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Original Article

Assessment of the WHO Stunting Framework using Ethiopia as a case study

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Abstract

Poor linear growth in children <5 years old, or stunting, is a serious public health problem particularly in Sub-Saharan Africa. In 2013, the World Health Organization (WHO) released a conceptual framework on the Context, Causes and Consequences of Childhood Stunting (the 'WHO framework') that identifies specific and general factors associated with stunting. The framework is based upon a global review of data, and we have applied it to a country-level analysis where health and nutrition policies are made and public health and nutrition data are collected. We reviewed the literature related to sub-optimal linear growth, stunting and birth outcomes in Ethiopia as a case study. We found consistent associations between poor linear growth and indicators of birth size, recent illness (e.g. diarrhoea and fever), maternal height and education. Other factors listed as causes in the framework such as inflammation, exposure to mycotoxins and inadequate feeding during and after illness have not been examined in Ethiopia, and the existing literature suggests that these are clear data gaps. Some factors associated with poor linear growth in Ethiopia are missing in the framework, such as household characteristics (e.g. exposure to indoor smoke). Examination of the factors included in the WHO framework in a country setting helps identifying data gaps helping to target further data collection and research efforts.

Keywords: stunting, conceptual framework, Ethiopia, contributors.

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Abbreviations: ARI, Acute respiratory infection; BMI, Body mass index; DHS, Demographic Health Survey; FCS, Food consumption score; HAZ, Height-for-age z-score; HDDS, Household dietary diversity score; HFIAS, Household Food Insecurity Access Scale; IDA, Iron deficiency anaemia; IUGR, Intrauterine growth restriction; LBW, Low birthweight; LRI, Lower respiratory infection; MUAC, Mid-upper arm circumference; SGA, Small for gestational age; SNNP, Southern Nations, Nationalities and Peoples' Region; WASH, Water, sanitation and hygiene; WHO, World Health Organization.

Introduction

Poor linear growth in children <5 years old, or stunting, is associated with increased morbidity and mortality; reduced neurocognitive function, decreased learning capacity and productivity; and poor long-term health outcomes (Black *et al.* 2013). The World Health Assembly in 2012 defined the reduction of stunting by 40% as one of six global nutrition targets to be achieved by 2025 (World Health Organization 2012). The United Nations Sustainable Development Goals have also identified stunting as a key development indicator used to measure progress towards its goal to end hunger (United Nations 2016).

Released in 2013, the WHO framework on the Context, Causes and Consequences of Childhood Stunting (refer to Fig. 1) presents numerous factors contributing specifically to stunted growth and development (Stewart *et al.* 2013). While the WHO framework was based on a review of global data, using the framework to assess the contributors of stunting at the national level is critical as national health policies are often based on the available national and sub-national data.

