counseling did not affect the linear growth of children[144]. Although the findings were not significant and WASH may not have a direct impact on stunting, but the broad-range of health and non-health benefits from safe drinking water, sanitation and hygiene cannot be undermined [145].

Household wealth and ownership of land: The prevalence of stunting decreases linearly with an increase in household wealth. Findings imply that increase is wealth is may increase the purchasing power of the household, including access to food. In Malawi, poverty is very prevalent in rural communities where more than 90 percent of the population subsists on farming, much of which consist of growing maize. With per capita land holding ranging from 0.18 to 0.26 hectares per household. Recent development initiatives in Malawi have promoted smallholder diversification through introducing additional crop and livestock species with the intention to improve household nutrition. However, the link between ownership of land/land area and stunting has not been explored. This study finds that three quarters of the households own some form of agricultural land, and children from these households have higher prevalence of stunting compared to households that do not have any agricultural land. Similarly, households that have large-farms have higher prevalence of stunted children compared to households with small or medium scale farms.

There are several explanations for the observed differences in the prevalence of stunting by ownership of land. First, ownership of land does not mean food crops are being cultivated which is especially true for large-scale farmers; second, even though food is being grown it may not be for household consumption. A higher farm production is not most beneficial to household nutrition needs [44]. In addition, in Malawi, exports heavily rely on key cash crops such as tobacco, tea, sugar and cotton, which provide more than 80 percent of export earnings with 50 percent stemming from tobacco alone. A study on tobacco producers found income source had no effect on stunting in children [146], further, when faced with an income shock, children in tobacco-producing families fared worse in terms of stunting[147].

Infant and young child feeding practices: Breastfeeding has been shown to reduce the risk of morbidity, especially the diarrheal disease. Stunting typically increases in children when complementary food is introduced. The current study shows that stunting is high (22.4 percent) in children as young as 0–5 months and this could be because exclusive breastfeeding in the first six months is not common as only 15.4 percent of children are exclusively breastfed. These findings are similar to other studies in Malawi that show that in addition to lower exclusive breastfeeding, complementary feeding is generally introduced early on which can possibly lead to high infection burden and stunting among children [95]. In Malawi, complementary feeding starts too early with poor quality complementary feeds. In the multivariate analysis, none of the child feeding factors remained significant.

Maternal factors: This study finds that short stature of the mother and BMI are highly significant in determining stunting in children at $p<0.001$ and $p<0..05$, respectively. Several studies have found a strong association between mother's nutritional status and stunting in children [115, 118, 120, 131, 135, 140, 148].

In this study, women's experience of emotional, physical or sexual violence is not statistically significantly associated with stunting in children Research is inconclusive regarding women's exposure of violence and stunting in children. A meta-analysis showed that children whose mothers had depression were 1.4 times more likely to be stunted than the children of non-depressed mothers [149]. The study did not show an association between woman's experience of physical/sexual violence and stunting in children. Studies have found that the odds of stunting increases with maternal exposure to emotional violence[150]. Other studies have found an association between intimate partner violence (any form) and poor child growth, specifically stunting and severe stunting has been reported in the literature [79, 80, 151]. The research shows that in poorer households, the effects of mother's experience of violence on stunting may be masked by larger impacts of food insecurity, micronutrient deficiencies, etc. [80].

Conclusion

The approach of USAID's flagship nutrition and food security initiatives such as Scaling up Nutrition (SUN), Food for Peace (FFP), and Feed the Future in Malawi is to integrate nutrition into a value chain through nutrition-sensitive agricultural productivity, finance and local capacity development. Programs are targeted at the local level, focusing on behavior change, dietary diversification, and improved feeding for pregnant women, young children, and infants [98]. In 2011, Malawi was the first country to join the SUN initiative and the 1,000 Days partnership which aimed to reduce undernutrition in children during the critical period of pregnancy through a child's second birthday [14].

Despite a strong government commitment, strong agricultural productivity, and economic growth in recent years, there is persistent severity of malnutrition in Malawi even in the upper wealth quintile [137]. This accentuates the importance of factors not related to income but associated with knowledge, attitudes and practices with regard to food production, preparation, and consumption; breastfeeding and other young child feeding practices; and disease prevention.

This study reveals that socio-demographic factors and maternal factors show a strong and significant association with stunting in children. Specifically, in this study, child's age, gender, birth interval, and mother's stature and BMI, appear to be the strongest determinants of childhood stunting. The study found that ownership of land was negatively associated with stunting, especially if the land area is more than 50 hectares. This is perplexing finding, but several reasons emerge for this finding. By 1990s more than a quarter of the Malawi's smallholder farmers adopted a hybrid breeding program [152] and several donors work with the Government of Malawi to support and improve the effectiveness of the input subsidy program for smallholders [152]. It is plausible that programs offer counseling on nutrition and diversification of crops, hence in addition to improving productivity and diversity of crops, it directly or indirectly improves nutrition knowledge and dietary intake among the small-holder farmers. The large farm holders may grow cash crops such as tobacco and even if the food crops are grown it may lack diverse cropping such as only cropping maize, and it may not be for household consumption. It has been studied that many medium-scale farmers are urban-based professionals/civil servants who initially had small-scale holdings but acquired lands that resulted in medium-scale holdings [153]. The findings from this study support biological influences and illustrate intergenerational cycle related to stunting. Further research is needed to understand the plausible biological pathways that result in stunting.

Paper III: Biomarkers of Nutrition, Infection, Inflammation and Childhood Stunting in Malawi

Abstract

Background. Micronutrient deficiencies, often termed as the ‘*hidden hunger’* can occur even when diets are adequate with respect to total calories. Micronutrients such as iron, vitamin A, zinc, selenium are deficient in diets around the world, including Malawi. Stunting is typically caused by chronic inadequate diet and illness. There is a plethora of research on underlying and immediate factors that are associated with stunting, whereas information on biochemical data and how it relates to stunting, infection, and inflammation at the population level are lacking.

Objective. The study aims to examine the micronutrient status, infection, inflammation in children ages 0–5 years.

Methods. The study conducts analysis of the nutrition data collected in the Malawi Micronutrient Survey, 2015-16.

Results. Markers of inflammation, both AGP, CRP and any inflammation are slightly elevated for the non-stunted children (1.27 g/l and 5 mg/dl) and much higher for stunted children (1.56 g/l and 9.1 mg/dl). There was a significant association between stunting and iron deficiency anemia, serum ferritin, and selenium deficiency. Children with inherited blood disorder (alpha-thalassemia, and sickle cell disease) have higher prevalence of stunting.

Conclusions. The results from the study confirm that age of the child, birth order, and mother’s report of child’s size at birth, and household hunger are major determinants of

childhood stunting. At the cellular level, iron deficiency anemia, vitamin A deficiency (low levels of RBP), markers of inflammation including CRP, and inherited blood disorders (sickle cell and alpha-thalassemia) are strongly associated with stunting in children.

Introduction

Micronutrient malnutrition is a health problem in Malawi, a small-land locked sub-Saharan country[154]. WHO estimates for Malawi suggest that malnutrition accounts for 16.5 percent of all deaths; unsafe water, sanitation, and hygiene (WASH) 6.7 percent; zinc efficiency, 4.9 percent; and vitamin A deficiency accounts for 4.9 percent of all deaths [126]. Although the complex determinants of child undernutrition have been suggested for decades the optimal mix of interventions to reduce stunting is much less clear, particularly in regions such as sub-Saharan Africa.

Evaluating the quality of child feeding practices and behavior's, specifically exclusive breastfeeding, and the timing of introduction of complementing foods does provide insights of these individual practices, but it does not allow an examination of the effect of the feeding practices on children's health and nutrition outcome [12]. In addition, stunting is typically caused by chronic inadequate diet and illness. Older age children living in a rural area and living in the southern region of Malawi are significantly more likely to have urinary schistosomiasis compared with younger children and those from the other regions[140]. Malaria also plays a role as an immune suppressor thereby leading to increased prevalence and severity of infections such as diarrhea and respiratory disease, which also cause malnutrition. Micronutrient deficiencies, often termed as the '*hidden hunger'* can occur even when diets are adequate with respect to total calories. Micronutrients such iron, vitamin A, zinc, selenium are deficient in diets around the world, including Malawi [42]. Hence, there is a complex interplay between undernutrition and infectious disease that results in stunting [54].

The Government of Malawi and partners have implemented a range of interventions to combat micronutrient malnutrition. These interventions include targeted micronutrient supplementation, nutrition education, and food fortification of staple foods, namely sugar and oil with vitamin A. The data on recent trends in micronutrient deficiencies among vulnerable populations in Malawi is lacking. The subjective nature of self-reports on dietary intake measures are forth with challenges to accurately obtain the information. The validity of nutritional status assessment is greatly improved by biomarker testing of nutritional markers. Measuring micronutrient indicators and markers of inflammation *in vivo* provides a quantifiable measure of importance of child nutrition in reducing infections and stunting.

Therefore, the study examines the determinants of stunting and examine the association between markers of nutrition and stunting. The study conducts a secondary analysis the 2015-16 Malawi Demographic and Health Survey (MDHS) and the jointly conducted Malawi Micronutrient Survey (MNS). The main purpose of the MNS survey was to provide program managers and policy makers with the data needed to plan, implement, and monitor and evaluate nutrition interventions for Malawi. The MNS survey collected data on micronutrient deficiencies, specifically for vitamin A, iron, and zinc among a nationally and regionally-representative sample of children age 0–5 years. The survey also collected information on coverage of nutrition and nutrition-related interventions, including micronutrient supplementation, anemia, malaria, inflammation and inherited blood disorders.

The study findings will assess determinants of stunting including nutrition markers to provide a basis for policy direction and planning to accelerate the reduction of stunting in Malawi.

Methods

Data source and design

The number of households selected for MDHS survey 2015-16 were 27,516. In a random sub-sample of one-third of these households per cluster, all men age 15–54 were eligible for individual interviews and HIV testing. In the same sub-sample, all eligible women and children were eligible for anthropometry measurements and anemia testing. The MNS survey was a stratified sub-sample of the MDHS survey to produce estimates of key indicators for the country as a whole, as well as results stratified by region and residence. A subsample of 105 clusters was randomly selected from the 850 MDHS survey clusters. Among the selected clusters, the one-third of households selected for the MDHS HIV subsample were excluded, and the remaining households (20 per urban cluster, and 22 per rural cluster) were included in the MNS survey.

The National Statistical Office, the Community Health Services Unit of the Ministry of Health, and the Department of Nutrition, HIV and AIDS (funding from Irish Aid), World Bank, and the Emory Global Health Institute, and UNICEF implemented the MNS survey. The technical assistance for the survey was provided by the Centers for Disease Control and Prevention (CDC), and Emory University.

This study is based on secondary analysis of the MNS survey that targeted 1,279 children age 0–59 months in the eligible households. The sample size estimated were based on predicted change in the prevalence of vitamin A deficiency in children age 0–5 years from 22 percent in 2009 to 15 percent in 2015. The overall response rate was 96 percent. Data on anthropometry was collected from 1,230 children, and venous blood was collected from 1,102 children. Informed consent for urine collection, blood draw and measurements were asked from parents or guardians of the children. Referral was provided to a local hospital if the child was found to have severe anemia (Hb <7g/dL), malaria, moderate to severe acute malnutrition based on MUAC assessment, and hematuria as a proxy diagnosis for urinary schistosomiasis.

Outcome Variable

Height-for-age/length-for-age is defined as height or length of a child relative to the height or length of a child of the same age in a reference population, expressed either as a Z–score or as a percentage relative to the median of the reference population. A child who has low height-for-age is described as being “stunted.” Standing height measurements in all four surveys were carried out in children ages 0–59 months using a measuring board developed by Shorr productions. Recumbent length was measured for children less than 24 months of age. Anthropometric indices for height for age Z score and its cut-off were calculated by using WHO Child Growth Standards (2010 STATA igrowup package). Stunting is defined as height-for-age Z–score <-2SD from the WHO Child Growth Standards.

Explanatory Variables

Socio-demographic variables: Common household and child variables were included in the analysis. Some of the variables were recoded into categories for a meaningful comparison. The household variables included residence (urban, rural), region (northern, central, and southern), wealth index (asset-based index grouped into five categories – poorest, poorer, middle, richer, and richest), and source of drinking water (improved and unimproved sources of drinking water) and sanitation facility (availability of improved and unimproved toilet facility). Child characteristics included in the study were age in months (<6, 6–9, 10–11, 12–15, 16–23, 24–35, 36–47, and 48–59 months), sex (male, female), and birth order (1, 2–3, 4–5, 6+).

Household wealth and land ownership: The DHS Wealth Index serves as a proxy for household economic status. It is a composite measure of household's cumulative living standard. The wealth index quintiles include: lowest, second, middle, fourth and highest [106]. The index is based on whether the household owns common items such as radio, television, bicycle, motorcycle, car, refrigerator, toilet, and has access to piped water, etc., and measures household wealth using an index derived from asset variables using principal components analysis (PCA) by placing individual households on a continuous scale of relative wealth. In addition, ownership of animals will be used as a proxy for environmental enteropathy since in the rural landscape of Malawi, households with livestock share close proximity of animals and children. Animals often share the area where children play or where food is being cooked and eaten. Ownership of agricultural land is used as a proxy for access to food. The reported agricultural land area in hectares by the farming household was further categorized as small-scale farm (<5 hectares); medium-scale farm (≥5 and <50 hectares); and large-scale farm (≥50 hectares).

WASH practices and ownership of livestock: Whether the household uses an improved drinking water source: improved drinking water sources are piped water into dwelling, plot, or yard; public tap/standpipe, tube well/borehole, protected dug well, protected spring and rainwater collection. Whether the household has access to an improved sanitation facility: improved sanitation is defined as having flush or pour/flush, facilities connected to a piped sewer system, septic system, or a pit latrine; pit latrines with a slab, composting toilets or ventilated improved pit latrines. Households with livestock share close proximity of animals and children, hence, ownership of livestock is used as proxy for environmental enteropathy. The dummy variables were created for each livestock and assigned a value of 1 for presence of livestock. Similarly, a composite indicator of the above variables was computed and assigned a value of 1 the household has goats, pigs, chicken, poultry, cows and cattle.

IYCF variables: IYCF practices during the first two years of life are important in growth and development of child. Poor infant and young child feeding practices are also known contributors to child undernutrition. Exclusive breastfeeding includes children aged 0–5 months who have received breast milk including expressed breast milk or breast milk from a wet nurse. Early initiation of breastfeeding includes a proportion of children born in the past 24 hours preceding the survey that were put to breast within one hour of birth, and continued breastfeeding of children age 12–15 months. The study explored age-appropriate breastfeeding, i.e., whether infants age 0–5 months received only breast milk during the previous day and whether children 6–23 months of age received breastmilk, as well as solid, semi-solid or soft foods during the previous day. In addition to computing the dietary diversity from seven food groups, the study also examined the consumption of animal source foods that are considered good sources of iron, zinc, vitamin A, and vitamin B12. The consumption of animal source foods provides highly bioavailable micronutrients, protein and improves bioavailability of other micronutrients [42]. The minimum dietary diversity is defined as the proportion of children aged 6–23 months that received foods from at least four out of seven food groups. The 7 foods groups used for calculation of WHO minimum dietary diversity indicator are: (i) grains, roots and tubers; (ii) legumes and nuts; (iii) dairy products; (iv) flesh foods; (v) eggs; (vi) vitamin A rich fruits and vegetables; and (vii) other fruits and vegetables. The dietary diversity score, therefore, ranged from 0–7 with a minimum of 0 if none of the food groups are consumed to 7 if all the food groups are consumed.

Maternal factors: The maternal variables included in the analysis were mother's education (no education, primary, secondary or higher). Mother's education is defined as mother having no education, primary, and secondary or higher education. The study computed the women's participation in household decisionmaking either alone or jointly with husband/partner. The index is constructed based on woman's response to her say in large household purchases, her own healthcare, the spending of money she earned, and visits to relatives. The index ranges from 0 to 3. Women's attitudes towards wife beating are the number of reasons for which a woman thinks it is justified to beat wife. The index ranges from 0 to 5; a lower score reflects a higher status of women. The MNS survey did not include the domestic violence module as it was implemented only in one-third of the sampled MDHS survey households.

Social protection and use of supplements: Malawi has implemented social protection programs to support household food security. This includes cash transfer program, food or cash support during droughts and floods, and coupons from the farm input ssubsidy program (FISP). Data was analyzed to determine the stunting level's children from households that received the social protection programs or not. Data was also analyzed to determine children who took iron-containing supplements, therapeutic foods, received a vitamin A capsule in the past six months, and received deworming treatment in the past six months.

Biomarkers of nutrition, infection and inflammation: The MNS Survey 2015-16 was designed to determine the prevalence of micronutrient deficiencies, specifically, vitamin A, iron, iodine, and zinc. Other biomarkers tested included markers of inflammation, infection, and inherited blood disorders. Whole blood collected in the EDTA vacutainer tube was used for hemoglobin and malaria testing. Dried blood spots were made from 100 µl of whole blood. The DBS cards were dried, stored, and transferred to the central laboratory for inherited blood disorder testing. The remaining blood from the vacutainer tube was centrifuged, and plasma was aliquoted and stored at Community Health Services Unit (CHSU) of the Ministry of Health and serum was harvested from the blue top vacutainer tube and was used for various micronutrient biochemical analysis.

In a subset, eligible children participated in the MRDR sub-sample. Venous blood sample was collected 4 to 6 hours after a small challenge dose of retinol analog along with a fatty snack was given to the children.

Measurement and testing: Anthropometry measurements, including mid-upper arm circumference (MUAC) were performed at the mobile laboratory. Hemoglobin concentration was measured from a peripheral blood using HemoCue 201+, malaria diagnosis was conducted using a rapid test, and hematuria were assessed in the mobile laboratory, and the results were provided to the respondents. The MRDR and retinol laboratory testing was conducted using HPLC. In addition, zinc, selenium, c-reactive protein, alpha-1-acid glycoprotein concentrations were measured.

Statistical methods

Statistical analysis was performed by using Stata 15.0 (StataCorp, College Station, TX). Data on demographic, social, and economic characteristics, nutrition status and nutrition risk factors of the respondents were analyzed. Both bivariate and multivariate analyses were performed to identify the determinants of stunting. Firstly, bivariate analyses for all the various risk factors were performed using Chi-square ($\chi 2$) tests and Pearson. The association between dependent variable (stunting) and independent variables, including biological markers was determined using multiple logistic regression modeling which included all potential socioeconomic, and demographic confounders.

A number of alternative logistic regression models were estimated to assess the relative significance of different confounding factors included in the analysis. The study also carried out the analysis using a continuous response variable of height-for-age Z–scores and using a linear regression model, but the results from this analysis (not shown) were similar to those from the logistic regression models presented. In the analysis, weights were used to restore the representativeness of the sample. Results of bivariate analysis are presented with standards errors and 95% confidence intervals (CIs), and the logistic regression outputs are presented as the odds ratios (ORs) with linearized standard errors and 95% CIs.

Results

In the MNS sub-sample, more than one-third of the children age 0–5 years (n=1,088) are stunted (34.53, CI 30.99-38.24). The prevalence is slightly lower than the MDHS survey 2015-16 (36.6 percent, CI 34.9-38.3) that included a sample of 5,149 children age 0–5 years. Despite the difference, both estimates have an overlapping confidence interval.

Background characteristics

Table 3.1 shows the prevalence of stunting among children by select socio-demographic and other variables, including WASH, ownership of assets, land and livestock. The prevalence of stunting increases with age from 14.1 percent in children age 0–11 months and 39.2 percent in children age 48–59 months. The highest prevalence of stunting is found in children 24–35 months (Figure 3.1). The results are statistically significant at p=0.0001.

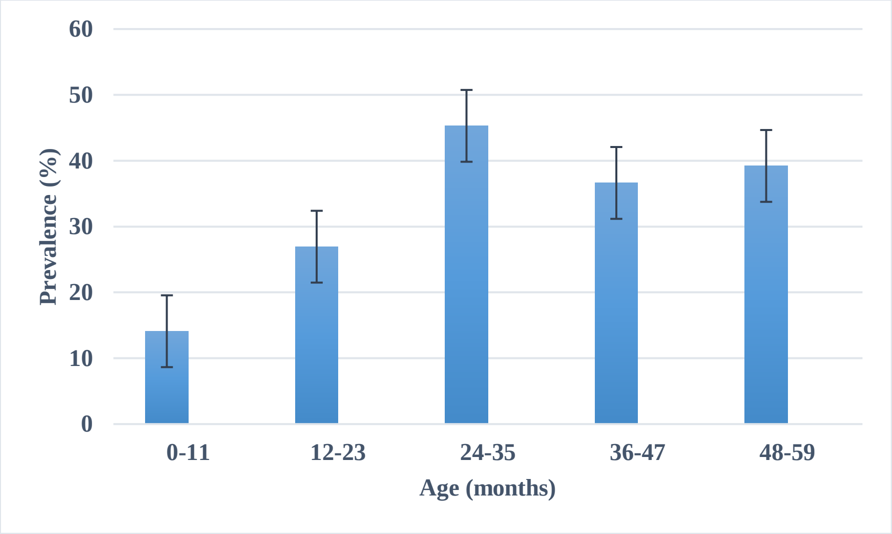

Figure 3.1 Prevalence of stunting by age groups, MDHS 2015-16

In the bivariate analysis, the study did not find statistically significant association between stunting and region, residence, birth interval and sex of the child. There is a linear relationship, however, between birth order and stunting. The prevalence of stunting in children increases as the birth order of the child increases ($p=0.001$).

