A conceptual framework of the impact of maternal early life drought exposure on newborn size in Malawi

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Abstract
The effects of adverse prenatal conditions are not only experienced over the life course but can be passed on intergenerationally. The present study took advantage of a natural experiment from three drought periods of 1981/82, 1987/88, and 1992/93 that occurred in Malawi with varying severity and used data from a randomized clinical trial (RCT), conducted between 2011–2015 (Protocol #NCT01239693). The present study aimed to assess the effect of the interactions between maternal exposure to drought in early life and prenatal supplementation with a novel supplement [small quantity (SQ), lipid-based nutrient supplement (LNS)], the standard of care prenatal supplement [iron-folic acid or IFA], or a close substitute of the standard of care [multiple micronutrients or MMN], on subsequent infant birth outcomes. During data analysis, ordinary least squares were used to run multiple regressions. The regression results were as follows. When there was no maternal exposure to drought, SQ-LNS compared to IFA appeared to improve subsequent infant birth outcomes for length-for-age Z score or LAZ (0.403 standard deviation (SD), Confidence interval CI [0.099, 0.708]), for subsequent infant weight-for-age Z score or WAZ (0.372 SD, CI [0.053, 0.691]), and for imputed infant birthweight or BTW (125.900 g, CI [2.901, 248.899]). In conclusion, the results show a pattern emerging whereby some positive associations can be observed, specifically, when maternal non-drought exposure variables and the SQ-LNS variable interact. Their combined effects on subsequent infant birth outcomes notably subsequent infant LAZ, subsequent infant WAZ, and subsequent infant imputed BWT appear to be positive.

Introduction
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 a brief exposure to early environmental deprivation by mothers, when they were children, had a negative impact on their subsequent offspring’s growth in utero, even among rural populations that were not necessarily very food insecure (Rickard et al., 2012). More recently, the intergenerational effects of in utero maternal exposure to drought or famine on subsequent child nutritional and birth outcomes have been explored in recent papers covering a range of droughts and famines from different countries (Belesova et al., 2019; Hanjahanja-Phiri, 2018; Johnson et al., 2017). The present study, however, will only explore the intergenerational effects of maternal early life exposure to drought (from age 0–5 yr) on subsequent infant birth outcomes.

The present study occurred in Malawi in Southern East Africa. 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 usually 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). Therefore, a drop below 1 standard deviation SD from the mean (i.e. Z score < -1.0) in annual rainfall would be an indicator of an impending drought. Thus, the lower the negative Z score, the greater the severity of the drought. In Malawi’s context, 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 in the cropping cycle had ended with failed rains in 1981, 1987, and 1992, respectively. The drought of 1992/93 was the most severe one with a return period (RP) of 25 years¹ (IFPRI, 2009). Moreover, the drought of 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 had improved as a precondition of receiving more donor aid (Resnick, 2012). With the subsequent increase in the price of a 90-kg bag of maize (an essential food staple in Malawi) surpassing a months’ wage in many regions of Malawi due to the 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 and may have mitigated some of the worse impacts of the drought.2

The drought of 1981/82 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 an important trade route to the Beira port for Malawi’s exports (Harrigan, 2003). Finally, the drought of 1987/88 was linked to a hot, dry spell whose impact compelled the Malawi Government to import maize from abroad (Kalinga, 2012).

This introduction provides the background for the present study in which we hypothesize that the same marginal difference in effect size for infants’ birth outcomes observed in other studies of nutritional supplementation (Adu-Afarwubah et al., 2007; Phuka et al., 2009) could be observed for the infants of women who may have been exposed to drought in early life, if they received a small quantity (SQ), lipid-based nutrient supplement (LNS) compared to IFA during their pregnancies.

Conceptual framework of the research

First, the onset of drought causes the affected geographical area to have an increased risk of crop failure. For example, in Malawi, the crop failure of 1987/88 affected the annual quantity of maize (corn) harvests

(IFPRI, 2009). Note that maize flour is the main ingredient used to prepare a traditional food staple called nsima, a savoury and bland version of a steamed pudding typically eaten with meat or fish, and/or with vegetables, plus tomato-based sauces. Then, household food insecurity due to inadequate food supply 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).

Historically, at the macro-level of our conceptual framework, concerns about increased food insecurity in Malawi during the 1981/82 drought were compounded by the World Bank’s structural adjustment programmes (SAPS) (Figure 1). The SAPs were programmes designed by the World Bank for donor-aid recipient countries to experimentally overhaul their economies by privatising government-owned corporations, as a precondition of receiving donor aid. The purpose of the SAPs was to remove government subsidies, which tended to keep consumer prices including food prices, lower and affordable. Unfortunately, inflation rates rose leading to rising food prices. Thus, instead of the expected trickle-down of economic benefits to the majority of the poor at grassroots level, more hardship was experienced.

As for the droughts of 1987/88 and 1992/93, the risk of increased food insecurity were mitigated by the Malawi Government through aid relief sourced both unilaterally and bilaterally from donor agencies (Babu & Chapasuka, 1997). Thus, the dichotomy at play here would be that SAPS would have had a negative influence on household food security while emergency aid would have a positive influence on household food security (Babu & Chapasuka, 1997).

