RESEARCH ARTICLE

Patterns and determinants of breastfeeding and complementary feeding practices over the first year of life in a rural Gambian population [version 1; peer review: 1 approved, 1 approved with reservations]

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Abstract

Background: Although breastfeeding is common in The Gambia, high rates of undernutrition in children under five highlight the importance of understanding drivers of particular feeding patterns in this environment, especially early introduction of non-breast milk foods (NBMFs). The country's marked seasonality, which is associated with annual food insecurity and heavy maternal workload, may influence breastfeeding patterns; however, longitudinal assessments of infant diet in relationship to such factors are limited. We aimed to characterize infant breastfeeding patterns and timing of introduction of local complementary foods in a rural Gambian population across the first twelve months of life. Potential environmental and sociodemographic predictors of exclusive breastfeeding (EBF) duration were explored in order to identify factors that may influence infant feeding decisions in this population.

Methods: Data from dietary questionnaires (administered every ten days until 12 months of age) collected as a part of the Hormonal and Epigenetic Regulators of Growth study (2013-2018) were used to calculate EBF duration in a subsample of 194 mother-infant pairs. Socioeconomic questionnaires and Principal Component Analysis

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were used to calculate household sociodemographic position (SEP). Multiple linear regression analyses were used to investigate potential predictors of EBF duration, including seasonality, SEP, and maternal and infant factors.

Results: Mean age at introduction of food or liquid other than maternal milk was five months (±1.5). At twelve months, 98.7% of infants continue to receive some maternal milk. Being born in May significantly predicted shorter EBF duration by -1.68 months (95% CIs: -2.52, -0.84mo; P<.0001). SEP, maternal parity, and infant sex were non-significant predictors of EBF duration.

Conclusions: Maternal milk is a vital component of infant diet across the first twelve months of life in this population. Earlier introduction of NBMFs coincides with the annual period where maternal agricultural workload intensifies in this region, though additional investigation is warranted.

Keywords

maternal milk, infant, diet, The Gambia, nutrition, complementary feeding, West Africa

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Introduction

The World Health Organization (WHO) recommends exclusive breastfeeding (EBF) until six months of age, followed by introduction of safe and nutritionally adequate foods in addition to continued breastfeeding until 24 months of age[1]. This duration has been identified as a key intervention for reducing mortality during childhood. However, a large proportion of infants begin consuming non-breast milk foods (NBMFs) much earlier[2–6]. A comprehensive characterization of early life diet is of particular importance in low-income populations that experience marked seasonality associated with annual food insecurity, heavy maternal workload, and fluctuations in infectious disease burden. These factors influence early life growth, the outcome of which is linked to infant/childhood – and later life – morbidity and mortality[7–9].

Globally, undernutrition is the underlying cause of more than 45% of deaths in children under 5 years of age[10]. This can occur directly through acute malnutrition, or through childhood diseases (such as malaria, diarrhea, pneumonia), which are more likely to become fatal in undernourished children[11]. In The Gambia in West Africa (Figure 1), more than 25% of children under five years of age are affected by chronic undernutrition[12–14]. The prevalence of undernutrition has increased in recent years, largely impacting rural areas of the country[7]. Chronic malnutrition is most prevalent among children 6–17 months of age in The Gambia; aligning with the period of transition from exclusive breastfeeding (EBF) to incorporation of liquids and foods other than maternal milk into the diet[15].

Suboptimal dietary intake can result in a myriad of adverse health consequences, including increasing susceptibility to infection. Mortality rates for children under five from diarrhea and pneumonia in The Gambia are high, and peak during ages when complementary foods are first introduced (~ five months)[16]. Infection rates and food security fluctuate across the year and are associated with the country's marked seasonality, with a long dry "harvest" season (November to June), and a short wet "hungry" season (July to October)[17]. Moore (2016) reports that The Gambia's strong seasonality creates a setting in which month of birth is a strong proxy of nutrition, infectious diseases, and mortality in early life. Additionally, long-term effects on immune programming in rural Gambian populations likely have a nutritional origin[18].

Breastfeeding is nearly universal in The Gambia, and the only sustainable option for many. Prior research shows that more than 95% of infants in The Gambia receive maternal milk throughout the first twelve months of life and nearly half of mothers continue to breastfeed until their infant is 24 months