There exists significant difference at $p<0.05$ with respect to use of cooking fuel, but less than 1 percent of children are from households that use electricity, liquefied petroleum gas (LPG), or natural gas for cooking. The prevalence of stunting in children is not significantly associated with access to safe and improved water for drinking Similarly, the sanitation facility of the household, diarrhea in children in the preceding two weeks before the survey, and ownership of livestock by the household and household wealth did not have an impact on stunting prevalence in children.

Infant and young child feeding practices

Tables 3.2a and 3.2b show prevalence of stunting among children 0–5 years and 0–23 months, respectively by variables associated with IYCF practices. Estimating the prevalence of stunting for the two age groups did not change the statistical relationship between stunting and IYCF practices except for bottle feeding. The bivariate results show that duration of breastfeeding, complementary feeding, and continued breastfeeding at 1 year has a statistically significant relationship with childhood stunting at $p<0.05$. There is approximately 50 percent reduction in the prevalence of stunting if the child continued to be breastfed by one year and complementary foods are introduced by 6–8 months. No statistical significant association was observed for dietary diversity, consumption of animal source food, and exclusive breastfeeding It should be noted that less than 0.1 percent of infant are exclusively breastfed in the MNS sample. Similarly, initiation of breastmilk within an hour of birth or bottle feeding is not significantly associated stunting in children.

Maternal factors

There is no significant association between stunting in children and mother's age, and marital statusSimilarly, this study did not find a significant association between stunting and women's decisionmaking/empowerment, and women's attitude on wife beating.

Table 3.3 shows that there is somewhat a linear relationship between prevalence of stunting among children and women's participation in decisiomaking. When the mother makes the health care decisions by herself, the prevalence of child's stunting is lower (30.4 percent) compared to when the healthcare decisions are made with husband/partner (34.8 percent), or husband/partner alone (39.3 percent). Similarly, prevalence of stunting is lower children if mother alone decides on purchase of large items (26.8 percent) compared to decisionmaking with her husband/partner (31.8 percent) or by husband/partner alone (39.4 percent). Prevalence of stunting was also lower in children when mother decides on her own to visit family or friends (32.0 percent) compared to when she decides with her husband/partner or by husband/partner alone (36.0 percent and 94.8 percent). The study, however, did not find an association between empowerment in women and stunting in children. These results failed to reach the statistically significance at $p<0.05$.

Most all women (98.2 percent) do not believe it is justified for husband or partner to beat the wife if she goes out without asking the husband, neglects children, argues with husband, refuses sex, or burns food. Women's attitude does not have an impact in reducing stunting among children.

Biomarker of nutrition, inflammation and inherited disorders

The mean of different nutrition, inflammation and select inherited disorder among stunted and non-stunted children are presented in Table 3.4. Hemoglobin levels are similar in stunted and non-stunted children. Overall levels of serum ferritin, an acute phase protein, and soluble transferrin receptor (sTfr) are higher in all children, and much higher in stunted children. The level of serum ferritin and sTfr in stunted children is 56.2 µg/dl and 10.9 mg/l compared to non-stunted children (48.5 µg/dl and 11.42 mg/l). Overall, retinol binding protein (RBP) levels are high (0.89 µmol/l) against the cutoff of <0.46 µmol/l, selenium levels are low (61.18ng/ml) compared to the normal range of 70-150 ng/ml, and serum zinc is 60 µg/dl. The normal level of serum zinc is in the range of <57-65 µg/dl.

Markers of inflammation, both AGP, CRP and any inflammation are slightly elevated for the non-stunted children (1.27 g/l and 5 mg/dl) and much higher for stunted children (1.56 g/l and 9.1 mg/dl). Any form of inflammation is also higher for stunted children compared to the non-stunted children. Overall, the levels of hemolytic disorders, G6PD and alpha-thalassemia are lower than the recommended range of 5-5-20.5 units/g and >9.5 g/dl Hb, respectively.

The bivariate analysis shows that anemia and serum ferritin levels (unadjusted or adjusted for inflammation) was not statistically significantly different among stunted and non-stunted children at $p<0.05$. The study failed to show an association between stunting and iron deficiency anemia (IDA). The higher prevalence of stunting exists among children with RBP levels of >0.46 µmol/l. Although the results are highly significant at p <0.0001, but the high levels of RBP exist in less than 4 percent of the children. Serum zinc levels did not show an association with stunting in children. The prevalence of stunting is higher in children with deficient levels of selenium (p=0.08), butnly 27 children were found to have selenium deficiency.

The mean concentrations of the micronutrients, markers of inflammation, and inherited hemolytic disorders are presented is Table 3.5. The prevalence of stunting is significantly higher for children with abnormal levels of AGP and CRP. Prevalence of stunting is 42.5 percent with abnormal AGP compared to 26.3 percent for normal AGP, and stunting was 51.8 percent with abnormal CRP compared to 30.1 percent for normal CRP levels. Similarly, any form of inflammation is highly associated with stunting in children (p=0.0003). Children who are carrier of inherited disorders such alpha-thalassemia, G6PD, and sickle cell have a much higher prevalence of stunting, and is statistically significant for G6PD and sickle-cell anemia.

Household hunger

Table 3.6 shows prevalence of stunting by household hunger. The proportion of households that experienced moderate to severe hunger in the past 4 weeks was 58.9 percent. Household hunger is associated with higher stunting among children in the study sample. Due to the small sample of children in the tail end of the HHS, the scale was recoded as households with little to no huger, moderate hunger, and severe hunger. The prevalence of stunting was 29.5 percent, 37.7 percent, and 36.5 percent, respectively and statistically significant at p=0.03. The scale was recoded as a binary variable (little to no hunger and moderate to severe household huger) shows that prevalence of stunting is higher among households that experience moderate to severe hunger (37.7 percent) compared to households that experience little to no hunger (29.5 percent).

Birthweight, size at birth and MUAC

Reported perception of child's size at birth and birth weight has an association with stunting in children at $p \leq 0.05$. Mothers who reported that infants were born large or larger than average has lower prevalence of stunting than other children who were reported as average, smaller than average or very small. Similarly, the prevalence of stunting is higher among children with recorded birthweight as low or very low (39.6 percent) compared to stunting in children who had birthweight recorded as normal (32.1 percent).

Fever and infections

The prevalence of stunting is higher among children who had (38.3 percent) compared to stunting in children who did not have a bout of fever in the past two weeks (31.8 percent).. Similar differences were observed for children who experienced fever in the past 24 hours, however, the results are not statistically significant (Table 3.8). The prevalence of malaria was 27 percent and children with malaria has higher prevalence of stunting (37 percent) compared to 34 percent stunting in children with no episode of malaria in the past two weeks. Cough in the past two weeks did not have an association with stunting in children. The prevalence of hematuria in children was four percent, but only 11 children were found to be both stunted and positive for hematuria.

Therapeutic supplements

The use of iron containing supplements was 2.7 percent, therapeutic foods 1.3 percent. The prevalence of children receiving a vitamin A capsule in the previous six months was 14.8 percent and 18.3 percent of children received deworming treatment in the past six months (Table 3.9). No statistical significant relationship was observed between stunting in children and iron/vitamin A supplementation or interventions such as therapeutic foods like plumy nut or deworming. Sleeping under a mosquito net did not have an impact on stunting in children. However, a recent record of receiving a vitamin A on the vaccination card shows a significant association with reduced stunting in children compared to the mother's report or having no card (p=0.02).

Safety net and interventions

Just over a third of households in Malawi received coupons from FISP program and approximately seven percent of households participated in the social cash transfer program. Approximately six percent of households reported being on the Malawian vulnerability assessment committee (MVAC) list for 2015-16 and percent households reported receiving food or cash support during last 2014's drought and flood response from the MVAC committee. Table 3.10 illustrates the coverage of social protection programs in Malawi and prevalence of stunting. None of the safety nets or government programs were significantly associated with reduced prevalence of stunting. In fact, as with supplements, deworming and therapeutic interventions, the recipients of the social programs have higher prevalence of stunting.

Multivariate analysis

The multivariate analysis includes two models –

Model I: Logistic regression model for all variables that were statistically significant in the bivariate analysis ($p<0.05$) for children age 0–24 months.

The multivariate logistic regression confirms most of the bivariate results. After adjusting for a range of variables, Table 3.11 shows that age of the child, birth order mother's report of child's size at birth, iron deficiency anemia, serum ferritin, and having vitamin A vaccination are major determinants of childhood stunting.

Older children (24–35 months) have higher prevalence of stunting compared to the younger children ($p<0.001$). The odds of stunting are significantly higher by a factor of 3 with higher birth order of children (birth order 4–5). Mother's report of a smaller than average size of child at birth is associated with stunting in children ($p<0.001$).

The odds of stunting is higher by a factor of 3.0 with higher serum ferritin concentrations Stunting is associated with iron deficiency anemia, and has a negative relationship with selenium deficiency ($p=0.05$). Normal levels of selenium reduce the odd of stunting by approximately 70percent.

. Children from the households that received vitamin A vaccination have 80 percent reduced the odds of stunting ($P<0.005$).

Model II: Logistic regression analysis that includes the biomarkers of nutrition, infection, and inherited blood disorders and household hunger for children under 5 years.

Table 3.12 shows that children with low serum ferritin concentrations (marker of iron deficiency) and low retinol binding protein (maker of vitamin A deficiency) have higher prevalence of stunting ($p<0.05$). In addition, children who carrier of or are affected by inherited blood disorders, specifically sickle cell disease and alpha-thalassemia are likely to be stunted ($p<0.05$). Figure 3.2 shows the odds of being stunted by biomarkers tested in children under 5.

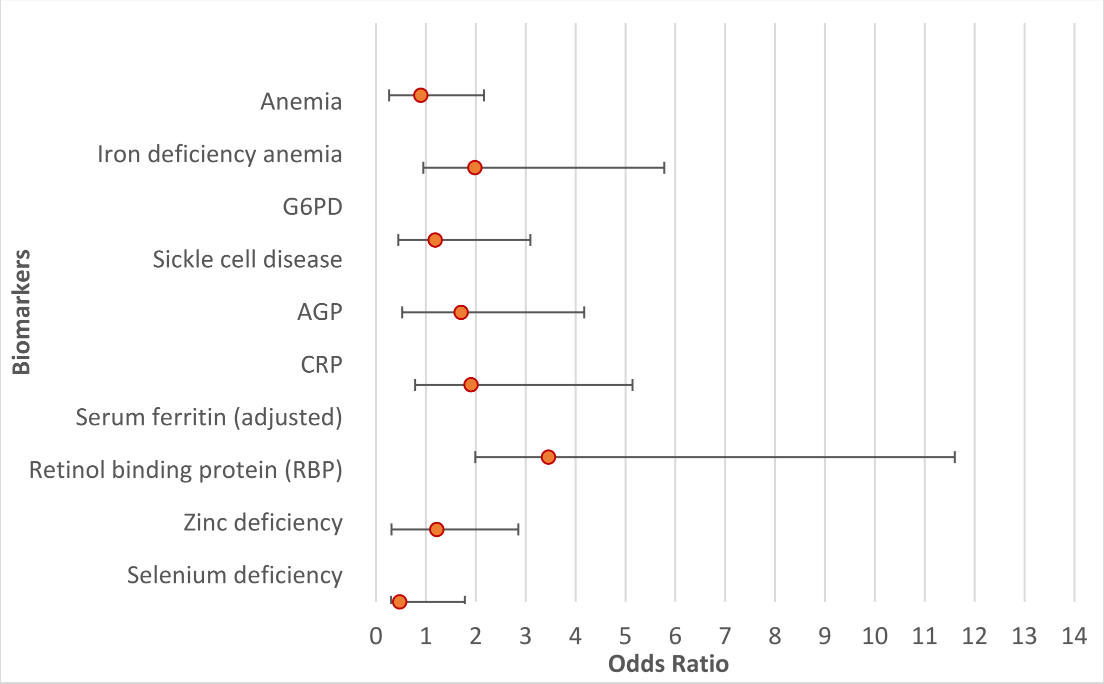

Figure 3.2 Odds of stunting in children by biomarkers, MDHS 2015-16

The study also finds that while controlling for other biological variables, children are almost twice as likely to be stunted from households that experience moderate to severe hunger ($p<0.005$).

Discussion

The study uses the datasets from MDHS 2015-16 and MNS 2016 to empirically examine the relationship of micronutrient status and stunting among children in addition to other determinants of stunting including dietary diversity, consumption of animal source/iron rich foods, WASH, women’s participation in decisionmaking, household hunger, social safety nets and other interventions.

Background characteristics: In the MNS sub-sample, more than one-third of the children age 0–5 years (n=1,088) is stunted (34.53, CI 30.99-38.24). The prevalence is slightly lower than the MDHS survey 2015-16 (36.6 percent, CI 34.9-38.3) that included a sample of 5,149 children age 0–5 years. Since stunting increases by age [115, 135], it is conceivable that a sample of higher age group children will have slightly higher prevalence of stunting. Despite the difference, both estimates have an overlapping confidence interval. Although it is well documented [155] and the other two papers (I & II) have found that boys have higher prevalence of stunting compared to girls, the gender differences were not strongly associated with stunting in this study.

Infant and young child feeding practices: It has been demonstrated that reduced dietary diversity was a strong predictor of stunting among children < 60 months of age[156]. In the multivariate analysis, the study did not find an association between stunting and dietary diversity and other IYCF indicators.   The bivariate analysis found approximately 50 percent reduction in the prevalence of stunting if the child continued to be breastfed by one-year and received complementary foods by 6–8 months. The timely introduction of first complementary food has been significantly found to reduce the incidence of stunting [141] [135]. Although the multivariate analysis did not show a correlation between stunting and dietary diversity, but The study did not find an association between stunting and consumption of animal source foods such as meat and organ meat. This could be because in rural Malawi, foods from animal sources are rarely eaten [20]. Since interventions include other components that may contribute to the effects observed during a study, it is difficult to tease apart the efficacy of supplementary animal source foods on prevention of growth faltering[90].

The risk of increased mortality and morbidity due to deviation from breastfeeding guidelines is well documented – exclusive bottle feeding in developing countries increases the risk in infants to 2 to 50 fold compared to exclusively breastfed infants[126]. And although there is strong evidence that breastfeeding is associated with an increase in the IQ and protection against non-communicable diseases, the data is inconclusive of its direct effect in reducing stunting [135]. The research also suggests that IYCF indicators may better explain weight-for-length Z–-scores than length-for-age Z–scores [141]. Poor complementary feeding practices are associated with stunting and growth faltering [40]. In the study, we observed the relationship in the bivariate analysis but not in the final model for children age 0–24 months (not shown), one reason for this observation could be that the most common complementary food is a think maize porridge which is not nutrient dense to impact stunting in children [126]. Furthermore, this is the period when infections increase in children [37, 115, 126].

Household hunger: The bivariate and the multivariate results show that household hunger is strongly associated with stunting in children ($p<0.05$). As the household hunger increases the odds of stunting increases by a factor of 1.74. This could be because dependence on rain fed agriculture interrupts food availability across seasons – these variations result in abundance of food during harvest and less food during the cropping season. The 2004 Malawi Integrated Household Survey found that children were less likely to be stunted during the lean cropping season compared to the post-harvest season [155].

Maternal factors: Although mother's education is a strong predictor of children's health and nutrition [9] and there exists an inverse relationship between stunting and mother's participation in decision-making and attitude towards violence[73], but the present study did not find an association between stunting and women's decision-making and empowerment or any other maternal factors examined including age, education, marital status, and attitudes towards wife beating.

Biomarker of nutrition, inflammation and inherited disorders: Biomarkers of nutrition are able to objectively assess dietary intake or status without bias of self-reported dietary intake data. The study examined the biomarkers of nutrition, inflammation, and infections.

Iron deficiency in preschool children is 58 percent in Malawi [126]. As per WHO'S classification (>40 percent prevalence of anemia), anemia is a public health problem in Malawi. The study found that hemoglobin levels are similar in stunted and non-stunted children and the mean hemoglobin is 11.4 g/dl, however, the serum transferrin receptor (sTfR) in high, and specifically higher among stunted children. Higher levels of serum transferring suggest a high prevalence of iron deficiency anemia. Table 3.5 shows that children have very high levels of serum ferritin (48.5 µg/l among non-stunted children vs. 56.2 µg/l in stunted children). The normal cutoff for serum ferritin is <12 µg/l and abnormal high ferritin levels observed in the study indicate imbalances in iron metabolism. In the bivariate and the multivariate analysis, abnormal levels of RBP, i.e., >0.46 µmol/l are highly associated with stunting (p=0.005)

Although not significant, the study shows that low zinc concentrations are associated with stunting in children. Zinc deficiency is now recognized by the UNICEF as a public health problem in many countries, especially developing countries, including Malawi. It is estimated that 34 percent of the Malawian population is at risk for insufficient zinc intake [157]. Dietary studies in Malawian children have documented that a high phytate content of maize diets is one of the leading causes of zinc deficiency. It is well documented that intestinal permeability is increased with zinc deficiency. Zinc deficiency also has a negative effect on growth – a meta-analysis of randomized controlled trials of zinc supplementation showed a significant benefit for linear growth in children aged 0–5 years. The effect was a gain of 0.37 cm in zinc-supplemented children. In fact, trials that used a dose of zinc of 10 mg per day for 24 weeks, rather than lower doses, showed a larger benefit of 0.46 cm [135]. The study did not find a significant association between selenium deficiency and risk of stunting.

Inflammation, fever and infection: Inflammation defined as either elevated CRP or AGP is common and found more than 50 percent of children. The prevalence of elevated AGP is 57 percent, and the prevalence of elevated CRP is 26 percent. The prevalence of elevated AGP is more than double the prevalence of CRP. Markers of inflammation, both AGP, CRP and any inflammation are slightly elevated for the non-stunted children (1.27 g/l and 5 mg/dl) and much higher for stunted children (1.56 g/l and 9.1 mg/dl). The multivariate analysis confirm that high levels of CRP is strongly associated with the risk of stunting in children (p=0.005). Other studies have also found that markers of inflammation are higher in stunted children than non-stunted children from as early as 6 weeks after birth [88]. Findings by the researchers suggest that an extensive enteropathy during infancy and that low-grade chronic inflammation may impair infant growth.

The prevalence of malaria is 20 percent. It is well documented that diarrheal disease is inversely associated with changes in HAZ [49], and increases in prevalence of diarrhea and malaria are associated with growth faltering [158]. iIn an analysis of data from nine community-based studies with daily diarrhea data and longitudinal anthropometric measurements, the odds of stunting by 24 months increased multiplicatively with each episode of diarrhea. Overall, 25 percent of stunting was attributed to five or more episodes of diarrhea [120]. Malaria is not only exacerbated by malnutrition, it also results in growth failure [126]. The study did not find an association between stunting and diarrhea malaria.

Schistosomiasis is also important risk factors for development of undernutrition especially micronutrient deficiencies [126]. The prevalence of urinary schistosomiases is one percent in children.

Malaria is not only exacerbated by malnutrition, but it also results in growth failure. In stunted children, malaria is associated with lower hemoglobin concentrations and higher serum concentrations of sTfR and C-reactive protein than in their non-stunted counterparts. There is no clear evidence that stunting is associated with an increased prevalence of malarial infection, but malaria-associated anemia, iron demand, and inflammation are greater in stunted than in non-stunted children [159]. Another important role of malaria in undernutrition is through its effects in pregnancy which leads to low birth weight.

Birthweight, size at birth and MUAC: Prolonged infections in endemic areas affect placental function and may depress birthweight [126]. Stunted infants are growth restricted at birth [88], hence, birthweight can be considered as the proxy indicator of stunting[160]. This paper shows that low birth and very low birth children are at a higher risk of stunting, prevalence of stunting is higher if the mother is stunted too. Studies in the literature support that women's nutritional status before and during pregnancy may contribute to intra-uterine growth retardation thereby increasing the odds of having a LBW infant which in turn is a risk factor for stunting in childhood [78]. Black et al explains that maternal stunting (height<145 cm) increases the risk of both term and preterm small for gestational age (SGA) babies [70]. Other studies have shown that LBW is associated with 2.5 to 3.5-fold higher the odds of stunting in children[93, 161]. Given that birthweight is associated with postnatal infant growth, micronutrients given during the antenatal period can help reduce infant malnutrition at least during the first few months [125].