At the micro-level of our conceptual framework, drought exposure would be characterized as maternal drought exposure in early life (Figure 2). As with the World Health Organisation’s (WHO) conceptual framework, decreased caloric and micronutrient and/or macronutrient intake in utero or in early life due to maternal drought exposure would be an example of nutritional adversity stemming from inadequate household food supply (WHO, 2013). Although maternal early life undernutrition compared to no nutritional adversity in early life would increase the risk of morbidity, permanent damage to cognitive development in the intermediate term, targeted nutritional interventions would not only reduce the risk of poor health outcomes in the intermediate term but also over the life course (WHO, 2013). Thus, in our conceptual framework, if a young girl survives early life nutritional adversity without nutritional interventions but through her own physiological resilience, thrives and becomes a mother in adulthood. Indeed, there is still an opportunity to be prenatally supplemented with a novel supplement called SQ-LNS before she gives birth to prevent latent nutritional adversity outcomes to be passed on intergenerationally, as illustrated in Figure 2. It is noteworthy that SQ-LNS in a smaller daily dose (20 g/day) compared to the large quantity daily dose (up to 50 g a day) will have a different impact along the nutritional causal pathways with the latter being typically used under therapeutic settings, i.e. to treat moderate malnutrition (Adu-Afarwubah et al., 2007; Phuka et al., 2009). As to the effectiveness of LNS in general and why it is needed for interventions, a recent systematic Cochrane review on
LNS complementary supplementation concluded that LNS compared to no intervention improved growth outcomes and anaemia rates among children aged six and 23 months in low-and middle-income countries. Further, there were no adverse effects reported and the intervention proved more effective if provided for 12 months (Das et al., 2019).

Although these effective LNS interventions were provided directly to children postnatally and after weaning, in our conceptual framework the intervention begins prenatally on mothers who may or may not have been exposed to drought in early life. The predicted intermediate outcomes would be increased maternal caloric, micronutrients, and macronutrient intakes during pregnancy (Figure 2). Thereafter, this improved maternal nutritional intake would supposedly lead to improved birth outcomes for infants whose mothers again may or may not have been exposed to drought in early life. Consequently, we would expect a decreased likelihood of mothers having stunted (Z score < −2), underweight (Z score < −2), or low birthweight babies (< 2600 g), adjusting for confounders such as child sex, maternal factors (e.g. height and weight), and socioeconomic variables (e.g. household asset index Z score).

In the present study, stunted infant growth is measured by length-for-age Z score or LAZ, underweight infant growth by weight-for-age Z score or WAZ, and low birthweight by imputed birthweight or BWT in grams (g).

**Methods**

**Ethics statement**

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

The data for the present study were derived from the iLiNS-DYAD-M trial (Protocol #NCT01239693), which was conducted according to Good Clinical Practice guidelines and adhered to the principles of Helsinki declaration (World Medical Association, 2001) and regulatory research guidelines in Malawi. The trial protocol was approved and monitored by the University of Malawi’s College of Medicine Research and Ethics Committee, and the ethics committee of Pirkanmaa Hospital District in Finland.
Study design and analysis

The study cohort included pregnant mothers who were enrolled in a randomized controlled trial (RCT) called iLiNS-DYAD-M and their children were also enrolled post-birth between 2011–2014 (Ashorn et al., 2015). Informed consent was obtained by study staff prior to randomization at the study clinic. Group assignment for pregnant mothers to receive SQ-LNS, multiple micro-nutrients (MMN), or iron folic acid (IFA) was done during randomization after enrollment. In the main trial, 1391 women with pregnancies of gestation < 20 weeks confirmed by ultrasound were accepted into the trial if their estimated or known age at enrollment was at least 15 yr (Protocol #NCT01239693). Other inclusion criteria included permanent maternal residence of the Mangochi District Hospital, Malindi Hospital or Lungwena Health Centre catchment areas, availability during the period of the study, and signed informed consent (Protocol #NCT01239693). Other exclusion criteria included frequent maternal medical attention for a chronic health condition, diagnosed and treated maternal asthma, diagnosed severe illness requiring a hospital referral, a known peanut allergy, known anaphylactic or serious allergic reaction to any substance requiring emergency medical care (Protocol #NCT01239693). Also, pregnancy complications discovered at the enrollment visit such as moderate to severe oedema, or blood Hb concentration <5 g/dl, or systolic blood pressure (BP) > 160 mmHg or diastolic BP >100 mmHg excluded women from participation. Finally, prior participation in the same iLINS-DYAD-M trial or concurrent participation in another clinical trial excluded women from being enrolled.

The retrospective enrollment of mothers and infants into the present study and therefore their eligibility for enrollment into the present study was based on a known date of birth (DoB) at enrollment during the main trial. Thus, inclusion of Dyad (or mother and child) participants into the present study was solely based on a known maternal DoB (n = 1262), while inclusion of participants in the study analyses was based on the availability of all the required data from both the mother and infant

Figure 2. Conceptual framework at the micro-level (intergenerational effects of maternal early life adversity on newborn size in rural Malawi). Source: Adapted by Author from WHO (2013)
dyad data (Figure 3). The main exposure variables of interest in the present study were maternal exposure to drought in early life during the preschool years (0–5 yr), or maternal exposure to drought early life by a narrower age range (0–2 yr or 3–5 yr). The outcomes of interest were subsequent infant (LAZ), subsequent infant WAZ, and subsequent imputed infant BWT.
Defining maternal exposure to drought in early life

The present study defined the onset of a drought period as the start of the expected harvest period (May YYYY) and ending just before the next harvest began (May YYYY*) the following year. For example, early life maternal exposure to the drought of 1981/82 included mothers born on 1 May 1977 up to 30 April 1982. Therefore, “0” in the indicator variable represented maternal non-drought exposure while “1” represented early life 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 enrolled mothers in the main RCT was a key determinant of the period of maternal drought exposure in early life. Maternal exposure to the drought of 1981/82 in early life included mothers born from 1 May 1977–30 April 1982 and, likewise, “0” denoted maternal non-drought exposure while “1” denoted maternal drought exposure in the indicator variable. Early life maternal exposure to drought included mothers born from 1 May 1983–30 April 1988 and, likewise, “0” denoted maternal non-drought exposure while “1” denoted maternal drought exposure in the indicator variable. Maternal exposure to the drought of 1992/93 in early life included mothers born from 1 May 1988–30 April 1993 and similarly, “0” denoted maternal non-drought exposure while “1” denoted maternal exposure in the indicator variable.