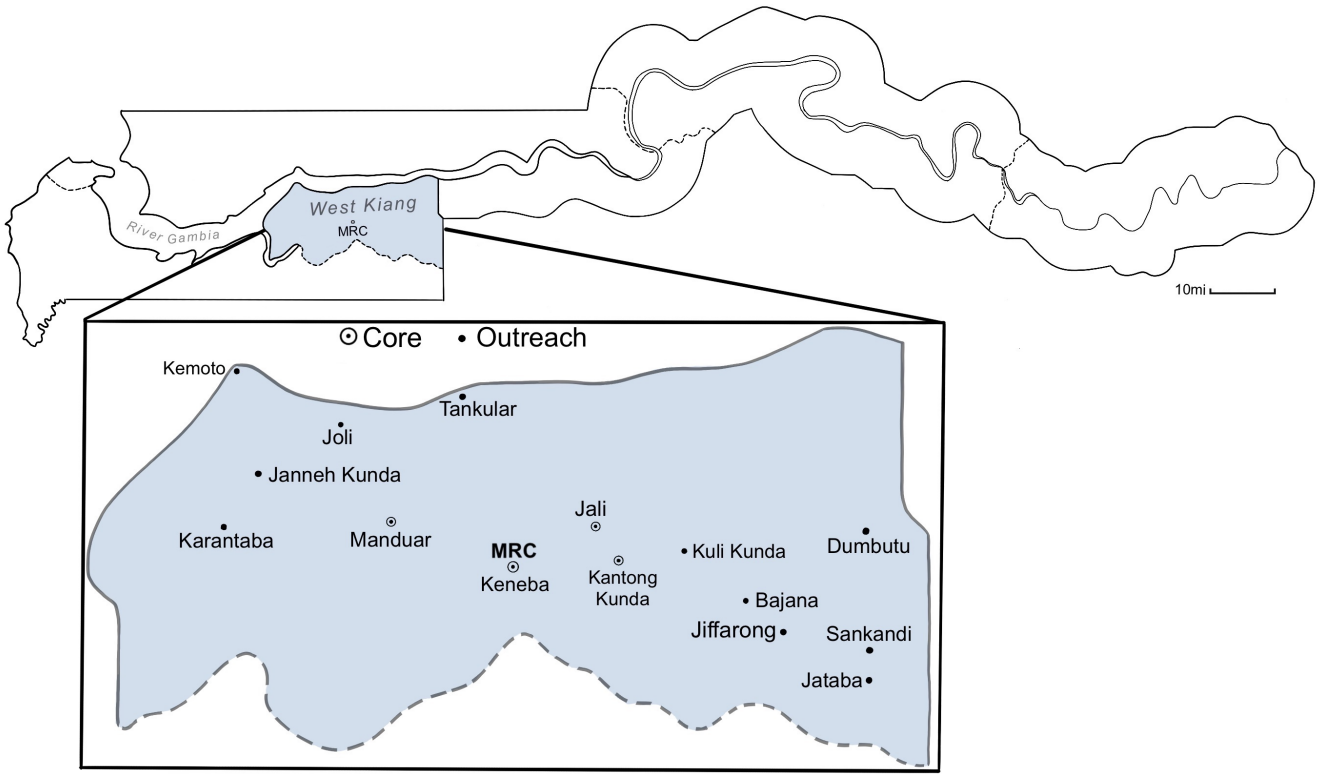

Figure 1. Map of The Gambia (West Kiang region shaded in gray). Figure 1 Footer: (MRC: Medical Research Council Keneba field station. *Note:* There are a total of 36 villages currently registered within the West Kiang Demographic Surveillance System. Only the villages included in the present analysis are depicted on the map.).

of age[19–22]. Existing research reports that cessation of EBF in The Gambia occurs between 3 to 6 months of age[2,22–26], generally earlier than the WHO recommended duration.

Earlier introduction of NBMF in populations in the West Kiang Region of The Gambia (Figure 1) may relate to fluctuations in maternal agricultural workload in this particular subsistence economy. Crop growth predominantly occurs during the wet season whereas crop harvesting takes place at the end of the wet season and into the start of the dry season. As such, the wet season is characterized by reduced food availability and increased maternal agricultural workload[27,28]. It is also associated with increased morbidity and mortality[29–31]. Food stores improve, physical labor related to subsistence practice is lessened, and morbidity prevalence is reduced during the dry season.

Women in the West Kiang region of The Gambia work for long periods (around 15 hours per day) in agricultural fields, conducting physically intensive tasks such as land preparation, planting, weeding, watering, harvesting, and transporting[32]. Rural Gambian women report that engaging in laborious work under harsh environmental conditions sometimes comes at the expense of the child's well-being, including reduction of time allocated towards child health and nutritional needs[33]. Physical activity level of mothers in this area has been reported to return to pre-pregnancy levels after the first month post-partum[34]; thus, an increase in agricultural workload may relate to a decision to begin introducing complementary foods earlier. Infants are often separated from their mothers from morning to evening during periods of heavy workload (the amount of physical effort required to carry a child to the field has been cited as a reason to introduce NBMFs at earlier ages[35,36] and are commonly left in the care of other children or an elderly family member[33,37–44]. When infants receive care from others, earlier cessation of EBF may be a necessary alteration to infant feeding[45,46].

Annual cropping patterns in The Gambia also determine food supply throughout the year, and thus the availability of certain ingredients for complementary foods. Traditional local complementary foods in rural Gambia include cereal dishes and other staples, such as rice (local name, 'mani'), millet ('sanyo', 'suno'), and maize ('tubanyo'), which are among the staple crops grown in The Gambia. Cereal crops are generally harvested between September and December in rural Gambia (most observations cited were made in Keneba, a remote subsistence farming village in the West Kiang Region), resulting in particularly plentiful food supplies in November and December[47]. Food shortages often occur in July and August. For example, the availability of groundnuts, the chief cash crop in the country and a primary ingredient of 'tiakere churo' (rice and groundnut porridge), decreases in August and September when the new crop has been planted but is not yet harvestable[47]. When food is scarce during the wet season, 'jidiyo,' a watery/thin gruel made with powder or any pounded grain, may be preferentially used over a thicker, 'mono,' porridge for infants[47]. Meat, fish, and animal milk are used less frequently as complementary foods[23,24,48]. Nutritional composition of raw ingredients and dietary information for recipes of locally prepared dishes (e.g., porridges) have been reported in previous studies[49–53].

Infant feeding practices and access to nutritious foods have been associated with household socioeconomic position (SEP) across various populations, which can add complexity to infant feeding decisions. In The Gambia, children from rural communities had significantly higher odds of not meeting the requirement for minimum acceptable diet (a core indicator for assessing infant and young child feeding practices developed by the WHO; includes minimum dietary diversity and minimum meal frequency) compared with their urban counterparts[12,54,55]. Prevalence of early life malnutrition and mortality are also higher in rural areas of the country compared to urban areas[15]. This may relate to a number of factors, such as general household poverty[56]. Over-dependence on subsistence rain-fed agriculture and consumption (insufficient dietary diversity) combined with high poverty, low literacy levels, and high prevalence of morbidity were also identified as major predisposing factors to undernutrition in rural areas of the country[15]. Because malnutrition is a significant contributor to infant and child morbidity and mortality, it is critical to regularly assess early life diet.

In this study, we aim to comprehensively characterize breastfeeding patterns and the timing of introduction of specific local complementary foods in a rural Gambian population across infants' first twelve months of life. We also explore potential environmental and sociodemographic predictors of EBF duration in order to identify factors that may influence infant feeding decisions in this population.

Methods

Ethics

The HERO-G study was approved by the joint Gambian Government/MRC Unit The Gambia Ethics Committee (Project No. SCC1313v3), and the University of Colorado, US, Institutional Review Board (Protocol No. 13-0441). Written informed consent was obtained from all participants before enrollment. Full details of the HERO-G study can be found in the published study protocol[57].

HERO-G

We use data collected as a part of the Hormonal and Epigenetic Regulators of Growth (HERO-G) study (2013–2018 active data collection), which was designed to investigate intrauterine and postnatal growth patterns in rural Gambian infants (N=238) using epigenetic, endocrine, and metabolic analyses. The HERO-G study was conducted in the West Kiang region of The Gambia. The present analysis includes data from 'core' (Kantong Kunda, Keneba, and Manduar) and 'outreach' (Bajana, Dumbuto, Jali, Janneh Kunda, Jattaba, Jiffarong, Joli, Karantaba, Kemoto, Kuli Kunda, Mandina, Sandeng, Sankandi, and Tankular) villages (Figure 1).