Therapeutic supplements: The use of iron containing supplements was 2.7 percent, therapeutic foods 1.3 percent. The prevalence of children receiving a vitamin A capsule in the previous 6 months was 14.8 percent and 18.3 percent of children received deworming treatment in the past 6 months (Table 3.9). Although micronutrient powders presented in small single- use sachets to add to a serving of complementary food have proven successful in preventing and treating anemia. Adding other micronutrients such as zinc has been explored, but as yet no formula has been shown to prevent stunting or promotes linear growth [120, 125, 127]. Similarly, this study did not find a statistical significant relationship between stunting in children and iron/vitamin A supplementation or interventions such as therapeutic foods like plumy nut or deworming. In fact, the relationship is negative, i.e., children receiving the supplements or interventions have higher prevalence of stunting compared to children who are not receiving supplements or interventions. It is possible that only the very malnourished children are, in fact, eligible to receive the supplements/interventions, and hence the stunting levels are higher in these children.

Other studies have shown beneficial effects of lipid based nutrient (LNS) supplements [162]. A study in Malawi confirmed better weight gain in moderately malnourished children with (LNS) compared to a cereal product [38], but there was no difference in linear growth.[125]. Similarly, a randomized controlled trial in Malawi found that LNS supplements during infancy, and childhood did not reduce stunting among Malawian children 6–18 months [13, 95, 96, 127]. This lack of effect of nutritional supplementation also supports the observation that causes and consequences of stunting are multifactorial and not responsive to a simply supplementation. A large-scale feeding programs have been problems in targeting the right groups, ensuring intake of the supplement by intended beneficiaries, spillover to other than intended beneficiaries and replacement of the habitual dietary intakes of the beneficiaries.

Lastly, sleeping under a mosquito net did not have an impact on stunting in children, whereas, a recent record of receiving a vitamin A on the vaccination card shows a significant association with reduced stunting in children compared to the mother's report or having no card ($p<0.05$).

Safety net and interventions: The study finds that households that receive coupons from Farm Input Subsidy Program (FISP) have more than 60 percent reduced the odds of having children who are stunted. It has been shown that social protection and provision of services, such as food or cash transfers, food vouchers, and support for inputs to highly vulnerable groups can increase their nutritional status, income and resilience specially in times of humanitarian disaster [9].

Conclusion

This study builds on our previous study to examine the micronutrient concentrations and its relationship with childhood stunting in Malawi. The implications of the study findings for policy are clear – single targeted short-term interventions are unlikely to succeed in an environment where the causes of malnutrition are not only multiple but also interrelated in a complex way integrated approaches combining several strategies. There is a strong evidence that promotion of appropriate complementary feeding practices and to promote early initiation of breastfeeding and exclusively doing so for six months. Ruel and Menon [12] explain clustering of positive practices in relation to feeding practices, i.e., there is evidence that hygiene and child feeding practices and behaviors (positive or negative) tend to cluster at any given time and over time. For example, mothers who engage in positive practices in early-on tend to continue over time and hence the cumulative effect of the improved practices is only evident after a certain age.

The key determinants of child undernutrition are food insecurity, poverty and high rates of illiteracy, especially among women. Children who were ill two weeks prior to the survey were more likely to be underweight [155]. Since stunting is a long-term process that results from a series of insults that start as early as in utero and continues until three years postnatally, we may not see an association between stunting and variables that are looking at exposure in the last 7 days or last 4 weeks even though exposures in the short term are generally considered proxy for practices and exposures over longer periods of time. These may include variables such as malaria, fever, etc. for which the study fails to see an association with stunting.

The study shows that having a quantifiable measure such as biomarkers of nutrition are able to objectively assess micronutrient status without bias of self-reported dietary intake data. Children who are malnourished during the first 1,000 days of life have weaker immune system predisposing them at risk for severe infectious diseases, including diarrhea and pneumonia. Therefore, measurement before clinical signs of disease occurs is crucial in reduction of stunting and its detrimental consequences. Subjective measures such as the dietary diversity score give each food group equal weight, but all food groups are not equally important for nutrition, especially for intake of micronutrients, which are most commonly deficient in African diets [42]. In addition, the effects of diet on body functions are subtle and less clear. Marginal deficiencies of nutrients are not associated with clinical symptoms, which makes their detection much more challenging. The absence of severe deficiency signs does not exclude detrimental effects on the body, underscoring the importance of early diagnosis [163].

Lastly, although biomarkers testing are objective assessments, at the population level, its use has potential limitations, including invasiveness of measurements and procedures, and cost.

Chapter 5: Discussion

Stunting – a health priority

Malawi is a small land-locked Sub-Saharan African country that is located south of the equator. It borders Tanzania, Mozambique and Zambia. Malawi's economy is primarily agriculture based providing 85 percent of Malawi's domestic exports (57). Agriculture in Malawi is mainly rain-fed and hence makes it vulnerable to climatic shocks.

The severe irreversible consequences of stunting in childhood, including physical and neurocognitive damage and an elevated risk of chronic disease later in life has now identified it as a major public health priority and focus of important initiatives like the Scaling Up Nutrition, Food for Peace, Zero Hunger Challenge, Feed the Future, and Nutrition for Growth Summit [115]. Stunting is a cross-cutting problem that requires a multi-sectoral response, including improvements in foods and nutrition security, education, WASH, health, poverty reduction, and improved status of women. Identification of these variables and the fact that nutrition interventions in past 3 decades have had marginal impact have prompted researchers to investigate other pathways that could lead to child undernutrition, specifically stunting [16, 17].

Evidence suggests that nutrition sensitive programs can improve access to diverse diets, foster women's empowerment, and support livelihoods. Similarly, through education, girls can be better informed and become empowered mothers. Other programs include deworming, micronutrient and iron supplementation, food fortification, and early childhood development programs. Some examples of nutrition-specific programs include using conditions to stimulate demand for program services, including cash transfer programs, routine immunization, antenatal services, and delivery of nutrition-specific interventions like counseling on infant and young child feeding, care, and hygiene. Hence, the study examined the relationship between stunting and determinants of stunting including markers of nutrition and inflammation.

Stunting trends

There is a linear trend in reduction of stunting across survey years, and this trend exists for all variables and sub-groups within each variable. Stunting in children decreased from 54.3 percent in 2000 to 36.6 percent in 2015-16 – an impressive 10.5 percentage points decrease in stunting occurred from 2010 to 2016.

Socio-demographic factors

Compared to children under6 months of age, the odds of stunting increases by more than 50 percent in children 6–9 months. This coincides with the period when protection from mothers antibodies have started to wane, and children become more mobile and hence exposed to infections [125, 126]. The odds of stunting is highest in the age group 16–23 months (Figures 1.1 and 1.4), which is consistent in the literature from Malawi [126]. Gender and urban-rural differences with respect to stunting have been observed in Africa and in Malawi. Findings from the multivariate analysis confirm that gender, age, and birth intervals are strong predictors of stunting in children. As observed in other studies [9], lack of safe drinking water and sanitation is correlated with stunting, but it did not reach statistical significance at $p<0.05$.

The study found that ownership of land was negatively associated with stunting, especially if the land area was more than 50 hectares. This is perplexing finding, but several reasons emerge for this finding. By 1990s more than a quarter of the Malawi's smallholder farmers adopted a hybrid breeding program [152] and several donors work with the Government of Malawi to support and improve the effectiveness of the input subsidy program for smallholders [152]. It is plausible that programs offered counseling on nutrition and diversification of crops, hence in addition to improving productivity and diversity of crops, it directly or indirectly improved nutrition knowledge and dietary intake among the small-holder farmers. Whereas the large farm holders may have grown cash crops such as tobacco. Even if the food crops are grown it may lack diverse cropping such as large-scale farming of only maize that is not for household consumption. In Malawi many medium-scale farmers are urban-based professionals and civil servants who initially had small-scale holdings but acquired lands that resulted in medium-scale holdings [153]. Ownership of livestock is not associated with stunting in the multivariate analysis.

Stunting is negatively correlated with household wealth in all four surveys. In fact, the prevalence of stunting decreases linearly with an increase in household wealth. Findings imply that increase is wealth is may increase the purchasing power of the household, including access to food.

Preceding birth interval is a predictor of stunting in children. Stunting was lower in children with improved and safe access to water. This study demonstrates the importance of maternal factors. Mother's education was consistently and significantly associated with stunting in all four surveys. Findings of the study show that attainment of higher education, i.e., secondary or higher was associated with lower odds of childhood stunting. This is consistent with other studies that have shown that mother's education is a major determinant of whether a child becomes malnourished or not [126, 133]. Similarly, maternal undernutrition is a determinant of child undernutrition. Children whose mothers were underweight (BMI <18.5) or had short stature were more likely to be stunted compared to mothers who had normal weight or overweight. This is an expected finding as mothers who have higher education are more empowered to be able to take decisions with regard to nutrition and care of their children.

Infant and young child feeding practices

The findings show that in addition to lower exclusive breastfeeding, complementary feeding is generally introduced early on which can possibly lead to high infection burden and stunting among children. In Malawi, complementary feeding starts too early with poor quality complementary feeds.

High incidence of stunting from 6–18 months, coincides with introduction of complementary feeding. Complementary feeds in most developing countries, including Malawi are not energy dense or hygienic resulting in reduced energy intake and increased morbidity, especially diarrhea, which in turn leads to undernutrition including stunting. Children are mobile and more exposed to infections and at the same time the protection from maternal antibodies starts of wane and further increases the infections and undernutrition in children. Further, undernutrition may begin in utero to mothers who are themselves undernourished.

A review of five efficacy trials and 16 programs in 14 countries from 1970-1997 showed improved growth rates by 0.10 – 0.50 SD in weight-for-age z scores (WAZ) and height-for-age Z– scores (HAZ). The programmatic interventions on a small sample (n= 112 to 200) led to higher changes WAZ than HAZ [17]. A systematic review of 42 papers from 29 efficacy trials and 13 effectiveness studies from 25 developing countries from 1996 to 2000 has found that impact of the nutrition interventions (complementary feeding, fortification, and energy density of foods) on child growth was mixed. Impact on growth appeared to be greater with interventions using key educational messages, provision of complementary food with or without fortification, or increased energy density of the complementary foods than interventions based on fortification alone. The effect sizes for growth were modest (0.1 – 0.5)[8].

Results from the meta-analysis by Fall et al (2009), and Ramakrishnan et al (2012), of the multiple micronutrient supplementation trials, and meta-analysis by Kramer and Kakuma (2003), Imdad & Bhutta (2012) on balanced protein-energy supplementation showed a significant increase in birth weight (+22 g to +78 g) but not birth length. On the other hand, prenatal and postnatal nutrition, combination of macro- and micro- nutrients, along with infection control and care for mother and child may have an impact on the linear growth as shown by Luntamo et al (2013)[164].

Bhutta et al (2008), reviewed nutrition-related interventions in 36 countries and demonstrated that food utilization outcomes are shaped not only by nutritional inputs, by other factors including disease burden, women’s empowerment, and water, sanitation, and hygiene factors[165].

Previous research has demonstrated positive, statistically significant associations between dietary diversity and household per capita consumption (food access), per capita daily caloric availability from staples and non-staples, and total per capita daily caloric availability [43, 166]. Though earlier studies have shown that dietary diversity is positively correlated with adequate micronutrient density of complementary foods for infants and young children and macronutrient and micronutrient adequacy for non-breastfed children [167]. Moursi et al. [168] found that for breastfed children, dietary diversity score predicts a low micronutrient adequacy (less than50 percent). Food variety and dietary diversity scores in children ages 1-8 years were found to have a high correlation with the mean adequacy ratio (MAR), a composite index of nutrient adequacy [169] calculated for 11 micronutrients, energy and protein. Furthermore, MAR and dietary diversity found to have a significant correlation with HAZ and WAZ.

Apart from timely initiation of breastfeeding, none of the WHO recommended IYCF indicators, including dietary diversity are significantly associated with stunting in the multivariate analysis. The bivariate analysis found approximately 50 percent reduction in the prevalence of stunting if the child continued to be breastfed by one-year and received complementary foods by 6–8 months. The timely introduction of first complementary food has been significantly found to reduce the incidence of stunting [141] [135]. The reduced dietary diversity is a strong predictor of stunting among children less than 60 months of age [156]. but this study did not show a correlation between stunting and dietary diversity.

The study did not find an association between stunting and consumption of animal source foods such as meat and organ meat. This could be because in rural Malawi, foods from animal sources are rarely eaten [20]. Since interventions include other components that may contribute to the effects observed during a study, it is difficult to tease apart the efficacy of supplementary animal source foods on prevention of growth faltering[90].

The findings from this study do not show a strong association of IYCF practices with stunting as more variables were examined in the multivariate analysis. The risk of increased mortality and morbidity due to deviation from breastfeeding guidelines is well documented – exclusive bottle feeding in developing countries increases the risk in infants to 2 to 50 fold compared to exclusively breastfed infants[126]. There is strong evidence that breastfeeding is associated with an increase in the IQ and protection against non-communicable diseases, the data is inconclusive of its direct effect in reducing stunting [135]. The research also suggests that IYCF indicators may better explain weight-for-length Z–-scores than length-for-age Z– scores [141]. Poor complementary feeding practices are associated with stunting and growth faltering [40]. In the bivariate analysis, we observed the relationship between complementary feeding and stunting but it failed to reach significance in the final model. One reason for this observation could be that the most common complementary food in Malawi is a thin maize porridge which is not nutrient dense to impact stunting in children [126]. Further, it is during this period when infections increase in children [37, 115, 126].

Maternal factors, empowerment and decisiomaking

The study finds that mother’s education is a significant predictor of child’s nutritional status (p=0.02). Other studies have also found that female or mothers’ education is a major determinant of whether a child becomes malnourished or not [77, 139, 162, 170]. Mother’s age and anemia levels were not significantly associated with stunting in children. The short stature of the mother and BMI are highly significantly in determining stunting in children at p=0.000 and p=0.0016, respectively. Several studies have found a strong association between mother's nutritional status and stunting in children [115, 118, 120, 131, 135, 140, 148].

Although mother's education is a strong predictor of children's health and nutrition [9] and there exists an inverse relationship between stunting and mother's participation in decision-making and attitude towards violence[73], but the present study did not find an association between stunting and women's decision-making and empowerment or any other maternal factors examined including age, education, marital status, and attitudes towards wife beating.

Although not statistically significant but children of women who make decisions with her husband or partner have lower prevalence of stunting compared to when decisions were made by women alone. This finding, however, does not reflect lower decisionmaking by women alone, it implies that most women are married and make a decision with their husbands or partners or husband alone and the single women, whether never married, divorced, widowed or separated may have more struggles in raising the children, including providing adequate nutrition or other resources. Similarly, the composite index of women's participation in decisionmaking is not significantly associated with stunting in children, however, lower score (higher decisionmaking) was associated with lower prevalence of stunting, and a higher score (lower decisiomaking) was associated with higher prevalence of stunting among children 6–23 months. A study from Nepal reports that women's autonomy in production and women's work in agriculture influence is associated with dietary diversity and reduction in stunting in children [171].

Women's experience of emotional violence is statistically significantly associated with stunting in children ($p=0.05$). Children of mothers who experience emotional violence have higher prevalence of stunting (34.9 percent) compared to children of mothers who do not experience emotional violence (29.3 percent). A meta-analysis showed that children whose mothers had depression were 1.4 times more likely to be stunted than the children of non-depressed mothers [149]. The study did not show an association between woman's experience of physical or sexual violence and stunting in children. Studies have found that the odds of stunting increases with maternal exposure to emotional violence[150]. Other studies have found an association between intimate partner violence (any form) and poor child growth, specifically stunting and severe stunting has been reported in the literature [79, 80, 151]. The research shows that in poorer households, the effects of mother's experience of violence on stunting may be masked by larger impacts of food insecurity, micronutrient deficiencies, etc. [80].

Household hunger

Both the bivariate and the multivariate results show that household hunger is strongly associated with stunting in children ($p<0.05$). As the household hunger increases the odds of stunting increases by a factor of 2.46. This could be because dependence on rain fed agriculture interrupts food availability across seasons – these variations result in abundance of food during harvest and less food during the cropping season. The 2004 Malawi Integrated Household Survey found that children were less likely to be stunted during the lean cropping season compared to the post-harvest season [155].

Biomarker of nutrition, inflammation, and inherited disorders

Biomarkers of nutrition are able to objectively assess dietary intake or status without bias of self-reported dietary intake data. The study examined the biomarkers of nutrition, inflammation, and infections.

Iron deficiency in preschool children is 58 percent in Malawi [126]. As per WHO'S classification (>40 percent prevalence of anemia), anemia is a public health problem in Malawi. The study found that hemoglobin levels are similar in stunted and non-stunted children and the mean hemoglobin is 11.4 g/dl. the sTfR is high, and specifically higher among stunted children. Higher levels of serum transferring suggest a high prevalence of iron deficiency anemia. Table 3.4 shows that children have very high levels of serum ferritin (48.5 µg/l among non-stunted children vs. 56.2 µg/l in stunted children). The normal cutoff for serum ferritin is <12 µg/l and abnormal high ferritin levels observed in the study indicate imbalances in iron metabolism. In the bivariate analysis, abnormal levels of RBP, i.e., >0.46 µmol/l are highly associated with stunting, the association is weaker but remains in the multivariate analysis.

Zinc deficiency is now recognized by the United Nations Children's Fund (UNICEF) as a public health problem in many countries, especially developing countries, including Malawi. It is estimated that 34 percent of the Malawian population is at risk for insufficient zinc intake [157]. Dietary studies in Malawian children have documented that a high phytate content of maize diets is one of the leading causes of zinc deficiency. It is well documented that intestinal permeability is increased with zinc deficiency. Zinc deficiency also has a negative effect on growth – a meta-analysis of randomized controlled trials of zinc supplementation showed a significant benefit for linear growth in children aged 0–5 years. The effect was a gain of 0.37 cm in zinc-supplemented children. In fact, trials that used a dose of zinc of 10 mg per day for 24 weeks, rather than lower doses, showed a larger benefit of 0.46 cm [135]. The study did not find an association between low zinc concentrations and stunting in children. The study also did not find a strong association between selenium deficiency and risk of stunting.

Infection and fever

Inflammation defined as either elevated CRP or AGP is common and found more than 50 percent of children. The prevalence of elevated AGP is 57 percent, and the prevalence of elevated CRP is 26 percent. The prevalence of elevated AGP is more than double the prevalence of CRP. Markers of inflammation, both AGP, CRP and any inflammation are slightly elevated for the non-stunted children (1.27 g/l and 5 mg/dl) and much higher for stunted children (1.56 g/l and 9.1 mg/dl). Other studies have found that markers of inflammation are higher in stunted children than non-stunted children from as early as 6 weeks after birth [88]. These studies suggest that an extensive enteropathy during infancy and that low-grade chronic inflammation may impair infant growth.

Birthweight, size at birth and MUAC

Prolonged infections in endemic areas affect placental function and may depress birthweight [126]. Stunted infants are growth restricted at birth [88], hence, birthweight can be considered as the proxy indicator of stunting[160]. This paper shows that low birth and very low birth children are not a higher risk of stunting, however, mother’s perception of child’s size (small) at birth was strongly associated with risk of stunting. Studies in the literature support that women’s nutritional status before and during pregnancy may contribute to intra-uterine growth retardation thereby increasing the odds of having a LBW infant which in turn is a risk factor for stunting in childhood [78]. Black et al explains that maternal stunting (height<145 cm) increases the risk of both term and preterm small for gestational age (SGA) babies [70]. Other studies have shown that LBW is associated with 2.5 to 3.5-fold higher the odds of stunting in children[93, 161]. Given that birthweight or size at birth is associated with postnatal infant growth, micronutrients given during the antenatal period can help reduce infant malnutrition at least during the first few months [125].

Therapeutic supplements

The use of iron containing supplements was 2.7 percent, therapeutic foods 1.3 percent. The prevalence of children who received a vitamin A capsule in the previous 6 months was 14.8 percent, and 18.3 percent of children received deworming treatment in the past 6 months (Table 3.8).The micronutrient powders presented in small single-use sachets to add to a serving of complementary food have proven successful in preventing and treating anemia. Adding other micronutrients such as zinc has been explored, but as yet no formula has been shown to prevent stunting or promotes linear growth [120, 125, 127]. This study did not find a statistical significant relationship between stunting in children and iron or vitamin A supplementation or interventions such as therapeutic foods like plumy nut or deworming. In fact, the relationship is negative, i.e., children receiving the supplements or interventions have higher prevalence of stunting compared to children who are not receiving supplements or interventions. It is possible that only the very malnourished children are, in fact, eligible to receive the supplements/interventions, and hence the stunting levels are higher in these children.

Studies have shown beneficial effects of lipid based nutrient (LNS) supplements [162]. A study in Malawi confirmed better weight gain in moderately malnourished children with (LNS) compared to a cereal product [38], but there was no difference in linear growth.[125]. Similarly, a randomized controlled trial in Malawi found that LNS supplements during infancy, and childhood did not reduce stunting among Malawian children 6–18 months [13, 95, 96, 127]. This lack of effect of nutritional supplementation also supports the observation that causes and consequences of stunting are multifactorial and not responsive to a simply supplementation. A large-scale feeding programs have been problems in targeting the right groups, ensuring intake of the supplement by intended beneficiaries, spillover to other than intended beneficiaries and replacement of the habitual dietary intakes of the beneficiaries.

