Seasonal variations in household food insecurity and dietary diversity and their association with maternal and child nutritional status in rural Ethiopia

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Abstract

Food availability and access are strongly affected by seasonality in rural households in Ethiopia. However, relationships between household food insecurity indicators and dietary diversity and nutritional status of reproductive age mothers and their young children are unclear. A longitudinal study was conducted among 800 farming households in lowland and midland agro-ecological zones of rural Ethiopia in pre and post-harvest seasons. A structured interview, which included measures of three food access indicators − household food insecurity access scale (HFIAS), household dietary diversity score (HDDS) and household food consumption score (HFCS) − was conducted. Additionally, a subset of 183 households was selected for assessment of indicators of nutritional status including maternal and child dietary diversity and anthropometric measurements for children 6-23 months of age. Magnitudes of household food insecurity indices were high by international standards, particularly during the lean season (pre-harvest). Using correlation, Chi square and multivariable regression models, HFCS in both seasons was related to maternal body mass index and haemoglobin, and weight-for-length of their children. HDDS was associated in the post-harvest season with haemoglobin level of the mothers, and weight-for-length of their children. HFCS was a better predictor of nutritional status of mothers and children in both the food surplus and lean seasons, while HDDS was a better predictor of maternal and child nutritional status post-harvest. It is recommended that nutritional interventions should therefore focus on household food insecurity as well as targeting the individual nutritional status of mothers and children.

Keywords HFIAS · HFCS · Malnutrition · Seasonality · Maternal and children · Ethiopia

1. Introduction

Undernutrition is most prevalent among vulnerable women and children in situations of food shortage (United Nations 2008). Undernutrition and micronutrient deficiency in reproductive age women increase the risk of maternal morbidity and mortality, and the nutritional status of a woman before and during pregnancy is important for a healthy pregnancy outcome (Kramer 1987).

During food shortages, households may have insufficient access to a nutritionally adequate and safe supply of food, leading to reduced dietary variety and nutrient intake, and undernutrition of household members (FAO 1996). A focus on seasonally-specific household food insecurity indices can add to our understanding of the relationship between poverty and nutritional status beyond what is discerned through socioeconomic variables such as household income and employment status (Passarelli et al. 2017; Manlosa et al. 2019). In addition, food insecurity indices may be a more sensitive measure of the food-related experiences of low-income families, including the psychological and social consequences of lack of food, than is household income alone.

Food security status is measured by a number of well-established indices. The Household Food Insecurity Access Scale (HFIAS) measures access to food and provides information on coping strategies in times of food shortage (Swindale and Bilinsky 2006). The Household Dietary Diversity Score (HDDS) and Household Food Consumption Score (HFCS) indicate the variety of food actually consumed over a specific period. HDDS reflects the ability of a household to access a variety of foods while individual dietary diversity scores − namely, IDDS and WDDS − are a measure of the likelihood of nutrient adequacy for individual household members (Swindale and Bilinsky 2006; Kennedy et al. 2011; Ruel et al. 2004; Mekonnen and Gerber 2017). Studies in different age groups have shown that an increase in individual dietary diversity score is related to increased nutrient adequacy of the diet (Swindale and Bilinsky 2006; Kennedy et al. 2011; Biederlack and Rivers 2009; Arimond and Ruel 2004; Hartikainen et al. 2005). Poor rural households often use income to purchase non-staple foods, thus increasing household dietary diversity (Tetens et al. 2003; Ruel et al. 2004; Yigrem et al. 2014).

A number of studies have revealed that food insecurity is more likely to occur in low-income families and in households with children (Ruel 2002; Nord et al. 2005; Furness et al. 2004). Studies conducted in Ethiopia, using a variety of measures, found that up to 82.3% of households experience seasonal food insecurity (Regassa and Stoecker 2012; Hadley et al. 2008). Rural populations in developing countries typically face a seasonal food shortage for the period between the depletion of cereal stocks and the next harvest, particularly in areas where people depend on the annual harvest of the staple crop following a single rainy season (Das et al. 2018). Studies have shown that seasonality has an effect on dietary patterns, and on both energy and nutrient intakes (Arsenault et al. 2014; Becquey et al. 2011; Bates et al 1994; Tetens et al. 2003; Adams 1995; Hassan et al. 1985).

Ethiopia exhibits four major forms of undernutrition: acute and chronic undernutrition, vitamin A deficiency (VAD), iron deficiency anaemia (IDA), and iodine deficiency disorder (IDD) (FMOH 2011). In Ethiopia, it is established that food availability and access are strongly affected by seasonality; many rural households are only able to produce enough food to meet their needs for six months of the year or less, and consequently face severe food scarcities during the lean (pre-harvest) season (Hirvonen et al. 2016; HEA 2007). A study by HEA (2007) has documented seasonal fluctuations in household diets in terms of both the quantity of calories consumed and the number of different food groups consumed (i.e., food quality). Similarly, various studies have identified seasonal variation in malnutrition among children and mothers in Ethiopia (Abay and Hirvonen 2017; Roba et al. 2015; Egata et al. 2013). We have previously reported that maternal parity (number of births), dietary diversity, education and agro-ecological zones are associated with maternal anaemia while maternal parity and agro-ecological zones are associated with maternal wasting (Roba et al. 2015). In addition, we found that infant dietary diversity is associated with maternal dietary diversity in this context (Roba et al. 2016a).

