Assessing the Intergenerational Effects of Maternal Exposure to Drought in Early Life Before and After Prenatal Supplementation and the Seasonality Effects on Birth Outcomes in Rural Malawi

by

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The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

BACKGROUND

Prenatal supplementation can positively influence birth outcomes by addressing and improving the nutritional status of infants in resource-poor settings. Nevertheless, evidence from historical disasters such the Dutch Famine and the Great Chinese Famines suggest that early life nutritional adversity can have spill-over, intergenerational, effects when an affected girl becomes pregnant. Little is known on whether early life nutritional adversity in the context of historical droughts in Malawi result in intergenerational effects on offspring's birth outcomes, whether the timing of the early life nutritional adversity (*in utero* vs. early childhood) matters, and whether prenatal supplements could offset any intergenerational effects.

In Malawi, some of the women who lived in Mangochi District as young children were exposed to one of the droughts of 1981/82, 1987/88, or 1992/93, *in utero* or at age 0-5 yr, for up to 12 months in each drought period, and to varying degrees of drought severity. This research took advantage of a natural experiment to explore the effects of maternal exposure to drought in early life on offspring's birth outcomes. In this natural experiment, there was no pre-determined randomization of exposure and non-drought exposure and, as such, assignment of pregnant women into the two groups was simply determined by date of birth (DoB). The outcomes of interest were infant length-for-age Z score (LAZ), weight-for-age Z score (WAZ), and birthweight (either actual birthweight where available, or imputed, where newborns were weighed within 3-5 days of birth). Additionally, this research assessed the impact of a novel prenatal supplement on the hypothesized intergenerational effects of maternal exposure to drought in Malawi compared to the standard of care prenatal supplement.

This research also took advantage of the existence of a unimodal weather pattern in Malawi which is divided into three parts, with a single rainy season and harvest: the cold and dry season (coincides with the harvest and post-harvest months), the hot and dry season (coincides with the pre-lean ["hunger"] months), and the hot and wet season (coincides with the lean "[hunger"] months). The literature cites the importance seasonality on birth outcomes. The exposures of interest were offspring's birth in the pre-lean months or lean months compared to birth in the harvest/post harvest months (based on known DoB). The outcomes of interest were measured birthweight – measured within 72 hours of birth – and imputed birthweight, if measured more

than 3 days after birth, measured infant LAZ and infant WAZ. Weight and length data were expressed as Z-scores (WAZ, LAZ) relative to the 2006 WHO growth standards.

OBJECTIVES

The primary objective of study #1 was to estimate the direct effects of *in utero* maternal exposure to the pooled droughts of 1981/82, 1987/88, and 1992/93 on infant LAZ, infant WAZ, and imputed birthweight [measured close to the time of birth depending on where the infant was born (i.e., clinic vs. non-clinic setting)]. The secondary objective of study #1 was to assess the effects of prenatal supplements to offset the impact of maternal exposure to drought *in utero* on infant LAZ and WAZ, and imputed birthweight.

The primary objective of study #2 was to estimate the direct effects of maternal exposure to drought in 1981/82, 1987/88, or 1992/93 at age 0-5 yr and maternal exposure to the pooled droughts in the narrower age groups of 0-2 yr and 3-5 yr on infant LAZ, infant WAZ, and imputed birthweight. The secondary objective of study #2 was to assess the effects of prenatal supplements to offset the impact of maternal exposure to drought in early childhood on infant LAZ, child WAZ, and imputed birthweight.

The primary objective of study #3 was to estimate the seasonality effects of month of birth on selected birth outcomes (measured birthweight and LAZ), for infants whose weight was measured within 72 hours of birth. The secondary objective of study #3 was to estimate the seasonality effects of month of birth on birth outcomes (imputed birthweight, LAZ, and child WAZ) for the whole sample, including imputed birthweight for children weighed more than 3 days after birth.

METHODS

From 2010-2012, the iLiNS-DYAD-M (a registered clinical trial, #NCT01239693 at clinicaltrials.gov) enrolled 1391 women with gestation age $\leq$ 20 weeks and randomized them to receive a prenatal supplement called a small-quantity, lipid-based nutrient supplement (SQ-LNS: a peanut-paste fortified with milk fats, 19 vitamins and minerals, and essential fatty acids), or to receive a multiple-micronutrients tablet, or to receive the standard ante-natal care - an iron-folic acid (IFA) tablet. In the main trial, the women were only supplemented if they signed an informed consent form. Ethical approval was obtained from the University of Waterloo Research Ethics Committee (ORE #22443) for the present research.

The DoBs of the study participants were self-reported. The data were collected during screening at four study clinics. Other pertinent data on demographic and socioeconomic status (SES) were mainly collected at the homes of the study participants by trained data collectors. Birthweight and length were measured by midwifery-nursing staff unless babies were born in non-clinical settings (e.g., at home). Thus, home births or births outside of study area clinics without accompanying measurements elicited infant measurements by trained field study staff. The data for the 1262 women with known DoBs were included in the main analyses for studies #1 and #2 if the dataset for the covariates was complete. Study #3 analyzed outcomes of singleton births with known infant DoBs.

Multiple regression analyses were conducted using ordinary least square (OLS) methods with birth outcomes as the dependent variables, maternal exposure to drought at various times in early life as well as covariates (maternal effects and sociodemographic variables) and dummy variables for type of prenatal supplement received.

RESULTS

Summary statistics: The average age of the study women was 24 years old with a range of 14 to 48 years. Of the 1262 out of the 1391 participants from the main trial with known DoBs, in study #1, 206 women in total were exposed to drought *in utero*. In study #2, 831 women were exposed to drought in early childhood (age 0-5 yr). In study #3, of the 1295 infants who could have been assessed, about 28% of infants were born during the lean “hunger” season (n = 368), about 41% of infants were born during the pre-lean season (n = 391), and about 30% were born during the harvest/post-harvest season (n = 536).

Regression results: Some of the more notable results were as follows: among infants born to women exposed to drought *in utero* during the second-third trimester, there was a positive and somewhat significant effects on imputed birthweight [+88.497g, 95% CI (11.572: 165.422), n = 1074] and when trial supplements were added to the models, only maternal first trimester exposure to drought interacted with MMN (compared to IFA) yielded quite strong and significant results on infant LAZ [-0.853 SD, 95% CI (-1.446: -0.259), n = 980]. In Study #2, among women not exposed to drought postnatally at age 0-5 yr, positive and quite large, significant effects of prenatal supplementation with SQ-LNS compared to prenatal supplementation with IFA were observed for infant LAZ, infant WAZ, and imputed birthweight, with stronger effects observed for infant LAZ and imputed birthweight ($p < 0.01$) [+0.403 SD, 95% CI (0.099: 0.708), n = 980; +0.372 SD, 95% CI (0.053: 0.691), n = 991; +125.900 g, 95% CI (2.901: 248.899), n = 1074, respectively]. In study #3, after controlling for year of birth and other covariates, birth in the lean season compared to the harvest/post-harvest season was negatively associated with measured birthweight ($p < 0.01$) and reduced-sample LAZ. The results for imputed birthweight, infant LAZ and infant WAZ, which were consistently significant ($p < 0.01$), repeated the pattern of previously reported associations in study #3.

CONCLUSION

For study #1, there was no evidence that maternal exposure to drought *in utero* adjusted for baby's sex, maternal effects and socio-economic variables decreased birth length and weight in offspring of rural Malawian mothers. Also, prenatal supplementation with SQ-LNS did not moderate the hypothesized intergenerational effects of maternal exposure to drought *in utero* by not improving rural Malawian offspring's birth size compared to prenatal supplementation with IFA. For study #2, maternal exposure to the 1981/82 drought at ages 0-5 yr, 0-2 yr, or 3-5 yr vs. non-drought exposure postnatally appeared to improve birth outcomes although not significantly, in rural Malawian offspring, adjusted for covariates. However, prenatal supplementation with SQ-LNS appeared to improve infant weight and length compared to prenatal supplementation with IFA, among infants of mothers not exposed to drought in early childhood. For study #3, the results showed that birth during the lean season led to a significantly lower weight and length for the sample for which actual birthweight was available compared to birth during the harvest/post-harvest season. When imputed birthweight, WAZ and LAZ in the larger samples were regressed against the exposure variables and covariates, the results were still significant and did not change.

Overall, among the three studies, the clinical significance of the effect sizes was markedly larger in the interactions between maternal drought-exposure in early life and prenatal supplements but were marginally smaller in the seasonality of birth assessments despite the sample sizes being larger in the latter assessments.

Finally, studies #1 and #2 were underpowered to detect the hypothesized intergenerational effects from the interacted variables due to limitations with sample sizes and the nature of natural experiments' inability to optimize sample sizes *a priori*. Also, the lack of a positive response to SQ-LNS supplementation in the nutritional status of infants may indicate that the relatively small 20g daily-dose of SQ-LNS was inadequate to overcome the hypothesized intergenerational effects of maternal exposure to drought in early life. Nonetheless, there may be a case for prenatally supplementing women from food insecure households with SQ-LNS (compared to IFA) who were not exposed to drought postnatally, in resource-poor settings.

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And finally, to Almighty God, the author and originator of our expansive universe, thank you for wisdom, knowledge, understanding, and discernment. In you *I live, I move, and have my being* (Acts 17: 28).

Dedication

I dedicate this labour of love to my two children who have inspired and energised me throughout my post-graduate academic journey - Philip and Arabella Phiri.

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List of Abbreviations

BMI	Body mass index
BMIZ	Body mass index for-age Z score
CI	Confidence interval
COMREC	College of Medicine Research and Ethics Committee
DoB	Date of birth
DOHaD	Developmental origins of health and disease
FFS	Fortified food supplement
HAIZ	Household asset index Z score
HAZ	Height for-age Z score
HFIAS	Household food insecurity access scale
HH	Head of household
HIV-AIDS	Human immunodeficiency virus – Acquired immune deficiency syndrome
IFA	Iron-folic acid
IFPRI	International food policy research institute
iLiNS	International lipid-based nutrient supplement
IPTp-SP	Intermittent preventive treatment in pregnancy-sulfadoxine-with pyrimethamine
LAZ	Length for-age Z score
LBW	Low birthweight
LQ-LNS	Large quantity-lipid-based nutrient supplement
MMN	Multiple micronutrients
OLS	Ordinary least squares
OR	Odds ratio
PE	Protein energy
RCT	Randomized controlled trial
SAP	Structural adjustment programme
SD	Standard deviation
SES	Socioeconomic status
SGA	Small-for-gestational age

SOP	Standard operating procedure
SQ-LNS	Small quantity-lipid-based nutrient supplement
SSA	sub-Saharan Africa
USA	United States of America
WAZ	Weight for-age Z score
WHO	World Health Organization
WHZ	Weight for-height Z score
WWII	World war two

Chapter 1

Introduction

1.1 Brief Background

In Malawi – the focus of this research – almost 37% of all children aged less than five years (5 yr) have moderate to severe stunted linear growth (National Statistical Office (NSO), 2016). Stunting as an outcome, [measured as moderate stunting: length-for-age Z score (LAZ) < -2 standard deviation (SD) and severe stunting: LAZ < -3 SD] affects the quality of life for young children resulting in poor health status, low education, and unfavorable future income prospects, and contributes to under-5 mortality (Grantham-McGregor et al., 2007; UNICEF, 2016). Notably, other forms of less pervasive undernutrition exist, such as, underweight and wasting [measured as moderate: weight-for-age Z score (WAZ) < -2 SD and severe: WAZ < -3 SD; weight-for-height Z score (WHZ) < -2 SD and severe: WHZ < -3 SD, respectively] (UNICEF, 2016). However, their incidence may acutely increase when there are external shocks exerted on households, such as, humanitarian crises (e.g., famines, floods, earthquakes, or wars). Globally, different interventions have been successfully implemented to reduce the incidence of undernutrition and its associated indicators of underweight and wasting but, comparatively, less so of stunting, especially in sub-Saharan Africa or SSA. For example, a meta-analysis released in 2017 of demographic health survey data (2006-2016) from most of the SSA countries (n = 32) and in the four sub-regions of SSA found that 7.1% of children aged younger than five years were wasted [95% CI (6.0: 8.2)], while 16.3% were underweight [95% CI (12.8:19.9)] (Akombi et al., 2017), which would be considered low prevalence rates. However, more than 30% of preschoolers from the SSA countries were stunted [33.2%, 95% CI (30.4: 36.1)], which would be considered a high prevalence rate and a public health concern (Akombi et al., 2017).

Although nutritional status assessments have components of physiological measures (anthropometry) there are also biochemical measurements that test for nutrient status (e.g., for iron and folate (Vitamin B9) (Shetty, 2003), this research's focus will be on perinatal length (adjusted for age and sex) and weight (adjusted for age and sex), and birthweight.

1.1.1 Review of the Literature on LNS and Comparators

Micronutrient deficiencies affect fetal growth and development but when maternal micronutrient status improves via prenatal supplementation, results from a meta-analysis showed improved infant growth, and, overall, increased birthweight in low and middle-income countries (Fall et al., 2009). Notably, a Lancet series discussed various nutritional interventions which aimed to improve maternal and child nutrition (Bhutta et al., 2013). The authors of the series, however, did not extensively review the recent trend of using lipid-based nutrient supplements (LNS) as a comparator against better known products such as corn-soy blends, zinc-alone and multiple micronutrients (MMN) in both tablet and powder form for young children and pregnant women (iLiNS Project, 2015). LNS has been and continues to be assessed because of its status as an atypical (food) and, supposedly, as a superior supplement in that it is fortified with both macronutrients and micronutrients [e.g., peanut paste as a source of protein, milk as a source of fat, plus 19 minerals and vitamins, respectively] (Ashorn et al., 2015a). The prescribed standard of care prenatal supplement in Malawi is iron-folic acid (IFA), which only contains iron and folate.[1] MMN supplements contain more micronutrients than IFA and are a close substitute for LNS but they are not formulated with macronutrients (e.g., fats and essential fatty acids). Notably, both IFA and MMN were reported in the 2013 Lancet series as being efficacious in reducing the incidence of LBW (at a 19% reduction rate and 11-13% reduction rate, respectively), in the reduction of small for gestation-for-age (SGA), and of course, in the reduction in anemia and iron deficiency anemia (Bhutta et al., 2013). The case for replacing IFA with MMN as the standard of care has been made on the premise that there are populations which are at risk of multiple micronutrient deficiencies and would, therefore, benefit from the provision of more than two micronutrients (Bhutta et al., 2013).

Despite the reported benefits of using MMN-alone, in areas with suboptimal protein consumption, the addition of the peanut paste and milk to MMN to create LNS could be viewed as nutritionally advantageous, especially in individuals with marked nutritional needs such as pregnant and lactating women, and growing children (Shetty, 2003). Nevertheless, a pressing question is how well the human body can absorb the micronutrients in LNS, IFA, and MMN if they are consumed consistently during pregnancy to prevent undernutrition and promote fetal growth. LNS in large quantities (e.g., ~ 90 g per day dose) have been typically used for therapeutic purposes in severely malnourished children and HIV-AIDS patients, or in emergency situations where there is a food crisis (Chaparro & Dewey, 2010). However, the efficacy of LNS in small doses (small quantity-LNS or SQ-LNS: 10g-40g per day) in healthy but often mildly malnourished children, (healthy defined as infants who at enrollment did not present with a fever, did not have malaria, were not anaemic, or due to be hospitalized) has not been consistently proven. In some randomized-controlled trials (RCTs), larger quantities of LNS (LQ-LNS, doses of 50g per day), which were relatively more expensive than smaller quantities of LNS, were shown to slightly improve infant height in severely stunted children at age 18 months, in rural settings (Adu-Afarwuah et al., 2007; Phuka et al., 2009)[2]. Notably, LNS in general were assessed against the standard of care prenatal supplements[3] (Adu-Afarwuah et al., 2015; Ashorn et al., 2015a). The results have been inconsistent, with improved birthweight associated with SQ-LNS supplementation observed, for example, in subgroup analyses in infants born to primiparous women in Ghana (Adu-Afarwuah et al., 2015) but not in Malawi (Ashorn et al., 2015a). What was noted in the Malawi study was that some infections and inflammation responses modified the effect of SQ-LNS on birth outcomes (Ashorn et al., 2015a).

Nevertheless, despite the inconsistent results, the importance of LNS-related research and pregnancy outcomes is evident in the academe. For example, a very recent 2017 Cochrane systematic review protocol aims to study and report on the impact of LNS on pregnant women, birth outcomes, and infant developmental outcomes in normal and emergency settings (Das et al., 2017).

1.2 Research Rationale

Martorell and Zongrone have asserted that the problems of undernutrition can be addressed in a single generation by using aggressive and effective programmes to protect the health and nutrition of mothers in rich, developed countries (Martorell & Zongrone, 2012). Martorell and Zongrone have claimed that when interventions that target the first critical 1000 days of life fail, the reason is unlikely due to intergenerational factors in rich, developed countries (Martorell & Zongrone, 2012). However, they have posited that this non-effect (i.e., the “washing out” of the intergenerational effects of undernutrition in developed countries also observed in animal models) is unlikely to be observed in countries with poor social services and pervasive poverty, even when an appropriate intervention is implemented (Martorell & Zongrone, 2012).

Therefore, in this research, it was hypothesized that SQ-LNS fortified with numerous minerals and vitamins could reduce, for example, the incidence of child stunting by improving dietary and micronutrient intake (iLiNS Project, 2015). Because some of the International Lipid-based Nutrient Supplements (iLiNS) studies, (e.g., the iLiNS-DYAD-M trial registered at clinicaltrials.gov), were conducted in drought-susceptible regions (IFPRI, 2015), this natural experiment provided an opportunity to test Martorell & Zongrone's (2012) theory about intergenerational effects in resource-poor settings by adding a prenatal supplements component to the research.

The rationale behind using data from the Ashorn et al. (2015a) study briefly mentioned in section 1.1.1 of this chapter was that in their study, they hypothesized that addition of macronutrients (proteins and milk fats) in prenatal supplements would promote fetal growth and prevent adverse birth outcomes such as low birthweight (LBW) and pre-term birth in resource-poor settings (Ashorn et al., 2015a). It is noteworthy that LBW and preterm birth are important measures for assessments because they are associated with an increased risk of chronic cardiometabolic diseases in adulthood (Barker, 1997; Barker, 2001). Although the main trial faced several challenges regarding the sample size, participant (in) adherence to the intervention protocol, and a temporary suspension of SQ-LNS distribution to participants, the authors reported that their sensitivity analyses were robust and, therefore, the results were credible (Ashorn et al., 2015a).

1.2.1 Life Course Impacts

In agricultural-dependent and food-insecure countries, maternal environmental exposure during pregnancy coupled with seasonal variations is a cause for concern. For example, the lean season vs. the harvest/post-harvest season often affects newborn size leading to low birthweight and stunting, if suitable interventions are not introduced (de Onis et al., 1998). In Africa and, generally, in developing countries, maternal exposure to the rainy season vs. other seasons during the second or third trimesters of pregnancy negatively affects the birthweight and birth length of offspring (Madan et al., 2017; Neufeld et al., 1999; Prentice et al., 2013). The consequences of this type of exposure during pregnancy can be evident over the life course of offspring via the developmental origins of health and disease (DOHaD) theory. For example, stunting in early life not only affects children's health and their academic performance in the short-term, but also affects them in adulthood in terms of the quality of their human capital (e.g., health and labour) in the long-term (Alderman, 2012; Uauy et al., 2011).

1.2.2 Intergenerational Transmission of the Effects of Maternal Early Life Adversity

Barker's hypothesis of the fetal origins of health and disease, states that health and disease in adulthood stems from the womb (Barker 1997, Barker 2001). A fetal experience that is vulnerable and maladapts to external stress has several consequences: pre-term birth, SGA, and LBW at the start of life, or metabolic syndrome (obesity, hypertension, and Type II diabetes mellitus), which increase the risk for cardiovascular diseases, stroke, and other chronic diseases later in life (Uauy et al. 2011). The external stress emanates from factors that influence the quality of life in pregnant women, such as stress related to compromised nutrition, living environment, mental health, substance use, noise levels, or social relationships (Epel 2011). Thus, intervening early or before postnatal life begins is essential. The type of stress that is most noteworthy in the context of the DOHaD is maternal undernutrition, which has intergenerational effects on offspring's birth outcomes (Barnes et al. 2016).

1.2.3 Conceptual Frameworks of the Thesis at the Macro and Micro Levels

At the macro-level, there are underlying and intermediate factors affecting household food security as seen in Figure 1.1. Ultimately, the onset of drought causes the affected area to have an increased risk of crop failure and crop failure affects households' food supply as shown in the macro-level conceptual framework (Figure 1.1). The actual timeline of events preceding the drought, during the drought, and after the drought can generally affect predictors of birth outcomes (e.g. the effect of malaria contracted during pregnancy on birthweight) in this way.

Unlike in normal seasonal conditions (Figure 1.2), low rainfall during the lean season can initially attenuate the effects of drought, which include the decrease in infections due to malaria during the rainy season since there is sparse water for mosquito breeding (Stanke, 2013). The lower than average harvest affects household food security leading to increased LBW low birthweight (Figure 1.3). For example, it has been reported that in Senegal, Niger, and Chad, malaria prevalence dropped to 23%, 32%, and 7%, respectively, after the onset of drought which also affected some major rivers (Stanke, 2013). Post-drought, there are increased malaria-related morbidity and mortality rates compared to the previous lean season even as recovery begins after the lean season negatively affecting the birthweight of drought-exposed offspring (Stanke, 2013).

Further, the effects of drought were compounded by other factors, such as, structural adjustment programmes (SAPs), whereby privatisation efforts by the Malawi Government under the guidance of the World Bank led to increased inflation (Ndaferankhande & Ndhlovu, 2006), which affected household food insecurity (Figure 1.4). Whereas the 1981/82 drought were magnified by the SAPS, the droughts of 1987/88 and 1992/93 were mitigated by the Malawi Government through aid relief unilaterally and bilaterally with donor agencies (Babu & Chapasuka, 1997). Thus, SAPS would historically have a negative influence on household food security while emergency aid would have a positive influence on household food security (Babu & Chapasuka, 1997). Household food *insecurity* affects the health and nutrition status of household members (Kalkuhl et al., 2013). Consequently, household expenditures are negatively impacted by ill health with resources likely diverted to deal with ill-health, resulting in opportunity costs of time and money (Kalkuhl et al., 2013).

At the micro-level, drought exposure can be generalised as maternal early life adversity as shown in Figure 1.5. Decreased caloric and micronutrient and/or macronutrient intake *in utero* or in early childhood leads to infant nutritional status (WHO, 2013). If maternal early life undernutrition is not addressed, it can lead to increased morbidity and permanent damage to cognitive development, leading to mortality and some disability, respectively (WHO, 2013). Further, in the framework, if a young girl survives early life adversity and becomes a mother in adulthood, there is an opportunity to be prenatally supplemented with the new SQ-LNS compared to IFA. An intermediate predicted outcome is increased maternal caloric, micronutrients, and macronutrient intake during pregnancy. Thereafter, in the framework, this improved maternal nutritional intake leads to improved birth outcomes, adjusting for confounders.

1.3 Research Aims and Questions

The main aim of this thesis was to estimate the direct effect of maternal exposure to drought in early life on infant LAZ, infant WAZ, and birthweight as birth outcomes. The droughts occurred in 1981/82 (Babu & Chapasuka, 1997), 1987/88 (IFPRI, 2009), and in 1992/93 (Babu & Chapasuka, 1997). Birth outcomes were measured close to the time of birth depending on where the infant was born (clinic vs. non-clinic setting).

The maternal drought exposure occurred at two levels:

(1) While the mother was growing in the womb (*in utero*); or,

(2) When the mother was already born, from age 0-5 yr (postnatal).

Next, narrower age groups were introduced in this postnatal category. The age groups included 0-2 years (0-24 months), a period that is vulnerable to irreversible growth impairment if undernutrition is not addressed, and 3-5 yr (25-60 months) a period of growth that is less vulnerable and provides an opportunity for catch-up growth (Martorell, 1999).:

An assumption made in this research was that prenatal supplements have the potential to moderate the effects or associations between maternal exposure to drought in early life and birth outcomes.

The second aim was to test Martorell and Zongrone's theory that unlike in developed countries intergenerational effects are not "washed out" in resource-poor settings even with proven nutritional interventions.

The third aim of this thesis was to estimate the seasonality effects of birth outcomes due to maternal exposure to periods of food insecurity during pregnancy (e.g., the lean season in the rainy months vs. the harvest season in the dry months).

Hence, the research questions were framed as follows:

a) Is maternal exposure to drought *in utero* (compared to no exposure *in utero*) associated with negative outcomes in rural Malawian offspring?

b) Does SQ-LNS vs. iron-folic acid (IFA) moderate the intergenerational effects of maternal exposure to drought *in utero* vs. non-drought exposure *in utero* in rural Malawian offspring?

c) Is maternal exposure to drought at age 0-5 yr, 0-2 yr, or 3-5 yr vs. post-natal non-drought exposure, associated with poor negative outcomes in rural Malawian offspring?

d) Does SQ-LNS vs. IFA moderate the intergenerational effects of maternal exposure to drought at age 0-5 yr, 0-2 yr, or 3-5 yr, vs. post-natal non-drought exposure in rural Malawian offspring?

e) Do seasonal variations in the timing of birth negatively influence birth outcomes in rural Malawian children?

1.4 Methodology for Assessing Droughts in Mangochi

Droughts can occur nationally or regionally, and these phenomena occur when expected annual rainfalls falls short of the average rainfall.

Malawi experiences regional droughts of varying intensities while mild droughts have historically been dominant. For Mangochi District, the study site located in Southeast Malawi, consistent annual rainfall levels are important because over 90% of households cultivate maize, which is the main staple food in Malawi (Figure 1.6) (Haggblade, 2007). The three droughts of interest, which affected the Southern region of Malawi where the study population resided occurred in 1981/82/ 1987/88, and 1992/93 (Babu & Chapasuka, 1997; IFPRI, 2009).

The thesis triangulated the drought occurrences in the study location with literature on historical rainfall data and climatic-geospatial software that models past global rainfall seasons (Haggblade, 2007; Climate Hazards Group., Internet). Thus, historical rainfall data has shown that only 74% of the water requirement was met in the 1981/82 cropping cycle (and only 50% was met in Mangochi) (Table 1.1) (Haggblade, 2007). Likewise, only 48% of water requirement was met in the 1987/88 cropping cycle, while the 1992/93 season was even worse with only 28% of the water requirement met (Haggblade, 2007).

Appendix B contains rainfall maps (B1-B3) that illustrate the extent of rainfall shortage below the long term mean by SD for the years of interest (Climate Hazards Group., Internet). On the 1981 rainfall map, Mangochi marked by a red circle, had annual rainfall which was 100-200 mm less than the average annual rainfall (-1.5 to -1.0 SD below the long-term mean). On the 1987 rainfall map, Mangochi marked by a red circle, had annual rainfall which was 100 mm less than the average annual rainfall (-1.0 to -0.5 SD below the long-term mean). Finally, on the 1992 rainfall map, Mangochi marked by a red circle, had annual rainfall which was 200-400 mm less than the average annual rainfall (-2.5 to -2.0 SD below the long-term mean).

1.4.1 Some Limitations of Assessing the Impact of Droughts in the Study Site

There are many key factors missing from the first two studies in this thesis, such as maternal residence during their prenatal, postnatal, or early childhood stage of life; migration patterns and associated remittances, complete reports of food aid distribution from the Malawi Government for droughts of 1981/82 and external donor agencies/governments and their impact on the welfare of household; and dietary intake during the drought period. The biggest limitation is an ethical one in that maternal exposure to drought cannot be assigned by researchers to one group for experimental purposes because that would be logistically problematic and, of course, unethical. Thus, the research relied on a natural experiment, i.e., nature and time provided the circumstances for exposure and non-exposure. A natural experiment presents problems of potential selection bias of excluded women due to sampling problems beyond the control of the research and potential omitted variable bias because some pertinent socioeconomic and dietary intake data were missing from the three drought periods.

Nevertheless, the research can be justified by using close proxies for residence in the area, such as the languages spoken by the participants (Fig 1.6-1.7) and government reports of relief efforts in 1992 (Babu & Chapasuka, 1997) [Appendix A: A2]. In May 1992, when the harvest would have begun, food distribution was targeted towards the Southern region, especially in Nsanje, where 354,000 people were affected by a drought. Between May 1992 and August 1992, 58,000 tonnes of maize had been delivered and distributed to rural populations. Next, commercial and food imports were distributed in June 1992. Overall, final crop estimates revealed a 59% production loss nationally.

There are also some data missing for the 1981/82 and 1987/88 droughts, but the annual rainfall data indicate that Mangochi experienced rain shortfalls (Table 1.1). However, official records reveal that the incidence of malnutrition was high during the drought of 1992/93 (drought defined as beginning after the lean season of the failed rains) and that malnutrition was markedly worse in the Southern region, a region where many of the women in the study population would have resided during their childhood (National Statistical Office, 1992). However, a final report released in February 1993 estimated that 46.9% of the cases of acute malnutrition had been eliminated with similar estimates provided for other districts.

In terms of residence during the droughts, because most of the iLiNS-DYAD-M trial participants' first spoken language was Chiyao (see Fig 1.7), this indicates that they have been historically and predominantly located in Mangochi District (National Statistical Office, 1992). In fact, over 80% of the study participants preferred to communicate in Chiyao when asked at enrollment. Comparatively, there are hardly any Chiyao speakers in the northern part of the country (see Fig 1.8) (National Statistical Office, 1992). Therefore, first spoken language is a good proxy of residence at birth for this cohort of women.

1.5 Summary of Thesis Chapters

As for the composition of this thesis, there are three additional chapters after the introductory chapter, which will present results from the following studies, namely, *Intergenerational Effects of Maternal Exposure to Drought in Utero: Evidence from a Retrospective Cohort Study in Malawi* (Chapter 2), *A Retrospective Cohort Study of the Intergenerational Effects of Maternal Exposure to Drought in Childhood on Birth Outcomes* (Chapter 3) and, *Associations between Seasonal Variations and Newborn Size in Rural Malawi - a Retrospective Cohort Study* (Chapter 4). The results will be separated into two sections, namely, summary statistics and regressions results. The summary statistics and regression results will be presented in tables and appropriate figures will be used to also illustrate the results. The last chapter, *Conclusions and Recommendations* will present a summary of the whole thesis and some policy implications (Chapter 5).

Specifically, Chapter 2 is a study on the *in utero* effects on birth outcomes after maternal exposure to drought in early life vs. non-drought exposure in early life. The chapter highlights other natural experiments which used exposure to famine during World War Two (WWII) in the Netherlands and from 1959-61 in China. The emphasis is on external stressors which change the intrauterine environment causing fetal growth to be impeded, with consequences observed at birth and in adulthood and passed on intergenerationally to offspring. The chapter also adds trial supplements used in the RCT in Ashorn et al. (2015a) to analyse the effects of prenatal supplementation when interacted with maternal exposure to drought *in utero*. The methods used to report on the statistical relationships between maternal exposure to drought *in utero* and the study outcomes are multiple regressions. The duration of maternal exposure is measured by pregnancy trimesters for the pooled droughts.

Chapter 3 focuses on the intergenerational effects of maternal exposure to drought in the preschool years on birth outcomes which includes exposure at ages 0-5 yr, 0-2 yr and 3-5 yr vs. post-natal non-drought exposure. The emphasis is on the nutritional needs of the mothers not being completely met during early childhood due to drought conditions and the negative effects being passed on to their offspring. As in Chapter 2, multiple regressions will estimate the statistical relationships between maternal exposure to drought (including their interactions with trial supplements) and birth outcomes but the maternal exposure now occurs at age 0-5 yr, 0-2 yr and 3-5 yr.

Chapter 4 complements the studies reported in Chapters 2-3 by introducing a new variable that will be assessed for its short-term effects on fetal growth. Hence, the focus shifts from drought exposure to seasonal variations during pregnancy and how they may negatively impact birth outcomes, especially in the lean season vs. the harvest/post-harvest season.

Chapter 5 summarises the thesis by reviewing the results presented in Chapters 2-4. The chapter highlights the most important results, addresses the research questions, discusses the implications of the findings on the famine and drought effects literature, and suggests the way forward for future research and policymaking.

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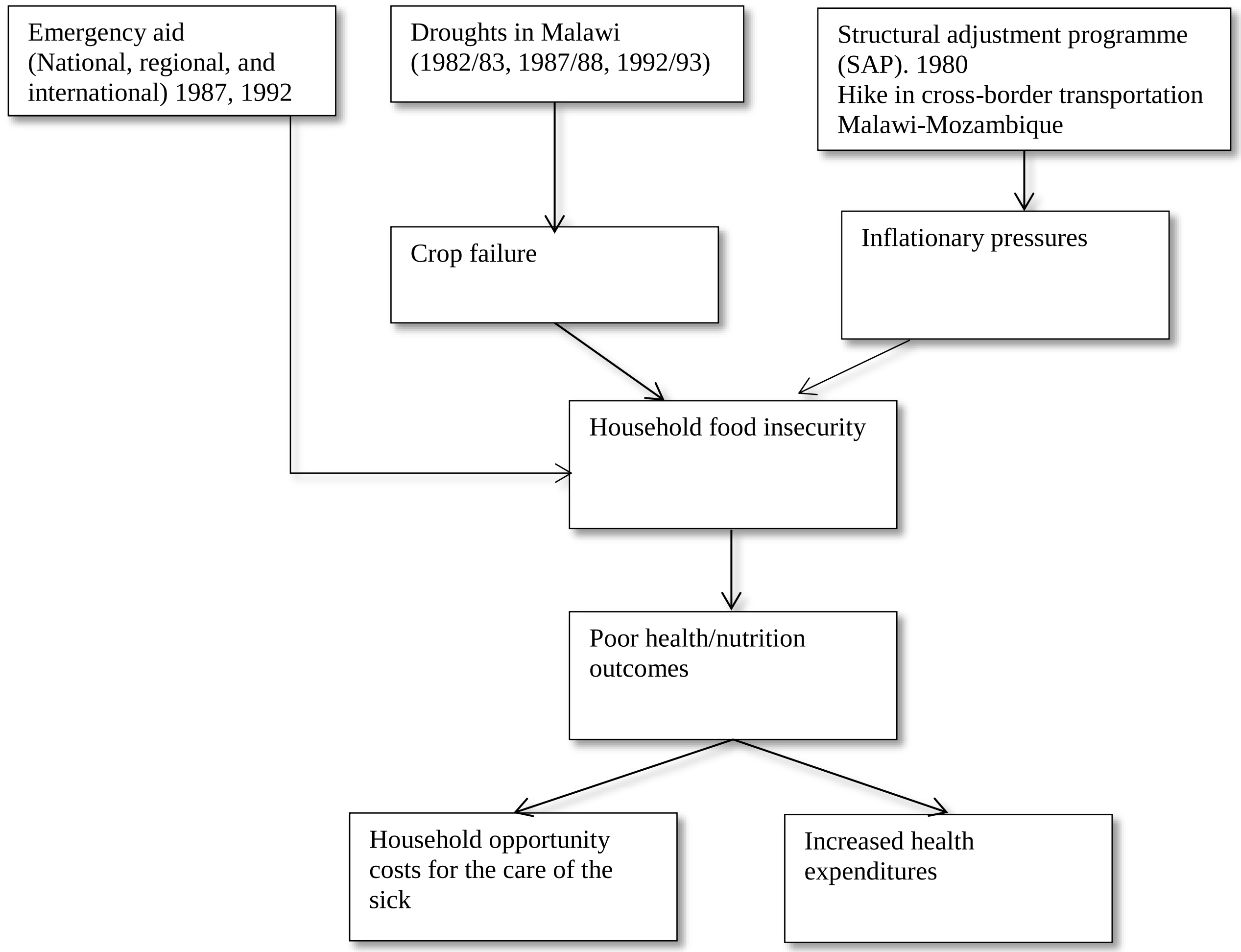
[1] Daily-dose IFA is also the World Health Organisation's (WHO's) standard of care for pregnant women and is recommended based on a 2012 Cochrane review (Peña-Rosas et al., 2012).

[2] The World Food Programme estimated the cost of large quantity- LNS (LQ-LNS) to be $0.20 per 45-50g dosage, per day (World Food Programme, 2010).

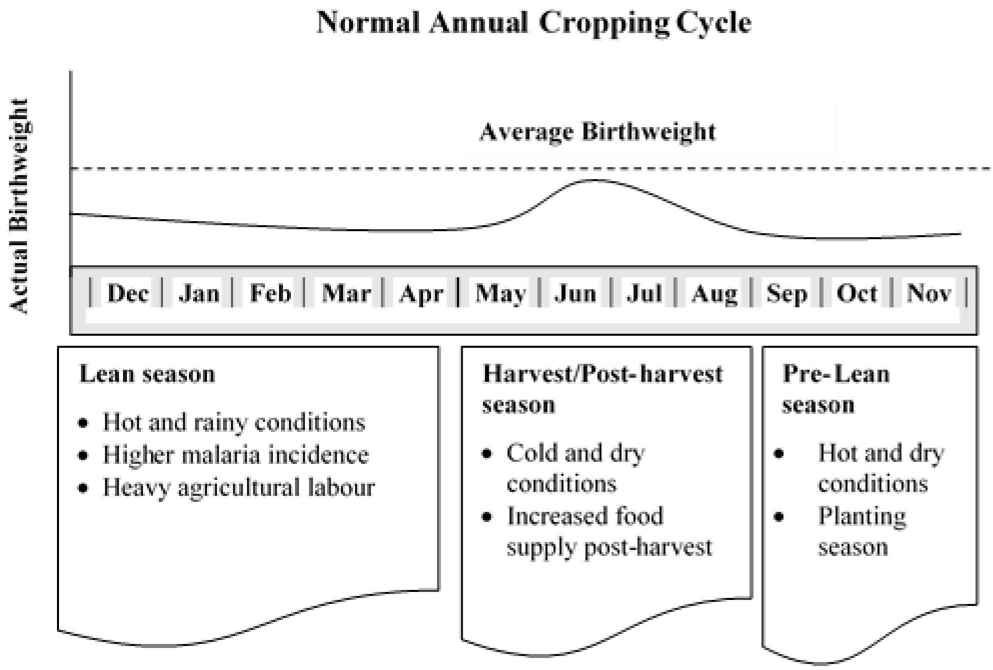
[3] SQ-LNS were fortified with numerous minerals and vitamins, which also contained amino acids, milk fat, protein, and energy (118 kcal per daily dose). See Appendix A (A1) for more details.

Figure 1.1: Macro-level External Pressures on Household Food Security and Impacts (1981-1992)



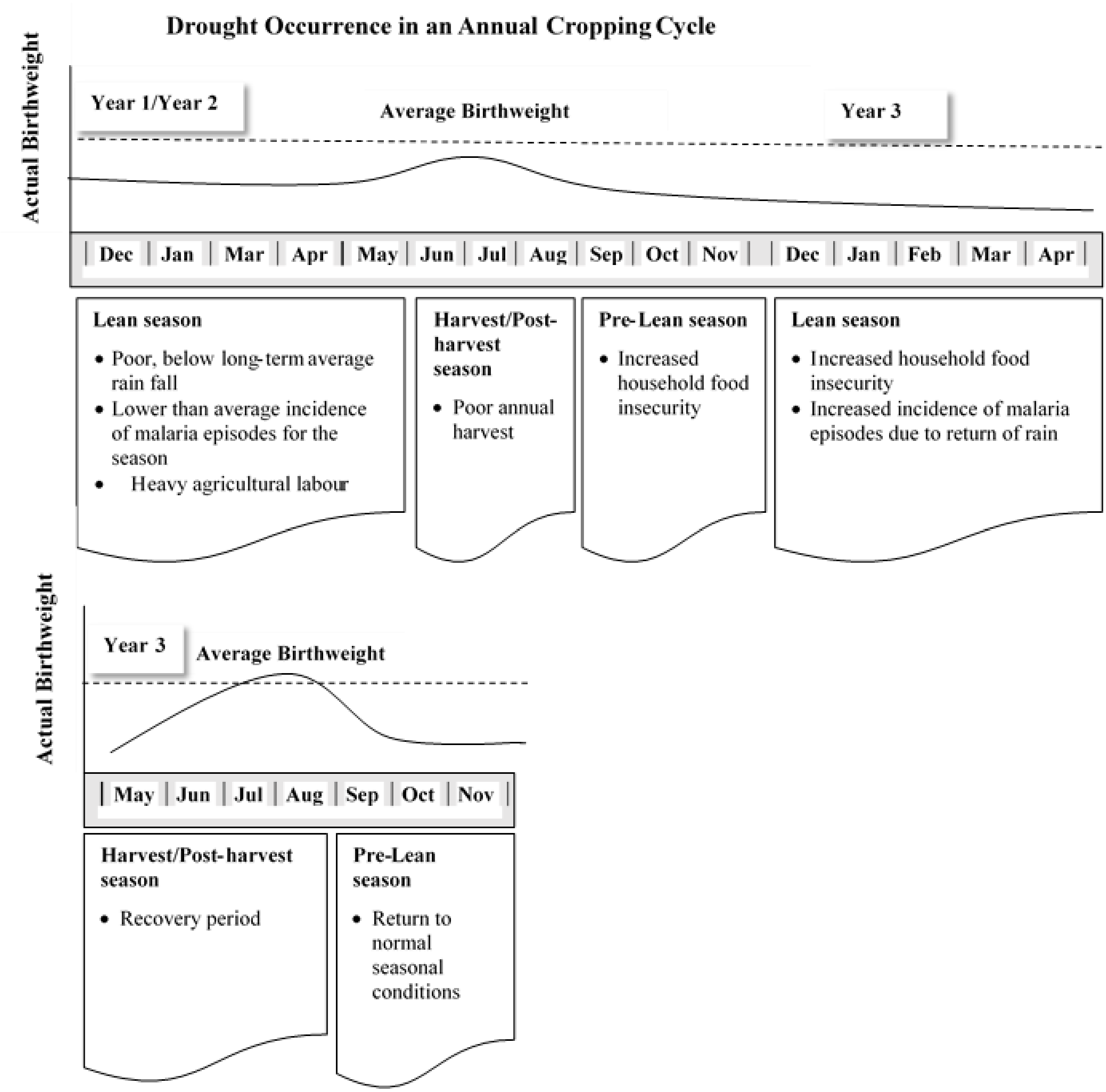
Source: Adapted by Author from Kalkuhl et al. (2013)

Figure 1.2: Timeline of Events and Outcomes with Normal Rainfall in Mangochi District



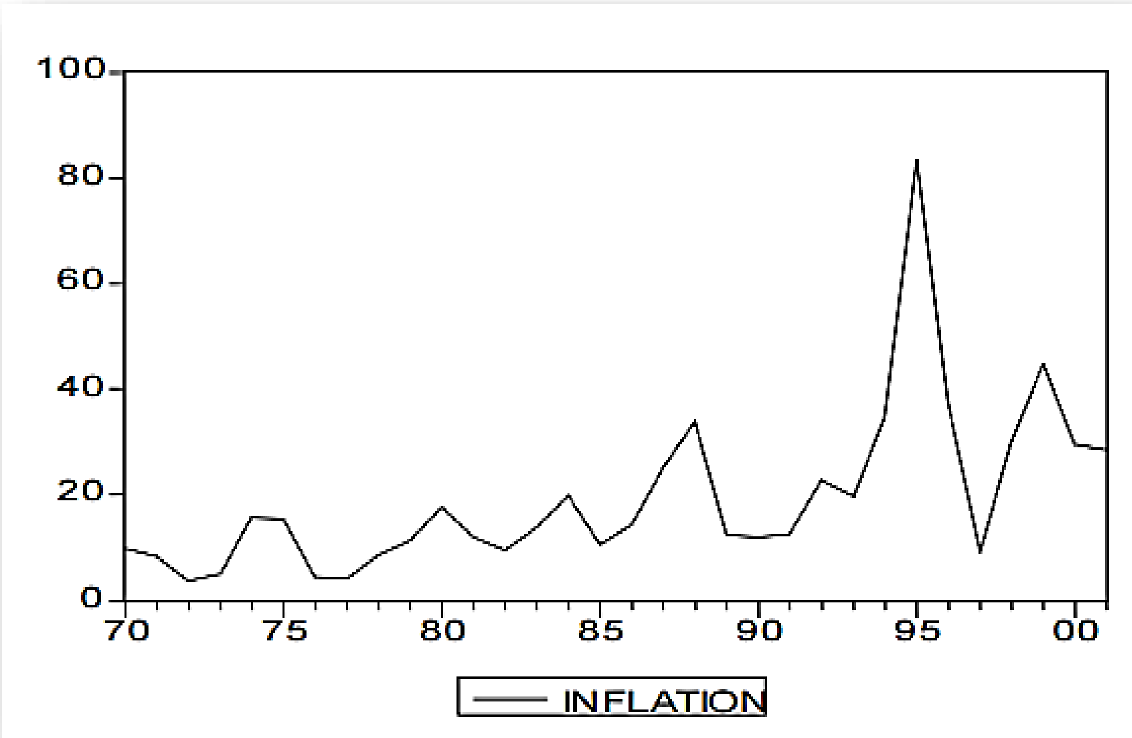
Source: Author's elaboration, based on suggestions from Mark Manary and Susan Horton

Figure 1.3: Timeline of Events and Outcomes Pre- and Post-Drought in Mangochi District