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 1 May 1980–30 April 1982; 1 May 1986–30 April 1988; 1 May 1991–30 April 1993). The number “0” was assigned to all mothers who were not part of that subgroup of drought exposures. Similarly, the number “1” was assigned to all mothers who were 3–5 yr old during each drought period (DoB from 1 May 1977–30 April 1980; 1 May 1983–30 April 1986; 1 May 1988–30 April 1991). The number “0” was assigned to all mothers who were not part of that subgroup of drought exposures.

Statistical analyses

Study variables

The present study differentiates the two generations (maternal and offspring) during analyses and throughout the paper by prefixing reported infant birth outcomes with the word “subsequent”. Thus the study outcomes were subsequent infant LAZ, subsequent infant WAZ, and subsequent imputed infant BWT. 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. The variables for maternal exposure to drought in early life comprised exposure at ages 0–5 yr, or 0–2 yr, and 3–5 yr. Covariates included sex of the child, maternal education, maternal BMI, maternal 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 status defined, as being pregnant at age 35 yr old and over, or being pregnant younger than 18 yr old. 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 maternal drought exposure in early life variables with the three trial arms.

Potential bias

The study may have been susceptible to overestimating the effects of non-exposure to drought because the comparison group included mothers who were exposed to drought in utero. To assess and remove the impact of this special group of mothers exposed to drought in utero, sensitivity analyses were conducted to exclude this group of mothers exposed to drought in utero from the Expanded Models described below.

Models

The general form of the models that excluded prenatal supplements was as follows:

\[ Y_i = \alpha + \beta X_i + Z_i^T + \epsilon_i \]

Where:

- \( Y_i \) is the study outcome (infant LAZ, infant WAZ, or imputed infant birthweight) for the i-th subject,
- \( \alpha \) is the intercept,
- \( \beta \) is the coefficient for the exposure variable,
- \( y \) are the coefficients for the covariates,
- \( X_i \) is the early life maternal exposure to drought in early life variable for the i-th subject,
- \( Z_i \) are the covariates for the i-th subject,
- \( \epsilon_i \) 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:

\[ Y_i = \alpha + \beta (X_i * W_i) + Z_i^T + \epsilon_i \]

Where:
Table 1. Characteristics of study population by maternal non-drought exposure or maternal drought exposure in early life

| Characteristics                                      | Maternal non-Exposure to drought [0–5 yr] | Maternal Exposure [0–2 yr] | Maternal Exposure [3–5 yr] |
|------------------------------------------------------|------------------------------------------|-----------------------------|-----------------------------|
| n [mean: range] n [count: %]                         | n [mean: range] n [count: %]             | n [mean: range] n [count: %] |
| Infant sex [girl]                                    | 397 [200: 50.38]                         | 378 [200: 52.91]            | 439 [220: 50.11]            |
| Maternal age [yr]                                    | 418 [23: 14.49]                          | 391 [25: 0. 18–40]         | 453 [26:9: 16–38]           |
| Maternal height [cm]                                 | 418 [155: 139, 171]                      | 389 [156: 132–171]         | 389 [156: 141,175]          |
| Maternal BMI [kg/m²]                                 | 417 [21.78: 16.10–30.65]                | 387 [22.12: 16.63–32.98]   | 450 [22.45: 16.26–37.81]    |
| Marital status [married]                             | 418 [349: 83.49]                         | 391 [346: 88.49]           | 453 [420: 92.72]            |
| Maternal education [yr]                              | 411 [3.8: 0–12]                          | 383 [4.0: 0–12]            | 449 [4.0: 0–12]             |
| Head of household [mother]                           | 418 [29: 6.94]                           | 391 [22: 5.63]             | 453 [33: 7.28]              |
| HH food insecurity access scale [0–10]               | 412 [5.01: 0, 27]                        | 382 [5.04: 0, 27]          | 443 [4.74: 0, 24]           |
| HH asset index Z score [SD]                          | 409 [−0.93: −0.73, 3.39]                | 385 [−0.7: −0.73, 3.29]    | 446 [0.10: −0.73, 3.29]     |
| Primiparity [yes]                                    | 418 [195: 46.65]                         | 390 [48: 12.31]            | 429 [23: 5.09]              |
| Normal vs. “at risk” pregnancy by age                | 418 [192: 45.93]                         | 386 [5: 1.28]              | 453 [34: 7.51]              |
| [At risk (< 18 yr or ≥ 35 yr)]                       |                                          |                             |                             |

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

$\alpha$ is the intercept,

$\beta$ are the coefficients for the interactions of maternal exposure to drought in early life variables (at age 0–5 yr for different years) and the prenatal supplements variables,

$\gamma$ are the coefficients for the covariates,

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

$W_i$ are the prenatal supplements variables for the i-th subject,

$Z_i$ are the covariates for the i-th subject,

$\varepsilon_i$ is the error term for the i-th subject.

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

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

Results

Summary statistics

The mean age of mothers was 24 years while the range was 14–48 years for mothers with known dates of birth (DOB: N = 1262) although 10% of mothers did not know their DOBs. Although being 15 years or older was another eligibility criterion for enrollement, some 14-year-old women slipped into the RCT (n = 2) but were nevertheless not excluded from participation. Likewise, the two 14-year-olds and their infants were not excluded from the present study.

Other characteristics of the mothers plus the distribution of their newborns by sex are outlined in Table 1 with columns divided by Maternal non-Exposure to drought [0–5 yr], Maternal Exposure [0–2 yr], and Maternal Exposure [3–5 yr]. The summary statistics are as follows.

In our retrospective study, all groups of mothers including those exposed to drought in early life at age 0–2 yr or 3–5 yr and those not exposed to drought in early life from age 0–2 yr or 3–5 yr were more likely to have baby girls (50.38%, 52.91% and 53%, respectively) than baby boys. The youngest group of mothers was the non-exposed group (23 yr) compared to those mothers exposed to drought in early life at age 0–2 yr or 3–5 yr (25 yr and 26.9 yr, respectively). The older group of mothers with maternal exposure at age 3–5 yr had quite a higher percentage of women who were married at 92% vs. 88% for the mothers with maternal exposure at age 0–2 yr or 83% for the non-exposed mothers at either age 0–2 yr or 3–5 yr. All maternal heights, on average, were about the same (155 cm, 155 cm, and 156 cm, respectively) across the three groups. Across the three groups, maternal body mass index (BMI), on average, ranged from 21.78–22.45. As for maternal education, nothing stood out in terms of number of years of completed education because all three maternal groups averaged around 4 years of completed education.