In recent years, nutritional studies in developing countries have shifted away from measuring only quantitative dietary parameters, particularly calories, to assessing the quality of diets using parameters such as dietary diversity scores. Research indicates that low diversity in diets is associated with increased risk of chronic undernutrition among children (Arimond and Ruel 2004; Mallard et al. 2014). HDDS and HFCS are proxy indicators of diet quality (Ruel 2002; Torheim et al. 2004; Working Group on Infant and Young Child Feeding Indicators 2006). It is known that as people diversify their diets from plant-based staple foods they increase their intake of essential micronutrients such as calcium, vitamin A, iron and zinc. To the best of our knowledge, there are few studies that have assessed the association between HFIAS, HDDS and HFCS and maternal and child nutritional status, and there is no study that assesses seasonal variations in these parameters in Ethiopia. Accordingly, this paper aims to assess the relationship between different indicators of household and individual food security status and measures of maternal and child nutritional status in pre and post-harvest seasons across two different agro-ecological zones in Ethiopia.

2. Methods and materials

This study was conducted in two areas in Ethiopia: Eastern Oromia (Babile District), and South-Central Tigray (Enderta and Hintalo Wajirat Districts). Data were collected in two seasons: post-harvest (January to February 2014) and pre-harvest, or lean season (July to August 2014). In Ethiopia, the rainy season runs from June to August, with the rest of the year being largely dry. Babile District is 560 km from Addis Ababa in the eastern part of Ethiopia and represents lowland agro-ecological conditions; data collection was concentrated in the area 1000-1500 meters above sea level. The staple food crops are sorghum and oil seeds, while groundnut and Chat (*Catha edulis,* a mild stimulant) are produced as cash crops. In Tigray region, Hintalo Wajirat and Enderta Districts (683 km and 773 km, respectively, from Addis Ababa) represent midland agro-ecological conditions; data were collected from elevations of greater than 2000 meters above sea level. Here, households are mainly engaged in mixed farming; the staple crops are teff and barley, while most households are also involved in animal husbandry (Roba et al. 2015).

The post-harvest season particularly from November to March is a food surplus season, usually marked by an increased household food basket. Households typically consume more preferred foods at this time and, through sales of farm produce, enjoy improved incomes. This is also a period of celebrations such as bridal ceremonies and visits to family and friends, with many associated feasts. In contrast, the pre-harvest rainy period (July to August) is a time of food shortages, when most households adopt coping strategies such as reducing the frequency and quantity of meals, borrowing food from relatives or better-off neighbours, shifting food allocations to children and restricting adults, and relying on less preferred foods (Sewnet 2015; Guja 2012; Tefera and Tefera 2014). Those with cash or other assets may supplement household stocks with food purchases, while others may look to public welfare programmes such as the Productive Safety Nets Programme to meet their food needs at this time (Berhane et al, 2014; Gilligan et al, 2009).

The main household study was conducted among 400 households from each of the two agro-ecological zones. Further interviews, anthropometric measurements and serum blood tests for selected indicators of micronutrient status were conducted with a sub-sample of one-fourth of the households from both agro-ecological zones. A few households were not available for the second round survey in the lean season (July to August 2014). Therefore, 183 households containing mothers with children 6-23 months of age were surveyed in both seasons for both nutritional and agricultural/socio-economic data. Sample households were selected randomly from a list available in each *kebele* (the lowest administrative unit in Ethiopia), which was also used to verify maternal and child ages. The number of mother/child pairs selected in each kebele was proportional to population size in the kebele. Interviews were conducted with the biological mother of each child to generate nutritional data, while the general household survey conducted interviews with both the mothers and head of the household/husbands, if applicable.

2.1 Socio-economic and demographic data

Data were collected in both seasons for a wide range of demographic and agriculture-related parameters, including family size, age and educational status of the household head, farm and off-farm activities, land size, involvement in markets, and a range of health and sanitation issues.

2.2 Dietary data

A range of dietary data were collected and computed in a standardized way for all households, using tools developed by Food and Nutrition Technical Assistance (FANTA) and UN agencies (FAO 2010; WHO et al. 2010; Coates et al. 2007). Household Dietary Diversity Score (HDDS) was calculated using a 12 food-group classification (FAO 2010). The recall period used was seven days for HDDS, and one month for both HFIAS and HFCS, based on established guidelines from different agencies (FAO 2010; WHO et al. 2010; Coates et al. 2007). HFCS and HDDS were based on the frequency of foods consumed on weekdays and on weekends, since weekends do not have any special significance with respect to dietary intake in the context of this study. We took care to not include atypical days or months (local feasts or celebrations) in the recall.

The Food Consumption Score (HFCS) is a composite score based on household dietary diversity, food frequency, and the relative nutritional importance of different foods. Data on consumption of each food group were collected for a 30-day recall period; these food groups were weighted based on their nutritional values as proposed by the World Food Program (WFP) and the Food and Agriculture Organization (FAO). HFCS was calculated by multiplying the weighting for each food group by the frequency (number of days) these food groups were consumed; finally, the values for all food groups consumed during the 30 days were summed (Wiesmann et al. 2009; McKinney 2009).