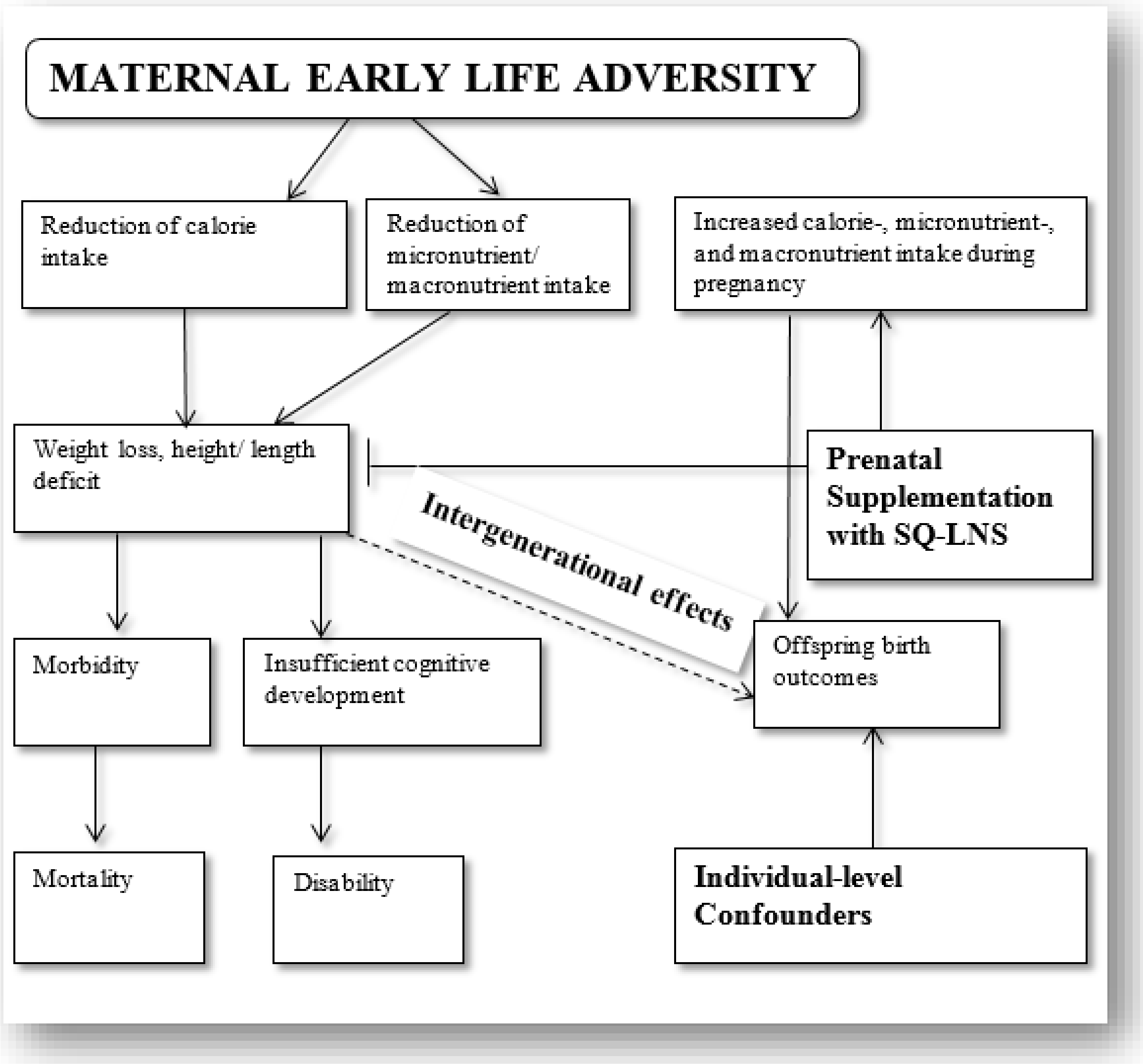
Source: Author's elaboration, based on suggestions from Mark Manary and Susan Horton

Figure 1.4: Rate of Inflation in Malawi, 1970 -2000 (Annual Percent)



Source: Ndaferankhande & Ndhlovu (2006)

Figure 1.5: Micro-Level Intergenerational Effects of Maternal Early Life Adversity

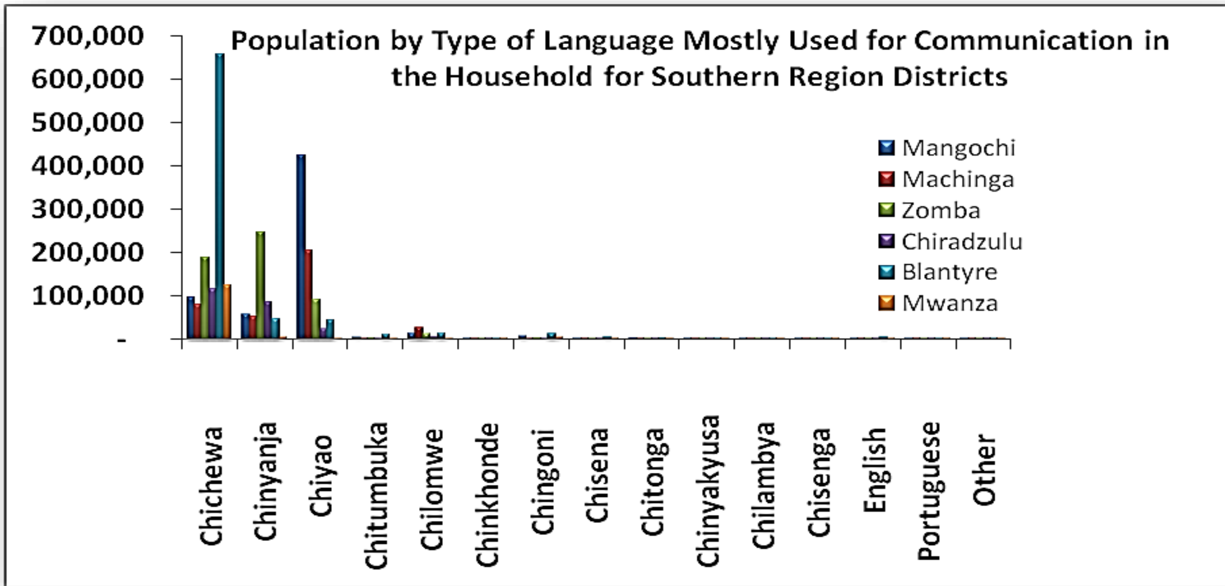


Source: Adapted by Author from WHO (2013)

Figure 1.6: Household Production of Maize in Malawi

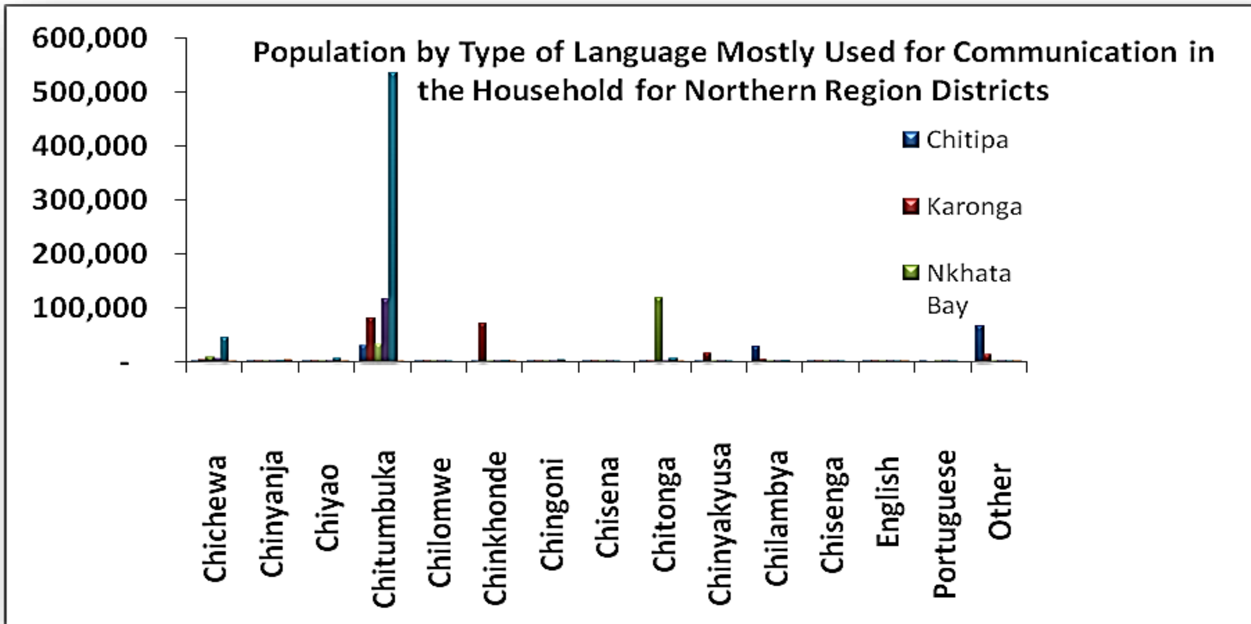
Source: Haggblade (2007)

Figure 1.7: Languages Spoken in the Southern Region of Malawi



Source: National Statistical Office (1992)

Figure 1.8: Languages Spoken in the Northern Region of Malawi



Source: National Statistical Office (1992)

Table 1.1: Water Requirements Satisfaction Index in Eight Weather Stations in Malawi

District/ Year	Karonga	Mzimba	Kasungu	Salima	Chitedze	Mangochi	Chileka	Ngabu
1971/72	-	-	49	-	100	-	-	-
1972/73	-	-	63	-	62	-	-	-
1973/74			100	-	100		-	-
1974/75	100	100	100	97	100	65	61	37
1975/76	100	100	100	100	100	100	85	67
1976/77	100	100	78	100	100	59	100	68
1977/78	100	100	100	100	100	100	100	76
1978/79	100	100	55	100	100	100	90	61
1979/80	100	100	100	100	86	60	65	13
1980/81	100	100	100	100	100	**50**	100	44
1981/82	66	100	100	77	100	74	80	89
1982/83	80	100	96	100	76	6	44	14
1983/84	100	100	100	72	97	100	59	100
1984/85	100	100	100	100	100	100	81	100
1985/86	80	100	100	100	100	77	96	86
1986/87	100	100	100	100	100	**48**	71	37
1987/88	100	100	100	100	100	59	100	100
1988/89	67	100	100	100	100	100	100	100
1989/90	53	100	100	100	94	58	72	48
1990/91	84	94	100	100	73	75	95	71
1991/92	100	93	52	91	54	**28**	31	5
1992/93	88	100	100	100	100	69	58	71
1993/94	72	100	-	72	-	7	42	42
1994/95	-	-	-	-	-	21	32	32
1995/96	-	-	-	-	-	77	97	68
1996/97	-	-	-	-	-	100	100	-

Source: Haggblade, (2007)

Chapter 2

Intergenerational Effects of Maternal Exposure to Drought in Utero: Evidence from a Retrospective Cohort Study in Malawi

2.1 Introduction

Despite decades of interventions and programmes, maternal and child undernutrition is still a global problem, almost invariably in developing countries (Martorell & Zongrone, 2012). For example, 30% of children aged 0-5 yr worldwide are stunted for their age (stunted, defined as more than two standard deviations (SD) below the median), which is a marker of chronic poor nutritional status (UNICEF, 2016). In addition, there is evidence that when stunted growth from childhood is not addressed there are spillover effects into adulthood in terms of future earnings and the ability to contribute to society (Alderman, 2012). Barker’s fetal origins of health and disease postulates that a fetal environment that promotes intrauterine growth restriction, low birthweight (LBW), and preterm birth is not conducive to good health outcomes in adulthood (Barker, 1997; Barker, 2001). Thus, if undernutrition persists during pregnancy, adverse effects can persist intergenerationally (Drake & Liu, 2010). In Guatemala, Ramakrishnan and colleagues reported that variations in offspring’s birth size were linked to intergenerational effects of maternal birth size, after controlling for maternal height and pre-pregnant weight (Ramakrishnan et al., 2012).

2.1.1 Review of the Literature

Although many studies on maternal intrauterine exposure to drought (or some other stressor) exist, none have included a prenatal supplementation component as a possible means of offsetting intergenerational (maternal) effects on birth size. Conversely, studies may have included prenatal supplements but not controlled for maternal intrauterine exposure to drought. For example, in a randomized-controlled trial (RCT) in Burkina Faso, a study compared birth outcomes for women supplemented during pregnancy with a multiple micronutrients (MMN) pill, or fortified food supplements (FFS), which contained MMN, energy, and protein components (Huybregts et al., 2012). The authors found higher birth length among the newborns of mothers in the FFS group after adjusting for gestational age (+4.6 mm; $p = 0.00$) for 87% of

1175 live births (Huybregts et al., 2012). In their subgroup analyses for underweight mothers [body mass index (BMI) in kg/m^2 < 18.5], Huybregts and colleagues observed clinically important treatment effects on birth length (+12.0 mm; p = 0.01) and on birthweight (+111 g; p = 0.13) for women who received FFS, an important finding in a country with a LBW rate of 16 percent (*ibid*). In an RCT in Ghana, Adu-Afarwuah and colleagues reported better birth outcomes for newborns of 1057 mothers supplemented with SQ-LNS vs. IFA, or MMN [mean birthweight (p = 0.04); weight-for-age Z score (WAZ; p = 0.05); and BMI-for-age z score (BMIZ; p = 0.04)], notably, in a country where 11% of all infants have LBW (Adu-Afarwuah et al., 2015). A greater effect was observed among primiparous women [mean birthweight (+85 g; p = 0.04), WAZ (+0.19; p = 0.05), and BMIZ (+0.21; p = 0.04)] (*ibid*). Almost concurrently, a similar RCT to the Ghana study was conducted in Malawi but the investigators did not find group differences for birth outcomes of newborns of mothers supplemented with IFA, MMN, or SQ-LNS, in either the main group or sub-groups similar to the Ghana study (Ashorn et al., 2015a).

The objectives of the present study were to examine:

(1) Associations between maternal exposure to drought *in utero* - an environmental exposure – and offspring's nutritional status namely LAZ, WAZ and imputed birthweight all used in a previous RCT. Imputed birthweight was used because some of the children in the sample did not have a birthweight record measured within 72 hours of birth.

(2) Associations between maternal exposure to drought *in utero* and infant LAZ, infant WAZ, and imputed birthweight after prenatal supplementation with SQ-LNS vs. IFA or MMN vs. IFA.

The present study drew from the iLiNS-DYAD-M trial by Ashorn and colleagues for the outcomes and covariates data (*ibid*). The study assessed the efficacy of prenatal supplements and their impact on adverse pregnancy outcomes (Ashorn et al., 2015a). In the present study, we would expect covariates such as increased maternal height to be linked to higher infant LAZ and vice versa (Fung & Ha, 2010; Kramer, 1987), and for higher maternal BMI to be linked to increased birthweight and increased infant WAZ (Bhargava, 2006). We would expect socioeconomic (SES) variables [a higher household asset index Z score (HAIZS)] (Reed et al.,

1996) and higher maternal education (Dreyfuss et al., 2001; Reed et al., 1996) – a proxy for maternal literacy – to be positively associated with the birth outcomes. We would expect food insecure households [measured by household food insecurity access scale (HFIAS)] (Saha et al., 2009) to have a higher incidence of infant stunting, infant underweight, and LBW. We would expect low SES maternal-headed households to be more likely have newborns with poorer birth outcomes, although in the literature female-headed households had decreased odds of pre-term births in the United States of America [USA] (Kaufman et al., 2003), but that may have been because of comparatively higher SES. We would expect marital status (married) to be positively associated with birth outcomes (Dreyfuss et al., 2001). We would expect primiparity to be negatively associated with all the birth outcomes (Dreyfuss et al., 2001), while a low-risk pregnancy by age (normal vs. "at risk": "at risk" defined as pregnant woman aged less than 18 yr or 35 yr and over) to positively influence birth outcomes.

The peri-urban/ rural factor is a proxy for socioeconomic status (SES) (Adell, 1999). In the African context, this peri-urban-rural divide stems from peri-urban theories, in which residents are a hybrid of rural existence and on the fringe of urbanity; in which residents may possess food transported from their home village, may remit cash income to their home villages, and have a greater access to consumer goods (and services), and information (*ibid*). Therefore, we would also expect maternal residence in rural areas during their pregnancies to have a larger and more negative effect on birth outcomes compared to maternal residence in peri-urban areas. Finally, we would expect the sex of the child (female vs. male) to be negatively associated with birthweight (Dreyfuss et al., 2001).

In this study, the term maternal exposure to drought *in utero* will be used interchangeably with *exposure to drought*, exposure *variable*, and *drought variable*.

2.2 Biological Mechanisms

The fetal origins of health and disease theory postulates that a fetal environment that promotes intrauterine growth restriction, LBW, and preterm birth is not conducive to good health outcomes in adulthood (Barker, 1997; Barker, 2001). The process by which fetal development is adapted to its environment to the detriment of future post-natal environments is called predictive adaptive response [PAR] (Barker, 1997). When a nutritionally restricted fetal environment (e.g., due to environmental exposure to drought *in utero*) and its subsequent effects on a baby girl who later becomes a mother herself are combined, the outcome is hypothesized to become embedded through changes at the epigenetic level[1] (Martorell & Zongrone, 2012). In human studies based on the natural experiments of the Dutch Hunger Winter or Dutch Famine[2], maternal exposure to the Dutch Famine for up to six months during pregnancy resulted in a higher incidence of LBW babies, although birthweight was not a key factor in determining poor adult health (Lumey et al., 2011; Wright & Saul, 2013). Notably, women that were exposed to famine in the second or third trimesters of pregnancy were more likely to have glucose intolerance while exposure during the first trimester was associated with a more atherogenic lipid profile - which is associated with low bone mineral density and rheumatoid arthritis, and coronary heart disease in adulthood (Roseboom et al., 2001). In another cohort study but from the Great Chinese Famine, Huang and colleagues found an unexpected result because maternal exposure from *in utero* to the first year of life was associated with increased birthweight (+ 65g), adjusted for age and cohort trends (Huang et al., 2010). In a recent study of the effects of extreme food insecurity during war intergenerational effects were observed for maternal exposure to famine from age 0-16 yr whereby survivors of the Biafran war famine were more likely to have stunted offspring especially if the exposure occurred in adolescence (Akresh et al., 2017). However, subsequent maternal exposure to the free primary education programme initiated in 1976 – six years post-war – mitigated some of the negative effects of the Biafran war famine.

2.3 Methods

2.3.1 Ethics Statement

The present study was approved by the University of Waterloo Research Ethics Committee (ORE #22443).

The data for the present study were derived from the iLiNS-DYAD-M trial which was conducted according to Good Clinical Practice guidelines (ICH-GCP) and adhered to the principles of Helsinki declaration (World Medical Association., 2001) and regulatory guidelines in Malawi. The trial protocol, registered as #NCT01239693 at clinicaltrials.gov, was approved and monitored by the University of Malawi - College of Medicine Research and Ethics Committee (COMREC), and the ethics committee of Pirkanmaa Hospital District, in Finland.

2.3.2 Study Design and Analysis

The present study reports on mothers who were enrolled in the iLiNS-DYAD-M trial from 2011-2013 but with a slightly smaller sample size (N = 1262) [see Ashorn et al. (2015a) for further details]. In the present study, only women with known DoB were assessed to ensure the derivation of maternal exposure to drought *in utero* was more accurate.

The adjusted trial groups comprised the SQ-LNS group (419 women), MMN group (421 women), and the IFA group (422 women). In the main trial, women were recruited from four health centres in four different geographical locations of Mangochi District in Malawi (namely, Lungwena: n = 508; Malindi: n = 232; Namwera: n = 210; Mangochi *Boma*: n = 312). Notably, Lungwena, Malindi, and Namwera were more rural, whereas Mangochi *Boma* was more urban.

2.3.3 Deriving Maternal Exposure to Drought in Utero

The main variable of interest in this study was maternal exposure to drought *in utero*. A drought was determined to have occurred if annual rainfall levels dropped below one SD from the mean precipitation patterns, with lower Z-scores marking increased severity (IFPRI, 2009).

The first step in determining the period of maternal exposure for the mother to drought was to identify the ages of the mothers at the time of enrollment in the main trial. The mean age was 24 yr old while the range was 14-48 years old. Data on place of birth for the mothers were not collected in the main trial, hence the primary spoken language of mothers at enrollment was used as a proxy for birthplace/ residence at the time of the drought for mothers who were exposed *in utero* (National Statistical Office, 1992). Three droughts were identified in the literature which corresponded with the range of ages of the study mothers: the 1981/82 (Babu & Chapasuka, 1997), 1987/88 (IFPRI, 2009), and 1992/93 (Babu & Chapasuka, 1997) droughts, which all began after the lean season ended with failed rains in 1981, 1987, and 1992, respectively. The software GeoCLIM was sourced online and was used to confirm the annual rainfall amount during the drought years in Mangochi District and the corresponding drought assessments (Climate Hazards Group., Internet).

The present study defined the start of the drought period as occurring from the start of the previously expected but failed harvest (from May YYYY, where YYYY refers to the relevant year), regardless of the preceding lean season (Dec XXXX – Apr YYYY, where XXXX is the preceding year), and ending just before the next harvest (May YYYY*) the following year.

(There is one rainy season in Malawi, which coincides with the lean period, followed by harvest time, which occurs once a year).

For mothers exposed to drought *in utero* and who were born in the twelve months immediately following May 1st, 1981/1987/1992, exposure was determined as follows. The duration of exposure was based on trimesters pooled from different droughts. The first trimester exposure to drought *in utero* was for mothers born from November YYYY-April YYYY* while the second-third trimester exposure to drought *in utero* was for mothers born from May YYYY-October YYYY (where YYYY denotes the drought year itself, i.e., the year of the initial failed/poor harvest and YYYY* is the year immediately following a drought).

2.4 Statistical Analyses

2.4.1 Study Variables

The study outcomes were infant LAZ, infant WAZ, and imputed birthweight. Appendix C (C1) provides details of how these measures, including the imputation of birthweight were achieved. Imputed birthweight for weight measured between 3-5 days from birth was calculated from a table in a statistical paper (Cheung, 2013). The reason birthweight was imputed was because the trial had missing data for measured birthweight, i.e., not measured within 72 hours of birth. Thereafter, infant length and weight were measured within 42 days from birth based on neonatal age using calculations for LAZ and WAZ in the WHO's 2006 child growth charts (Ashorn et al., 2015a).

Note that the reference population used by the WHO was from a combination of six population-based studies which collected anthropometric measurements between 1997 and 2003, for infants and children born in Ghana, India, Norway, Brazil, Oman, and North America (Bloem, 2007). The studies recruited 8440 infants and children who were adequately breast-fed and fed as per international nutritional standards and whose mothers were adequately nourished with no tobacco exposure (Bloem, 2007). Despite the different ethnicities, cultures and SES represented, the growth charts can be used for any population according to the WHO study group (WHO Multicentre Growth Reference Study Group., 2006).

The variables for maternal exposure to drought *in utero* comprised exposure during the first and second-third trimesters pooled from the individual droughts. The covariates [described in detail Appendix C (C2)] comprised the sex of the child, maternal education, maternal BMI, marital status, maternal height, mother as head of household (HH), household food insecurity access scale (HFIAS), household asset index Z score (HAIZ), primiparity, and normal vs. "at risk" pregnancy by age. There was also a locality dummy variable called peri-urban (vs. rural). The main clinical trial arms for mothers were the treatment groups of SQ-LNS, MMN, and the control group, IFA (the standard of care). The covariates were added to the ordinary least multiple regression models to minimize confounding.

The study incorporated interactions by multiplying the drought exposure variables with the three trial arms. A causal relationship between a study outcome (y) and an explanatory variable (x) can be strengthened or weakened by the presence of a third variable (z) [via an interactive relationship whereby variable z "moderates" or "modifies" the effect of variable x on variable y] (Murray, Internet).

The data were collected using study guides, standard operating procedures (SOPs), and study questionnaires (Appendix F).

2.4.2 Potential Bias

The drought exposure variables have not been randomized at the outset of the study given that it was a natural experiment hence the need to be aware of potential selection bias. For example, women who knew their dates of births (DoB) may have exhibited similar characteristics to each other compared to the group of women who did not know their DoB potentially leading to systematic bias.

The study may have overestimated or underestimated the effect of maternal non-exposure to drought *in utero* because this group also included mothers who were exposed to drought between ages 0-5 yr. Therefore, some sensitivity analyses were conducted to find out if the exclusion of mothers exposed after birth but prior to age five altered the results (see Appendix D: D1 & D2).

2.4.3 Models

The models for infant LAZ, infant WAZ, and imputed birthweight took the following general form below. The trial supplement IFA was dropped from the slope and intercept terms to be used as the base category (or reference case). Using the ordinary least squares (OLS) method from the statistical software Stata 14 and Stata 14.2, equations were regressed for the birth outcomes. In statistics, OLS is a method that estimates unknown parameters (betas) in a linear regression model[3]. The effect size measure for the analyses was determined based on the continuous nature of the outcomes and hence linear regressions and t-tests were conducted.

In the present study, alpha was set at 0.05, which meant that a regression coefficient with a probability of $p < 0.05$ was deemed statistically significant. With the exclusion of prenatal supplements, the general form of the restricted models was as follows:

(1)

$$Y_i = \alpha + \beta X_i + \boldsymbol{\gamma} \boldsymbol{Z}'_i + \varepsilon_i,$$

Where:

Y_i is the study outcome (LAZ, WAZ, or imputed birthweight) for the i-th subject,

α is the intercept,

β are the coefficients for the maternal exposure to drought *in utero* variables,

$\boldsymbol{\gamma}$ are the coefficients for the covariates,

X_i are the maternal exposure to drought *in utero* variables for the i-th subject,

$\boldsymbol{Z'}_i$ are the covariates for the i-th subject,

ε_i is the error term for the i-th subject.

After adding trial supplements variables interacted with drought variables, non-drought exposure variables interacted with the IFA the base category, the general form of the expanded models was as follows:

(2)

$$Y_i = \alpha + \beta(X_i * W_i) + \boldsymbol{\gamma} \boldsymbol{Z}'_i + \varepsilon_i,$$

Where:

Y_i is the study outcome (LAZ, WAZ, or imputed birthweight) for the i-th subject,

α is the intercept,

β are the coefficients for the interactions of maternal exposure to drought *in utero* and trial supplements variables,

$\boldsymbol{\gamma}$ are the coefficients for the covariates,

X_i are the maternal exposure to drought *in utero* variables for the i-th subject,

W_i are the trial supplements variables for the i-th subject,

$\boldsymbol{Z'}_i$ are the covariates for the i-th subject,

ε_i is the error term for the i-th subject.

2.4.4 Joint-Significance Tests

The drought exposure variables are inherently time-dependent and, as such, are at risk of being correlated (through overlaps in time periods that are not immediately apparent) possibly causing OLS models to produce statistically non-significant results (Esarey & Sumner, 2016). In (student's) t-tests, correlated predictor variables might yield statistically non-significant results because their standard errors magnify each other's size. Whereas in F-tests, the joint-significance tests of the parameters could show statistically significant results for correlated predictor variables because the standard errors are more robust.

Joint-significance tests were conducted in the present study, post-regression, for all the models using Stata 14 and Stata 14.2. Specifically, F-tests were used to jointly-test the regression coefficients for maternal drought exposure variables and their interactions with the trial supplements variables. The F-test followed the F_o ~ distribution of $F_{(k,\ n\text{-}l\text{-}k)}$ (where k = number of independent variables in the regression model and n = total number of observations). Alpha (α) was set at 0.05 with any p-value < 0.05 deemed statistically significant and p < 0.01 more rigorous and reliable.

The joint-significance testing took the following form by assuming that (1) the intercepts for the first and second-third trimester exposure to drought variables in the restricted model and (2) the interactions of first and second-third trimester exposure to drought variables with the trial supplements in the expanded model were all equal to zero. The variable IFA was used as the base category for all the modelling.

Drought Exposure in Utero (Restricted Models)

(1) H_o: $\beta_{first\_trimester} = \beta_{second\text{-}third\_trimester} = 0$

(2) Ha: At least one of the intercepts was non-zero

Drought Exposure in Utero (Expanded Models)

(1) H_o: $\beta_{first\_trimesterLNS} = \beta_{first\_trimesterMMN} = \beta_{first\_trimesterIFA} = \beta_{second\text{-}third\_trimesterLNS} = \beta_{second\text{-}third\_trimesterMMN} = \beta_{second\text{-}third\_trimesterIFA} = \beta_{no\_droughtLNS} = \beta_{no\_droughtMMN} = \beta_{no\_droughtIFA} = 0$

(2) Ha: At least one of the intercepts was non-zero

The null hypotheses (H_o) were that (1) the regression coefficients for the maternal exposure drought *in utero* variables in the restricted models and (2) the regression coefficients for the interaction terms were equal to zero and did not provide different effect sizes on the study outcomes in the expanded models. The alternative hypothesis (Ha) stated that at least one of the regression coefficients was different from zero and exerted an effect on the corresponding study outcome.

2.5 Results

2.5.1 Summary Statistics

Table 2.1 summarises the descriptive statistics of the data among the three trial groups (SQ-LNS: n = 419; MMN: n = 421; IFA: n = 422), restricted to those mothers with known DoB. Using moderate to severe stunting and underweight as reference points (moderate $\leq$ -2SD; severe $\leq$ -3SD), all the groups appeared to have babies who, on average were slightly short, but not moderately stunted (-2 $\leq$ mean LAZ < 0), and who were moderately underweight (-2 $\leq$ mean WAZ < 0). On average, the newborns were above the LBW threshold ($\geq$ 2500 g) but below the 2006 World Health Organization (WHO) growth charts average birthweight [~ 3200g] (WHO Multicentre Growth Reference Study Group., 2006).

Of the 1262 out of the 1391 women from the main trial with known DoB, 195 women were exposed to drought *in utero*. In terms of maternal exposure to the pooled droughts during the first trimester, 18 women received SQ-LNS; 21 women received MMN; and, 20 women received IFA. In terms of maternal exposure to the pooled droughts during the second and third trimesters of pregnancy, 46 women received SQ-LNS; 41 women received MMN; and 49 women received IFA.

Mothers, on average, had about 4 years of primary school education, had a BMI of 22, and were about 156 cm tall across the three trial arms, which was just 1 cm above the low stature threshold. Between 87-89% of the mothers were married while 6-8% were household heads. On average, households had close to a zero-household asset index score, while primary caregivers' self-reported food insecurity in the past 4 weeks scored between 4 and 5 out of a possible score of 27, with a higher score indicating increasing perceived food insecurity. In terms of gender distribution, 46-50% of the mothers had male babies, with the IFA group's male to female baby ratio exceeding 50%. Among eligible mothers, 19-22% had their first child during the trial, while at enrollment, 16-20% of the pregnancies could have been considered high risk due to the mother's age bracket (< 18 yr or > 35 yr). Finally, approximately 24-25% of the mothers lived in the peri-urban area of Mangochi District (Mangochi *Boma*). For statistics on means and SDs of the birth outcomes by maternal drought exposure *in utero*, please see Table 2.2.

2.5.2 Regression Results

The results in Tables 2.3 and 2.4 show a list of the variables, the predictor coefficients with the confidence intervals (CIs) in parentheses set at the 95% level of confidence for the three outcomes (LAZ, WAZ, and imputed birthweight). The strength of the associations between predictors and study outcomes were represented by asterisks ("*") with "**" representing $p < 0.05$, and "***" representing $p < 0.01$. Results with a single reported "*" represented $p < 0.10$ but were not reported or discussed in this study. Robust standard errors were used for all the regressions.

There were no statistically significant first trimester effects on birth outcomes from maternal exposure to drought *in utero*, controlling for maternal effects variables and socioeconomic variables (see restricted models, Table 2.3). Maternal second-third trimester exposure *in utero* was associated with a fairly larger birthweight than non-drought exposure *in utero*. All the associations between the maternal exposure to drought *in utero* variables and the birth outcomes variables were positive although all were statistically insignificant except for one result in the imputed birthweight model.

In terms of statistical significance, the results changed somewhat when the models were additionally controlled for trial supplements (expanded model, Table 2.4). Among infants of mothers who received IFA, there was a larger effect on LAZ [+0.540 SD, 95% (CI (0.136:

0.943), n = 980] if mothers were exposed to drought during the first trimester compared to mothers not exposed to drought *in utero*. Among infants of mothers not exposed to drought *in utero,* there was a slight improvement in infant LAZ [+0.198 SD, 95% CI (0.014: 0.383), n = 980], if their mothers received MMN (compared to IFA). Finally, among infants of mothers exposed to drought in the first trimester *in utero,* there was a larger but negative effect of maternal prenatal supplementation with MMN on infant LAZ, [-0.853 SD, 95% CI (-1.446: -0.259), n = 980] compared to prenatal supplementation with IFA. The study's sensitivity analyses (see Appendix D: D1 & D2), which removed the effect of maternal exposure to drought at age 0-5 yr in the models generally did not alter the results of the restricted models and the expanded models. However, the interaction between maternal non-drought exposure *in utero* was no longer statistically significant.

Among the results for the covariates, maternal height had a positive effect on infant LAZ, infant WAZ, and imputed birthweight. (Table 2.4). The position of mother as household head was negatively associated with infant WAZ, being in a peri-urban household was negatively associated with infant LAZ and imputed birthweight, while primiparity negatively affected all the birth outcomes. Primiparity had the largest effect size (negative) on the birth outcomes [Mean LAZ: -0.315 SD, 95% CI (-0.491: -0.139) , n = 980; mean WAZ, -0.376 SD, 95%, CI (-0.543: -0.209), n = 991; and mean imputed birthweight, -122.488 g, 95% CI (-192.859: -52.117), n = 1074] (Table 2.3), followed by peri-urban (vs. rural) [Mean LAZ: -0.287 SD, 95% CI (-0.484: -0.091), n = 980; and mean imputed birthweight, 93.357 g, 95% CI (-165.202: -21.512) , n = 1074] (Table 2.4).

2.5.3 Other Results

Next, when joint-significance tests were conducted for the maternal *in utero* exposure to drought variables, and the interactions between maternal *in utero* exposure to drought variables and trial supplements variables, the drought variables as a group were statistically significant in the restricted model of infant LAZ: $F_{(2, 960)}$, p = 0.016 but not statistically significant for WAZ: $F_{(2, 971)}$, p = 0.588; imputed birthweight: $F_{(2, 1054)}$, p = 0.282. The maternal *in utero* drought exposure and trial supplements interactions were statistically significant in the expanded models for LAZ: $F_{(4, 960)}$, p = 0.018, however they were statistically insignificant in the expanded models for WAZ: $F_{(4, 971)}$, p = 0.367 and imputed birthweight: $F_{(4, 1054)}$, p = 0.206.

The regression coefficients for maternal *in utero* exposure to drought alone and the interactions between maternal exposure to drought *in utero* variables and the trial supplements variables were not statistically significant for all the birth outcomes models with one exception. Therefore, we do not reject the null hypothesis that the regression coefficients for (1) the maternal *in utero* exposure to drought variables and (2) for the interactions between maternal *in utero* exposure to drought variables and the trial supplements were equal to zero with one exception. This means that neither the maternal *in utero* exposure to drought variables nor the interactions between maternal *in utero* exposure to drought variables and the trial supplements variables appeared to have an important effect on birth outcomes with one exception.

The exception was that the regression coefficients for the interactions between maternal *in utero* exposure to drought and the trial supplements were statistically significant for the infant LAZ model. Therefore, in the imputed birthweight expanded model we rejected the null hypothesis that the regression coefficients for the interactions between maternal *in utero* exposure to drought variables and the trial supplements were equal to zero. This means that the interactions between maternal *in utero* exposure to drought variables and the trial supplements variables may have had an important effect on infant LAZ.

2.6 Discussion

First, the study investigated the effects of maternal exposure to drought on offspring's birth outcomes. Second, the study investigated whether prenatal supplementation could offset any intergenerational effects of maternal exposure to drought *in utero*. Overall, any intergenerational effects and prenatal supplementations effects in the present study centred on infant LAZ and not the other birth outcomes.

Surprisingly there was a positive association observed between maternal exposure to drought during the second-third trimester *in utero* and infant LAZ, controlled for covariates. The sensitivity analyses, which removed the effect of maternal exposure to drought at age 0-5 yr in the control group, did not significantly alter the results. The little evidence there is in the literature has shown, for example, that in a study on neonatal adiposity and later adult health, mothers with gestational exposure to the Dutch Famine were more likely to report that their offspring had decreased birth length but not decreased birthweight compared to unexposed controls (Painter et al., 2008). In terms of the Great Chinese Famine, Fung and Ha reported more theoretically-aligned results for the Great Chinese Famine (Fung & Ha, 2010). For example, maternal exposure to famine *in utero* was negatively and significantly associated with infant LAZ and infant WAZ (Fung & Ha, 2010). However, the anthropometry measurements were taken between age 0-18 yr, a range that extends beyond the scope of the present study and Fung & Ha did not have data on birthweight (Fung & Ha, 2010). In comparison, the present study's *in utero* effects results, specifically for maternal second-third trimester exposure, produced a larger positive effect size on birthweight than reported in a Dutch cohort study [which controlled for maternal birthweight but not maternal adult height] (Lumey et al., 2011). Therefore, there is a marked difference in the direction of the intergenerational effects of maternal exposure to drought *in utero* on infant birth length in the present study akin to the unexpected result reported in Huang et al. (2010), whereby intergenerational associations, surprisingly, increased offspring birthweight (+72g) and, less remarkably, birth length (+0.3cm), even after controlling for maternal height, maternal education, and maternal age at delivery, in a Great Chinese Famine cohort.

Of course, the famines and droughts varied in scope, timing, duration, and recurrence. Maternal exposure to the Dutch Famine was the shortest (22 months) and occurred in a predominantly white European, urban population during a German military food embargo of the 1940s in the Netherlands. The Dutch Famine occurred a decade before the Great Chinese Famine emerged within a mix of urban and rural populations and at least four decades before the droughts occurred in rural and peri-urban Malawi. Malawi had three different droughts occur within a decade compared to the two distinct famines in China and the Netherlands. Further, the highlighted famines were man-made whereas the Malawi droughts were meteorological phenomena. Further still, there was a clear rural-urban divide in impact whereas the lines were blurred for the Malawi droughts since most of the sample population lived in rural areas. Finally, the biggest difference was that some of the drought-exposed Malawi cohort was prenatally supplemented with SQ-LNS which was compared to IFA as a control supplement.

Subsequently, the present study showed some notable prenatal supplementation effects on maternal first trimester exposure *in utero* on infant LAZ. For example, among mothers who received IFA, there was an increased likelihood of improved infant LAZ if mothers experienced first-trimester exposure *in utero* compared to non-drought exposure *in utero*, controlling for covariates. Conversely, among mothers exposed to drought during the first trimester *in utero*, a large but negative effect of prenatal supplementation with MMN was observed on infant LAZ compared to prenatal supplementation with IFA. Finally, among mothers not exposed to drought i*n utero,* there was an increased likelihood of improved infant LAZ if mothers where supplemented with MMN compared to mothers supplemented with IFA. Post-sensitivity analyses, which removed the effect of maternal exposure to drought at age 0-5 yr in the control group, the expanded models remained largely unchanged expect for the interaction between maternal non-exposure to drought and MMN, which was no longer statistically significant. The joint-tests for the sensitivity analyses were all statistically significant which confirms that the apparent intergenerational effects of maternal exposure to drought *in utero* effects and the subsequent modifying effects of prenatal supplementation with MMN (compared to IFA) on infant LAZ were important.

It is noteworthy that there were problems with the statistical integrity and validity of the present study. For example, the estimation of maternal *in utero* drought exposure and subsequent analyses were limited by the lack of data on the residence of the women in early life, by some of the women in the main trial being unaware of their DoB, and by a dependence on self-reported DoB without supporting documents. Although the initial RCT was appropriately powered to detect effects of supplements in the main study, this study was underpowered to detect effects within different drought exposure sub-groups in this study because their numbers were very small (notably, $n < 18$ for SQ-LNS and IFA among women exposed to drought during the first trimester, $n < 46$ for SQ-LNS and IFA among women exposed to drought during the second-third trimester. It is also possible that the effect of the droughts in Malawi was not as strong as those of the Great Chinese Famine and the Dutch Famine, hence the lack of significant effects.

2.7 Conclusion

To summarise, the present study assessed the impact of maternal exposure to drought *in utero* on three birth outcomes: infant LAZ, infant WAZ, and imputed birthweight. Deficits of growth *in utero* have been linked to poor birth outcomes and chronic adult diseases via the fetal origins of health and disease (Barker, 1997; Barker, 2001). There is a growing body of evidence that these negative effects observed over the life course can be passed to offspring through environmental mediations (Drake & Liu, 2010). Prenatal supplementation with SQ-LNS, MMN, or IFA may alleviate the impact of nutritional deficiencies that affect nutrition pathways through maternally-derived intergenerational effects. The present study aimed to test the following hypotheses:

- We expected to find shorter children for age, LBW children, and underweight children for age to be born to mothers who were exposed to drought *in utero* vs. mothers who were not exposed to drought *in utero* while holding other variables constant.
- We expected to find comparatively taller children for age and heavier children to be born to mothers who were prenatally supplemented while holding other variables constant.
- We expected to find the effect of mothers' exposure to drought *in utero* vs. non-drought exposure *in utero* to be moderated by prenatal supplementation while holding other variables constant.

Overall, in the restricted models, maternal *in utero* exposure to drought did not yield any important effect sizes on birth outcomes, controlling for covariates, although there was a positive and significant effect of maternal second-third trimester exposure to drought *in utero* on imputed birthweight compared to maternal non-drought exposure *in utero*. When the trial supplements variables were added to the expanded models which retained the previous covariates, the interactions yielded some notable results. Notably, among mothers exposed to drought, prenatal supplementation with IFA was more likely to increase infant LAZ than prenatal supplementation with MMN while among mothers not exposed to drought *in utero*, prenatal supplementation with MMN was more likely to increase infant LAZ than prenatal supplementation with IFA.

In conclusion, this study found that there was a seemingly intergenerational effect of maternal exposure to drought during the second-third trimester *in utero* on birth outcomes. Prenatal supplementation with MMN significantly showed no beneficial effects from compared to the standard ante-natal care (IFA) on infant LAZ, controlling for covariates, among mothers exposed to drought during the first trimester *in utero*. Overall, similar but not significant effects on infant LAZ were observed for prenatal supplementation with SQ-LNS compared to the standard ante-natal care (IFA) on infant LAZ, controlling for covariates

[1] Epigenetics is the suppression of, or switching on, of gene expression which leaves the DNA base structure intact while changing the pattern of gene expression (Holliday, 1994; Holliday, 2006). This epigenetic activity implies that the body's response to external stressors changes the emphasis of the expression of genes and will either encourage resilience or lack of resilience to future stress (Cutfield et al., 2007; Hivert et al., 2013; Jang & Serra, 2014).

[2] The Dutch Famine occurred towards the end of WWII during which food rations were imposed due to a food embargo.

[3] OLS is a method that estimates unknown parameters in a linear regression model, which minimizes the sum of squares of the differences between the measured observations for "Y" and the estimates from "a set of predictor variables "X" (Benoit, 2010).

Table 2.1: Summary Statistics of Outcome and Independent Variables of the Cohort Study

Variables	LNS Mean (SD, range, n) %, n	MMN Mean (SD, range, n) %, n	IFA Mean (SD, range, n) %, n	Total n n/N
Mean Length-for-Age [a] Z Score (SD)	-0.97 (1.08, -4.64 : 2.13, 331)	-0.98 (1.10, -6.52 : 1.92, 352)	-1.09 (1.19, -5.32 : 1.52, 328)	1011
Mean Weight-for-Age[b] Z Score (SD)	-0.54 (1.08, -4.02 : 2.42, 338)	-0.57 (1.04, -6.00 : 1.97, 354)	-0.64 (1.05, -451 : 1.95, 330)	1022
Mean Imputed Birthweight (g)	2970.66 (468.64, 1308.08 : 4315, 372)	2964.32 (464.12, 1100 : 4260, 368)	2937.09 (446.38, 1212.12 : 4300, 372)	1112
First Trimester Effects	4.30%, 18	4.99%, 21	4.74%, 20	59/1262
Second-Third Trimester Effects	10.98%, 46	9.74%, 41	11.61%, 49	136/1262
Child Sex (Male)	49.8%, 404	46.8%, 406	50.3%, 404	1214
Maternal Education (yr)	4.0 (3.6, 1 - 12, 413)	4.0 (3.43, 1 - 12, 413)	3.9 (3.3, 1 - 12, 417)	1243
Maternal BMI (kg^2/cm)	22.2 (22.20, 16.26 : 36.85, 418)	22.1 (22.09, 16.63 : 37.81, 417)	22.0 (22.08, 16.10 : 34.49, 419)	1254
Marital Status	88.78%	87.41%	88.86%	1262

Notes:

[a] Length-for-age was calculated using the WHO 2006 growth standards (WHO Multicentre Growth Reference Study Group., 2006)

[b] Weight-for-age was calculated using the WHO 2006 growth standards (*ibid*).

	(419)	(421)	(422)	
Maternal Height (cm)	156.2 (156.21, 132.8 : 172.6, 419)	156.0 (156.00, 140.9 : 175.7, 418)	156.1 (156.20, 139.1 : 171.8, 421)	1258
Mother Household Head	5.97%, 25	7.60%, 32	6.40%, 27	84/1262
Food Insecurity Access Scale	4.5 (4.1, 0 : 23, 412)	5.3 (4.7, 0 : 24, 410)	5.0 (4.5, 0 : 27, 415)	1237
Household Asset index Z Score	0.02 (0.99, -0.73 : 3.29, 412)	-0.08 (0.99, -0.73 : 3.29, 412)	-0.06 (0.96, 0.73 : 3.29, 415)	1240
Primiparous	22.20%, 93	21.67%, 91	19.48%, 82	266/1262
Normal (vs. “At Risk”) Pregnancy by Age	20.05%, 84	16.39%, 69	18.48%, 78	231/1262
Peri-urban (vs. Rural)	24.11%, 101	25.18%, 106	24.88%, 105	312/1262

Notes:

LNS (n = 419); MMN (n = 421); IFA (n = 422): N = 1262

Table 2.2: Birth Outcomes by Maternal Exposure to Drought in Utero

Outcomes	Non-exposure	First trimester exposure	Second trimester exposure	Total (n)
Infant LAZ[a] Mean SD (n)	-1.04 1.139 (904)	-0.865 1.024 (51)	- 0.810 1.027 (105)	1060
Infant WAZ[b] Mean SD (n)	-0.598 1.077 (915)	-0.434 1.000 (51)	-0.552 0.934 (105)	1071
Mean Imputed BWT Mean SD (n)	2943.98 465.897 (994)	3009.519 412.63 (54)	3043.934 387.594 (115)	1163

Notes:

[a] Length-for-age was calculated using the WHO 2006 growth standards (WHO Multicentre Growth Reference Study Group., 2006)

[b] Weight-for-age was calculated using the WHO 2006 growth standards (*ibid*).