Infant feeding questionnaire

As a part of the HERO-G study, dietary questionnaires regarding infant feeding were administered to mothers by trained field workers every ten days, starting at 1 week of infant age (mothers and infants traditionally stay home together to rest and recover for a week after birth, after which a naming ceremony is held) until 12 months of age. Mothers or caregivers were asked to recall infant feeding practices in the previous 10 days. Questions included those such as infant breastfeeding status, if NBMFs were given, the frequency of intake of those foods or liquids, and specification of food type (e.g., water, tea, cow's milk, watery or thick gruel, etc.). The full dietary questionnaire is detailed in Table 1.

To characterize infant feeding patterns, we calculated descriptive statistics from the dietary questionnaire responses, including mean, standard deviation (SD), and ranges where appropriate. Infant feeding practice was defined by EBF status at 6 months of age, based on the WHO recommended EBF duration of 6 months[1]. Infants were categorized as either 'EBF <6 months' (provision of breast milk and non-breast milk foods/liquids before 6 months of age) or 'EBF ≥6 months' (provision of breast milk only until 6 months or later)[21,58].

Subsample inclusion/exclusion criteria

A subsample (N=194) of mother-infant pairs from the larger HERO-G cohort (N=238) were included in the present analysis based on completeness of collected data over the first 12 months of life. Specifically, mother-infant pairs with no available infant feeding data (N=10), and those missing infant feeding data from three consecutive visits (the equivalent of one month) during the first 6 months of life (N=34) were excluded from this analysis (Figure 2). Instances of no available infant feeding data were attributable to unavailability of mother at the time of questionnaire distribution, either related to maternal travel or undocumented reasons. In many cases, missing infant feeding data from > three consecutive reports of infant feeding practices occurred if mothers were traveling or working and thus unavailable to provide responses to the questionnaire.

Table 1. HERO-G subsample (N=194) maternal and infant baseline characteristics.

Variable	HERO-G Subsample (N=194)
Maternal age, years (SD)	32.0 (±6.9)
Parity, N (%)	
Primiparous	18 (9.3)
Multiparous	176 (90.7)
Infant season of birth, N (%)	
Wet season (Jul-Oct)	64 (33.0)
Dry season (Nov-Jun)	130 (67.0)
Infant sex, N (%)	
Male	103 (53.1)
Female	91 (46.9)

To determine the statistical power of a sample size of 194 in examining associations between EBF duration and environmental, sociodemographic, and maternal and infant factors using multiple linear regression (F-test), a post-hoc power analysis was conducted using G*Power 3.1[59]. With a medium effect size (f^2=0.15) and a significance level of α = 0.05, a sample size of 194 has a power (1-ß err prob) of 0.99. Baseline characteristics of the HERO-G subsample are described in Table 1. There were no significant differences between baseline characteristics of the full HERO-G cohort and the HERO-G subsample.

Socioeconomic position

Fieldworkers administered a socioeconomic questionnaire during the 'booking' visit for the HERO-G study, which refers to the first clinic visit after pregnancy confirmation (variable gestational age)[57]. Mothers were asked to provide information regarding sociodemographic variables (maternal education attainment), household characteristics (crowding index [number of persons per room within a dwelling], material of dwelling walls and floor), and durable assets (livestock ownership, possession of a cart). Details of the full socioeconomic questionnaire are described in Table 2. Other economic indicators commonly used in assessments of socioeconomic position (SEP), such as occupation, income, consumption expenditure, water source, ownership of a bicycle or vehicle, ownership of a radio, and/or access to electricity, were not documented as a part of the HERO-G study. The present analysis focuses only on the responses collected from mothers included in subsample (N=194) from the larger HERO-G study (N=238).

Available data for variables documented in the above questionnaire describing sociodemographic characteristics, household characteristics, and durable assets were used to generate an asset score using Principal Component Analysis (PCA). First, data were cleaned and descriptive statistics were calculated to determine the distributions of participant responses. Categorical variables were re-coded in order to meet continuous variable requirements of PCA analyses. Next, JMP Pro 15.0 statistical software (©2019 SAS Institute, Inc.) was used to perform the PCA using the Multivariate Methods function. It is assumed in the literature that the first principal component is an appropriate measure of economic status[60].

Item inclusion/exclusion

Of the 194 mothers included in the HERO-G subsample, full socioeconomic questionnaire responses were available for 166 individuals. A total of ten items were collected in the questionnaire, four of which were used in the present PCA. Descriptive statistics and inclusion/exclusion status are described below and detailed in Table 2 for each of the ten items collected in the questionnaire. First, of the ten items