The Household Food Insecurity Access Scale (HFIAS) is derived from nine questions that have been used in several countries and it is reported to effectively distinguish food-secure from food-insecure households across different cultural contexts (Coates et al. 2007). The nine occurrence questions are followed by frequency questions from which four levels of food insecurity are computed based on the formula provided with HFIAS version 3 (Coates et al. 2007). Finally, the HFIAS is used to assign households along a continuum from no hunger to hunger. This method of analysis has been used by Regassa and Stoecker (2012) in a study in southern Ethiopia. A higher HFIAS score indicates higher levels of food insecurity, whereas higher HDDS and HFCS scores indicate lower levels of food insecurity. Data on individual dietary diversity scores were collected using 24-hour recall from mothers. The methods used for maternal and infant dietary diversity data collection and analyses have been published elsewhere (Roba et al. 2015; Roba et al. 2016a).

Maxwell et al. (2014) discuss the different dimensions of food security captured by the various measures used. Although they find quite high correlations between different food security measures when treated as continuous variables, the situation changes when the measures are used in categorical form: for example, for the same households in their sample in the Tigray Region of Ethiopia, Maxwell et al. (2014) found that HFIAS provided higher estimates of food insecurity than other measures, including HFCS. This analysis indicates the importance of careful interpretation of findings with respect to each food security indicator.

2.3 Anthropometric data and blood collection

The anthropometric measurements for mothers and children were performed using the standardized procedures recommended by World Health Organisation (2009). A sample of three to five millilitres of venous blood from the antecubital vein was taken from each study subject. The samples were taken in the morning (from 8:00 a.m. to 10:00 a.m.) (IZiNCG 2004); these were aliquoted into tubes without anticoagulants by a trained health professional, and samples were clotted and centrifuged to separate serum. The serum was stored frozen at -20^{O}C and transported by plane to the Ethiopian Public Health Institution (EPHI) in Addis Ababa. Details on the methods of data collection and analysis of selected micronutrients have been published elsewhere (Roba et al. 2015; Roba et al. 2016a; Roba et al. 2016b).

2.4 Data collectors and quality control

Experienced data collectors were recruited and trained on the data collection procedures, the context of specific questions and the anthropometric measurement procedures. The questionnaire was prepared first in English and then translated to Tigrigna and Afan Oromo, the local languages of the two agro-ecological zones. The process of data collection was overseen by supervisors and the principal investigators (the present authors). A pre-test survey was conducted on 5% of the total sample size in another rural area with similar characteristics. Problems identified during the pre-test survey were corrected before the start of the actual survey. The principal investigators were responsible for co-ordination and supervision of the overall data collection process.

2.5 Data processing and analysis

The data were double entered by separate data clerks into EPI Data version 3.1. Data cleaning and editing were undertaken before being transferred to SPSS (v 16.0) and Stata (v 11). Frequency, mean and standard deviation were computed for the variables of interest, while normality, homoscedasticity and linearity were checked graphically using different plots (P-P and/or Q-Q-plot). The Anthro 2005 and ENA software of the WHO were used for calculating Length-for-Age Z score (LAZ), Weight-for-Age Z score (WAZ) and Weight-for-Length Z score (WLZ), and cut-off points of negative two (-2) standard deviations were used to define undernutrition. Dietary diversity was categorized as inadequate for an infant if they ate less than four food groups in the reference period, and inadequate for a woman if she ate less than five food groups. Household dietary diversity was classified as 'low' if members consumed three food groups or less over the reference period; 'medium' for 4-5 food groups; and 'good' for greater than five food groups. Household Food Consumption Score (HFCS) was categorized as poor for scores less than 21, borderline for scores between 21 and 34, and good for scores of 35 and above. Paired t-tests were used to determine if significant differences existed between post- and pre-harvest seasons in household dietary diversity, food consumption score, food insecurity access scale, and nutritional status of mothers and their children. Independent t-tests were used to compare mean differences between agro-ecological zones, nutritional status of mothers and children, and HDDS, HFCS and HFIAS, in both seasons. Poisson regression was used to estimate associations of the indicators with women's and infant's dietary diversity (measured as a count variable). Probit regression was applied to isolate associations between HDDS, HFCS and HFIAS with maternal and child dietary diversity (measured by whether or not individuals attained a minimum threshold of dietary diversity) and nutritional status, while controlling for socio-economic status of the household.

3. Results

3.1 Descriptive results

Out of 800 samples collected for the general household survey, venous blood for nutritional analysis was collected from 200 reproductive age mothers and their children aged between six and 23 months during the post-harvest season, and 183 of these were repeated in the following pre-harvest season. Seventeen households were lost in the second round (in the lean season) due to migration, absence from home (after repeat visits) or divorce. The mean and standard deviations for the key anthropometric indicators were -1.72 (1.47) for LAZ, -1.3 (1.3) for WAZ, and -0.56 (1.39) for WLZ in the post-harvest season; these changed to -2.02 (1.47) for LAZ, -1.22 (1.5) for WAZ and 0.8 (2.76) for WLZ, in the pre-harvest season. The main differences between post- and pre-harvest season were thus a significant decrease for LAZ ($P=0.009$) and increase for WLZ ($P<0.001$). The mean infant dietary diversity score decreased from 2.67 post-harvest to 2.59 in the pre-harvest season. The means for maternal haemoglobin and BMI decreased significantly in the pre-harvest season compared to post-harvest (Table 1).