Table 2.3: Regressions of Infant LAZ, Infant WAZ, BWT on Maternal Exposure to Drought In Utero (Restricted)

Variables	 **Restricted Model: LAZ**	**(2)** **Restricted Model: WAZ**	**(3)** **Restricted Model: Imputed BWT**
First trimester	0.032	0.039	15.138
	(-0.257 , 0.321)	(-0.246 , 0.323)	(-102.126 , 132.403)
Second-third trimester	0.150	0.004	88.497**
	(-0.064 , 0.365)	(-0.190 , 0.197)	(11.572 , 165.422)
Child sex (girl)	0.109	0.035	-85.784***
	(-0.026 , 0.244)	(-0.094 , 0.164)	(-138.988 , -32.580)
Maternal education	0.008	0.010	-1.103
	(-0.016 , 0.032)	(-0.012 , 0.032)	(-10.195 , 7.990)
Maternal BMI	0.022	0.030**	15.070***
	(-0.006 , 0.050)	(0.004 , 0.057)	(4.373 , 25.766)
Marital status (married)	-0.097	0.032	-28.681
	(-0.337 , 0.143)	(-0.191 , 0.256)	(-112.587 , 55.226)
Maternal height	0.052***	0.042***	18.415***
	(0.039 , 0.066)	(0.030 , 0.055)	(13.534 , 23.297)
Head of household (mother)	-0.314	-0.433**	-107.974
	(-0.691 , 0.064)	(-0.778 , -0.088)	(-245.038 , 29.090)
HH food insecurity access scale	0.007	0.013*	4.219
	(-0.009 , 0.024)	(-0.002 , 0.028)	(-1.936 , 10.374)
HH asset index Z score	0.073	0.067	26.544
	(-0.022 , 0.167)	(-0.023 , 0.157)	(-10.849 , 63.937)
Primiparous	-0.329***	-0.384***	-121.193***
	(-0.506 , -0.152)	(-0.551 , -0.217)	(-191.620 , -50.766)
Normal (vs. “at risk”) pregnancy by age	0.207**	0.083	53.175
	(0.021 , 0.393)	(-0.091 , 0.257)	(-18.495 , 124.846)
Periurban (vs. rural)	-0.304***	-0.093	-98.788***
	(-0.497 , -0.110)	(-0.272 , 0.086)	(-170.267 , -27.308)

Constant	-9.884***	-8.018***	-114.263
	(-12.144 , -7.625)	(-10.069 , -5.966)	(-894.377 , 665.851)
N	980	991	1,074
R-squared	0.118	0.102	0.100
F	9.950	8.517	10.54
Adjusted R-squared	0.106	0.0899	0.0893

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT – birthweight

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Table 2.4: Regressions of Infant LAZ, Infant WAZ, BWT on Maternal Exposure to Drought in Utero (Expanded)

Variables	(1) Expanded Model: LAZ	(2) Expanded Model: WAZ	(3) Expanded Model: Imputed BWT
First trimester # IFA	0.540***	0.234	24.605
	(0.136 , 0.943)	(-0.220 , 0.688)	(-143.246 , 192.456)
Second-third trimester #IFA	0.297	-0.025	110.030
	(-0.102 , 0.697)	(-0.420 , 0.371)	(-25.770 , 245.829)
Non exposure # MMN[a]	0.198**	0.097	55.322
	(0.014 , 0.383)	(-0.073 , 0.267)	(-15.964 , 126.608)
Non exposure # LNS[b]	0.127	0.082	25.426
	(-0.054 , 0.308)	(-0.092 , 0.256)	(-46.539 , 97.391)
First trimester # MMN	-0.853***	-0.436	-117.519
	(-1.446 , -0.259)	(-1.053 , 0.181)	(-382.257 , 147.218)
First trimester # LNS	-0.662*	-0.107	115.521
	(-1.385 , 0.060)	(-0.855,0.642)	(-163.765 , 394.806)
Second-third trimester # MMN	-0.460*	-0.122	-129.559
	(-0.975 , 0.055)	(-0.636 , 0.392)	(-314.264 , 55.146)
Second-third trimester # LNS	0.002	0.195	47.540
	(-0.524 , 0.529)	(-0.269 , 0.660)	(-135.650 , 230.730)
Child sex (girl)	0.108	0.036	-84.443***
	(-0.028 , 0.243)	(-0.093 , 0.165)	(-137.691 , -31.196)
Maternal education	0.008	0.011	-0.932
	(-0.016 , 0.032)	(-0.011 , 0.033)	(-10.025 , 8.162)
Maternal BMI	0.021	0.030**	14.883***
	(-0.006 , 0.049)	(0.004 , 0.057)	(4.248 , 25.518)
Marital status (married)	-0.081	0.047	-21.808

Notes:

[a,b] The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

	(-0.319 , 0.157)	(-0.176 , 0.269)	(-106.184 , 62.568)
Maternal height	0.053***	0.043***	18.636***
	(0.040 , 0.066)	(0.030 , 0.055)	(13.768 , 23.505)
Head of household (mother)	-0.319*	-0.446**	-112.054
	(-0.695 , 0.056)	(-0.792 , -0.099)	(-249.209 , 25.101)
HH food insecurity access scale	0.007	0.013*	4.006
	(-0.009 , 0.024)	(-0.002 , 0.029)	(-2.186 , 10.197)
HH asset index Z score	0.071	0.064	24.454
	(-0.023 , 0.165)	(-0.026 , 0.154)	(-12.709 , 61.618)
Primiparous	-0.315***	-0.376***	-122.488***
	(-0.491 , -0.139)	(-0.543 , -0.209)	(-192.859 , -52.117)
Normal (vs. “at risk”) pregnancy by age	0.204**	0.080	49.629
	(0.020 , 0.388)	(-0.094 , 0.253)	(-21.930 , 121.187)
Periurban (vs. rural)	-0.287***	-0.079	-93.357**
	(-0.484 , -0.091)	(-0.260 , 0.102)	(-165.202 , -21.512)
Constant	-10.073***	-8.150***	-177.658
	(-12.310 , -7.836)	(-10.192 , -6.107)	(-951.830 , 596.515)
N	980	991	1,074
R-squared	0.128	0.106	0.105
F	7.957	6.344	7.991
Adjusted R-squared	0.111	0.0884	0.0893

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

Trial supplements: LNS - lipid-based nutrient supplement, MMN - multiple micronutrient supplement, IFA - iron-folic acid

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Chapter 3

A Retrospective Cohort Study of the Intergenerational Effects of Maternal Exposure to Drought in Childhood on Birth Outcomes

3.1 Introduction

The long-term effects of adversity experienced during early life (or early childhood) continue to be topical. In the short-term, exposure to nutritional deprivation in early life leads to negative outcomes in child nutritional status. A study which used data from the District Level Household Survey (DLHS-2) wave 2 in India – where 46% of 0-5 yr old children have a WAZ < –2 SD (moderately underweight) and 22% percent of the same age group have a WAZ < –3 SD (severely underweight) – found that exposure to drought in the year of birth significantly reduced child WAZ (Kumar et al., 2016). A study which focused on drought exposure at age 12-24 months old (1-2 yr old) found that a Zimbabwean cohort of children exposed to drought was shorter on average compared to their non-exposed siblings and children of the same age in developed countries (Hoddinott, 2006). One study found that rural Chinese mothers who were exposed to drought in early life were more likely as adults to have a height deficit of -2.89 cm (Gørgens et al., 2012)

Despite maternal recovery from early life undernutrition, the negative childhood experience can spill over and be phenotypically expressed in the next generation via the mother and child dyad (Martorell & Zongrone, 2012). For example, in The Gambia, Rickard and colleagues found that even brief exposure to early environmental deprivation by mothers when they were children, had a negative impact on their offspring's *in utero* growth, even in rural populations that were not necessarily very food insecure (Rickard et al. 2012). Using data from the China Health and Nutrition Survey, a study on the Great Chinese Famine did not find an important effect from maternal exposure to the famine during the first or second year of life on HAZ and WAZ in children aged 0-18 yr (Fung & Ha, 2010). The lack of statistically significant, clinical impacts in the Fung and Ha study on early childhood maternal exposure to the Great Chinese Famine contrast with their significant results on *in utero* maternal exposure to the Great Chinese Famine with respect to birth length (Fung & Ha, 2010).

3.1.1 Review of the Literature

The present study aimed to examine the effects of maternal drought-exposure during the mother's preschool years, and particularly, at age 0-60 months (0-5 yr), age 0-24 months (0-2 yr), and at age 25-60 months (3-5 yr) by taking advantage of a natural experiment in Southern Malawi. The study separated these two age groups since Martorell reported that the first two to three years of life are very critical for growth because its velocity is at its greatest during these years (Martorell, 1999). Therefore, nutritional requirements are also markedly larger to support this growth spurt and, as such, any persistent nutritional deficits could lead to irreversible effects such as stunted stature (Martorell, 1999). There is, however, an opportunity for catch-up growth to occur after age three years as nutritional needs begin to taper out (Martorell, 1999). Therefore, the present study is justified to study the critical window of growth and development during the first two years of life in which chronic malnutrition is linked to irreversible, impaired cognitive development which is mediated partly by stunted growth (Alderman et al, 2006; WHO, 2013).

Therefore, the present study assessed whether a similar impact could be observed when maternal exposure to drought occurred at age 0-2 yr relative to maternal exposure to drought at age 3-5 yr. However, the study will replace human capital as the outcome with birth size to investigate patterns of associations between maternal undernutrition and offspring birth size. [It is noteworthy that the present study does report on and control for maternal human capital via a proxy of maternal education and household assets (wealth)]. The present study provides an opportunity to study the critical window of growth and development (during first two years of life) in which concurrent undernutrition can cause irreversible impairment of cognitive development. We assume that impairment of cognitive development is associated with stunted linear growth via maternal exposure to drought are age 0-2 yr but, also compare outcomes at age 3-5 yr, and, overall, at age 0-5 yr. We would expect *in utero* effects reported in Chapter 2 to be stronger for imputed birthweight than the maternal effects from drought exposure at age 0-2 yr studied in this chapter based on the DOHaD theory, but not for birth length (Uauy et al., 2011).

We predict that early life maternal exposure to drought will be similar to the findings of the Fung and Ha's study on maternal drought exposure to drought during early childhood (different to the *in utero* exposure assessed by the same authors reported in Chapter 2, section 2.1.1, on page 21). That is, low infant LAZ will be positively associated with early life maternal drought exposure just as in Fung & Ha, 2010). Finally, since the Malawi cohort received a new prenatal supplement called SQ-LNS, which was tested against one control group, IFA (Ashorn et al., 2015a), the study will examine whether any early life effect of maternal drought exposure can be moderated by SQ-LNS vs. IFA. The study proposes that SQ-LNS will produce a larger and positive effect compared to IFA when it interacts with the early life maternal exposure to drought variables.

The present study differs from other studies on the Great Chinese Famine cohort in that the present study introduced more than one drought into the models, whereas the other studies only considered one famine (The Great Chinese Famine 1959-1961). In the present study, early life maternal exposure to drought will be used interchangeably with exposure to drought, or drought exposure variable. Newborns in the study will also be referred to as babies or infants, and the study outcomes may be referred to as birth outcomes, or simply outcomes.

3.2 Methods

3.2.1 Ethics Statement

The present study was approved by the University of Waterloo Research Ethics Committee (ORE # 22443).

The data for the present study were derived from the iLiNS-DYAD-M trial, which was conducted according to Good Clinical Practice guidelines (ICH-GCP) and adhered to the principles of Helsinki declaration (World Medical Association., 2001) and regulatory guidelines in Malawi. The trial protocol was approved and monitored by the University of Malawi - College of Medicine Research and Ethics Committee (COMREC), and the ethics committee of Pirkanmaa Hospital District, in Finland.

3.2.2 Study Design and Analysis

The cohort included pregnant mothers who were enrolled in the iLiNS-DYAD-M trial and their children. Eligibility, post-trial, was based on the availability of a known DoB at enrollment (N = 1262). Group assignment for pregnant mothers to receive SQ-LNS, MMN, or IFA was done during randomization at enrollment. The main variables of interest in this study were early childhood maternal exposure to drought during the preschool years (0-5 yr), and early childhood maternal exposure to drought by narrower age groups (0-2 yr and 3-5 yr).

3.2.3 Defining Early Childhood Maternal Exposure to Drought

The weather and climate play a major role in Malawi's agriculture, which is mostly rain-fed. Therefore, when crop-related droughts occur in Malawi they are meteorological in nature (IFPRI, 2009). Droughts differ from dry spells because they are abnormal events, i.e., the precipitation, or soil moisture levels are less than the long-run mean (IFPRI, 2009). A drop below 1 SD from the mean (Z score ≤ -1.0) in annual rainfall would precede a drought - the lower the Z score the greater the severity of the drought. According to the International Food Policy Research Institute (IFPRI), Malawi's agriculture is mostly rain-fed, therefore a meteorological definition of drought is appropriate (IFPRI, 2009). As explained in Chapter 2, three of the droughts that have been cited in literature as noteworthy occurred in 1981/82 (Babu & Chapasuka, 1997), in 1987/88 (IFPRI, 2009), and in 1992/93 (Babu & Chapasuka, 1997), which all began after the lean season ended with failed rains in 1981, 1987, and 1992, respectively. The drought of 1992/93 was the most severe with a return period (RP) of 25 years[1] (IFPRI, 2009). The incidence of drought in 1992/93 was compounded by the World Bank's and bilateral donors' suspension of all *non-humanitarian* aid until Malawi's human rights track-record improved (Resnick, 2012). With a subsequent increase in the price of a 90-kg bag of maize (a food staple in Malawi) surpassing a months' wage in many regions of Malawi due to crop failure, a food crisis was in full effect (United Nations, Internet). Nonetheless, the Malawi Government's efforts to mitigate the effects of the 1992/93 drought cannot be discounted[2].

The 1981/82 drought occurred amid other important events, such as, the World Bank's structural adjustment programmes (SAPs), which were rolled out in 1980[3]; the OPEC oil crisis of the 1970s; and, the civil war in neighbouring Mozambique, which blocked the route to the Beira port for Malawi's exports (Harrigan, 2003). Finally, the 1987/88 drought was linked to a hot spell in the same year which compelled the Malawi Government to import maize contradicting its policy of self-sufficiency (Kalinga, 2012).

The present study defined the start of the drought period as the start of the expected harvest period (May YYYY), regardless of the preceding lean season (December XXXX-April YYYY, where XXXX is the preceding year), and ending just before the next harvest began (May YYYY*) the following year. For example, early childhood maternal exposure to the drought of 1981/82 included mothers born on 1st May 1977 up to 30th April 1982. Therefore, "0" in the indicator variable represented maternal non-drought exposure while "1" represented early childhood maternal exposure to one of the droughts at age 0-5 yr, or the pooled droughts at age 0-2 yr or 3-5 yr.

The age of the trial-enrolled mothers was a key determinant of the period of drought exposure. The mean age of mothers was 24 years while the range was 14-48 years for known dates of birth (DoB: N = 1262) with close to 10% with unknown DoB. Being 15 years or older was an eligibility criterion, although some 14-year-old women slipped into the sample (n = 2). Early childhood maternal exposure to the drought of 1981/82 included mothers born from 1st May 1977-30th April 1982 and, likewise, "0" denoted maternal non-drought exposure while "1" denoted maternal drought exposure in the indicator variable. Early childhood maternal exposure to the drought of 1987/88 included mothers born from 1st May 1983-30th April 1988 and, likewise, "0" denoted maternal non-drought exposure while "1" denoted maternal drought exposure in the indicator variable. Early childhood maternal exposure to the drought of 1992/93 included mothers born from 1st May 1988-30th April 1993 and similarly, "0" denoted maternal non-drought exposure while "1" denoted maternal exposure in the indicator variable (Table 3.1).

Maternal exposure by a narrower age group - an indicator variable - was created by assigning the number "1" to all mothers who were 0-2 yr old during each drought period (DoB from 1st May 1980-30th April 1982; 1st May 1986-30th April 1988; 1st May 1991-30th April 1993 (Table 3.1). The number "0" was assigned to all mothers who were not part of that subgroup of exposures. Similarly, the number "1" was assigned to all mothers who were 3-5 yr old during each drought period (DoB from 1st May 1977-30th April 1980; 1st May 1983-30th April 1986; 1st May 1988-30th April 1991). The number "0" was assigned to all mothers who were not part of that subgroup of exposures (Table 3.1).

3.3 Statistical Analyses

3.3.1 Study Variables

The variables used in the present study were compiled and described in detail in Appendix C (C1 & C2). The study outcomes were infant LAZ, infant WAZ, and imputed birthweight (Appendix C1). Birthweight was imputed for babies born at home or outside the catchment area clinics with incomplete birth records, i.e., who were not weighed until after three days of age (see Chapter 2, section 2.4.1, on page 26 for more details). The variables for early childhood maternal exposure to drought comprised exposure at ages 0-5 yr, 0-2 yr, and 3-5 yr. Other covariates included sex of the child, maternal education, maternal BMI, marital status, maternal height, mother as HH, HFIAS, HAIZ, primiparity, and normal vs. "at risk" pregnancy, defined as being pregnant at age 35 yr old and over or younger than 18 yr old (Appendix C: C2). The main clinical trial arms for mothers consisted of two treatment groups, SQ-LNS and MMN, and one control group, IFA. Interaction terms were created by multiplying the four drought exposure variables with the three trial arms.

The data were collected using study guides, standard operating procedures (SOPs), and study questionnaires (Appendix F).

3.3.2 Potential Bias

The study may have been susceptible to overestimating the effects of non-exposure to drought because it included in the comparison group mothers who were exposed to drought *in utero*. To assess the impact of this special group, sensitivity analyses were conducted by excluding this group of mothers during analysis (Appendix D3-D6). See Chapter 2, section 2.4.2, on page 27 for an explanation of other expected biases for this study.

3.3.3 Models

This study on the intergenerational effects of maternal exposure to drought during childhood used the same techniques and software for analyses as for the study of the *in utero* effects. Please refer to Chapter 2, section 2.4.3, on page 27. The general form of the models that excluded prenatal supplements was as follows:

(1)

$$Y_i = \alpha + \beta X_i + \boldsymbol{Z}_i'\boldsymbol{\gamma} + \varepsilon_i,$$

Where

Y_i is the study outcome (LAZ, WAZ, or birthweight) for the i-th subject,

α is the intercept,

β is the coefficient for the exposure variable,

$\boldsymbol{\gamma}$ are the coefficients for the covariates,

X_i is the early childhood maternal exposure to drought variable for the i-th subject,

$\boldsymbol{Z}_i$ are the covariates for the i-th subject,

ε_i is the error term for the i-th subject.

Subsequently, the general form of the models which included drought variables and prenatal supplements with IFA used as the base category was as follows:

(2)

$$Y_i = \alpha + \beta(X_i * W_i) + \boldsymbol{Z}_i'\boldsymbol{\gamma} + \varepsilon_i$$

Where:

Y_i is the study outcome (LAZ, WAZ, or birthweight) for the i-th subject,

α is the intercept,

β are the coefficients for the interactions of maternal exposure to drought variables (at age 0-5 yr for different years) and the trial supplements variables,

$\boldsymbol{\gamma}$ are the coefficients for the covariates,

X_i is the maternal exposure to drought variable (at age 0-5 yr for different years) for the i-th subject,

W_i are the trial supplements variables for the i-th subject,

$\boldsymbol{Z}_i$ are the covariates for the i-th subject,

ε_i is the error term for the i-th subject.

(3) The general form for restricted models which excluded prenatal supplements focused on maternal drought exposure at ages 0-2 yr and 3-5 yr for the pooled droughts was similar to equation (1), whereas;

(4) The general form for the expanded models which included prenatal supplements and focused on maternal drought exposure at ages 0-2 yr and 3-5 yr for the pooled droughts was similar to equation (2).

3.3.4 Joint-Significance Tests

In section 2.4.4 of Chapter 2 (page 29), there is a justification for the use of joint-significance test in the analyses. The variables of interest were maternal exposure to any of the three droughts; exposure to any of three droughts interacted with supplements; exposure to any drought at two different ages (compared to non-exposure), and exposure to any drought at two age ranges interacted with trial supplements (compared to non-exposure).

Using Stata 14 and Stata 14.2, joint-significance tests were conducted post-hoc, in the present study, for all the models. Specifically, F-tests were used to jointly-test the regression coefficients for the maternal drought exposure variables, and their interactions with the trial supplements variables. The F-tests followed the F_o distribution of $F_{(k, n-l-k)}$ where k = number of independent variables in the regression models and n = total number of observations. Alpha (α) was set at 0.05 with any p-value < 0.05 deemed statistically significant.

The joint-significance testing took the following form by assuming that (1) the intercepts for the maternal exposure to drought in 1981/82, 1987/88, or 1992/93 variables (restricted models) and (2) the interaction terms between maternal exposure to drought in 1981/82, 1987/88, or 1992/93 and trial supplements were all equal to zero (expanded models). Further, it was assumed that (1) maternal exposure to drought at age 0-2 yr and 3-5 yr variables (restricted models) and (2) the interaction terms between maternal exposure to drought at age 0-2 yr and 3-5 yr and trial supplements were all equal to zero (expanded models). The variable IFA was used as the base category in all the models.

Drought Exposure at Age 0-5 yr (Restricted Models)

(1) H_o: $\beta_{drought81} = \beta_{drought87} = \beta_{drought92} = 0$

(2) Ha: At least one of the intercepts was non-zero

Drought Exposure at Age 0-5 yr (Expanded Models)

(1) H_o: $\beta_{drought81LNS} = \beta_{drought81MMN} = \beta_{drought81IFA} = \beta_{drought87LNS} = \beta_{drought87MMN} = \beta_{drought87IFA} = \beta_{drought92LNS} = \beta_{drought92MMN} = \beta_{drought92IFA} = \beta_{no\_droughtLNS} = \beta_{no\_droughtMMN} = \beta_{no\_droughtIFA} = 0$

(2) Ha: At least one of the intercepts was non-zero

The null hypotheses (H_o) were that (1) the regression coefficients for the maternal exposure to drought in 1981/82, 1987/88, or 1992/93 (restricted models) and (2) the regression coefficients for the interaction between the maternal exposure to drought in 1981/82, 1987/88, or 1992/93 and trial supplements were equal to zero and did not provide different effect sizes for the study outcomes (expanded models). The alternative hypothesis (Ha) was that at least one of the regression coefficients for each model was different from zero and influenced the corresponding study outcome.

Drought Exposure at Age 0-2 yr and 3-5 yr (Restricted Models)

(1) H_o: $\beta_{0\text{-}2agegroup} = \beta_{3\text{-}5agegroup} = 0$

(2) Ha: At least one of the intercepts was non-zero

Drought Exposure at Age 0-2 yr and 3-5 yr (Expanded Models)

(1) H_o: $\beta_{0\text{-}2agegroupLNS} = \beta_{0\text{-}2agegroupMMN} = \beta_{0\text{-}2agegroupIFA} = \beta_{3\text{-}5agegroupLNS} = \beta_{3\text{-}5agegroupMMN} = \beta_{3\text{-}5agegroup\ IFA} = \beta_{no\text{-}drought\ LNS} = \beta_{no\text{-}drought\ MMN} = \beta_{no\text{-}drought\ IFA} = 0$

(2) Ha: At least one of the intercepts was non-zero

The null hypotheses (H_o) were that (1) the regression coefficients for the maternal exposure to drought at age 0-2 yr and 3-5 yr (restricted models) and (2) the regression coefficients for the interactions between maternal drought exposure at age 0-2 yr or 3-5 yr and trial supplements were equal to zero and did not provide different effect sizes on the study outcomes (expanded models). The alternative hypothesis (Ha) was that at least one of the regression coefficients for each model was different from zero and influenced the study outcomes.

3.4 Results

3.4.1 Summary Statistics

Table 3.2 summarises the proportions of mothers who were exposed to drought at age 0-5 yr, 0-2 yr, or 3-5 yr and who received SQ-LNS (n/N, where N = 419), MMN (n/N, where N = 421), or IFA (n/N, where N = 422). Thus, about 12%, 27%, and 28% of mothers who received SQ-LNS were exposed to the 1981/82, 1987/88, and 1992/93 droughts, respectively. About 15%, 26%, and 29% of mothers who received MMN were exposed to the 1981/82, 1987/88, and 1992/93 droughts, respectively. Finally, about 15%, 24%, and 31% of mothers who received IFA were exposed in to the 1981/82, 1987/88, and 1992/93 droughts, respectively.

In other results from the same Table 3.2, about 28% of mothers who received SQ-LNS, 29% who received MMN, and 29% who received IFA were exposed to drought at age 0-2 yr. About 41% of mothers who received SQ-LNS, 38% who received MMN, and 35% who received IFA were exposed to drought at age 3-5 yr.

To review the summary statistics of the study's independent variables arranged by trial supplements, please go to section 2.5.1 on page 30 and to Table 2.1 on page on page 38, in Chapter 2. For statistics on means and SDs of the birth outcomes by maternal drought exposure by age group, please see Appendix C: C3.

3.4.2 Regression Results

The results in Tables 3.3-3.6 show the estimated regression coefficients for the exposure variables and independent variables. Confidence intervals (CIs) are provided in parentheses set at the 95% level of confidence. The strength of the associations between the independent variables and study outcomes are represented at three levels: $p < 0.05$[**], $p < 0.01$ [***], and $p < 0.1$ [*], although results with $p < 0.1$ will not be summarised or discussed. Robust standard errors were used for all the regressions.

In the restricted models, there were no statistically significant associations between early childhood maternal exposure to the three separate droughts and birth outcomes, controlled for covariates (Table 3.3), although the effects of the 1981/82 drought were consistently negative. When the trial supplements variables were added to the list of covariates in the expanded models, among mothers who received IFA, maternal exposure to the drought of 1987/88 at age 0-5 yr was associated with slightly (significantly) improved infant WAZ compared to postnatal non-drought exposure (Table 3.4). Also, among mothers exposed to drought in 1987/88 at age 0-5 yr, prenatal supplementation with SQ-LNS did not improve infant LAZ compared to prenatal supplementation with IFA. Among mothers exposed to drought in 1992/93 at age 0-5 y, prenatal supplementation with LNS did not improve any of the birth outcomes compared to prenatal supplementation with IFA. The effects of prenatal supplementation were largest for the imputed birthweight model and for the drought of 1992/93 (-175.820 g, 95% CI (-339.850: -11.791). Finally, among mothers not exposed to drought postnatally, prenatal supplementation with LNS significantly improved all birth outcomes compared to prenatal supplementation with IFA as did MMN (compared to IFA), although in this case not significantly.

In the restricted models, when the narrower age groups (0-2 yr and 3-5 yr) were used instead of 0-5 yr, there were no statistically significant associations observed between maternal exposure to drought at age 0-2 yr or age 3-5 yr and the birth outcomes, adjusted for covariates (Table 3.5). After including trial supplements variables in the expanded models, among mothers exposed to drought, prenatal supplementation with LNS did not improve infant WAZ compared to prenatal supplementation with IFA if the exposure occurred at age 0-2 yr and did not improve imputed birthweight if the exposure occurred at age 3-5 yr (Table 3.6).

As for the covariates in the main regressions, only maternal height and primiparity consistently influenced the birth outcomes in the expected direction for all the models and were also statistically significant with the strongest associations observed for primiparity [$p < 0.01$] compared to the other significant covariates (Table 3.3-3.6). Taller mothers were more likely to have children with a higher LAZ and a higher infant WAZ. Primiparity had a negative relationship with birth outcomes as did “at risk” age meaning that older and younger mothers were more likely to have children with a lower LAZ, lower WAZ, and lower birthweight compared to mothers with normal pregnancies by age.

Finally, the sensitivity analyses (Appendix D: D3-D6), which assessed the impact of excluding mothers exposed to drought *in utero* from the control groups in the infant LAZ, infant WAZ and imputed birthweight models did not change the results significantly with two exceptions. Among mothers exposed to drought in 1987/88 at age 0-5 yr, prenatal supplementation with SQ-LNS did not improve infant LAZ or infant WAZ compared to prenatal supplementation with IFA (sub-Appendix D4). Among mothers exposed to drought in 1993/93, prenatal supplementation with SQ-LNS (compared to IFA) no longer significantly affected infant WAZ (sub-Appendix D4). If anything, the sample sizes for the models were reduced by 170-185 observations. Further, there was a tendency for some of the significant covariates (e.g., child sex, maternal BMI, mother as HH, normal vs. “at risk” pregnancy by age) to lose some the strength of their associations with birth outcomes but, overall, the patterns of associations were replicated.

3.4.3 Other Results

Subsequently, none of the joint-significance tests conducted for the maternal exposure to drought at age 0-5 yr variables were statistically significant in the restricted models (LAZ: $F_{(3, 958)}$, $p = 0.144$); WAZ: $F_{(3, 969)}$, $p = 0.062$; imputed birthweight: $F_{(3, 1052)}$, $p = 0.351$). Further, none of the joint-significance tests conducted for the interactions between maternal exposure to drought at age 0-5 yr variables and the trial supplements variables in the expanded models were significant either (LAZ: $F_{(6, 958)}$, p = 0.218); WAZ: $F_{(6, 969)}$, p = 0.402; imputed birthweight: $F_{(6, 1052)}$, p = 0.3570).

Therefore, we do not reject the null hypothesis that the regression coefficients for (1) the maternal exposure to drought variables at age 0-5 yr for the different years, and (2) the interactions between the maternal exposure to drought variables at age 0-5 yr for the different years and the trial supplements variables were equal to zero. This means that neither the maternal exposure to drought variables at age 0-5 yr for the different years, nor the interactions between maternal exposure to drought variables at age 0-5 yr for the different years and the trial supplements variables had important effects on birth outcomes in this study.

The results of the models with maternal exposure to drought by age groups (0-2 yr and 3-5 yr) were similar to those observed in the joint-significance tests for the age group 0-5 yr. Consequently, none of the joint-significance tests conducted for the maternal exposure to drought variables were statistically significant in the restricted models (LAZ: $F_{(2, 961)}$, p = 0.198); WAZ: $F_{(2, 972)}$, p = 0.223; imputed birthweight: $F_{(2, 1055)}$, p = 0.389) and not statistically significant for the interactions between maternal exposure to drought variables and the trial supplements variables in the expanded models [LAZ: $F_{(4, 961)}$, p = 0.151); WAZ: $F_{(4, 972)}$, p = 0.319; imputed birthweight: $F_{(4, 1055)}$, p = 0.189)].

Therefore, we do not reject the null hypothesis that the regression coefficients for (1) the maternal exposure to drought variables at age 0-2 yr or at age 3-5 yr, and (2) the interactions between the maternal exposure to drought variables at age 0-2 yr or at age 3-5 yr and the trial supplements variables were equal to zero. This means that neither the maternal exposure to drought at age 0-2 yr or at age 3-5 yr variables nor the interactions between maternal exposure to drought at age 0-2 yr or at age 3-5 yr variables and the trial supplements variables had important effects on birth outcomes in this study.

3.5 Strengths and Limitations

One of the strengths of this study was the addition of infant WAZ as a study outcome in the context of early childhood maternal exposure to drought during the preschool years, which is currently absent in literature. A second strength of the study was the random assignment of mothers into the three trial arms in the RCT, thus, ensuring that any systematic variations would be randomized across the three trial arms. By adding a dimension of a new intervention (SQ-LNS) assessed against a control group (IFA), the natural experiment was strengthened having drawn the prenatal supplements data from the RCT.

The following were the limitations: the dataset was incomplete for mothers who participated in the iLiNS-DYAD-M clinical trial in terms of known DoB, thus limiting the sample size of the original study by about 9%. A further limitation imposed on the sample was the use of imputed values in place of birthweight for any measurements taken between 3-5 days. This could result in the overestimation of results for outcomes of both exposures and controls. Further, the dyad of mothers and children excluded from the study could have possibly helped the results to be more robust had they known their DoB because a larger sample is almost invariably preferable. In effect, the study was underpowered to detect an effect for all the models with maternal exposure to drought and SQ-LNS interactions (e.g., n < 60 for SQ-LNS and IFA among mothers exposed to the 1981/82 drought at age 0-5 yr). Missing documentation of DoB and the lack of knowledge of DoB is common in resource-poor countries and the same phenomenon was apparent in this study. Maternal (postnatal) anthropometric and clinical data from that may have been collected at time of drought exposure were unavailable – an expected consequence of a historical cohort study (natural experiment) vs. an RCT – which inevitably limited the discussion on causality.

3.6 Discussion

The present study predicted that early childhood maternal exposure to drought would mirror the findings of the Fung and Ha's study, for example, low infant LAZ would be positively associated with early childhood maternal drought exposure. Also, the present study also added a prenatal supplements dimension to its models and hypothesized that the supplements would offset any intergenerational effects from maternal exposure to drought in the first few years of childhood.

Among the significant results, mothers who were exposed to drought in 1992/93 at age 0-5 yr were more likely to have infants with worse birth outcomes if they received SQ-LNS compared to mothers who received IFA. The effects were quite large and clinically significant (e.g., +175.820 g for imputed birthweight), which suggests that the hypothesized intergenerational maternal effects were more prominent in the worst of the three droughts and were more responsive to IFA than to SQ-LNS. Thus, the outcomes contradict the study's prediction that SQ-

LNS would offset any intergenerational effects of maternal exposure to drought in early childhood and would increase the likelihood of better birth outcomes compared to mothers who received IFA. A probable explanation is that SQ-LNS was not designed for therapeutic situations, i.e., to address the effects of nutritional crises but to prevent the onset of malnutrition. Although the following result was not anticipated *a priori*, among mothers not exposed to drought postnatally, there was an increased likelihood of improved birth size when mothers received SQ-LNS compared to IFA. The significant outcome for the interaction between SQ-LNS (compared to IFA) and maternal drought exposure *in utero* was not evident in Chapter 2; however, in Chapter 2, the interaction between MMN (compared to IFA) and maternal drought exposure *in utero* was significant for a few models. One possible explanation for the efficacy of IFA compared to SQ-LNS and MMN is that although IFA is only packed with a duo of micronutrients, it has been the WHO-recommended prenatal standard of care for several years to prevent the onset of maternal anaemia, puerperal sepsis, LBW, and preterm birth in resource-poor settings (WHO, 2016)[4].

The present study's sensitivity analyses improved the result for the interaction between maternal exposure to the drought of 1987/88 and SQ-LNS (compared to IFA) in the WAZ model whereas the result for the interaction between SQ-LNS (compared to IFA) and maternal drought exposure of 1992/93 was no longer significant. Next, some of the significant results of the narrower age groups were as follows: Maternal exposure to drought at age 0-2 yr or at age 3-5 yr were important for the infant WAZ and imputed birthweight models, respectively, if mothers received SQ-LNS (compared to IFA) during pregnancy as the children were more likely to weigh less for their age or at birth. Conversely, birth size increased in infants of mothers who received SQ-LNS (compared to IFA) during pregnancy and were not exposed to drought at age 0-2 yr or 3-5 yr.

In the sensitivity analyses, which removed the effect of maternal exposure to drought *in utero* from the control group, only prenatal supplementation with MMN compared to prenatal supplementation with IFA was important, similar to the results reported in Chapter 2 whereby mothers were exposed to drought *in utero* instead of postnatally. Also, similar to the results in the wider age group of age 0-5 yr, the postnatally non-drought exposed mothers were more likely to have bigger sized infants if they were prenatally supplemented with SQ-LNS (compared to IFA), a result which did not change with sensitivity analyses. One of the weaknesses of the present study's analyses was that the joint-tests of significance for the maternal drought exposure variables and their interactions with the trial supplements were not statistically significant which implies that their effects sizes were similar to each other and did not influence the birth outcomes significantly.

Vis-à-vis the results gleaned from the sparse literature on maternal postnatal exposure to famine, the intergenerational effects on infant LAZ and infant WAZ were larger for maternal exposure to the 1992/93 drought at age 0-5 yr in the present study than maternal exposure to the Great Chinese Famine during the first and second years of life (Fung & Ha, 2010). The present study certainly differs from other studies on the Great Chinese Famine cohort (Fung & Ha, 2010) because the present study introduced more than one drought into the models, whereas the other studies only considered one famine (e.g., studies on the Great Chinese Famine 1959-1961). Meanwhile, the Chinese samples originated from predominantly rural populations because the China of the 1950s had 85% of its population comprised of rural inhabitants (Gørgens et al., 2012). Providentially, China's population compositions were comparable to Malawi's population segmentation between 1980s and 1990s, with Malawi's rural population estimated at 89% in 1987 (National Statistical Office, 1992).

3.7 Conclusion

The present study assessed the impact of maternal exposure during preschool years, (and more narrowly at age 0-2 yr and age 3-5 yr), on three birth outcomes, namely, infant LAZ, infant WAZ, and imputed birthweight. The present study tested the hypothesis that maternal exposure to drought during early childhood would negatively affect birth outcomes. The study also tested the hypothesis that the interaction of SQ-LNS (compared to IFA) or the interaction of MMN (compared to IFA) with maternal exposure to drought during early childhood would decrease negative effects on birth outcomes.

In sum, all the study outcomes in the restricted models appeared to be negatively influenced by maternal exposure only to the 1981/82 drought at age 0-5 yr, although the effects were not statistically significant. The associations regarding the other drought years and birth outcomes were mostly positive. When the supplements variables were added to the models and were interacted with the maternal exposure to drought variables for age 0-5 yr, some statistically significant effects were evident among the interacted variables. More statistically significant results appeared in the sensitivity analysis for the interactions between maternal exposure to the droughts of 1987/88 and 1992/93 and prenatal supplementation with SQ-LNS (compared to IFA) although the joint-significance tests for the maternal drought exposure variables at age 0-5 yr and their interactions with the trial supplements yielded insignificant results.

The pattern of results did not change much when maternal exposure to drought at age 0-2 yr and age 3-5 yr were assessed because maternal drought exposure did not significantly influence birth outcomes, controlled for covariates. However, models with prenatal supplements produced more statistically significant results, which indicated that IFA increased infant WAZ and imputed birthweight when maternal exposure occurred at age 0-2 yr and 3-5 yr. Meanwhile, the sensitivity analyses showed more significant results for infants with mothers who received SQ-LNS but were not exposed to drought having offspring with increased birth size compared to the offspring of mothers who received IFA but were not exposed to drought.

In conclusion, the findings for the present study suggest that:

a) No intergenerational effects of maternal exposure to drought at age 0-5 yr, 0-2 yr, or 3-5 yr, controlled for covariates. However, the models were underpowered to detect strong effects;
b) Among mothers not exposed to drought postnatally, there appeared to be some benefits of SQ-LNS prenatal supplementation on all birth outcomes compared to prenatal supplementation with IFA.

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[1] The shorter the return period, i.e., the number of years that pass before a similar type of drought occurs, the lower the intensity of the drought is. Conversely, the longer the return period, the more severe the drought is.

[2] Emergency relief begun with government distribution of maize to needy areas followed by distribution of maize from donors, which begun to arrive in July 1992 (Babu & Chapasuka, 1997).

[3] SAPs were economic interventions designed to liberalise sectors of the economy such as the agricultural sector, financial sector from government majority control, and parastatal reform and rationalisation of the Budget, but which inadvertently increased poverty levels (Southern African Regional Poverty Network (SARPN)., Internet).

[4] Daily oral IFA comprised of elemental iron (30 mg- 60 mg) and folic acid [400 µg (0.4 mg)].

Table 3.1: Variables for Maternal Exposure During Childhood

Variables	Type	Description	Additional notes
Drought exposure at age 0-5 yr	Indicator	0 = non-exposed (Includes women exposed to drought *in utero*) 1 = exposed from age 0-5 yr to the 1981/82, 1987/88, or 1992/93 drought	All mothers born from May 1st, 1977-April 30th, 1982; May 1st, 1983-April 30th, 1988; May 1st, 1988- April 30th, 1993.
Drought exposure at age 0-2 yr	Indicator	0 = non-exposed (Includes women exposed to drought *in utero*) 1 = exposed from age 0-2 yr to any drought	All mothers born from May 1st, 1980- April 30th, 1982; May 1st, 1986-April 30th, 1988; May 1st, 1991-April 30th, 1993.
Drought exposure at age 3-5 yr	Indicator	0 = non-exposed (Includes women exposed to drought *in utero*) -1 = exposed from age 3-5 yr to any drought	All mothers born from May 1st, 1977-April 30th, 1980; May 1st, 1983-April 30th, 1986; May 1st, 1988-April 30th, 1991.