Mothers as heads of their households (HHs) was an occasional occurrence in the present study with only about 7% of non-drought exposed mothers at either age group (0–2 yr or 3–5 yr). About 6% of mothers with maternal exposure at age 0–2 yr, and about 7% of mothers with maternal exposure at age 3–5 yr claiming to be HHs. Self-reported household food insecurity
average scores showed that perceived household food insecurity based on responses to a set of 9 questions (covering about different levels of experiences with food insecurity in the past 4 weeks) were relatively low across the groups (5, 5, and 4.74, respectively), although some households scored a 27, the highest and severest score on the food insecurity access score. The present study used household asset index Z score also called the first principal components score that uses housing quality and asset variables, as an indicator of household wealth. The indicators were obtained from a past Malawi Demographic Health Survey. The results showed little variation among the groups in terms of standard deviations (SDs) from the mean factor of “0” (−0.93 SD, −0.7 SD and 0.10 SD, respectively), meaning that households’ wealth status was quite similar among the three groups.

Finally, there was a marked difference among the groups in terms of frequency of primiparity (first pregnancy) and “at risk” pregnancies by age (<18 yr or >35 yr). For example, about 47% of women in the non-drought exposed group had primiparous pregnancies while only less than 13% and less than 23% of mothers exposed to drought in early life at age 0–2 yr or 3–5 yr, respectively, had primiparous pregnancies. Similarly, there was a marked difference in terms of the frequency of “at risk” pregnancies by age. Notably, about 46% of women in the non-drought exposed group had “at risk” pregnancies by age while only less than 2% and less than 8% of mothers exposed to drought in early life at age 0–2 yr or 3–5 yr, respectively, had “at risk” pregnancies.

Table 2 summarizes the proportions of mothers who were exposed to drought in early life at age 0–5 yr, 0–2 yr, 3–5 yr and mean birth outcomes. 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 to the 1981/82, 1987/88, and 1992/93 droughts, respectively.

Finally, about 28% of mothers who received SQ-LNS, 29% of mothers who received MMN, and 29% of mothers who received IFA were exposed to drought in early life at age 0–2 yr. Also, about 41% of mothers who received SQ-LNS, 38% of mothers who received MMN, and 35% of mothers who received IFA were exposed to drought at age 3–5 yr.

Regression results

Ordinary least squares generated in Stata (versions 14 and 14.2) were used to both run multiple regressions and to create models. The results show that the estimated regression coefficients for the exposure variables and independent variables. Confidence intervals (CIs) provided in parentheses are set at the 95% level of confidence with lower and upper bounds. 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 a p-value < 0.1 will not be summarized or discussed. Robust standard errors were used for all the regressions.

When the prenatal supplements were added to the list of covariates in the expanded models (Table 3), among mothers who received IFA, maternal exposure to the drought of 1987/88 in early life at age 0–5 yr was associated with slightly (and significantly) improved subsequent infant WAZ compared to non-drought exposure at the same age. Next, among mothers exposed to the drought of 1987/88 in early life at age 0–5 yr, prenatal supplementation with SQ-LNS did not improve subsequent infant LAZ compared to prenatal supplementation with IFA but the results were not significant. Similarly, among mothers exposed to the drought of 1992/93 in early life at age 0–5 yr, prenatal supplementation with SQ-LNS did not improve any of
the subsequent infant birth outcomes compared to prenatal supplementation with IFA, however the results were significant. Notably, the biggest effect size from the prenatal supplementation with SQ-LNS compared to prenatal supplementation with IFA was observed for the imputed infant birthweight model where maternal drought exposure in early life occurred in 1992/93 (−175.820 g, 95% CI (−339.850: −11.791). Finally, among mothers not exposed to drought in early life, prenatal supplementation with SQ-LNS significantly improved all subsequent infant birth outcomes compared to prenatal supplementation with IFA as did MMN compared to IFA, although in the latter case the result was not significant.

After including prenatal supplements variables in the expanded models, among mothers exposed to drought in early life, prenatal supplementation with SQ-LNS neither improved subsequent infant WAZ compared to prenatal supplementation with IFA if the exposure occurred at age 0–2 yr nor improved subsequent imputed infant birthweight if the exposure occurred at age 3–5 yr (Table 4).
Table 4. Regressions for infant LAZ, infant WAZ, and imputed infant B/Weight with early life maternal exposure to drought (Age 0–2 yr and 3–5 yr) and prenatal supplements