Mean values for Household Dietary Diversity Score (HDDS), Infant Dietary Diversity Score (IDDS) and Women's Dietary Diversity Score (WDDS) decreased in the pre-harvest season compared to post harvest, but the change was significant only for HDDS ($P<0.042$). HFIAS increased from a mean of 3.7 in post-harvest to 6.6 in pre-harvest, indicating worsening household food security, which was statistically significant

(<0.001). The incidence of women's minimum dietary diversity (≥ 5 food groups), maternal anaemia and maternal wasting (low level of BMI) increased in the pre-harvest season compared to the post-harvest season, as did child stunting (Table 1). The increase in women's minimum dietary diversity pre-harvest reflects an increase in the Eastern Oromia study site only, which may be due to increased cash income from sales of chat; this increase in minimum dietary diversity did not, however, result in improvements in women's nutritional status.

3.2 Prevalence of undernutrition and household food insecurity

As expected, the results generally indicated a higher rate of food insecurity in the lean (pre-harvest) season compared to the food surplus (post-harvest) season. Food insecurity as measured by HFIAS showed the highest change between the seasons (an increase from 54.1% of households in the post-harvest to 86.2% in pre-harvest season), while food insecurity measured by HFCS increased from 60.1% post-harvest to 64.9% in the pre-harvest season (Table 1). Counter to expectations, the proportion of women who did not attain minimum dietary diversity decreased from 94% in the post-harvest season to 82.7% in the pre-harvest season, whereas the proportion of infants who did not attain minimum dietary diversity increased marginally, from 77.6 to 80.3% (Table 1).

Amongst children, the proportion of stunting increased from 39.3% post-harvest to 48.1% in the pre-harvest season; underweight increased from 27.3% to 31.0%; while acute malnutrition (wasting) decreased marginally from 14.2% in the post-harvest to 13.1% in the pre-harvest season. Maternal wasting increased from 45.4% in the post-harvest season to 51.5% in the pre-harvest season, while maternal anaemia increased from 21.5 to 34.1%, suggesting a strong impact of food shortages in the lean season on women's nutritional status (Table 1).

INSERT TABLE 1 HERE

This study found no statistically significant correlation between HDDS and parameters used to assess nutritional status of children in either season. HFCS, however, was positively correlated with Weight-for-Age Z score (WAZ) and Weight-for-Length Z score (WLZ) in the pre-harvest season. HFIAS was negatively correlated with Weight-for-Length Z score (WLZ) (Pearson correlation, -0.32, p=0.028) in the post-harvest season (Table 2): this is consistent with the HFCS correlation, since a higher HFIAS indicates an inferior food security condition.

Interestingly, maternal haemoglobin was positively correlated with HDDS in both seasons, but more strongly in pre-harvest, indicating the importance of household dietary diversity in reducing anaemia amongst women across seasons. Maternal BMI and haemoglobin were positively and significantly (P<0.05) correlated with HFCS in the postharvest season, when food is generally more available. Maternal BMI was negatively correlated with HFIAS in the postharvest season which again is consistent with the other indicators.

INSERT TABLE 2 HERE

3.4 Relation between household food security indicators (HDDS, HFCS, HFIAS) and nutritional status of mothers in post and pre-harvest season

Regression analyses in Tables 3 and 4 examined the associations between the food security indicators of the households and the nutritional status of mothers and children, controlling for other household characteristics. Models were estimated using Poisson regression for associations with women's and infant's dietary diversity where dietary diversity was measured as a count variable (number of food groups), and using probit models where the outcome variable is minimum dietary diversity. Other models were estimated using ordinary least squares (OLS). All regression estimates are marginal effects.

Significant associations were found between maternal dietary diversity and all three household-level food security indicators in both seasons, and the association was stronger in the pre-harvest (lean) season. This suggests that greater access to food at the household level (including through purchases) contributes to improved dietary quality of women, most particularly during the lean season when food is generally scarce. Other studies of food security in Ethiopia (Regassa and Stoeker 2012; Kahsay 2017) found that education of mothers is significantly associated with household food security indicators: Kahsay (2017) found a stronger association in the pre-harvest season. This suggests that women's education and knowledge are important factors influencing household food security.

Maternal haemoglobin was also significantly associated with HDDS and HFCS in both seasons, indicating that improved household dietary diversity had a positive effect on the iron status of women. Maternal BMI was positively associated with HFCS only (in both seasons), albeit at a relatively low magnitude, confirming that quantity (frequency) of food intake is important as well as diversity.

INSERT TABLE 3 HERE

3.5. Relation between household food security indicators (HDDS, HFCS, HFIAS) and nutritional status of children 6-23 months of age in post and pre-harvest season

This study identified different associations by season between the measures of infant dietary diversity (IDDS and attaining minimum dietary diversity) and household food security indicators. Significant positive associations were found with HDDS in both seasons, but strongest in the pre-harvest, and with HFCS in the pre-harvest season only; a negative association was found with HFIAS in the post-harvest season only (Table 4). Household dietary diversity thus appeared to be a good indicator of infant dietary diversity across both seasons. The differing seasonal pattern of association with HFCS and HFIAS may be indicative of the greater capacity of better-off households to maintain infant dietary quality compared to highly food-insecure households who struggle to maintain minimum infant dietary diversity at all times of year. However, it is difficult to draw definitive conclusions, particularly given the low R^2 values of the models.