A recent record of receiving a vitamin A on the vaccination card shows a significant association with reduced stunting in children compared to the mother's report or having no card (p=0.02).

Safety net and interventions: The study finds that households that receive coupons from FISP have more than 60 percent reduced odds of having children who are stunted. It has been shown that social protection and provision of services, such as food or cash transfers, food vouchers, and support for inputs to highly vulnerable groups can increase their nutritional status, income and resilience specially in times of humanitarian disaster [9].

Limitations

The proposed study aims to explore the effect of proximate determinants of food security, as proxied by stunting, in children age 0–59 months. Since the DHS surveys are population based cross-sectional household surveys, a causal relationship between proximate determinants of food security and nutritional outcomes cannot be established. As a result, findings should be interpreted purely as indications of association between proximate determinants and stunting. The DHS questionnaire does not collect information on frequency and quantity of consumption of foods. Therefore, the child's dietary diversity score was analyzed based on whether a food group was consumed or not consumed in the day before the survey.

As a proxy of environmental enteropathy, the study explored the association between ownership of livestock and stunting in children. The use of secondary data from a cross-sectional survey precludes more specific analysis of the animal excreta for *E.coli* or examination of the subclinical infections and biomarkers for mucosal damage and immune stimulation in children.

The controls for confounding factors are limited by the data available in the dataset; and hence there may be unobserved influences and/or confounders that may not be accounted for in the models. Lastly, findings from this study may not apply to other countries. Although there was a significant overlap between MDHS 2015-16 and the MNS survey 2016, but no effort was made to mitigate the seasonal influences which can have adverse effect on consumption of certain foods and infections such as malaria, etc.

Chapter 5: Conclusion

Stunting is said to be a self-perpetuating intergenerational cycle of poverty and impaired human capital [115, 120]. There is evidence that proximate and distal determinants such as child feeding practices, inadequate care and complementary feeding, WASH practices, infections, and environmental enteropathy play an important role in stunting [130]. The determinants of malnutrition are multifaceted, ranging from an individual's health status, access to safe, nutritious diverse foods, water, sanitation, and hygiene, feeding and caring practices, etc., and therefore, it requires a multi-sectoral approach that includes agriculture, health, economic growth and livelihoods, education and humanitarian assistance.

The approach of USAID's flagship nutrition and food security initiatives such as Scaling up Nutrition, Food for Peace, and Feed the Future in Malawi is to integrate nutrition into a value chain through nutrition-sensitive agricultural productivity, finance and local capacity development. Programs are targeted at the local level, focusing on behavior change, dietary diversification, and improved feeding for pregnant women, young children, and infants [98]. In 2011, Malawi was the first country to join the SUN initiative and the 1,000 Days partnership which aimed to reduce undernutrition in children during the critical period of pregnancy through a child's second birthday [14].

Despite a strong government commitment, strong agricultural productivity, and economic growth in recent years, there is persistent severity of malnutrition in Malawi even in the upper wealth quintile [137]. This accentuates the importance of factors not related to income but associated with knowledge, attitudes and practices with regard to food production, preparation, and consumption, breastfeeding and other young child feeding practices, and disease prevention.

This study builds on our previous studies to examine the micronutrient concentrations and its relationship with childhood stunting in Malawi. The implications of the study findings for policy are clear – single targeted short-term interventions are unlikely to succeed in an environment where the causes of malnutrition are not only multiple but also interrelated in a complex way integrated approaches combining several strategies.

At the national level, stunting decreased from 54.3 percent to 36.6 percent from 2000 to 2016. Despite the remarkable decrease in stunting, it remains of high public health significance in Malawi. According to the Global Nutrition Report, Malawi has made some progress in reducing stunting among children, but the progress remains off-course [138]. Findings from our study indicate that child's age is an important factor in the prevalence of stunting. Higher stunting in children under 6 months of age in 2016 compared to previous years, in general, does not align with the existing research, however, studies in rural Malawi have found highest incidence of stunting in children under 6 months of age. Stunting during intrauterine period and first six months needs to be examined in future studies.

The key determinants of child undernutrition are food insecurity, poverty and high rates of illiteracy, especially among women. Children who were ill two weeks prior to the survey were more likely to be underweight [155]. Since stunting is a long-term process that results from a series of insults that start as early as in utero and continues until three years postnatally, we may not see an association between stunting and variables that are looking at exposure in the last 7 days or last 4 weeks even though exposures in the short term are generally considered proxy for practices and exposures over longer periods of time. These may include variables such as malaria, fever, etc. for which the study fails to see an association with stunting.

The study shows that having a quantifiable measure such as biomarkers of nutrition are able to objectively assess micronutrient status without bias of self-reported dietary intake data. Children who are malnourished during the first 1,000 days of life have weaker immune system predisposing them at risk for severe infectious diseases, including diarrhea and pneumonia. Therefore, measurement before clinical signs of disease occurs is crucial in reduction of stunting and its detrimental consequences. Subjective measures such as the dietary diversity score give each food group equal weight, but all food groups are not equally important for nutrition, especially for intake of micronutrients, which are most commonly deficient in African diets [42]. In addition, the effects of diet on body functions are subtle and less clear. Marginal deficiencies of nutrients are not associated with clinical symptoms, which makes their detection much more challenging. The absence of severe deficiency signs does not exclude detrimental effects on the body, underscoring the importance of early diagnosis [163].

Results of the micronutrient levels in stunted children show evidence for change in the rhetoric and policy to focus attention not only on the quantity, but quality of foods consumed by children. In conclusion, findings from the study suggest that biomarkers offer clues to tackling stunting in children. The information contained in the DHS data sets should be complemented by nutritional biomarkers to help understand the effects of stunting at the cellular level. Lastly, although biomarkers testing are objective assessments, at the population level, its use has potential limitations, including invasiveness of measurements and procedures, and cost.

Table 1.1 Stunting (HAZ <2 SD) in children age 0-59 months by background characteristics, Malawi Demographic and Health Survey (MDHS), 2000-2016

Table 1.2 Coefficient of change in HAZ for children 0-59 months for comparison years, MDHS 2000-2016

Table 1.3 Trend of odds of being stunted by survey year and other background characteristics in children 0-59 months, MDHS 2000-2016

Table 1.4 Change in stunting by background characteristics, MDHS 2000 - 2016

Table 1.5 Change in stunting (<2 SD) in children age 0-59 between survey years, MDHS 2000-2016

Table 2.1 Number of children by anthropometric measurements, Malawi 2015-16

Table 2.2 Stunting in children 0-23 months by socio-demographic variables, Malawi 2015-16

Table 2.3 Stunting in children 0-23 months by household environment and WASH practices, Malawi 2015-16

Table 2.4 Stunting in children 0-23 months by infant and young child feeding practices, Malawi 2015-16

Table 2.5 Stunting in children 0-23 months by maternal factors, Malawi 2015-16

Table 2.6 Stunting in children age 0-23 months by maternal decisionmaking and empowerment, Malawi 2015-16

Table 2.7 Model I: Logistic regression model for association of socio-demographic factors and stunting in children 0-23 months, Malawi 2015-16

Table 2.8a Model II: Logistic regression model for association of access to food and stunting in children 0-23 months, Malawi 2015-16

Table 2.9a Model III: Logistic regression model for association of children's environment/WASH and stunting in children 0-23 months, Malawi 2015-16

Table 2.10a Model IV: Logistic regression model for association of IYCF practices and stunting in children 0-23 months, Malawi 2015-16

Table 2.11a Model V: Logistic regression model for association of maternal factors including empowerment and stunting in children in children 0-23 months, Malawi 2015-16

Table 3.8 Prevalence of stunting by common infections and fever in children age 0-5 years, MNS Survey, 2015-16

Table 3.9 Prevalence of stunting in children by therapeutic supplements and prevention to infection, MNS Survey, 2015-16

Table 3.10 Prevalence of stunting among children age 0-5 years by social intervention programs, MNS Survey 2015-16

Table 3.11 Multivariate analysis of determinates of childhood stunting, MNS Survey 2015-16

Table 3.12 Multivariate analysis of biomarkers on childhood stunting, MNS Survey 2015-16

Table 1.1 Stunting (HAZ <2 SD) in children age 0-59 months by background characteristics, Malawi Demographic and Health Survey (MDHS), 2000-2016

	MDHS 2000				MDHS 2004				MDHS 2010				MDHS 2015-16				Total Sample	
	%	SE	95% CI	n	%	SE	95% CI	n	%	SE	95% CI	n	%	SE	95% CI	n	N	%
Variables																		
Age in months																		
<6	21.2	1.42	[18.6 - 24.2]	2,081	20.4	1.66	[17.3 - 23.8]	1,529	17.3	2.65	[12.7 - 23.1]	699	23.7	2.38	[19.3 - 28.6]	506	**4,815**	9.8842
6-9	32.0	2.39	[27.6 - 36.8]	1,486	34.5	2.35	[30.0 - 39.1]	1,317	24.7	2.96	[19.4 - 30.1]	68	20.5	2.76	[15.6 - 26.4]	358	**3,229**	6.6285
10-11	35.8	2.99	[30.1- 41.8]	749	44.5	2.84	[39.1 - 50.2]	620	29.3	4.17	[21.8 - 38.1]	338	26.8	3.79	[20.1 - 34.9]	201	**1,908**	3.9167
12-15	46.3	2.27	[41.9 - 50.8]	1,458	49.8	2.23	[45.5 - 54.2]	1,344	41.9	3.30	[35.6 - 48.5]	650	32.6	2.75	[27.5 - 38.3]	385	**3,837**	7.8766
16-23	63.9	1.89	[60.1 - 67.6]	2,633	64.2	1.58	[61.0 - 67.2]	2,352	59.7	2.24	[55.2 - 64.0]	1,432	41.6	2.11	[37.6 - 45.8]	638	**7,055**	14.482
24-35	66.6	1.33	[63.9 - 69.1]	3,806	59.3	1.69	[55.9 - 62.5]	2,851	56.5	2.04	[52.4 - 60.4]	1,844	42.8	2.06	[38.8 - 46.8]	1,023	**9,524**	19.551
36-47	65.4	1.37	[62.7 - 68.1]	3,581	59.3	1.68	[56.0 - 62.5]	2,879	51.1	2.14	[46.9 - 55.3]	1,778	44.2	1.87	[40.6 - 47.9]	1,084	**9,322**	19.136
48-59	59.6	1.64	[56.3 - 62.7]	2,891	56.1	1.66	[53.8 - 59.3]	2,859	48.6	2.17	[44.4 - 52.9]	1,695	34.4	1.99	[30.6 - 38.4]	965	**8,410**	17.264
Sex																		
Male	56.09	1.14	[53.8 - 58.3]	9,171	54.79	0.97	[52.9 - 56.7]	7,827	51.20	1.35	[48.6 - 53.8]	4,447	38.40	1.21	[36.1 - 40.8]	2,497	**23,942**	49.148
Female	52.54	0.99	[50.6 - 54.5]	9,514	49.61	1.07	[47.5- 51.7]	7,925	43.10	1.30	[40.6 - 45.7]	4,671	34.85	1.16	[32.6 - 37.2]	2,662	**24,772**	50.852
Residence																		
Urban	40.4	1.98	[36.6 - 44.4]	2,476	41.8	2.44	[37.1 - 46.6]	2,019	39.7	2.72	[34.5 - 45.1]	1,381	24.1	2.50	[19.6 - 29.4]	670	**6,546**	13.438
Rural	56.4	0.83	[54.8 - 58.0]	16,209	53.7	0.79	[52.2 - 55.3]	13,732	48.4	1.02	[46.4 - 50.4]	7,738	38.4	0.88	[36.7 - 40.2]	4,489	**42,168**	86.562
Region																		
Northern	45.8	2.51	[40.9 - 50.8]	2,079	46.5	1.74	[43.1 - 50.0]	2,158	44.9	2.28	[40.5 - 49.4]	980	35.3	2.10	[31.3 - 39.5]	551	**5,768**	11.841
Central	59.7	1.31	[57.1 - 62.3]	8,019	56.4	1.39	[53.7 - 59.1]	6,172	47.0	1.55	[44.0 - 50.1]	4,190	37.8	1.43	[35.0 - 40.6]	2,208	**20,589**	42.265
Southern	51.2	0.96	[49.4 - 53.1]	8,587	50.3	1.04	[48.3 - 52.3]	7,422	47.6	1.42	[44.8 - 50.4]	3,948	35.7	1.25	[33.3 - 38.2]	2,400	**22,357**	45.894
Birth order																		
1	55.1	1.34	[52.4 - 57.7]	3,992	52.5	1.44	[49.7 - 55.4]	3,389	47.0	2.15	[42.9 - 51.3]	1,751	36.5	1.69	[33.3 - 39.9]	1,278	**10,410**	21.37
2-3	53.7	1.23	[51.3 - 56.1]	6,594	50.5	1.20	[48.1 - 52.8]	5,918	46.0	1.75	[42.6 - 49.5]	3,422	36.2	1.39	[33.6 - 39.0]	1,994	**17,928**	36.803
4-5	53.0	1.46	[50.1 - 55.9]	3,966	53.9	1.26	[51.4 - 56.3]	3,546	48.2	1.81	[44.6 - 51.7]	2,226	35.4	1.94	[31.7 - 39.3]	1,179	**10,917**	22.41
6+	55.6	1.38	[52.9 - 58.3]	4,133	53.1	1.56	[50.1 - 56.2]	2,898	47.6	2.19	[43.4 - 52.0]	1,719	39.5	2.26	[35.2 - 44.0]	707	**9,457**	86.562

	MDHS 2000				MDHS 2004				MDHS 2010				MDHS 2015-16				Total Sample	
	%	SE	95% CI	n	%	SE	95% CI	n	%	SE	95% CI	n	%	SE	95% CI	n	N	%
Variables																		
Birth interval																		
First birth	55.4	1.34	[52.7 - 58.0]	4,030	52.7	1.45	[49.9 - 55.6]	3,420	47.0	2.14	[42.9 - 51.2]	1,763	36.7	1.69	[33.5 - 40.1]	1,290	**10,503**	21.561
<24 months	57.7	1.85	[54.1 - 61.3]	2,357	56.2	1.81	[52.6 - 59.7]	1,662	53.8	3.22	[47.5 - 60.1]	1,009	44.1	2.97	[38.4 - 50.0]	402	**5,430**	11.147
24 - 35 months	54.3	1.29	[51.7 - 56.8]	5,749	53.5	1.38	[50.8 - 56.2]	4,492	51.6	1.72	[48.2 - 55.0]	2,741	40.3	2.05	[36.3 - 44.4]	1,026	**14,008**	28.756
36 - 47 months	52.4	1.35	[49.8 - 55.1]	3,476	50.8	1.42	[48.0 - 53.6]	3,199	44.3	2.02	[40.4 - 48.3]	1,860	33.1	1.75	[29.8 - 36.7]	1,029	**9,564**	19.633
48+ months	52.4	1.75	[49.0 - 55.8]	3,073	48.8	1.62	[45.7 - 52.0]	2,978	38.9	2.16	[34.7 - 43.2]	1,746	34.1	1.71	[30.8 - 37.5]	1,411	**9,208**	18.902
Drinking water																		
Unimproved	53.7	1.09	[51.5 - 55.8]	8,780	55.4	1.10	[53.3 - 57.6]	7,912	51.9	2.23	[47.5 - 56.2]	2,262	41.1	2.13	[37.0 - 45.3]	787	**17,526**	35.86
Improved	54.7	1.23	[52.3 - 57.2]	11,186	49.9	1.02	[47.9 - 51.9]	11,206	47.7	1.09	[43.5 - 47.9]	8,030	35.8	0.09	[34.0- 37.7]	4,597	**31,351**	64.14
Sanitation facility																		
Unimproved	60.6	1.75	[57.1 - 64.0]	3,401	58.8	1.72	[55.4 - 62.1]	2,569	48.0	1.00	[46.0 - 49.9]	7,488	39.1	1.81	[35.6 - 42.7]	997	**14,528**	29.72
Improved	52.9	0.91	[51.1 - 54.7]	15,284	50.9	0.86	[49.2 - 52.6]	13,183	42.9	2.66	[37.8 - 48.2]	1,631	36.0	0.99	[34.1 - 37.9]	4,163	**34,349**	70.28
Wealth Index																		
Lowest	62.0	1.43	[59.2 - 64.8]	4,336	58.5	1.60	[55.3 - 61.6]	3,045	55.8	2.44	[51.0 - 60.5]	1,632	45.1	1.71	[41.8 - 48.5]	1,232	**10,245**	21.031
Second	56.6	1.57	[53.5 - 59.7]	3,899	56.7	1.25	[54.2 - 59.1]	3,374	51.1	1.98	[47.2 - 54.9]	2,047	40.8	1.80	[37.4 - 44.4]	1,207	**10,527**	21.61
Middle	57.9	1.49	[55.0 - 60.8]	3,749	55.8	1.46	[52.9 - 58.6]	3,589	46.5	1.89	[42.8 - 50.2]	2,014	36.3	1.85	[32.8 - 40.0]	989	**10,341**	21.228
Fourth	52.5	1.52	[49.5 - 55.4]	3,405	49.6	1.47	[46.8 - 52.5]	3,208	46.8	2.23	[42.5 - 51.2]	1,680	31.5	2.04	[27.7 - 35.6]	923	**9,216**	18.919
Highest	39.1	1.48	[36.2 - 42.0]	3,296	36.7	1.83	[33.2 - 40.4]	2,535	35.1	2.42	[30.5 - 40.0]	1,746	23.3	2.12	[19.4 - 27.7]	808	**8,385**	17.213
Mother's education																		
No education	59.1	1.24	[56.6 - 61.5]	5,966	56.1	1.34	[53.5 - 58.7]	3,978	53.2	2.43	[48.4 - 57.9]	1,543	43.3	2.33	[38.8 - 47.9]	679	**12,166**	24.974
Primary	54.3	0.96	[52.4 - 56.2]	11,437	53.0	0.90	[51.2 - 54.7]	10,101	47.5	1.21	[45.1 - 49.9]	6,194	37.9	1.08	[35.8 - 40.0]	3,407	**31,139**	63.922
Secondary or higher	31.8	2.18	[27.7 - 36.2]	1,282	38.2	2.31	[33.8 - 42.8]	1,672	38.2	2.76	[33.0 - 43.8]	1,381	28.2	1.70	[24.9 - 31.6]	1,074	**5,409**	11.104
Mother's BMI																		
Underweight	56.9	2.60	[51.8 - 61.9]	934	53.8	2.79	[48.3 - 59.2]	939	49.9	3.97	[42.2 - 57.6]	463	48.8	4.46	[40.1 - 57.5]	225	**2,561**	5.2572
Normal	55.0	0.91	[53.2 - 56.8]	15,283	53.0	0.87	[51.3 - 54.7]	12,489	48.7	1.13	[46.4 - 50.9]	7,009	38.3	1.01	[36.3 - 40.3]	3,868	**38,649**	79.339
Overweight	48.5	1.95	[44.7 - 52.3]	2,274	44.4	2.03	[40.5 - 48.4]	1,989	37.8	2.49	[33.1 - 42.8]	1,460	27.7	1.83	[24.2- 31.4]	992	**6,715**	13.785
Total	**54.3**	**0.84**	**[52.6 - 55.9]**	**18,685**	**52.2**	**0.79**	**[50.6 - 53.7]**	**15,751**	**47.1**	**0.97**	**[45.1 - 49.0]**	**9,119**	**36.6**	**0.87**	**[34.9 - 38.3]**	**5,159**	**48,714**	100

Table 1.2 Coefficient of change in HAZ for children 0-59 months for comparison years, MDHS 2000-2016

Survey year	Coef.	Linearized Std. Err.	[95% Conf. Interval		t	P>t
2000 vs. 2004	9.132037	4.376279	0.5501685	17.71391	2.09	0.037
2000 vs. 2010	27.8541	4.540648	18.94991	36.7583	6.13	0.000
2000 vs. 2016	52.89456	4.279489	44.5025	61.28662	12.36	0.000
2004 vs. 2010	18.72207	4.151452	10.58109	26.86305	4.51	0.000
2004 vs. 2016	43.76252	3.883128	36.14772	51.37732	11.27	0.000
2010 vs. 2016	25.04046	4.082082	17.03551	33.04541	6.13	0.000

Table 1.3 Trend of odds of being stunted by survey year and other background characteristics in children 0-59 months, MDHS 2000-2016