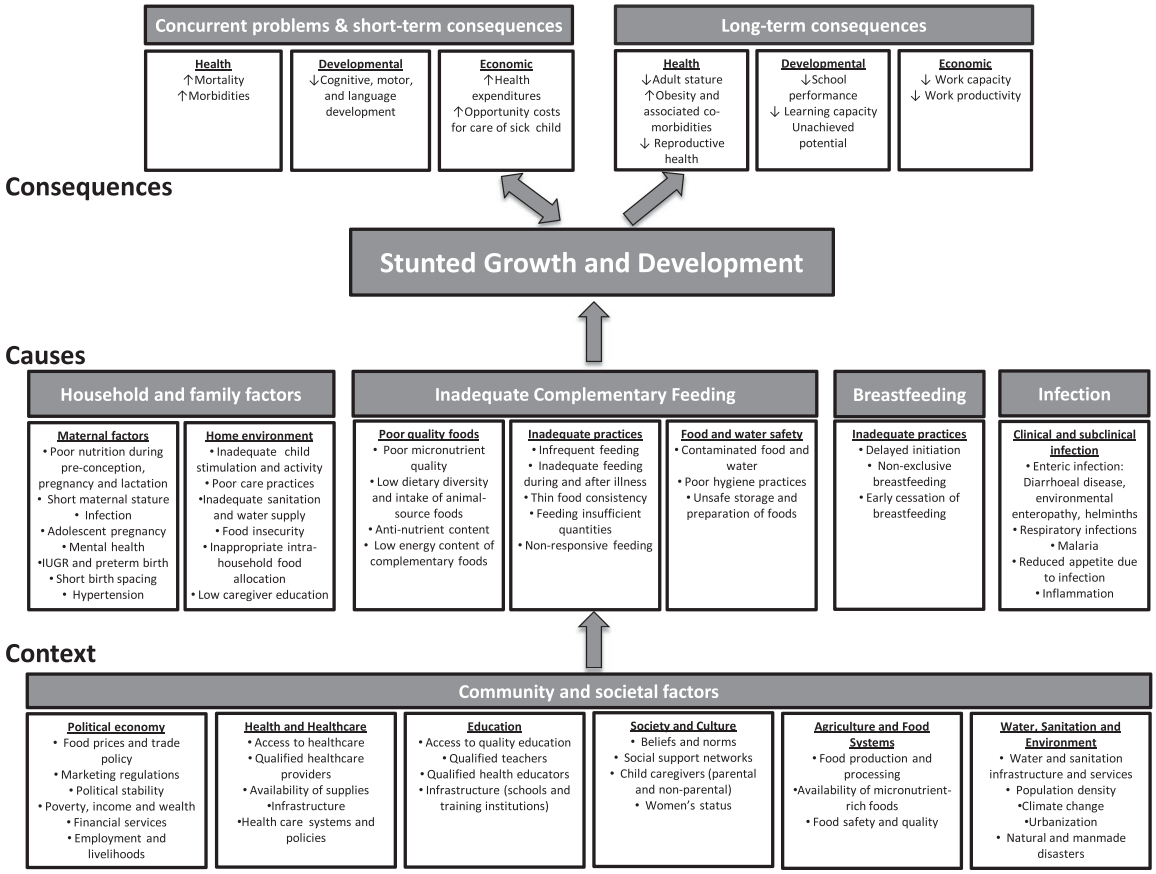

Fig. 1 WHO conceptual framework on Childhood Stunting: Context, Causes, and Consequences, 2013 – (reprinted with permission from the World Health Organization).

This paper aims to assess the current evidence base for factors associated with poor linear growth and stunting in Ethiopia and how this evidence aligns with the WHO Stunting Framework (Fig. 1). Ethiopia provides an appropriate opportunity to test the application of the WHO Stunting Framework at the country level as it is one of the 34 countries with the highest burden of stunting and has more than five million stunted children (UNICEF & WHO & the World Bank 2014). Moreover, while Ethiopia reduced child stunting by 13% between 2000 and 2011 (de Onis *et al.* 2013; UNICEF 2013), the specific factors that led to this

Key messages

- The WHO Stunting Framework provides the first internationally endorsed causative model that focuses specifically on stunting.
- When applying the framework to available evidence in Ethiopia, stunting was most consistently associated with indicators of birth size, recent illness and maternal height and education.
- Notable data gaps in Ethiopia include data on the associations between stunting and infection, and exposure to mycotoxins.
- Recurrence of water and sanitation factors in the framework illustrates the multiple pathways by which poor WASH conditions impair child growth; this is supported by strong evidence linking stunting and WASH in Ethiopia.

decline require further elucidation. By exploring the relevance and applicability of the WHO Stunting Framework to Ethiopia, we hope to support the data collection and analysis efforts of policy makers in Ethiopia and other countries affected by stunting.

Methods

The WHO Stunting Framework is structured in three levels: the short- and long-term health, developmental and economic 'consequences' of stunting; proximate 'causes' (i.e. household and family factors, inadequate complementary feeding, breastfeeding, infection) and 'context' (i.e. community and societal factors). The causes and context described by the framework represent the major contributors to child stunting and adverse health, developmental and economic consequences. As this review is concerned with the determinants of poor linear growth, we discuss the contributors to stunting but do not discuss indicators of the consequences of stunting, which have been reviewed extensively by others (Dewey & Begum 2011; Black *et al.* 2013; Hoddinott *et al.* 2013; Stewart *et al.* 2013).

To identify as many risk factors related to stunting as possible, an extensive literature review was conducted using key reports of stunting in Ethiopia (Silva 2005; Shrimpton 2011) and global reviews of maternal and child health and nutrition (Black *et al.* 2008; UN Standing Committee on Nutrition 2011; Meeks 2012; Stewart *et al.* 2013). A review of the references in these articles was used to identify initial source material. While our review predominantly uses peer-reviewed sources, high-quality grey literature such as Demographic Health Survey (DHS) reports, working papers and academic theses were also included if relevant. To augment this literature, a structured keyword search in Web of Science, PubMed and Google Scholar was conducted to identify articles related to the determinants of stunting that were published from 2000 until February 2015. Literature released in or after the year 2000 only was included to ensure that findings from cross-sectional studies and trials were relevant to the recent socio-economic conditions in Ethiopia and other countries in Sub-Saharan Africa. The search used the following word combinations: (stunting AND Ethiopia) OR (determinants AND stunting) OR (stunting AND reduction). Research conducted in Ethiopia was prioritized, but we also included meta-analyses and studies from other countries because the applicable literature from Ethiopia is not extensive. When literature from outside of Ethiopia is presented, we give the country name to clarify the origin of the data.

We have limited our assessment of the WHO Stunting Framework in several ways. First, we focused on studies investigating linear growth, often measured by length/height for age *z*-score (HAZ) or the prevalence of stunting (i.e. proportion of children with HAZ < -2 standard deviations). Thus, we focus on 'growth' as the main outcome rather than both 'growth and development', which would include mental and psychosocial development. Second, we focus on individual, household, community and societal factors associated with stunting. Thus, multi-country ecologic studies that identify national-level factors (e.g. gross domestic product, Gini index, etc.) were excluded. Last, individual studies and trials examining the link between vitamin and mineral supplements and stunting were also excluded because of the variability between the dosage and content of supplements used in studies. In contrast, the findings of systematic reviews and meta-analyses of supplementation studies have been included.