Regarding the association between HDDS and nutritional status among children 6–23 months of age, regression results showed that HDDS was strongly ($P<0.05$) associated with children's Length-for-Age Z score (LAZ), stunting, and Weight-for-Length Z score (WLZ) in the post-harvest season only. This may be indicative of the greater availability of a more diverse range of food groups post-harvest which positively influences infants' nutritional status. WLZ is positively associated with HFCS in both seasons (albeit stronger in post-harvest) and marginally negatively associated with HFIAS in the pre-harvest season only (Table 4). HFCS is an indicator of quantity/frequency as well as diversity, suggesting that both are important for the nutritional status of infants. The negative association of WLZ with HFIAS, in the absence of any association between HFIAS and infant dietary diversity, may reflect absolute food shortages at household level in the pre-harvest (lean) season which directly affect the nutrition of infants. The low R^2 value of this model made it difficult to draw definitive conclusions in relation to this association.

INSERT TABLE 4 HERE

4. Discussion

Effective food security measurement is based on a combination of different indicators that address temporal, spatial and demographic parameters, and a variety of specific conditions, experiences and behaviours of the populations (Bickel et al. 2000). The purpose of this study was to investigate the associations between different measures of household food insecurity and the food security and nutritional status of mothers and their children, taking into account seasonal variation. The study used three household-level food insecurity indicators: Household Food Insecurity Access Scale (HFIAS), Household Food Consumption Score (HFCS) and Household Dietary Diversity Score (HDDS). These indicators have been developed and promoted as proxy measures of food access (Swindale and Bilinsky 2006; Webb et al. 2006; Maxwell et al 2014) and are used to measure the link between indicators of food insecurity and indicators of malnutrition (Gittelsohn et al. 1998; Saaka and Osman 2013).

Food security in the study areas is affected by the season and particularly by the adequacy of rainfall during the cropping season, as most of the crops grown are rain fed (Hirvonen et al. 2016; HEA 2007). During this survey year (2014), production conditions were good with a normal harvest season, and no households were affected by drought that year or in the previous year. In other publications, we reported seasonal variations in prevalence of anaemia and undernutrition among mothers, which were higher during the lean season, and this was more pronounced in the midland zone than in the lowlands (see Roba et al. 2015). There was also a high rate of selected micronutrient deficiencies among mothers (measured in the post-harvest season only), again with higher magnitude of deficiencies in the lowland agro-ecological zone (Roba et al. 2016b). We also reported poor Infant and Young Child Feeding (IYCF) practices and nutritional status, with seasonal and agro-ecological variations (Roba et al. 2016a; Roba et al. 2016c). These findings prompted us to analyse associations in both post-harvest and pre-harvest seasons between nutritional status of mothers and their children and household food security as measured by HDDS, HFIAS and HFCS.

4.1 Prevalence of food insecurity

Results for all three indicators of food insecurity (HDDS, HFCS and HFIAS) suggest that there are significant levels of food insecurity across the study population in both seasons, but with greater severity in the pre-harvest season. This is in line with our expectation and consistent with previous studies (Hirvonen et al. 2016; HEA

2007). Among the food insecurity measures used, the magnitude of change was highest for HFIAS. This may be because HFIAS includes the psychosocial aspects of food accessibility which can be magnified in conditions of food shortage. Maxwell et al. (2014) noted that HFIAS gave the highest estimates of prevalence of food insecurity amongst the six indicators they measured and compared for Tigray Region.

The proportion of households affected by food insecurity, as measured by HFIAS, in this study was lower in the post-harvest season and higher in the pre-harvest season when compared to the results reported by Regassa and Stoecker (2012) in southern Ethiopia (82.3%) and by Kidane et al. (2005) in south east Oromia (79.3%). HFIAS in this study was also higher than reported by Vaitla et al. (2012) in Tigray in both seasons. The prevalence of households with poor food consumption scores (HFCS) also increased in the pre-harvest season, but not as much as indicated by Vaitla et al. (2012). Overall the indicators suggest pervasive food insecurity across Ethiopia, with a strong seasonal dimension and some local variation (Bogale and Shimelis 2009; Ali et al. 2013).

4.2 Food insecurity and maternal diet and nutrition

Our study found significant associations between both HDDS and HFCS and maternal dietary diversity in both seasons, indicating that as household dietary diversity increases, the dietary diversity of mothers also improves. This suggests that the dietary status of mothers is closely tied to that of their household and, from a methodological perspective, that household dietary diversity may be an important indicator for maternal nutrition; this is further supported by the positive association found between HDDS and HFCS and maternal haemoglobin levels in both seasons. A previous study has also found HDDS to be an important indicator of the micronutrient status of women (Arimond et al. 2010).

Maternal body mass index (BMI) was positively associated with HFCS in both seasons, but was not associated with either HFIAS or HDDS. This indicates the effect on women's BMI of food quantity consumed/frequency of consumption as well as diversity of food groups consumed. The association between maternal BMI and HFCS was reported in previous studies (Saaka and Osman 2013; Savy et al. 2006). A previous study from Nepal (Bhattacharya et al. 2004) found a significant association between low BMI and HFIAS, but no significant association was found in this present study.