Table 3.2: Summary Statistics of Maternal Drought Exposure Variables

Variables	LNS n, %	MMN n, %	IFA n, %	Total n/N
Early life maternal exposure to drought of 1981/82 (age 0-5 yr)	52, 12.41%	63, 14.96%	64, 15.17%	179/1262
Early life maternal exposure to drought of 1987/88 (age 0-5 yr)	113, 26.97%	109, 25.89%	100, 23.70%	322/1262
Early life maternal exposure to drought of 1992/93 (age 0-5 yr)	118, 28.16%	124, 29.45%	129, 30.57%	371/1262
Early life maternal exposure to any drought (age 0-2 yr)	119, 28.40%	137, 32.54%	146, 34.60%	402/1262
Early life maternal exposure to any drought (age 3-5 yr)	172, 41.05%	159, 37.77%	143, 34.83%	474/1262

Notes:

LNS (n = 419) MMN (n = 421) IFA (n = 422): N = 1262

Table 3.3: Regressions for Infant LAZ, Infant WAZ, and BWT with Early Life Maternal Exposure to Drought (Age 0-5 yr)

Variables	**(1)** **Restricted Model:** **LAZ**	**(2)** **Restricted Model:** **WAZ**	**(3)** **Restricted Model:** **Imputed BWT**
Drought exposure in 1981/82	-0.126	-0.061	-33.540
	(-0.389 , 0.137)	(-0.297 , 0.174)	(-133.000 , 65.921)
Drought exposure in 1987/88	0.080	0.174	55.287
	(-0.145 , 0.305)	(-0.043 , 0.390)	(-30.302 , 140.876)
Drought exposure in 1992/93	-0.024	0.052	34.709
	(-0.238 , 0.189)	(-0.147 , 0.252)	(-44.727 , 114.145)
Child sex (girl)	0.116*	0.035	-86.352***
	(-0.018 , 0.251)	(-0.092 , 0.162)	(-139.564 , -33.140)
Maternal education	0.006	0.008	-2.210
	(-0.019 , 0.030)	(-0.014 , 0.030)	(-11.411 , 6.991)
Maternal BMI	0.022	0.032**	15.022***
	(-0.006 , 0.050)	(0.005 , 0.058)	(4.170 , 25.875)
Marital status (married)	-0.091	0.037	-24.073
	(-0.330 , 0.149)	(-0.187 , 0.260)	(-109.153 , 61.007)
Maternal height	0.052***	0.042***	18.496***
	(0.039 , 0.066)	(0.030 , 0.055)	(13.572 , 23.419)
Head of household (mother)	-0.356*	-0.448**	-113.464
	(-0.726 , 0.014)	(-0.789 , -0.106)	(-249.117 , 22.189)
HH food insecurity access scale	0.007	0.013*	4.205
	(-0.010 , 0.023)	(-0.002 , 0.028)	(-1.974 , 10.383)
HH asset index Z score	0.027	0.063	9.434
	(-0.058 , 0.112)	(-0.018 , 0.143)	(-24.881 , 43.749)
Primiparous	-0.312***	-0.364***	-116.247***
	(-0.497 , -0.127)	(-0.539 , -0.189)	(-190.189 , -42.305)
Normal (vs. “at risk”) pregnancy by age	0.223*	0.032	42.292
	(-0.007 , 0.453)	(-0.179 , 0.244)	(-41.440 , 126.024)

Constant	-9.810***	-8.013***	-236.880
	(-12.054 , -7.566)	(-10.046 , -5.981)	(-1,018.062 , 544.301)
N	980	991	1,074
R-squared	0.110	0.106	0.094
F	8.820	8.698	9.171
Adjusted R-squared	0.0981	0.0941	0.0832

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT – birthweight

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Table 3.4: Regressions for Infant LAZ, Infant WAZ, and BWT with Maternal Exposure to Drought (Age 0-5 yr) and Trial Supplements

Variables	**(1) Expanded Model: LAZ**	**(2) Expanded Model: WAZ**	**(3) Expanded Model: Imputed BWT**
Drought exposure in 1981/82# IFA	-0.100	-0.000	6.593
	(-0.527 , 0.327)	(-0.383 , 0.383)	(-148.096 , 161.282)
Drought exposure in 1987/88# IFA	0.315*	0.360**	54.661
	(-0.030 , 0.659)	(0.033 , 0.686)	(-75.446 , 184.769)
Drought of exposure in 1992/93# IFA	0.165	0.285*	106.607
	(-0.172 , 0.501)	(-0.029 , 0.599)	(-21.894 , 235.109)
Non exposure# MMN[a]	0.186	0.181	28.212
	(-0.131 , 0.502)	(-0.116 , 0.479)	(-89.556 , 145.981)
Non exposure# LNS[b]	0.403***	0.372**	125.900**
	(0.099 , 0.708)	(0.053 , 0.691)	(2.901 , 248.899)
Drought exposure in 1981/82# MMN	0.097	-0.004	11.046
	(-0.431 , 0.624)	(-0.473 , 0.466)	(-201.432 , 223.524)
Drought exposure in 1981/82# LNS	-0.218	-0.199	-136.802
	(-0.816 , 0.379)	(-0.747 , 0.350)	(-357.689 , 84.085)
Drought exposure in 1987/88# MMN	-0.252	-0.188	65.352
	(-0.713 , 0.208)	(-0.624 , 0.249)	(-101.413 , 232.117)
Drought exposure in 1987/88# LNS	-0.482**	-0.390*	-66.503
	(-0.923 , -0.041)	(-0.830 , 0.050)	(-246.306 , 113.301)
Drought exposure in 1992/93# MMN	-0.113	-0.232	-37.918
	(-0.543 , 0.318)	(-0.632 , 0.169)	(-206.689 , 130.853)
Drought exposure in of 1992/93# LNS	-0.487**	-0.488**	-175.820**
	(-0.906 , -0.068)	(-0.901 , -0.076)	(-339.850 , -11.791)
Child sex (girl)	0.116*	0.038	-85.498***
	(-0.020 , 0.252)	(-0.091 , 0.167)	(-139.293 , -31.704)

Notes:

[a,b] The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

Maternal education	0.005	0.008	-2.011
	(-0.019 , 0.029)	(-0.013 , 0.030)	(-11.295 , 7.273)
Maternal BMI	0.022	0.032**	15.594***
	(-0.005 , 0.050)	(0.006 , 0.059)	(4.902 , 26.286)
Marital status (married)	-0.106	0.032	-24.611
	(-0.347 , 0.135)	(-0.193 , 0.256)	(-110.743 , 61.522)
Maternal height	0.052***	0.042***	18.250***
	(0.038 , 0.065)	(0.029 , 0.055)	(13.257 , 23.242)
Head of household (mother)	-0.367*	-0.456***	-119.346*
	(-0.738 , 0.004)	(-0.798 , -0.114)	(-255.881 , 17.189)
HH food insecurity access scale	0.008	0.015*	4.479
	(-0.009 , 0.024)	(-0.001 , 0.030)	(-1.657 , 10.615)
HH asset index Z score	0.020	0.053	5.792
	(-0.066 , 0.105)	(-0.028 , 0.134)	(-28.530 , 40.115)
Primiparous	-0.317***	-0.363***	-119.744***
	(-0.504 , -0.130)	(-0.538 , -0.187)	(-193.549 , -45.938)
Normal (vs. “at risk”) pregnancy by age	0.239**	0.043	40.073
Constant	-9.898***	-8.172***	-261.472
	(-12.148 , -7.647)	(-10.229 , -6.115)	(-1,048.719 , 525.775)
N	980	991	1,074
R-squared	0.119	0.113	0.101
F	5.998	6.064	6.345
Adjusted R-squared	0.0995	0.0939	0.0831

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

Trial supplements: LNS - lipid-based nutrient supplement, MMN - multiple micronutrient supplement, IFA - iron-folic acid

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Table 3.5: Regressions for Infant LAZ, Infant WAZ, and BWT with Early Childhood Maternal Exposure to Drought (Age 0-2 yr and 3-5 yr)

Variables	**(1)** **Restricted Model: LAZ**	**(2)** **Restricted Model: WAZ**	**(3)** **Restricted Model: Imputed BWT**
Drought exposure at age 0-2 yr	0.036	0.085	50.942
	(-0.179 , 0.251)	(-0.119 , 0.289)	(-29.187 , 131.072)
Drought exposure at age 3-5 yr	-0.055	0.051	6.670
	(-0.266 , 0.156)	(-0.145 , 0.247)	(-71.880 , 85.219)
Child sex (girl)	0.119*	0.037	-83.554***
	(-0.015 , 0.254)	(-0.090 , 0.164)	(-136.919 , -30.189)
Maternal education	0.006	0.009	-1.916
	(-0.018 , 0.030)	(-0.013 , 0.031)	(-11.059 , 7.226)
Maternal BMI	0.021	0.030**	14.646***
	(-0.007 , 0.049)	(0.004 , 0.057)	(3.910 , 25.381)
Marital status (married)	-0.089	0.037	-26.047
	(-0.329 , 0.152)	(-0.185 , 0.259)	(-111.311 , 59.217)
Maternal height	0.052***	0.042***	18.290***
	(0.039 , 0.066)	(0.030 , 0.055)	(13.376 , 23.205)
Head of household (mother)	-0.345*	-0.437**	-113.258*
	(-0.715 , 0.024)	(-0.779 , -0.096)	(-248.087 , 21.570)
HH food insecurity access scale	0.006	0.013*	4.060
	(-0.010 , 0.023)	(-0.002 , 0.028)	(-2.124 , 10.244)
HH asset index Z score	0.019	0.052	7.866
	(-0.066 , 0.104)	(-0.029 , 0.134)	(-26.627 , 42.358)
Primiparous	-0.323***	-0.371***	-115.481***
	(-0.503 , -0.143)	(-0.544 , -0.198)	(-188.785 , -42.176)
Normal (vs. “at risk”) pregnancy by age	0.226*	0.039	44.760
	(-0.005 , 0.457)	(-0.173 , 0.251)	(-39.089 , 128.609)
Constant	-9.772***	-8.006***	-198.197
	(-12.012 , -7.532)	(-10.046 , -5.967)	(-977.833 , 581.439)
N	980	991	1,074
R-squared	0.108	0.101	0.092

F	9.750	9.110	9.992
Adjusted R-squared	0.0969	0.0904	0.0821

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT – birthweight

HH - household,

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Table 3.6: Regressions for Infant LAZ, Infant WAZ, and BWT with Early Childhood Maternal Exposure to Drought (Age 0-2 yr and 3-5 yr) and Trial Supplements

Variables	**(1)** **Expended Model: LAZ**	**(2)** **Expanded Model: WAZ**	**(3)** **Expanded Model: Imputed BWT**
Drought exposure at age 0-2 yr#IFA	0.254	0.260*	82.512
	(-0.060 , 0.569)	(-0.045 , 0.566)	(-37.172 , 202.196)
Drought exposure at age 3-5 yr#IFA	0.053	0.227	42.023
	(-0.287 , 0.392)	(-0.080 , 0.535)	(-85.138 , 169.185)
Non exposure# MMN[a]	0.188	0.183	27.905
	(-0.128 , 0.504)	(-0.114 , 0.480)	(-89.698 , 145.508)
Non exposure# LNS[b]	0.404***	0.373**	126.150**
	(0.100 , 0.708)	(0.054 , 0.692)	(3.298 , 249.002)
Drought exposure at age 0-2 yr#MMN	-0.006	-0.133	37.178
	(-0.432 , 0.420)	(-0.520 , 0.254)	(-123.981 , 198.336)
Drought exposure at age 0-2 yr#LNS	-0.350*	-0.410**	-149.026*
	(-0.766 , 0.065)	(-0.815 , -0.005)	(-313.677 , 15.626)
Drought exposure at age 3-5 yr#MMN	0.117*	0.037	-81.654***
	(-0.018 , 0.253)	(-0.091 , 0.166)	(-135.216 , -28.092)
Drought exposure at age 3-5 yr#LNS	0.005	0.009	-1.970
	(-0.019 , 0.029)	(-0.013 , 0.031)	(-11.100 , 7.161)
Child sex (girl)	0.021	0.031**	15.273***
	(-0.007 , 0.048)	(0.004 , 0.057)	(4.712 , 25.834)
Maternal education	-0.088	0.042	-26.622
	(-0.327 , 0.151)	(-0.179 , 0.263)	(-112.476 , 59.232)
Maternal BMI	0.052***	0.042***	17.959***
	(0.038 , 0.065)	(0.029 , 0.054)	(13.037 , 22.880)
Marital status (married)	-0.106	0.032	-24.611
	(-0.347 , 0.135)	(-0.193 , 0.256)	(-110.743 , 61.522)

Notes:

[a,b] The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

Maternal height	0.052***	0.042***	18.250***
	(0.038 , 0.065)	(0.029 , 0.055)	(13.257 , 23.242)
Head of household (mother)	-0.367*	-0.456***	-119.346*
	(-0.738 , 0.004)	(-0.798 , -0.114)	(-255.881 , 17.189)
HH food insecurity access scale	0.008	0.015*	4.479
	(-0.009 , 0.024)	(-0.001 , 0.030)	(-1.657 , 10.615)
HH asset index Z score	0.025	0.060	6.439
	(-0.061 , 0.110)	(-0.021 , 0.141)	(-28.026 , 40.903)
Primiparous	-0.317***	-0.363***	-119.744***
	(-0.504 , -0.130)	(-0.538 , -0.187)	(-193.549 , -45.938)
Normal (vs. “at risk”) pregnancy by age	0.239**	0.043	40.073
	(0.011 , 0.467)	(-0.166 , 0.253)	(-43.926 , 124.072)
Constant	-9.898***	-8.172***	-261.472
	(-12.148 , -7.647)	(-10.229 , -6.115)	(-1,048.719 , 525.775)
N	980	991	1,074
R-squared	0.116	0.108	0.099
F	7.176	6.786	7.572
Adjusted R-squared	0.0991	0.0912	0.0841

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

LNS - lipid-based nutrient supplement, MMN - multiple micronutrient supplement, IFA - iron-folic acid

HH - household,

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Chapter 4

Associations between Seasonal Variations and Newborn Size in Rural Malawi – a Retrospective Cohort Study

4.1 Introduction

Maternal undernutrition during pregnancy negatively influences fetal growth and has been linked to poor pregnancy outcomes, such as low birth weight (LBW) and small-for-gestational-age (SGA) (Abu-Saad & Fraser, 2010; de Onis, 2013). Consequently, LBW increases the risk of infant mortality (de Onis, 2013). The infant mortality rate per 1000 live births in Malawi was reported at 650 for babies with LBW < 1500 g, 276 for babies with LBWs of 1500-1999 g, 58 for babies with LBW 2000-2499 g, and 24 for babies heavier than 2500 g (Steketee et al., 2012). Stunted child growth is still a problem in sub-Saharan Africa, with more than 30% of preschoolers reported as stunted [33.2%, 95% CI (30.4: 36.1)] (Akombi et al., 2017), which is a high prevalence rate and of public health concern. In Malawi, an even higher prevalence rate of child stunting was reported (37%) in 2016 (National Statistical Office (NSO), 2016).

Maternal nutritional effects on birth outcomes may be compounded by seasonal variations, especially in developing countries (de Onis et al., 1998). There are several implications: (a) bimodal weather patterns typically result in two harvests because of the two rainy seasons, consequently boosting annual food availability; whereas, while unimodal weather patterns produce, at most, a single harvest (Kigutha, 1994). Nevertheless, (b) in most cases, in agriculture-dependent and resource-poor settings, household food supply is depleted during the rainy (lean) season for both weather patterns (Kigutha, 1994). Malawi, for example, has a unimodal pattern, i.e., annual rainfall for agriculture occurs in one season only, which may result in different seasonal variations in food insecurity (Kigutha, 1994). There are several implications: (1) bimodal weather patterns typically produce two harvests because of two rainy seasons, which boost annual food availability whereas unimodal weather patterns produce, at most, a single harvest. Nevertheless, (2) in most cases, household food supply is depleted during the rainy season for both weather patterns (Kigutha, 1994). Notably, most disruptions to agricultural output in Malawi are linked to adverse meteorological changes - i.e., too little, or too much rain (IFPRI, 2009; Our Africa, Internet).

The rainy season is pivotal especially among low income countries because maternal agricultural labour increases and if pregnant women expend more energy than they are consuming while tending to their fields, their pregnancy weight gain falters (Ramachandran, 2002). Since maternal pregnancy weight gain is positively correlated with fetal weight gain, any deficits in maternal pregnancy weight can have adverse effects on birthweight (Ramachandran, 2002). Maternal calorie gaps can, therefore, be minimised by reducing energy expenditure or by targeted food supplementation programmes (Ramachandran, 2002).

4.1.1 Review of the Literature

What has been more commonly reported in the literature on maternal exposure to the rainy season during pregnancy are the trimester effects on birthweight not birth length (Prentice et al., 2013). However, there is some literature on the seasonal variations of birth length. For example, decreased birth length was associated with maternal exposure to the rainy season vs. other seasons in the second or third trimesters of pregnancy in several developing countries (Madan et al., 2017; Neufeld et al., 1999; Prentice et al., 2013).

Notably, during the third trimester the fetus is at risk of LBW if disruptions in weight gain occur because by that point fetal organs have been fully developed and fetal growth shifts to adding fat deposits on the body (BC Open textbooks, 2016). Comparatively, during the first trimester, organogenesis begins in an embryo whereby its organs and tissues develop from the ectoderm, mesoderm, and endoderm (*ibid*). Organogenesis is the process by which organs begin to develop and grow in the embryo during the first eight weeks of gestation (*ibid*). The neural tube is also in its early development stages during this period (*ibid*). At week nine, the fetal period begins during which the circulatory system becomes more specialized, the brain continues to grow, and its structures become more defined (*ibid*). Also, facial features develop, while the fetal body lengthens, and the skeleton ossifies [becomes hardened and turns into bone] (*ibid*). Therefore, the fetus is more at risk of stunted growth during the first trimester because the elongation of the fetal body and skeletal ossification intensify during that period (*ibid*).

In a prospective, longitudinal study conducted in rural Malawi, maternal exposure to the pre-harvest rainy season during the third trimester of pregnancy was linked to a lower birthweight in offspring (Neufeld et al., 1999). In a population-based, longitudinal study by a different research group conducted in rural Southern Malawi, infant weight-for-age (WAZ) and infant length-for-age (LAZ) dropped during the rainy, lean months among slightly older children (aged 1-6 mo), and the same age group fared better in June and July just after the harvest season (Maleta et al., 2003). Further, results from other African countries have followed similar patterns for fetal growth. A study in rural Lesotho found that intrauterine exposure to the "hungry" season during the third trimester of pregnancy, specifically from December-January, affected birthweight negatively (Mathule et al., 2005). No specific effect sizes were reported in the Lesotho study and, moreover, the sample was restricted to women who attended prenatal care at least five times and did not have gestational diabetes, hypertension, and multiple pregnancies, factors known as confounders for birthweight (*ibid*)[1].

Finally, a retrospective cohort study conducted in a rural area of The Gambia found that there were more cases of SGA – with birthweight below the 10th percentile for gestational age – towards the end of the hunger season [August-December] (Rayco-Solon et al., 2005).

Other Impacts of the Rainy Season on Pregnancy Outcomes

Another problem related to the rainy season is the incidence of malaria. Contracting malaria during pregnancy, which is more prevalent in the rainy season, increases the risk of low birthweight (LBW), stillbirth and infant mortality (Guyatt & Snow, 2004; Mathule et al., 2005; Rayco-Solon et al., 2005). Malaria infections may inhibit fetal nutrient absorption and/or divert the absorption of oxygen and glucose through the placenta from the fetus to the parasites, which compromises fetal growth (Guyatt & Snow, 2004). A WHO- prescribed intervention is to provide malaria-ridden regions of Africa with intermittent preventive treatment in pregnancy-sulfadoxine-with pyrimethamine (IPTp-SP) as the recommended drug to reduce the incidence of maternal malaria episodes, maternal and fetal anemia, placental parasitemia, and to reduce the risk of LBW, and neonatal mortality (WHO., 2017).

Nutrition-Related Interventions

Protein energy (PE) and/or MMN supplementation have been reported to moderate the negative effects of the seasonal variations on birth outcomes (Johnson et al., 2017). Supplementation with PE during a cluster RCT in The Gambia increased birthweight during the hunger season (June-October) and reduced the risk of LBW (OR: 0.61, 95% CI (0.47-0.79, $p < 0.001$) (Ceesay et al., 1997). An RCT in Burkina Faso found that prenatal supplementation with small-quantity lipid-based nutrient supplement (SQ-LNS) vs. MMN-alone during the third trimester of pregnancy was linked to increased birth length, after adjusting for health center, intervention, primigravidity, year of birth, group of malaria prophylaxis (3 vs. 2 doses of sulfadoxine-pyrimethamine), maternal height, and infant sex (+13.5 mm, 95% CI: 6.5-20.5; n=1019) during the transition from the rainy to dry season to dry season [September to November] (Toe et al., 2015).

The objective of the study was to assess seasonal effects on offspring's birthweight (either measured within 72 hours of birth, or imputed (if weight was measured after 72 hours), plus infant LAZ and infant WAZ measured within 6 weeks of birth.

4.2 Methods

4.2.1 Study Design and Data Analyses

A full description of the study design for the main trial can be retrieved from published material (Ashorn et al., 2015). In brief, pregnant women, gestation age < 20 weeks (N = 1391) were recruited from four health centres (Lungwena: n = 521; Malindi: n = 244; Namwera: n = 223; Mangochi Boma: n = 415) in Mangochi District, Southern Malawi. Lungwena, Malindi, and Namwera were more rural compared to Mangochi *Boma*, which was peri-urban. All babies whose dates of birth (DoB) were recorded (n = 1319) and were singletons (n = 1295) were eligible to be included in this retrospective cohort study.

4.2.2 Ethics Statement

This study was approved by the University of Waterloo Research Ethics Committee (ORE # 22443). The data for the present study were derived from the iLiNS-DYAD-M trial, which was conducted according to Good Clinical Practice guidelines (ICH-GCP) and adhered to the principles of Helsinki declaration (World Medical Association., 2001) and regulatory guidelines in Malawi. The trial protocol registered as NCT01239693 at clinicaltrials.gov was approved and monitored by the University of Malawi - College of Medicine Research and Ethics Committee (COMREC), and the ethics committee of Pirkanmaa Hospital District, in Finland.

4.2.3 Derivation of Seasonal Variations Variables

During the lean season (December-April) in Malawi, the weather is hot and wet with frequent rainfall. The weather transitions into the harvest/post-harvest season from (May-August), where the weather is mostly cold and dry, to the hot and dry in the pre-lean season (September-November), with no or very sparse rainfall.

To capture the seasonal variations linked to the annual cropping cycle in Malawi, dummy variables, which were categorical, 1 = birth during the harvest/post-harvest season, 2 = birth during the pre-lean season, and 3 = birth during the lean season, were created (Our Africa, Internet). The harvest/post-harvest season was the base category[2].

4.2.4 Study Variables

The variables used in the models have been described in detail elsewhere in Appendix C (C1 & C2). The variables comprised birthweight, LAZ, and WAZ as the study outcomes. Birthweight was measured between 72 hours from delivery, and was not available for all children (only for a reduced sample). For the remaining children, weight and length were measured as soon as possible, and prior to 42 days of age. Imputed birthweight was calculated from a table in a statistical paper (Cheung, 2013) solely for weight measured between 3-5 days from birth. Thereafter, birth length and weight were measured adjusted for neonatal age within 42 days of birth using calculations for LAZ and WAZ in the WHO's 2006 child growth standards (Ashorn et al., 2015a). See Chapter 2, section 2.4.1 for more details and a justification for the use of the WHO 2006 growth standards' calculations.

The exposure variables comprised the pre-lean (hot and dry) season, lean (hot and wet) season, and the harvest/post-harvest (cold and dry) season. The year of birth was also added to control for time variation. The season-invariant covariates were sex of the newborn, maternal education, maternal height, mother as head of household (HH), household food insecurity access scale (HFIAS), household asset index Z score (HAIZS), and primiparity.

The data were collected using study guides, standard operating procedures (SOPs), and study questionnaires (Appendix F).

4.2.5 Potential Bias

Only the data of children with known DoB were used in this study which increased the likelihood of selection bias due to a reduced sample, which was reduced further when the mothers and children had missing data for some variables.

4.2.6 Models

The models for birthweight (reduced sample and full sample including imputed values), LAZ (reduced sample and full sample), and WAZ adopted the following general form. The period May-August (harvest/post-harvest) was used as the base category.

The ordinary least squares (OLS) regression analysis (linear regressions) with robust standard errors were conducted for the birth outcomes of the study using Stata 14 and Stata 14.2. Alpha (α) was set at 5% ($\alpha = 0.05$), meaning that a coefficient with a probability of being zero less than 5% ($p < 0.05$) was deemed statistically significant.

Subsequently, the general form of the models for mean birthweight for newborns weighed within 72 hours of birth and mean LAZ corresponding to newborns with weight measured within 72 hours was as follows:

(1)

$$Y_i = \beta_0 + \beta X_i + \boldsymbol{Z}_i'\boldsymbol{\gamma} + \varepsilon_i,$$

Where:

Y_i is the study outcome (birthweight) for the i-th subject,

β_0 is the intercept,

β are the coefficients for the seasonal effects variables,

$\boldsymbol{\gamma}$ are the coefficients for the covariates,

X_i are the seasonal effects variables for the i-th subject,

$\boldsymbol{Z'}_i$ are the covariates for the i-th subject,

ε_i is the error term for the i-th subject.

The same general form of the previously described models was used for the larger sample, including imputed birthweight, which was used when measured birthweight was not available, and LAZ and WAZ measured when the infants were older than three days but younger than 6 days old.

4.2.7 Joint-Significance Tests

For a justification of joint-significance test, please review section 2.4.4 in Chapter 2 (page 29). The joint-significance tests took the following form by assuming that the intercepts for the seasonal effects variables were all equal to zero.

(1) H_o: $\beta_{harvest/post\text{-}harvest} = \beta_{pre\text{-}lean} = \beta_{lean} = 0$

(2) Ha: At least one of the intercepts was non-zero

Thus, the null hypothesis (H_o) was that the regression coefficients for the seasonal effects variables were equal to zero and did not provide different effect sizes on the study outcomes. The alternative hypothesis (Ha) was that at least one of the regression coefficients for each model was different from zero and influenced the corresponding study outcome.

4.3 Results

4.3.1 Summary Statistics

For a summary of the mean values of birth outcomes, exposure variables and covariates used in this study, see Table 4.1.

The outcome variables comprised mean measured birthweight (2968.39g, n = 1020), mean imputed birthweight (2970.21g, n = 1144), mean LAZ for the reduced sample (-0.967 Z score, n = 890), mean LAZ for the larger sample (-0.989 Z score, n = 1045), and mean WAZ (-0.550 Z score, n = 1054). Note that although the study differentiated between measured and imputed birthweight, and that about 9.6% (124/1295) of all singleton infants with known DoBs in this study did not have a birthweight measured before 72 hours expired. In Table 4.2, there was not much variation between measured and imputed average birthweight across the months.

The exposure variables comprised the pre-lean season (hot and dry), lean season (hot and wet), and the harvest/post-harvest season (cold and dry) [Table 4.1]. There were 536 children (41.39%) born in the pre-lean season, 391 children (30.19%) born in the lean season, and 368 children (28.42%) were born in the harvest/post-harvest season (the controls). The year of birth was also added to control for time variation and 225 children were born in 2011 (17.37%), 1027 were born in 2012 (79.31%), while 43 were born in 2013 (3.32%).

The season-invariant covariates were sex of the newborn (609 males, 48.72%), maternal education (3.97 yr, n = 1278), maternal height (156.08 cm, n = 1291), mother as head of household (91, 7.03%), household food insecurity access scale (4.94, n = 1272), household asset index Z score (-0.174 Z score, n = 1275), and primiparity (272, 21.04%) [Table 4.1].

Table 4.3 summarises the average (mean) imputed birthweight across the iLiNS-DYAD-M trial years (2011-2013). Notably, from July 2011-September 2012, only July 2012 had a mean imputed birthweight > 3000 g whereas from October 2012-February 2013 all the monthly mean imputed birthweights were > 3000 g. Further, Figure 4.1 shows that in relation to Table 4.3 the peaks for both measured and imputed birthweights occurred three months into the cold and dry (harvest/post-harvest) season (July), and the troughs occurred both in the lean and pre-lean seasons.

In Figure 4.2, mean measured birthweight decreased from the beginning of the lean season and peaked in end July-August i.e., towards the end of the harvest/post-harvest season for the six-month moving average, which is designed to smooth out the numerous fluctuations (see the chapter’s end notes for computational details). In Figure 4.3, mean imputed birthweight followed a similar pattern to the peaks and nadirs in the mean birthweight from the reduced sample’s monthly time series. Mean LAZ and WAZ also followed the trend of peaking in the harvest/post-harvest season and ebbing in the lean season for both time series (Figure 4.4 and Figure 4.5, respectively).

Finally, a brief assessment on the impact of the troughs and peaks in the graphs showed that the difference between the peak (maximum) and the trough (minimum) raw values of birthweight (transformed to a Z score) and LAZ (maximum Z score - minimum Z score) was bigger by 1.63 SD for birthweight vs. birth length (8.65 SD vs. 7.02 SD) implying that there was more variation with mean birthweight across the months compared to mean LAZ.

4.3.2 Regression Results

The results in Tables 4 and 5 show the mean values of the estimated coefficients for the WHO 2006 Child Growth Standards birthweight model (restricted to children with measured birthweight within 72 hours of birth) and the imputed birthweight model (including children without measured birthweight within 72 hours of birth), similarly LAZ for children with measured birthweight available, and LAZ for everyone, and similarly the WAZ models. CIs are provided in parentheses set at the 95% level of confidence. The strength of the associations between the independent variables and study outcomes are represented at three levels: $p < .05$

[**], p < 0.01 [***], and p < 0.1 [*], although results with p < 0.1 will not be summarised or discussed. Robust standard errors were used for all the regressions.

Overall, in a model which did not control for year of birth for the reduced sample, measured birthweight appeared to be negatively associated with the pre-lean season (September-November) and the lean season (December-April) vs. the harvest/post-harvest season (May-August, which was the base category). However, the results were not statistically significant (results not shown in a table). In Table 4.4, after controlling for year of birth and other covariates, the seasonal variations coefficients became statistically significant and their sizes were consistently larger for the lean season vs. the harvest/post-harvest season in the reduced sample, birthweight model. There were strong associations between the lean season vs. the harvest/post-harvest and all the birth outcomes (p < 0.01). In Table 4.5, the model for imputed birthweight (n = 111) had similar results to the reduced sample using measured birthweight (n = 989) but with a lower (i.e. smaller in absolute size) effect size of the lean season vs. the harvest/post-harvest season. The lean season vs. the harvest/post-harvest season produced negative effects on LAZ and WAZ (p < 0.01) as did the pre-lean season vs. the harvest/post-harvest season but only for WAZ (p < 0.05).

Of the covariates, only child sex, maternal height, and primiparity were statistically significant with primiparity variables producing the largest effect sizes in the large-sample models (Table 4.4 and Table 4.5). On average, baby girls were longer but weighed less than baby boys. Taller mothers, on average, had longer and heavier babies while primiparous women were more likely to have smaller-sized babies compared to multiparous women.

4.3.3 Other results

All the joint-significance tests conducted for the birth outcomes models produced statistically significant results [namely, measured birthweight: $F_{(2, 976)}$, p = 0.003; LAZ: $F_{(2, 938)}$, p = 0.037) for the reduced samples (namely, imputed birthweight: $F_{(2, 1098)}$, p = 0.013; LAZ: $F_{(2, 1049)}$, p = 0.023; WAZ: $F_{(2, 1014)}$, p = 0.002) for the full samples.

Therefore, we reject the null hypotheses that the regression coefficients for the seasonal effects variables (harvest/post-harvest season, pre-lean season, and the lean season) were equal to zero for the reduced samples and full samples. This means that seasonality matters for determining birth outcomes in this study.

4.4 Discussion

In the regression models, children born in the lean season fared significantly worse compared to children born in the harvest/post-harvest season but only after first controlling for year of birth and seasonal-invariant variables. This result suggests that birth size worsened due to environmental changes occurring in the lean season vs. in the harvest/post-harvest season with modest clinical significance. The results appear to show, approximately, a -7 mm difference in neonatal length, a -100g difference in neonatal weight, and a -97g difference in imputed birthweight between babies born in the lean season and babies born in the harvest/post-harvest season. The findings agree with the existing literature that in African birth cohorts, a range of birth outcomes worsen significantly more in the lean season compared to other time periods (Maleta et al., 2003; Mathule et al., 2005; Neufeld et al., 1999; Rayco-Solon et al., 2005). However, the dry season which coincides with the harvest/post-harvest season leads to more favourable pregnancy outcomes because maternal labour decreases and food stocks are replenished (Neufeld et al., 1999), especially in unimodal rainy seasons (Kigutha, 1994).

In the monthly time series for all the birth outcomes, the peaks of both actual and mean imputed birthweight, mean LAZ, and mean WAZ all occurred three months into the cold and dry (harvest/post-harvest) season, while the nadirs occurred mainly in the hot and wet (lean) season. Notably, towards the end of the RCT, September 2012-February 2013, all the monthly mean birthweights were above 3000 g, a trend for which there is no viable explanation. The average birthweight during this period is almost comparable to developed countries [birthweight > 3000g] (Mathule et al., 2005). The finding suggests that there was an unmeasured (unobserved) effect during the clinical trial, which systematically affected the pregnant women and their unborn as the RCT neared the end. This puzzling result could be linked to improvement in maternal health. However, improved health would not have just affected a part of the cohort since all mothers who fell ill during their pregnancies had free access to, not so very good but available, primary health care. Alternatively, the participants were treated at fee-charging private and semi-public clinics and reimbursed for treatment and prescriptions costs by the RCT.

In terms of the rainfall patterns between 2010-2013, there was consistently a shortage of -100 mm of annual rainfall in Mangochi District except for some selected areas in 2011-2012 [see Appendix E (E1-E3). In terms of the rainfall patterns affecting birth outcomes, between 2010-2013, there was consistently a shortage of -100 mm of annual rainfall in Mangochi District except for some selected areas in 2011-2012, which had an overage of +100 mm to +200 mm of rainfall above the expected annual average rainfall [see Appendix E (E1-E3). As such, the rainfall pattern would have been relatively worse at the beginning and towards the end of the trial. Overall, there was a mixture of poor and good rainfall in 2012. If anything, children born in October 2012-February 2013 relative to children born before October 2012, children born after October 2012 should have been as badly off, assuming the harvest was not very good that year.

Finally, the results from the joint-tests of significance for the seasonal effects variables were statistically significant. This means that seasonality matters for birth outcomes in this study.

Inevitably, this present study faced limitations and challenges present in other seasonality of birth studies (Ramachandran, 2002). First, the analyses were limited to infants with recorded DoB (n = 1319) and, thus, approximately 6% of the sample was not included in the analyses, increasing the risk of selection bias, and reducing the power of the sample. Second, the contracted sample problem was compounded by the clinical trial not possessing the full datasets for the children, particularly, in the reduced samples for LAZ (n = 899), and birthweight model (n = 989) and not much better for the imputed LAZ, WAZ, and birthweight models (n = 1027, 1111, and 1018, respectively). Third, a reduced sample, which somewhat decreased the statistical power of the study. Fourth, imputed birthweight based on non-Malawi reference populations [see (WHO Multicentre Growth Reference Study Group., 2006)] may have weakened the consistency of the results; however, in the present study, the estimated parameters for imputed birthweight were not that different from measured birthweight. Moreover, the disadvantages of having a reduced sample size (e.g., reduced sample size power) may be offset by the type of measurements used for the outcomes (e.g., continuous variables vs. binary variables) (Chin, Internet).

4.5 Conclusion

The present study examined the seasonal effects on birth size of children from predominantly rural Malawi. The present study found that seasonal effects were important in influencing birthweight, LAZ, and WAZ, especially in the lean season vs. the harvest/post-harvest season. Offspring size was more likely to be smaller on average when childbirth occurred during the rainy season vs. the harvest/post-harvest season, since during the rainy season their mothers were more likely to expend more energy tending to field (Mathule et al., 2005) and were more susceptible to malaria infections (Guyatt & Snow, 2004; Mathule et al., 2005; Rayco-Solon et al., 2005). Overall, the results showed that birthweight was predisposed to larger seasonal variations than birth length (measured in Z-score).

In conclusion, the results of the present study confirm what is in the literature that birth during the lean or the pre-lean season compared to the harvest/post-harvest season is associated with compromised fetal growth. All factors being equal, the harvest/post-harvest season in a year with adequate rainfall would provide more caloric energy from maize, a food staple common to Southern Africa (Haggblade, 2007). The vulnerable time points for pregnant women in this study were related to birth in the lean season and (therefore, some third-trimester exposure in the pre-lean season). Therefore, future seasonality of birth assessments could incorporate prenatal supplementation with SQ-LNS from the RCT linked to this study to assess its impact on seasonality of birth outcomes compared to prenatal supplementation with IFA in rural Malawi.

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[1] Lesotho is different from countries closer to the tropics or with bimodal weather because it experiences continental weather including quite cold, snowy winters and hot, humid, and rainy summers, however the lean months are still impactful (SADC, 2012).

[2] Moving average formula: $(1/6) * [x(t-3) + x(t-2) + x(t-1) + x(t) + x(t+1) + x(t+2)]$; $x(t)$ = mean study outcomes. The moving average for 6 months is calculated using the sum of the mean of three lagged months from the current observed mean, the current observed mean, and the mean of two leading months from the current observed mean and by dividing the total sum by six (Stata.com., Internet).

Figure 4.1: Mean Measured and Imputed Birthweights by Month

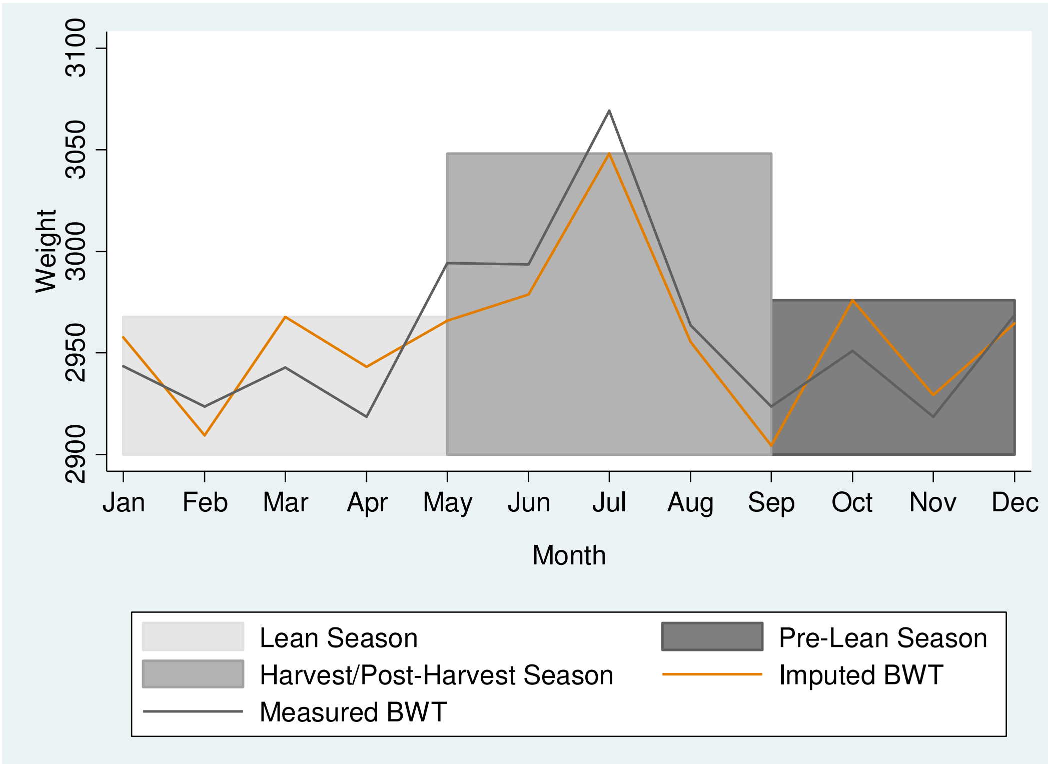

Figure 4.2: Mean Measured Birthweight by Month of Birth

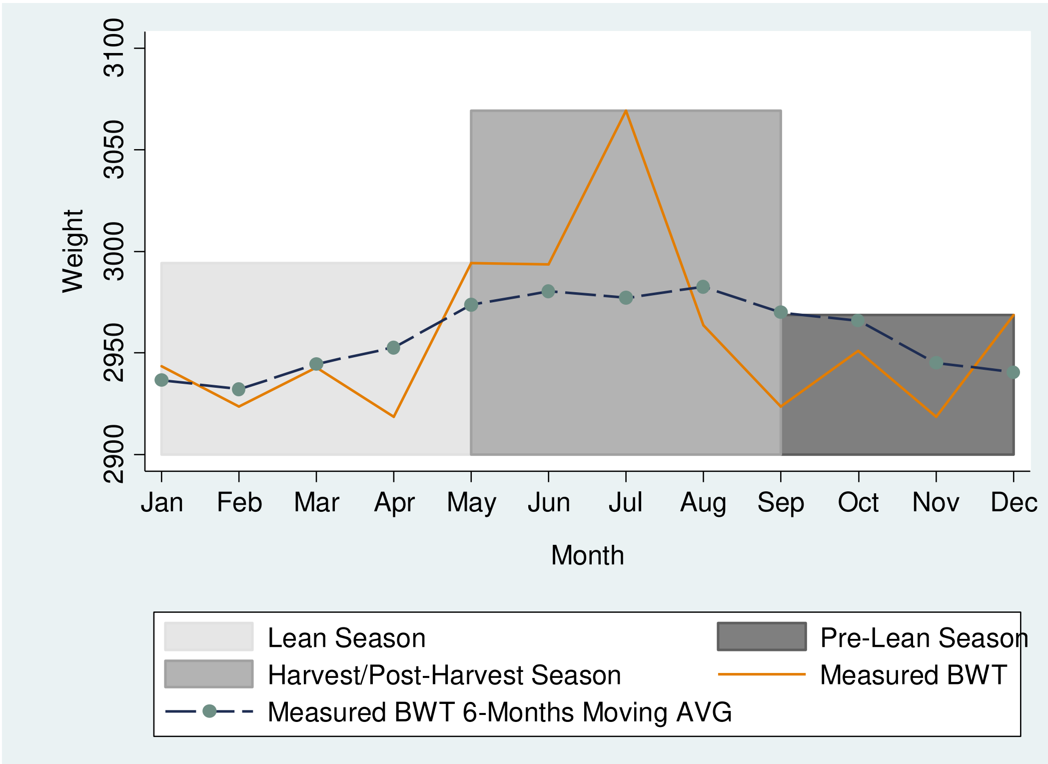

Figure 4.3: Mean Imputed Birthweight by Month of Birth

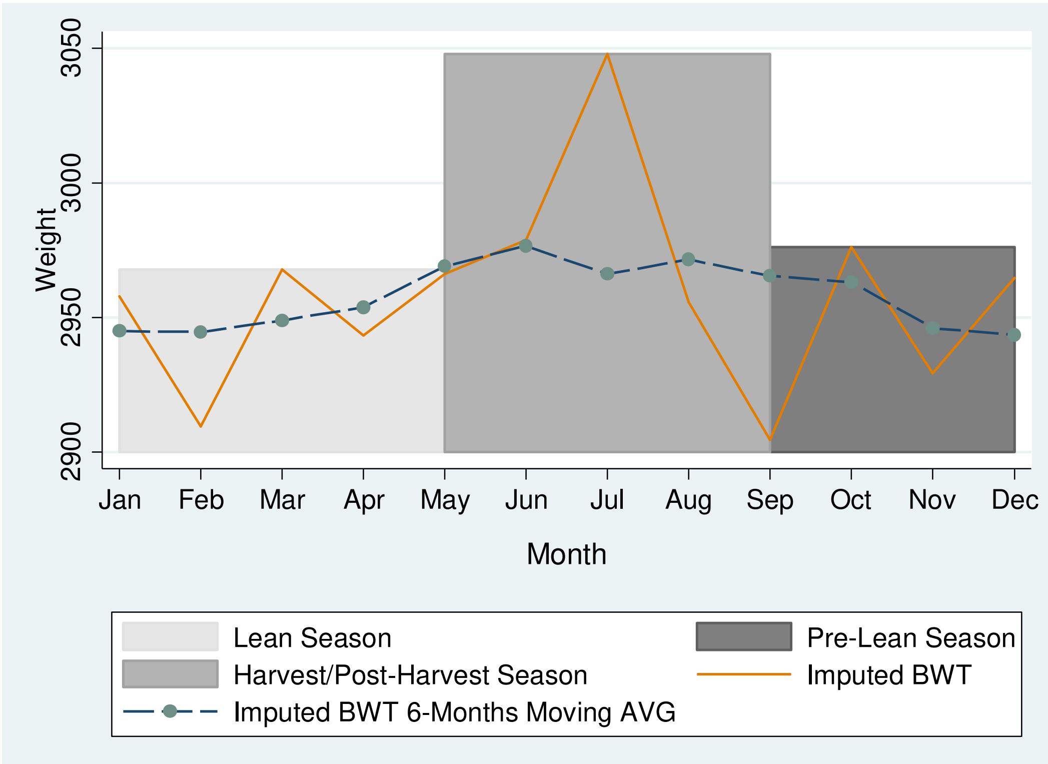

Figure 4.4: Mean LAZ by Month of Birth

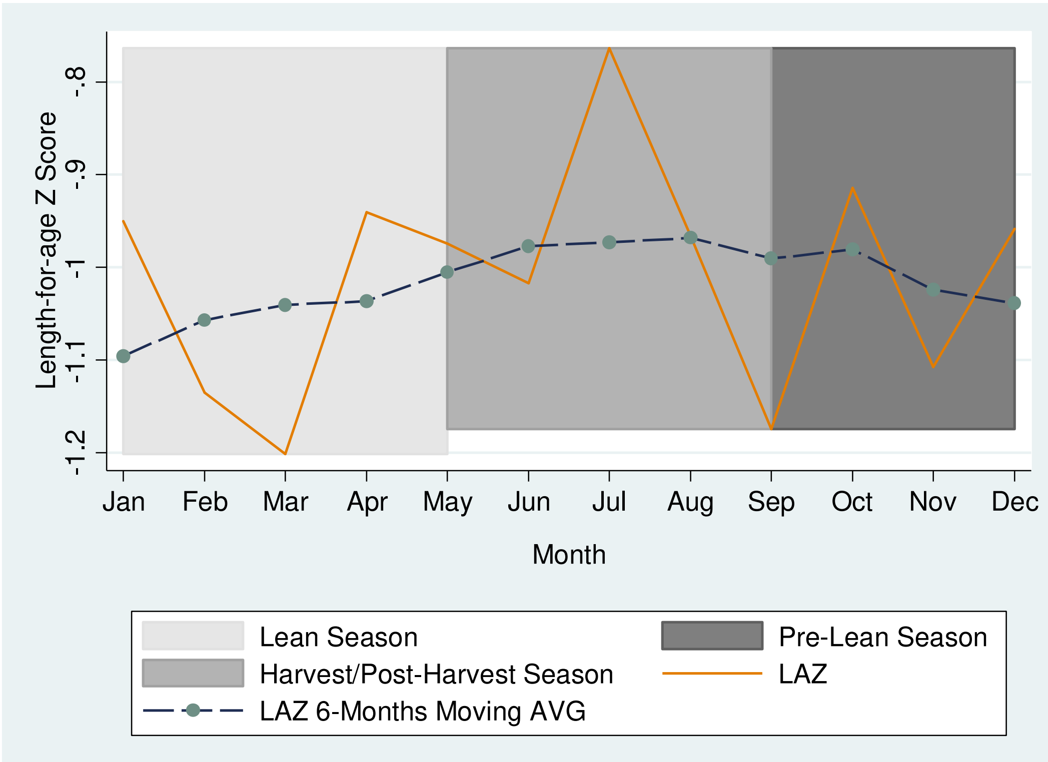

Figure 4.5: Mean WAZ by Month of Birth

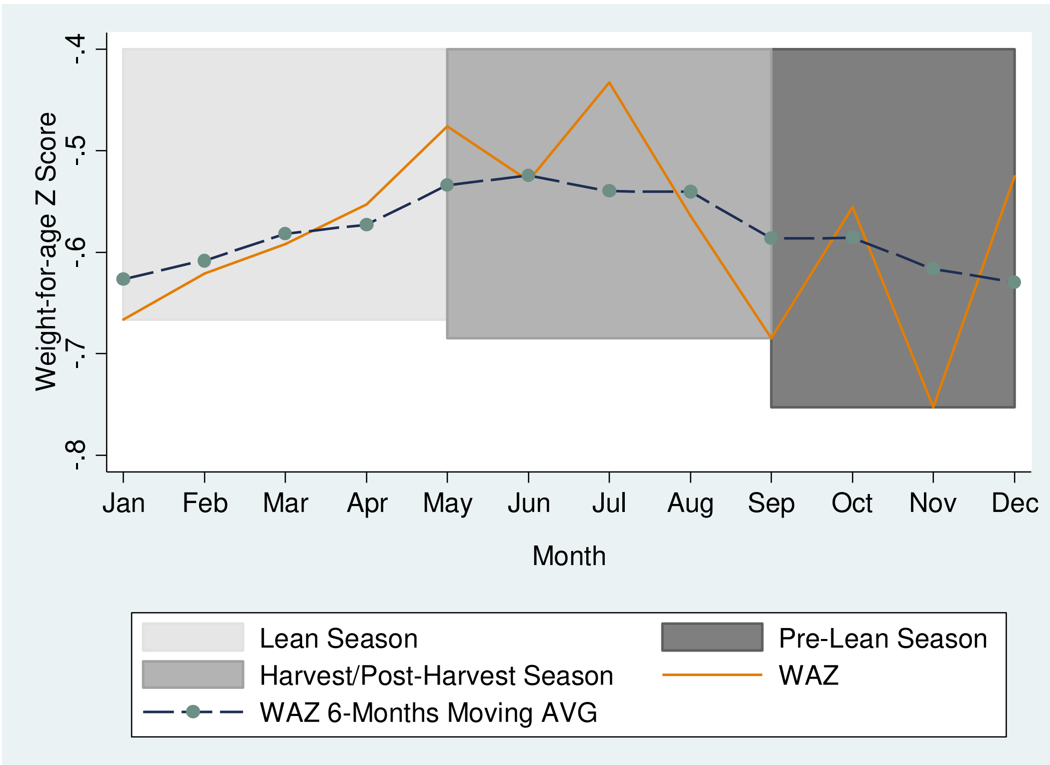

Table 4.1: Summary Statistics of Outcome and Independent Variables

Variables	Mean (SD) n (%)	Min	Max	Total n n/N
Measured Mean Birthweight[a]	2968.39 (437.39)	1,100	4,315	1,020
Mean Imputed Birthweight[b]	2970.21 (446.69)	1,100	4,315	1,144
Mean Length-for-age Z Score (Reduced)[c]	-0.967 (1.10)	-6.52	2.13	890
Mean Length-for-age Z Score (Full)[d]	-0.99 (1.13)	-6.52	2.13	1,045
Mean Weight-for-age Z Score[e]	-0.55 (1.02)	-6.00	2.42	1,054
Lean Season	368 (28.48)			368/1295
Pre-Lean Season	536 (41.39)			536/1295
Harvest/Post-Harvest Season	391 (30.19)			391/1295
Maternal Education (yr)	3.97 (3.43)	0	12	1278
Maternal Height (cm)	156 (5.66)	133	176	1291
Food Insecurity Access Scale	4.94 (4.48)	0	27	1272
Household Asset Index (Z Score)	-.017 (0.99)	-0.73	3.3	1,275
Child sex (male)	609 (48.72)			609/1250
Mother HH	91 (7.03)			91/1295
Primiparous	272 (21.04)			272/1293