Results

Household and family factors

The WHO Stunting Framework includes sub-sections on maternal and home environment factors affecting stunting. Maternal factors influence stunting through two distinct pathways: *in utero* and postnatal.

Factors influencing *in utero* growth include maternal infection, adolescent pregnancy, maternal short stature and short birth spacing. Poor nutrition during preconception and pregnancy is not a discrete and measurable factor but represents a wide range of potential indicators. Gluckman & Pinal (2003) and Darnton-Hill & Mkparu (2015) conclude that deficiencies of vitamin A, vitamin E, zinc, calcium and iodine *in utero* likely have adverse consequences, but we found no studies

in Ethiopia examining these deficiencies on birth outcomes. A systematic review of vitamin A supplementation trials concluded that vitamin A supplementation during pregnancy was only protective against low birthweight in the children of HIV-positive women and did not improve birth outcomes (e.g. birthweight, preterm birth) of children of HIV-negative women (Thorne-Lyman & Fawzi 2012). In Tanzania, children born to vitamin D-deficient mothers were more likely to be stunted and suffer from cough (Finkelstein *et al.* 2012). Despite the plausible link between maternal iron deficiency anaemia (IDA) and stunting (Black *et al.* 2013), little is known about the effects of maternal IDA during pregnancy on infant and young child growth.

Maternal infection with malaria, helminths and HIV may lead to intrauterine growth restriction and later stunted growth in the infant (Stewart *et al.* 2013). No studies from Ethiopia could be found directly linking malaria or helminth infections during pregnancy with later child stunting. Globally, few studies have investigated the association between infection during pregnancy and birth outcomes or stunting in early childhood. Some studies have examined the impact of antihelminthic administration during pregnancy, but a Cochrane review found only three randomized controlled trials (Haider *et al.* 2009) and concluded that provision of antihelminthics did not result in significant improvements in maternal anaemia or the perinatal outcomes of low birthweight, preterm birth and perinatal deaths.

Adolescent pregnancy has a well-established link with nutrition outcomes and is of particular importance in Ethiopia where teenage pregnancy is common. In a study from northwestern Ethiopia, Haidar *et al.* (2005) show that children born to girls <15 years old were significantly more likely to be stunted. A multi-country analysis that included Ethiopia also showed markedly higher rates of stunting in children of teenage mothers (Finlay *et al.* 2011). In Ethiopia and many other developing countries, a birth spacing interval of <24 months is associated with significantly higher stunting prevalence (Maleta *et al.* 2003; Mukuria *et al.* 2005).

While stunting's association with poor birth outcomes, such as intrauterine growth retardation and preterm birth, is common in African countries (Chopra 2003; Mamiro *et al.* 2005; Adekanmbi *et al.* 2013), data on birthweight and birth length are not routinely collected or recorded. As a proxy measure for these indicators, DHS surveys ask a child's mother about the perceived size of the child at birth, which is recorded as very small, smaller than average, average, larger than average or very large. While this measure has limitations, a multi-country review of DHS surveys (including the Ethiopian 2000 DHS) found an increased likelihood of stunting in children characterized as 'very small' and 'smaller than average' (Mukuria *et al.* 2005).

Maternal factors influencing postnatal child growth include poor nutrition during lactation and mental health. Umeta *et al.* (2003) found that in Ethiopia's Oromia region, children 5–11 months of age whose mothers' milk had low concentrations of zinc were more stunted than children of mothers with normal levels of breastmilk zinc. Studies investigating the association between self-reported common mental disorders (WHO 1994) and stunting in Ethiopia, Peru, India, Vietnam and Bangladesh found significant associations in the Asian countries but not in Peru or Ethiopia (Harpham *et al.* 2005; Nguyen *et al.* 2014).

Short maternal stature and other anthropometric measures are common proxies of maternal nutritional status, which can affect *in utero* and postnatal growth. Studies from Ethiopia have repeatedly shown significant associations between maternal height and weight and child stunting (Silva 2005; Gibson *et al.* 2009; Mulugeta *et al.* 2010), with the exception of Fentaw *et al.* (2013) who found no association between low maternal body mass index (BMI) and child stunting.

Maternal hypertension is included in the framework because of its influence on birth outcomes, such as preterm birth, still birth and low birthweight (Thangaratinam *et al.* 2012). While no studies on maternal hypertension and subsequent stunting could be identified, maternal hypertension has been associated with low birthweight and still birth in northwest Ethiopia (Adane *et al.* 2014). These findings are supported by a systematic review showing consistent associations between chronic hypertension and preterm delivery and low birthweight (Bramham *et al.* 2014).