4.3 Food insecurity and children's diet and nutrition

A key finding of this study was that Weight-for-Length Z score (WLZ) of children had a statistically significant association with HFCS in both seasons. This may indicate that wasting (WLZ) responds relatively rapidly to undernutrition when compared to stunting (chronic malnutrition). Our data also indicate that WLZ has a significant association with HDDS in the post-harvest season. The association between wasting and HDDS was reported among pre-school children in other studies (Ruel 2002). Tiwari et al. (2013) also reported that HFCS and HDDS had better correlation with the nutritional status of children than HFIAS.

In our study we found a statistical association between stunting (LAZ) and HDDS in the post-harvest season but not in the pre-harvest season, and found no significant association with the other food security indicators. This may reflect the fact that availability of/access to a wider range of food groups has some influence on stunting rates but that, in resource-poor settings, children after six months of age tend to show a marked decline in nutritional status due to changes in diet and morbidity and this deterioration is partially due to other non-food related influences (Saaka and Osman 2013).

Research on the association between HFIAS and nutritional status of children has produced mixed findings; an association between household food insecurity and childhood LAZ has been reported by some previous studies (see Psaki et al. 2012; Gooding et al. 2012; Hackett et al. 2009), but others could not establish any significant relationship (Bhattacharya et al. 2004; Kaiser et al. 2002; Alaimo et al. 2001). In our study, HFIAS was not associated with stunting in either season. This could be because households faced with severe food insecurity may shift their available food resources to children, or because chronic malnutrition (stunting) is a long-term rather than short-term phenomenon and may not, therefore, be influenced by seasonal variations in food availability. The findings may also be influenced by recall bias, as reported in another study (Saaka and Osman 2013).

Possible limitations of this study were its relatively small sample size, which may affect statistical power, and because data were collected from two different agro-ecological zones, each with its own farming system.

5. Conclusion

In this paper we analysed the association between household food insecurity indicators and the nutritional status of mothers and their children aged 6-23 months. In order to overcome the limitations of single measures, a combination of different indicators was used that indicate temporal, spatial and demographic dimensions of food security. A strength of this study is that it surveyed households in both food surplus and lean seasons, across two agro-ecological zones in Ethiopia, enabling the determination of variability in HDDS, HFCS and HFIAS between seasons. Nutritional status was measured by both anthropometry and assessment of selected biomarkers. Significant levels of undernutrition and food insecurity were found across the study population during both seasons according to all three indicators of food insecurity (HDDS, HFCS and HFIAS), with worse conditions in the pre-harvest season in most cases.

HFCS appears to be a particularly consistent predictor of women's food security and nutritional status across both seasons. This is not surprising but does emphasise the importance of quantity/frequency of food intake as well as dietary diversity. HDDS appears to be a more consistent predictor of infant food security and nutritional status, especially in the post-harvest season.

Children's WLZ was associated with HFCS in both seasons, suggesting that HFCS may be a useful tool in measuring acute undernutrition in infants as well as mothers. An improvement in HFCS has a positive influence on the nutritional status of children 6-23 months, and we therefore recommend that both agricultural and health professionals focus on improving the components of HFCS. This implies a greater focus on increasing availability of, and access to, a wider range and greater quantity of nutritionally-important foods, allied to information dissemination and other measures, as a means to address infant undernutrition. Children's WLZ and LAZ were found to be associated with HDDS in the post-harvest season. Although agricultural production was not directly addressed in this study, these findings lend some support to the conclusions of Kumar et al. (2015) for Zambia where they suggest that diversity of agricultural production can have a positive influence on dietary diversity of young children. Similar findings were reported from previous international studies, such as Darapheak et al. (2013), for Cambodia, and Saaka and Osman (2013).

HFIAS was generally found to have some association with measures of women's and infants' dietary diversity, but not with measures of their nutritional status. This is not very surprising given the behavioural and psychological foundations of the HFIAS measure, but it does highlight the differing interpretations and coverage of these indicators and underscores the importance of choosing measures appropriate to the specific phenomena being investigated. More broadly the fact that different household food security indicators have different associations with the nutritional status of mothers and children over the post-harvest and pre-harvest seasons suggests the importance of using multiple indicators and measurements.

It is also reasonable to conclude from the analysis that nutritional interventions should focus on addressing household food insecurity as well as targeting the individual nutritional status of children and mothers. This amounts to a recognition of the need to promote nutrition-sensitive interventions in agriculture, as well as nutrition-specific interventions which might be more directly targeted.

There is a need to conduct further studies to gain a greater understanding of the relationships between household food security and the nutritional status of women and their children. This study (in line with Maxwell et al. 2014) has emphasised the need to measure food security using different indicators, and has also introduced the issues of seasonality and measurement of women's nutritional status using biomarkers. However, the study findings are somewhat constrained by relatively small sample sizes (dictated by resource constraints in data collection), and it is also recognised that the models described here only explain a relatively small percentage of the variation in the data. Despite these limitations the study should provide a basis and direction for further in-depth studies to explore the complex relationships between food security, nutrition and seasonality in resource-poor settings such as those found in Ethiopia.