	Stunting					Chi-square
	Yes	No	Odds	[95% Conf.	Interval]	Score test for trend of odds (p-value)
Survey years						
2000	9608	8768	1.0958	1.06454	1.12799	0.000
2004	8486	7694	1.10294	1.06943	1.1375	
2010	4258	4914	0.8665	0.83167	0.9028	
2016	1814	3335	0.54393	0.5137	0.57594	
Age in months						
<6	1033	3833	0.2695	0.25161	0.28867	0.000
6-9	1141	2700	0.42259	0.39434	0.45287	
10-11	695	1202	0.5782	0.52665	0.63481	
12-15	1752	2156	0.81262	0.76297	0.86549	
16-23	4223	2916	1.44822	1.38146	1.5182	
24-35	5592	3895	1.43569	1.37815	1.49563	
36-47	5312	3955	1.34311	1.28894	1.39955	
48-59	4418	4054	1.08979	1.04431	1.13725	
Gender						
Male	12618	11587	1.08898	1.06186	1.11679	0.000
Female	11548	13124	0.87991	0.85818	0.9022	
Residence						
Urban	2647	4191	0.63159	0.60159	0.66309	0.000
Rural	21519	20520	1.04868	1.02882	1.06893	
Region						
Northern	3353	4335	0.77347	0.73938	0.80913	0.0155
Central	9524	8321	1.14457	1.1114	1.17874	
Southern	11289	12055	0.93646	0.91273	0.96081	
Birth order						
1	5210	5243	0.99371	0.95633	1.033	0.0035
2-3	8572	9239	0.92781	0.90093	0.955	
4-5	5480	5582	0.98173	0.94581	1.019	
6+	4904	4647	1.0553	1.0138	1.099	

	Stunting					Chi-square
	Yes	No	Odds	[95% Conf.	Interval]	Score test for trend of odds (p-value)
Birth interval						
First birth	5275	5269	1.00114	0.96364	1.0401	0.000
<24 months	2893	2497	1.15859	1.09819	1.22231	
24 - 35 months	7221	6855	1.05339	1.01915	1.08879	
36 - 47 months	4620	5087	0.9082	0.87273	0.9451	
48+ months	4157	5003	0.8309	0.79742	0.86579	
Mother's education						
No education	6577	5199	1.26505	1.21986	1.31191	0.000
Primary	15712	15974	0.9836	0.96217	1.0055	
Secondary or higher	1877	3538	0.53053	0.50165	0.56106	
Drinking water						
Unimproved	9274	8252	1.12385	1.091	1.15768	0.000
Improved	14892	16459	0.90479	0.88496	0.92507	
Sanitation facility						
Unimproved	7370	7158	1.02962	0.99667	1.06366	0.0002
Improved	16796	17553	0.95687	0.93684	0.97733	
Wealth Index						
Lowest	5559	4340	1.28088	1.23102	1.33275	0.000
Second	5501	4908	1.12082	1.07851	1.1648	
Middle	5541	5026	1.10247	1.06117	1.14537	
Fourth	4631	5168	0.89609	0.86125	0.93234	
Highest	2934	5269	0.55684	0.53226	0.58256	
Mother's BMI						
Underweight	1443	1206	1.19652	1.10843	1.2916	0.000
Normal	19527	19229	1.0155	0.99548	1.03592	
Overweight	2774	3890	0.71311	0.67921	0.7487	

Table 1.4 Change in stunting by background characteristics, MDHS 2000 - 2016

	Stunting -2SD (Logistic Regression)					
	Coef.	Linearized Std. Err.	[95% Conf. Interval		t	P>t
Survey year						
2000	Reference category					
2004	-0.0757	0.0447178	-0.1501923	0.0254646	-1.69	0.091
2010	-0.3627	0.067159	-0.4944055	-0.231008	-5.4	0.000
2016	-0.7605	0.0549408	-0.8682627	-0.652785	-13.84	0.000
Age in months						
< 6 months	Reference category					
6-9	0.5266	0.0848691	0.3601981	0.6930543	6.21	0.000
10-11	0.8347	0.0986771	0.6411902	1.028202	8.46	0.000
12-15	1.202	0.0803422	1.044442	1.359544	14.96	0.000
16-23	1.8857	0.0737595	1.741078	2.030362	25.57	0.000
24-35	1.8583	0.0697155	1.72156	1.994984	26.66	0.000
36-47	1.7708	0.0714774	1.630628	1.910962	24.77	0.000
48-59	1.5546	0.0722297	1.412975	1.696259	21.52	0.000
Gender						
Male	Reference category					
Female	-0.2287	0.031605	-0.2906818	-0.166727	-7.24	0.000
Residence						
Urban	Reference category					
Rural	0.1363	0.0617326	0.0152292	0.2573442	2.21	0.000
Region						
Northern	Reference category					
Central	0.2918	0.0558483	0.1823106	0.4013475	5.23	0.000
Southern	0.0821	0.054172	-0.0240842	0.1883782	1.52	0.130
Birth Order						
1	Reference category					
2-3	1.3745	0.4140555	0.562563	2.186487	3.32	0.001
4-5	1.3821	0.4166071	0.5650989	2.19903	3.32	0.001
6+	1.3924	0.4176591	0.5733623	2.211419	3.33	0.001

	Stunting -2SD (Logistic Regression)					
	Coef.	Linearized Std. Err.	[95% Conf. Interval		t	P>t
Birth interval						
First birth	Reference category					
<24 months	-1.3841	0.4153667	-2.1986	-0.569534	-3.33	0.001
24 - 35 months	-1.4673	0.4156438	-2.282421	-0.652268	-3.53	0.000
36 - 47 months	-1.5925	0.4157468	-2.407802	-0.777245	-3.83	0.000
48+ months	-1.6439	0.4174989	-2.462615	-0.825186	-3.94	0.000
Drinking water						
Unimproved	Reference category					
Improved	0.0606	0.040091	-0.0180062	0.1392305	1.51	0.131
Sanitation facility						
Unimproved	Reference category					
Improved	-0.0458	0.0500649	-0.143966	0.0523882	-0.91	0.361
Wealth Index						
Lowest	Reference category					
Second	-0.1911	0.0534771	-0.2959398	-0.086203	-3.57	0.000
Middle	-0.2081	0.0519638	-0.3100231	-0.106221	-4.01	0.000
Fourth	-0.3607	0.0565487	-0.4716372	-0.249854	-6.38	0.000
Highest	-0.7756	0.0699821	-0.9128792	-0.63841	-11.08	0.000
Mother's education						
No education	Reference category					
Primary	-0.0939	0.0435289	-0.1792822	-0.008562	-2.16	0.031
Secondary or higher	-0.3916	0.0746141	-0.5378768	-0.245241	-5.25	0.000
Mother's BMI						
Underweight	Reference category					
Normal	-0.1088	0.0734966	-0.2529491	0.0353041	-1.48	0.139
Overweight	-0.4103	0.0860214	-0.5789897	-0.241614	-4.77	0.000
_cons	-0.7695	0.1377907	-1.039729	-0.499314	-5.58	0.000

Table 1.5 Change in stunting (<2 SD) in children age 0-59 between survey years, MDHS 2000-2016

	MDHS 2000 vs. MDHS 2004					MDHS 2004 vs. 2010					MDHS 2010 vs. 2016				
	Coeff	SE	95% CI	t	P-value	%	SE	95% CI	t	P-value	%	SE	95% CI	t	P-value
Variables															
Overall															
Stunting	9.1	4.38	[0.55 , 17.71]	2.09	0.037	18.7	4.15	[10.58 , 26.86]	4.51	0.000	25	4.08	[17.03 , 33.05]	6.13	0.000
Age in months															
<6	-0.85	2.19	[-5.14 , 3.44]	-0.39	0.697	-3.07	3.17	[-9.27 , 3.14]	-0.97	0.333	6.35	3.58	[-0.67 , 13.37]	1.77	0.077
6-9	2.43	3.36	[-4.16 , 9.03]	0.72	0.469	-9.71	3.80	[-17.16 , -2.26]	-2.56	0.011	-4.23	4.07	[-12.22 , 3.75]	-1.04	0.299
10-11	8.77	4.12	[0.68 , 16.86]	2.13	0.034	-15.22	5.04	[-25.11 , -5.33]	-3.02	0.003	-2.51	5.68	[-13.65 , 8.64]	-0.44	0.659
12-15	3.51	3.19	[-2.73 , 9.76]	1.10	0.270	-7.91	3.97	[-15.69 , -0.12]	-1.99	0.047	-9.28	4.26	[-17.62 , -0.93]	-2.18	0.029
16-23	0.23	2.47	[-4.61 , 5.08]	0.09	0.926	-4.47	2.72	[-9.81 , 0.87]	-1.64	0.100	-18.07	3.08	[-24.09 , -12.04]	-5.88	0.000
24-35	-7.30	2.16	[-11.53 , -3.06]	-3.38	0.001	-2.78	2.69	[-8.05 , 2.50]	-1.03	0.302	-13.73	2.89	[-19.40 , -8.06]	-4.74	0.000
36-47	-6.16	2.17	[-10.42 , -1.90]	-2.84	0.005	-8.19	2.74	[-13.55 , -2.82]	-2.99	0.003	-6.92	2.84	[-12.47 , -1.35]	-2.44	0.015
48-59	-3.50	2.34	[-8.08 , 1.08]	-1.50	0.134	-7.43	2.71	[-12.74 , -2.11]	-2.74	0.006	-14.19	2.91	[-19.89 , -8.49]	-4.88	0.000
Sex															
Male	-1.30	1.51	[-4.26 , 1.67]	-0.86	0.390	-3.59	1.68	[-6.89 , -0.29]	-2.13	0.033	-12.81	1.79	[-16.32 , -9.29]	-7.14	0.000
Female	-2.93	1.47	[-5.81 , -0.05]	-2.00	0.046	-6.50	1.68	[-9.80 , -3.20]	-3.86	0.000	-8.25	1.76	[-11.70 , -4.80]	-4.69	0.000
Residence															
Urban	1.40	3.14	[-4.77 , 7.57]	0.45	0.656	-2.10	3.65	[-9.26 , 5.17]	-0.58	0.565	-15.54	3.67	[-22.76 , -8.33]	-4.23	0.000
Rural	-2.70	1.16	[-4.96 , -0.43]	-2.33	0.020	-5.34	1.29	[-7.86 , -2.82]	-4.15	0.000	-9.94	1.34	[-12.57 , -7.31]	-7.41	0.000
Region															
Northern	0.72	3.07	[-5.31 , 6.76]	0.24	0.814	-1.63	2.90	[-7.33 , 4.07]	-0.56	0.574	-9.57	3.11	[-15.68 , -3.46]	-3.08	0.002
Central	-3.32	1.93	[-7.11 , 0.47]	-1.72	0.086	-9.37	2.09	[-13.47 , -5.27]	-4.49	0.000	-9.25	2.11	[-13.39 , -5.10]	-4.38	0.000
Southern	-0.94	1.41	[-3.71 , 1.84]	-0.66	0.507	-2.71	1.76	[-6.16 , 0.74]	-1.54	0.123	-11.87	1.87	[-15.54 , -8.20]	-6.34	0.000
Birth order															
1	-2.52	1.98	[-6.39 , 1.36]	-1.27	0.204	-5.50	2.57	[-10.53 , -0.46]	-2.14	0.032	-10.53	2.75	[-15.92 , -5.14]	-3.83	0.000
2-3	-3.24	1.73	[-6.63 , 0.14]	-1.88	0.061	-4.46	2.13	[-8.63 , -0.29]	-2.10	0.036	-9.81	2.25	[-14.22 , -5.39]	-4.36	0.000
4-5	0.88	1.94	[-2.92 , 4.68]	0.45	0.650	-5.71	2.21	[-10.04 , -1.37]	-2.58	0.010	-12.74	2.63	[-17.88 , -7.59]	-4.85	0.000
6+	-2.50	2.09	[-6.60 , 1.59]	-1.20	0.231	-5.49	2.71	[-10.80 , -0.17]	-2.02	0.043	-8.13	3.15	[-14.31 , -1.95]	-2.58	0.010
Birth interval															
First birth	-2.62	1.99	[-6.51 , 1.27]	-1.32	0.187	-5.71	2.56	[-10.73 , -0.69]	-2.23	0.026	-10.32	2.74	[-15.68 , -4.95]	-3.77	0.000
<24 months	-1.51	2.59	[-6.58 , 3.57]	-0.58	0.560	-2.38	3.70	[-9.62 , 4.87]	-0.64	0.521	-9.70	4.40	[-18.34 , -1.07]	-2.20	0.028
24 - 35 months	-0.77	1.89	[-4.47 , 2.95]	-0.40	0.686	-1.86	2.18	[-6.12 , 2.41]	-0.86	0.393	-11.35	2.65	[-16.53 , -6.16]	-4.29	0.000
36 - 47 months	-1.62	1.97	[-5.47 , 2.24]	-0.82	0.411	-6.45	2.51	[-11.37 , -1.52]	-2.57	0.010	-11.21	2.67	[-16.44 , -5.98]	-4.20	0.000
48+ months	-3.59	2.39	[-8.27 , 1.09]	-1.51	0.132	-9.96	2.71	[-15.26 , -4.65]	-3.68	0.000	-4.78	2.74	[-10.15 , 0.60]	-1.74	0.081
Drinking water															
Unimproved	0.02	0.02	[-1.32 , 4.78]	1.11	0.266	-0.04	2.48	[-8.40 , 1.33]	-1.42	0.155	-10.76	3.05	[-16.73 , -4.78]	-3.53	0.000
Improved	-4.89	1.62	[-8.07 , 1.70]	-3.01	0.003	-4.16	1.51	[-7.11, -1.19]	-2.75	0.006	-9.90	1.44	[-12.72 , -7.07]	-6.87	0.000
Sanitation facility															
Unimproved	-1.86	2.45	[-6.67 , 2.95]	-0.76	0.448	-10.80	2.00	[-14.71 , -6.88]	-5.40	0.000	-8.86	2.05	[-12.87 , -4.85]	-4.33	0.000
Improved	-1.97	1.26	[-4.44 , 0.50]	-1.56	0.118	-8.02	2.77	[-13.45 , -2.58]	-2.89	0.004	-6.92	2.83	[-12.47 , -1.37]	-2.44	0.015
Wealth Index															
Lowest	-3.56	2.15	[-7.77 , 0.67]	-1.65	0.099	-2.72	2.91	[-8.42 , 2.98]	-0.94	0.349	-10.67	2.96	[-16.48 , -4.86]	-3.60	0.000
Second	0.07	2.01	[-3.86 , 4.01]	0.04	0.971	-5.63	2.32	[-10.17 , -1.09]	-2.43	0.015	-10.23	2.69	[-15.49 , -4.96]	-3.81	0.000
Middle	-2.12	2.09	[-6.21 , 1.98]	-1.01	0.312	-9.35	2.39	[-14.03 , -4.65]	-3.91	0.000	-10.14	2.66	[-15.35 , -4.93]	-3.81	0.000
Fourth	-2.82	2.12	[-6.97 , 1.34]	-1.33	0.184	-2.82	2.72	[-8.14 , 2.51]	-1.04	0.299	-15.32	3.08	[-21.37 , -9.28]	-4.97	0.000
Highest	-2.37	2.37	[-7.01 , 2.27]	-1.00	0.316	-1.57	3.04	[-7.52 , 4.38]	-0.52	0.604	-11.83	3.20	[-18.11 , -5.54]	-3.69	0.000
Mother's education															
No education	-3.00	1.83	[-6.59 , 0.59]	-1.64	0.102	-2.89	2.75	[-8.27 , 2.51]	-1.05	0.294	-9.91	3.35	[-16.48 , -3.33]	-2.95	0.003

	MDHS 2000 vs. MDHS 2004					MDHS 2004 vs. 2010					MDHS 2010 vs. 2016				
	Coeff	SE	95% CI	t	P-value	%	SE	95% CI	t	P-value	%	SE	95% CI	t	P-value
Primary	-1.34	1.33	[-3.93 , 1.26]	-1.01	0.312	-5.47	1.50	[-8.40 , -2.53]	-3.65	0.000	-9.61	1.61	[-12.77 , -6.45]	-5.95	0.000
Secondary or higher	6.40	3.18	[0.15 , 12.64]	2.01	0.044	0.01	3.62	[-7.07 , 7.10]	0.00	0.997	-10.08	3.23	[-16.40 , -3.75]	-3.12	0.002
Mother's BMI															
Underweight	-3.17	3.81	[-10.64 - 4.31]	-0.83	0.406	-3.83	4.79	[-13.22 , 5.56]	-0.80	0.424	-1.17	5.94	[-12.80 , 10.48]	-0.20	0.844
Normal	-1.95	1.27	[-4.43 , 0.54]	-1.54	0.125	-4.39	1.42	[-7.17 , -1.60]	-3.08	0.002	-10.40	1.51	[-13.34 , -7.44]	-6.90	0.000
Overweight	-4.11	2.83	[-9.65 , 1.43]	-1.45	0.146	-6.56	3.26	[-12.95 , -0.17]	-2.01	0.044	-10.17	3.11	[-16.27 , -4.06]	-3.27	0.001

Table 2.1 Number of children by anthropometric measurements, Malawi 2015-16

	Proportion	Lin. Std. Error	95% CI	n	MDHS 2015-16	
					%	N
Variables						
Stunting						
< 2 SD	29.73	1.22	27.38 - 32.18	589	29.19	2,018
< 3SD	7.64	0.68	6.40 - 9.10	169	8.37	2,018
Wasting						
< 2 SD	3.66	0.48	2.82 - 4.74	83	4.09	2,028
< 3SD	0.63	0.21	0.33 - 1.22	14	0.69	2,028
Underweight						
< 2 SD	9.53	0.78	8.10 - 11.18	193	9.38	2,058
< 3SD	2.21	0.43	1.52 - 3.22	37	1.80	2,058

Table 2.2 Stunting in children 0-23 months by socio-demographic variables, Malawi 2015-16

	Proportion	Lineraized SE	95% CI	p-value	Study sample	
					%	n
Variables						
Age (months)						
0-5	22.46	2.48	17.97 - 27.70	0.0000	22.92	451
6-8	20.96	3.13	15.48 - 27.75		13.09	262
9-12	26.73	2.84	21.54 - 32.66		19.26	380
13-17	34.16	2.58	29.29 - 39.39		22.77	462
18-23	40.56	2.50	35.76 - 45.55		21.94	463
Sex						
Male	34.56	1.76	31.20 - 38.09	0.0000	50.32	1022
Female	24.83	1.58	21.86 - 28.05		49.68	996
Region						
Northern	26.36	3.04	20.83 - 32.75	0.4383	11.15	355
Central	31.15	2.09	27.20 - 35.40		41.97	709
Southern	29.25	1.67	26.08 - 32.62		46.86	954
Residence						
Urban	21.99	3.54	15.82 - 29.72	0.0297	14.08	338
Rural	30.99	1.29	28.52 - 33.58		85.91	1680
Birth order						
1	30.89	2.61	26.01 - 36.22	0.9240	26.83	544
2-3	29.63	2.00	25.86 - 33.70		38.8	797
4-5	28.43	2.52	23.74 - 33.63		22.03	431
6+	29.82	3.46	23.49 - 37.02		12.27	246
Birth interval						
First birth	31.40	2.60	26.53 - 36.71	0.0888	27.08	549
<24 months	29.57	4.99	20.78 - 40.18		6.358	126
24-35 months	35.63	2.96	30.05 - 41.62		18.7	369
36-47 months	25.78	2.49	21.21 - 30.95		19.33	394
48+	26.98	2.19	22.90 - 31.49		28.52	580

Table 2.3. Stunting in children 0-23 months by household enviroment and WASH practices, Malawi 2015-16

					Study Sample	
	Proportion	Lineraized SE	95% CI	p-value	%	n
Variables						
Type of floor						
Natural/Rudimentary	32.04	1.42	29.32 - 34.88	0.0022	78.56	1571
Finished	21.26	2.76	16.33 - 27.18		21.43	447
Type of wall						
Natural/Rudimentary	32.07	2.42	27.51 - 36.99	0.2471	27.82	536
Finished	28.82	1.43	26.10 - 31.71		72.17	1482
Type of roof						
Natural/Rudimentary	32.76	1.68	29.56 - 36.13	0.0028	62.04	1205
Finished	24.77	1.89	21.25 - 28.67		37.99	813
Cooking fuel						
Electricity/LPG/NG	31.84	19.18	7.62 - 72.59	0.1846	1.32	20
Kerosene/coal	22.17	2.84	17.10 - 28.23		15.6	329
Wood/dung	31.11	1.31	28.61 - 33.73		83.05	1669
Safe drinking water						
No	33.49	3.36	27.24 - 40.37	0.2014	14.8	306
Yes	29.07	1.29	26.61 - 31.65		85.13	1712
Improved water						
No	30.07	1.26	27.66 - 32.60	0.2694	94.67	1889
Yes	23.55	5.32	14.71 - 35.50		5.32	129
Sanitation facility						
Natural/Rudimentary	29.36	3.03	23.78 - 35.63	0.9017	13.19	274
Improved	29.78	1.37	27.17 - 32.54		86.8	1744
Shared with other HH						
No	30.90	1.69	27.69 - 34.31	0.2854	60.35	1178
Yes	27.94	2.06	24.08 - 32.16		39.64	726
Number of HH shared toilet						
<=2	28.12	2.68	23.17 - 33.66	0.7921	20.5	406
>2 and <5	29.36	3.62	22.79 - 36.92		12.4	241
>=5	30.29	1.56	27.32 - 33.42		67.03	1371
Diarrhea in last 2 weeks						
No	28.23	1.46	25.46 - 31.18	0.0513	68.05	1393
Yes	32.91	2.04	29.04 - 37.02		31.94	625
Own livestock*						
No	31.61	1.64	28.47 - 34.92	0.0835	55.02	1065
Yes	27.42	1.78	24.07 - 31.06		44.97	953
Cows and cattle						
No	29.97	1.28	27.53 - 32.54	0.3537	95.25	1922
Yes	24.80	5.05	16.24 - 35.94		4.74	96
Goats and pigs						
No	30.75	1.52	27.84 - 33.81	0.1707	76.18	1551
Yes	26.46	2.46	21.93 - 31.55		23.81	467
Chicken and poultry						
No	31.11	1.54	28.17 - 34.22	0.1495	62.27	1219
Yes	27.44	2.00	23.68 - 31.54		37.72	799