The 'home environment' sub-section includes six factors: (1) inadequate child stimulation and activity; (2)

poor care practices; (3) inadequate sanitation and water supply; (4) food insecurity; (5) inappropriate intrahousehold food allocation; and (6) low caregiver education. There is only limited evidence linking inadequate child stimulation with poor child growth, and no studies investigating the topic in Ethiopia were identified. While multiple studies have shown that psychosocial stimulation can improve mental and motor development (Hamadani *et al.* 2006; Walker *et al.* 2007), no studies found an independent effect of psychosocial stimulation on growth. In Ethiopia's Oromia region, Gibson & Mace (2005) explored grandmothers assisting their daughters with difficult household chores, and found that maternal grandmother support was associated with taller children <16 years of age. The authors speculate that by reducing mothers' workloads, grandmothers enabled mothers to spend more time caring for their children, which resulted in improved nutritional status. Food storage and preparation practices have also been identified as a household-level 'care' practice that can influence child nutrition, yet no studies from Ethiopia were found examining this association. There are few data on care practices to prevent or treat a child illness, and the data predominantly focuses on the linkage between stunting and immunization. In a multi-country analysis (including Ethiopia), Mukuria *et al.* (2005) found no difference in the prevalence of stunting between vaccinated and non-vaccinated Ethiopian children 0–35 months of age. However, in other countries, a lower stunting prevalence was found in children vaccinated for measles.

Household water and sanitation indicators typically include the safety and distance of the drinking water source and the type of toilet used. Both have been repeatedly identified as risk factors for stunting and are often included in causal models separately or as composite indices. In Ethiopia, Medhin *et al.* (2010) and Outes & Porter (2013) showed a significant relationship between stunting and composite indices containing both drinking water source and type of toilet. Using data from Ethiopia's 2000 DHS, Silva (2005) found no associations between household water source and growth; only the water quality was significantly associated with underweight at the community level. Yimer (2000) and Woodruff *et al.* (2016) also failed to find an association between household water source and stunting. Haidar *et al.* (2005) observed a positive association between the distance from a household to its water source and the prevalence of stunting. It is unclear, however, if distance to a water source affects child nutrition because of diminished child care or use and consumption of unsafe water by children, or is merely a indicator for some other contributing indicator.

Household food insecurity can plausibly influence stunting via two pathways: (1) by contributing to poor *in utero* growth by affecting maternal dietary intake during pregnancy (Ivers & Cullen 2011); and (2) by limiting a child's dietary intake and diet quality (of breast milk and/or complementary foods) and thus restricting growth. Food security is frequently measured using the Household Food Insecurity Access Scale (HFIAS), household dietary diversity score (HDDS) and food consumption score (FCS). Using data from Ethiopia's Tigray and Southern Nations, Nationalities and Peoples' (SNNP) region, Ali *et al.* (2013) found that children from severely food insecure households (measured using HFIAS) were significantly more likely to be stunted; the authors found similar results in Bangladesh as part of the same study. In Ghana, Saaka & Osman (2013) compared all three aforementioned measures of food security with child nutritional status and found a significant association between the HDDS and FCS and stunting but no association between HFIAS and stunting, wasting or underweight.

The risk of undernutrition is unequally distributed among members of the same household in Ethiopia, and it is hypothesized that this is because of the sociocultural context in Ethiopia (Kaluski *et al.* 2002). For example, adolescent boys are sometimes provided with a greater proportion of the household food compared with adolescent girls in food insecure households (Hadley *et al.* 2008). However, a recent literature review did not find strong evidence for a disadvantage of girls in terms of food allocation based on energy intake vs. requirements (Berti 2012).

Low maternal education has been associated with higher levels of stunting in children 6–23 months of age in southern Ethiopia (Agedew & Chane 2015) and among children 0–59 months in an analysis of Ethiopia's DHS data from 2000 and 2005 (Alemayehu & Huang 2014). Our pooled analysis of Ethiopia's 2000, 2005, and 2011 DHS data did not find any

association between maternal education and HAZ in children 0–23 months of age, but maternal education was significantly associated with child growth in children 24–59 months, and improvements in maternal education since 2000 were associated with reductions in stunting for this age group (Woodruff *et al.* 2016). Results were mixed for parental literacy's influence on linear growth. While Fentaw *et al.* (2013) observed that the proportions of stunted, wasted and underweight children were higher in households with illiterate parents (either mother or father), no association between maternal literacy and child stunting was observed by Beyene (2012).

Inadequate complementary feeding

The framework divides complementary feeding into three sub-sections related to poor quality foods, inadequate feeding practices and food and water safety.

Inadequate nutrient intake during early childhood is recognized as a causal factor of growth failure, but evidence on specific nutrients other than zinc and protein is limited and mixed (Branca & Ferrari 2002). In Ethiopia's SNNP region, a study assessing nutrient intake from weighed food records for children 6–23 months of age found that while caloric intake was significantly lower in stunted children 6–8 months of age, no difference in caloric intake between stunted and non-stunted children in other age groups and no significant difference in micronutrient intake of stunted and non-stunted children were observed (Gibson *et al.* 2009). With respect to consumption of multi-micronutrient supplements, a meta-analysis from African and Asian studies has shown a relationship between micronutrient supplementation and growth (Ramakrishnan *et al.* 2004).