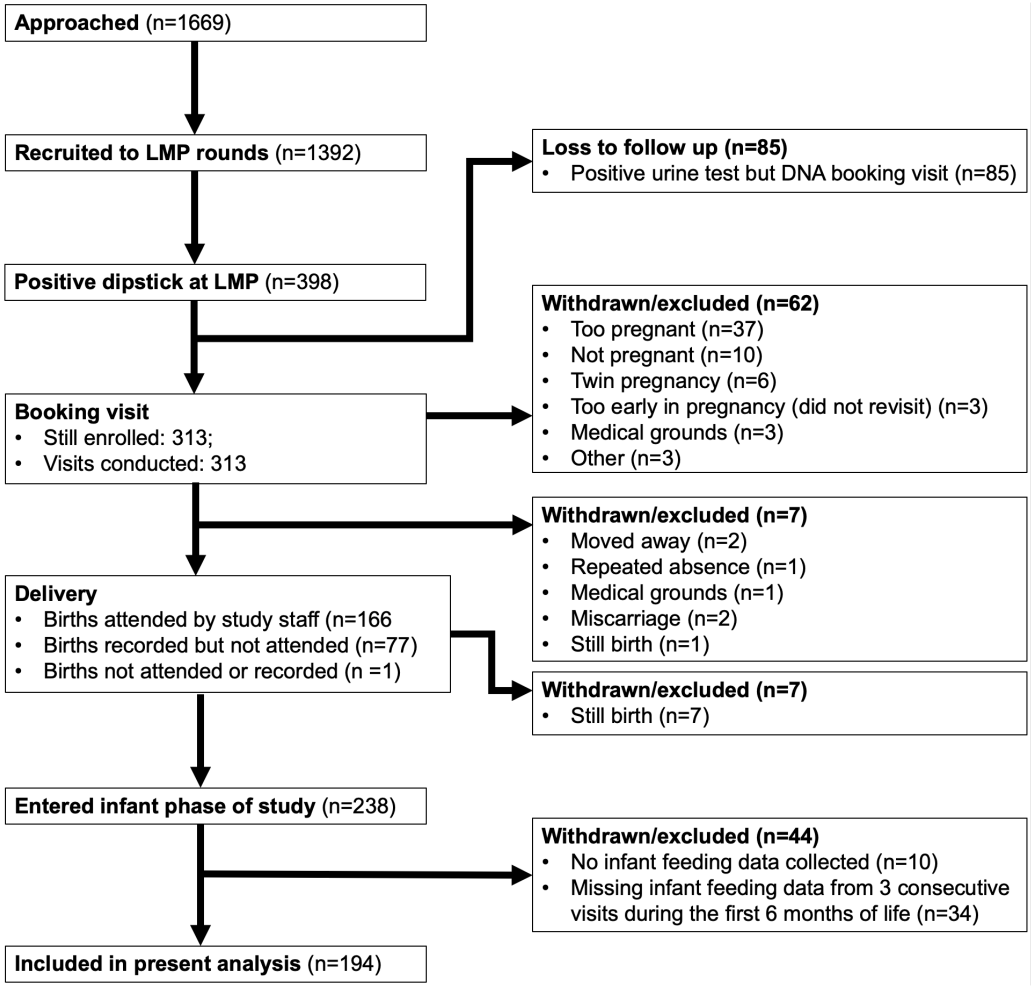

Figure 2. Flow diagram of included and excluded HERO-G participants in the HERO-G subsample.

collected, two were removed from the PCA due to inadequate variation: (1) present enrollment in education (1.2 in Table 2), where only one participant reported being in education at the time the questionnaire was administered); and (2) cart ownership (5.1 in Table 2), where only one participant reported owning a cart. Number of years of completed maternal education was incorporated as a continuous variable in the PCA and also categorized into one of three groups based on the response distribution for descriptive purposes: No Education (0 years), Low (1–7 years), and Medium (8–14 years) Education. These categories are based on previous studies in populations from the West Kiang Region of The Gambia[21].

Additionally, livestock ownership (cow, goat, and sheep) was removed from the PCA. The value and importance of livestock species in The Gambia have well-established links to household income[61–63] and studies in the West Kiang region have used cattle ownership as a single indicator of wealth (households owning < 10 cattle considered poor and those owning > 10 cattle considered wealthy[64]). However, without data on female-only ownership, male-only ownership, or mixed ownership of livestock, confirmation that the mothers enrolled in HERO-G were the sole owner (which is unlikely because of the distinct gender differences in livestock ownership practices in the country) is not feasible. Because the potential inconsistencies in reporting based on varying definitions of ownership; for example, a mother may report owning eight cows when the cows are owned by a co-wife's family who lives in the same compound, which therefore may not adequately represent individual household wealth. Such inconsistencies may influence the accuracy of the explanatory power of the variable, so therefore livestock ownership was excluded as a variable from further calculations.

Following the WHO Housing and Health Guidelines[65], crowding was defined as more than one person per room, and severe crowding as more than 1.5 persons per room. Crowding index was calculated using a ratio between the number of

Table 2. Descriptive statistics of SEP questionnaire responses and excluded/included variables.

Item	Value	Included/Excluded
1. Sociodemographic		
Maternal education attainment, N (%)		Included (treated as continuous)
No education	125 (75.3)	
Low (1–7 years)	17 (10.2)	
Medium (8–14 years)	24 (14.5)	
Present education enrollment, N (%)		Excluded (inadequate variation)
Yes	1 (0.6)	
No	40 (26.5)	
N/A	125 (75.3)	
2. Household Characteristics		
Crowding index, (people:rooms)		Included (treated as continuous)
< 1	21 (12.7)	
≥1 (crowded)	145 (87.3)	
Wall material, N (%)		Included
Mud	151 (91.0)	
Cement	15 (9.0)	
Other	0 (0.0)	
Unknown	0 (0.0)	
Floor material, N (%)		Included
Mud	55 (33.1)	
Cement	111 (66.9)	
Other	0 (0.0)	
Unknown	0 (0.0)	
3. Durable Assets		
Livestock Ownership		
Sheep, N (%)		Excluded
1	7 (3.6)	
2	6 (3.6)	
5+	3 (1.8)	
Goats, N (%)		Excluded
1	26 (15.7)	
2	20 (12.0)	
3	17 (10.2)	
4	10 (6.0)	
5+	13 (7.8)	
Cattle, N (%)		Excluded
1	5 (3.0)	
2+	5 (3.0)	
Possessions, N (%)		Excluded (inadequate variation)
Cart		
Yes	1 (0.6)	
No	165 (99.4)	

rooms within the dwelling (2.1 in Table 2), and the number of persons living in the dwelling (2.2 in Table 2), thus combining 2 items from the questionnaire into 1 value. Crowding was coded as 0 and a non-crowded dwelling was coded as 1. Full descriptive statistics are presented below.

In total, three of the components had an eigenvalue of greater than one. The first principal component explained 30.2% of the variation within the data and had an eigenvalue of 1.21 and was thus considered appropriate to be used as an index. Table 3 shows the eigenvectors (the weight for each eigenvalue) and the factor loadings (correlation of each item in the principal component) of the first principal component on items included in the PCA. The highest contributors to the SEP score were floor material, wall material, and household crowding. Maternal education attainment had the lowest contribution.

Each item was multiplied by its respective factor loading value to account for its individual weighted contribution and then each item was summed to produce an SEP score. SEP score was used as a continuous variable in the multiple linear regression models described in the following section.

Statistical models

Multiple linear regression analyses were used to investigate potential predictors of infant EBF duration, including seasonality, household SEP, and maternal and infant factors. Multicollinearity was determined using a conservative VIF > 5. Significant associations identified in the models were summarized using the beta regression coefficients and 95% confidence intervals (CI). Model effect size is reported as Cohen's f^2, where $f^2 \geq 0.02$, $f^2 \geq 0.15$, and $f^2 \geq 0.35$ represent small, medium, and large effect sizes, respectively. The level of statistical significance was set to $P < 0.05$ for all analyses. All statistical analyses were conducted using JMP Pro 15.0 statistical software.

Results

Maternal and infant characteristics

A total of 194 mother-infant pairs were included in the analysis, with a mean (±SD) maternal age of 32.0 (±6.9) years. Most mothers (N=176; 90.7%) were categorized as multiparous. Of the 194 infants, there were a total of 103 male and 91 female, with 145 born during the dry ("harvest") season and 49 born during the wet ("hungry") season.