Notes:

[a, b, c, d, e] Measured according to the WHO 2006 Child Growth Standards (WHO Multicentre Growth Reference Study Group., 2006)

N = 1295

Table 4.2: Mean Imputed Birthweight by Year and Month of Birth

Year and Month of Birth	Mean	SD	N
2011			
July	2632.18	741.92	6
August	2806.58	483.60	14
September	2611.93	637.33	23
October	2882.13	361.51	33
November	2799.02	511.06	48
December	2888.21	522.89	68
2012			
January	2895.76	356.66	66
February	2900.62	505.29	76
March	2967.70	502.11	94
April	2943.26	441.00	64
May	2966.01	398.80	81
June	2978.83	450.51	77
July	3084.73	449.61	68
August	2979.28	452.60	88
September	2987.49	436.84	81
October	3013.79	393.17	82
November	3014.90	399.59	73
December	3031.40	438.25	78
2013			
January	3065.46	459.61	38
February	3044.00	246.74	5

Table 4.3: Mean Measured and Imputed Birthweight Collapsed by Month of Birth

Variables	Month	Mean	SD	Min	Max	N
Measured Birthweight	January	2943.54	412.70	1820	4260	94
Imputed Birthweight		2957.77	403.61	1820	4260	104
Measured Birthweight	February	2923.52	432.23	1860	3940	66
Imputed Birthweight		2909.47	493.56	1212.12	4036.46	81
Measured Birthweight	March	2943.04	485.99	1400	4050	84
Imputed Birthweight		2967.70	502.11	1400	4166.67	94
Measured Birthweight	April	2918.73	418.47	1740	3765	55
Imputed Birthweight		2943.26	441.00	1740	3857.14	64
Measured Birthweight	May	2994.16	358.43	1860	3950	73
Imputed Birthweight		2966.01	398.80	1308.08	3950	81
Measured Birthweight	June	2993.54	440.31	1325	3900	65
Imputed Birthweight		2978.83	450.51	1325	3900	77
Measured Birthweight	July	3069.19	475.19	1600	4315	65
Imputed Birthweight		3048.04	488.57	1600	4315	74
Measured Birthweight	August	2963.69	430.19	1100	3902.50	91
Imputed Birthweight		2955.57	458.39	1100	4052.08	102
Measured Birthweight	September	2923.55	493.00	1200	4050	95
Imputed Birthweight		2904.43	509.42	1200	4050	104
Measured Birthweight	October	2951.05	390.16	1940	3805	101
Imputed Birthweight		2976.01	387.42	1940	3805	115
Measured Birthweight	November	2918.73	465.26	1335	4125	112
Imputed Birthweight		2929.26	457.55	1335	4125	121

Variables	Month	Mean	SD	Min	Max	N
Measured Birthweight	December	2968.74	491.75	1400	4300	135
Imputed Birthweight		2964.71	483.18	1400	4300	146

Table 4.4: Regressions of Seasonality of Measured Birthweight and Infant LAZ (Reduced Samples)

Variables	(1) Model: BWT	(2) Model: LAZ
Birth from Sep-Nov[a]	-54.342*	-0.114
	(-116.260 , 7.575)	(-0.268 , 0.041)
Birth from Dec-Apr[b]	-115.344***	-0.227**
	(-183.043 , -47.646)	(-0.407 , -0.048)
2012.yearofbirth[c]	152.877***	0.204**
	(74.817 , 230.938)	(0.002 , 0.405)
2013.yearofbirth[d]	301.247***	0.638***
	(137.784 , 464.710)	(0.215 , 1.061)
Child sex (girl)	-91.925***	0.149**
	(-144.109 , -39.741)	(0.015 , 0.284)
Maternal education	1.712	0.016
	(-7.282 , 10.706)	(-0.008 , 0.041)
Maternal height	18.059***	0.059***
	(13.378 , 22.740)	(0.046 , 0.072)
Head of household (mother)	-85.808	-0.228
	(-215.399 , 43.784)	(-0.580 , 0.124)
HH food insecurity access scale	2.138	0.008
	(-3.730 , 8.006)	(-0.009 , 0.024)
HH asset index Z score	8.061	0.005
	(-24.285 , 40.407)	(-0.074 , 0.083)
Primiparous	-149.520***	-0.428***
	(-220.468 , -78.572)	(-0.604 , -0.251)
Constant	126.646	-10.374***
	(-604.490 , 857.783)	(-12.472 , -8.276)
N	988	950
R-squared	0.115	0.137
F	11.76	12.78
Adjusted R-squared	0.105	0.126

Notes:

[a, b] The base category was Birth from May-August

[c, d] The base category was child birth year of 2011

Outcomes: BWT – birthweight, LAZ - length-for-age Z score

HH - household,

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Table 4.5: Regressions of Seasonality of Imputed Birthweight, Infant LAZ and Infant WAZ (Full Samples)

Variables	**(1) Model: Imputed BWT**	**(2) Model: LAZ**	**(3) Model: WAZ**
Birth from Sep-Nov[a]	-45.835	-0.124	-0.162**
	(-105.270 , 13.601)	(-0.275 , 0.028)	(-0.309 , -0.014)
Birth from Dec-Apr[b]	-97.403***	-0.226***	-0.253***
	(-163.598 , -31.207)	(-0.394 , -0.058)	(-0.402 , -0.104)
2012.yearofbirth[c]	149.650***	0.204**	0.392***
	(73.849 , 225.451)	(0.006 , 0.402)	(0.207 , 0.577)
2013.yearofbirth[d]	284.609***	0.602***	0.548***
	(130.373 , 438.845)	(0.200 , 1.004)	(0.182 , 0.915)
Child sex (girl)	-93.355***	0.139**	0.038
	(-143.719 , -42.991)	(0.011 , 0.268)	(-0.082 , 0.157)
Maternal education	-0.468	0.014	0.008
	(-9.135 , 8.199)	(-0.009 , 0.036)	(-0.013 , 0.028)
Maternal height	17.368***	0.050***	0.039***
	(12.664 , 22.073)	(0.038 , 0.063)	(0.027 , 0.051)
Head of household (mother)	-101.386	-0.282*	-0.422***
	(-225.499 , 22.727)	(-0.608 , 0.044)	(-0.723 , -0.122)
HH food insecurity access scale	4.327	0.009	0.013*
	(-1.423 , 10.076)	(-0.007 , 0.025)	(-0.001 , 0.027)
HH asset index Z score	11.841	0.013	0.057
	(-20.219 , 43.900)	(-0.063 , 0.089)	(-0.017 , 0.130)
Primiparous	-151.514***	-0.449***	-0.467***
	(-217.880 , -85.148)	(-0.615 , -0.284)	(-0.622 , -0.311)
Constant	232.982	-9.022***	-6.855***

Notes:

[a, b] The base category was the period May-August (harvest/post-harvest season)

[c, d] The base category was child birth year of 2011

	(-504.739 , 970.703)	(-11.040 , -7.003)	(-8.699 , -5.010)
N	1,110	1,061	1,026
R-squared	0.103	0.114	0.123
F	11.74	12.00	12.34
Adjusted R-squared	0.0942	0.105	0.114

Notes:

Outcomes: Imputed BWT – birthweight, LAZ - length-for-age Z score, WAZ - weight-for-age Z score

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

Chapter 5

Conclusion and Policy Recommendations

5.1 Background of the Thesis

The field of early life adversity and health outcomes is not new. Previous studies have examined the impact of early life adversity on adult health and nutritional status. The context of early life adversity has included (civil) war (Domingues & Barre, 2013), embargos, sanctions, and sieges (Lumey et al., 2011), man-made famines, e.g., food shortages due to poor government planning (Gørgens et al., 2012), drought/ rainfall/ flood-related famines (Kumar et al., 2016), and the lean seasons in agriculture-dependent communities (Neufeld et al., 1999). Furthermore, the long-term impacts of maternal early life adversity on offspring's health outcomes and nutritional status have been well documented (Gørgens et al., 2012; Lumey, 1992; Ramakrishnan et al., 1999) although with much less evidence for maternal exposure in early childhood (Rickard et al. 2012, Fung & Ha, 2010).

Several studies have focused on the dyad of mother and child health and assessed interventions with LNS that supplemented the diets of expectant mothers, lactating mothers, and their young children (Adu-Afarwuah et al., 2007; Ashorn et al., 2015b; Iannotti et al., 2014; Mangani et al., 2015; Phuka et al., 2009). None, however, have combined the intergenerational effects of maternal exposure to drought in early life with prenatal supplementation and assessed the combined impact on offspring's birth outcomes. Based on the conceptual frameworks described in Chapter 1 (see section 1.2.3 and Figures 1.1 and 1.5), this thesis combined the two topics by taking advantage of a natural experiment in Malawi from the 1981/82, 1987/88, and 1992/93 droughts and drew from the data of a single-blind RCT in Malawi that tested the efficacy of prenatal supplementation with SQ-LNS vs IFA and MMN vs. IFA on birth outcomes.

One of the grounding theories for the research was Barker's hypothesis of the fetal origins of health and disease and the consequent intergenerational transmission of prenatal nutritional deficits and poor health. The theory laid the foundation for Chapter 2 which assessed the impact of maternal exposure to drought *in utero* vs. non-drought exposure *in utero*. The thesis reported on the *in utero* effects first because the life course experience begins prenatally during which maternal effects influence the intrauterine conditions and prepare the unborn for different trajectories in life. The trajectories are related to long-term health and may determine how productive the individual will be physically, educationally, socially, and economically (Alderman 2006).

While studies on *in utero* effects are numerous for animal studies and human studies, the dimension of prenatal supplementation with LNS is lacking. This gap in knowledge is where the present thesis can contribute to the literature.

5.2 Summary of Findings and Conclusions

5.2.1 Findings and Conclusions

The main aim of this thesis was to estimate the direct effect of maternal exposure to drought in early life on infant LAZ, infant WAZ, and birthweight as birth outcomes. Maternal drought exposure occurred at two levels:

(1) While the mother was growing *in utero*; or,

(2) When the mother was already born, from age 0-5 yr and, in a narrower age group context, at age 0-2 yr or age 3-5 yr.

The second aim was to test Martorell and Zongrone (2012)'s theory that intergenerational factors may contribute to programme failure or the ineffectiveness of interventions in resource-poor settings.

The third aim of this thesis was to estimate the seasonality of birth outcomes due to maternal exposure to periods of food insecurity during pregnancy (e.g., the lean season in the rainy months vs. the harvest season during the dry months).

In **Chapter 2**, this thesis investigated whether maternal exposure to drought *in utero* associated with three poor birth outcomes in rural Malawian offspring. We also examined whether SQ-LNS vs. IFA moderated the intergenerational effects of maternal exposure to drought *in utero* vs. non-drought exposure *in utero* in rural Malawian offspring. The findings in **Chapter 2** suggest that when regressions were first adjusted by baby's sex, maternal characteristics and socio-economic variables in the restricted model, the effects of maternal exposure to drought *in utero* by trimesters on birth outcomes were small and not statistically significant. Notably, adjusted for trial supplements variables and the other covariates, the direction of associations between the outcomes and the exposure variables and covariates remained mostly unchanged in the expanded model. However, among mothers exposed to drought during the first trimester *in utero,* prenatal supplementation with MMN appeared not to improve infant WAZ and birthweight compared to prenatal supplementation with IFA. Sensitivity analysis results added infant LAZ into the mix of significant outcomes while the associations became stronger but still negative for all the outcomes.

We can, therefore, conclude that the study in **Chapter 2** found some indication that maternal exposure to drought during the second-third adjusted for baby's sex, maternal effects and socio-economic variables increased imputed birthweight in offspring of rural Malawian mothers. The rest of the associations between the maternal *in utero* exposure to drought variables and birth outcomes were positive but not significant contrary to Barker's hypothesis fetal origins of health and disease. Next, prenatal supplementation with SQ-LNS did not moderate the intergenerational effects of maternal exposure to drought *in utero* in rural Malawian offspring as expected compared to prenatal supplementation with IFA. Some possible explanatory factors of the lack of expected results were that the present study was underpowered to detect effects within the different drought exposure sub-groups and the interacted variables

In the next chapter, the thesis investigated whether maternal exposure to any of the droughts (1981/82, 1987/88, or 1992/93) at ages 0-5 yr, 0-2 yr, or 3-5 yr vs. postnatal non-drought exposure was associated with poor negative outcomes in rural Malawian offspring. We also assessed whether SQ-LNS vs. IFA moderated the intergenerational effects of maternal exposure to drought at ages 0-5 yr, 0-2 yr, or 3-5 yr vs. postnatal non-drought exposure in rural Malawian offspring. The findings in **Chapter 3** showed that maternal exposure to any of the droughts at age 0-5 yr produced relatively small to very small and statistically non-significant effects, adjusted for baby's sex, maternal effects, and socio-economic variables in the restricted model. Despite adding the trial supplements variables to the covariates in the expanded model, the effects did not change significantly. Notably, maternal exposure to the drought of 1981/82 at age 0-5 yr was negatively associated with all the birth outcomes.

The rest of the associations for maternal exposure to any drought in the narrower age groups (0-2 yr and 3-5 yr) and the birth outcomes were inconsistent with the stated hypotheses because there were mostly positive associations, controlling for baby's sex, maternal effects, and socio-economic variables. Moreover, there were no statistically significant associations observed. Further adjustments of the models for trial supplements did not produce statistically significant positive associations between maternal exposure to drought at age 0-2 yr and age 3-5 yr vs.

postnatal non-drought exposure and infant WAZ. However, among mothers not exposed to drought postnally, infants whose mothers received SQ-LNS had significantly improved birth outcomes compared to infants whose mothers received IFA , consistent with the results obtained for the *in utero* effects in **Chapter 2**, although they were statistically and clinically non-significant **in Chapter 2**. Also, the models for the interactions of postnatal non-drought exposure and SQ-LNS were severely underpowered to detect an effect in **Chapter 3**. Conversely, prenatal supplementation with SQ-LNS did not improve infant WAZ and birthweight in offspring of mothers exposed to drought at age 0-2 yr compared to prenatal supplementation with IFA. Similarly, prenatal supplementation with LNS did not improve WAZ in offspring of mothers exposed to drought at age 3-5 yr compared to prenatal supplementation with IFA**.**

Thus, the theory by Martorell and Zongrone (2012) that intergenerational effects may not easily be "washed out" by (improved) nutritional interventions in resource-poor settings vis-à-vis rich countries appears to be supported by the interactions reported in Chapters 2 & 3 since prenatal supplementation with SQ-LNS (compared to IFA) or MMN (compared to IFA) did not improve birth size, among mothers exposed to drought *in utero* or postnatally.

Finally, seasonal variations in the timing of birth were investigated to find out whether or not they negatively influenced birth outcomes in rural Malawian children. The findings in **Chapter 4** suggest that birth during the lean season led to a lower weight and length (transformed to a Z score) for the reduced sample measured very close to birth (up to 72 hours) compared to birth during the harvest/post-harvest season. When the outcomes with a larger measurement window of up to 6 days for imputed birthweight and 42 days for infant WAZ and infant LAZ in the larger samples, the results remained significant and did not change in terms of direction of associations.

We can, therefore, conclude and confirm what is known in the literature that seasonal variations in the timing of birth negatively influences a variety of birth outcomes in rural Malawian children and in rural children from other African countries, especially in the lean season compared to the harvest and/or the post-harvest seasons.

5.2.2 Theoretical Contributions

This thesis studied the direct effects of maternal exposure to drought *in utero* and in the first few years of life in resource-poor and rural settings dependent on agriculture. This research is part of the broader research on the impact of drought exposure on health outcomes (Stanke, 2013). The research also fits in with emerging research on the impact of multiple exposures to drought in different settings (desert, agricultural, or more temperate) such as in California (USA), whereby multiple exposures to drought have been more frequent due to climate change (Balbus, 2017).

First, the thesis hypothesized that there would be intergenerational effects on birth outcomes from maternal exposure to drought *in utero* and in early childhood. Second, the thesis hypothesized that prenatal supplementation would offset any intergenerational effects of maternal exposure to drought *in utero* or in early childhood on birth outcomes. The human body may respond to severe household food insecurity associated with adverse birth outcomes via changes that become embedded "under the skin" (Epel, 2011). As per Barker's hypothesis of the fetal origins of health and disease, plasticity is a dynamic response to external stress at the cellular level, which causes phenotypic changes to genes and subsequent physical structure while maintaining the programmed DNA sequence (Barker, 2001; Barnes et al., 2016). These epigenetic modifications occur for the survival of the individual in the short term but at the cost of longevity for the individual in the long term (Barker, 2001). In the short term, blood glucose (energy) and nutrients are diverted to accelerate brain development during organogenesis and fetal development. In the long term, the affected individual has an increased risk of adult cardiometabolic diseases related to the *in utero* suppression of metabolic functions of some organs such as the pancreas, livers, and kidneys (*ibid*). This response mechanism to adapt to future environments by modifying the present environments around gene functions is called the predictive adaptive response (PAR) (Barker, 2001). Further, epigenetic activities in response to external stressors changes the emphasis of the expression of genes; hence, either resilience or lack of resilience to future stress will be an environmental outcome (Cutfield et al., 2007; Hivert et al., 2013; Jang & Serra, 2014).

Unfortunately, early life adversity can be passed on intergenerationally via epigenetic processes even when "normal" household food security is restored (Akresh et al, 2017; Lumey et al., 2011; Fu & Ha, 2010), and in some cases, irrespective of the intensity and duration (or brevity) of the early life adversity (Rickard et al., 2016). This intergenerational phenomenon has been observed in studies on the three famines from three different continents, but which were similar in several ways. For example, the famines of The Netherlands (1944-45), China (1959-61), and Nigeria (1967-68) were either directly an outcome of war [namely, the trade embargo in World War II and the Biafran War food blockade] (Lumey, 2011; Akresh et al., 2017), or a consequence of detrimental policymaking regarding food distribution [Great Chinese Famine and the Biafran War food blockade] (Gørgens et al, 2012; Akresh et al., 2017]. Also, the famines had, overall, high mortality rates (excess death rates) with millions of deaths reported, which included child mortality (Lumey, 2011; Gørgens et al, 2012; Akresh et al., 2017). In contrast, intergenerational effects were not observed in the Malawi study probably due to the lower severity of the droughts. Further, it may be the case that multiple exposures to recurring mild-moderate droughts over the life course in Malawi (as opposed to single exposures *in utero* or in early childhood) may have led to epigenetic modifications which encouraged resilience and produced a protective effect intergenerationally passed on to drought unexposed offspring.

Despite the methodological limitations of the studies in this research, some of the new findings appeared to confirm the proposed theory about the effects of prenatal supplementation although not in the direction of magnitude. Notably, it was IFA (the standard of care) that had a larger and positive effect on birth outcomes not SQ-LNS (the new treatment) among mothers exposed to drought during the first trimester. While the effects of the interactions between maternal exposure to drought and prenatal supplementation are more challenging to explain, it appeared that the offspring of mothers exposed to drought i*n utero* were less responsive to the macronutrients and numerous micronutrients in SQ-LNS compared to IFA with only two micronutrients. In the literature, prenatal supplementation with SQ-LNS has not conclusively led to better outcomes than prenatal supplementation with IFA (Adu-Afarwuah et al., 2015; Ashorn et al., 2015a) but in some instances, it has fared better than MMN (Toe et al., 2015), which suggests that the macronutrient components mixed together with the MMN component in SQ-LNS increases the effect size on birth outcomes.

Of course, the observations for the impact of maternal exposure to drought *in utero* and in early childhood and their interactions with prenatal supplements have been emphasized because they tie in to the thesis' hypotheses. However, there were other important predictors of offspring outcomes such as maternal physiology variables that either negatively impacted the studies' birth outcomes [e.g., primiparity (Dreyfuss et al., 2001)] or positively influenced infant growth [e.g., maternal height (Fung & Ha, 2010; Kramer, 1987)], if the mother was taller. Thus, the evidence shows that primiparous women are a subgroup in need of special attention due their increased vulnerability since they are likely to experience their first pregnancies probably in food insecure environments compounded by drought effects. Moreover, because the studies also showed a link between increased maternal height and improved infant nutritional status (i.e., higher LAZ and WAZ) in rural Malawi, interventions that promote linear growth should be prioritized since, according to UNICEF (2016), there is a high prevalence of stunting of preschoolers in Malawi.

In sum, the famines were unprecedented events borne from geopolitical forces whereas the droughts in Malawi were meteorological with a higher likelihood of recurrent moderate drought in future cropping cycles. Therefore, there was an aspect of predictability in Malawi vs. unpredictability in The Netherlands, China, and Nigeria with more widespread adverse outcomes present in the latter countries associated with increased stress in affected households. Although there was a severe drought in Malawi (1992/93) with some areas experiencing marked levels of starvation (e.g., in Nsanje District but not Mangochi District), there were strong mitigating factors such government-led and bilateral donor agencies food relief (Babu & Chapasuka, 1997).

5.3 Implications and Policy Recommendations

Early life adversity and stress have long-term implications for individuals and communities. Stress and hardship create less stable environments which lead to poor health outcomes for children and inequitable access to human capital formation (Barnes et al., 2016). The *in utero* effects on birth size (as defined by this thesis) from maternal exposure to drought showed that, overall, the impact of the three Malawi droughts may not have been as impactful in the intrauterine environment compared to the more severe famines in the literature. Perhaps, SQ-LNS did not perform as expected perhaps due to its small dose (20g, 118 kcal/day), which was inadequate to offset intergenerational effects in populations with low SES and exposed to other sources of food insecurity compared to IFA, in rural Malawi. Indeed, the more affluent study population of Ghana's iLiNS study bore children who were more responsive to the benefits of SQ-LNS compared to IFA. The study area in Ghana was predominantly urban with most participating households engaged in petty trading or small-scale businesses (Adams et al., 2017).

5.3.1 Recommendations

The first cautious recommendation from this research – cautious due to its limitations in sample sizes and methodology of drought derivation in this thesis – is that there may be a case to be made for supplementing food insecure pregnant women - with the smaller-sized LNS [SQ-LNS (20g daily dose with a lower supply of energy of 118 kcal/dose)] compared to IFA in the absence of droughts and famines. Nevertheless, because of contrasting circumstances (e.g., SES) and outcomes from famines and meteorological droughts suggest that there may be no “universal” model to equally address household food insecurity present in different regions and countries. Rather, more prescriptive, and specialized programmes would be required to address household food insecurity compounded by intergenerational effects of maternal life adversity, such as drought, at country-level.

In future, if additional SQ-LNS trials were to be conducted to assess pregnancy or birth outcomes in drought-prone countries like Malawi, then the next major drought to take advantage of in terms of early life maternal exposure occurred in 2002/03. To strengthen the estimated associations, the study design would require the collection of maternal data on place of birth and place of residence from age 0-5 years by way of village/city and district so that the samples would precisely include participants with the correct place of birth and place of residence from age 0-5 yr.

Also, since the literature states that pregnant women who tend to their fields during pregnancy and expend more energy than they consume daily due to nutritional challenges, an LNS study on the effects of prenatal supplementation with SQ-LNS on the seasonality of birth outcomes in rural Malawi compared to prenatal supplementation IFA could be informative.

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Appendix A

A1: Nutrient and Energy Compositions of Prenatal Supplements

Nutrient and energy contents of the dietary supplements[1]

Nutrient	IFA	MMN	LNS	US Dietary Reference Intakes[2]: AI/RDA pregnancy (19–50 y)	US Dietary Reference Intakes[2]: AI/RDA lactation (19–50 y)	US Dietary Reference Intakes[2]: UL
Ration	1 tablet	1 tablet	20-g sachet			
Total energy, kcal	0	0	118			
Protein, g	0	0	2.6			
Fat, g	0	0	10			
Linoleic acid, g	0	0	4.59	13*	13*	—
α-Linolenic acid, g	0	0	0.59	1.4*	1.3*	—
Vitamin A, μg RE	0	800	800	770	1300	3000
Vitamin C, mg	0	100	100	85	120	2000
Vitamin B-1, mg	0	2.8	2.8	1.4	1.4	—
Vitamin B-2, mg	0	2.8	2.8	1.4	1.6	—
Niacin, mg	0	36	36	18	17	35
Folic acid, μg	400	400	400	600	500	1000
Pantothenic acid, mg	0	7	7	6*	7*	—
Vitamin B-6, mg	0	3.8	3.8	1.9	2.0	100
Vitamin B-12, μg	0	5.2	5.2	2.6	2.8	—
Vitamin D, μg	0	10	10	15	15	100
Vitamin E, mg	0	20	20	15	19	1000
Vitamin K, μg	0	45	45	90*	90*	—
Iron, mg	60	20	20	27	9	45
Zinc, mg	0	30	30	11	12	40
Copper, mg	0	4	4	1	1.3	10
Calcium, mg	0	0	280	1000*	1000*	2500
Phosphorus, mg	0	0	190	700	700	3500/4000
Potassium, mg	0	0	200	4700*	5100*	—
Magnesium, mg	0	0	65	350/360[3]	310/320[3]	350
Selenium, μg	0	130	130	60	70	400
Iodine, μg	0	250	250	220	290	1100
Manganese, mg	0	2.6	2.6	2.0*	2.6*	11

[1]Where 2 values are given, the first is for pregnancy and the second is for lactation. AI, adequate intakes (denoted with an asterisk); IFA, iron and folic acid; LNS, lipid-based nutrient supplement; MMN, multiple micronutrients; RDA, Recommended Dietary Allowances; RE, retinol equivalent; UL, Tolerable Upper Intake Level; —, not determinable or data insufficient.

[2]US Dietary Reference Intakes from reference 18. Historical vitamin D and calcium Dietary Reference Intakes are from Otten et al. 2006 (19).

[3]Values for ages 19–30 y/31–50 y.

Source: Ashorn et al. (2015a, p.389)

A2: An Outline of Emergency Relief Efforts in Malawi (1992)

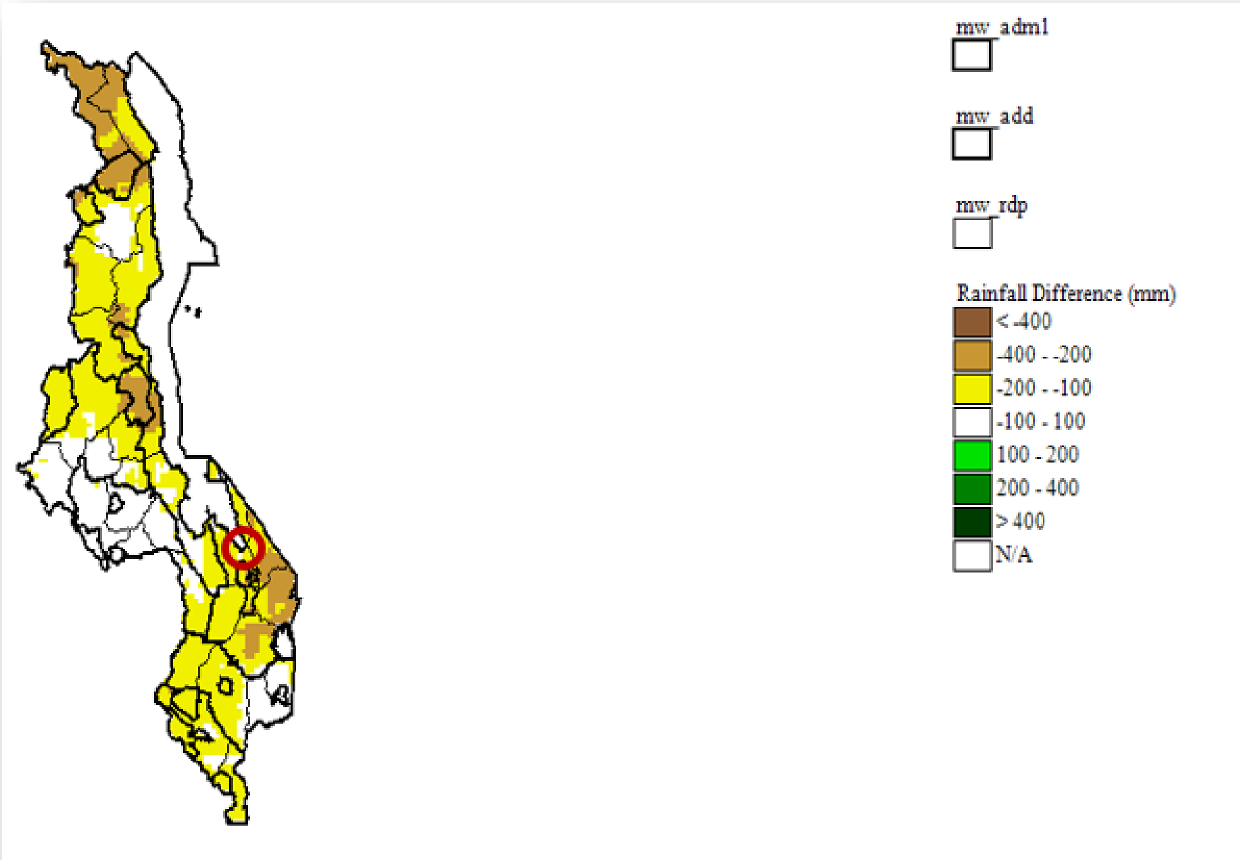
Date	Action	Outcome
10 Apr 1992	"Emergency assessment of effects of drought (United Nations report released) called for major food distribution to be jointly organized by donors under WFP coordination.	Estimated 354, 000 people affected in Nsanje district alone. Free distribution of food started in the southern part of the country.
25 Apr 1992	Nutrition subcommittee released its first report on the health and nutrition situation in the areas affected by drought.	Ministry of Health and Ministry of Agriculture jointly used the FSNM system that was already in place.
8 May 1992	Food assessment and monitoring reports from the affected areas released by the DPC.	District commissioners given the mandate for distribution of free food based on the estimates prepared by the Ministry of Agriculture through FSNM reports.
30 Jun 1992	Government of Malawi released confidential report on food security for donors.	Final crop estimates showed 59% production loss. Commercial and food aid imports begun, with 16,700 tonnes arriving in the country.
20 July 1992	Nutrition Monitoring During Drought initiated under FSNM system by the Ministry of Agriculture	About 49,000 of donor-pledged food imported so far. Strategic Grain Reserve continued to be depleted. Internal food aid distribution already underway in several districts for some months. Also seed and fertilizer distribution for the next cropping season initiated by NGOs in severely affected areas.
31 Aug 1992	Food Security Update released by the Government of Malawi	Estimated 58000 tonnes of maize delivered to rural distribution centres since May 92, most of which was distributed to the affected households.

31 Oct 1992	Food Security Update released by the Government of Malawi	Government imported an additional 28,502 tonnes of maize for the month of October, while the target for imports was 35,000 tonnes per month. Government also borrows 44,433 tonnes of maize imported as food aid for refugees for free distribution. Food aid pledges from donors for the marketing year 1992-1993 continued to be 400,000 tonnes.
15 Dec 1992	DPC meeting to review food distribution and the aftermath of the drought	Reports from various sources indicated that the food distribution programmes were implemented well, although logistical problems in some districts slowed the delivery of food. Good rains reported in all parts of the country. Earlier estimates of crop area indicated a good crop for 1992-93.
28 Feb 1993	Ministry of Agriculture released Nutrition Monitoring During Drought report	Drop of 46.9% in the rate of acute malnutrition in Nsanje, the worst affected district, compared with the previous month (Jan) indicated that food distribution had a positive impact in reducing acute malnutrition. Similar reduction in malnutrition figures reported from other districts".

Source: Babu & Chapasuka (1997, Appendix 1. Chronology of events in the management of the 1992/1993 drought in Malawi)

Appendix B

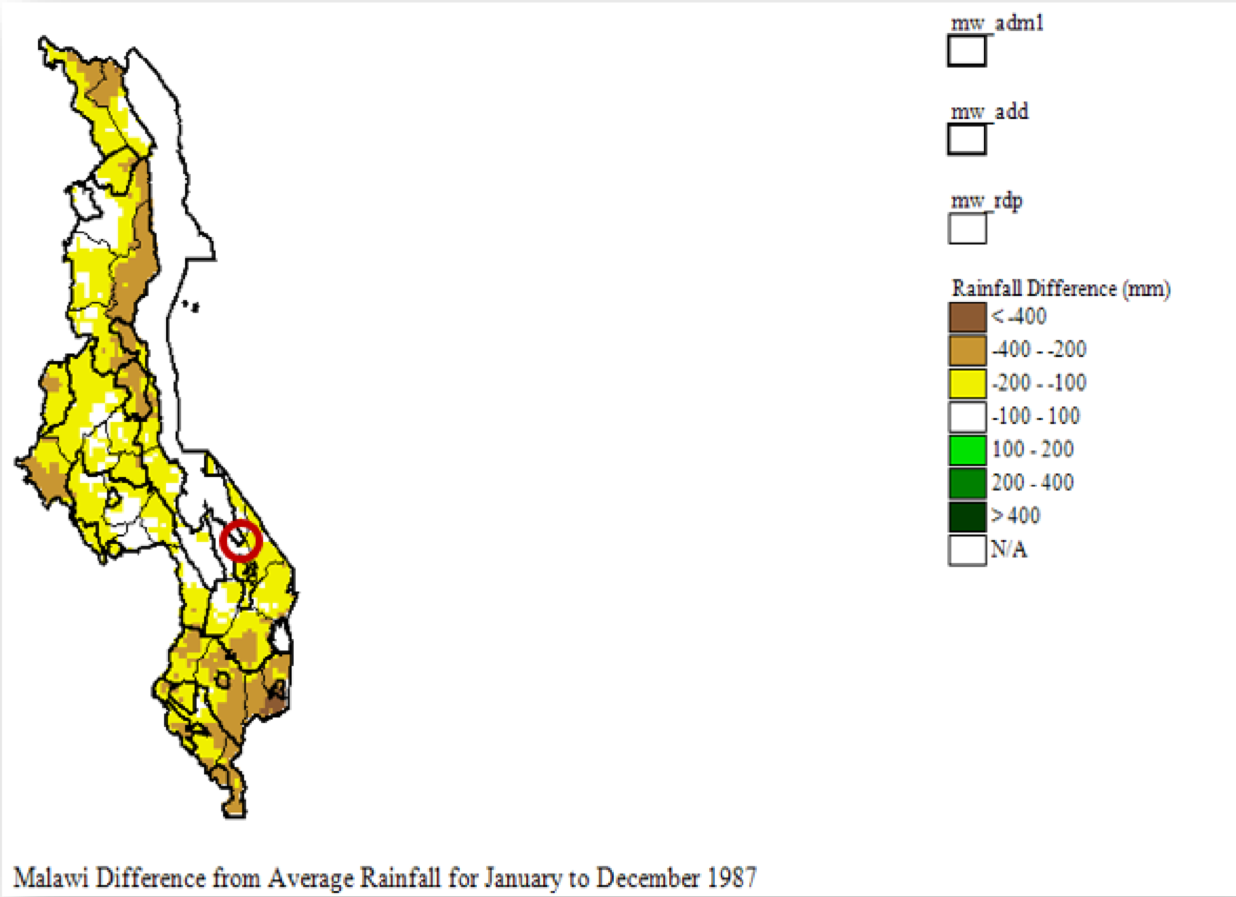
B1: Precipitation Map for Malawi in 1981



Malawi Difference from Average Rainfall for January to December 1981

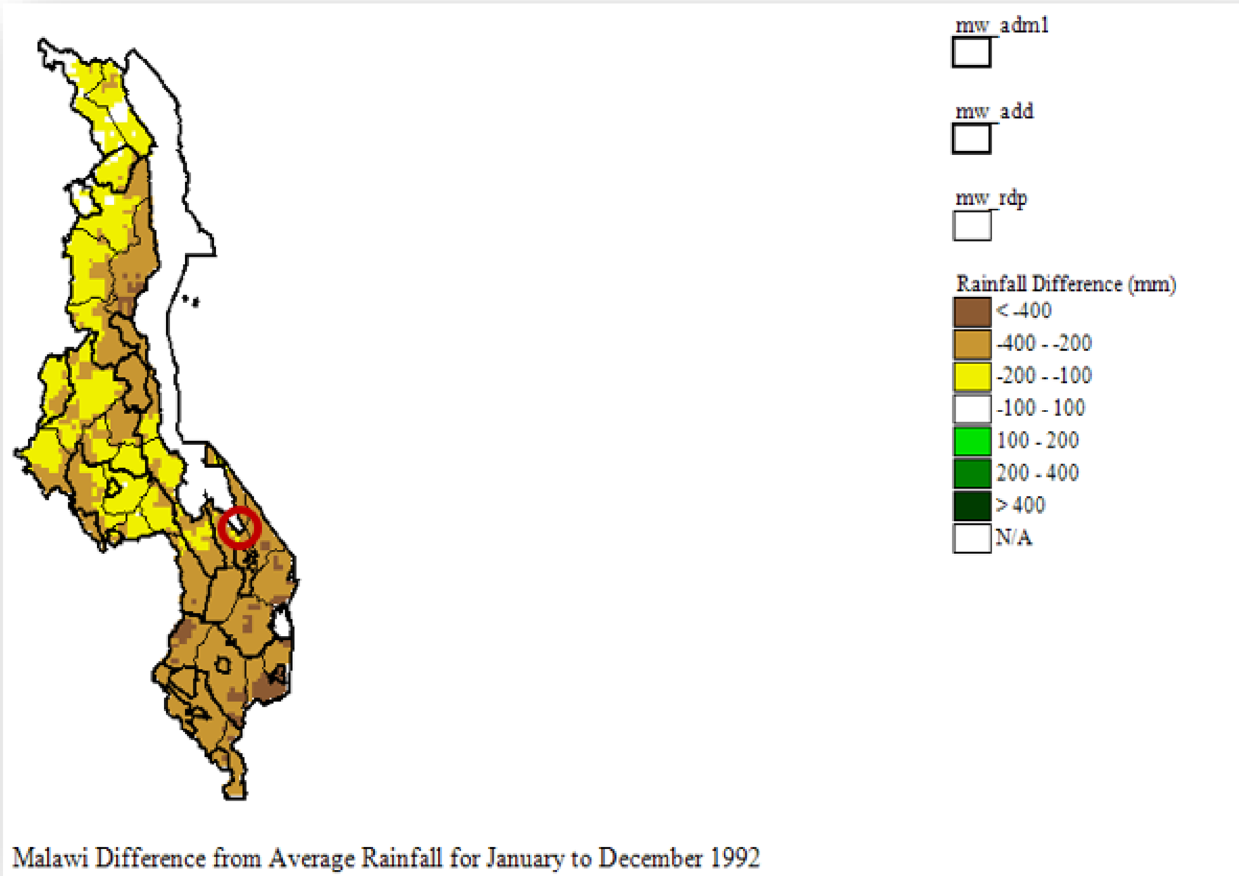
Source: Generated by Author from Climate Hazards Group (Internet)

B2: Precipitation Map for Malawi in 1987



Source: Generated by Author from Climate Hazards Group (Internet)

B3: Precipitation Map for Malawi in 1992



Source: Generated by Author from Climate Hazards Group. (Internet)

Appendix C

C1: Outcome and Exposure Variables

Outcome Variables	Type	Description	Additional notes
Length-for-age z score	Continuous	Measured within 42 days of delivery, using a variable from WHO 2006 Child Growth Standard variable (WHO Multicentre Growth Reference Study Group., 2006).	The newborn was weighed 3 times according to the protocol. The mean of the first two readings of the birthweight was used if their discrepancy fell within a tolerance limit.
Weight-for-age z score	Continuous	Was measured within 42 days of delivery - WHO 2006 Child Growth Standard variable (WHO Multicentre Growth Reference Study Group., 2006)	
Measured/imputed birthweight	Continuous	Birthweight was recorded within 48 hours of delivery if time of delivery and measurement was known. Birthweight was measured within 72 hours of delivery if time of delivery/measurement was not specified by the mother. If birthweight was measured within 3-5 days of delivery, birthweight was imputed with a predetermined value (Cheung, 2013). If birthweight was measured between 6-14 days of delivery, WAZ	The newborn was weighed 3 times according to the protocol. The mean of the first two readings of the birthweight was used if their discrepancy fell within a tolerance limit. If the first two readings exceeded the tolerance limit, the third reading was compared with the first and second readings, the reading with the smallest discrepancy was picked, and the mean calculated.

		was calculated with WHO 2006 Child Growth Standard and back translated to birthweight - male and female WAZ calculated separately) (WHO Multicentre Growth Reference Study Group., 2006).	If there was only one reading it was used; if two, the mean of the readings was used.
First trimester exposure	Indicator	0 = non-exposed (Includes women exposed to drought at age 0-5 yr) 1 = Exposure occurring during the first three months of pregnancy	Born November 1981-April 1982, November 1987-April 1988, or November 1992-April 1993
Second-third trimester exposure	Indicator	0 = non-exposed (Includes women exposed to drought at age 0-5 yr) 1 = Exposure occurring after three months of pregnancy	Born May 1981-Oct 1981, May 1987-Oct 1987, or May 1992-Oct 1992

C2: Covariates for Adjusted Analysis

Covariate	Type	Description	Additional Notes
Trial Supplements	Indicator	0 = IFA 1 = MMN 2 = LNS	
Child Sex	Indicator	1 = baby boy 2 = baby girl	
Mother Education	Continuous	Maternal education	Primary school = 0-8 yr Secondary = 0-4 yr Tertiary = 0-4 yr (> 4 yr in some cases)
Maternal BMI	Continuous		(Mean Maternal weight/Mean Maternal height/1000) ^2
Maternal Married	Indicator	0 = not married 1 = married	
Maternal Height	Continuous	Mean maternal height at enrollment	The mother was measured 3 times according to the protocol. The mean of the first two readings of the maternal height was used if their discrepancy fell within a tolerance limit. If the first two readings exceeded the tolerance limit of 0.05 unit, the third was compared with the first and second readings, the reading with the smallest discrepancy was picked, and the mean was calculated. If there was only one reading that reading was used; if two, the mean of the readings was used. Half a unit (0.05) was added to account for measurement bias towards rounding down measurements by the iLiNS-DYAD-M trial.
Mother as Head of Household (HH)	Indicator	0 = not HH (other than enrolled pregnant woman) 1 = HH (enrolled pregnant woman)	An important factor in Hoddinott et al. study, a woman's relationship to the HH household (Hoddinott & Kinsey, 2001) is also derived from the 2004/05 Malawi Integrated Household Survey (World Bank, Internet), which asks the question who is the HH and what is their relationship to the pregnant woman. All the other designations of HH in

			the present study e.g., grandfather to the pregnant woman are grouped together.
Household Food Insecurity Access Scale	Continuous	Score showing levels of perceived and self-reported levels of food insecurity also called household food insecurity access scale (HFIAS)	Used 9 questions of the HFIAS score each collapsed into responses 0-2. The variable values ranged from 0- 27, with 0 = 1 point, 1 = 2 points, and 2 = 3 points (FANTA, 2007).
Household Asset Index Score	Continuous	Housing quality and asset variables called household asset index Z (HAIZ) score	First principal components score used housing quality and asset variables from the Malawi Demographic Health Survey.
Primiparous	Indicator	0 = multiparous (base category) 1 = primiparous	Multiparous = more than one pregnancies Primiparous = first pregnancy
Normal (vs. "At Risk") Pregnancy by Age	Indicator	0 = normal pregnancy based on age 1 = "at risk" pregnancy based on age	Pregnant aged < 18 years or $\geq$ 35 years or pregnancy aged 18-35 years.
Peri-urban (vs. Rural)	Indicator	0 = elsewhere 1= Mangochi Boma	Peri-urban means on the periphery of urban centres.

Source: The present study and internal documents from iLiNS Project.

C3: Birth Outcomes by Maternal Exposure to Drought by Different Age Groups

Outcomes	Never exposed at age 0-5 yr (Excluding *in utero* exposure)	Exposure at age 0-5 yr (1981/82)	Exposure at age 0-5 yr (1987/88)	Exposure at age 0-5 yr (1992/93)	Exposure at age 0-2 yr	Exposure at age 3-5 yr
Infant LAZ[a]	-1.048	-1.013	-0.835	-1.015	-0.899	-0.992
Mean SD (n)	1.125 (844)	1.164 (156)	1.096 (262)	1.082 (304)	1.068 (333)	1.139 (389)
Infant WAZ[b]	-0.641	-0.626	-0.385	-0.591	-0.610	-0.519
Mean SD (n)	1.038 (852)	-0.587 (157)	1.083 (266)	0.968 (304)	1.009 (334)	1.044 (393)
Mean Imputed BWT[c]	2942.108	2947.383	3027.244	2969.268	3009.975	2965.826
Mean SD (n)	452.048 (923)	488.081 (168)	456.898 (292)	428.415 (303)	432.519 (362)	468.520 (431)

Notes:

[a] Length-for-age was calculated using the WHO 2006 growth standards (WHO Multicentre Growth Reference Study Group., 2006)

[b] Weight-for-age was calculated using the WHO 2006 growth standards (*ibid*).