Using Ethiopia's 2005 DHS, Ali *et al.* (2013) and Jones *et al.* (2014) found associations between stunting and dietary diversity and minimum acceptable diet, respectively. A separate study using pooled data from Ethiopia's DHS in 2000, 2005 and 2011 identified only milk consumption as significantly associated with HAZ in children 6–23 and 24–59 months of age (Woodruff *et al.* 2016). Feeding frequency is correlated with energy intake from complementary foods in two cross-sectional studies in rural Ethiopia, where feeding fewer than three times a day was associated with increased risk for stunting (Umeta *et al.* 2003; Teshome *et al.* 2009).

A wide range of compounds, such as phytate, polyphenols, inhibitors of trypsin and chymotrypsin and lectins (Roos *et al.* 2013), haemaglutinins, goitrogens, saponins and oxalates (Melese 2013a) have been identified in the global nutrition literature as antinutrients. In Ethiopia, these antinutrients are present in complementary foods and regularly consumed by Ethiopian children (Melese 2013b). Unfortunately, no studies could be found examining the effect of consumption of these compounds on child growth in Ethiopia. We could also not identify data specific to Ethiopia that investigated energy content and thin consistency of complementary foods in association with stunting.

Regarding caloric and nutrient density of food (i.e. thin food consistency), no specific data from Ethiopia could be identified. As an indirect measure, Teshome *et al.* (2009) compared stunting prevalence among children fed by spoon, hand and bottle. Those fed by bottle were more likely to be stunted than those fed by hand or spoon, which could potentially be explained by the food density or infections from compromised hygiene in bottle feeding. No studies linking feeding insufficient quantities to stunting could be found in Ethiopia. Because of varying approaches to measuring responsive feeding, its impact on stunting remains inconclusive, although there are data suggesting better nutritional status where responsive feeding is practiced (Bentley *et al.* 2011).

While the framework associates stunting with 'poor micronutrient quality' in foods, it does not include child anaemia and micronutrient status. While anaemia and micronutrient status can be viewed as *co-outcomes* of stunting rather than causal factors at the same level as low food intake or poor quality foods, we explored the literature examining the association between anaemia and selected micronutrient deficiencies (i.e. iron, iodine, vitamin A, zinc) and child growth to determine if there is indeed a gap in the framework. In a small study ($n = 300$) in the Oromia Region, a significant association between anaemia and stunting was found but not between iron deficiency and stunting (Good 2009), a finding consistent with the results of studies carried out outside Ethiopia (Ramakrishnan *et al.*

2004; Siegel *et al.* 2006). To our knowledge there are no data on the association between iodine deficiency and growth faltering among Ethiopian children <5 years of age. While epidemiologic studies have shown a relationship between vitamin A status and child growth (Sempertegui 2001), no relationship between vitamin A and anthropometric status was observed in Ethiopia's 1990 national vitamin A deficiency survey (Wolde-Gebriel *et al.* 1991). This was confirmed in a meta-analysis of 14 vitamin A supplementation studies from developing countries that showed no improvements in linear or ponderal growth in children (Ramakrishnan *et al.* 2004). The prevalence of zinc deficiency in Ethiopia is unknown; however, there are studies of zinc's relationship to stunting. Umeta *et al.* (2000) showed a significant increase in growth in both stunted and non-stunted Ethiopian children 6–12 months of age receiving daily supplementation with 10 mg zinc.

In the context of complementary feeding, food and water safety relates most directly to exposure to mycotoxins, the most well-known example of which is aflatoxin, and handwashing. The exposure of children living in Africa to aflatoxin is known to be high and has been shown to limit growth in several studies (Gong *et al.* 2002; Gong *et al.* 2004; Khlangwiset *et al.* 2011; Shouman *et al.* 2012). In Ethiopia, mycotoxins have been found in multiple cereal grains (Ayalew *et al.* 2006) and high aflatoxin concentrations have been repeatedly found in groundnuts (Guchi 2015). However, no studies examining the association between mycotoxin consumption and linear growth in Ethiopia were found.

Breastfeeding

The breastfeeding section of the WHO Stunting Framework includes three well-defined indicators of inadequate breastfeeding practices: delayed initiation, non-exclusive breastfeeding and early cessation of breastfeeding.

In Ethiopia, 52 and 80% of the newborns are put to breast within the first hour and 1 day after birth, respectively (Central Statistical Agency [Ethiopia] & ICF International 2012). While no studies in Ethiopia have examined the association of delayed breastfeeding initiation with stunting (or HAZ), a small study from northern Ethiopia showed that children *not* given colostrum were twice as likely to be stunted as children who received it (Teshome *et al.* 2009). Evidence from Uganda indicates that delayed breastfeeding initiation may influence wasting but is not associated with stunting (Engebretsen *et al.* 2007). The associations between exclusive breastfeeding and growth are mixed in Ethiopia. In the SNNP region, Fikadu *et al.* (2014) found that children 24–59 months of age who were exclusively breastfed for the first 6 months of life were less likely to be stunted than non-exclusively breastfeed children. In contrast, Jones *et al.* (2014) observed a significantly lower HAZ in children exclusively breastfed from 0 to 6 months of age. In our analysis of pooled DHS data from 2000, 2005 and 2011 (Woodruff *et al.* 2016), exclusive breastfeeding was not associated with HAZ. Regarding early cessation of breastfeeding, WHO recommends that children be breastfed up to 2 years of age or beyond (World Health Organization *et al.* 2008). In Ethiopia, Teshome *et al.* (2009) observed increased prevalence of stunting when breastfeeding was continued past 12 months, but the consequences of early cessation of breastfeeding were not reported.