Table 3. PCA Component 1 eigenvectors and factor loadings of items included in SEP score.

Item	Eigenvectors	Factor Loadings
Education attainment	0.10577	0.11629
Household Crowding	-0.41567	-0.45702
Wall Material	0.53699	0.59041
Floor Material	0.72641	0.79867

Household sociodemographic characteristics

Maternal education levels were low and in line with previous findings in this population[19,21], with 75.3% of mothers having received no formal education. Over 87% of households examined in this analysis were considered crowded (people: rooms ≥1). The majority of households (N=151, 91.0%) contained wall material made from mud and the remaining households (N=15, 9.0%) had walls made of cement. Floor material was most commonly made of cement (N=111, 66.9%) followed by mud (N=55, 33.1%). Livestock ownership was mixed, with ownership of goats reported most frequently (N=86, 44.3%), followed by sheep (N=16, 9.0%) and cattle (N=10, 6.0%).

Infant feeding

The mean (±SD) age for introducing any food or liquid other than breast milk was 5 months (±1.5) with 59 (30.4%) infants EBF ≥6 months and 135 (69.6%) of infants EBF < 6 months. The mean duration of EBF for infants categorized as EBF <6 months was 4.4mo (±1.4) and those categorized as EBF ≥6 months was 6.5 months (±0.4). At 1 month of age, all infants were EBF. By 3 months of age, 5.6% of infants had been given water and 5.6% given semi-solids, which increased to 62.9% and 47.1% by 6 months of age, respectively. At 12 months of age, 98.7% of infants still received breast milk. Non-breast milk liquids given before 6 months of life included tea with milk (8.2%), powdered milk (3.1%), cow's milk (1.5%), and tinned milk (1.0%). At 6 months of age, 0.01% of infants received solid foods compared to 66.9% at 12 months of age. Broad feeding practice categorizations (provision of maternal milk only, maternal milk plus non-breast milk liquids, and maternal milk plus non-breast milk semi-solids) are depicted according to age in months in Figure 3. Specific common NBMFs (including liquids and semi-solids) given over the first year of life are depicted by monthly reports in Figure 4.

Predictors of EBF duration using multiple linear regression analyses

The multiple linear regression model of predictors of EBF duration had a medium effect size (f^2=0.15). VIF was < 2 for each variable, meeting the criteria for parameters of collinearity. Results of multiple linear regression analyses showed that infant birth month was a significant predictor of EBF duration in the HERO-G subsample (P=0.0370). Being born in the month of May predicted significantly shorter EBF duration by -1.68mo (95% CIs: -2.52, -0.84mo; P<.0001) in the multiple linear regression. None of the other birth months were significant predictors of breastfeeding practices. There was no significant predictive effect of infant sex, maternal parity, or household SEP on EBF duration. Table 4 details the statistical model results.

Infants born in the month of May (N=13) – shortly before the start of the wet ("hungry") season – had the shortest average EBF duration at 3.54 months (±1.9). Infants born in August had the longest average EBF duration at 5.65 months (±1.1). Average EBF durations according to birth month are detailed in Table 5.