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Ethical consideration and informed consent

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were registered and approved by University College Cork, Ireland and Haramaya University College of Health and Medical Sciences Institution, Ethiopia, Research Ethics Review Committees. Subsequently, the final registration and approval of the protocol was granted by the Ethiopian National Ministry of Science and Technology Ethical Review Committee with registration no of 310/592/06 dated 08/05/06 Ethiopian calendar. Informed consent was obtained from the mothers, and verbal informed consent was obtained from the caregivers of the children; they were informed that they have the right to refuse or exit from the study at any time and refusing to participate in the study would not have any negative implications for them. Verbal consent was witnessed and formally recorded. Children and women who were found to be undernourished during assessment were referred to the nearest health institution for health care services.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Table 1 Descriptive statistics and paired t test between pre- and post-harvest season

	Postharvest	Pre-harvest	Paired t-test	
	Mean(SD)	Mean(SD)	Mean difference(SE)[a]	P-value
HDDS	6.1(1.63)	5.8(1.6)	0.25(0.12)	0.042**
Food insecure (HDDS) (%)	16.4	17.8	-	-
HFIAS	3.7(4.0)	6.6(6.0)	-2.9(0.5)	<0.001***
Food insecure (HFIAS) (%)	54.1	86.2	-	-
HFCS	31.7(9.9)	33.1(14,4)	-1.32(1.0)	0.22
Food insecure (HFCS) (%)	60.1	64.9	-	-
IDDS	2.67(1.32)	2.59(1.33)	0.07(0.14)	0.60
Poor IDDS (%)	77.6	80.3	-	-
WDDS	3.04(0.85)	2.87(1.7)	0.17(0.14)	0.25
Poor WDDS (%)	94.0	82.7	-	-
LAZ	-1.72(1.47)	-2.02(1.47)	0.3(0.009)	0.009**
Stunting (%)	39.3	48.1	-	-
WLZ	-0.56(1.39)	0.8(2.76)	-1.3(<0.001)	<0.001***
Wasting (%)	14.2	13.1	-	-
WAZ	-1.3(1.3)	-1.22(1.5)	-0.12(0.13)	0.37
Underweight (%)	27.3	31.0	-	-
Maternal haemoglobin	13.1(1.3)	12.4(1.7)	0.76(0.15)	<0.001***
Maternal anaemia (%)	21.5	34.1	-	-
Maternal BMI	19.1(2.1)	18.6(2.6)	0.5(-0.2)	0.012**
Maternal wasting (%)	45.4	51.5	-	-

[a] Mean difference between pre and post-harvest season
**p<0.01, *p<0.05,
LAZ, Length-for-Age Z score; WAZ, Weight-for-Age Z score; WLZ, Weight-for-Length Z score; BMI, Body Mass Index; HDDS, Household Dietary Diversity Score; HFIAS, Household Food Insecurity Access Scale; HFCS, Household Food Consumption Score; IDDS, Infant Dietary Diversity Score; WDDS, Women's Dietary Diversity Score
% shows the prevalence of each indicator (based on standard cut-off points) in post- and pre-harvest seasons.

Table 2 Correlation between HDDS, HFCS, HFIAS and nutritional status of mothers and children 6-23 months of age in pre and post-harvest seasons in rural Ethiopia

	Post-harvest	Pre-harvest
Correlations with HDDS	P. corr. (p-value)	P. corr. (p-value)
LAZ	0.6(0.41)	0.09(0.25)
WAZ	0.13(0.076)	0.048(0.5)
WLZ	0.033(0.8)	0.9(0.25)
Maternal BMI	-0.1(0.2)	0.07(0.36)
Maternal Haemoglobin	0.18(0.014)*	0.75(<0.001)**
Correlations with HFCS		
LAZ	0.02(0.7)	0.11(0.15)
WAZ	0.01(0.9)	0.176(0.026)*
WLZ	0.01(0.9)	0.16(0.042)*
Maternal BMI	0.21(0.005)*	0.014(0.86)
Maternal Haemoglobin	0.18(0.014)*	0.04(0.57)
Correlations with HFIAS		
LAZ	-0.08(0.37)	-0.002(0.98)
WAZ	-0.07(0.45)	-0.09(0.25)
WLZ	-0.32(0.028)*	-0.023(0.77)
Maternal BMI	-0.27(0.02)*	-0.002(0.98)
Maternal Haemoglobin	-0.02(0.78)	-0.029(0.75)

**P<0.01, *P<0.05

P.corr, Pearson's Correlation coefficient; LAZ, Length-for-Age Z score; WAZ, Weight-for-Age Z score; WLZ, Weight-for-Length Z score; BMI, Body Mass Index; HDDS, Household Dietary Diversity Score; HFIAS, Household Food Insecurity Access Scale; HFCS, Household Food Consumption Score

Table 3 Relationships between HFIAS, HFCS, HDDS and maternal nutritional status across the seasons in rural Ethiopia