Infection

The infection section of the WHO Stunting Framework includes factors related to both clinical and sub-clinical infection, including enteric infections (e.g. diarrheal disease, environmental enteropathy, helminths), respiratory infections, malaria, reduced appetite from infection and inflammation.

Data describing diarrhoea's association with stunting in Ethiopia are scarce; we found only one study conducted in the Amhara Region, reporting that diarrhoea during the 2 weeks prior to the study was strongly associated with stunting in children less than 5 years of age (Teshome *et al.* 2009). Globally, evidence linking environmental enteropathy to growth is limited to a handful of studies (Campbell *et al.* 2003; Humphrey 2009; Lin *et al.* 2013), and we could find no studies from Ethiopia that measured environmental enteropathy biomarkers and explored their association with child growth. Intestinal helminth infections affect a large proportion (~52%) of Ethiopian school-aged children

(Abera *et al.* 2013), and a study investigating the intestinal parasitic burden in children <5 years of age in southern Ethiopia reported that <6% of children had a parasitic infection. Moreover, mothers identified loss of appetite as a key symptom of parasitic infections (Nyantekyi *et al.* 2010). A program evaluation of Ethiopia's Enhanced Outreach Strategy screening program, which includes the provision of antihelminthic drugs, has been shown to reduce stunting (Skau *et al.* 2009).

Acute respiratory infections (ARIs) are common among Ethiopian children; the 2011 DHS reported that 7% had ARI in the past 2 weeks (Central Statistical Agency [Ethiopia] & ICF International 2012). Although no data examining the association between ARI and stunting could be identified in Ethiopia, Okiro *et al.* (2008) found an association between moderate to severe stunting and lower respiratory tract infection in Kenya.

No correlation between malaria and stunting was reported from a study conducted in Oromia's Jimma Zone (Deribew *et al.* 2010); however, recent fever history has been associated with stunting in Uganda (Wamani *et al.* 2006) and Bangladesh (Jesmin *et al.* 2011). To our knowledge, no studies in Ethiopia have examined the link between markers of sub-clinical inflammation and stunting.

Community and societal factors

The WHO Stunting Framework labels community and social factors as 'contextual' and categorizes them into six groups: (1) political economy; (2) health and health care; (3) education; (4) society and culture; (5) agriculture and food systems; and (6) water, sanitation and environment. The current evidence for association between these factors and stunting is limited (Stewart *et al.* 2013), and many context factors (e.g. population density, per-capita national income, level of democracy (Pridmore & Hill 2009)) are calculated at the national level and are thus not applicable for analysis at the household or community level.

Of the 'political economy factors' identified in the WHO Stunting Framework, food prices have been explored in relation to stunting in Ethiopia. Christiansen and Alderman (2001) show mixed associations in a regional analysis of commodity prices and child stunting; 'higher teff, kerosene and charcoal prices are associated with shorter children… [and] …higher maize, sorghum, beef and milk prices on the other hand are associated with taller children'.

Of the community health and health care factors identified in the framework, access to health care is the only one associated with stunting in Ethiopia. In the Afar region, Fentaw *et al.* (2013) observed that stunted children lived about 2 km farther away from the nearest health clinic than non-stunted children. The same relationship was observed in South Africa with distance measured in time (Chopra 2003). Regarding quality of health care providers, a process evaluation of health extension services in Oromia in 2010 (Miller *et al.* 2014) reported that nearly all health extension workers were trained in treatment and management of pneumonia, diarrhoea, malaria and severe acute malnutrition, and 70% of health posts had all essential supplies to treat these conditions. This evaluation did not, however, measure the association between the delivery of these services and child growth. Factors related to education quality and infrastructure are not readily applicable to sub-national analyses related to child growth or stunting. UNESCO's Institute for Statistics (2009) compiled more than 40 education indicators, the vast majority of which are calculated at the national level.

Cultural beliefs, norms and social support networks are posited to contribute to poor feeding and dietary patterns. Women's status in particular is seen as a cultural factor that can influence child health, and it is frequently assessed using data on household decision-making relating to cooking, purchase of food and household items, ability to take short trips to market or relatives' homes, etc. In Ethiopia, women with high decision-making autonomy are less likely to have a low BMI themselves (Tebekaw 2011). In a multi-country review of DHS data, Smith (2003) assessed the association between child HAZ and two indices of women's status: relative decision-making power and societal gender equality. They found that while both indices have a positive effect on children's HAZ in South Asian countries, positive effects on children's HAZ in Sub-Saharan African countries (not including Ethiopia) are restricted to relative decision-making power only.