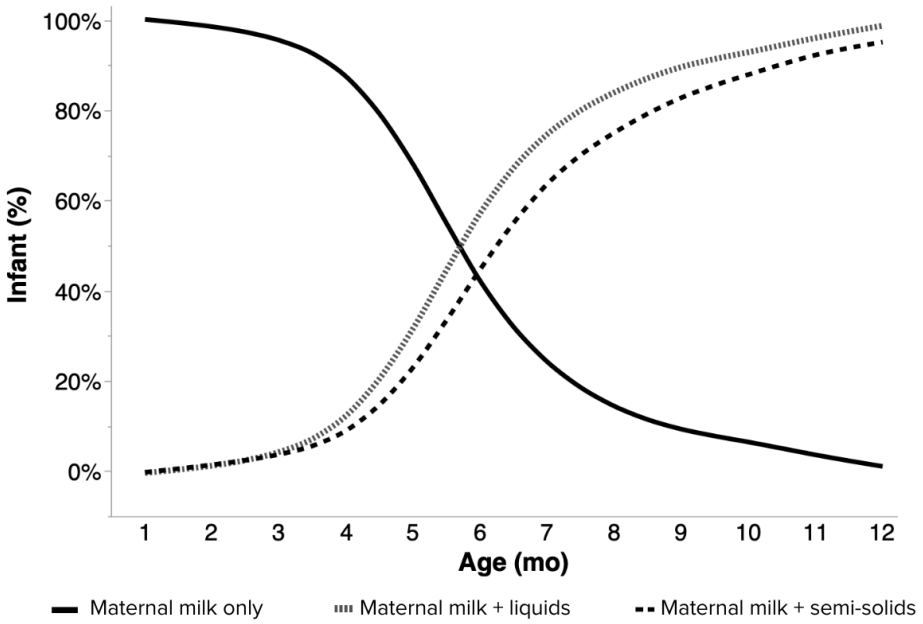

Figure 3. **Rural Gambian infant feeding practices by age.**

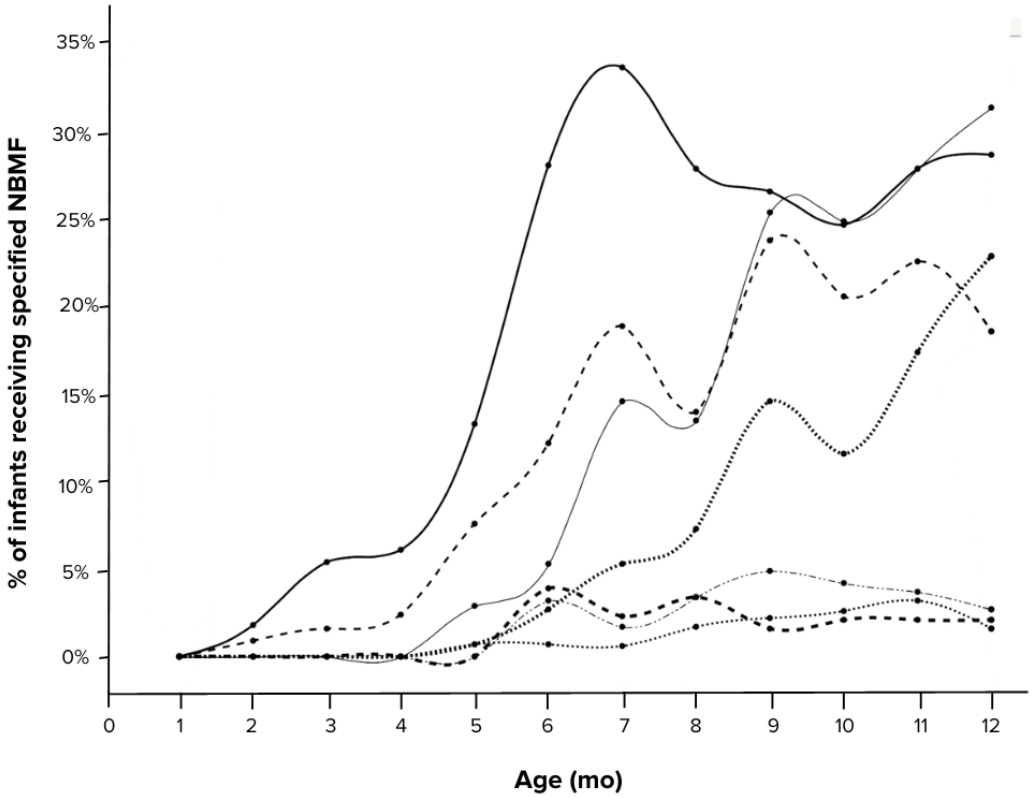

Figure 4. **Common NBMFs given over the first year of life.**

Table 4. Multiple linear regression model results of predictors of EBF duration.

EXPLANATORY VARIABLES	B	95% CIs	P
Intercept	5.21	4.71, 5.71	**<.0001***
Birth month			
Jan	0.12	-0.53, 0.78	0.7102
Feb	0.34	-0.31, 1.0	0.3017
Mar	0.24	-0.38,0.87	0.4474
Apr	-0.11	-0.89, 0.67	0.7854
May	-1.68	-2.52, -0.84	**<.0001***
Jun	-0.20	-1.09, 0.70	0.6667
Jul	0.51	-0.44, 1.46	0.2928
Aug	0.71	-0.01, 1.51	0.0846
Sept	0.08	-0.79, 0.96	0.8529
Oct	-0.50	-1.45, 0.46	0.3044
Nov	0.06	-0.84, 0.97	0.8890
Dec (referent)	-	-	-
Infant sex			
Female	-0.14	-0.38, 0.11	0.2699
Parity (continuous)	-0.03	-0.12, 0.07	0.5735
SEP Score (continuous)	0.08	-0.13, 0.29	0.4708

B: Coefficient estimate; 95% CIs: Confidence Intervals (Lower Bound, Upper Bound); P: P-value; *P<.0001; Statistical significance indicated by boldface font.

Table 5. Average EBF duration based on birth month.

Birth Month	N	Mean	SD	Std Err Mean	95% CIs
Jan	23	5.15	1.09	0.23	4.68, 5.62
Feb	25	5.32	1.06	0.22	4.87, 5.77
Mar	26	5.23	1.38	0.27	4.68, 5.79
Apr	20	4.87	1.68	0.38	4.08, 5.66
May	13	3.54	1.98	0.55	2.34, 4.73
Jun	14	4.96	1.24	0.33	4.25, 5.68
Jul	12	5.39	1.49	0.43	4.45, 6.33
Aug	14	5.65	1.07	0.29	5.04, 6.27
Sept	11	5.09	1.49	0.45	4.09, 6.09
Oct	12	4.47	1.74	0.50	3.36, 5.57
Nov	12	4.97	1.89	0.54	3.77, 6.17
Dec	12	5.43	1.76	0.51	4.31, 6.55

95% CIs: Confidence Intervals (Lower Bound, Upper Bound)

Discussion

Here, one-third of rural Gambian infants were EBF until the WHO recommended 6 months of age, which corroborates results from both investigations of breastfeeding practices in another rural Gambian population from the West Kiang region over the past decade[21,44] and reports from decades prior[25,40]. Similar findings have been documented in other populations across sub-Saharan Africa[66,67]. Breastfeeding duration is relatively long in this rural Gambian population, with nearly all infants still receiving maternal milk at 12 months of age, the latest age at which the questionnaire was administered. This percentage aligns with other reports in the literature[20–22].

The most common NBMFs incorporated into the infant diet during the first 12 months of life in this analysis were grain-based porridges, which include some of the country's staple crops as ingredients. In particular, gruels made with 'suno' (millet), 'sanyo' (millet), and 'tiakere churo' (groundnut porridge) were reported most commonly. It is well-established that local agriculture is central to the diets of communities in this area, including infant dietary intake[21,40,68–70]. Around 70% of small-scale agricultural production in The Gambia is done by women[28,63,71,72], including subsistence work conducted throughout pregnancy and shortly after giving birth[34]. Thus, the NBMF types commonly reported in the present study highlights the key connection between maternal agricultural workload and complementary feeding.

Assessment of potential predictors of EBF duration showed that seasonality is an important driver of the timing of introduction of NBMFs into the infant diet. This may relate to maternal agricultural workloads, which fluctuate with the annual rains and may influence infant caregiving and subsequently infant feeding practices. Birth month was the only significant predictor of EBF duration in our multiple linear regression model, with May, the month before the start of the wet ("hungry") season, predicting earlier introduction of NBMFs. During the wet season in The Gambia, mothers commonly spend much of the day separated from their infants, resulting in less frequent breastfeeding and alternative caregivers responsible for infant feeding[43,73]. The results from the present analysis support that earlier introduction of NBMF coincides with the annual period where maternal agricultural workload intensifies. Infants born in May were weaned, on average, by 3.54 months of age, suggesting that those born right before the start of the wet season are likely to cease EBF before the end of the wet season.

This finding may, however, relate to the uneven number of births across different months in the HERO-G cohort. The greatest number of births occurred in January, February, and March in the HERO-G subsample, with the greatest number of infants receiving their first NBMF in the month of June (which aligns with the median age of weaning in this study). This may be an artifact of the clustering of recruitment to women for this study at a particular time in the year. Thus, it is possible this finding is a byproduct of the proportion of births during the early months of the year as opposed to directly stemming from maternal subsistence activities and seasonality.

Future works should consider investigating 'month' as a continuum rather than category, as using a coefficient of cyclic variation (as in Fourier analysis) could provide an even deeper understanding of the magnitude and temporal patterns at play[74].