	Proportion	Lineraized SE	95% CI	p-value	Study Sample	
					%	n
Owns agriculture land						
No	25.96	2.45	21.44 - 31.05	0.1008	22.68	476
Yes	30.83	1.43	28.09 - 33.71		77.31	1542
Landarea owned						
Small-scale (< 5 hectares)	30.25	2.10	26.29 - 34.52	0.6838	33.14	659
Medium-scale (≥ 5 & < 50 hectares)	30.42	1.92	26.79 - 34.31		40.63	806
Large-scale (≥50 hectares)	27.99	2.29	23.72 - 32.69		26.23	553
Wealth Index						
Poorest	35.08	2.30	30.72 - 39.71	0.0035	25.01	459
Poorer	32.02	2.82	26.75 - 37.80		22.77	449
Middle	30.11	2.79	24.93 - 35.86		20.32	408
Richer	27.87	2.83	22.67 - 33.74		15.93	362
Richest	19.40	3.14	13.96 - 26.30		15.95	340
Child's anemia						
Not anemic	28.63	3.20	22.79 35.29	0.1956	18.78	292
Mild anemia	29.68	2.37	25.24 34.54		26.70	418
Moderate anemia	33.50	2.05	29.59 37.64		50.40	749
Severe anemia	43.73	8.75	27.88 60.97		4.01	48

** n<20, dropped bservations for horses and sheep*

Table 2.4 Stunting in children 0-23 months by infant and young child feeding practices, Malawi 2015-16

	Proportion	Lin. Std. Error	95% CI	p-value	Study Sample	
					%	n
Variables						
Breastfeeding status						
Ever breastfed, not currently	29.64	3.81	22.73 - 37.62	0.9127	10.16	208
Never breastfed	34.74	12.87	14.87 - 61.87		1.19	18
Still breastfeeding	29.67	1.33	27.12 - 32.35		86.64	1792
Initiation of breastfeeding						
After more than one hour	30.30	2.81	25.08 - 36.08	0.8123	22.55	402
Within one hour	29.56	1.35	26.97 - 32.29		77.44	1616
Child feeding						
Not breastfeeding	30.17	3.60	23.61 - 37.66	0.0553	11.35	226
Exclusive breastfeeding	24.35	3.05	18.87 - 30.83		15.41	309
Breastfeeding and water	16.84	4.91	9.24 - 28.72		4.46	85
Breastfeeding and liquids	38.03	10.24	20.74 - 59.01		1.53	35
Breastfeeding and other milk	36.36	12.23	16.84 - 61.71		0.63	8
Breastfeeding and solids	31.50	1.52	28.61 - 34.55		66.6	1355
Milk from bottle						
No	30.19	1.26	27.78 - 32.71	0.0828	95.11	1930
Yes	20.73	4.71	12.96 - 31.47		4.88	88
Exclusive breastfeeding						
No	30.70	1.32	28.18 - 33.35	0.0690	84.59	1709
Yes	24.35	3.05	18.87 - 30.83		15.41	309
Complementary feeding						
No	31.05	1.30	28.55 - 33.65	0.0199	86.9	1756
Yes	20.96	3.13	15.48 - 27.75		13.09	262
Continued breastfeeding at 12 months						
No	29.54	1.23	27.19 - 32.01	0.4946	95.13	1914
Yes	33.30	5.65	23.25 - 45.14		4.87	104
Dietary Diversity Score						
0	24.16	2.35	19.85 - 29.08	0.0348	26.69	528
1	28.84	3.06	23.22 - 35.20		16.88	329
2	36.25	2.78	30.98 - 41.87		20.85	400
3	29.26	2.67	24.30 - 34.77		17.95	380
4	34.61	3.62	27.88 - 42.01		10.41	230
5	29.37	5.65	19.58 - 41.52		5.28	107
6	23.67	8.35	11.13 - 43.44		1.35	32
7	20.31	11.30	6.08 - 50.09		0.53	12
Dietary Diversity Index						
<=3	29.29	1.35	26.71 - 32.02	0.4288	82.39	1637
>=4	31.75	2.84	26.44 - 37.58		17.6	381
Consumed flesh foods (Meat, fish, poultry)						
No	28.91	1.45	26.15 - 31.83	0.2537	75.9	1500
Yes	32.32	2.56	27.52 - 37.52		24.01	518

Table 2.5 Stunting in children 0-23 months by maternal factors, Malawi 2015-16

	Proportion	Lin. Std. Error	95% CI		p-value	Study Sample	
						%	n
Variables							
Mother's age							
15-19	26.94	3.43	20.76	34.17	0.1617	14.19	278
20-24	33.23	2.25	28.97	37.79		32.3	675
25-29	27.73	2.68	22.79	33.28		23.03	453
30-34	26.32	2.78	21.23	32.12		16.7	334
35-39	30.16	3.89	23.10	38.30		9.35	186
40-44	30.68	6.31	19.83	44.20		3.56	78
45-49	58.48	14.89	29.70	82.44		0.75	14
BMI							
Normal	30.53	1.39	27.86	33.33	0.0016	81.18	1576
Underweight	44.56	6.51	32.40	57.42		4.45	95
Overweight	21.35	2.88	16.24	27.53		14.35	321
Stunting							
No	25.77	1.32	23.27	28.45	0.0000	79.21	1566
Yes	44.80	2.62	39.74	49.97		20.78	452
Mother's education							
No education	36.12	3.92	28.83 -	44.12	0.0219	10.66	208
Primary	30.71	1.51	27.83 -	33.75		67.013	1345
Secondary or higher	23.68	2.72	18.75 -	29.43		22.19	465
Mother's anemia							
Not anemic	30.52	1.54	27.59	33.62	0.4581	18.78	1371
Mild anemia	27.21	2.21	23.09	31.76		26.78	533
Moderate anemia	34.39	6.21	23.39	47.37		50.41	91
Severe anemia	18.22	14.48	3.20	60.01		4.01	5

Table 2.6 Stunting in children age 0-23 months by maternal decisionmaking and empowerment, Malawi 2015-16

	Proportion	Lin. Std. Error	95% CI	p-value	Study Sample	
					%	N
Variables						
Health care descisiomaking						
Woman alone	30.99	3.19	25.10 - 37.57	0.8360	18.81	318
Woman and husband/partner	29.50	1.94	25.84 - 33.44		49.8	865
Husband/partner alone	31.24	2.44	26.66 - 36.21		31.29	520
large HH purchases						
Woman alone	36.31	4.54	27.94 - 45.60	0.3705	8.21	147
Jointly with husband/partner	30.58	2.05	26.72 - 34.74		47.38	842
Husband/partner alone	29.24	1.97	25.52 - 33.25		44.41	715
Visit family						
Woman alone	31.04	3.23	25.09 - 37.70	0.9749	16.71	272
Jointly with husband/partner	30.39	1.78	27.01 - 33.98		61.51	1,075
Husband/partner alone	30.10	2.76	24.97 - 35.78		21.77	350
Composite Score- woman's partcipation in decisionmaking						
0	28.60	2.29	24.33 - 33.30	0.7019	27.8	548
1	28.95	3.35	22.83 - 35.94		12.9	263
2	28.22	2.85	22.98 - 34.12		19.41	365
3	31.50	1.94	27.82 - 35.43		39.72	842
Marital Status						
Never married/divorced/widowed/separate	25.65	3.02	20.18 - 32.01	0.1597	15.03	307
Married/living with partner	30.45	1.33	27.91 - 33.11		84.96	1711
Women's attitude toward's wife beating justified if goes out						
No	28.74	1.24	26.37 - 31.24	0.0077	92.2	1867
Yes	41.89	5.23	32.11 - 52.36		7.79	147
Women's attitude toward's wife beating justified if neglects children						
No	29.27	1.26	26.87 - 31.80	0.2429	91.32	1842
Yes	34.47	4.49	26.27 - 43.72		8.67	171
Women's attitude toward's wife beating justified if argues with husband						
No	29.35	1.27	26.92 - 31.90	0.2832	92.61	1866
Yes	34.43	4.74	25.80 - 44.21		7.39	152
Women's attitude toward's wife beating justified if refuses sex						
No	29.03	1.28	26.59 - 31.61	0.0643	91.99	1848
Yes	37.70	4.74	28.94 - 47.34		8.01	170
Women's attitude toward's wife beating justified if burns food						
No	29.33	1.26	26.91 - 31.87	0.1995	94.5	1901
Yes	36.57	5.76	26.14 - 48.43		5.49	117
Composite - women's attitude						
No	29.52	1.23	27.16 - 32.00	0.2396	98.31	1983
Yes	41.55	10.95	22.68 - 63.26		1.69	35

	Proportion	Lin. Std. Error	95% CI	p-value	Study Sample	
					%	N
Composite Score- woman's beating justified						
0	28.53	1.31	26.02 - 31.17	0.1225	84.55	1706
1	33.40	5.42	23.71 - 44.73		5.16	107
2	43.48	6.87	30.77 - 57.11		3.83	72
3	27.00	7.14	15.36 - 42.97		3.17	61
4	40.05	9.86	22.98 - 59.93		1.77	37
5	41.55	10.95	22.68 - 63.26		1.69	35
Experienced emotional violence						
No	29.27	1.44	26.53 - 32.17	0.0517	74.58	1247
Yes	34.98	2.68	29.91 - 40.41		25.41	412
Experienced physical violence						
No	30.79	1.35	28.21 - 33.51	0.2938	84.18	1476
Yes	27.01	3.27	21.09 - 33.89		15.81	256
Experienced sexual violence						
No	29.20	1.37	26.58 - 31.96	0.1241	80.55	1395
Yes	34.31	3.14	28.44 - 40.71		19.44	337

** 'Someone else' and 'other' categories removed due to small sample*

Table 2.7 Model I: Logistic regression model for association of socio-demographic factors and stunting in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lineraized SE	t	P>|t|	95% CI	
Variables						
Age (ref: 0-5 months)						
6-8	0.87341	0.19597	-0.60	0.547	0.56225	1.35675
9-12	1.22427	0.23892	1.04	0.300	0.83465	1.79577
13-17	1.77804	0.32457	3.15	0.002	1.24257	2.54427
18-23	2.36848	0.45975	4.44	0.000	1.61803	3.46700
Sex (ref: male)						
Female	0.60739	0.07154	-4.23	0.000	0.48201	0.76540
Residence (ref: urban)						
Rural	2.31394	0.32698	2.02	0.044	1.01227	2.33363
Birth interval (ref: first birth)						
<24 months	0.82428	0.23502	-0.68	0.498	0.47098	1.44262
24-35 months	1.11749	0.19938	0.62	0.534	0.78730	1.58618
36-47 months	0.71126	0.12232	-1.98	0.048	0.50748	0.99686
48+	0.79307	0.13589	-1.35	0.176	0.56654	1.11018
_cons	0.28943	0.07046	-5.09	0.000	0.17948	0.46675

Logistic model for stunted, goodness-of-fit test
F(9,774) = 0.33
Prob > F = 0.9655

Table 2.8a Model II: Logistic regression model for association of access to food and stunting in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lineraized SE	t	P>|t|	95% CI	
Variables						
Owns agriculture land (ref. no land)						
Yes	1.75988	0.58582	1.70	0.09	0.91559	3.38273
Landarea owned (ref. small scale farmers)						
Medium-scale (≥ 5 & < 50 hectares)	1.07489	0.13979	0.56	0.58	0.83270	1.38750
Large-scale (≤ 50 hectares)	1.81786	0.57594	1.89	0.06	0.97603	3.38578
Wealth Index (ref. Poorest)						
Poorer	0.87203	0.13835	-0.86	0.39	0.63867	1.19067
Middle	0.77609	0.12534	-1.57	0.12	0.56523	1.06560
Richer	0.70148	0.12593	-1.98	0.05	0.49315	0.99783
Richest	0.43850	0.10895	-3.32	0.00	0.26925	0.71414
Constant	0.29237	0.10334	-3.48	0.00	0.14609	0.58514

Logistic model for stunted, goodness-of-fit test
F(9,774) = 0.98
Prob > F = 0.4532

Table 2.9a Model III: Logistic regression model for association of children's environment/WASH and stunting in children 0-23 months, Malawi 2015-16

	Proportion	Lineraized SE	t	P>|t|	95% CI	
Variables						
Safe drinking water (ref. no)						
Yes	0.80765	0.13240	-1.30	0.19	0.58542	1.11425
Improved water (ref. no)						
Yes	1.02847	0.17053	0.17	0.87	0.74274	1.42413
Diarrhea in last 2 weeks (ref. no)						
Yes	1.22475	0.13845	1.79	0.07	0.98102	1.52904
HH has livestock (ref. no)						
Yes	0.82418	0.09468	-1.68	0.09	0.65779	1.03267
Constant	0.50373	0.10429	-3.31	0.00	0.33551	0.75630

Logistic model for stunted, goodness-of-fit test
F(9,684) = 0.99
Prob > F = 0.4488

Table 2.10a Model IV: Logistic regression model for association of IYCF practices and stunting in children 0-23 months, Malawi 2015-16

	Proportion	Lin. Std. Error	t	P>|t|	95% CI	
Variables						
Breastfeeding status (ref. ever breastfed)						
Still breastfeeding	0.79666	0.443396	-0.41	0.683	0.267172	2.37552
Consumption of solid or semi-solid food among children 6-8 months (ref. no)						
Yes	0.60307	0.118006	-2.58	0.01	0.410721	0.885491
Dietary Diversity (ref. < = 3 food groups)						
4 or > 4 food groups	1.36265	0.169148	2.49	0.013	1.067967	1.738636
Constant	0.46959	0.26275	-1.35	0.177	0.156571	1.408413

Logistic model for stunted, goodness-of-fit test
F(9,774) = 0.10
Prob > F = 0.9997

Table 2.11a Model V: Logistic regression model for association of maternal factors including empowerment and stunting in children in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lin. Std. Error	t	P>|t|	95% CI	
Variables						
BMI (ref. normal)						
Underweight	2.06709	0.64917	2.31	0.02	1.11583	3.82929
Overweight	0.61715	0.12663	-2.35	0.02	0.41253	0.92328
Mother's stunting (ref. no)						
Yes	2.30014	0.32277	5.94	0.00	1.74627	3.02969
Mother's education (ref. no education)						
Primary	0.75930	0.16043	-1.30	0.19	0.50150	1.14962
Secondary or higher	0.68557	0.16512	-1.57	0.12	0.42727	1.10001
Experienced emotional violence (ref. no)						
Yes	1.21070	0.18913	1.22	0.22	0.89094	1.64524
Experienced physical violence (ref. no)						
Yes	0.95345	0.15175	-0.30	0.77	0.69759	1.30317
Experienced sexual violence (ref. no)						
Yes	1.17924	0.20746	0.94	0.35	0.83484	1.66569
Constant	0.45673	0.09219	-3.88	0.00	0.30730	0.67881

Logistic model for stunted, goodness-of-fit test
F(9,703) = 0.24
Prob > F = 0.9892

Table 2.8b Stepwise Model II: Logistic regression model for association of socio-demographic and access to food variables and stunting in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lineraized SE	t	P>|t|	95% CI	
Variables						
Age (ref: 0-5 months)						
6-8	0.89679	0.20145	-0.48	0.63	0.57701	1.39378
9-12	1.23237	0.24067	1.07	0.29	0.83995	1.80812
13-17	1.78702	0.32335	3.21	0.00	1.25276	2.54911
18-23	2.35885	0.45961	4.40	0.00	1.60913	3.45787
Sex (ref: male)						
Female	0.61399	0.07238	-4.14	0.00	0.48714	0.77387
Residence (ref: urban)						
Rural	1.01420	0.26729	0.05	0.96	0.60457	1.70138
Birth interval (ref: first birth)						
<24 months	0.82628	0.23271	-0.68	0.50	0.47537	1.43625
24-35 months	1.08056	0.19446	0.43	0.67	0.75898	1.53840
36-47 months	0.70427	0.12216	-2.02	0.04	0.50103	0.98997
48+	0.80882	0.14035	-1.22	0.22	0.57533	1.13706
Owns agriculture land (ref. no land)						
Yes	1.56311	0.51504	1.36	0.18	0.81863	2.98464
Landarea owned (ref. small scale farmers)						
Medium-scale (≥ 5 & < 50 hectares)	1.05450	0.13985	0.40	0.69	0.81279	1.36809
Large-scale (≥ 50 hectares)	1.56325	0.48361	1.44	0.15	0.85170	2.86924
Wealth Index (ref. Poorest)						
Poorer	0.87026	0.14187	-0.85	0.39	0.63193	1.19848
Middle	0.75506	0.12158	-1.74	0.08	0.55044	1.03574
Richer	0.72942	0.13302	-1.73	0.08	0.50993	1.04340
Richest	0.47036	0.12554	-2.83	0.01	0.27854	0.79427
Constant	0.32219	0.13509	-2.70	0.01	0.14147	0.73376

Logistic model for stunted, goodness-of-fit test
F(9,774) = 0.95
Prob > F = 0.4781

Table 2.9b Stepwise Model II: Logistic regression model for association of socio-demographic, access to food, household environment, sanitation and stunting in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lineraized SE	t	P>|t|	95% CI	
Variables						
Age (ref: 0-5 months)						
6-8	0.87866	0.20033	-0.57	0.57	0.56164	1.37464
9-12	1.19024	0.23370	0.89	0.38	0.80955	1.74995
13-17	1.74767	0.31710	3.08	0.00	1.22399	2.49541
18-23	2.30310	0.45045	4.27	0.00	1.56883	3.38106
Sex (ref: male)						
Female	0.62177	0.07346	-4.02	0.00	0.49307	0.78405
Residence (ref: urban)						
Rural	1.10702	0.28935	0.39	0.70	0.66271	1.84919
Birth interval (ref: first birth)						
<24 months	0.82078	0.22831	-0.71	0.48	0.47543	1.41700
24-35 months	1.08621	0.19725	0.46	0.65	0.76050	1.55141
36-47 months	0.71406	0.12453	-1.93	0.05	0.50706	1.00556
48+	0.82502	0.14372	-1.10	0.27	0.58607	1.16139
Owns agriculture land (ref. no land)						
Yes	1.64393	0.53922	1.52	0.13	0.86348	3.12980
Landarea owned (ref. small scale farmers)						
Medium-scale (≥ 5 & < 50 hectares)	1.07351	0.14503	0.53	0.60	0.82344	1.39951
Large-scale (≥ 50 hectares)	1.59713	0.49040	1.52	0.13	0.87412	2.91814
Wealth Index (ref. Poorest)						
Poorer	0.92283	0.16314	-0.45	0.65	0.65224	1.30567
Middle	0.83023	0.14840	-1.04	0.30	0.58454	1.17918
Richer	0.80796	0.16077	-1.07	0.28	0.54670	1.19407
Richest	0.52410	0.14675	-2.31	0.02	0.30248	0.90809
Safe drinking water (ref. no)						
Yes	0.92656	0.16288	-0.43	0.66	0.65616	1.30840
Sanitation facility (ref. unimproved)						
Improved	1.11350	0.19124	0.63	0.53	0.79484	1.55993
Diarrhea in last 2 weeks (ref. no)						
Yes	1.10717	0.13048	0.86	0.39	0.87851	1.39534
HH has livestock (ref. no)						
Yes	0.83544	0.11558	-1.30	0.19	0.63676	1.09612

Logistic model for stunted, goodness-of-fit test
F(9,684) = 1.08
Prob > F = 0.3737

Table 2.10b Stepwise Model II: Logistic regression model for association of socio-demographic, access to food, household environment, sanitation, child feeding practices and stunting in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lineraized SE	t	P>|t|	95% CI	
Variables						
Age (ref: 0-5 months)						
6-8	0.88985	0.20850	-0.50	0.62	0.56177	1.40951
9-12	1.20668	0.26591	0.85	0.39	0.78293	1.85976
13-17	1.76606	0.37322	2.69	0.01	1.16639	2.67404
18-23	2.32547	0.49821	3.94	0.00	1.52709	3.54125
Sex (ref: male)						
Female	0.61939	0.07332	-4.05	0.00	0.49096	0.78142
Residence (ref: urban)						
Rural	1.10805	0.29057	0.39	0.70	0.66221	1.85405
Birth interval (ref: first birth)						
<24 months	0.82092	0.22993	-0.70	0.48	0.47371	1.42260
24-35 months	1.08573	0.19703	0.45	0.65	0.76034	1.55037
36-47 months	0.70659	0.12361	-1.99	0.05	0.50122	0.99611
48+	0.81833	0.14442	-1.14	0.26	0.57872	1.15715
Owns agriculture land (ref. no land)						
Yes	1.65183	0.54329	1.53	0.13	0.86611	3.15036
Landarea owned (ref. small scale farmers)						
Medium-scale (≥ 5 & < 50 hectares)	1.06927	0.14412	0.50	0.62	0.82070	1.39314
Large-scale (≥ 50 hectares)	1.60323	0.49224	1.54	0.13	0.87750	2.92919
Wealth Index (ref. Poorest)						
Poorer	0.91952	0.16291	-0.47	0.64	0.64941	1.30196
Middle	0.82965	0.14909	-1.04	0.30	0.58305	1.18057
Richer	0.80723	0.16063	-1.08	0.28	0.54621	1.19300
Richest	0.52187	0.14797	-2.29	0.02	0.29912	0.91052
Safe drinking water (ref. no)						
Yes	0.93229	0.16396	-0.40	0.69	0.66011	1.31670
Sanitation facility (ref. unimproved)						
Improved	1.11569	0.19177	0.64	0.52	0.79617	1.56343
Diarrhea in last 2 weeks (ref. no)						
Yes	1.10639	0.13024	0.86	0.39	0.87811	1.39401
HH has livestock (ref. no)						
Yes	0.84002	0.11594	-1.26	0.21	0.64066	1.10144
Breastfeeding status (ref. ever breastfed)						
Still breastfeeding	0.66094	0.37219	-0.74	0.46	0.21882	1.99636
Dietary Diversity (ref. < = 3 food groups)						
4 or > 4 food groups	0.99140	0.14654	-0.06	0.95	0.74171	1.32515
Constant	0.40516	0.28377	-1.29	0.20	0.10246	1.60223

Complementary feeding omitted due to collinearity.