Regarding agriculture and food system factors, Stewart *et al.* (2013) cite the effects of programmatic interventions such as agricultural extension, biofortification and production of livestock. A recent analysis in Ethiopia shows that household ownership of cows in rural areas is associated with increased milk consumption and reduced prevalence of stunting (Hoddinott *et al.* 2014), but the effects are weaker in communities with good access to markets. In addition, Sadler *et al.* (2012) found that the provision of livestock support of pastoral communities in Ethiopia (Somali Region) prevented growth faltering in children <5 years old during the dry season.

Community-level water, sanitation and environmental factors have recently emerged in the literature as important predictors of nutritional status in children. In particular, the practice of open defecation in the community – measured as the percentage of households in each survey cluster reporting open defecation – has been identified as a potential cause of child stunting. In a multi-country (including Ethiopia) econometric analysis of DHS data, Spears (2013) concludes that the practice of open defecation significantly explains international variations in child height. In Ethiopia, two separate pooled analyses of DHS showed that reduced prevalence of open defecation is associated with a reduction in stunting (Headey 2014; Woodruff *et al.* 2016). In addition, a reduction of stunting was observed following the implementation of a water, sanitation and hygiene project in northern Ethiopia where handwashing was a key intervention (Fenn *et al.* 2012). Although independent associations between stunting and handwashing were not assessed in this Ethiopian study, a systematic review (Curtis & Cairncross 2003), multi-country reviews (Dangour *et al.* 2013) and a pooled analysis of several studies (Bhutta *et al.* 2008) show a decreased risk of diarrhoea following handwashing promotion interventions.

Discussion

Ethiopia findings

In reviewing available evidence, we find that the WHO Stunting Framework includes many factors found to be important determinants of stunting in Ethiopia. The strongest and most consistent associations with stunting were found with indicators of birth size, recent illness (e.g. diarrhoea, respiratory infection) and maternal height and education. Nonetheless, there are notable data gaps in Ethiopia, including data on the associations between stunting and infection, sanitation and hygiene and exposure to mycotoxins despite evidence of the existence of mycotoxin-contaminated groundnuts and cereal grains. There are also no data from Ethiopia showing that inadequate feeding during and after illness is associated with sub-optimal growth. Of the framework's community and societal factors, only commodity prices and community-level sanitation factors can be readily measured at the sub-national level in Ethiopia.

The majority of studies examining the determinants of stunting in Ethiopia used either national DHS data or data from regional- or district-level studies. DHS surveys in Ethiopia have been conducted every 5 years since 2000 and enable researchers to track stunting at the national and regional levels and to investigate stunting's association with various demographic factors. The DHS has notable limitations, however, as it does not contain data related to nutrient intake, food insecurity, micronutrient status, participation in nutrition/health programs and other factors. Because of Ethiopia's geographic and cultural diversity, regional- and district-level studies are essential as they enable the identification of factors associated with stunting in various locales.

The collection of both national and local data related to stunting is warranted and in line with the Ethiopian programmatic landscape. The Ethiopian government is addressing stunting and nutrition outcomes through national and large-scale programs (Wirth *et al.* 2016) that use standardized interventions. In addition, there are numerous district-focused projects in Ethiopia that are designed to match the needs of certain population groups.

Framework assessment

The WHO Stunting Framework includes both specific and general factors. Given the myriad factors that can cause sub-optimal growth, the use of general factors is indeed appropriate. Nonetheless, greater detail in some

areas of the framework would be useful for national and sub-national researchers and policy makers. Specifically, poor micronutrient quality could be described in more detail to identify which micronutrients are most important to support linear growth. Evidence from Ethiopia suggests that while there is an association between zinc status and growth, there is no association between iron and vitamin A status and growth. In addition, a more detailed description of complementary feeding factors such as 'low caloric and nutrient density', 'feeding insufficient quantities', and 'poor hygiene practices' would help researchers examine associations between specific indicators and child growth.

Water, sanitation and hygiene (WASH) factors and infection occur in nearly all sections of the framework. Recurrence of WASH factors illustrates the multiple pathways by which poor WASH conditions impair child growth; this is supported by strong evidence linking stunting and WASH at the maternal, household and community levels in Ethiopia. We find that only a small number of community and societal variables have been examined in non-ecologic studies related to stunting, yet these studies showed a moderate or strong association with stunting. As community and societal-level factors comprise a large portion of the framework, it is recommended that these indicator be explored further, particularly in non-ecologic studies.