| Variables | (1) Expended Model: LAZ | (2) Expanded Model: WAZ | (3) Expanded Model: Imputed B/Weight |
|-----------|-------------------------|-------------------------|-------------------------------------|
| Drought exposure at age 0–2 yr#IFA | 0.082 | 0.251* | 40.033 |
| Drought exposure at age 3–5 yr#IFA | (−0.238, 0.402) | (−0.046, 0.548) | (−77.913, 157.979) |
| Non exposure#MMN* | 0.154 | 0.287* | 43.839 |
| Non exposure#MMN* | (−0.163, 0.471) | (−0.002, 0.576) | (−67.671, 155.350) |
| Non exposure#MMN* | 0.110 | 0.214 | 9.083 |
| Non exposure#LNS | (−0.178, 0.397) | (−0.059, 0.487) | (−98.255, 116.420) |
| Drought exposure at age 0–2 yr#MMN | 0.151 | −0.087 | 62.945 |
| Drought exposure at age 0–2 yr#LNS | (−0.254, 0.556) | (−0.466, 0.292) | (−93.710, 219.599) |
| Drought exposure at age 0–2 yr#LNS | −0.316 | −0.429** | −179.687** |
| Drought exposure at age 0–2 yr#LNS | (−0.742, 0.110) | (−0.849, −0.010) | (−348.050, −113.24) |
| Child sex (girl) | 0.117* | 0.035 | −83.153*** |
| Child sex (girl) | (−0.018, 0.253) | (−0.093, 0.162) | (−136.402, −29.903) |
| Maternal education | 0.005 | 0.009 | −1.817 |
| Maternal BMI | (−0.019, 0.029) | (−0.013, 0.031) | (−10.929, 7.294) |
| Marital status (married) | 0.023 | 0.032** | 15.037*** |
| Marital status (married) | (−0.005, 0.050) | (0.006, 0.058) | (4.461, 25.614) |
| Maternal height | −0.084 | 0.051 | 26.725 |
| Maternal height | (−0.324, 0.155) | (−0.170, 0.272) | (−111.957, 58.508) |
| Head of household (mother) | 0.053*** | 0.042** | 18.280*** |
| Head of household (mother) | (0.039, 0.066) | (0.030, 0.055) | (13.340, 23.219) |
| HH food insecurity access scale | −0.739, 0.002 | −0.804, −0.125 | −127.807* |
| HH food insecurity access scale | 0.006 | 0.013* | 4.172 |
| HH asset index Z score | (−0.010, 0.023) | (−0.002, 0.028) | (−1.945, 10.289) |
| HH asset index Z score | 0.015 | 0.047 | 3.634 |
| Primiparous | −0.369* | −0.465*** | −127.807* |
| Primiparous | (−0.739, 0.002) | (−0.804, −0.125) | (−263.357, 7.743) |
| Normal (vs. “at risk”) pregnancy by age | 0.013* | 0.013* | 4.172 |
| Normal (vs. “at risk”) pregnancy by age | (0.006, 0.0415) | (0.006, 0.0415) | (4.172, 4.172) |
| constant | −10.017*** | −8.271*** | −250.759 |
| constant | (−12.289, −7.746) | (−10.329, −6.213) | (−1036.422, 534.904) |
| N | 980 | 991 | 1,074 |
| R-squared | 0.115 | 0.112 | 0.100 |
| F | 6.748 | 7.131 | 7.588 |
| Adjusted R-squared | 0.0987 | 0.0957 | 0.0842 |

Notes:
Outcomes: LAZ—length-for-age Z score, WAZ—weight-for-age Z score, BWT—birthweight
Prenatal supplements: LNS—lipid-based nutrient supplement, MMN—multiple micronutrient supplement, IFA—iron-folic acid
HH—household
Confidence intervals (CI): 95% CI in parentheses (lower bound, upper bound)
Statistical significance (p-values): *p < 0.1, **p < 0.05, ***p < 0.01

As for the covariates in the main regressions, only maternal height and primiparity consistently influenced the subsequent infant 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. Taller mothers were more likely to have children with a higher subsequent infant LAZ and a higher subsequent infant WAZ. Primiparity or being pregnant for the first time was negatively associated with all subsequent infant birth outcomes as did “at risk” pregnancy age suggesting that older and younger mothers were more likely to have children with a lower subsequent infant LAZ, lower subsequent infant WAZ, or lower subsequent imputed infant birthweight compared to mothers considered to have normal pregnancies because of their age.

Finally, the sensitivity analyses summarized in Tables 5 and 6 assessed the impact of excluding mothers exposed to drought in utero from the respective control groups in the subsequent infant LAZ, subsequent infant WAZ and subsequent imputed birthweight models. However, reducing the control group size did not change the results significantly with two exceptions. Among mothers exposed to the drought of 1987/88 in early life at age 0–5 yr, prenatal supplementation with SQ-LNS did not improve subsequent infant LAZ or subsequent infant WAZ compared to prenatal...
supplementation with IFA. Also, among mothers exposed to the drought of 1992/93 in early life, prenatal supplementation with SQ-LNS compared to IFA no longer significantly influenced subsequent infant WAZ. Further, there was a tendency for some of the previously significant covariates (e.g. child sex, maternal BMI, mother as HH, normal vs. “at risk” pregnancy by age) to lose some of the strength of their associations with

### Table 5: Sensitivity analysis for regressions on infant LAZ, infant WAZ, and B/Weight with early life maternal exposure to drought (Age 0–5 yr) and prenatal supplements

| Variables | (1) Expanded Model: LAZ | (2) Expanded Model: WAZ | (3) Expanded Model: Imputed B/Weight |
|-----------|--------------------------|-------------------------|-------------------------------------|
| Drought exposure in 1981/82 IFA | -0.229 (-0.694, 0.237) | -0.085 (-0.503, 0.334) | -15.305 (-180.962, 150.351) |
| Drought exposure in 1987/88 IFA | 0.425* (0.035, 0.815) | 0.474** (0.117, 0.831) | 88.896 (-63.828, 241.620) |
| Drought of exposure in 1992/93 IFA | 0.197 | 0.242 | 113.420 |
| Non exposure# MMN* | 0.171 | 0.179 | 26.360 |
| Non exposure# LNS# | 0.396* (0.092, 0.699) | 0.364* (0.043, 0.684) | 123.720* (0.158, 247.282) |
| Drought exposure in 1981/82 MMN | 0.028 | -0.018 | -28.830 |
| Drought exposure in 1981/82 LNS | 0.029 | -0.059 | -87.829 |
| Drought exposure in 1987/88 MMN | -0.366 | -0.305 | 24.651 |
| Drought exposure in 1987/88 LNS | -0.628* (-0.860, 0.128) | -0.482* (-0.762, 0.151) | -162.298 (211.600) |
| Drought exposure in 1992/93 MMN | -0.163 | -0.201 | -30.268 |
| Drought exposure in 1992/93 LNS | -0.644, 0.317 | -0.650, 0.248 | -210.055, 149.520 |
| Child sex (girl) | 0.167* (0.018, 0.315) | 0.052 (-0.088, 0.193) | -61.298* (-120.463, -2.133) |
| Maternal education | 0.010 | 0.011 | -2.163 |
| Maternal BMI | 0.022 | 0.0261 | 14.732* |
| Expended 2011/12 SUSTAINABLE ENVIRONMENT | 0.000, 0.052 | -0.004, 0.055 | (0.038, 26.426) |