Logistic model for stunted, goodness-of-fit test
F(9,684) = 1.76
Prob > F = 0.0724

Table 2.11b Stepwise Model II: Logistic regression model for association of socio-demographic, access to food, household environment, sanitation, maternal factors, empowerment, child feeding practices and stunting in children 0-23 months, Malawi 2015-16

	Odds Ratio	Lineraized SE	t	P>|t|	95% CI	
Variables						
Age (ref: 0-5 months)						
6-8	0.69043	0.17004	-1.50	0.13	0.42574	1.11969
9-12	0.95328	0.23723	-0.19	0.85	0.58486	1.55379
13-17	1.30387	0.29677	1.17	0.24	0.83402	2.03841
18-23	1.91766	0.45287	2.76	0.01	1.20620	3.04875
Sex (ref: male)						
Female	0.62315	0.08296	-3.55	0.00	0.47983	0.80928
Residence (ref: urban)						
Rural	1.20006	0.33270	0.66	0.51	0.69636	2.06812
Birth interval (ref: first birth)						
<24 months	0.95860	0.28518	-0.14	0.89	0.53456	1.71902
24-35 months	0.99598	0.20551	-0.02	0.98	0.66424	1.49341
36-47 months	0.60481	0.12544	-2.42	0.02	0.40251	0.90878
48+	0.75289	0.15371	-1.39	0.17	0.50428	1.12408
Owns agriculture land (ref. no land)						
Yes	2.35261	0.90786	2.22	0.03	1.10290	5.01838
Landarea owned (ref. small scale farmers)						
Medium-scale (≥ 5 & < 50 hectares)	1.12994	0.16979	0.81	0.42	0.84128	1.51766
Large-scale (≥ 50 hectares)	2.24844	0.83316	2.19	0.03	1.08630	4.65387
Wealth Index (ref. Poorest)						
Poorer	0.85610	0.16684	-0.80	0.43	0.58394	1.25511
Middle	0.78847	0.16221	-1.16	0.25	0.52648	1.18084
Richer	0.94805	0.21877	-0.23	0.82	0.60268	1.49132
Richest	0.63381	0.20284	-1.42	0.16	0.33814	1.18800
Safe drinking water (ref. no)						
Yes	1.04315	0.19872	0.22	0.83	0.71767	1.51624
Sanitation facility (ref. unimproved)						
Improved	1.02171	0.19016	0.12	0.91	0.70899	1.47236
Diarrhea in last 2 weeks (ref. no)						
Yes	1.10718	0.15196	0.74	0.46	0.84567	1.44956
HH has livestock (ref. no)						
Yes	0.85510	0.13162	-1.02	0.31	0.63209	1.15678
Breastfeeding status (ref. ever breastfed)						
Still breastfeeding	0.52833	0.31497	-1.07	0.29	0.16391	1.70292
Dietary Diversity (ref. < = 3 food groups)						
4 or > 4 food groups	1.14924	0.19337	0.83	0.41	0.82594	1.59908
BMI (ref. normal)						
Underweight	1.75431	0.57162	1.73	0.09	0.92533	3.32596
Overweight	0.69567	0.14784	-1.71	0.09	0.45837	1.05583
Mother's stunting (ref. no)						
Yes	2.438702	0.510826	4.26	0.00	1.616203	3.679777
Mother's education (ref. no education)						
Primary	0.78783	0.16343	-1.15	0.25	0.52429	1.18385

Secondary or higher	0.78586	0.19774	-0.96	0.34	0.47953	1.28789
Experienced emotional violence (ref. no)						
Yes	1.26874	0.20256	1.49	0.14	0.92737	1.73578
Experienced physical violence (ref. no)						
Yes	0.91959	0.14512	-0.53	0.60	0.67460	1.25355
Experienced sexual violence (ref. no)						
Yes	1.06379	0.18427	0.36	0.72	0.75713	1.49467
Constant	0.44936	0.35417	-1.01	0.31	0.09563	2.11145

Logistic model for stunted, goodness-of-fit test

F(9,585) =	0.70
Prob > F =	0.7213

Table 2.12 Model V: Logistic regression model for association of maternal factors including empowerment and stunting in children in children 0-23 months, Malawi 2015-16

Reference Category	Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Sex (ref: male)	Female	-0.499***	-0.488***	-0.475***	-0.479***	-0.491***
Age (ref: 0-5 months)	6-8	-0.135	-0.109	-0.129	-0.117	-0.377
	9-12	0.202	0.209	0.174	0.188	-0.001
	13-17	0.576**	0.581**	0.558**	0.569**	0.311
	18-23	0.862***	0.858***	0.834***	0.844***	0.685**
Residence (ref: urban)	Rural	0.420*	0.014	0.102	0.103	0.099
Birth interval (ref: first birth)	<24 months	-0.193	-0.191	-0.197	-0.197	-0.097
	24-35 months	0.111	0.077	0.083	0.082	0.036
	36-47 months	-0.341*	-0.351*	-0.337	-0.347*	-0.490*
	48+	-0.232	-0.212	-0.192	-0.2	-0.262
Wealth Index (ref. poorest)	Poorer		-0.139	-0.08	-0.084	-0.167
	Middle		-0.281	-0.186	-0.187	-0.194
	Richer		-0.316	-0.213	-0.214	-0.057
	Richest		-0.754**	-0.646*	-0.650*	-0.452
Owns agriculture land (ref. no land)	Yes		0.447	0.497	0.502	0.825*
Landarea owned (ref. small scale farmers)	Medium-scale (≥ 5 & < 50 hct)		0.053	0.071	0.067	0.109
	Large-scale (≥ 50 hectares)		0.447	0.468	0.472	0.777*
Safe drinking water (ref. no)	Yes			-0.076	-0.07	0.064
Sanitation facility (ref. unimproved)	Improved			0.108	0.109	0.028
Diarrhea in last 2 weeks (ref. no)	Yes			0.102	0.101	0.099
HH owns livestock (ref. no)	Yes			-0.18	-0.174	-0.114
Breastfeeding status (ref. ever breastfed)	Still breastfeeding				-0.414	-0.567
Dietary Diversity (ref. <=3 food groups)	4 or > 4 food groups)				-0.009	0.107
Mother's education (ref. no education)	Primary					-0.297
	Secondary or higher					-0.245
BMI (ref. normal)	Underweight					0.633*
	Overweight					-0.384
Mother's stunted status (ref. no)	Mother stunted					0.829***
Experienced emotional violence (ref. no)	Yes					0.196
Experienced physical violence (ref. no)	Yes					-0.022
Experienced sexual violence (ref. no)	Yes					0.086
Constant		-1.240***	-1.133**	-1.303**	-0.903	-0.986
N		2018	2018	1425	1425	1012

Legend: * p<0.05; ** p<0.01; *** p<0.001

Complimentary food omitted due to collinearity

Logistic model for stunted, goodness-of-fit test

F(9,729) = 0.70

Prob > F = 0.7213

Table 3 Prevalence of stunting, wasting and underweight, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	n
Variables				
Stunting				
No	65.47	1.83	61.76 - 69.01	1088
Yes	34.53	1.83	30.99 - 38.24	1088
Wasting				
No	95.58	0.79	93.73 - 96.91	1088
Yes	4.42	0.79	3.09 - 6.27	1088
Underweight				
No	81.71	1.92	77.59 - 85.21	1088
Yes	18.29	1.92	14.79 - 22.41	1088

Table 3.1 Prevalence of stunting by socio-demographic variables, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Age (months)						
0-11	14.11	3.58	8.37 - 22.78	10.68	111	P = 0.0001
12-23	26.94	4.02	19.74 - 35.61	22.89	254	
24-35	45.30	4.33	36.92 - 53.95	23.46	246	
36-47	36.63	4.04	29.03 - 44.95	22.05	239	
48-59	39.21	3.41	32.69 - 46.14	20.91	238	
Sex						
Male	34.86	2.37	30.31 - 39.69	50.41	548	P = 0.8413
Female	34.19	2.58	29.27 - 39.47	49.58	540	
Region						
Northern	29.89	3.01	24.28 - 36.17	31.34	341	P = 0.5010
Central	34.54	2.78	29.24 - 40.25	37.32	406	
Southern	35.78	2.99	30.09 - 41.89	31.34	341	
Residence						
Urban	30.12	3.99	22.83 - 38.58	8.25	124	P = 0.2925
Rural	34.97	2.00	31.11 - 39.03	91.74	964	
Birth order						
1	27.23	3.21	21.35 - 34.03	26.48	260	P = 0.0019
2-3	31.09	2.82	25.79 - 36.94	33.25	385	
4-5	42.25	3.52	35.47 - 49.35	25.4	276	
6+	42.10	4.22	34.01 - 50.63	14.85	167	
Birth interval						
First birth	29.21	3.82	22.24 - 37.33	27.02	263	P = 0.3966
<24 months	37.26	6.67	25.22 - 51.11	8.01	84	
24-35 months	38.58	4.12	30.79 - 47.01	20.07	225	
36-47 months	37.57	4.22	29.64 - 46.23	20.55	231	
48+	33.91	2.89	28.43 - 39.86	24.33	285	
Type of floor						
Rudimentary	35.98	2.11	31.91 - 40.26	83.65	874	P = 0.0616
Improved	26.86	4.71	18.58 - 37.15	16.34	214	
Type of roof						
Rudimentary	36.13	2.73	30.90 - 41.71	62.13	645	P = 0.3433
Improved	31.86	3.01	26.21 - 38.10	37.86	443	
Type of wall						
Rudimentary	37.90	3.70	30.89 - 45.46	21.16	228	P = 0.3043
Improved	33.53	2.12	29.46 - 37.85	78.83	860	
Cooking fuel						
Electricity/LPG/NG	20.35	19.50	2.29 - 73.54	0.34	8	P = 0.0384
Kerosene /Coal	25.76	3.62	19.24 - 33.57	10.9	139	
Wood/Dung	35.75	2.06	31.77 - 39.93	88.74	941	
Source of drinking water						
Not safewater	40.42	4.20	32.43 - 48.96	15.6	184	P = 0.1531
Safewater	33.35	2.16	29.22 - 37.75	84.3	904	
Improved water						
No	34.91	1.91	31.22 - 38.79	96.72	1037	P = 0.3113
Yes	22.62	10.33	8.31 - 48.53	3.27	51	
Type of sanitation						
Not improved	34.88	5.75	24.48 - 46.96	12.55	134	P = 0.9437
Improved	34.48	1.79	31.01 - 38.12	87.45	954	
Shared toilet						

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
No	33.74	2.70	28.61 - 39.28	61.55	672	P = 0.5422
Yes	36.03	2.48	31.26 - 41.09	38.44	352	
Number of households sharing toilet						
Less than 2 households	38.09	3.69	31.09 - 45.63	20.97	208	P = 0.4861
3-5 households	36.73	5.04	27.40 - 47.16	12.77	121	
More than 5 households	32.97	2.45	28.31 - 38.00	66.24	759	
Diarrhea						
No	35.73	4.24	27.81 44.50	23.62	276	P = 0.7437
Yes	34.30	1.89	30.66 38.15	76.37	799	
Livestock in the household						
No	35.38	2.57	30.46 40.63	44.04	455	P = 0.6669
Yes	33.77	2.64	28.76 39.19	55.95	633	
Chicken/Poultry						
No	34.88	2.37	30.34 39.72	53.5	560	P = 0.8379
Yes	34.07	3.05	28.29 40.36	46.48	528	
Goats/Pigs						
No	33.86	2.08	29.86 38.10	68.45	736	P = 0.5001
Yes	36.10	2.97	30.44 42.18	31.54	352	
Cows/Cattle						
No	34.45	1.91	30.77 38.33	94.96	1032	P = 0.7819
Yes	36.15	5.80	25.60 48.24	5.03	56	
Wealth Index						
Poorest	39.87	3.48	33.20 46.93	26.58	257	P = 0.0814
Poorer	36.13	4.71	27.39 45.89	22.69	231	
Middle	32.61	3.84	25.49 40.64	21.38	238	
Richer	33.86	4.68	25.27 43.67	19.41	208	
Richest	20.17	5.95	10.82 34.46	9.91	154	
Ownership of land						
No	31.19	4.30	23.34 40.28	15.3	168	P=0.0824
Yes	35.17	2.05	31.21 39.34	84.69	920	
Size of land area						
Small-scale-farmers	35.58	3.17	29.56 42.09	32.35	348	P = 0.1836
Medium-scale farmers	34.97	2.92	29.43 40.96	49.49	548	
Large-scale farmers	31.43	3.91	24.24 39.64	18.14	192	

Table 3.2a Prevalence of stunting among children age 0-5 years by infant and young child feeding practices, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Duration of breastfeeding						
Never breastfed	0.47	0.50	0.06 – 3.76	1.29	12	P = 0.0000
Ever breastfed, not currently breastfeeding	39.91	2.09	35.85 – 44.11	65.55	729	
Still breastfeeding	25.67	2.70	20.68 – 31.38	33.15	347	
Exclusive breastfeeding						
No	33.45	1.91	29.76 – 37.34	94.50	1028	P = 0.0216
Yes	52.92	8.30	36.73 – 68.52	0.06	60	
Feeding						
No breastfeeding	39.12	2.07	35.09 – 43.30	66.84	741	P = 0.0002
Exclusive breastfeeding	52.92	8.30	36.73 – 68.52	5.69	60	
Breastfeeding and liquids	59.24	28.25	12.48 – 93.68	0.71	5	
Breastfeeding and solids	19.92	3.47	13.92 – 27.69	26.01	276	
Initiation of breastmilk						
More than an hour	27.87	4.76	19.45 – 38.19	15.76	160	P = 0.1372
Within an hour	35.73	1.87	32.11 – 39.52	84.23	928	
Milk with bottle						
No/Don't know	34.77	1.84	31.20 – 38.51	98.51	1061	P = 0.0370
Yes	14.73	6.99	5.41 – 34.26	1.48	27	
Soft, semi-solid food at 6-8 months						
No	35.44	1.94	31.70 – 39.38	95.57	1033	P = 0.0071
Yes	15.22	5.47	7.19 – 29.39	4.42	55	
Continued breastfeeding at 1 year						
No	35.03	1.89	31.38 – 38.87	98.32	1070	P = 0.0457
Yes	9.15	7.64	1.60 – 38.42	1.65	18	
Dietary diversity score						
0	28.87	5.88	18.70 – 41.74	8.33	89	P = 0.0862
1	36.06	6.05	25.10 – 48.71	11.11	110	
2	38.94	2.22	34.63 – 43.43	61.01	677	
3	21.62	5.10	13.18 – 33.39	11.81	120	
4	23.15	8.76	10.18 – 44.45	5.42	67	
5	33.33	17.34	9.60 – 70.17	1.82	16	
Dietary diversity cut-off						
Less than or equal to 3 food groups	35.39	1.92	31.68 – 39.30	92.27	996	P = 0.2379
More than or equal to 4 food groups	24.05	8.24	11.46 – 43.66	7.732	92	
Consumption of animal source food						
No	29.80	3.67	23.07 – 37.54	36.76	392	P = 0.0508
Yes	37.30	2.21	33.03 – 41.79	63.23	696	

Table 3.2b Prevalence of stunting among children age 0-2 years by infant and young child feeding practices, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Duration of breastfeeding						
Never breastfed	1.26	1.32	0.15 – 9.54	1.29	12	P = 0.0000
Ever breastfed, not currently breastfeedi	39.09	1.85	35.50 – 42.81	65.55	729	
Still breastfeeding	25.01	2.70	20.04 – 30.75	33.15	347	
Exclusive breastfeeding						
No	33.22	1.79	29.78 – 36.86	94.50	1028	P = 0.0750
Yes	45.76	7.17	32.23 – 59.95	0.06	60	
Feeding						
No breastfeeding	38.36	1.85	34.76 – 42.10	66.84	741	P = 0.0004
Exclusive breastfeeding	45.76	7.17	32.23 – 59.95	5.69	60	
Breastfeeding and liquids	49.47	27.92	9.64 – 89.98	0.71	5	
Breastfeeding and solids	20.52	3.18	14.92 – 27.54	26.01	276	
Initiation of breastmilk						
More than an hour	28.45	4.27	20.78 – 37.62	15.76	160	P = 0.1436
Within an hour	34.96	1.71	31.65 – 38.42	84.23	928	
Milk with bottle						
No/Don't know	34.06	1.78	30.63 – 37.67	98.51	1061	P = 0.3560
Yes	25.59	8.30	12.64 – 44.96	1.48	27	
Soft, semi-solid food at 6-8 months						
No	34.78	1.85	31.21 – 38.54	95.57	1033	P = 0.0043
Yes	15.68	4.95	8.13 – 28.09	4.42	55	
Continued breastfeeding at 1 year						
No	35.09	1.90	31.42 – 38.95	98.32	1008	P = 0.0236
Yes	18.92	5.52	10.26 – 32.26	1.65	80	
Dietary diversity score						
0	29.80	5.29	20.45 – 41.21	8.33	89	P = 0.0722
1	33.24	5.66	23.09 – 45.24	11.11	110	
2	38.10	1.97	34.27 – 42.07	61.01	677	
3	22.47	4.82	14.33 – 33.42	11.81	120	
4	23.84	7.47	12.15 – 41.45	5.42	67	
5	31.38	15.21	10.11 – 65.01	1.82	16	
Dietary diversity cut-off						
Less than or equal to 3 food groups	34.76	1.78	31.31 – 38.38	92.27	996	P = 0.1832
More than or equal to 4 food groups	24.10	7.00	12.94 – 40.42	7.732	92	
Consumption of animal source food						
No	28.90	3.32	22.78 – 35.89	36.76	392	P = 0.0508
Yes	36.87	2.06	32.88 – 41.05	63.23	696	

Table 3.3 Prevalence of stunting in children by maternal factors, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Mother's age						
15-19	26.57	7.70	14.19 – 44.19	4.86	44	P = 0.0682
20-24	28.08	2.91	22.68 – 34.19	31.32	336	
25-29	35.64	3.36	29.28 – 42.56	23.52	269	
30-34	37.78	4.15	29.95 – 46.30	19.76	201	
35-39	42.21	4.16	34.25 – 50.59	13.47	151	
40-44	43.69	6.54	31.40 – 56.79	5.67	73	
45-49	36.51	12.28	16.74 – 62.19	1.37	14	
Marital status						
Never married/Divorced/Widowed/Separated	31.00	4.30	23.17 – 40.10	14.37	155	P = 0.3957
Married/living with partner	35.14	2.03	31.23 – 39.26	85.62	933	
Mother's education						
No education	34.01947	5.59	23.93 – 45.8	10.36	98	P = 0.3750
Primary	35.27654	2.09	31.26 – 39.52	69.81	760	
Secondary or higher	29.17585	3.54	22.67 – 36.67	19.81	230	
Health decisionmaking						
Respondent alone	30.39	5.21	21.13 – 41.58	16.34	159	P = 0.3720
Respondent and husband/partner	34.78	2.65	29.72 – 40.20	47.36	456	
Husband/partner alone	39.34	4.15	31.47 – 47.80	36.28	312	
Purchase of large item decisionmaking						
Respondent alone	26.82	5.96	16.71 – 40.12	5.88	59	P = 0.0810
Respondent and husband/partner	31.79	2.94	26.26 – 37.89	48.62	466	
Husband/partner alone	39.44	3.04	33.60 – 45.59	45.48	405	
Visit family/friends decisionmaking						
Respondent alone	32.01	4.65	23.55 – 41.84	18.23	165	P = 0.8031
Respondent and husband/partner	36.01	2.66	30.91 – 41.44	57.63	547	
Husband/partner alone	34.80	5.25	25.22 – 45.78	24.12	218	
Composite decisionmaking score						
0	33.20	3.63	26.43 – 40.74	30.31	322	P = 0.1726
1	40.18	5.90	29.22 – 52.23	14.24	133	
2	40.99	3.95	33.44 – 49.00	15.93	180	
3	30.43	2.55	25.62 – 35.72	39.51	453	
Women's attitude to wife beating						
No	34.85	1.88	31.21 – 38.66	98.19	1070	P = 0.1198
Yes	14.62	9.38	3.71 – 43.21	1.81	18	
Goes out without asking husband						
No	35.34	1.94	31.60 – 39.27	94.44	1014	P = 0.0079
Yes	17.51	4.98	9.67 – 29.62	5.55	14	
Neglects children						
No	35.31	1.93	31.58 – 39.23	93.65	1005	P = 0.0769
Yes	21.33	6.47	11.20 – 36.83	6.34	83	
Argues with husband						
No	35.05	1.91	31.36 – 38.92	94.87	1024	P = 0.0760
Yes	23.06	6.57	12.56 – 38.46	5.12	64	
Refuses sex						
No	34.63	1.90	30.96 – 38.49	92.46	1001	P = 0.8039
Yes	32.90	6.63	21.26 – 47.09	7.53	87	
Burns food						

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
No	35.47	1.97	31.66 – 39.48	95.01	1036	P = 0.0174
Yes	15.87	5.90	7.28 – 31.20	4.98	52	
Women's beating justified score						
0	35.53	2.02	31.64 – 39.63	87.56	932	P = 0.3046
1	34.79	9.82	18.43 – 55.75	4.68	58	
2	22.63	7.99	10.57 – 41.98	3.31	45	
3	13.46	8.67	3.43 – 40.51	1.29	18	
4	32.52	15.58	10.54 – 66.35	1.33	17	
5	14.62	9.38	3.71 – 43.21	1.81	18	

Table 3.4 Estimated mean and linearized standard errors of biomarkes of nutrition, MNS Survey 2015-16.