	Estimation method	Post-harvest	Pre-harvest
Adjusted correlations with HDDS:			
Women's dietary diversity Dietary diversity (9 food group) Pseudo R-squared Observation	Poisson regression	0.32 (0.3) 0.002 183	0.34** (0.03) 0.04 183
Women minimum dietary diversity (≥5 food groups) Pseudo R-squared Observation	Probit regression	0.04* (0.06) 0.07 183	0.21** (0.08) 0.12 183
Maternal BMI Pseudo R-squared Observation	OLS	0.008 0.09 (0.001) 183	0.05 (0.07) (0.003) 183
Maternal haemoglobin Pseudo R-squared Observation	OLS	0.21** (0.9) 0.007 181	0.21** (0.9) 0.07 181
Adjusted correlations with HFCS:			
Women's dietary diversity Dietary diversity (9 food group) Pseudo R-squared Observation	Poisson regression	0.01* (0.05) 0.006 183	0.20** (0.08) 0.004 183
Women minimum dietary diversity (≥5 food groups) Pseudo R-squared Observation	Probit regression	0.02** (0.01) 0.09 183	0.022** (0.001) 0.13 183
Maternal BMI Pseudo R-squared Observation	OLS	0.04** (0.16) 0.008 183	0.05** (0.16) 0.08 183
Maternal haemoglobin Pseudo R-squared Observation	OLS	0.004** (0.016) 0.01 181	0.004** (0.02) 0.01 181
Adjusted correlations with HFIAS			
Women's dietary diversity Dietary diversity (9 food group) Pseudo R-squared Observation	Poisson regression	-0.016 (0.01) 0.003 183	-0.05** (0.006) 0.01 183
Women minimum dietary diversity (≥5 food groups) Pseudo R-squared Observation	Probit regression	-0.07** (0.03) 0.1 183	-0.05** (0.025) 0.07 183
Maternal BMI Pseudo R-squared Observation	OLS	-0.016 (0.03) 0.008 183	-0.02 (0.02) 0.002 183
Maternal haemoglobin Pseudo R-squared Observation	OLS	-0.06 (0.04) 0.001 181	-0.07 (0.03) 0.001 181

Notes: Robust standard errors in parentheses.
***<0.001, **P<0.01, *P<0.05
All regression analyses include controls for age of household, family size, maternal and husband education, cultivated land size, agro-ecological zone. Dietary diversity based on 9 food groups was estimated using poisson regression; those for attaining minimum dietary diversity were estimated using probit.

HDDS, Household Dietary Diversity Score; HFIAS, Household Food Insecurity Access Scale; HFCS, Household Food Consumption Score; IDDS, Infant Dietary Diversity Score; WDDS, Women's Dietary Diversity Score. All coefficients are marginal effects

Table 4 Relationships between HFIAS, HFCS, HDDS and children dietary diversity and nutritional status across the seasons in rural Ethiopia

	Estimation method	Post-harvest	Pre-harvest
Adjusted correlations with HDDS:			
Infant Dietary Diversity Score (7 food groups) Pseudo R-squared Observation	Poisson regression	0.02 (0.03) 0.0007 183	0.86** (0.31) 0.026 183
Infant dietary diversity (attaining ≥4 food groups) Pseudo R-squared Observation	Probit regression	0.13** (0.07) 0.07 183	0.38*** (0.10) 0.04 183
Height-for-Age z score Pseudo R-squared Observation	OLS	0.44** (0.22) 0.005 183	0.1 (0.16) 0.003 183
Stunted Pseudo R-squared Observation	Probit regression	0.44** (0.22) 0.005 183	0.21 (0.9) 0.07 183
Weight-for-Length z score Pseudo R-squared Observation	OLS	0.26** (0.12) 0.05 183	0.15 (0.13) 0.01 183
Adjusted correlations with HFCS:			
Infant Dietary Diversity Score (7 food groups) Pseudo R-squared Observation	Poisson regression	0.004 (0.005) 0.005 183	0.008** (0.003) 0.010 161
Infant dietary diversity (attaining ≥4 food groups) Pseudo R-squared Observation	Probit regression	0.013 (0.1) 0.06 183	0.03*** (0.01) 0.03 183
Height-for-Age z score Pseudo R-squared Observation	OLS	0.08 (0.27) 0.005 183	0.11 (0.008) 0.003 183
Stunted Pseudo R-squared Observation	Probit regression	0.08 (0.27) 0.005 183	0.05 (0.07) 0.003 183
Weight-for-Length z score Pseudo R-squared Observation	OLS	0.38** (0.21) 0.05 183	0.03** (0.015) 0.03 183
Adjusted correlations with HFIAS			
Infant Dietary Diversity Score (7 food groups) Pseudo R-squared Observation	Poisson regression	-0.05* (0.01) 0.058 183	-0.001 (0.008) 0.010 183
Infant dietary diversity (attaining ≥4 food groups) Pseudo R-squared Observation	Probit regression	-0.07** (0.03) 0.09 183	-0.02 (0.03) 0.01 183
Height-for-Age z score Pseudo R-squared Observation	OLS	-0.37 (0.4) 0.006 183	-0.1 (0.4) 0.001 181
Stunted	Probit regression	-0.37 (0.4)	-0.19 (0.9)

Pseudo R-squared Observation		0.006 183	0.07 183
Weight-for-Length z score Pseudo R-squared Observation	OLS	-0.031 (0.042) 0.07 183	-0.01** (0.036) 0.005 183

Notes: Robust standard errors in parentheses.
**P<0.01, *P<0.05
All regression analyses include controls for age of household, family size, maternal and husband education, cultivated land size, agro-ecological zone. Dietary diversity based on 7 food groups was estimated using poisson regression; those for attaining minimum dietary diversity were estimated using probit.
HDDS, Household Dietary Diversity Score; HFIAS, Household Food Insecurity Access Scale; HFCS, Household Food Consumption Score; IDDS, Infant Dietary Diversity Score; WDDS, Women's Dietary Diversity Score. All coefficients are marginal effects