**Notes:**
- The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

| Variables | (1) Expanded Model: LAZ | (2) Expanded Model: WAZ | (3) Expanded Model: Imputed B/Weight |
|-----------|--------------------------|-------------------------|-------------------------------------|
| Marital status (married) | -0.243† (-0.507, 0.021) | -0.040 (-0.272, 0.192) | -37.851 (-131.693, 55.992) |
| Maternal height | 0.055** (0.040, 0.070) | 0.046** (0.032, 0.060) | 20.571** (14.905, 26.238) |
| Head of household (mother) | -0.441* (-0.826, -0.056) | -0.471* (-0.832, -0.109) | -102.863 (-248.461, 42.735) |
| HH food insecurity access scale | 0.010 | 0.015 | 5.330 |
| HH asset index Z score | -0.009, 0.028 | -0.002, 0.032 | -1.425, 12.084 |
| Primiparous | 0.010 | 0.069 | 2.286 |
| Normal (vs. “at risk”) pregnancy by age | -0.081, 0.100 | -0.017, 0.154 | -35.392, 39.963 |
| Constant | -0.412** (-0.617, -0.207) | -0.393** (-0.591, -0.196) | -109.087** (-188.901, -29.272) |
| 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 < 0.1, ‡p < 0.05, **p < 0.01
Table 6. Sensitivity Analysis for Regressions on Infant LAZ, Infant WAZ, and B/Weight with Early Life Maternal Exposure to Drought (Age 0-2 yr and 3-5 yr) and Prenatal Supplements

| Variables | (1) Expanded Model: LAZ | (2) Expanded Model: WAZ | (3) Expanded Model: Imputed B/Weight |
|-----------|-------------------------|-------------------------|-----------------------------------|
| Drought exposure at age 0-2 yrIFA | 0.422* | 0.239 | 122.896 |
| Drought exposure at age 3-5 yrIFA | 0.046* | 0.235 | 47.624 |
| Non exposure# MMN | -0.296, 0.386 | (-0.074, 0.543) | (-79.733, 174.982) |
| Non exposure# LNS | 0.177 | 0.184 | 27.700 |
| Drought exposure at age 0-2 yrMMN | -0.138, 0.492 | (-0.114, 0.481) | (-90.004, 145.404) |
| Drought exposure at age 0-2 yrLNS | 0.396* | 0.364* | 124.672 |
| Drought exposure at age 3-5 yrMMN | -0.109 | -0.191 | -125.272 |
| Drought exposure at age 3-5 yrLNS | -0.076, 0.068 | (-0.802, 0.011) | (-311.768, 61.225) |
| Child sex (girl) | 0.171** | 0.051 | -54.973 |
| Maternal education | 0.011 | 0.012 | -1.756 |
| Maternal BMI | -0.015, 0.037 | (-0.011, 0.036) | (-11.981, 8.470) |
| Marital status (married) | 0.018 | 0.023 | 13.786 |
| Maternal height | -0.013, 0.048 | (-0.006, 0.052) | (2.422, 25.150) |
| Head of household (mother) | -0.069, 0.055 | (-0.242, 0.218) | (123.630, 63.738) |
| HH food insecurity access scale | 0.008 | 0.014 | 4.731 |
| HH asset index Z score | -0.001, 0.027 | (-0.003, 0.031) | (-1.962, 11.424) |
| Primiparous | 0.067** | 0.046** | 20.133** |
| Normal (vs. “at risk”) pregnancy by age | 0.009 | 0.069 | 14.571, 25.696 |
| Constant | -0.003, 0.039 | (-0.005, 0.028) | (-258.114, 27.884) |

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

subsequent infant birth outcomes. Overall, the patterns of statistical associations were replicated in the expanded models subjected to sensitivity analyses.

**Strengths and limitations**

One of the strengths of this study was the addition of subsequent infant WAZ as a study outcome in the context of early life maternal exposure to drought during the preschool years, which is not widely reported in literature. A second strength of the study was the random assignment of mothers into the three trial arms of the RCT; thus, ensuring that any systematic variations would be randomized across the three trial arms. A third strength was the inclusion of a new intervention SQ-LNS assessed against a control group IFA to the regression models.

The study, however, was not without its limitations. First, missing documentation of DoB and the lack of knowledge of one’s DoB is common in resource-poor countries and this study was not exempted from this disparity. Many mothers did not know their DoB, thus reducing the sample size of the original study by about 9%. A second limitation imposed on the sample was the use of imputed values in place of infant birthweight for any measurements taken between 3–5 days post-birth.
This imputation of birthweight could result in the overestimation of results for outcomes of both the exposure groups and the control group. Third, the dyad of mothers and their children excluded from the sample could have possibly helped the results to be more robust since a larger sample is almost invariably preferable. Also, the study was underpowered to detect an effect for all the models with maternal exposure to drought in early life and SQ-LNS interactions since sample size was much smaller (e.g. the sample size was n < 60 for SQ-LNS compared to IFA among mothers exposed to the drought in early life at age 0–5 yr). Finally, maternal early life anthropometric and clinical data from during the years of exposure to drought in early life were unavailable — not surprisingly, since this is an expected consequence of using a historical cohort study (natural experiment) with no access to historical records. This gap in data inevitably limits on causality in our discussion below.

**Discussion**

The study hypothesized that the same marginal difference in effect size for infants’ birth outcomes observed in other studies of nutritional supplementation could be observed for the infants of women who may have been exposed to drought in early life if they received SQ-LNS compared to IFA during their pregnancies.