In contrast, although factors such as 'poor nutrition during preconception, pregnancy and lactation' influence both *in utero* and postnatal growth, they are not further elaborated on in the framework. A notable feature is its acknowledgement that a specific factor can influence child growth at various times. Stewart *et al.* (2013) do not explicitly define poor care practices but rather cite Imdad *et al.* (2011) and Semba *et al.* (2008) as examples of how 'low caregiver education shows a strong and consistent relationship with poor child nutrition outcomes and likely drives other caring practices associated with stunted development and growth'. Semba's study uses child vitamin A supplementation, vaccination, household use of iodized salt, latrine use, family planning methods and visits to local health posts in the past year as proxies for parental caregiving practices. While family planning, visits to local health posts and vitamin A supplementation/immunization represent practices that are available to Ethiopian households and thus can be attributed to inadequate care, other practices identified by Semba (i.e. iodized salt use and latrine use), which are not accessible to all households, cannot be attributed only to inadequate care in Ethiopia.

The framework also does not specify which factors are associated with linear growth and which are associated with child development. To illustrate, the global evidence suggests that exclusive breastfeeding is more strongly associated with child development outcomes than linear growth. Optimal breastfeeding is consistently associated with reduced mortality, reduced morbidity (Black *et al.* 2008) and increased IQ (Brion *et al.* 2011; Horta *et al.* 2015). Optimal breastfeeding is not associated, however, with linear growth in Ethiopia (Marriott *et al.* 2012; Woodruff *et al.* 2016) and several other countries (Kramer & Kakuma 2012). The framework can thus be enhanced by clarifying which factors are associated most strongly with stunted growth, development or both. This clarification could greatly assist programme planners at the national level by clarifying the possible outcomes achievable by modifying specific factors.

Although not explicitly mentioned in the framework, a strong and consistent predictor of stunting in Ethiopia is the child's age when complementary food is introduced (Yimer 2000; Teshome *et al.* 2009; Mulugeta *et al.* 2010). A higher prevalence of stunting has been detected when children started complementary feeding after 6 months (Yimer 2000) or 12 months (Teshome *et al.* 2009) of age. Umeta and colleagues (Umeta *et al.* 2003) reported that children with a high meal frequency (i.e. >3 meals per day) were less likely to be stunted than their peers. Other measures of complementary feeding, such as dietary diversity and overall dietary acceptability, have also been investigated in Ethiopia's SNNP region, however, no differences between stunted and non-stunted children were observed (Tessema *et al.* 2013).

Missing indicators

Most notably, the framework does not include household characteristics that are often associated with child growth. While there is a sub-section dedicated to home environment, it does not include specific factors associated with stunting and poor birth outcomes in studies in

Ethiopia and elsewhere, such as low household socioeconomic status (Gibson *et al.* 2009; Assefa *et al.* 2012), dwelling quality (Mukuria *et al.* 2005; Gibson *et al.* 2009), exposure to indoor smoke because of low-quality cooking fuel (Mishra & Retherford 2007), number of children <5 years (Yimer 2000; Fentaw *et al.* 2013), dependency ratio (Fentaw *et al.* 2013), family size (Fentaw *et al.* 2013) and female sex of the household head (Haidar *et al.* 2005; Fentaw *et al.* 2013). It is plausible, however, that these household factors may affect stunting via the pathways already described in the framework. To illustrate, household socioeconomic status may highly correlate with a household's food security; and the number of children <5 years of age may correlate with short birth spacing. Nonetheless, given the multiple household-level factors that have shown significant associations with stunting, an expansion of the framework's 'home environment' factors may be considered.

The framework also does not contain physical violence against women during pregnancy, which was associated with higher risks of having a low birthweight child (Assefa *et al.* 2012) in the Oromia region. While physical violence against women could be classified under the framework's 'women's status' in the community and societal factors, additional studies are needed to better understand if domestic violence during pregnancy ultimately results in sub-optimal child growth or stunting.

Conclusion

Despite reductions in the prevalence of stunting globally, stunting remains a serious public health concern in Sub-Saharan Africa where the number of stunted children is rising. The WHO Stunting Framework provides the first internationally-endorsed causative model that focuses specifically on stunting and identifies many factors associated with child growth. The WHO Stunting Framework builds upon the long-standing UNICEF framework for malnutrition (UNICEF 1990), which presents the causes of malnutrition for women and children in general and does not focus specifically on stunting in children.

In applying the WHO framework to available evidence in Ethiopia, we found that stunting was most consistently associated with indicators of birth size, recent illness and maternal height and education. Although few of the contextual factors can be easily measured for sub-national analyses, commodity prices and community-level sanitation show some associations with child growth. Clear data gaps in Ethiopia's stunting literature are sub-clinical inflammation, exposure to mycotoxins and inadequate feeding during and after illness.

This case study illustrates that by applying the framework to national data, researchers can identify the most consistent risk factors for stunting and pinpoint national data gaps. In Ethiopia, more rigorous, experimental research studies are needed to further elucidate the determinants of stunting and to assess the relative contribution of these various factors that operate synergistically to affect child growth.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

JPW, FR, NP and BW drafted the first version of the manuscript, and all authors thoroughly reviewed to subsequent versions, including the finally submitted.

Disclaimer

AWO and MdO are staff members of the World Health Organization; AB and JM are staff members of UNICEF. The authors alone are responsible for the views expressed in this publication, and they do not

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