Household SEP was not a significant predictor of breastfeeding practices in the multiple linear regression model. This differs from factors established in the literature from other populations, where SEP is associated with earlier EBF cessation due to influences such as limited access to resources such as transportation, access to roads, lower income to purchase nutritionally adequate and hygienic complementary foods, and lower education levels[75–78]. The present finding challenges that of Issaka *et al*., (2017), where Gambian children from poor households had significantly higher odds of not meeting the recommendations for timing introduction and type of solids, semi-solids, or other soft complementary foods compared to children from wealthy households.

There were some limitations to this study. First, it important to note that calculation of household SEP was less robust here than in other studies due to the reduction of items from the PCA. Acknowledgement of possible bias must be given to the exclusion of livestock ownership in the PCA. Because cattle are valuable as sources of food, income, and transportation and traction (e.g., field plowing), ownership of a cow contributes a high score to the SEP calculation. The calculation used to assess household SEP, however, takes multiple variables into consideration at once, which is more appropriate here than using variables such as maternal education or livestock ownership as single predictor variables.

Employment and household income are variable and difficult to measure in settings such as rural Gambia. For example, broad occupation information may not accurately capture the individual income for self-employed farmers in rural Gambia if it cannot take into account factors such as crop type, seasonality, and transitory market conditions[79]. Thus, asset scores are often calculated in order to measure relative wealth. Interviews or focus groups, to supplement questionnaires, might enhance the ability of future studies to provide additional context for the interpretation of the causes and consequences of infant feeding decisions in a highly seasonal environment. Revisiting details of household SEP, especially as it relates to maternal agricultural employment in the contemporary setting throughout pregnancy and over the course of lactation in the West Kiang region – a topic that has been rigorously investigated in earlier studies – would provide further insight into the influence of livelihood on dietary patterns.

Other characteristics of this population must be considered in the evaluation of the impact of SEP on EBF practices. In this region, there is low education attainment and prevalent household crowding. Formal education may be less relevant as a driver of infant feeding decisions in this region, as locally designed and run programs such as the Baby Friendly Community Initiative (BFCI) (developed by the National Nutrition Agency) in The Gambia provide local support and education to improve infant and young child feeding practices, including promoting EBF to 6 months of age[80]. The villages included in the HERO-G study are among those implementing the BFCI in the West Kiang region. The WHO (2009) reports significant success from implementation of BFCI initiatives in The Gambia with marked improvement in early initiation of breastfeeding and EBF to 4 months of age. Specifically, the adoption of certain BFCI strategies contributed to the increase in the national average of EBF from 0% in 1989, to 17.4% in 1998, to 36% in 2000[81]; and 41% in 2006[20].

Next, collection of retrospective dietary intake data may introduce bias through recall error[82–84]. However, studies comparing maternal recall methods found that 24- and 48-hour recall periods resulted in overestimated EBF durations, and report that 7 to 10 day recall intervals are adequate for general assessment of food intake, and may more accurately capture the complexity of infant feeding patterns compared to shorter intervals[84–86]. Future analyses may benefit from analyses of dietary diversity scores, details of ingredients and preparation processes for homemade complementary foods, assessment of food volumes, focus groups on local feeding decisions/motivations, in particular the transfer of knowledge between generations/sources of information that influence decisions to introduce NBMFs. Future study designs may consider adopting methods to assess any specific relationships between infant complementary feeding practices and shifts in availability of certain food ingredients and/or quantified maternal workload across the seasons.

Studies incorporating detailed analyses of food preparation and microbial composition of local complementary foods in this region would also strengthen the present analysis. In older research (>40 years ago), reports indicate that it was common practice in The Gambia for infant foods to be prepared in large quantities in the morning, sufficient enough for several meals throughout the day and so it is available if another caregiver is responsible for feeding the infant while the mother is away[34,87]. It is important to note that this may be out of date. This form of food preparation is convenient and efficient but has an associated downside of high levels of pathogenic bacterial contamination due to extended and poor storage conditions[87–93]. After preparation, common local complementary foods are stored at ambient temperatures, which allows the child to be fed on demand[87]. Additionally, these traditional complementary foods and some of their commonly used ingredients have been shown to contain high abundance of pathogens such as *Staphylococcus aureus* and *Escherichia coli,* which are associated with gastrointestinal infection[92–94]. In addition, foods prepared in the wet season contained higher levels of potential pathogens compared to foods prepared during the dry season, presumably because the environmental conditions during the wet season are very hospitable for bacterial growth[87]. There is also evidence that some gruels are prepared using contaminated water that contains potentially pathogenic coliform bacteria from both animal and human sources[70], though this too is out of date research.

Though not incorporated into the present analysis, infant health and growth attainment may also impact a mother's decision to wean her infant earlier. Research on the directionality of these associations, however, provides mixed results. For example, mothers may cease EBF or modify feeding practices because their infants are ill, perhaps related to hospitalization, type of illness, or perception that maternal milk is not meeting the infant's immunological needs[95]. Others may wean infants perceived as healthy (e.g., fewer morbidities) earlier, which may result in increased incidence of morbidity as it relates to reduced immunological protection from maternal milk. Infants perceived as growing well may receive NBMFs earlier if they appear to demand more feeding; mothers may also EBF for longer durations if they regard breastfeeding as causal to healthy growth[21]. This should be explored in future studies, and the present study sets a strong foundation for such research.

Because malnutrition is a significant contributor to infant and child morbidity and mortality, it is critical to regularly assess early life diet. Although breastfeeding is a common practice in The Gambia, high rates of undernutrition in children under five warrant continued investigations of particular feeding patterns and their possible determinants. Environmental conditions in The Gambia temporally affect many aspects of diet, health, and behavior. Birth month has been identified as a strong proxy of nutritional status, infectious diseases, and mortality in early life in this environment, but to our knowledge has not previously been investigated as a predictor of exclusive breastfeeding duration. We found evidence to suggest that the age at which NBMFs are introduced to the infant diet has a temporal pattern, potentially related to annual shifts in maternal agricultural workload in this population. Further research is warranted to further explore the significance of the observed seasonally driven effects of dietary patterns on infant health and growth outcomes in this region. The present exploration of longitudinal infant feeding data provides context for future research on such topics.