As expected, the interaction of the maternal exposure to the drought of 1992/93 at age 0–5 yr variable and the prenatal supplementation with SQ-LNS variable negatively influenced not only the subsequent infant LAZ and subsequent infant WAZ, but also the subsequent infant imputed BWT because drought of 1992/93 was the most severe among the three meteorological phenomena. Although, surprisingly, when the non-maternal drought exposure in early life variable was interacted with the prenatal supplementation with the SQ-LNS variable, mothers were more likely to have offspring with significantly increased birth size compared to mothers who received IFA if they were not exposed to drought in early life. Post-sensitivity analyses, however, prenatal supplementation with SQ-LNS compared to IFA appeared to no longer significantly improved subsequent infant WAZ or subsequent imputed infant BWT if maternal exposure to drought occurred at age 0–2 yr. Similarly, when the maternal drought exposure at age 0–5 yr (during the 1992/93 drought) variable was interacted with the SQ-LNS prenatal supplementation variable, subsequent infant WAZ was longer statistically significant. By contrast, when maternal non-drought exposure from ages 0–5 yr, 0–2 yr or 3–5 yr were interacted with SQ-LNS supplementation compared with IFA supplementation, subsequent infant LAZ, subsequent infant WAZ, and subsequent imputed infant BWT were more likely to increase overall infant size.

Compared to other studies, a similarity between the sample characteristics in the present study and the Chinese studies, for example, is evident as both study populations originated from predominantly rural populations. It is noteworthy that the China of the 1950s comprised of 85% rural inhabitants and 15% urban inhabitants (Gørgens et al., 2012), while Malawi’s population compositions of 1980 to 1990 when the droughts occurred were estimated as 89% predominantly rural in 1987 (National Statistical Office (NSO), 1992).

However, the present study also differs from other studies informing the sparse literature on maternal exposure to famine in early life. For example, the estimated changes in subsequent infant LAZ and subsequent infant WAZ were larger for maternal exposure to drought in early life at age 0–5 yr in the present study than the impact of maternal exposure to the Great Chinese Famine during the first and second years of life on subsequent infant LAZ and subsequent infant WAZ (Fung & Ha, 2010). The difference may be attributed to the introduction of prenatal supplements of SQ-LNS compared to IFA which did not exist in the Great Chinese Famine models. The present study also differs from other studies on the Great Chinese Famine cohort because the present study introduced more than one drought or a close meteorological phenomenon into its models, whereas the other studies only considered one famine (i.e., the Great Chinese Famine of 1959–1961 reported in Fung & Ha, 2010 and Gørgens et al., 2012).

**Conclusion**

The present study assessed the impact of maternal exposure during the preschool years at age 0–2 yr or age 3–5 yr on three subsequent infant birth outcomes, namely, subsequent infant LAZ, subsequent infant WAZ, and subsequent imputed infant birthweight after prenatal supplementation with SQ-LNS compared to IFA. The study hypothesized that the same marginal difference in effect size for subsequent infants’ birth outcomes observed in other studies of nutritional supplementation would be observed for the infants of women who may have been exposed to drought in early life, if they received a SQ-LNS compared to IFA during their pregnancies.

In lieu of reporting definite conclusions, some interesting questions can be raised from these results. For example, does the fact that SQ-LNS is a small dose of 20 g/daily cause it to contribute less effectively to improving subsequent infant birth outcomes such as subsequent infant WAZ, especially when maternal drought exposure...
(and therefore nutritional adversity) may have occurred in early life? Further, do the positive associations between improved birth outcomes and SQ-LNS supplementation of mothers not exposed to drought at age 0–5 yr (or more narrowly at age 0–2 yr or 3–5 yr) speak to the uniqueness of the study population or make a case for using SQ-LNS in settings where severe maternal nutritional adversity in early life has not occurred?

Notes

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. Conversely, the longer the return period, the more severe the drought.
2. Emergency relief began with government distribution of maize to needy areas followed by distribution of maize from donors, which began to arrive in July 1992 (Babu & Chapasuka, 1997).
3. World Bank SAPs were economic interventions designed to liberalise different sectors of the economy such as the agricultural sector, financial sector from government majority control. Parastatal reforms and rationalisation of the Budget were prioritized, however SAPs inadvertently increased poverty levels in Malawi (Southern African Regional Poverty Network (SARPN), Internet).
4. The base category was non exposure to drought interacted with IFA (Non exposure#IFA)
5. The base category was non exposure to drought interacted with IFA (Non exposure#IFA)

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PUBLIC INTEREST STATEMENT

This study introduces a framework for overcoming the inter-generational effects of being born in a drought setting by providing prenatal interventions for the intermediate generation in a resource-poor country. The study contributes new information to the literature on droughts and famines, in particular, where they intersect with food insecurity and undernutrition to affect the physical well-being of newborns.

Key messages

- In geographical areas affected by drought, unfavourable pregnancy outcomes may be made worse by intergenerational effects of maternal exposure to drought early in life and passed on to their offspring by negatively affecting subsequent birth size.
- The effects of latent maternal undernutrition from early life on subsequent infant birth outcomes may be mitigated by prenatal supplementation with the standard of care iron-folic acid (IFA) not small-quantity, lipid-based nutrient supplements (SQ-LNS) under certain conditions and settings.
- When there is no prior historical exposure of mothers to drought early in life, prenatal supplementation with SQ-LNS may improve subsequent birth outcomes compared to prenatal supplementation with IFA under certain conditions and settings.