[c] BWT - birthweight

Appendix D

D1: Sensitivity Analysis for Chapter 2, Restricted Models

Variables	**(1)** **Restricted Model: LAZ**	**(2)** **Restricted Model: WAZ**	**(3)** **Restricted Model: BWT**
First trimester	0.036	0.045	13.336
	(-0.250 , 0.323)	(-0.236 , 0.327)	(-103.170 , 129.843)
Second-third trimester	0.153	0.009	86.528**
	(-0.060 , 0.367)	(-0.184 , 0.202)	(9.988 , 163.068)
Child sex (girl)	0.140**	0.052	-81.290***
	(0.008 , 0.272)	(-0.074 , 0.178)	(-133.225 , -29.355)
Maternal education	0.010	0.012	-0.611
	(-0.013 , 0.034)	(-0.009 , 0.034)	(-9.502 , 8.280)
Maternal BMI	0.021	0.026**	15.454***
	(-0.005 , 0.048)	(0.001 , 0.052)	(5.114 , 25.794)
Marital status (married)	-0.062	0.085	-20.412
	(-0.293 , 0.169)	(-0.135 , 0.304)	(-102.916 , 62.093)
Maternal height	0.050***	0.040***	17.956***
	(0.037 , 0.063)	(0.028 , 0.052)	(13.231 , 22.681)
Head of household (mother)	-0.295	-0.393**	-93.497
	(-0.647 , 0.058)	(-0.715 , -0.070)	(-224.208 , 37.213)
HH food insecurity access scale	0.008	0.013*	4.120
	(-0.008 , 0.024)	(-0.001 , 0.028)	(-1.791 , 10.030)
HH asset index Z score	0.070	0.074	26.130
	(-0.022 , 0.162)	(-0.014 , 0.162)	(-10.333 , 62.592)
Primiparous	-0.341***	-0.380***	-111.633***
	(-0.514 , -0.167)	(-0.546 , -0.215)	(-181.817 , -41.449)
Normal (vs. "at risk") pregnancy by age	0.177*	0.062	48.404
	(-0.006 , 0.359)	(-0.108 , 0.232)	(-22.147 , 118.955)
Periurban (vs. rural)	-0.297***	-0.085	-91.182***
	(-0.478 , -0.115)	(-0.252 , 0.082)	(-158.271 , -24.094)
Constant	-9.510***	-7.567***	-64.258
	(-11.692 , -7.328)	(-9.567 , -5.567)	(-821.484 , 692.969)

N	1,029	1,040	1,125
R-squared	0.112	0.094	0.095
F	10.09	8.281	10.31
Adjusted R-squared	0.100	0.0824	0.0846

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

D2: Sensitivity Analysis for Chapter 2, Expanded Models

Variables	(1) Expanded Model: LAZ	(2) Expanded Model: WAZ	(3) Expanded Model: BWT
First trimester # IFA	0.536***	0.234	21.434
	(0.136 , 0.935)	(-0.219 , 0.686)	(-142.765 , 185.634)
Second-third trimester #IFA	0.294	-0.022	105.728
	(-0.103 , 0.691)	(-0.415 , 0.372)	(-28.961 , 240.416)
Non exposure # MMN[a]	0.178*	0.085	47.032
	(-0.003 , 0.358)	(-0.080 , 0.250)	(-21.674 , 115.739)
Non exposure # LNS[b]	0.129	0.078	26.437
	(-0.048 , 0.306)	(-0.091 , 0.248)	(-43.142 , 96.017)
First trimester # MMN	-0.834***	-0.423	-111.261
	(-1.423 , -0.244)	(-1.037 , 0.191)	(-373.958 , 151.436)
First trimester # LNS	-0.656*	-0.098	113.067
	(-1.370 , 0.058)	(-0.837 , 0.641)	(-163.346 , 389.480)
Second-third trimester # MMN	-0.443*	-0.117	-122.934
	(-0.956 , 0.071)	(-0.629 , 0.395)	(-306.985 , 61.117)
Second-third trimester # LNS	0.001	0.196	47.213
	(-0.523 , 0.525)	(-0.266 , 0.658)	(-134.597 , 229.023)
Child sex (girl)	0.140**	0.054	-79.512***
	(0.008 , 0.273)	(-0.073 , 0.180)	(-131.454 , -27.570)
Maternal education	0.010	0.013	-0.403
	(-0.013 , 0.034)	(-0.009 , 0.034)	(-9.303 , 8.496)
Maternal BMI	0.020	0.026**	15.262***
	(-0.006 , 0.047)	(0.001 , 0.052)	(4.956 , 25.569)
Marital status (married)	-0.046	0.098	-13.728
	(-0.275 , 0.183)	(-0.121 , 0.318)	(-96.665 , 69.208)
Maternal height	0.050***	0.040***	18.143***
	(0.037 , 0.063)	(0.028 , 0.052)	(13.431 , 22.856)
Head of household (mother)	-0.299*	-0.404**	-96.680
	(-0.650 , 0.052)	(-0.728 , -0.080)	(-227.492 , 34.133)
HH food insecurity access scale	0.008	0.014*	4.058

Notes:

[a,b] The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

	(-0.008 , 0.024)	(-0.001 , 0.029)	(-1.874 , 9.990)
HH asset index Z score	0.068	0.071	24.451
	(-0.023 , 0.160)	(-0.017 , 0.159)	(-11.772 , 60.674)
Primiparous	-0.327***	-0.373***	-112.258***
	(-0.500 , -0.154)	(-0.538 , -0.207)	(-182.418 , -42.098)
Normal (vs. "at risk") pregnancy by age	0.175*	0.059	45.714
	(-0.006 , 0.355)	(-0.111 , 0.228)	(-24.724 , 116.152)
Periurban (vs. rural)	-0.282***	-0.073	-86.651**
	(-0.466 , -0.099)	(-0.241 , 0.096)	(-153.968 , -19.333)
Constant	-9.690***	-7.695***	-121.847
	(-11.855 , -7.525)	(-9.691 , -5.698)	(-873.986 , 630.292)
N	1,029	1,040	1,125
R-squared	0.121	0.098	0.100
F	8.013	6.173	7.773
Adjusted R-squared	0.104	0.0809	0.0843

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

LNS - lipid-based nutrient supplement, MMN - multiple micronutrient supplement, IFA - iron-folic acid

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** $p<0.01$, ** $p<0.05$, * $p<0.1$

D3: Sensitivity Analysis for Chapter 3, Restricted Models (Age 0-5 yr)

Variables	**(1)** **Restricted Model: LAZ**	**(2)** **Restricted Model: WAZ**	**(3)** **Restricted Model: BWT**
Drought exposure in 1981/82	-0.211	-0.113	-54.582
	(-0.485 , 0.063)	(-0.357 , 0.131)	(-158.918 , 49.754)
Drought exposure in 1987/88	0.094	0.212*	73.034
	(-0.142 , 0.330)	(-0.012 , 0.435)	(-19.410 , 165.479)
Drought exposure in 1992/93	-0.004	0.043	42.839
	(-0.232 , 0.224)	(-0.168 , 0.254)	(-40.392 , 126.070)
Child sex (girl)	0.162**	0.050	-61.962**
	(0.014 , 0.309)	(-0.090 , 0.189)	(-120.509 , -3.416)
Maternal education	0.011	0.011	-2.376
	(-0.015 , 0.037)	(-0.013 , 0.035)	(-12.729 , 7.977)
Maternal BMI	0.020	0.025*	13.939**
	(-0.011 , 0.051)	(-0.005 , 0.054)	(2.095 , 25.783)
Marital status (married)	-0.229*	-0.035	-34.628
	(-0.493 , 0.034)	(-0.265 , 0.195)	(-127.108 , 57.851)
Maternal height	0.055***	0.046***	20.830***
	(0.041 , 0.070)	(0.033 , 0.060)	(15.253 , 26.408)
Head of household (mother)	-0.419**	-0.457**	-98.375
	(-0.806 , -0.033)	(-0.819 , -0.096)	(-242.981 , 46.231)
HH food insecurity access scale	0.008	0.013	4.896
	(-0.011 , 0.026)	(-0.004 , 0.030)	(-1.848 , 11.640)
HH asset index Z score	0.011	0.070	5.536
	(-0.079 , 0.102)	(-0.015 , 0.155)	(-31.862 , 42.933)
Primiparous	-0.414***	-0.398***	-104.959***
	(-0.615 , -0.212)	(-0.595 , -0.202)	(-184.203 , -25.715)
Normal (vs. “at risk”) pregnancy by age	0.186	-0.003	39.292
	(-0.044 , 0.416)	(-0.213 , 0.208)	(-44.994 , 123.578)
Constant	-10.102***	-8.416***	-588.550
	(-12.579 , -7.624)	(-10.610 , -6.222)	(-1,477.040 , 299.940)
N	810	820	889
R-squared	0.134	0.124	0.104
F	9.446	8.585	7.961
Adjusted R-squared	0.115	0.109	0.0873

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

D4: Sensitivity Analysis for Chapter 3, Expanded Models (Age 0-5 yr)

Variables	**(1)** **Expanded Model: LAZ**	**(2)** **Expanded Model: WAZ**	**(3)** **Expanded Model: BWT**
Drought exposure in 1981/82# IFA	-0.229	-0.085	-15.305
	(-0.694 , 0.237)	(-0.503 , 0.334)	(-180.962 , 150.351)
Drought exposure in 1987/88# IFA	0.425**	0.474***	88.896
	(0.035 , 0.815)	(0.117 , 0.831)	(-63.828 , 241.620)
Drought of exposure in 1992/93# IFA	0.197	0.242	113.420
	(-0.178 , 0.573)	(-0.105 , 0.588)	(-24.108 , 250.947)
Non exposure# MMN[a]	0.171	0.179	26.560
	(-0.145 , 0.486)	(-0.119 , 0.476)	(-91.415 , 144.536)
Non exposure# LNS[b]	0.396**	0.364**	123.720**
	(0.092 , 0.699)	(0.043 , 0.684)	(0.158 , 247.282)
Drought exposure in 1981/82# MMN	0.028	-0.018	-28.830
	(-0.548 , 0.604)	(-0.535 , 0.499)	(-263.333 , 205.674)
Drought exposure in 1981/82# LNS	0.029	-0.059	-87.829
	(-0.587 , 0.645)	(-0.621 , 0.503)	(-312.162 , 136.504)
Drought exposure in 1987/88# MMN	-0.366	-0.305	24.651
	(-0.860 , 0.128)	(-0.762 , 0.151)	(-162.298 , 211.600)
Drought exposure in 1987/88# LNS	-0.628**	-0.482**	-81.123
	(-1.123 , -0.133)	(-0.953 , -0.010)	(-287.590 , 125.343)
Drought exposure in 1992/93# MMN	-0.163	-0.201	-30.268
	(-0.644 , 0.317)	(-0.650 , 0.248)	(-210.055 , 149.520)
Drought exposure in of 1992/93# LNS	-0.478**	-0.415*	-177.674**
	(-0.939 , -0.018)	(-0.864 , 0.035)	(-352.909 , -2.439)
Child sex (girl)	0.167**	0.052	-61.298**
	(0.018 , 0.315)	(-0.088 , 0.193)	(-120.463 , -2.133)
Maternal education	0.010	0.011	-2.163
	(-0.016 , 0.036)	(-0.013 , 0.034)	(-12.636 , 8.309)
Maternal BMI	0.022	0.026*	14.732**
	(-0.009 , 0.052)	(-0.004 , 0.055)	(3.038 , 26.426)

Notes:

[a,b] The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

Marital status (married)	-0.243*	-0.040	-37.851
	(-0.507 , 0.021)	(-0.272 , 0.192)	(-131.693 , 55.992)
Maternal height	0.055***	0.046***	20.571***
	(0.040 , 0.070)	(0.032 , 0.060)	(14.905 , 26.238)
Head of household (mother)	-0.441**	-0.471**	-102.863
	(-0.826 , -0.056)	(-0.832 , -0.109)	(-248.461 , 42.735)
HH food insecurity access scale	0.010	0.015*	5.330
	(-0.009 , 0.028)	(-0.002 , 0.032)	(-1.425 , 12.084)
HH asset index Z score	0.010	0.069	2.286
	(-0.081 , 0.100)	(-0.017 , 0.154)	(-35.392 , 39.963)
Primiparous	-0.412***	-0.393***	-109.087***
	(-0.617 , -0.207)	(-0.591 , -0.196)	(-188.901 , -29.272)
Normal (vs. "at risk") pregnancy by age	0.211*	0.012	38.716
	(-0.018 , 0.439)	(-0.197 , 0.221)	(-46.096 , 123.529)
Constant	-10.249***	-8.579***	-613.767
	(-12.723 , -7.775)	(-10.800 , -6.358)	(-1,511.601 , 284.067)
N	810	820	889
R-squared	0.145	0.133	0.111
F	6.578	6.127	5.451
Adjusted R-squared	0.122	0.110	0.0890

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

D5: Sensitivity Analysis for Chapter 3, Restricted Models (Age 0-2 yr, 3-5 yr)

Variables	**(1)** **Restricted Model: LAZ**	**(2)** **Restricted Model: WAZ**	**(3)** **Restricted Model: BWT**
Drought exposure at age 0-2 yr	0.081 (-0.163 , 0.326)	0.069 (-0.159 , 0.297)	77.160* (-12.893 , 167.213)
Drought exposure at age 3-5 yr	-0.059 (-0.271 , 0.153)	0.063 (-0.134 , 0.259)	12.846 (-66.128 , 91.820)
Child sex (girl)	0.164** (0.016 , 0.312)	0.046 (-0.094 , 0.185)	-59.485** (-118.281 , -0.688)
Maternal education	0.011 (-0.015 , 0.038)	0.012 (-0.012 , 0.036)	-1.998 (-12.271 , 8.275)
Maternal BMI	0.018 (-0.013 , 0.049)	0.023 (-0.006 , 0.052)	13.265** (1.591 , 24.939)
Marital status (married)	-0.224* (-0.489 , 0.041)	-0.029 (-0.260 , 0.203)	-35.093 (-128.090 , 57.903)
Maternal height	0.055*** (0.040 , 0.069)	0.046*** (0.033 , 0.060)	20.370*** (14.806 , 25.933)
Head of household (mother)	-0.416** (-0.804 , -0.028)	-0.448** (-0.812 , -0.083)	-101.945 (-246.441 , 42.550)
HH food insecurity access scale	0.007 (-0.012 , 0.026)	0.013 (-0.004 , 0.030)	4.716 (-2.042 , 11.473)
HH asset index Z score	0.000 (-0.091 , 0.091)	0.055 (-0.031 , 0.142)	3.266 (-34.566 , 41.098)
Primiparous	-0.416*** (-0.614 , -0.219)	-0.402*** (-0.596 , -0.209)	-105.403*** (-183.947 , -26.860)
Normal (vs. “at risk”) pregnancy by age	0.191 (-0.040 , 0.422)	0.003 (-0.206 , 0.213)	41.592 (-42.555 , 125.739)
Constant	-9.933*** (-12.386 , -7.480)	-8.361*** (-10.551 , -6.171)	-503.957 (-1,388.374 , 380.459)
N	810	820	889
R-squared	0.129	0.116	0.100

F	10.44	8.967	8.740
Adjusted R-squared	0.116	0.103	0.0879

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight HH - household

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

D6: Sensitivity Analysis for Chapter 3, Expanded Models (Age 0-2 yr, 3-5 yr)

Variables	(1) Expanded Model: LAZ	(2) Expanded Model: WAZ	(3) Expanded Model: BWT
Drought exposure at age 0-2 yr#IFA	0.422**	0.239	122.896*
	(0.039 , 0.805)	(-0.144 , 0.622)	(-17.331 , 263.124)
Drought exposure at age 3-5 yr#IFA	0.045	0.235	47.624
	(-0.296 , 0.386)	(-0.074 , 0.543)	(-79.733 , 174.982)
Non exposure# MMN	0.177	0.184	27.700
	(-0.138 , 0.492)	(-0.114 , 0.481)	(-90.004 , 145.404)
Non exposure# LNS	0.396**	0.364**	124.672**
	(0.093 , 0.700)	(0.044 , 0.685)	(1.216 , 248.127)
Drought exposure at age 0-2 yr#MMN	-0.594**	-0.339	-125.272
	(-1.079 , -0.109)	(-0.819 , 0.141)	(-311.768 , 61.225)
Drought exposure at age 0-2 yr#LNS	-0.457*	-0.182	-24.983
	(-0.965 , 0.051)	(-0.671 , 0.306)	(-214.426 , 164.461)
Drought exposure at age 3-5 yr#MMN	0.003	-0.132	36.386
	(-0.424 , 0.429)	(-0.520 , 0.256)	(-125.121 , 197.893)
Drought exposure at age 3-5 yr#LNS	-0.347	-0.395*	-146.397*
	(-0.763 , 0.068)	(-0.802 , 0.011)	(-311.353 , 18.558)
Child sex (girl)	0.171**	0.051	-54.973*
	(0.023 , 0.319)	(-0.090 , 0.191)	(-113.811 , 3.866)
Maternal education	0.011	0.012	-1.756
	(-0.015 , 0.037)	(-0.011 , 0.036)	(-11.981 , 8.470)
Maternal BMI	0.018	0.023	13.786**
	(-0.013 , 0.048)	(-0.006 , 0.052)	(2.422 , 25.150)
Marital status (married)	-0.207	-0.012	-29.946
	(-0.469 , 0.055)	(-0.242 , 0.218)	(-123.630 , 63.738)
Maternal height	0.054***	0.046***	20.133***
	(0.039 , 0.069)	(0.032 , 0.059)	(14.571 , 25.696)
Head of household (mother)	-0.421**	-0.465**	-115.115
	(-0.803 , -0.038)	(-0.828 , -0.101)	(-258.114 , 27.884)
HH food insecurity access scale	0.008	0.014	4.731

	(-0.011 , 0.027)	(-0.003 , 0.031)	(-1.962 , 11.424)
HH asset index Z score	0.000	0.053	0.116
	(-0.089 , 0.090)	(-0.033 , 0.139)	(-37.514 , 37.745)
Primiparous	-0.407***	-0.394***	-110.796***
	(-0.604 , -0.210)	(-0.587 , -0.201)	(-188.898 , -32.694)
Normal (vs. "at risk") pregnancy by age	0.206*	0.011	41.570
	(-0.021 , 0.433)	(-0.196 , 0.219)	(-42.306 , 125.446)
Constant	-10.077***	-8.519***	-533.807
	(-12.500 , -7.654)	(-10.702 , -6.336)	(-1,411.749 , 344.136)
N	810	820	889
R-squared	0.143	0.126	0.113
F	8.008	7.001	7.256
Adjusted R-squared	0.123	0.106	0.0947

Notes:

Outcomes: LAZ - length-for-age Z score, WAZ - weight-for-age Z score, BWT - birthweight

LNS - lipid-based nutrient supplement, MMN - multiple micronutrient supplement, IFA - iron-folic acid

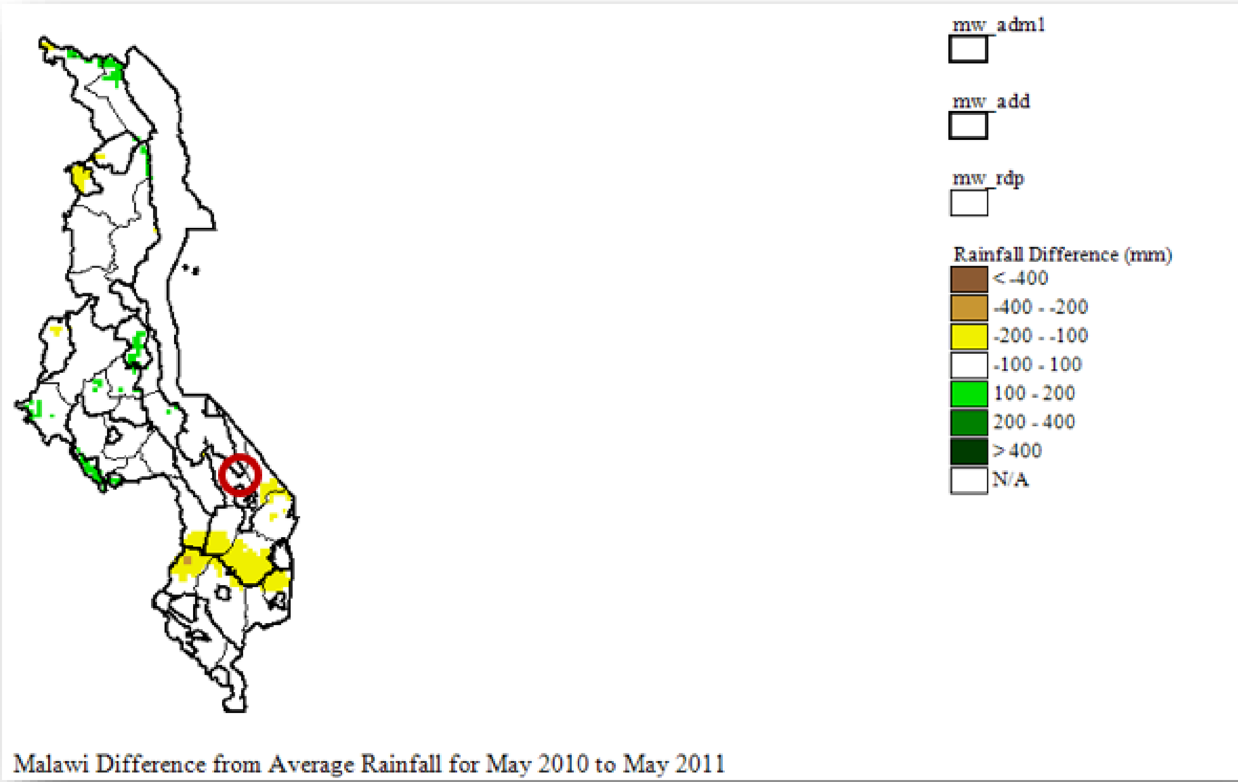
HH - household,

Confidence intervals (CI): 95% CI in parentheses

Statistical significance (p-values): *** p<0.01, ** p<0.05, * p<0.1

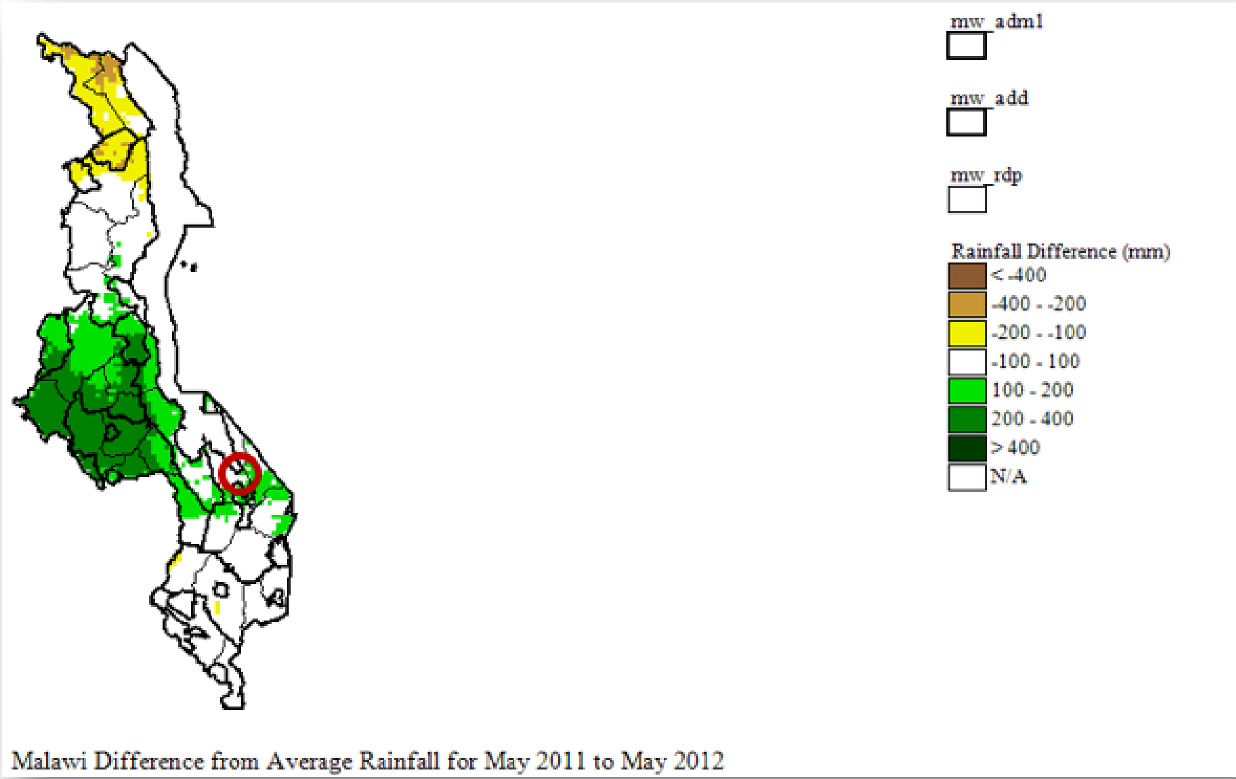
Appendix E

E1: Precipitation Map for Malawi May 2010-May 2011



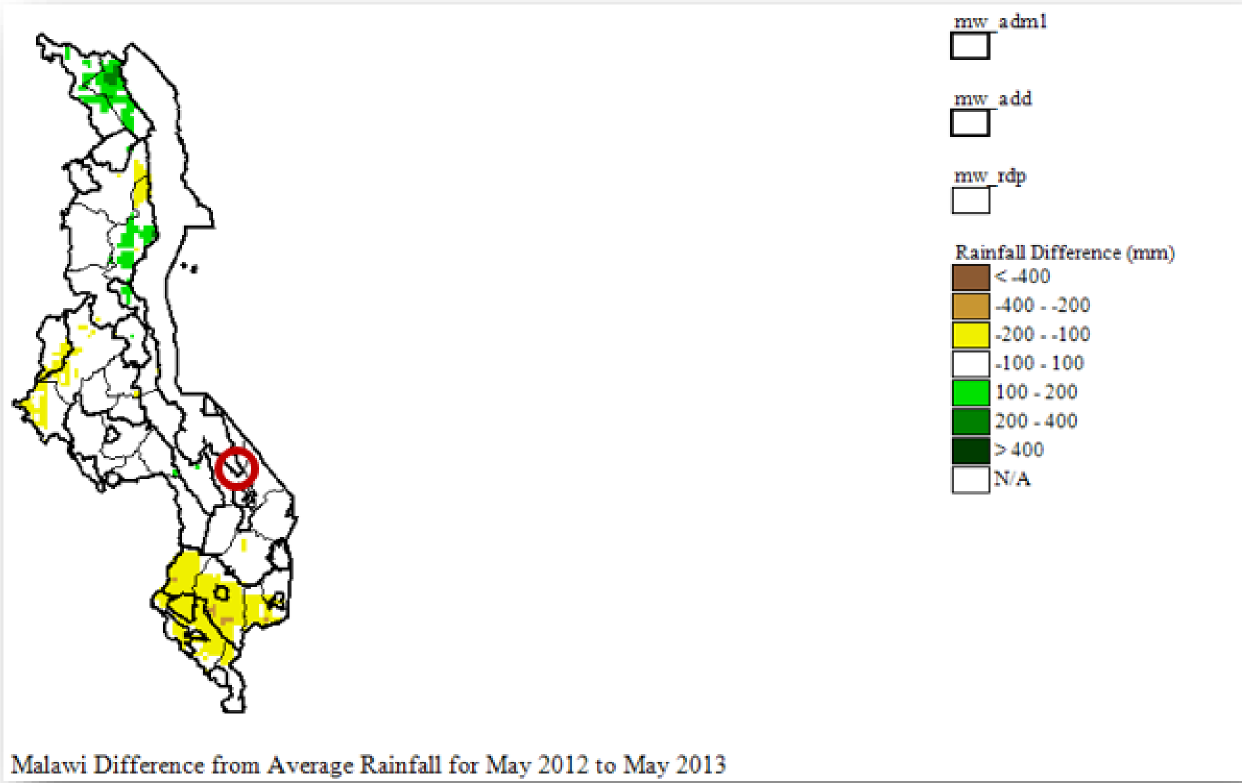
Source: Generated by Author from Climate Hazards Group (Internet)

E2: Precipitation Map for Malawi May 2011-May 2012



Source: Generated by Author from Climate Hazards Group (Internet)

E3: Precipitation Map for Malawi May 2012-May 2013



Source: Generated by Author from Climate Hazards Group (Internet)

Appendix F

iLiNS-DYAD-M trial selected Study Guides, SOPs, and Study Questionnaires

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 02, Screening **(form version 2011-12-02)**
Version Number: 6.0 (2011-12-02)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The purpose of completing form 02 is to be able assess the how well the obtained study sample represents the entire target population, i.e. all those who were pregnant at the study site and attended antenatal clinic. This assessment is done by comparing the characteristics of the enrolled participants to those, who came to the antenatal clinic but did not participate in the study.

2.0 RESPONSIBLE PERSONNEL

2.1 Form 02 should be filled in by data collectors and data monitors who have been trained in the use of this form.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

3.1 The form will be filled in at the beginning of a regular antenatal clinic, offered in the health facility where the study is conducted.

3.2 A study nurse will first address the antenatal clinic attendees. S/he will explain the College of Medicine is conducting a study on maternal and child health in the health facility and that as part of that study, the team first ask a few questions from all antenatal clinic attendees. Responding to these questions will take less than three minutes. The study nurse will then provide further information to those individuals who are interested in joining the study. After informing more about the study, the study team will carry out the antenatal clinic visit and assess the eligibility of those women who are interested in joining the study. Whilst doing the eligibility assessment, the team will also complete all other examinations and procedures that are a normal part of an antenatal care enrolment visit in Malawi. Those who are eligible and willing, can then join the study on the same day or consult their family members and join a bit later.

3.3 The study nurse will explain that participation in the screening, eligibility assessment and the actual study are all voluntary and the antenatal care attendees need not give any explanations if they are not interested in giving out their information or joining the study.

3.4 Once the study nurse has completed her part, one to three trained data collectors will administer the forms 02. One form 02 will be completed for each antenatal clinic visitor who is starting her antenatal follow-up i.e. making her first ANC visit during this pregnancy – the form will be filled in even if the participant declines the actual screening i.e. prefers not to disclose any of her personal information.

3.5 The data collectors will first fill in top parts of the form (until q 1.4), and then ask question 1.4 (Can the screening be completed). If the answer is "yes" the data collector will proceed with rest of the form. If the answer is "no", the data collector will thank the respondent, skip questions 1.4 – 2.13, mark "0 = no" to question 2.14 and indicate "Declined screening" in question 2.15.

3.6 Once all the forms 02 for that day have been completed, the data collectors will separate those with a "yes" answer in question 2.14 (will eligibility assessment be completed), The data collectors will then take these forms to a study nurse and guide the women, whose forms they were to a separate counselling session with her.

3.7 All fields which take numbers should be filled with leading "0" if the number does not occupy all spaces in the field. Dates should take the "dd-mm-yy" format.

3.8 To fill in the form, the data collector will need the following materials and equipment:

- **3.8.1** A pen
- **3.8.2** A chart indicating the codes for all villages in the catchment area

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Screening ID {ScreeNumber): Self-explanatory

Participant code {Participant): Self-explanatory

1 Visit Information

1.1 NumberVisit: This is the same number as the weeks of follow up in the study.

1.2 DateVisit: See general instructions

1.3 ScrPermission: Ask if the respondent is willing to spend 2-3 minutes on answering approximately 10 questions. The questions do not include any personal details and we ask them to be able to tell if those participants who come to our study are similar to all other women who attend ANC at this health facility. Indicate "1 = yes" for those who are willing to answer all questions, "0=no" for all others.

1.4 ScrLanguage: Self-explanatory

2 Information on, mother and household

2.1 Catchment area {SrcArea}. Indicate here the health facility where the screening is done, not the residential area of the woman.

2.2 Home Village: {SrcNameVillage}. Ask this from the participant.

2.2.1 Code {SrcCodeVillage}. Check code from a table and mark here. If code not available, i.e. if the mother does not live in a village that belongs to the study catchment area, write '999'.

2.3 What is the age of the woman? {SrcMotherAge}. Indicated completed years. If the mother does not know, ask her to estimate. If she cannot estimate, the data collector will make the estimate.

2.4 What is your marital status? {Scotomas'}. This means woman's own opinion, not necessarily a legal status.

2.5 How many children does the woman have? {SrcMotherAge}. Includes children were born to this woman and who are currently alive, whether living with her or not.

2.6 What is the highest grade completed by the women at Primary school? {SrcMotPrimSch}. Completion means that the individual was transferred to the next grade, i.e. s/he could have started the next grade (whether or not s/he eventually started it). A grade that needed to be repeated without transfer to the next grade is not considered repeated. Mark 0 for those who never went to school or did not finish first year, mark 8 for those who went to secondary school.

2.7 What is the highest grade completed at Secondary school? {SrcMotSecnSch}. For completion, see above. Mark 4 for those who took MSCE.

2.8 How many goats does the household own? {ScrHouseGoats}. The definition of a household is those who eat together or share resources together to obtain food. Include here any items owned by any member of the household.

2.9 Does anyone in the household own a cell-phone {ScrHousePhone}. See above.

2.10 What is the building material of the house {ScrHouseWalls}. If the guardian is not sure, ask her to estimate / guess.

2.11 What is the roofing material {ScrHouseRoof}. See above.

2.12 Has the mother participated in the iLiNS-DYAD trial before? {ScrPreviousParticipation}. Mark “yes”, if the candidate has previously participated in the same iLiNS-DYAD trial, i.e. she has received an iLiNS-DYAD identification number before. This is possible e.g. if the participant was enrolled earlier and she experienced an early miscarriage and then became pregnant again.

2.13 Will the mother be living in her current address or otherwise be available to participate in the iLiNS-DYAD trial for the next 12 months? {ScrAvailabilit}. The question is whether or not the participant is expected to live in the catchment are for this health facility during the duration of the study. The study involves quite a lot of visits and hence further living people are not eligible.

2.14 Is the mother willing to undergo eligibility assessment? {ScrInterested}. Being willing to undergo eligibility assessment does not necessarily mean that the participant will be enrolled, but it means the team will start filling in forms 3-10 from her. If eligibility assessment will not be done, it is important to differentiate between no interest in the study (answer option “0”) and no interest in the assessment because the participant herself thinks she would anyway not be eligible because her pregnancy is already advanced -- answer alternative “2”.

The interviewed individuals have the right to decline without giving any reasons, so it is important not to strongly press for a reason for non-interest. But the data collector will gently probe for this, by asking something along the lines: "We appreciate and thank you for your time this far and honour you wish not to undergo further eligibility assessment. You do not have to give us any explanations for your decision, but your opinions might help us to develop our trial further. So, if there is anything special you might like to share with us, on something that makes the program unattractive to you, we would be very happy to hear that."

If the answer to this question is either “0” (no interest) or “2” no, because thinks not being eligible), the data collector will mark the expressed explanation to questions 2.16.

2.15 Will eligibility assessment be completed? {ScrEliAssess}. This question will be filled in by the data monitor, who fills in form 03. If the woman does **not** meet all inclusion criteria, answer “no” to q2.15.

2.16 Free comments {ScrComments}: Mark here any comments about the visit, e.g. if the respondent declines participation in the screening; reason for exclusion (why the woman did not to meet all the inclusion criteria or met any of the exclusion criteria). If no comments, mark “None”.

HomCollector, HomMonitor, HomEntry1, HomEntry1: The iLiNS ID-codes for the individuals, who recorded the data on the form, inspected the form after completion, or did the 1st or 2nd data entry into the iLiNS-DYAD database.

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original SOP version (dated 2011-01-06, approved by Per Ashorn)

2.0 First Amendment (dated 2011-03-15, approved by Per Ashorn). Corrected numbering in Section 1.0 of the form. Added data monitors to staff responsible for completing this form; modified list of required materials in 3.8.1 and added instructions for filling q2.14 and q2.15.

3.0 Second Amendment (dated 2011-07-06, approved by Per Ashorn). Form otherwise unchanged. User guide revised to add instructions how to complete the village code if code not available. (Q2.2.1)

4.0 Third Amendment (dated 2011-08-11, approved by Per Ashorn). An error was corrected from the form where q2.5 had same variable name as q2.3 (*SrcMotherAge).* Q2.5 variable name was changed to *SrcMotherChild* as it was in the database.

5.0 Fourth Amendment (dated 2011-09-12, prepared by Minyanga Nkhoma, approved by Per Ashorn). Added explanation to q2.12 that was earlier missing from the user guide. Modified explanation to question 2.14 (formerly 2.13).

6.0 Fifth amendment (dated 2011-12-02, edited by John Phuka, approved by Per Ashorn). Edited section 2.14 to reflect changes to question 2.14. Converted the form into traditional Teleform version.

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 04, Anthropometrics, women **(form version 2012-06-11)**

Version Number: 4.0 (2014-06-25)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The primary purpose of filling in and storing information on form 04 is to document anthropometric measurements of the woman and the equipment used to get the measurements.

2.0 RESPONSIBLE PERSONNEL

1.2 Form 04 should be filled in only by an anthropometrist who has been trained in the use of this form.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

1.3 Form 04 is filled in when taking anthropometric measurements. Two anthropometrists are needed in order to fill this form i.e. one anthropometrist takes the measurements and the second anthropometrist records the measurements on this form.

1.4 To fill in the form, the anthropometrists will need the following materials and equipment:

- **1.4.1** Copies of iLiNS-DYAD form 04
- **1.4.2** Two pens
- **1.4.3** One stadiometer (Harpenden)
- **1.4.4** One digital adult weighing scale (SECA 874)
- **1.4.5** One MUAC tape

1.4.6 One Holtain Skinfold caliper

1.4.7 SOPxxx (enrollment health centre visit)

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Screening ID {ScreeNumber}: Self explanatory

Participant code {Participant}: Self-explanatory

2 Visit Information

2.1 Number (code) of visit {NumberVisit}: Self explanatory

2.2 DateVisit: Dates should take the “dd-mm-yy” format. Fill leading fields with “0” if the number does not occupy all spaces in the field.

3 Maternal anthropometry

3.1 Participant main mode of transport to health centre today {AntTransMode }: Ask the participant the means of travel from home to the health centre.

3.2 Maternal Clothing {AntClothing}: Estimate the clothing that the woman is wearing when she is being weighed. Light clothing [1] is for example shirt and a skirt, light clothing + sweater [2] is like the previous example plus a long-sleeved shirt. If the participant wears more clothes than this, choose Heavy Clothing [3].

3.3 Height (cm) {AntHeightA}{AntHeightB}{AntHeightC}. Height measurements are taken using a calibrated stadiometer (Harpenden). The measurement is carried out by two anthropometrists, one doing the examination and the other one recording the measurements. Repeat the measurement three times i.e. after the first measurement, ask the participant to get entirely off the stadiometer and reposition the instrument before taking the second and third measurements. After the measurement is read, record each numerical value on the form to the nearest 0.1 cm. This measurement is only taken at the enrolment visit, at other visits mark 999.9.

3.4 Weight (kg) {AntWeightA}{AntWeightB}{AntWeightC}. The weight will be measured with a digital adult scale (SECA 874). The measurement is carried out by two anthropometrists, one doing the examination and the other one recording the measurements. Repeat the measurement three times i.e. after the first measurement, -stop and ask the participant to get entirely off the scale and reposition in the instrument before taking the second and third measurements. Record the weight as indicated on the scale – use leading zeroes where necessary, do not round any results.

3.5 Arm circumference , MUAC (mm){ AntuacA }{ AntuacB }{ AntuacC }. Arm circumference is measured using a standard MUAC tapes. Repeat the measurement three times. After the measurement is read, record each numerical value on the form, using leading zeroes where necessary.

3.6 Triceps skinfold (mm) {AntSkinTriA } {AntSkinTriB}{AntSkinTriC}. Triceps skinfold measurements are done using a standard calibrated Holtain skinfold calipers. Repeat the measurement three times. After the measurement is read, record each numerical value on the form, using leading zeroes where necessary.

3.7 Subscapular skinfold (mm) { AntSkinSubA }{ AntSkinSubB }{AntSkinSubC}. Subscapular skinfold measurements are done using a standard calibrated Holtain skinfold calipers. Repeat the measurement three times. After the measurement is read, record each numerical value on the form, using leading zeroes where necessary.

3.8 Scale ID{AntScaleId}. Record the ID number of the scale used to take the measurements.

3.9 Stadiometer ID{AntStadioId}. Record the ID number of the stadiometer used to take the measurements.

4 Free comments

4.1 Free comments {AntComments}. Indicate here any further comments (e.g. reason for no measurements). If no further comments, mark “none”.

AntCollector, AntMonitor: The iLiNS ID-codes for the individuals, who recorded the data on the form or inspected the form after completion.

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original SOP version (dated 2011-02-07, approved by Per Ashorn)

2.0 First amendment (dated 2011-03-10, approved by Per Ashorn). User guide otherwise unchanged, but added one box in the form for q2.4.1, to allow documentation of weight with two decimals.

3.0 Second amendment (dated 2011-12-08, prepared by Abgail Sibande, approved by Per Ashorn). Converted the form into a Traditional Teleform version.

4.0 Third amendment (dated 2014-06-25, prepared by Emma Kortekangas, approved by Per Ashorn). Corrected the form version, clarified the recording of measurements in 4.2.3 and 4.2.4, deleted MedcEntry1 and MedcEntry2 as Teleform doesn't accommodate them.

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 06a, Maternal Medical Examination

(form version Chewa and Yao 2011-12-01)

Version Number: 4.0 (2011-12-08)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The primary purpose of filling in and storing information on form 06a is to collect data on maternal age; past medical history; current pregnancy history; medical examination findings; laboratory results; ultrasound findings and referral for treatment during all health centre visits.

2.0 RESPONSIBLE PERSONNEL

1.2 Form 06a will be filled by a study nurse.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

1.3 The form will be filled at visit mEli at the iLiNS-DYAD study clinic.

1.4 All fields will be filled and those which take numbers should be filled with leading "0" if the number does not occupy all spaces in the field. Dates should take the "dd-mm-yy" format and time should be in 24-hour clock format.

1.5 For all optional check-boxes check in one box only using "X" in the chosen box.

1.6 To fill in the form, the data collector will need the following materials and equipment:

- **1.6.1** A pen
- **1.6.2** The participant's health passport
- **1.6.3** A BP cuff (sphygmomanometer)
- **1.6.4** A plastic measuring tape
- **1.6.5** A digital thermometer
- **1.6.6** The participant's file.

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Participant code: Self-Explanatory

Screening ID: Self-Explanatory

1 Visit Information

1.1 Numbervisit: The code for this visit is mEli.

1.2 DateVisit: See general instructions

2 Maternal Age

2.1 Date of mother's birth MedDateBirth: The nurse will record the birth date as reported by the mother.

2.2 Maternal age MedAge: This must be the number of completed years as calculated from the reported birthdate or estimated if unknown. If estimated, please write "Maternal age estimated at q2.2" in Free comments (q8.3)

2.3 How was the age determined: Self-Explanatory

3 Past Medical History

3.1 Does the woman need frequent medical attention due to a chronic condition? MedChronCond: These are medical conditions that the woman has had for more than 14 days for which she requires medical attention. Examples of such conditions are diabetes, epilepsy, asthma, hypertension, TB. These conditions warrant exclusion at enrolment.

3.2 Does the woman have a disease that is treated with regular medication? MedRegularMedi: These are medical conditions that require treatment with regular medication such as asthma, epilepsy, Asthma that requires regular medication

3.3 What is the HIV-status of the woman? MedHivStatus: Record the HIV test result as documented in the health passport.

3.4 Since the woman became pregnant, has she ever been admitted to hospital? MedAdmit: This should include all hospital admissions the woman has had since she became pregnant excluding only those occasions where she stayed in hospital for social reasons e.g. spending a night at the hospital because it was too late to walk back home.

3.4.1 If yes, does the woman know what the cause was? MedAdmitCause: Self-explanatory.

3.4.2 If yes, specify MedSpecAdmitCause: Self-explanatory

4 This Pregnancy

4.1 Are there any problems in this pregnancy? MedProblems: Record here whether the woman has had any problems in this pregnancy. These problems could be any illness or other problems such as swelling of the legs or anaemia.

4.1.1 If yes, specify MedSpecProblems: Self-explanatory.

4.2 During the past week, has the woman had any of the following? Check in the answer option 1-9 if the participant had the event or not in the past 7 days (1 week).

5 Medical Examination

5.1 Systolic blood pressure, mmHg MedBpSystA / MedBpSystB / MedBpSystC: The nurse will perform blood pressure measurements in triplicate from the same arm, in a standardised fashion (woman sitting, arm freely hanging, midpoint of humerus. All three measurements of the systolic blood pressure should be recorded here from A to C with the first measurement recorded as A, second B and third C. All the three measurements should be independent of each other where the cuff is removed from the arm and deflated completely before taking the next measurement.

5.2 Diastolic blood pressure, mmHg MedBpDiastA / MedBpDiastB / MedBpDiastC: The diastolic blood pressure will be obtained and recorded in triplicate as in 5.1 above.

5.3 Oedema MedOedema: Oedema refers to swelling which is caused by an accumulation of fluid in the tissues beneath the skin. Indicate here whether the woman has any oedema of the feet. Oedema will be assessed by depressing the dorsum of the foot. The dorsum of the foot is the surface opposite the sole of the foot. Record the depth of the depression in centimetres.

5.4 Temperature MedTemperature: Measure the axillary or tympanic temperature using a digital thermometer.

5.5 Does the woman have an acute condition that warrants hospital referral MedAccuteCond: This is an illness of recent onset that requires further medical attention at the hospital in the opinion of the nurse.

5.6 Fundal height MedFundal: The nurse will explain the procedure to the mother and obtain verbal consent. The mother must be made comfortable in a recumbent position and a non-elastic tape measure must be available. The abdomen must be exposed enough for thorough examination. Ensure the abdomen is soft, not contracting. Perform abdominal palpation to accurately identify the uterine fundus. Secure the tape measure at the fundus with one hand; measure from the top of the fundus to the symphysis pubis with the tape measure staying in contact with the skin. Measure along the longitudinal axis WITHOUT correcting to the abdominal midline. Measure only once.

6 Hb and malaria test

6.1 Blood haemoglobin concentration MedHb: The blood haemoglobin concentration of the blood collected at this visit and must be expressed as grams per litre.

6.2 Malaria rapid test result MedMalariaRDT: Record here the result of the malaria rapid test after performing the test according to the user-manual from insert leaflet.

7 Ultrasound assessment

7.1 Was an ultrasound assessment done at this visit ?Self-Explanatory

7.2 How many foetuses can be seen? Self-Explanatory

7.3 Biparietal diameter MedFoetBipDia1/2: The study nurse or physician will take two measurements of the biparietal diameter in millimetres and record to one decimal places. And will record the first measurement under 7.3.1 and the second under 7.3.2.

7.4 Femur length MedFoetFemLengt1/2: The study nurse or physician will take two measurements of the femur length in millimetres and will record to one decimal place. record the first measurement under 7.4.1 and the second under 7.4.2

7.5 Abdominal circumference MedFoetAbdoCirc1/2: The study nurse or physician will take two measurements of the abdominal circumference in millimeters and will record the first measurement under 7.5.1 and the second under 7.5.2.

7.6

To complete questions 7.6.1 and 7.6.2 below, first you will do first US reading and record all values under the '1st Value' column of the USS measurements table. Then do a second reading and record all values under the '2nd Value' column of the USS measurements table, then fill in 7.6.1 and 7.6.2 BASED ON THE SECOND READING. For example, if on the second US readout the gestational age is 14 weeks and 4 days, you will record '14' in question 7.6.1 and '4' in question 7.6.2.