Data availability

Underlying data

OSF: Gates Open Research HERO-G Infant Complementary Feeding Paper https://doi.org/10.17605/OSF.IO/GVWF2[96]

This project contains the following underlying data:

- HERO-G_Infant-complementary-feeding-manuscript-extended-data-survey-questions.docx

Extended data

https://doi.org/10.17605/OSF.IO/GVWF2[96]

This project contains the following extended data:

- HERO-G_Infant-complementary-feeding-manuscript-raw-data.xlsx

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Open Peer Review

Current Peer Review Status: ? ✓

Version 1

Reviewer Report 18 August 2023

https://doi.org/10.21956/gatesopenres.15804.r34094

✓ **Rodrigo Vega-Sánchez**

Departamento de Nutrición y Bioprogramación, Instituto Nacional de Perinatología Isidro Espinosa de los Reyes, Ciudad de México, Mexico

Thank you for the opportunity to review this article by Jennifer R. Washabaugh and colleagues. This is a very interesting article where the authors describe infant breastfeeding practices and the timing of the introduction of complementary foods in a population from rural Gambian villages. The authors further explore some potential environmental and sociodemographic predictors of exclusive breastfeeding that may influence infant feeding decisions in this population.

The article is very clear and thorough when presenting the population context, methodological details, and results. The authors adequately discuss the article's limitations and the main differences between their findings and what has been reported for similar study populations, particularly in Gambia.

Rather than being a shortcoming, such differences highlight the need and importance of publishing articles such as this one, providing comprehensive descriptions of breastfeeding practices in regional settings worldwide, particularly in rural areas.

This is important not only for understanding specific contexts and eventually designing tailored nutritional interventions but also for challenging theoretical and methodological assumptions that may be drawn from different or broader settings. The authors adequately do this with regard to, for example, socioeconomic status, a variable traditionally measured through indicators such as maternal education, material wealth, employment, or household income.

The most salient result of the study was that being born in May, near the onset of the wet "hunger" season in The Gambia, significantly predicted shorter EBF duration. Such "seasonality", related to women's return to agricultural work, is of great interest. It speaks not only about environmental factors impacting infant feeding practices but also hints at larger sociocultural implications that may include women's labor and education, gender inequalities, childcare practices, social support, and many others.

I only have some minor comments and questions:

- A primary concern (and also a very simple one to address) is that no legend appears in Figure 4 in its current form. This makes it impossible for the reader to distinguish between and analyze the different NBMFs presented in the figure.

- Did the authors investigate any cultural or individual beliefs of the mothers around EBF and ICF?

  We have found such beliefs to be significant predictors of EBF/NBMFs in a rural area of southeast Mexico (Vázquez-Osorio et al. Front. Pediatr. 2022; Maas-Mendoza et al. Nutrients 2022).

  Based on the authors' statement that "Future analyses may benefit from analyses of... the transfer of knowledge between generations/sources of information that influence decisions to introduce NBMFs", I am under the impression that they may not have investigated such beliefs in the present study. However, could the authors please clarify and comment in this regard?

- Were there any differences in the study variables/outcomes between participants from different villages/areas?

- The study presents very interesting findings regarding the influence of seasonality and maternal workload on EBF. Are these types of findings currently taken into consideration (if at all) in programs that provide support and education to mothers, such as the Baby Friendly Community Initiative mentioned by the authors? Could the authors please comment in this regard?

Thank you again for the opportunity to review this article. I wish the authors all the best with their research.

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Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Nutrition during pregnancy and the first year of life. Sociodemographic factors that influence maternal eating behaviors and infant feeding practices.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 17 August 2023

https://doi.org/10.21956/gatesopenres.15804.r34098

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Cecília Tomori
Johns Hopkins University, Baltimore, Maryland, USA

Thank you for the opportunity to review this manuscript on an important topic. The study is well-conceptualized, the manuscript is clearly-written and the findings are compelling. Based on the work presented it appears that heavier seasonal agricultural labor demands are driving the introduction of NBMF and cessation of EBF. I agree with the authors that additional work is needed to explore this further, especially as perhaps a larger, mixed-methods study would provide more nuance in the variation in EBF practices in relation to agricultural labor (eg perhaps could provide a more fine-grained portrait of infant feeding during the “hungry” season).

There are a few areas where the paper could benefit from additional revision:

1. Colonial & postcolonial context - Currently the reader does not have adequate context in the introduction. Please briefly describe historical context in the area, especially as it pertains to root causes of poverty in the region, related to colonial exploitation and postcolonial dynamics. Have patterns of infant feeding and care shifted in the region over time? Have mothers in this region always struggled with this extent of agricultural labor, or has there been an increase over time? How much outmigration has been happening from this region? We have examples from the ethnographic literature (e.g. among the Beng, as well as others) where mothers’ agricultural workload has increased driven by these historical dynamics, and women increasingly have less time after birth to recover and get help from

others to do the intensive labor when their infants are young, whereas in the past they had more help from kin. It's important to provide a few sentences on this, since colonial and post-colonial dynamics are usually associated with major disruptions in kinship, infant care, labor patterns, and poverty.

2. Public health context - Additionally, what recent work has been carried out in the region in relation to maternity care and infant and young child feeding practices? This would be important to know upfront. The discussion has some information on this, which should be moved to the introduction and expanded as it has major relevance for the study's context. Some very important context comes quite late in the text. For instance:"The WHO (2009) reports significant success from implementation of BFCI initiatives in The Gambia with marked improvement in early initiation of breastfeeding and EBF to 4 months of age. Specifically, the adoption of certain BFCI strategies contributed to the increase in the national average of EBF from 0% in 1989, to 17.4% in 1998, to 36% in 200081; and 41% in 200620."

   However, the latest data here are quite old (2006). I would like to see data from the latest DHS, which seems to be from 2019-2020 and any other relevant IYCF/malnutrition prevention work in the region. There is some literature on this that I found with a brief search.

3. I agree strongly that qualitative work is needed to better understand how women make infant feeding decisions and would add that these data can also contextualize how these decisions may have changed over time.

4. There is rich recent literature on the determinants of growth faltering and the prevention and management of malnutrition, including a recently updated WHO guideline on this topic https://www.childwasting.org/normative-guidance . It would be helpful to incorporate a bit more of this literature in the introduction and especially the discussion. Relatedly, are any interventions planned to address growth faltering and malnutrition in the region?

5. In the discussion it would be very important to discuss the implications of the potential impacts of climate change in relation to the findings. What do the current and anticipated impacts of accelerating climate change mean for the future if no intervention is taken?

Minor issues:

1. References – some references are quite old. References should be reviewed again to make sure that the most current literature is cited when not discussing historical/prior issues. One important addition - the latest evidence on breastfeeding is collected in the 2023 Lancet Breastfeeding Series.

2. The text states that the full dietary questionnaire is detailed in Table 1 but Table 1 does not include this. Please correct.

3. Figure 4 does not have a key.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Anthropology & public health of breastfeeding and infant and young child feeding.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.