References

Kalkuhl, Matthias; Kornher, Lukas; Kozicka, Marta; Boulanger, Pierre; and Torero, Maximo. 2013. Conceptual framework on price volatility and its impact on food and nutrition security in the short term. FOODSECURE Working Paper 15. The Hague, Netherlands: Wageningen University and Research Centre (WUR). https://www.wecr.wur.nl/WECRGGeneral/FoodSecurePublications/15_Kalkuhl_conceptualFrameworkPriceVolatilityFNS.pdf
Adu-Afarwuah, S., Larney, A., Brown, K. H., Zlotkin, S., Briend, A., & Dewey, K. G. (2007). Randomized comparison of 3 types of micronutrient supplements for home fortification of complementary foods in Ghana: Effects on growth and motor development. The American Journal of Clinical Nutrition, 86(2), 412–420. https://doi.org/10.1093/ajcn/86.2.412
Ashorn, P., Alho, L., Ashorn, U., Cheung, Y., Dewey, K., Harjunmaa, U., Larney, A., Nkhoma, M., Phiri, N., Phuka, J., Vosti, S. A., Zeilani, M., & Maleta, K. (2015). The impact of lipid-based nutrient supplement provision to pregnant women on newborn size in rural Malawi: A randomized controlled trial. The American Journal of Clinical Nutrition, 101(2), 387–397. https://doi.org/10.3945/ajcn.114.088617
Babu, S. C., & Chapasuka, E. (1997). Mitigating the effects of drought through food security and nutrition monitoring:
Lessons from Malawi. *Food and Nutrition Bulletin, 18*(1), 71–83. https://doi.org/10.1177/156482659701800106

Belesova, K., Agabirwe, C. N., Zou, M., Phalkey, R., & Wilkinson, P. (2019). Drought exposure as a risk factor for child undernutrition in low- and middle-income countries: A systematic review and assessment of empirical evidence. *Environment International, 131*, 104973. https://doi.org/10.1016/j.envint.2019.104973

Das, J. K., Salam, R. A., Hadi, Y. B., Sheikh, S. S., Bhatta, A. Z., Prinzo, Z. W., & Bhatta, Z. A. (2019). Preventive lipid-based nutrient supplements given with complementary foods to infants and young children 6 to 23 months of age for health, nutrition, and developmental outcomes. *Cochrane Database of Systematic Reviews, 5*(5), CD012611. https://doi.org/10.1002/14651858.CD012611.pub3

Fung, W., & Ha, W. (2010). Intergenerational effects of the 1959–61 China famine. In R. Fuentes-Nieva & P. A. Seck (Eds.), *Risks, shocks, and human development: On the brink* (pp. 222–254). Palgrave Macmillan.

Gørgens, T., Meng, X., & Vaithianathan, R. (2012). Stunting and selection effects of famine: A case study of the great Chinese famine. *Journal of Development Economics, 97*(1), 99–111. https://doi.org/10.1016/j.jdeveco.2010.12.005

Hanjahanja-Phiri, T. (2018). Intergenerational effects of maternal exposure to drought in utero on newborn size in rural Malawi. *Annals of Nutrition & Metabolism, 73*(1), 74–76. https://doi.org/10.1159/000490671

Harrigan, J. (2003). U-turns and full circles: Two decades of agricultural reform in Malawi 1981-2000. *World Development, 31*(5), 847–8635. https://doi.org/10.1016/S0305-750X(03)00019-6

IFPRI. (2009). *Droughts and floods in Malawi assessing the economywide effects*. Retrieved April 12, 2015 from http://www.preventionweb.net/files/13792_ifpripdf009621.pdf

Johnson, W., Darboe, M. K., Sosseh, F., Nshe, P., Prentice, A. M., & Moore, S. E. (2017). Association of prenatal lipid-based nutritional supplementation with fetal growth in rural Gambia, *Maternal & Child Nutrition, 13*(2), e12367. Epub 2016 Oct 2 https://doi.org/10.1111/mcn.12367

Kalinga, O. J. M. (Ed.). (2012). *Historical dictionary of Malawi* (4th ed.). Scarecrow Press.

Martorell, R., & Zongrone, A. (2012). Intergenerational influences on child growth and undernutrition. *Paediatric and Perinatal Epidemiology, 26*(Suppl 1), 302–314. https://doi.org/10.1111/j.1365-3016.2012.01298.x

National Statistical Office (NSO). (1992). *Malawi demographic health survey*. Retrieved June 3, 2015 from http://dhsprogram.com/pubs/pdf/FR49/FR49.pdf

Phuka, J., Thakwalakwa, C., Maleta, K., Cheung, Y. B., Briend, A., Manary, M., & Ashorn, P. (2009). Supplementary feeding with fortified spread among moderately underweight 6–18-month-old rural Malawian children. *Matern. Child. Nutr., 5*(2), 159–170.

Resnick, D. (2012). Foreign aid in Africa. Tracing channels of influence on democratic transitions and consolidation working paper No. 2012/15, Helsinki: UNU-WIDER. Retrieved July 6, from http://www.wider.unu.edu/publications/working-papers/2012/en_GB/wp2012-015/

Rickard, I. J., Courtiol, A., Prentice, A. M., Fulford, A. J., Clutton-Brock, T. H., & Lummaya, V. (2012). Intergenerational effects of maternal birth season on offspring size in rural Gambia. *Proceedings of the Royal Society B: Biological Sciences, 279* (1745), 4253–4262. https://doi.org/10.1098/rspb.2012.1363

Southern African Regional Poverty Network (SARP). *Chapter 3- structural adjustment and poverty*. (Internet). http://www.sarpn.org/CountryPovertyPapers/Malawi/PRSPDraft/PRSPDraftChapter3.pdf

WHO. (2013). *Childhood stunting: Context, causes and consequences WHO conceptual framework*. Retrieved April 12, 2015 from http://www.who.int/nutrition/events/2013_ChildhoodStunting_colloquium_14Oct_ConceptualFramework_colour.pdf

WHO Multicentre Growth Reference Study Group. (2006). *WHO child growth standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development* (2006). WHO Geneva.

World Medical Association. (2001). World medical association declaration of Helsinki. Ethical principles for medical research involving human subjects. *The Bulletin of the World Health Organization, 79*(4), 373–374.