7.6.1 Estimated Gestational Age (Weeks), (MedGestWeek)

7.6.2 Estimated Gestational Age (Days){MedGestDay}

8 Treatment and Referral

8.1 Was IPTp or other antimalarial given? Indicate here whether the woman received SP for intermittent preventive therapy or any other antimalarial at this visit. (IPTp with SP must be given at this visit – mEli). If malaria positive treat with Lumefantrine-Artemether for simple malaria or refer to health facility for treatment of complicated malaria.

8.2 Referred to: Self-Explanatory

8.3 Free comments: Indicate here any further clarifications, e.g. if the gestation age is NOT within the eligibility window; any unusual findings from USS or other assessment; the reason for not giving SP, if maternal age is an estimate etc.

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original SOP version (dated 2011-01-21, approved by Per Ashorn)

2.0 First Amendment (dated 2011-03-31, approved by Per Ashorn). User Guide updated to correct materials required for completing the form (3.4.1); added instructions for completing q4.2 (During the past week, has the woman had any of the following?) and q9 (free comments). Revised instructions for completing visit number (q1.1); maternal age (q2.2, to estimate if unknown); how to obtain BP measurements (q5.1); how to measure temperature (q5.4) how to perform malaria RDT (q6.2); recording and calculating fetal parameters from USS (q7.3-7.5); modified slightly variable names for q7.3 , 7.7 and clarified how to handle IPT and malaria treatment. Form (both Chewa and Yao versions) also updated to revise the instruction for recording mother's birthdate if unknown (q2.1); changed instruction to estimate age if unknown (q2.2); removed the 'not applicable option' to q3.4 (Since the woman became pregnant, has she ever been admitted to hospital?), corrected variable names for gestational age and estimated date of delivery (q7.6-q7.7). for Chewa version also removed D from screening ID and added Chewa to the header. For the Yao version also added one box for the screening ID; made minor typo corrections and q7.6-7.7 and 8.3 which were missing from this version.

3.0 Second Amendment (dated 2011-11-11, prepared by Minyanga Nkhoma, approved by Per Ashorn). The form updated to revise the number of digits for the recording of USS measurements to be uniform and without decimal places (q 7.3.1 – 7.5.2). Deleted the average values for the US readings (q7.3.3, 7.4.3 and 7.5.3.) and question 7.6. Also added new questions 7.6.1 and 7.6.2 to record the estimated gestation age in weeks and days. The user guide updated to reflect these changes.

4.0 Third amendment (dated 2011-12-08, prepared by Abgail Sibande, Approved by Per Ashorn). Converted the form into a Traditional Teleform version

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 10, Eligibility assessment **(form version 2011-12-14)**

Version Number: 7.0 (2011-12-27)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The primary purpose of filling in and storing information on form 10 is to ensure and verify that all individuals, who will be offered a possibility to enroll in the iLiNS-DYAD-M are eligible for participation. Further aims include the documentation of the participant's interest in the study and a planned date for the actual randomisation and enrolment.

2.0 RESPONSIBLE PERSONNEL

1.2 Form 10 should be filled in only by a data monitor (or his / her assistant) who has been trained and assigned to do the randomization and supplement provision in the iLiNS-DYAD trial.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

1.3 Form 10 should always be filled in before form 11 (informed consent and randomization). The same data monitor will usually fill in both forms, either at the same session or – if the woman wishes to consult family members about the participation , in two consecutive sessions.

1.4 The form will be filled in at an iLiNS-DYAD study clinic. Because there are no direct questions to the guardian, the form is only available in English.

1.5 After completing the form, the data monitor will explain the outcome to the potential participant and encourage her to ask clarifications to any unclear issues.

1.6 Upon departure, all individuals from home will be given a one-page written summary of the trial, including the results and interpretation of any laboratory tests that were done during the enrolment session. Individuals who were assessed but not enrolled will get another document, explaining the reasons for exclusion.

1.7 To fill in the form, the data collector will need the following materials and equipment (and other resources):

1.7.1 A pen

1.7.2 Completed forms 4-9 from eligibility assessment

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Screening ID {ScreeNumber): Self-explanatory

Participant code {Participant): Self-explanatory

5 Visit Information

5.1

5.2 DateVisit: Enter as dd.mm.yy. Use leading zeroes form values below 10 (e.g. 09.02.2010)

6 INCLUSION AND EXCLUSION CRITERIA

General Point: If at any point the woman does not meet an inclusion criterion or meets an exclusion criterion, the eligibility assessment will be stopped. Mark an “X” under “99 = Not known” for all subsequent questions.

6.1 q2.1 – 2.3.1 (inclusion criteria): Check the values for the indicated variables from the original forms and mark an “X” in the appropriate box. For the participant to be eligible, all of the marks should be in the “1 = yes” column. An individual who has missing data from any of the questions 2.1 – 2.3,1 cannot be enrolled to the iLiNS-DYAD trial – i.e. eligibility requires documentation that the participant meets all defined inclusion criteria. Thus, to be eligible, a participant needs to be living in one of the villages belonging to the defined catchment area for the study, as indicated by a study village code written in q2.2.1

of form 02. If the village of residence does not have a study village code (i.e. answer in question 2.2.1 is 777.7), then the person is NOT eligible.

6.2 See above. To be eligible, a participant needs to be available throughout the entire planned follow-up period of the study (as indicated in q2.13of form 02)

6.3 See above. To be eligible, a participant needs to have shown an interest in study participation (as indicated in q2.14 of form 02)

6.3.1 See above. To be eligible, a participant needs to have both an ultrasound confirmed pregnancy and a known ultrasound-determined gestation age (as indicated in q7.6 of form 06). Scenarios where an ultrasonographer fails to determine pregnancy or its gestation age from ultrasound scan include but are not limited to technical challenges to precisely measure very small foetus and multiple gestation. Actually, for the later, twin gestation, triplets etc., it is not possible to determine gestation age using the current ultrasound method. For all such cases, the response to this question should always be "No" -- in which cases, the potential participant should not be included into the study. However, for those that have very small foetuses or very young gestation, the ultrasonographer (study nurse) should reschedule them to come back for rescreening after a few weeks.

6.3.2 q2.3.2 – 2.14 (exclusion criteria): Check the values for the indicated variables from the original forms and mark an "X" in the appropriate box. For the participant to be eligible, none of these marks may be in the "1 = yes" column. An individual who has missing data from any of the questions 2.5 – 2.14 can be enrolled to the iLiNS-DYAD trial – i.e. exclusion will be done only on the basis of a documented exclusion criterion.

7 ELIGIBILITY

7.1 RanEligibility: Self-explanatory, see above

7.2 RanIdentCard: Self-explanatory. The card should be made by the data monitor doing the randomization.

7.3 RanComments: Give here any free comments, e.g. reason for exclusion.

EliCollector, EliMonitor, EliEntry1, EliEntry1: The iLiNS ID-codes for the individuals, who recorded the data on the form, inspected the form after completion, or did the 1st or 2nd data entry into the iLiNS-DYAD-M database.

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original SOP version (dated 2011-01-06, approved by Per Ashorn)

2.0 First Revision (dated 2011-03-09, approved by Per Ashorn). Form revised to add a column for "99 = Not known" to Question 2. Added further instructions for completing the eligibility assessment (q2).

3.0 Second Amendment (dated 2011-03-18, approved by Per Ashorn). Form updated to remove HIV as an exclusion criterion (removed q 2.12) and to correct a minor typo.

4.0 Third Amendment (dated 2011-03-29, approved by Per Ashorn). User guide otherwise unchanged. Form revised to correct the numbers of the reference form and question numbers of the inclusion and exclusion criteria.

5.0 Fourth Amendment (dated 2011-06-23, approved by Per Ashorn). Form revised to add one exclusion criterion i.e. "Earlier participation in iLiNS-DYAD trial". User Guide updated to change numbering of the inclusion/exclusion criteria and also removed all references to "DOSE" (trial) and replaced with "DYAD" (trial).

6.0 Fifth Amendment (dated 2011-12-02, edited by John Phuka and approved by Per Ashorn, form version 2011-11-26). Form was edited by rephrasing q 2.1 (earlier: "Permanent resident of Mangochi or Malindi Hospital, or Lungwena, Namwera, Jalasi or Koche Health Centre", now "Permanent resident in the study catchment area"). Form was further edited by splitting q 2.14 (earlier inclusion criterion: Ultrasound confirmed pregnancy of no more than 20 weeks) into inclusion criterion 2.3.1 (Ultrasound confirmed pregnancy) and exclusion criterion 2.3.2 (Suspected or confirmed pregnancy duration of more than 20 completed gestation weeks). Clarified eligibility criteria recording in q2.1 – 2.4 in the user guide.

7.0 Sixth Amendment (dated 2011-12-27, edited by John Phuka and approved by Per Ashorn, form version 2011-12-14). Form edited to further clarify question 2.3.1 so that for potential participant to be eligible she should have both ultrasound determined pregnancy and ultrasound determined gestation age.

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 11, Consent and randomisation

(**form version 2011-12-01**)

Version Number: 4.0 (2011-12-08)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The primary purpose of filling in and storing information on form 11 is to ensure and verify that all enrolled iLiNS-DYAD participants have provided their consent to participate in the trial. Further aims include the documentation that the participants have been properly randomised into one of the intervention groups.

2.0 RESPONSIBLE PERSONNEL

1.2 Form 11 should be filled in only by a data monitor (or his / her assistant) who has been trained and assigned to do the randomization.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

1.3 The form will be filled in at an iLiNS-DYAD study clinic. The monitor filling in the form should explain to the guardian of the potential participant the purpose of the form and encourage her / him to ask clarifications to any unclear issues.

1.4 After completing the form, the data monitor should give the first supplement to the woman.

1.5 Upon departure, all participants will be given a one-page written summary of the trial, including the results and interpretation of any laboratory tests that were done during the enrolment session. Individuals who were assessed but not enrolled will get another document, explaining the reasons for exclusion.

1.6 To fill in the form, the data collector will need the following materials and equipment:

1.6.1 A pen and a writing pad

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Participant code: Self-explanatory

Screening ID: Self-explanatory

1 Visit Information

1.1 Number code of visit: This is the same number as the weeks of follow up in the study.

1.2 DateVisit: Enter as dd.mm.yy. Use leading zeroes form values below 10 (e.g. 09.02.2010)

2 Demographic Information

2.1 What is the participant's village of residence? {ConHomeVillage}. This is the village where the potential participant normally sleeps.

2.2 Participant's village code {ConCodeVillage}: Refer to the village code list

2.3 The names of the participating woman {ConNamesWoman}. If the potential participant has several different names, write them all here.

2.4 The names of the head of the household? {ConNamesHeadHH}. The person considered the head of the household is defined by the potential participant. If the person has several different names, write them all here.

2.5 Does the participant have a personal mobile phone? {ConPersonPhone}. Indicate here if the participant owns a mobile phone.

2.6 Does someone else in the participant's household have a personal phone? {ConHHPhone}. Indicate here if there is another person who owns a phone in the participant's household.

2.6.1 Self-Explanatory

2.62 Indicate here the relationship of that person to the participant e.g. mother, father-in-law, sister etc.

3 Consent

______. Write here the name of the data monitor who takes the consent

4 Date, signatures and randomisation outcomes

Signature of the participant.: If the person cannot write, ask her to mark the consent with a thumbprint.

Signature of the informant. This is the data monitor

Signature of the impartial witness. This needs to have a name and signature if the participant cannot adequately read – for instances in cases where thumbprint is used to document consent.

Record on the form with space provided expected date of delivery.

4.5 Free comments. Mark here any comments about the visit, e.g. if the respondent declines participation in the study after hearing more about the study. If no comments, mark "None".

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original SOP version (dated 2011-01-06, approved by Per Ashorn)

2.0 First amendment (dated 2011-03-18, approved by Per Ashorn). Form updated to remove English text of the consent from page 1 to Page 2 (so that all information for data entry is on page 1); added q3.5 (expected date of delivery) which is required for visit planning and also added instructions for finding the participant's home on page 2.

3.0 Second amendment (dated 2011-03-29, approved by Per Ashorn). User guide otherwise unchanged. Corrected the variable name for q3.5 (estimated date of delivery).

4.0 Third amendment (dated 2011-12-08, prepared by Abgail Sibande, approved by Per Ashorn). Converted the form into a Traditional Teleform version.

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 13a, Demographic background **(form version 2011-12-08)**

Version Number: 5.0 (2012-01-26)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The primary purpose of this User guide) is to describe the standard procedure for collecting socio-economic background data of iLiNS participants by administering form 13a. Our assumption is that socio-economic context is associated with infant growth.

2.0 RESPONSIBLE PERSONNEL

1.2 This responsibility of administering Form 13a is with the data monitors form undergone specific training. Trained data collectors may administer Form 13a when the data monitors are unable to do so due to unexpected circumstances. Senior study coordinator and project scientists (Thokozani Phiri and Nozga Phiri) are responsible for data collection and data quality. This visit will be conducted by data monitors trained for this form.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

1.3 Form 13a will be administered during the first home visit mSo1 to all iLiNS-DYAD participants. During the same visit, forms 14a, and 15 (see respective user guides, see also SOP 003 describing the visit). Also form 01 will be filled in relation to this visit.

1.4 Whom to interview?

Information is collected by interviewing the pregnant mother, who is referred to as “mother”, on the actual form (question 1.3). If she is not available for an interview when you go to the first home visit, agree about a new visit in the nearest future with mother or with other family members. Report to the data monitor if a new visit is needed. Repeat this as long as you can interview the mother.

1.5 How to ask questions?

In general, questions should be asked as they are written in the form. However, do modify the wording according to the person whom you are interviewing. For example, when you are interviewing the pregnant mother, ask "What is your relationship to the head of household?" instead of asking "What is mother's relationship to the head of household?

When administering this form, do not read the answering options to the respondents. If respondent is shy or reluctant to answer the questions for some other reasons, help her by prompting in a neutral way.

1.6 How to fill in the questionnaire?

Codes to be used are listed below each question. In addition to that, please note the general coding options:

- Always tick 66 if the answer is **other** and write the answer on the line that is provided. It there is a tick for other option, a written answer is mandatory.
- Always tick 77 if **not applicable** / question cannot be meaningfully answered.
- Avoid using the 99 option, **not known**, as much as possible, because we want to get the information concerning the question you asked.

Also note that an answer is required to each and every question.

1.7 Language

If you need to write the answer, for example when answer is 66, please use the language the respondent is speaking.

1.8 Family relationship

Where ever family relationship is asked about in this form, it is expressed in relation to the pregnant woman.

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Below there are question specific detailed instructions to questions in the form especially for such questions that may be difficult to administer.

Participant code {Participant): Self-explanatory

Section 1: Visit information

1.1 Number (code) of visit {NumberVisit}:Self explanatory

1.2 Date of visit {DateVisit}: please use leading zeroes

1.4 GPS position of the home: fill in according to user manual

Section 2: Demographic information

Most of the questions in this section are self-explanatory. For some selected questions there are instructions below.

*** First fill out participants name and name of the head of the household. By head of household we mean the main decision-maker of the family and the person who decides how finances and resources will be allocated. You can tell the participant that this information will not be entered in the data base but will be used for finding her house for the next visit.

*** Question 2.6 and 2.7 are about mother's age and Q 2.20 and 2.21 are about father's age. The interviewer has to make sure to get an estimate for the mother/father's age. If the age is not known, try estimating it as with techniques that have been used during training sessions and avoid using "99", not known. It is not acceptable to leave this blank.

***After the respondent answers question 2.8 only proceed to 2.8.1, if the pregnant woman is married and let the respondent answer whether she is in a monogamous or polygamous marriage.

*** When you fill in current composition of household section (Q 2.35, Q 2.36 and the table), do it in the following manner:

First ask Q 2.35 and 2.36. This information is meant to help you to establish the family composition. In the table you should list the same number of people as indicated in these two questions.

Then move on to the table. Start by reading the sentence "Next I would like to ask you to tell me which people live in your household. By household we mean …"

Then ask: Can you start listing the members of your household by telling me who is the eldest man?

Then fill in his name on the first line of the table and continue with the rest of the questions on the same line.

Tick: Sex

Ask: What is his relationship to pregnant woman?
Use codes from the list above the table.

Ask: What is his age?

Ask: Can he read?

Ask: Can he write?

Ask: What is his main occupation?
Use codes from the list below the table.

Ask: How many years of primary school has he completed?

Ask: How many years of secondary school has he completed?

Ask: Has he got any chronic illness that limits his ability to work or study?

Ask: Who is the next eldest male in the household?
Repeat the questions from the table.

After listing all the male members of the household, ask: Who is the eldest woman in your household?
Repeat the questions from the table.

Ask: Can you please list all the children who live in your household?
Repeat the questions from the table but do not ask questions about reading, writing and school for children who are under 5 years in the household; instead, write 77 = not applicable.

,

Note 1:

Do not include information about the pregnant woman (respondent) and father in the table because this information has been collected already.

Note 2:

If there is discrepancy in the answers between the total number of persons in the household (Q 2.35) or total number of children below 5 (Q2.36) and the people who are listed in the table, try to sort that out by asking more questions.

Note 3:

If the household consists of the pregnant woman and her husband, there is no need to fill in the table. Instead, tick the relevant box below the table.

Note 4:

By household we mean here people who live together and share some of the resources, most often food. However, in a household people do not necessarily eat together.

It could be, for example, that the pregnant woman lives with her sister, their children and her parents together. This is considered a household even if they live in different houses.

Or, it could be that pregnant woman, her husband and children live together with her husband's parents. There could be also other family members like uncles or aunts living there. This is also considered as a household.

If people are uncertain who should be included in their household, encourage them to use as wide definition as possible.

Living environment

All questions are self-evident.

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original user guide version (dated 2011-01-06, approved by Ulla Ashorn)

2.0 First Amendment (dated 2011-03-21, approved by Ulla Ashorn)

Under Section 2, demographic section, a definition of head of household has been added. An instruction has also been added for information collected about under-5 children in the household. Under *Note 4*, in the same section, "children" has been added to "pregnant woman and her husband".

3.0 Second Amendment (dated 2011-08-23, approved by Ulla Ashorn)

Form version has changed to 2011-06-21.

4.0 Third amendment (dated 2011-12-10, prepared by Ulla Harjunmaa, approved by Ulla Ashorn). Converted form into traditional Teleform version

5.0 Fourth amendment (dated 2012-01-26, approved by Ulla Ashorn). Added clause in section 2.1 to allow data collectors to administer Form 13a and corrected some typos.

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to Form 15, Food security and economics **(form version Chewa and Yao 2011-12-08|)**

Version Number: 6.0 (2011-12-09)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 All households whose participants (864) have been enrolled into the trial will be asked questions from this questionnaire regarding accessibility of food (stocks and purchases), household coping strategies and other economic activities of the household.

2.0 RESPONSIBLE PERSONNEL

1.2 The data collectors and data monitors who have been approved to take part in the conducting of the iLiNS DYAD study will primarily use Form 15.

2.0 **<u>GENERAL INSTRUCTIONS AND GUIDELINES</u>**

2.1 To fill in the form, the data collector will need the following materials and equipment:

2.1.1 A pen and a writing pad/log book.

3.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

2.2 Participant code (Child number): Self-explanatory – Fill in as trained.

Date of visit {DateVisit}: Self-explanatory – Fill in as trained.

2.3 PART 1: HOUSEHOLD FOOD INSECURITY ACCESS SCALE

2.3.1 Q.2.1 Worry about food

This question asks the respondent to report their anxieties and about getting food in the past 4 weeks. The interviewer should read the definition of a 'Household' and mention that this definition of household applies to all questions with that term.

2.3.2 Q.2.2 Unable to eat preferred foods

In food insecurity, we also consider limited choices that the household eats. This question asks whether any household member was not able to eat according to their preferences due to lack of resources. Preference can mean a particular food, staple food or high-quality food.

2.3.3 Q.2.3 Eat just a few kinds of foods

This question concerns food groups, food types and variety of food – whether the household has to eat the same foods. This question concerns all members of the households and not only the respondent.

2.3.4 Q.2.4 Eat foods they really do not want to eat

This question, which concerns limited choices, asks whether the households ate foods that were not socially desirable or acceptable. These foods are prepared under hardship. Do not provide examples, as these socially undesirable foods may vary from community to community.

2.3.5 Q.2.5 Eating a smaller meal

This question asks whether the respondent felt that the amount of food (any kind of food, not just the staple food) that any other household member ate in any meal during the past four weeks was smaller than they felt they needed due to a lack of resources. The respondent should answer according to their understanding of what is enough food for the needs of household members. The respondent needs to answer on behalf of all household members.

2.3.6 Q. 2.6 Eat fewer meals in a day

This question is different from Q.2.5 in that it asks whether the respondent missed breakfast, lunch or dinner. In the Chichewa version, please be aware that *kadzutsa* is breakfast; *nkhomaliro* is lunch and *m'gonero* is dinner. Do note that the focus is on the number of meals the household members ate and not the quantity of the meal.

2.3.7 Q. 2.7 No food of any kind in the household

This question asks about a situation in which the household has no food of any kind in the home. This describes a situation where there is no food available to any household members in which the household members, through purchasing, dimba or farm, storage, etc.

2.3.8 Q. 2.8 Going to sleep hungry

This question asks whether the respondent felt hungry at bedtime because of lack of food.

2.3.9 Q. 2.9 Going a whole day and night without eating

This question asks whether any household member did not eat from the time they awoke in the morning to the time they awoke the next morning.

2.4 PART 2: HOUSEHOLD FOOD CONSUMPTION RELATED COPING STRATEGIES

2.4.1 Q. 3.1 Borrow food or money

This question asks whether the respondent had to borrow food from people outside of the household, such as relatives or friends, for food to feed the members of the household.

2.4.2 Q.3.2 Purchase food on credit

This question asks whether the household had to purchase any food on credit (that is, receive food before paying with an agreement to pay in the future).

2.4.3 Q.3.3 Rely on help elsewhere

This question asks whether the household had to receive food or money to buy food from outside their household through others; e.g., relatives or friends from another household, due to lack of food.

PART 3: CHILDREN CHILD FOOD-CONSUMPTION-RELATED COPING STRATEGIES

2.4.4 Q4.1 Limit own (respondent’s) intake

This question asks the respondent, who is primarily responsible for food and meal preparations in the household, whether they have limited their own intake of food so that the youngest child/children in the household may have enough.

4.0 ECONOMICS

2.5 Introduce the section to the respondent and be sure to explain that their answers will not result in any assistance from the project since we are conducting research. *Those receiving Chiponde or multiple-micronutrients will continue receiving Chiponde or multiple-micronutrients (MMN), while those not receiving Chiponde or MMN will receive standard ante-natal care. After delivery, those receiving Chiponde and MMN will continue to do so while those who received standard care will receive a placebo tablet.*

2.6 Ask the questions 5.1-5.9, as they are written in the form. For questions 5.2.32-5.2.40 on assets related to children, do refer to the iLiNS DOSE/DYAD user guide for developmental assessments for explanations.

2.7 For question 5.11.1 and 5.12.1, please use the value of the vouchers to mean the total they would have paid, if they did not have a voucher minus the money actually paid for the seeds or fertilizers. E.g. they pay K500 while the market value of fertilizer is K4000. This means the value of the voucher is K4000-K500 = K3500. Help the respondent arrive at this conclusion by guiding them with the computing.

2.8 For questions 5.11-5.12, be aware that at different stages in the cropping cycle, there will be different answers given. For example, from November-December, they will be increased activities in seed/fertiliser distribution to coincide with the planting stage. During harvest time in April-May, such activities will not be observed, however, the questions ask about the past 6 months.

Finally, fill the iLiNS ID-codes for the individuals, who recorded the data on the form, or inspected the form after completion should be filled in.

5.0 VERSION HISTORY (AMENDMENTS)

6.0 Original user guide version (dated 2011-02-11, approved by Steve Vosti)

7.0 First Amendment (dated 2011-03-09, approved by Steve Vosti).

8.0 For question 5.11.1 and 5.12.1 on the form, there is an explanation on how to calculate the values of the vouchers. See section 5.3.

9.0 Second Amendment (dated 2011-04-26, approved by Steve Vosti).

Previous form version has changed to 2011-04-26.

10.0 Third Amendment (dated 2011-10-03, approved by Steve Vosti).

The formatting was off on the forms in the Chichewa and Chiyao versions. This has now been fixed.

11.0 Fourth Amendment (dated 2011-12-01), approved by Steve Vosti).

Sections 3.1.1, 4.4.1 and 5.3 have some additional text to clarify the instructions or explanations.

1.0 Fifth amendment (dated 2011-12-09, prepared by Abgail Sibande, approved by Per Ashorn). Converted the form into a Traditional Teleform version.

Instructions for data collection; iLiNS-DYAD-M trial.

User guide to form 24, Newborn details
(form version Chewa and Yao 2011-12-01)
Version Number: 7.0 (2011-12-09)

1.0 BACKGROUND AND PURPOSE OF THIS DATA COLLECTION FORM

1.1 The primary purpose of filling in and storing information on form 24 is to document the birth weight of the baby (one of primary pregnancy outcomes for the trial). Further aims include the documentation of the participants' vital status and wellbeing after delivery, other anthropometric measurements and early feeding practices.

2.0 RESPONSIBLE PERSONNEL

1.2 Form 24 should be filled in only by a data collector who has been trained in the use of this form.

3.0 GENERAL INSTRUCTIONS AND GUIDELINES

1.3 Form 24 should preferably be filled in as soon as possible after delivery, i.e. on the day of delivery or on the following day. If the baby was born in a health facility, the form is ideally filled in whilst the baby and mother are still at the facility.

- **1.3.1** If the form cannot be filled in within the indicated period, it will still be completed on the first contact with the mother / baby dyad.

1.4 To fill in the form, the data collector will need to see the baby and interview the mother. Ideally, the delivery attendant would also be present whilst form 24 is being filled in.

1.5 To fill in the form, the data collector will need the following materials and equipment:

- **1.5.1** A pencil and a writing pad
- **1.5.2** A digital newborn scale
- **1.5.3** A white cloth
- **1.5.4** A plastic measuring tape

1.5.5 Delivery chart / description if he baby was born in a health facility

4.0 SPECIFIC INSTRUCTIONS ON INDIVIDUAL QUESTIONS

Participant code {Participant): Note that this form is for the child and the participant code will be in the format **XXXX.1, e.g. 3030.1 or 8010.1**.

2 Visit Information

4.1 Number (code) of visit {NumberVisit}: Self evident

4.2 DateVisit: Enter as dd.mm.yy. Use leading zeroes to form values below 10 (e.g. 09.02.2010)

4.3 Respondent (relationship to participating child) {NewInterviewee}: Indicate the relationship of the person being interviewed to the participating child by checking the appropriate box.

4.3.1 If the response is other in Q1.3, specify the relationship here.

5 Condition after delivery and at inspection; Baby A

5.1 Vital status of the first baby {NewStatusBabyA}: Check the appropriate box. Miscarriages should be recorded as 'fresh stillbirths'

5.2 Sex of the baby {NewChildSexA}: Check external genitalia to verify sex. If the sex cannot be verified because the child is dead, check "Not Applicable".

5.3 Was an APGAR score given {NewApgarGivenA}: Given only for those born at health facilities. Answer "yes" if the score is available, "no" if not.

5.3.1 APGAR score at 1 minute {NewApgarB1min}: Indicate here the Apgar score given at 1 minute. *Write '99' if APGAR score is not available.*

5.3.2 APGAR score at 5 minutes {NewApgarB5min} Indicate here the Apgar score given at 5 minutes. *Write '99' if APGAR score is not available.*

5.4 Baby A Weight (g) {NewWeightA},{NewWeightB},{NewWeightC}: The weight will be measured with a digital scale, without any clothing or diaper on the baby. A clean piece of soft white paper is first placed on the scale. Then a button is pressed to reset the scale to 0 grams. Then the baby is placed on the scale to get the reading. For each measurement, the baby will be taken up and repositioned on the paper. Record the weight as indicated on the scale – use leading zeroes where necessary.

5.5 Baby A Chest circumference (mm) {NewChestA},{NewChestB},{NewChestC}: The chest circumference will be measured with a plastic measuring tape. The tape will be placed at the level of the xiphoid process and below the inferior angles of the scapulae. The tape will be applied in such manner as to permit skin contact without compression of underlying tissues. The result will be recorded to the nearest 1 mm – use leading zeroes where necessary.

5.6 Baby A Head circumference (mm) {NewHeadA},{NewHeadB},{NewHeadC}: The head circumference will be measured with a plastic measuring tape. The tape will be placed at a level that measures the largest head circumference, with the tape passing above the supraorbital ridges and over the maximum occipital prominence. Before read-out, the data collector will ensure that the tape is at the same level on each side. The result will be recorded to the nearest 1 mm – use leading zeroes where necessary.

Condition after delivery and at inspection; Baby B

5.7 Vital status of the **2nd** baby {NewStatusBabyB}: Check the appropriate box. Miscarriages should be recorded as 'fresh stillbirths'

5.8 Sex of the **2nd** baby {NewChildSexB}: Check external genitalia to verify sex. If the sex cannot be verified because the child is dead, check "Not Applicable".

5.9 Was APGAR score given to the second baby {NewApgarGivenB}: Given only for those born at health facilities. Answer "yes" if the score is available, "no" if not.

5.9.1 APGAR score at 1 minute {NewApgarB1min}: Indicate here the Apgar score given at 1 minute. *Write 77 if not applicable ore 99 if APGAR score is not available*

5.9.2 APGAR score at 5 minutes {NewApgarB5min}: Indicate here the Apgar score given at 5 minutes. *Write 77 if not applicable or 99 if APGAR score is not available.*

5.10 Baby B Weight (g) {NewWeightB1},{NewWeightB2},{NewWeightB3}: The weight will be measured with a digital scale, without any clothing or diaper on the baby. A clean piece of soft white paper is first placed on the scale. Then a button is pressed to reset the scale to 0 grams. Then the baby is placed on the scale to get the reading. For each measurement, the baby will be taken up and repositioned on the paper. Record the weight as indicated on the scale – use leading zeroes where necessary.

5.11 Baby B Chest circumference (mm) {NewChestB1},{NewChestB2},{NewChestB3}: The chest circumference will be measured with a plastic measuring tape. The tape will be placed at the level of the xiphoid process and below the inferior angles of the scapulae. The tape will be applied in such manner as to permit skin contact without compression of underlying tissues. The result will be recorded to the nearest 1 mm – use leading zeroes where necessary.

5.12 Baby B Head circumference (mm) {NewHeadB1},{NewHeadB2},{NewHeadB3}: The head circumference will be measured with a plastic measuring tape. The tape will be placed at a level that measures the largest head circumference, with the tape passing above the supraorbital ridges and over the maximum occipital prominence. Before read-out, the data collector will ensure that the tape is at the same level on each side. The result will be recorded to the nearest 1 mm – use leading zeroes where necessary.

6 Early breastfeeding practices after delivery

(Do not ask questions in this section in cases of stillbirths/miscarriages instead record the responses as follows: q3.1= No; q3.2=Not applicable; q3.3=No, q3.4=Lost child; q3.5-3.14= not applicable)

6.1 Have you ever breastfed the infant? {NewEverBF}: Ask this question first. Mark "yes", if the baby has ever been on the breast and mouthed or sucked it, whether the attempt was successful or not (as judged by the respondent). If the answer is "no", do not ask questions 3.2 and 3.3 from the mothers, but just mark alternatives "77" to Q3.2 and option "0" for option 3.3 and ask question 3.4 next.

6.2 How long after birth did you put the infant to the breast? {NewHowSoonBF}: Choose the closet option. If the mother is not sure, try to help her choose by probing if breastfeeding happened "very soon after birth", "on the day of delivery" etc. If the birth attendant is present and witnessed the first-time baby was put to the breast, birth attendant can also be consulted along with the mother.

6.3 Are you currently breastfeeding the infant? {NewCurrentBF}: Accept the mothers answer. For example, even if she has only breastfed once, if she intends to continue, and she herself considers that she is breastfeeding the child, tick “1” for “yes”. However, if she says “no” accept her answer, tick “0” for no, and find out the reason in the next question.

6.4 Why are you not breastfeeding? {NewWhyNotBF}: Choose only one option. If the respondent feels that there are several reasons, ask her to tell the main reason, or most important reason. If the woman is currently breastfeeding, do not ask this question but instead mark “77” for “not applicable” and move to question 3.5.

6.4.1 If other, please specify {NewSpecNotBF}: Self evident

6.5 -3.14. Liquids and foods that the infant may have had since birth/ during the first seven days after birth {NewPlainWater} , {NewOther}: In this part, we try to collect information about anything the baby was given to drink (or eat) in the first week of life. If the baby has been given anything most likely it will be liquids (drinks) but we ask about porridge (Q3.13) and any other liquids or foods (Q3.14) just in case. Ask each item separately and mark down if the baby has ever had that liquid or food item (1=yes) or not (0=no). If the respondent is not sure, mark “99”. If the child has died, mark “77”. Even if the baby is not yet one week old, fill in this section just the same. In this case, we are finding out what the baby has been given since birth. If the baby is more than one week old (this should usually not happen) ask the mother to think back to the first seven days of the baby’s life, and answer what the baby was given then.

7 Free comments

7.1 Free comments {NewComments}: Indicate here any further comments (e.g. explain missing APGAR or Ballard scores, mother miscarried, still birth etc.). If no further comments, mark “none”.

NewCollector, NewMonitor, NewEntry1, NewEntry1: The iLiNS ID-codes for the individuals, who recorded the data on the form, inspected the form after completion, or did the 1st or 2nd data entry into the iLiNS-DYAD-M database.

5.0 VERSION HISTORY (AMENDMENTS)

1.0 Original SOP version (dated 2010-12-31, approved by Per Ashorn)

2.0 First Amendment (dated 2011-05-25, approved by Per Ashorn). No changes to the form, but changed the date of the form. Clarified recording if the child is not breastfed (q3.4). Clarified data collection on liquids and other foods (q3.5 – 3.14).

3.0 Second Amendment (dated 2011-06-10, approved by Per Ashorn). The form revised to add description of respondent (q1.3 and q1.3.1); added “Not Applicable” option to responses for sex of the baby (q2.1); added “77=Not Applicable” option to questions on liquids and other foods intake (q3.5 – 3.14). User guide updated to reflect the above changes to the form and added examples of what to write in “Free comments” (q5.1).

4.0 Third Amendment (dated 2011-06-16, approved by Per Ashorn). The form revised to add provision for documentation of birth details of second baby in cases of twins, removed section 4 (New born status and size) and integrated content into section 2.0 (Condition after Delivery and at Inspection). User guide updated to reflect the above changes to the form and also added instructions on how to handle section 3 (early breastfeeding practices after delivery) in cases of still births or neonatal deaths immediately after delivery.

5.0 Fourth Amendment (dated 2011-06-25, approved by Per Ashorn). The form revised to simplify the collection of APGAR score data by deleting the table showing detailed APGAR score per category and adding q2.3.1 and q2.3.2. added collection of APGAR score from second twin (q2.10, 2.10.1 and 2.10.2). The user guide amended to reflect these changes.

6.0 Fifth Amendment (dated 2011-11-03, prepared by Minyanga Nkhoma, approved by Per Ashorn). The form revised to change variable names to match with how they appear in the database (q2.7; 2.10.1 and 2.10.2); removed question 10. Added instructions for completing q1.1 (Participant code); q2.3.1, 2.3.2, 2.10.1 and 2.10.2 (APGAR Scores).

7.0 Sixth amendment (dated 2011-12-09, prepared by Abgail Sibande, approved by Per Ashorn). Converted the form into a Traditional Teleform version.

13010
iLiNS-DYAD trial: Form 02 (version 2011-12-02)
Screening, English

Screening ID{ScreeNumber}
Participant Code {Participant} .

1. **Visit information**

1.1 Number (code) of visit (NumberVisit)..........

1.2 Date of visit (DateVisit) .... dd - mm - 20 yy

1.3 Can screening be completed: (ScrPermission)

☐ [1] Yes ☐ [0] No

1.4 Language of interview: (ScrLanguage)

☐ [1] Chiyao ☐ [2] Chichewa ☐ [66] Other

2. **Information on, mother and household** (mark 99, if any information is not available)

2.1 Catchment area: (SrcArea)

☐ [1] Mangochi ☐ [3] Malindi ☐ [5] Namwera
☐ [2] Lungwena ☐ [4] Koche ☐ [6] Jalasi

2.2 Home Village: (SrcNameVillage) ____________________

2.2.1 Code (SrcCodeVillage) (Mark 999.9 if code not available, i.e. if the woman does not live in a village that belongs to the study catchment area) .

2.3 What is the age of the woman? (SrcMotherAge)............... years (completed years)

2.4 What is your marital status? (ScrMothMarSt)

☐ [1] Single ☐ [3] Divorced/separated ☐ [99] Not Known
☐ [2] Married ☐ [4] Widow

2.5 How many children does the woman have? (SrcMotherChild) (Include the study child)

2.6 What is the highest grade completed by the women at Primary school? (SrcMotPrimSch) (Indicate 0, if none)

2.7 What is the highest grade completed at Secondary school? {SrcMotSecnSch} (Indicate 0, if none)

2.8 How many goats does the household own? (ScrHouseGoats)

2.9 Does anyone in the household own a cell-phone (ScrHousePhone)

☐ [0] No ☐ [1] Yes ☐ [99] Not Known

2.10 What is the building material of the house (ScrHouseWalls)

☐ [1] Burnt Brick ☐ [2] Unburned brick ☐ [3] Straw,grass or mud ☐ [66] Other

2.11 What is the roofing material (ScrHouseRoof)

☐ [0] None ☐ [1] Grass ☐ [2] Iron sheets or tiles ☐ [66] Other

2.12 Has the mother participated in the iLiNS-DYAD trial before? (ScrPreviousParticipation)

☐ [0] No ☐ [1] Yes ☐ [99] Not known

2.13 Will the mother be living in her current address or otherwise be available to participate in the iLiNS-DYAD trial for the next 12 months? (ScrAvailabilit)

☐ [1] Yes ☐ [2] Probably yes ☐ [0] No

2.14 Is the mother willing to undergo eligibility assessment (ScrInterested)

☐ [1] Yes ☐ [2] No, believes her pregnancy is over 20 weeks ☐ [3] No, Not interested

2.15 Will eligibility assessment be completed? (ScrEliAssess) ☐ [0] No ☐ [1] Yes

2.16 Free Comments{ScrComments}: ____________________

i. Collector (ScrCollector)

ii Date (ScrDateCollector) - - 20

iii. Monitor (ScrMonitor)

iv. Date (ScrDateMonitor) - - 20

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iLiNS-DYAD trial: Form 04 (version 2012-06-11) Screening ID{ScreeNumber} [ ][ ][ ][ ][ ]

Anthropometrics, women Participant Code {Participant} [ ][ ][ ][ ].[ ]

1. Visit information

1.1 Number (code) of visit *(NumberVisit)*...... [ ][ ][ ][ ]

1.2 Date of visit *(DateVisit)* .... [ ][ ] - [ ][ ] - [2][0][ ][ ]

dd mm yy

2. Maternal anthropometry

2.1 Participant's main mode of transport to heath centre today: *(AntTransMode)*

- [1] On foot
- [2] Bicycling
- [3] Bike Taxi
- [4] Motorised vehicle

2.2 Maternal Clothing *(AntClothing)*............

- [1] Light clothing
- [2] Light clothing + sweater
- [3] Heavy clothing

2.3 Height (cm) *(Record only at enrollment visit, mark 999,9 on other visits)* *(AntHeightA/AntHeightB/AntHeightC)*

2.3.1 [ ][ ][ ].[ ] 2.3.2 [ ][ ][ ].[ ] 2.3.3 [ ][ ][ ].[ ]

2.4 Weight (kg) *(Record three measurements) (AntWeightA/AntWeightB/AntWeightC)*

2.4.1 [ ][ ][ ].[ ][ ] 2.4.2 [ ][ ][ ].[ ][ ] 2.4.3 [ ][ ][ ].[ ][ ]

2.5 Arm circumference – MUAC (mm) *(Record three measurements) (AntuacA/AntuacB/AntuacC)*

2.5.1 [ ][ ][ ] 2.5.2 [ ][ ][ ] 2.5.3 [ ][ ][ ]

2.6 Triceps skinfold (mm) *(Record three measurements) (AntSkinTriA/AntSkinTriB/AntSkinTriC)*

2.6.1 [ ][ ].[ ] 2.6.2 [ ][ ].[ ] 2.6.3 [ ][ ].[ ]

2.7 Subscapular skinfold (mm) *(AntSkinSubA/AntSkinSubB/AntSkinSubC)*

2.7.1 [ ][ ].[ ] 2.7.2 [ ][ ].[ ] 2.7.3 [ ][ ].[ ]

2.8 Scale ID *(AntScaleId)*........... [ ][ ]

2.9 Stadiometer ID *(AntStadioId)* ..... [ ][ ]

2.10 Free comments *{AntComments}* *(e.g., reason for no mesurements)*

____

____

i. Collector (AntCollector) [ ][ ][ ] *iii. Monitor (AntMonitor)* [ ][ ][ ]

ii Date (AntDateCollector) [ ][ ] - [ ][ ] - [2][0][ ][ ] *iv. Date (AntDateMonitor)* [ ][ ] - [ ][ ] - [2][0][ ][ ]

5766

iLiNS-DYAD trial: Form 06a (version 2012-05-31)
Maternal medical examination, enrolment, Chewa

Last digit of Participant number (before decimal point) ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Screening ID(ScreeNumber) ☐☐☐☐☐

4. This pregnancy

4.1 Pali mavuto ena ali onse okhudzana ndi mimba iyi? Are there any problems in this pregnancy? *(MedProblems)*

☐ [0] No
☐ [1] Yes

4.1.1 Ngati eya, fotokozani If yes, please specify (MedSpecProblems) ____________________

4.2 Mkati mwa mulungu wathawu, mayiyu anakhalapo ndi zina mwa izi?
During the past week, has the woman had any of the following?