Stunting	Normal	Mean	Lin. SE	95% CI	n	Mean	Lin. SE	95% CI	n	Mean	Lin. SE	95% CI	n
Variables													
		Not Stunted				**Stunted**				**Total**			
Hemoglobin	> 11 gm/dl	11.43	0.09	11.24 – 11.61	682	11.47	0.11	11.26 – 11.68	352	11.44	0.07	11.30 – 11.58	1082
Serum ferritin	< 12 µg/l	48.49	3.06	42.41 – 54.57	644	56.19	4.68	46.91 – 65.47	331	51.22	3.17	44.94 – 57.51	975
Soluble transferrin receptor (sTfR)	1.8-4.6 mg/l	11.42	0.53	10.36 – 12.47	644	10.87	0.41	10.06 – 11.68	331	11.22	0.43	10.37 – 12.07	975
Retinol binding protein (RBP)	< 0.46 µmol/l	0.91	0.02	0.87 – 0.94	644	0.86	0.02	0.82 – 0.90	331	0.89	0.01	0.86 – 0.90	975
Selenium	70-150 ng/ml	61.18	2.69	55.83 – 66.53	575	61.18	2.69	55.83 – 68.30	293	61.18	2.69	55.83 – 66.75	868
Serum zinc	< 57 - 65 µg/dl	60.1	1.27	57.6 – 62.7	638	62.1	2.56	57.1 – 67.2	322	60.8	1.27	58.3 – 63.4	960
alpha-1 acid glycoprotein (AGP)	< 1.0 g/l	1.27	0.05	1.17 – 1.36	644	1.56	0.07	1.42 – 1.70	331	1.37	0.05	1.27 – 1.47	975
C-reactive protein (CRP)	< 5 mg/l	5.0	0.58	3.8 – 6.2	644	9.1	1.15	6.8 – 11.4	331	6.5	0.67	5.1 – 7.8	975
Any inflammation (AGP/CRP)	>1 CRP or >5 AGP	7.6	0.58	6.4 – 8.7	644	11.4	0.92	9.6 – 13.3	331	8.9	0.59	7.8 – 10.1	975
Glucose-6-phosphate dehydrogenase	5.5-20.5 units/g	4.86	0.47	3.93 – 5.79	620	5.32	0.62	4.09 – 6.54	328	5.02	0.39	4.24 – 5.81	958
alpha thalassemia	>9.5 g/dl Hb	7.82	0.76	6.32 – 9.32	627	8.83	0.79	7.26 – 10.41	326	8.18	0.55	7.08 – 9.28	953

Table 3.5 Prevalence of stunting in childen by micronutrient status, MNS Survey, 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Anemia						
No	35.16	2.25	30.83 – 39.74	72.17	772	P = 0.6219
Yes	33.01	3.59	26.31 – 40.47	27.82	310	
Serum ferritin (Cut-off) using unadjusted ferritin						
Deficient	36.14	2.15	32.00 – 40.50	89.77	873	P = 0.3920
Normal	29.65	6.33	18.75 – 43.50	10.22	102	
Serum ferritin adjusted for inflammation						
Deficient	34.69	2.45	30.00 – 39.70	79.04	767	P = 0.5561
Normal	38.13	4.63	29.45 – 47.65	20.95	208	
Iron deficiency anemia (corrected inflammation and anemia)						
Deficient	36.59	2.00	32.72 – 40.65	95.01	925	P = 0.0807
Normal	18.26	8.02	7.14 – 39.35	4.99	47	
Retinol binding protein (RBP <0.46 umol/l)						
Yes	34.21	1.90	30.54 – 38.08	96.6	939	P = 0.0000
No	70.43	7.16	54.61 – 82.50	3.39	36	
Retinol binding protein (RBP <0.70 umol/l)						
Yes	35.28	1.87	31.67 – 39.07	96.6	974	P = 0.0000
No	99.04	1.09	91.34 – 99.90	3.39	4	
Serum zinc (corrected for fasting and time of collection)						
Deficient	33.82	3.12	27.94 – 40.26	41.53	404	P = 0.6340
Normal	36.00	2.65	30.91 – 41.41	58.46	556	
Selenium						
deficient	52.83	11.36	31.19 – 73.46	3.08	27	P = 0.0892
normal	34.18	2.34	29.70 – 38.97	96.91	841	
alpha1-acid glycoprotein (AGP)						
Normal	26.27	3.22	20.39 – 33.14	42.84	401	P = 0.0003
Abnormal	42.50	3.00	36.68 – 48.53	57.15	574	
c-reactive protein (CRP)						
Normal	30.13	1.99	26.33 – 34.22	74.26	724	P = 0.0000
Abnormal	51.82	3.87	44.16 – 59.40	25.74	251	
Any inflammation (AGP/CRP)						
0	25.88	3.28	19.91 – 32.90	41.8	390	P = 0.0003
1	35.86	3.84	28.64 – 43.77	33.95	345	
2	52.07	3.93	44.28 – 59.76	24.24	240	
alpha thalassemia						
unaffected (aa/aa)	33.62	2.96	28.02 – 39.72	59.57	584	P = 0.5563
affected (-a/-a)	34.32	7.28	21.58 – 49.80	8.73	75	
carrier (-a/aa)	38.80	3.63	31.90 – 46.19	31.68	294	
Glucose-6-phosphate dehydrogenase						
unaffected	35.69	2.49	30.92 – 40.75	72.03	692	P = 0.0031
affected	27.90	6.43	17.04 – 42.18	11.6	113	
carrier	41.10	4.82	31.97 – 50.88	16.39	153	
Sickle cell anemia						
unaffected aa	34.77	2.16	30.61 – 39.17	89.52	861	P = 0.0000
affected ss	0.00	0.00	0.00 0.00	0.00	0	
carrier as	45.39	7.29	31.67 59.84	10.4	95	

Table 3.6 Prevalence of stunting in childen by household hunger, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Hungry because of no food						
No	37.61	2.31	33.16 – 42.28	66.91	668	P = 0.0091
Yes	27.13	3.02	21.56 – 33.52	33.13	418	
Times hungry because of no food						
1	38.20	3.85	30.90 – 46.07	36.91	245	P = 0.7641
2	37.69	3.01	31.94 – 43.82	59.07	383	
3	29.15	9.91	13.69 – 51.63	4.01	36	
Household member slept hungry						
No	38.00	2.58	33.03 – 43.23	60.02	602	P = 0.0410
Yes	28.73	3.19	22.84 – 35.45	39.97	482	
Times household member slept hungry						
1	33.60	3.72	26.65 – 41.34	41.91	272	P = 0.2062
2	41.84	3.51	35.06 – 48.94	55.32	305	
3	30.19	14.62	9.82 – 63.19	2.77	20	
Household member did not eat all day and all night						
No	34.09	2.76	28.83 – 39.76	39.24	397	P = 0.7699
Yes	35.06	2.14	30.93 – 39.43	60.75	688	
Times household member did not eat all day and all night						
1	37.79	3.07	31.91 – 44.05	60.85	253	P = 0.1107
2	27.01	4.51	19.01 – 36.85	35.61	129	
3	41.83	14.40	18.14 – 70.01	3.53	14	
Household Hunger Scale (HHS)						
0	26.67	2.98	21.19 – 32.98	29.65	376	P = 0.0854
1	35.47	7.41	22.43 – 51.10	11.36	117	
2	41.41	3.96	33.83 – 49.42	22.62	230	
3	34.90	2.82	29.53 – 40.69	33.53	329	
4	45.95	11.96	24.64 – 68.85	1.43	18	
5	26.58	20.81	4.18 – 75.02	0.57	10	
6	24.61	17.21	4.92 – 67.29	0.82	7	
Household Hunger Index1						
little to none	29.51	3.19	23.59 – 36.21	41.02	493	P = 0.0356
moderate	37.69	2.57	32.75 – 42.91	56.15	559	
severe	36.49	11.60	17.55 – 60.81	2.82	35	
Household Hunger Index2						
little to none	29.51	3.19	23.59 – 36.21	41.02	493	P = 0.0662
moderate to severe	37.65	2.52	32.80 – 42.76	58.97	594	

Table 3.7 Prevalence of stunting in children age 0-5 years by mother's perception of child size at birth, birthweight, and MUAC, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Chid size at birth						
Very large	26.84	5.58	17.28 – 39.19	9.64	88	P = 0.0585
larger than average	29.13	3.09	23.40 – 35.62	25.73	300	
average	35.86	2.55	30.97 – 41.07	49.05	531	
smaller than average	45.54	7.99	30.61 – 61.32	10.61	118	
Very small	35.79	10.13	18.86 – 57.21	3.83	41	
Don't Know	48.59	14.86	22.49 – 75.47	1.13	10	
Birthweight						
Very Low birth weight/Low birth weight	39.62	6.67	27.40 – 53.29	10.54	115	P = 0.0314
Normal	32.11	2.19	27.92 – 36.60	73.27	816	
Not Weighted/Don't know	41.75	3.98	34.11 – 49.80	16.18	157	
MUAC						
Well nourished	33.99	1.93	30.28 – 37.91	92.17	992	P = 0.5268
At risk for acute malnutrition	41.24	5.70	30.57 – 52.81	6.75	69	
MAM	38.24	20.23	10.16 – 77.22	1.06	10	

Table 3.8 Prevalence of stunting by common infections and fever in children age 0-5 years, MNS Survey, 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Fever in the last 2 weeks						
Yes	38.32	2.72	33.08 – 43.85	45.51	509	P = 0.0708
No	31.81	2.34	27.35 – 36.63	56.49	567	
Fever in the past 24 hours						
Yes	39.30	6.93	26.68 – 53.53	12.04	134	P = 0.4428
No	34.06	1.82	30.55 – 37.75	87.98	942	
Cough in the past 2 weeks						
Yes	32.53	4.78	23.84 – 42.62	28.93	339	P = 0.5730
No	35.53	1.98	31.71 – 39.55	71.07	727	
Malaria in the past 2 weeks						
Yes	37.15	3.34	30.80 – 43.97	20.21	233	P = 0.3502
No	34.07	1.91	30.39 – 37.96	79.78	843	
Blood in urine						
Yes	11.59	7.42	3.02 – 35.54	1.09	11	P = 0.0344
No	34.81	1.85	31.24 – 38.56	98.91	1071	

Table 3.9 Prevalence of stunting in children by therapeutic supplements and prevention to infection, MNS Survey, 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Iron tablets synrup, multiple micronutrients powder in last week						
Yes	39.08	12.29	18.73 – 64.11	2.71	29	P = 0.6996
No	34.43	1.86	30.83 – 38.21	97.29	1053	
Received deworming trtment last 6 months						
Yes	37.28	4.25	29.29 – 46.03	17.26	198	P = 0.4409
No	33.88	1.95	30.12 – 37.85	82.73	884	
Received therapeutic foods (e.g., plumpy nut)						
Yes	44.62	18.05	15.90 – 77.44	0.98	14	P = 0.5438
No	34.37	1.81	30.87 – 38.06	99.01	1066	
Received vitamin A capsule last month						
Yes	36.66	3.58	29.89 – 44.00	14.49	160	P = 0.5022
No	34.21	1.96	30.44 – 38.20	85.51	920	
Slept under mosquito net						
No	30.74	6.15	20.01 – 44.06	12.62	123	P = 0.5365
all children	34.30	2.86	28.87 – 40.18	45.04	520	
some children	42.96	6.32	31.11 – 55.68	8.75	106	
no net in HH	33.86	2.84	28.46 – 39.70	33.57	335	
Vaccination card - vitamin A						
No/DK	33.33	4.76	24.63 – 43.33	24.05	151	P = 0.0242
vaccination date on card	10.35	5.62	3.36 – 27.73	5.31	40	
Reported by mother	35.24	2.97	29.59 – 41.34	62.67	382	
vaccination marked on card	15.80	6.69	6.48 – 33.71	7.96	38	

Table 3.10 Prevalence of stunting among childern age 0-5 years by social intervention programs, MNS Survey 2015-16

	Proportion	Lineraized SE	95% CI	%	n	Sign.test
Variables						
Received coupons for the farm input subsidy program (FISP) this season						
Yes	35.17	3.23	29.05 – 41.82	35.83	376	P = 0.8920
No	34.62	2.28	30.24 – 39.29	64.16	706	
Household participates in the social cash transfer programme						
Yes	22.45	6.56	12.06 – 37.95	6.12	72	P = 0.3246
No	35.61	1.84	32.04 – 39.34	93.22	1005	
Household on Malawian Vulnerability Assessment Committee (MVAC) this season						
Yes	29.80	8.87	15.46 – 49.62	5.01	62	P = 0.1475
No	35.00	1.87	31.39 – 38.80	94.61	1022	
No/Don't know	0.71	1.00	0.04 – 10.63	0.37	3	
Household received food or cash during 2014-2015 drought and MVAC						
Yes	35.93	8.84	20.75 – 54.57	3.49	42	P = 0.8760
No	34.48	1.94	30.74 – 38.41	96.51	1045	
Replacement items provided						
Yes	34.93	1.81	31.43 – 38.59	99.12	998	P = 0.1731
No	18.71	9.57	6.19 – 44.51	0.87	19	

Table 3.11 Multivariate analysis of determinats of chilhood stunting, MNS Survey 2015-16

stunted	Odds Ratio	Linearized Std. Error	t	P>t	[95% Conf.	Interval]
Age (ref. <12 months)						
12-23 months	3.76182	1.64905	3.02	0.00	1.57483	8.98594
24-35 months	6.81482	3.11417	4.20	0.00	2.74940	16.89160
Residence (ref. urban)						
	0.83987	0.35527	-0.41	0.68	0.36249	1.94591
Birth order (ref 1)						
2-3	0.94537	0.35399	-0.15	0.88	0.44935	1.98895
4-5	3.15677	1.15095	3.15	0.00	1.53008	6.51285
6+	2.30596	1.04903	1.84	0.07	0.93412	5.69247
Child's size at birth (ref. very large)						
Larger than average	1.34355	0.71962	0.55	0.58	0.46366	3.89326
Average	2.21559	1.17838	1.50	0.14	0.77031	6.37249
Smaller than average	4.88204	2.93897	2.63	0.01	1.47665	16.14086
Very small	5.68987	5.80331	1.70	0.09	0.75029	43.14927
Birthweight (ref. underweight)						
Normal	1.78477	0.75717	1.37	0.18	0.76843	4.14538
Exclusive breastfeeding (ref. No)						
	1.05518	0.47026	0.12	0.90	0.43537	2.55735
Continued breastfeeding at 1 year (ref. No)						
	0.60277	0.28766	-1.06	0.29	0.23359	1.55539
Household Hunger Scale (ref. mild hunger)						
Moderate to severe hunger	1.19025	0.32079	0.65	0.52	0.69684	2.03301
Glucose-6-Phosphate Dehydrogensae (ref. normal)						
Affected or carrier	0.80435	0.20994	-0.83	0.41	0.47895	1.35084
Sickle cell disease (ref. normal)						
Affected or carrier	1.86328	0.83798	1.38	0.17	0.76261	4.55252
Anemia (ref. no)						
Yes	0.92961	0.27494	-0.25	0.81	0.51660	1.67282
Serum ferritin (adjusted for inlammation) (ref. normal)						
High	3.04403	0.87982	3.85	0.00	1.71440	5.40490
Retinol binding protein (RBP) (ref. normal)						
Yes	2.77450	2.01557	1.40	0.16	0.65537	11.74584
Iron deficiency anemia (ref. normal)						
Yes	0.38682	0.18870	-1.95	0.06	0.14678	1.01938
Low zinc concentration (ref. normal)						
Yes	1.17003	0.28520	0.64	0.52	0.72097	1.89880
Selenium deficiency (ref. normal)						
Yes	0.31968	0.18956	-1.92	0.06	0.09844	1.03813
C-reactive protein (CRP) (ref. normal)						
High	1.69706	0.46808	1.92	0.06	0.98120	2.93520
alpha-1 acid glycoprotein (AGP) (ref. normal)						
High	1.33108	0.40403	0.94	0.35	0.72838	2.43250
alpha-thalassemia (ref. normal)						
Affected or carrier	1.27500	0.36548	0.85	0.40	0.72148	2.25317
Recent vaccination (ref. no card)						
Vaccination date on card	0.19858	0.10048	-3.19	0.00	0.07269	0.54254
Reported by mother	0.81909	0.24542	-0.67	0.51	0.45170	1.48529
Vaccination marked on card	0.49958	0.29538	-1.17	0.24	0.15436	1.61683
_cons	0.03931	0.03983	-3.19	0.00	0.00525	0.29415

Table 3.12 Multivariate analysis of biomarkers on chilhood stunting, MNS Survey 2015-16

stunted	Odds Ratio	Linearized Std. Error	t	P>t	[95% Conf.	Interval]
Age (ref. <12 months)						
12-23 months	2.74649	1.06404	2.61	0.01	1.27264	5.92722
24-35 months	5.28651	2.28046	3.86	0.00	2.24489	12.44925
36-47 months	3.80652	1.66883	3.05	0.00	1.59398	9.09020
48-59 months	5.18057	2.15789	3.95	0.00	2.26568	11.84558
Household Hunger Scale (ref. mild hunger)						
Moderate to severe hunger	1.74184	0.33515	2.88	0.01	1.18875	2.55228
Glucose-6-Phosphate Dehydrogensae (ref. normal)						
Affected or carrier	0.89642	0.15649	-0.63	0.53	0.63383	1.26780
Sickle cell disease (ref. normal)						
Affected or carrier	1.97949	0.64975	2.08	0.04	1.03159	3.79836
Anemia (ref. no)						
Yes	0.84657	0.20546	-0.69	0.49	0.52287	1.37069
Serum ferritin (adjusted for inlammation) (ref. normal)						
High	1.90538	0.50820	2.42	0.02	1.12199	3.23573
Retinol binding protein (RBP) (ref. normal)						
Yes	3.45663	1.49220	2.87	0.01	1.46692	8.14518
Iron deficiency anemia (ref. normal)						
Yes	0.56638	0.27762	-1.16	0.25	0.21402	1.49890
Zinc deficiency (ref. normal)						
Yes	1.21784	0.18044	1.33	0.19	0.90746	1.63437
Selenium deficiency (ref. normal)						
Yes	0.47326	0.24227	-1.46	0.15	0.17126	1.30777
C-reactive protein (CRP) (ref. normal)						
High	1.70822	0.31538	2.90	0.01	1.18397	2.46459
alpha-1 acid glycoprotein (AGP) (ref. normal)						
High	1.18940	0.28205	0.73	0.47	0.74275	1.90464
alpha-thalassemia (ref. normal)						
Affected or carrier	1.55046	0.27199	2.50	0.01	1.09444	2.19648
_cons	0.09798	0.06168	-3.69	0.00	0.02807	0.34195

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