4.2.1 Nseru Nausea *(MedNausea)*	☐ [0] No	☐ [1] Yes
4.2.2 Kusanza Vomiting *(MedVomiting)*	☐ [0] No	☐ [1] Yes
4.2.3 Kutsekula m'mimba Diarrhea *(MedDiarrhea)*	☐ [0] No	☐ [1] Yes
4.2.4 Chimbudzi cha madzi koposa katatu patsiku More than 3 watery stools in a day *(MedWateryStoo)*	☐ [0] No	☐ [1] Yes
4.2.5 Magazi m'chimbudzi Blood in stool *(MedBloodStool)*	☐ [0] No	☐ [1] Yes
4.2.6 Zonanda m'chimbudzi Mucus in stool *(MedMucusStool)*	☐ [0] No	☐ [1] Yes
4.2.7 Chifuwa Cough *(MedCough)*	☐ [0] No	☐ [1] Yes
4.2.8 Mamina olimba achikasu Thick, yellow nasal discharge *(MedNasalDischa)*	☐ [0] No	☐ [1] Yes
4.2.9 Kutentha thupi Fever *(MedFever)*	☐ [0] No	☐ [1] Yes
4.2.10 Zina, fotokozani If other, specify *(MedSpec)*:		

5. Medical examination

5.1 Systolic blood pressure, mmHg *(MedBpSystA / MedBpSystB / MedBpSystC)*

5.1.1 ☐☐☐ 5.1.2 ☐☐☐ 5.1.3 ☐☐☐

5.2 Diastolic blood pressure, mmHg *(MedBpDiastA / MedBpDiastB / MedBpDiastC)*

5.2.1 ☐☐☐ 5.2.2 ☐☐☐ 5.2.3 ☐☐☐

5.3 Oedema *(depress the dorsum of foot)* *(MedOedema)*

☐ [0] None ☐ [2] 0.5 - 1 cm
☐ [1] <0.5 cm ☐ [3] > 1cm

5.4 Temperature *(MedTemperature)*............ ☐☐.☐ °C

5.5 Does the woman have an acute condition that warrants hospital referral *(MedAccuteCond)*
☐ [0] No ☐ [1] Yes

5.5.1 If yes, please specify *(MedSpecAcute)* ____________________

5.6 Fundal height *(MedFundal)*............. ☐☐.☐ cm

i. Collector ☐☐☐ iii. Monitor ☐☐☐

iiDateCollector ☐☐-☐☐-☐☐☐☐ iv DateMonitor ☐☐-☐☐-☐☐☐☐

5766

iLiNS PROJECT

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

iLiNS-DYAD trial: Form 06a (version 2012-05-31)
Maternal medical examination, enrolment, Chewa

Screening ID{ScreeNumber} ☐☐☐☐☐

Participant Code {Participant} ☐☐☐☐.☐

6. Hb and malaria test *(Blood collection + form 09 at mEli & m36c, Hb at all visits, malaria RDT at mEli & m32c)*

6.1 Blood haemoglobin concentration *(MedHb)*.... ☐☐☐ *g / l (999 if not measured)*

6.2 Malaria rapid test result *(MedMalariaRDT)*
(Should only be done at visits mEli & m32c)

- ☐ [0] Negative
- ☐ [1] Positive, P. falciparum
- ☐ [2] Positive, other malaria
- ☐ [3] Invalid
- ☐ [99] Test not done

7. Ultrasound Assessment

7.1 Was an ultrasound assessment done at this visit *(MedUltrasound)*

- ☐ [0] No
- ☐ [1] Yes

7.2 How many foetuses can be seen? *(MedNumbFoetus)* ☐

Measurements	1st Value (mm)	2nd Value (mm)
7.3 Biparietal diameter (MedFoetBipDia1/2/A)	7.3.1 ☐☐.☐	7.3.2 ☐☐.☐
7.4 Femur length (MedFoetFemLengt1/2/A)	7.4.1 ☐☐.☐	7.4.2 ☐☐.☐
7.5 Abdominal circumference (MedFoetAbdoCircl/2/A)	7.5.1 ☐☐☐	7.5.2 ☐☐☐

Estimated gestational age (Weeks, Days)	7.6.1 *(MedGestWeek)* ☐☐ **weeks**	7.6.2 *(MedGestDay)* ☐ days

7.7 Estimated date of delivery *(MedEstDateDel)* ☐☐ - ☐☐ - 2 0 ☐☐
dd mm yy

8. Treatment and referral

8.1 Was IPTp or other antimalarial given? *(MedIPTp): (IPTp with SP to be given at visits mEli & m32c)*

- ☐ [0] No
- ☐ [1] Yes, SP
- ☐ [2] Yes, Other antimalarial drug

8.2 Referred to *(MedReferral)* : ....

- ☐ [0] Healthy, no referral needed
- ☐ [1] Local Health Centre
- ☐ [2] Hospital
- ☐ [66] Other

8.2.1 If other, please specify *(MedSpecReferra)* ____________________

8.3 Free comments *(MedComments)* ____________________

i. Collector ☐☐☐ iii. Monitor ☐☐☐

iiDateCollector ☐☐-☐☐-☐☐☐☐ iv DateMonitor ☐☐-☐☐-☐☐☐☐

10948

iLiNS

iLiNS-DYAD trial: Form 10 (version 2011-12-14)
Eligibility assessment

Screening ID{ScreenNumber} [ ][ ][ ][ ][ ]

Participant Code {Participant} [ ][ ][ ][ ].[ ]

1. Visit information

1.1 Number (code) of visit *(NumberVisit)*...... [ ][ ][ ][ ]

1.2 Date of visit *(DateVisit)* .... [ ][ ] - [ ][ ] - [2][0][ ][ ]
dd mm yy

2. Inclusion and exclusion criteria

Exclude if any check here **0 = No**

Inclusion criteria:	**0 = No**	**1 = Yes**	**99 = Not known**
2.1 Permanent resident in the study catchment area {EliInclResidence}(f02, q2.2.1)	☐	☐	☐
2.2 Availability during the period of the study {EliAvailable} (f02, q2.13)	☐	☐	☐
2.3 Interest in trial participation {EliInterest} (f02, q2.14)	☐	☐	☐
2..3.1 Ultrasound confirmed pregnancy of known duration (f06a, q7.2) {EliUsPregnan}	☐	☐	☐

Exclude if any check here **1 = Yes**

Exclusion criteria:	**0 = No**	**1 = Yes**	**99 = Not known**
2.3.2 Suspected or confirmed pregnancy duration of more than 20 completed gestation weeks {EliOvAgePregnan}(f02, q2.14 / f06a, q7.6.1)	☐	☐	☐
2.5 History of allergy towards peanuts *{EliExclPNAller} (f05, q3.1)*	☐	☐	☐
2.6 History of anaphylaxis or serious allergic reaction to any substance, requiring emergency medical care {EliExclAnaphy} (f05, q3.2)	☐	☐	☐
2.7 Pregnancy complications evident at enrollment visit (moderate to severe oedema, blood Hb concentration < 5 g / dl, systolic blood pressure (BP) > 160 mmHg or diastolic BP > 100 mmHg {EliExclPregComp} (f06, q5.1-5.3 and q6.1)	☐	☐	☐
2.8 Concurrent participation in any other clinical trial {EliExclOthePart} (f05, q3.4)	☐	☐	☐
2.9 Less than 15 years of age {EliExclAge} (f06a, q2.2)	☐	☐	☐
2.10 Need for frequent medical attention due to a chronic health condition {EliExclChroCon} (f06a, q3.1)	☐	☐	☐
2.11 Diagnosed asthma treated with regular medication {EliExclAsthma} (f06a, q3.2)	☐	☐	☐
2.13 Severe illness warranting hospital referral {EliExclSeveIll} (f06a, q5.5)	☐	☐	☐
2.14 Earlier participation in iLiNS-DYAD trial {EliExclEarlier}	☐	☐	☐

3. Eligibility and plan for randomization

3.1 Is the woman eligible to participate in iLiNS-DYAD {EliEligibility}
☐ [0] No
☐ [1] Yes

If "yes", give written information on the trial and agree on the time when she might be visited at her home.?
If "no", explain why , give written information, and thank the woman

3.2 Date & time for randomization visit {EliDateRanVisi} [ ][ ] / [ ][ ] / [2][0][ ][ ] [ ][ ] : [ ][ ]
dd mm yy hr min

3.3 Free comments (e.g. explain exclusion): {EliComments}

____

i. Collector (EliCollector) [ ][ ][ ]

iii. Monitor (EliMonitor) [ ][ ][ ]

ii Date (EliDateCollector) [ ][ ] - [ ][ ] - [2][0][ ][ ]

iv. Date (EliDateMonitor) [ ][ ] - [ ][ ] - [2][0][ ][ ]

62180

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

iLiNS-DYAD trial: Form 11 (version 2011-12-01)
Consent and randomisation, Chewa

Screening ID{ScreeNumber} ☐☐☐☐☐

Participant Code {Participant} ☐☐☐☐.☐

1. Visit information

1.1 Number (code) of visit *(NumberVisit)*...... ☐☐☐☐

1.2 Date of visit *(DateVisit)* .... ☐☐ - ☐☐ - 2 0 ☐☐
dd mm yy

2. Demographic information

2.1 Otenga nao mbali amakhala mudzi uti? *(ConHomeVillage)*
What is the participant's village of residence ____________

2.2 Participant's village code *(ConCodeVillage)*............... ☐☐☐.☐

2.3 Maina a mayi yemwe akutenga nao mbali?*(ConNamesWoman)*
Names of the participating woman ____________

2.4 Maina a amene amapeza zosowa pakhomo pano?*(ConNameHeadHH)*
Names of the head of the household? ____________

2.5 Kodi otenga nao mbali ali ndi foni yao yam'manja?... ☐ [0] No
Does the participant have a personal mobile phone ☐ [1] Yes
(ConPersonPhone)

2.5.1 Ngati eya, nambala yake ndi iti?
If yes, what is the number? *(ConOwnPhoneNum)* ☐☐☐☐☐☐☐☐☐

2.6 Pali ena pakhomo pa amene akutenga nao mbali omwe alinso ndifoni? ***Does someone else in the participant's household have a personal phone*** *(ConHHPhone)* ☐ [0] No ☐ [1] Yes

2.6.1 Ngati eya, nambala yake ndi iti?
If yes, what is the number? *(ConHHPhoneNum)* ☐☐☐☐☐☐☐☐☐

2.6.2 Ngati eya, ubale wao ndiotenga nao mbali ndiotani? *{ConRelHHphone}*
If yes, relationship to the participant ____________

3. Consent text

A________________________ andifotokozera pamaso ndi pachikalata zacholinga ndimomwe kafukufuku wa iLiNS-DYAD atayendere. Ndapatsidwa mwayi ofunsa mafunso ena ndipo zonse zomwe sindinamvetse andifotokozera. Ndikudziwa kuti kutenga nao mbali kapena kusatenga nao mbali sikusintha mwina muli monse chithandizo chimene ndimalandira kuchipatala kumene kuki kafukufuku kapena kwina kuli konse. M'mene ndalandira ndikulingalira uthenga oyenerera, mwachifuniro changa ndikubvomereza kutenga nao mbali mukafukufuku watchulidwayu. Komabe ndili ndi ufulu osiya kutenga nao mbali mukafukufukuyu nthawi ina ili yonse popanda kupeleka chifukwa
Date, signatures and randomization outcome

Otenga nao mbali: ___.____ 20____ Ofotokoza: ___.____ 20_____ Mboni: ___.____ 20_____
Participant Informant Witness

____________ ____________ ____________

3.1 How did the participant sign the form? *(ConTypeSign)* ☐ [1]Thumbprint ☐ [2]Signature

3.1.1 If thumbprint, name of impartial witness ____________

3.2 Group allocation (letter code): ***{ConGroupCode}*** ☐

3.3 Follow-up scheme: *(ConFollowUp)* ☐ [1] Complete ☐ [2] Simplified

3.4 Preferred language for interviews: *(ConLanguage)* ☐ [1] Yao ☐ [2]Chewa ☐ [3]English

3.5 Expected Date of Delivery *(ConEDD)* ☐☐ - ☐☐ - 2 0 ☐☐

3.6 Free comments: *(ConComments)* ____________

i. Collector (ConCollector) ☐☐☐ *iii. Monitor (ConMonitor)* ☐☐☐

ii Date (ConDateCollector) ☐☐ - ☐☐ - 2 0 ☐☐ *iv. Date (ConDateMonitor)* ☐☐ - ☐☐ - 2 0 ☐☐

62180

iLiNS-DYAD trial: Form 11 (version 2011-12-01)
Consent and randomization, Chewa

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Screening ID{ScreeNumber} ☐☐☐☐☐

Participant Code {Participant} ☐☐☐☐ . ☐

Consent Text

__has given me information in person and in writing about the purpose and the implementation of the iLiNS-DYAD trial. I have been given a possibility to ask further questions and all unclear issues have been explained to me. I know that participation or non- participation in the study does not influence in any way the health services I am getting from the trial health facility or elsewhere.

After getting and considering all relevant information, I voluntarily give my consent to participate in the indicated study. I do, however, retain the right to withdraw from the study at any point, without giving any reason for my decision.

Instructions For Finding the Participant's Home

____

____

____

____

____

i. Collector ☐☐☐

iii. Monitor ☐☐☐

iiDateCollector ☐☐ - ☐☐ - ☐☐☐☐

iv DateMonitor ☐☐ - ☐☐ - ☐☐☐☐

58604

iLiNS-DYAD trial: Form 13a (version 2012-03-24)
Social and demographic environment, Chichewa

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code *(Participant)* ☐☐☐☐ . ☐

1. Visit information

1.1 Number (code) of visit *(NumberVisit)*...... ☐☐☐☐

1.2 Date of visit *(DateVisit)*................ ☐☐ - ☐☐ - 2 0 ☐☐ (dd mm yy)

1.4 GPS position of the home (UTM system, region 36L)

1.4.1 Longitude {*SocGpsLongitud*}.............. ☐☐☐☐☐☐☐

1.4.2 Latitude *(SocGpsLatitude)*.................. ☐☐☐☐☐☐☐

2. Demographic information

Choyamba, ndifunsa zambiri zokhudzana ndi moyo wanu. Kenako, ndifunsanso za abale anu pa nyumba ino.
Dzina la oyankha: ______________________________

Dzina la amene amapeza zosowa za panyumba pano ndi ndani ______________

2.1 Kodi pali ubale wanji pakati pa mayi ndi amene amapeza zosowa za pa nyumba pano? *(SocMotRelation)*

☐ [1] Wamkulu wapanyumba
☐ [2] Mlamu wawo
☐ [3] Mayi wawo
☐ [4] Mwana wawo wamkazi
☐ [66] Ena
☐ [5] Msuweni
☐ [6] Mkazi
☐ [7] Agogo akazi
☐ [8] Achemwali

2.1.1 Ngati pali ena fotokozani *(SocSpecMotRela)* ______________________________

2.2 Kodi mtundu wa mayi ndi chani? *(SocMotTribe)*

☐ [1] Yao
☐ [2] Chewa
☐ [66] Other

2.2.1 Ngati pali wina, fotokozani *(SocSpecMotTrie)* ______________________________

2.3 Kodi mayi ndi wachipembedzo chanji? *(SocMotReligion)*

☐ [1] Chisilamu
☐ [2] Katolika
☐ [3] Alibe chipembedzo
☐ [66] Other
☐ [99] Sichikudziwika

2.3.1 Ngati pali wina fotokozani *(SocSpecMotReli)* ______________________________

2.4 Kodi mayiwa amachitachiyani? *(SocMotheOccup) See codes on page 6* ☐☐ (Mark 99 not known)

2.5 Tsiku la kubadwa la Mayi *(SocMotDateBirth)* ☐☐ - ☐☐ - ☐☐☐☐ (dd mm yyyy) (Mark 01-01-2099, if the DOB is not known)

2.6 Zaka zakubadwa: *(SocMotherAge)* ☐☐ (Mark 99 not known)

2.7 How was the age determined? *(SocMotherAgeDet)*

☐ [1] Known, based on birth date
☐ [2] Estimated by respondent
☐ [3] Estimated by data collector
☐ [77] Not applicable (Age not known)

i. Collector (SocMotCollector) ☐☐☐
ii Date (SocMotDateCollector) ☐☐ - ☐☐ - 2 0 ☐☐

iii. Monitor (SocMotMonitor) ☐☐☐
iv. Date (SocMotDateMonitor) ☐☐ - ☐☐ - 2 0 ☐☐

Last digit of Participant number (before decimal point) ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code {Participant} ☐☐☐☐.☐

2.8 Kodi mayiyu ali pabanja?{SocMotMarriage}
- ☐ [1] Wosakwatiwa
- ☐ [2] Wokwatiwa
- ☐ [3] Analekana/ separated
- ☐ [4] Anafedwa
- ☐ [99] Not known

2.8.1 (Ngati ndiwokwatiwa) Banja lanu ndi lamitala kapena ayi {SocMarPolyMono}
- ☐ [1] Monogamous
- ☐ [2] Polygamous
- ☐ [77] Not applicable

2.9 Kodi mayiwa ali ndi ana angati? {SocMotChiAlive} ☐☐ (Mark 99 not known)

2.10 Kodi kupulayimale adalekera kalasi liti? {SocMotPrimaSch} ☐☐ (Mark 99 not known)

2.11 Kodi kusekondale adalekera kalasi liti?{SocMotSecondSch} ☐☐ (Mark 99 not known)

2.12 Kodi mayi amatha kuwelenga? {SocMotherRead}
- ☐ [0] Ayi
- ☐ [1] Movutikira
- ☐ [2] Bwino bwino

2.13 Kodi mayi amatha kulemba? {SocMotherWrite}
- ☐ [0] Ayi
- ☐ [1] Movutikira
- ☐ [2] Bwino bwino

2.14 Kodi, kwa miyezi isanu ndi umodzi yapitayi mayiyu anadwala mpaka kulephera kusamalira ana? {SocMotLimiCare}
- ☐ [1] Ayi kapena kamodzikamodzi (twice or less often in 6 months)
- ☐ [2] Nthawi zina (3-6 times in 6 months)
- ☐ [3] Kawirikawiri (more than six times in 6 months)
- ☐ [4] Nthawi zonse

2.15 Kodi kwa miyezi isanu ndi umodzi yapitayi mayiyu anadwala mpaka kulephera kugwira ntchito kapena kupeza ndalama? {SocMotLimiWork}
- ☐ [1] Ayi kapena kamodzikamodzi (twice or less often in 6 months)
- ☐ [2] Nthawi zina (3-6 times in 6 months)
- ☐ [3] Kawirikawiri (more than six times in 6 months)
- ☐ [4] Nthawi zonse

Tsopano, ndikufuna ndifunse za bambo a mwana amene mukuyembekezerayu.

2.16 Kodi bamboyo ali moyo? {SocFatherAlive}
- ☐ [1] Eya
- ☐ [2] Ayi Go to question 2.35
- ☐ [99] Not known

2.17 Kodi pali ubale wanji pakati pa bambo wa mwanayo ndi munthu amene amapeza zosowa pakhomo pano? {SocFatRelation}

☐ [1] Wamkulu wapanyumba	☐ [6] Mwamuna
☐ [2] Mlamu	☐ [7] Agogo amuna
☐ [3] Bambo	☐ [8] Mchimwene
☐ [4] Mwana wammuna	☐ [9] Palibe ubale
☐ [5] Msuweni	☐ [66] Zina

i. Collector{SocCollector} ☐☐☐ iii. Monitor{SocMonitor} ☐☐☐

ii Date{SocDateCollector} ☐☐-☐☐-☐☐☐☐ iv. Date {SocDateMonitor} ☐☐-☐☐-☐☐☐☐

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code *(Participant)* ☐☐☐☐.☐

2.17.1 Ngati pali ena fotokozani *(SocSpecFatRela)* ______

2.18 Kodi bambowa ndi a mtundu wanji? *(SocFatTribe)*
- ☐ [1] Yao
- ☐ [2] Chewa
- ☐ [66] Zina

2.18.1 Ngati mtundu wina fotokozani *(SocSpecFatLang)* ______

2.19 Kodi bambowa ndi achipembedzo chanji? *(SocFatReligion)*
- ☐ [1] Chisilamu
- ☐ [2] Katolika
- ☐ [3] Alibe chipembedzo
- ☐ [66] Zina
- ☐ [99] Sichikudziwika

2.19.1 Ngati pali chipembedzo china fotokozani *(SocSpecFatReli)* ______

2.20 Tsiku lakubadwa bamboyu *(SocFatDateBirth)* ☐☐ - ☐☐ - ☐☐☐☐ *(Mark 01-01-2099, if the DOB is not known)*
dd mm yyyy

2.21 Zaka zakubadwa: *(SocFatherAge)* ☐☐ (Mark 99 not known)

2.22 How was the age determined? *(SocFatheAgeDet)*
- ☐ [1] Known, based on birth date
- ☐ [2] Estimated by respondent
- ☐ [3] Estimated by data collector
- ☐ [77] Not applicable (Age not known)

2.23 Kodi bamboyu amachita chiyani?) *(SocFatherOccup) See codes on page 6* ☐☐ (Mark 99 not known)

2.24 Kodi bamboyu amakhala limodzi ndi mayi? *(SocFatWithMoth)*
- ☐ [0] Ayi, amakhala kwina
- ☐ [1] Ayi, amakhala kwina moyembekezera (<2 months)
- ☐ [2] Eya

2.25 Kodi bambowa ali pabanja? *(SocFatMarriage)*
- ☐ [1] Wosakwatiwa
- ☐ [2] Wokwatiwa
- ☐ [3] Analekana/ separated
- ☐ [4] Anafedwa
- ☐ [99] Not known

2.26 Kodi bamboyu anakwatila akazi angati asanamange banja ndi mayi akuyembekezelayu? *(SocFatWifeBefo)* ☐☐ (Mark 99 not known)

2.27 Kodi bamboyu anakwatira akazi angati atamanga kale banja ndi woyembekezerayu *(Mark 99 not known)* *(SocFatWifeAfter)* ☐☐ (Mark 99 not known)

2.28 Padakali pano bamboyu ali ndi akazi angati? *(SocFatWifeNow)* ☐☐ (Mark 99 not known)

2.29 Kodi kupulayimale adalekera kalasi liti? *(SocFatPrimaSch)* ☐☐ (Mark 99 not known)

2.30 Kodi ku sekondale adalekera kalasi liti? *(SocFatSecondSch)* ☐☐ (Mark 99 not known)

i. Collector{SocCollector} ☐☐☐ iii. Monitor{SocMonitor} ☐☐☐

ii Date{SocDateCollector} ☐☐ - ☐☐ - ☐☐☐☐ iv. Date {SocDateMonitor} ☐☐ - ☐☐ - ☐☐☐☐

58604

iLiNS-DYAD trial: Form 13a (version 2012-03-24)
Social and demographic environment, Chichewa

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code *(Participant)* ☐☐☐☐ . ☐

2.31 Kodi bamboyu amatha kuwelenga *(SocFatherRead)*
☐ [0] Ayi
☐ [1] Movutikira
☐ [2] Bwino bwino

2.32 Kodi bamboyu amatha kulemba? *(SocFatherWrite)*
☐ [0] Ayi
☐ [1] Movutikira
☐ [2] Bwino bwino

2.33 Mumiyezi isanu ndi umodzi yapitayi bamboyu anadwala mpaka kulephera kusamala ana? *(SocFatLimiCare)*
☐ [1] Ayi kapena kamodzikamodzi (twice or less often in 6 months)
☐ [2] Nthawi zina (3-6 times in 6 months)
☐ [3] Kawirikawiri (more than six times in 6 months)
☐ [4] Nthawi zonse

2.34 Mumiyezi isanu ndi umodzi yapitayi bamboyu anadwalapo mpaka kulephera kugwira ntchito kapena kupeza ndalama? *(SocFatLimiWork)*
☐ [1] Ayi kapena kamodzikamodzi (twice or less often in 6 months)
☐ [2] Nthawi zina (3-6 times in 6 months)
☐ [3] Kawirikawiri (more than six times in 6 months)
☐ [4] Nthawi zonse

2.35 Total number of persons in household *(SocNumPersonHH)*
☐☐ Mark (99 not known)

2.36 Total number of children below 5 years of age in household *(SocChild_U5_HH)*
☐☐ (Mark 99 not known)

2.37 Tick if no other family members except the study mother and her husband ☐
(SocNuclear)

If 2.37 NOT selected, before proceeding to Section 3, complete household roster on page 6

3. Living environment

3.1 Kodi khoma lanyumbayi linamangidwila zipangizo zanji? *(SocHouseWalls)*
☐ [1] Njerwa zowotcha
☐ [2] Zidina
☐ [3] Tsekera/udzu/matope
☐ [66] Zina

3.1.1 Ngati pali zina fotokozani ______________________________

3.2 Kodi denga la nyumbayi lidamangidwira zipangizo zanji? *(SocHouseRoof)*
☐ [0] Palibe
☐ [1] Udzu
☐ [2] Malata/matailosi
☐ [66] Zina

3.2.1 Ngati pali zina fotokozani ______________________________
(SocSpecRoof)

3.3 Kodi nyumba yanu ndi yazipinda zingati? ☐ number of rooms
(SocHouseRooms)

i. Collector{SocCollector} ☐☐☐ iii. Monitor{SocMonitor} ☐☐☐

ii Date{SocDateCollector} ☐☐ - ☐☐ - ☐☐☐☐ iv. Date {SocDateMonitor} ☐☐ - ☐☐ - ☐☐☐☐

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code (Participant) ☐☐☐☐.☐

3.4 Kodi madzi okumwa mumatunga kuti? {SocSourceWater}

☐ [1] Pa mpopi
☐ [2] Mjigo
☐ [3] Chitsime chowaka
☐ [4] Chitsime chosawaka
☐ [5] Nyanja
☐ [6] Mutsinje, pa damu
☐ [66] Zina

3.4.1 Ngati pali malo ena fotokozani (SocSpecWater) ____________________

3.5 Kodi nyumbayi ili ndi malo ozithandizira otani? (SocSanitaryFac)

☐ [0] Palibe
☐ [1] Chimbudzi chokumba
☐ [2] Chimbudzi chokumba chamakono
☐ [3] Chimbudzi chogejemula (WC)

3.5.1 Ngati pali china fotokozani (SocSpecSanitary) ____________________

3.6 Kodi mphamvu ya magetsi a nyumba yanu amachokera kuti (SocElectricity)

☐ [0] None
☐ [1] Jenereta
☐ [2] Batire la galimoto
☐ [3] Magetsi a ESCOM
☐ [4] Solar
☐ [66] Zina

3.6.1 Ngati pali ina fotokozani (SocSpecElec) ____________________

3.7 Kodi mumaphikirachani? (SocCookingFuel)

☐ [1] Nkhuni zotola
☐ [2] Nkhuni zogula
☐ [3] Paraffin
☐ [4] Makala
☐ [5] Gasi
☐ [6] Magetsi a ESCOM
☐ [7] Mapesi/zisononkho
☐ [8] Ndowe
☐ [9] Utuchi
☐ [66] Zina

3.7.1 Ngati pali zina fotokozani (SocSpecCookFuel) ____________________

3.8 Kodi chakudya cha nyumbayi chikumaphikilidwa kuti? (SocMealPrepare)

☐ [1] Kitchini la nyumba
☐ [2] M'chipinda chogonamo
☐ [3] Kitchini la panja
☐ [4] Panja

3.9 Kodi mumaphikira kangati muchipinda momwe m'mene mumagonamo/amayi oyembekezera amagonamo? (SocBurnChiSlee)

☐ [0] Ayi
☐ [1] Kosakwana mulungu umodzi
☐ [2] Kamodzi pa mulungu koma osati tsilu lili lonse
☐ [3] tsiku lili lonse

i. Collector{SocCollector} ☐☐☐
ii Date{SocDateCollector} ☐☐-☐☐-☐☐☐☐
iii. Monitor{SocMonitor} ☐☐☐
iv. Date {SocDateMonitor} ☐☐-☐☐-☐☐☐☐

20916

iLiNS-DYAD trial: Form 15 (version 2011-12-08)
Food security and economics, Chichewa

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code *(Participant)*: ☐☐☐☐.☐

1. Visit information

1.1 Number (code) of visit *(NumberVisit)*...... ☐☐☐☐

1.2 Date of visit *(DateVisit)* .... ☐☐-☐☐-20☐☐
dd mm yy

1.3 Respondent *(Respondent)*
If mother or other main guardian is not available, do not continue the interview but try to arrange a new appointment with the mother or other main guardian.

☐ [1] Mother
☐ [2] Father
☐ [66] Other

1.3.1 If other, Specify *(SpecRespondent)* ____________________

2. Household food insecurity access scale

Introductory Statement
Mwadzuka bwanji/mwaswera bwanji/mwatandala bwanji. Ndachokela ku pulojekiti ya iLiNS imene ikuchita kafukufuku. Ndabwera pano kudzadziwa zambiri zapakhomo pano. Zimene ndimve pano zidzasungidwa mwa chinsinsi ndipo zidzatithandiza kumasulira zotsatila za kafukufukuyu. Ndikuthokoza koposa chifukwa cha nthawi ndi chithandizo chanu lero.

Nditenga mphindi zochepa kukufunsani za chakudya pakhomo pano. Ndikufunsani kuti mulingalire pamasabata anayi apitawa kuti muthe kukumbukira ndi kangati pakhomo pano panasowa chakudya. Ngati muli ndi mafunso nthawi ina iliyonse, masukani kundiyimitsa kuti mufunse. Khalani omasuka.

Questions	**How often did this happen?** [0]=Never [1]=Rarely (once or twice/4 weeks) [2]=Sometimes (three to ten times) [3]=Often (More than ten times)
2.1. Kodi munali ndi nkhawa kuti banja lanu silizakhala ndi chakudya chokwanila? {FSeNotEnouFood}	
2.2. Kodi inuyo kapena wina wa m'banja mwanu samadya chakudya chomwe amachikonda chifukwa chosowa zofunikira? {FSeNotRigtFood}	☐
2.3. Kodi inuyo kapena wina wa m'banja mwanu amadya chakudya cha mtundu umodzi chifukwa chosowa zofunikira? {FSeLimitVariet}	☐
2.4. Kodi inuyo kapena wina wa m'banja mwanu amadya zakudya zomwe samazifuna chifukwa chosowa zofunikila kuti apeze zakudya za mtundu wina? {FSeUnwanteFood}	☐
2.5. Kodi inuyo kapena wina wa m'banja mwanu mumadya chakudya chochepa ndi mmene mumafunira chifukwa chinali chosakwanira? {FSeSmallMeals}	☐
2.6. Kodi inuyo kapena wina wa m'banja mwanu sanadye kadzutsa, nkhomaliro kapena m'gonero chifukwa panalibe chakudya chokwanira? {FSeFewerMeals}	☐
2.7. Kodi m'banja mwanu munakhalapo opanda chakudya cha mtundu uliwonse chifukwa chosowa zofunikira zopezera chakudya? {FSeEverNoFood}	☐
2.8. Kodi inu kapena wina wa m'banja mwanu anagonapo ndi njala usiku chifukwa panalibe chakudya chokwanira? {FSeSleepHungry}	☐
2.9. Kodi inu kapena wina wa pa banja panu anakhalapo ndi njala osadya kalikonse usana ndi usiku chifukwa chosowa chakudya? {FSeFastFullDay}	☐

3. Household food-consumption-related coping strategies

3.1. Kodi munakabwerekako chakudya kapena kubwereka ndalama zogulira chakudya chifukwa chakudya chinali chochepa kapena ndalama zogulira chakudya zinali zochepa? {FSeBorrowMoney} ☐

3.2. Kodi munatenga chakudya pangongole chifukwa chakudya chinali chochepa kapena ndalama zogulira chakudya zinali zochepa? {FSeFUseCredit} ☐

3.3. Kodi munadalira thandizo lochokera kwa achibale kapena anzanu okuti siapakhomo pano chifukwa chakudya chinali chochepa kapena ndalama zogulira chakudya zinali zochepa? {FSeOutsideHelp} ☐

i. Collector (FSeCollector) ☐☐☐
ii Date (FSeDateCollector) ☐☐-☐☐-20☐☐
iii. Monitor (FSeMonitor) ☐☐☐
iv. Date (FSeDateMonitor) ☐☐-☐☐-20☐☐

20916

iLiNS-DYAD trial: Form 15 (version 2011-12-08)

Food security and economics, Chichewa

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code (Participant): ☐☐☐☐.☐

4. Child food-consumption-related coping strategies

4.1. Kodi munadzimana chakudya chifukwa chakudya chinali chochepa kapena ndalama zinali zochepa zogulira chakudya cha mwana wanu wamng'ono kwambiri? (FSeLimitOwnEat)	☐

5. Economics

Tsopano ndikufunsani mafunso pa za katundu wa pakhomo pano ndipo zimene muyankhe zikagwiritsidwa ntchito mu kafukufuku wathuyu. Izi zitithandiza kumvetsa bwino zakapezedwe kanu ka chakudya chokwanira; koma sitikupatsani zakudya kapena katundu ngakhale muyankhe mafunsowa.

5.1. Kodi __________ muli nazo zingati pakhomo pano (Mark 99 if not known)

5.1.1. Ng'ombe (FSeNumbCows)	☐☐☐	5.1.2. Mbuzi (FSeNumbGoats)	☐☐☐
5.1.3. Nkhosa (FSeNumbSheep	☐☐☐	5.1.4. Nkhuku (FSeNumbChicken) Bed	☐☐☐
5.1.5. Zina (FSeNumbOther)	☐☐☐	5.1.5.1. Ngati ndi zina, fotokozani:	______

5.2. How many __________ does your household own FSeNumbMortar , FSeNumbWashing , etc.

Item	Number of item	Item	Number of item
5.2.1 Mtondo/Musi	☐☐☐	5.2.2 Makina ochapila zovala	☐☐☐
5.2.3 Bedi (kama)	☐☐☐	5.2.4 Nyale	☐☐☐
5.2.5 Tebulo (gome)	☐☐☐	5.2.6 Mbiya yofululira mowa	☐☐☐
5.2.7 Mpando	☐☐☐	5.2.8 Ukonde owedzera nsomba	☐☐☐
5.2.9 Desiki	☐☐☐	5.2.10 Chisikilo	☐☐☐
5.2.11 Matilesi	☐☐☐	5.2.12 Khasu	☐☐☐
5.2.13 Fani	☐☐☐	5.2.14 Chikwanje	☐☐☐
5.2.15 Air Conditioner	☐☐☐	5.2.16 Chopopera mankhwala	☐☐☐
5.2.17 Wayilesi	☐☐☐	5.2.18 Wilibala	☐☐☐
5.2.19 Wayilesi ya kaseti kapena CD	☐☐☐	5.2.20 Bwato	☐☐☐
5.2.21 Kanema	☐☐☐	5.2.22 Njinga ya kapalasa	☐☐☐
5.2.23 Foni ya m'manja	☐☐☐	5.2.24 Njinga ya moto	☐☐☐
5.2.25 Makina osokera zovala	☐☐☐	5.2.26 Galimoto	☐☐☐
5.2.27 Mbaula yaParafini	☐☐☐	5.2.28 Galimoto ya lole	☐☐☐
5.2.29 Chophikira cha magetsi kapena gasi	☐☐☐	5.2.30 Masikito neti	☐☐☐
5.2.31 Firiji	☐☐☐	5.2.32 Mabuku a ana a zojambula	☐☐☐
5.2.33 Zidole zoyankhula kapena kuyimba	☐☐☐	5.2.34 Ma bloko oseweretsa ana	☐☐☐
5.2.35 Zinthu zojambulila/zolembela	☐☐☐	5.2.36 Zidole zoyenda kapena kuwuluka	☐☐☐
5.2.37 Zophinsilira ana mitundu ndi zina zotere	☐☐☐	5.2.38 Zidole zogula kusitolo	☐☐☐
5.2.39 Mabuku	☐☐☐	5.2.40 Magazini/Nyuzipepala	☐☐☐

5.3. Kodi muli ndi malo pakhomo panu olima chimanga kapena chakudya china chodalilika chanu kapena chogulitsa? (FSeAccessLand)

☐ [0] No ☐ [2] Yes, we own arable land

☐ [1] Yes, we rent arable land ☐ [3] Yes, we allowed to cultivate arable land

5.4. Ndi miyezi ingati imene munagwiritsa ntchito chimanga/zokolola za munthawi yokokola yapitawia (FSeMaizeHarves) ☐☐ months

5.5. Kodi zakudya zotsatilazi zatsala masabata angati kuti mudye pakhomo pano **Last for [X] weeks** *(Mark 0 if no stock)* **Last for [X] weeks** *(Mark 0 if no stock)*

5.5.1. Chimanga (FSeMaizeLast)	☐☐☐	5.5.2. Mbatata (FSePotatoLast)	☐☐☐
5.5.3. Chinangwa (FSeCassavaLast)	☐☐☐	5.5.4. Mpunga (FSeRiceLast)	☐☐☐
5.5.5. Zina (FSeNumbsOther)	☐☐☐		

i. Collector ☐☐☐ iii. Monitor ☐☐☐

iiDateCollector ☐☐-☐☐-☐☐☐☐ iv DateMonitor ☐☐-☐☐-☐☐☐☐

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Participant Code *(Participant)*: ☐☐☐☐☐ . ☐

5.6. Mwezi wapitawu, alipo pakhomo pano amene anagwira koposera sabata imodzi ntchito (FSeHHActivity)
You may choose multiple options!

☐ [0] None
☐ [1] Farming
☐ [2] Family shop
☐ [3] As a driver
☐ [4] Fishing
☐ [5] Tailoring/sewing
☐ [6] As a carpenter/repair work
☐ [7] Teaching
☐ [8] Brick layer
☐ [9] Ganyu
☐ [66] Other

5.6.1. If other, please specify *(FSeSpecHHActiv)* ______________________

5.7. Ndi ndani anathandizapo ndi ndalama kuti mugule zosowa pakhomo pano mwezi wapitawu?
(Relationship to study child) *(FSeHHCashContr) You may choose multiple options!*

☐ [0] No one
☐ [3] Maternal grandmother
☐ [4] Maternal grandfather
☐ [5] Paternal grandmother
☐ [6] Paternal grandfather
☐ [7] Uncle
☐ [8] Aunt
☐ [99] Not known
☐ [66] Other

5.7.1. Ngati ndi ena, fotokozani *(FSeSpecHHCashC)* ______________________

5.8. Mwezi wathawu, alipo pakhomo pano amene walandira ndalama kuchokera [SOURCE]? *(FSeHHIncome) You may choose multiple options!*

☐ [1] Local friend or relative in Mangochi or Namwera
☐ [2] Remittance from Malawi, outside Mangochi or Namwera
☐ [3] Remittance from outside Malawi
☐ [4] Social Security
☐ [5] Retirement benefits
☐ [6] State pension
☐ [0] None of these
☐ [7] Dowry or inheritance
☐ [8] Rent from the land (Farming)
☐ [99] Not known
☐ [66] Other

5.8.1. If other, please specify *(FSeSpecHHIncome)* ______________________

5.9. Miyezi isanu ndi umodzi yapitayi alipo pakhomo pano anakabwereka ndalama kwina____________
(FSeHHCredit) You may choose multiple options!

☐ [0] None of these
☐ [1] Purchase land
☐ [2] Purchase food for the household
☐ [3] Purchase agricult inputs for food crops
☐ [4] Purchase items for home repairs
☐ [5] Purchase inputs for tobacco
☐ [6] Purchase school supply or pay school fees
☐ [7] Purchase inputs for other cash crops
☐ [8] Purchase medical supplies or medicines
☐ [9] Business start-up capital
☐ [10] Pay for health center/hospital
☐ [11] Borrowed money or taken credit for any other activity
☐ [99] Not known

5.10. Miyezi isanu ndi umodzi yapitayi, inuyo kapena wina wa pakhomo pano munaperakako ndalama ku khomo lina zowathandiza kupezera zakudya? *(FSeHHLendMoney)*

☐ [0] No ☐ [1] Yes ☐ [99] Not known

5.11. Miyezi isanu ndi umodzi yapitayi, inuyo kapena wina wa pakhomo panu analandirako makuponi a mbewu? *(FSeHHCoupseed)*

☐ [0] No ☐ [1] Yes ☐ [99] Not known

5.11.1. Ngati eya, makuponi anali a ndalama zingati mu makwacha? (FSeHHValueseed)

____

5.12. Miyezi isanu ndi umodzi yapitayi, inuyo kapena wina wa pakhomo panu analandirako makuponi afeteleza? (FSeHHCoupfert)

☐ [0] No ☐ [1] Yes ☐ [99] Not known

5.12.1. Ngati eya, makuponi anali a ndalama zingati mu makwacha? *(FSeHHValuefert)*

____

i. Collector ☐☐☐ iii. Monitor ☐☐☐

iiDateCollector ☐☐ - ☐☐ - ☐☐☐☐ iv DateMonitor ☐☐ - ☐☐ - ☐☐☐☐

35051

iLiNS-DYAD trial: Form 24 (version 2011-12-01) Participant Code *(Participant)* ☐☐☐☐.☐
Newborn details questionnaire, Yao

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

1. Visit information

1.1 Number (code) of visit *(NumberVisit)*................. ☐☐☐☐

1.2 Date and time of visit *(DateVisit)*...... ☐☐ - ☐☐ - 2 0 ☐☐ ☐☐:☐☐
dd mm yy hh min

1.3 Respondent (relationship to the participating child): *(NewRespondent)*
☐ [1] Mother
☐ [2] Father
☐ [66] Other

1.3.1 If other, specify *(NewSpecRespon)*: ____________________

2. Condition after delivery and at inspection; Baby A

2.1 Vital status of the first baby... *(NewStatusBabyA)*
☐ [1] Alive
☐ [2] Born alive, died
☐ [3] Fresh stillbirth
☐ [4] Macerated stillbirth
☐ [99] Not known

2.2 Sex of the first born baby....... *(NewChildSexA)*
☐ [1] Boy
☐ [2] Girl
☐ [99] Not known

2.3 Was APGAR score given to the firstborn baby *(NewApgarGivenA)*
☐ [0] No
☐ [1] Yes

2.3.1 APGAR score at 1 minute *(NewApgarA1min)*................. ☐☐

2.3.2 APGAR score at 5 minutes *(NewApgarA5min)*................ ☐☐

2.4 Baby A weight (g) *(Record 3 measurements, mark 9999 if not known / baby not present)* *(NewWeightA1, NewWeightA2, NewWeightA3)*

2.4.1 ☐☐☐☐ 2.4.2 ☐☐☐☐ 2.4.3 ☐☐☐☐

2.5 Baby A chest circumference (mm) *(Record 3 measurements, mark 9999 if not known / baby not present)* *(NewChestA1, NewChestA2, NewChestA3)*

2.5.1 ☐☐☐☐ 2.5.2 ☐☐☐☐ 2.5.3 ☐☐☐☐

2.6 Baby A head circumference (mm) *(Record 3 measurements, mark 9999 if not known / baby not present)* *(NewHeadA1, NewHeadA2, NewHeadA3)*

2.6.1 ☐☐☐☐ 2.6.2 ☐☐☐☐ 2.6.3 ☐☐☐☐

i. Collector (NewCollector) ☐☐☐ *iii. Monitor (NewMonitor)* ☐☐☐

ii Date (NewDateCollector) ☐☐ - ☐☐ - 2 0 ☐☐ *iv. Date (NewDateMonitor)* ☐☐ - ☐☐ - 2 0 ☐☐

35051

iLiNS PROJECT

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

iLiNS-DYAD trial:Form 24 (version 2011-12-01) Participant Code *(Participant)* ☐☐☐☐ . ☐
Newborn details questionnaire, Yao

Condition after delivery and at inspection; Baby B

2.8 **Vital status of the 2nd baby....** *(NewStatusBabyB)*
☐ [1] Alive
☐ [2] Born alive, died
☐ [3] Fresh stillbirth
☐ [4] Macerated stillbirth
☐ [77] Not applicable
☐ [99] Not known

2.9 **Sex of the 2nd baby.............** *(NewChildSexB)*
☐ [1] Boy
☐ [2] Girl
☐ [77] Not applicable
☐ [99] Not known

2.10 Was APGAR score given to the second baby *(NewApgarGivenB)*
☐ [0] No
☐ [1] Yes

2.10.1 APGAR score at 1 minute *(NewBpga1min)*................. ☐☐

2.10.2 APGAR score at 5 minute *(NewBpga5min)*................. ☐☐

2.11 Baby A weight (g) *(Record 3 measurements, mark 9999 if not known / baby not present, mark 7777 if not applicable, i.e. singleton delivery)* *(NewWeightB1, NewWeightB2, NewWeightB3)*

2.11.1 ☐☐☐☐   2.11.2 ☐☐☐☐   2.11.3 ☐☐☐☐

2.12 Baby A chest circumference (mm) *(Record 3 measurements, mark 9999 if not known / baby not present, mark 7777 if not applicable, i.e. singleton delivery)* *(NewChestB1, NewChestB2, NewChestB3)*

2.12.1 ☐☐☐☐   2.12.2 ☐☐☐☐   2.12.3 ☐☐☐☐

2.13 Baby A head circumference (mm) *(Record 3 measurements, mark 9999 if not known / baby not present, mark 7777 if not applicable, i.e. singleton delivery)* *(NewHeadB1, NewHeadB2, NewHeadB3)*

2.13.1 ☐☐☐☐   2.13.2 ☐☐☐☐   2.13.3 ☐☐☐☐

3. Early breastfeeding practices after delivery

3.1 **Ana pakwete pamjonjesye mwanacheju?** *(NewEverBF)*
Have you ever breastfed the infant?

☐ [0] No
☐ [1] Yes

3.2 **Ana papitile ndawi jajilewu uli kuti amjonjesye mwanacheju ali napagwape?** *(NewHowSoonBF)*
How long after birth did you put the infant to the breast?
(if the answer to q3.1 was 0 = No, don't ask this question from the participant but just mark option 77 = not applicable as answer)
☐ [0] Ndawi jijojo. Immediately
☐ [1] Mu awala jandanda. Within the first hour
☐ [2] Palipapite awala jimo. kunandipila ma awala makumi gawili ni mcheche (24) More than one hour, less than 24 hours
☐ [3] Kupitilila ma awala makumi gawili ni mcheche (24). More than 24 hours
☐ [77] Not applicable (not breastfed, or not yet breastfed)
☐ [99] Don't know

3.3 **Ana mwanacheju apano akumjonjesyaga?** *(NewCurrentBF)*
Are you currently breastfeeding the infant?
(if the answer to q3.1 was 0 = No, don't ask this question from the participant but just mark option 0 = no as answer)

☐ [0] No
☐ [1] Yes

i. Collector   iii. Monitor ☐☐☐

iiDateCollector ☐☐-☐☐-☐☐☐☐   iv DateMonitor ☐☐-☐☐-☐☐☐☐

35051

iLiNS-DYAD trial:Form 24 (version 2011-12-01) Participant Code *(Participant)* [ ][ ][ ][ ] . [ ]

Newborn details questionnaire, Yao

Last digit of Participant number (before decimal point)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

3.4 Ngakumjonjesyaga ligongo chichi? *(NewWhyNotBF)*
Why are you not breastfeeding?
(if the answer to q3.3 was 1 = Yes, don't ask this question from the participant but just mark option 77 = not applicable as answer)

- ☐ [0] Mwanache/Wanache wawile. Lost child(ren)
- ☐ [1] Mwanache akulwala/alwasileje. Baby is/was sick
- ☐ [2] Une (Mayi) ngulwala/naliji nkulwala. I (mother) am/was sick
- ☐ [3] Mwanache akanileje konga. Baby refused to nurse
- ☐ [4] Adokotala wandekasisye konjesya. Nurses/Doctor said I should not
- ☐ [5] Pangali ligongo, nganindande kumjonjesya. There's no problem; I have yet to begin
- ☐ [77] Not applicable (mother is breastfeeding)
- ☐ [66] Other (specify)

3.4.1 Naga pana magongo gane, chonde asale.
If other, please specify *(NewSpecNotBF)* ______________________

Kaneka ngusaka nausye yakwayana ni yakumwa kapena yakulya yapochele mwanacheju chipagwileni/m`masiku nsano ni gawili gandanda ali napagwape, chonde alongosolele antamusa kuwa kuti mwana gwawo wamwele kapena kupasya panandipe. mwanache jwao chipagwileni/m`masiku nsano ni gawili ali napagwape, ana wampeje:
Next, I would like to ask you about some drinks or foods that the infant may have had since birth/ during the first seven days after birth. Please tell me about it, even if your baby only drank or tasted a very small amount. Since your baby was born/ in the first seven days after birth, has your child been given any:

	0 = no, 1 = yes, 99 = Do not know, 77 = Not Applicable
3.5 Mesi *(NewPlainWater)* Plain water	[ ][ ]
3.6 Mesi ga shuga *(NewSugarWater)* Sugar water	[ ][ ]
3.7 "Gripe Water" (NewGripeWater) Gripe water	[ ][ ]
3.8 Nkaka wa wanache mpela Lactogen kapena Nan kaena Aspen *(NewFormula)* Infant formula, such as Lactogen or NAN or Aspen	[ ][ ]
3.8.1 Asale Specify *(NewSpecFormula)* ______________________	
3.9 Mkaka, mpela wamchitini, wautandi, mkaka wakutochela ku nyama *(NewMilk)* Milk, such as tinned, powdered, or fresh animal milk	[ ][ ]
3.9.1 Asale Specify *(NewSpecMilk)* ______________________	
3.10	
3.11 Mtela wamesimesi (mpela wakutetesya ku kalongolongo) *(NewHerbalFlu)* Herbal fluids (e.g to prevent Kalongolongo)	[ ][ ]
3.12 Juwisi jwa ipaso julijose *(NewFruitJuice)* Fruit juice of any kind	[ ][ ]
3.13 Likoko *(NewPorridge)* Porridge	[ ][ ]
3.14 Yamesimesi, yakumwa kapena yakulya iliyose *(NewOther)* Any other fluid, drink, or food	[ ][ ]

4. Free comments

4.1 Ndemanga Free comments (e.g. explain missing APGRAR or Ballard) *(NewComments)*

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i. Collector [ ][ ][ ] iii. Monitor [ ][ ][ ]

iiDateCollector [ ][ ] - [ ][ ] - [ ][ ][ ][ ] iv DateMonitor [ ][ ] - [ ][ ] - [ ][ ][ ][ ]