

Nutritional adequacy in rural Limpopo Province, South Africa: Maternal and child dietary diversity in the context of perinatal HIV exposure

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Background. Children younger than 5 years old are a vulnerable group whose growth is affected by nutritional intake. However, few studies have evaluated dietary diversity–a proxy measure of dietary adequacy–among HIV-exposed uninfected (HEU) and HIV-unexposed uninfected (HUU) children in resource-limited settings.
Objective. To measure dietary diversity in a cohort of HEU and HUU children in Limpopo.
Methods. Data were collected from 305 mother-child dyads enrolled in a cluster-randomised trial in rural Limpopo, South Africa. HIV exposure was based on maternal self-reported status. Height-for-age Z scores (HAZ) and weight-for-age Z scores (WAZ) were calculated using World Health Organization standards. Dietary diversity (DD) was defined as the number of different food groups consumed in the past 24 hours. Mean differences in outcomes between HEU and HUU children were estimated at 7 and 17 months of age.
Results. At 7 months, the mean DD was 2.30 (standard deviation 1.63) and showed no differences by sex or HIV exposure (HEU 2.26 (1.63) v. HUU 2.32 (1.63); p=0.08). At 17 months, the mean DD was 3.38 (1.62) and remained similar between HUU and HEU children (3.41 (1.57) v. 3.29 (1.82); p=0.333). No significant association was found between sub-optimal DD score (<5 of 8 food groups) and being underweight or stunted (p>0.05). At 7 months, compared with HUU children (n=234), HEU children (n=71) had a lower median HAZ of −0.54 (interquartile range (IQR) −1.21 - 0.11) v. median −0.1, IQR −0.76 - 0.99 (p<0.0001) and WAZ (median 0.50, IQR −0.27 - 1.24 v. 0.01, IQR −0.69 - 1.02; p<0.018).
Conclusion: At 7 months, DD was notable given the prevalence of early weaning. By 17 months, DD had improved, likely reflecting the children's psychological readiness to try various food combinations and textures at that age.

Keywords. HIV-exposed uninfected; HIV-unexposed uninfected; weight-for-age Z score; height-for-age Z score; food variety score; household dietary diversity.

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Food insecurity, poverty and exposure to infectious diseases such as HIV are well-known factors increasing malnutrition in children living in sub-Saharan Africa.[1] HIV is most prevalent in the African region, with ~70% of all infections occurring in sub-Saharan Africa.[2] Globally, ~1.4 million pregnancies are reported among women living with HIV each year. These infants face exposure and potential risk of HIV infection *in utero*, during labour and delivery, and through breastfeeding.[3] The advent of antiretroviral therapy (ART) has almost eliminated the transmission of *in-utero* HIV infection.[4] However, it remains unclear whether children exposed to the virus face any adverse outcomes.

The principles of infant and young child nutrition apply to all children, irrespective of their HIV status. From 6 months onward, breastfeeding alone cannot meet all the nutritional requirements of a developing child; therefore, the consumption of nutritionally adequate, diversified foods is necessary.[5]

The nutritional status of children is heavily influenced by caregivers, who must ensure adequate (quantity and diversity) and frequent feedings, as a single meal cannot meet the nutritional needs of children.[6] Child feeding practices are affected by many factors, including household-level food security, socioeconomic status (SES), and caregiver knowledge and understanding of nutrition and care practices.[7] In addition, traditional diets are increasingly being replaced by more modern diets, which are often high in sugars and fats but low in essential nutrients.[8] In South Africa (SA), the average diet tends to be energy-dense yet poor in micronutrients, placing individuals at risk of 'hidden hunger', characterised by a deficiency in essential vitamins and minerals.[9]

The United Nations Children's Fund (UNICEF) provides data on the percentage of children aged 6 - 23 months consuming at least 5 of 8 food groups (minimum dietary diversity) by country, type, and age category across Eastern and southern Africa. However, little is known about how SA compares with this regional estimate or whether it differs by HIV exposure.[10] Some studies in SA suggest that HIV-exposed but uninfected (HEU) children are more likely to have poorer dietary diversity,[11] possibly owing to the later introduction of complementary foods in HEU children.[12,13] We aimed to assess the consequences of maternal HIV infection on the growth of infants and toddlers.

Methods

Sampling

This cohort study was nested within a larger intervention trial (South African National Clinical Trials Register reference number 4407/PACTR201710002683810). The trial tested a package of community health worker (CHW) interventions, primarily centred on promoting early stimulation and positive mother-child interactions to assess their impact on child development during the first two years of life. Overall, 1 095 caregiver-child dyads were enrolled at birth between December 2018 and March 2019, and the children were followed for two years. Caregiver-child dyads were randomly assigned to either the intervention or control group at the level of ward-based outreach teams (WBOTs) (cluster), which included eligible CHWs who delivered the intervention and notified the study team of potentially eligible dyads. Details of the trial have been previously described.[14]

Caregiver-child dyads were invited to participate in a sub-study nested within the larger intervention study to determine the impact of the CHW home visits on child neurodevelopment. To be eligible for the sub-study, caregiver-child dyads had to meet the following criteria: the child was born to a mother aged at least 18 years, after 37 weeks of gestation, with a birthweight >2 500 g, and without a known genetic abnormality or neurological disorder. Dyads from Greater Tzaneen were invited to attend a centrally located laboratory for assessment visits at 7 and 17 months of age.

Household survey data were collected at baseline (2018) and at the end line (2021), when the children were 36 months old. Neurodevelopment assessments for the sub-study were conducted during lab visits at the end line (September 2020 - June 2021) and at two interim time points when the children were, on average, 7 months old (July - November 2018) and 17 months old (April - August 2019). This study focuses on data from 7 - 17 months, as previous research has shown a strong association between being underweight in the first two years and having lower body mass and height-for-age scores in later childhood.[15]

Study population

Data were collected from 317 caregiver-child dyads attending three study visits—just after birth (0 - 3 months old), at 7 months, and at 17 months of age. The cohort was further restricted to mothers who self-reported their HIV status and to children who were HIV-negative. Ultimately, 305 caregiver-child dyads were included.

Procedures

Data collection forms were used to gather demographic information, including age, education level, and household wealth, from mothers at enrolment (immediately after birth) at the household and again when the children were 7 and 17 months old during visits to the central laboratory in Tzaneen. Questions about food in the past 24 hours were drawn directly from the Food and Agriculture Organisation's Infant and Young Child Feeding (FAO's IYCF) 24-hour dietary recall questionnaire.[20] Surveys were available in English and then verbally translated into the local languages, Xitsonga and Sepedi, by trained local study staff, who administered the survey to the participants. The study team standardised the wording for the translations during the training and piloting phase. The local study team also recorded child length/height and weight measurements from the Road to Health Booklet at the household immediately after birth and again in the central laboratory when the children were 7 and 17 months old. Study data were collected and managed using REDCap, an electronic data capture tool hosted by the University of the Witwatersrand.[21]

Ethical considerations

Ethical clearance was obtained from the institutional review boards of Boston University (protocol no. 65), the Human Research Ethics Committee of the University of Witwatersrand (ref. no. M160251 and M180229) and the Limpopo Department of Health. All experiments were conducted in accordance with the relevant guidelines and regulations, including the Declaration of Helsinki. Written informed consent was obtained from all participants and/or their parents/legal guardians in their local languages, Sepedi and Xitsonga, with the help of local study staff who served as interpreters.

Study variables

Dietary diversity score (DDS) was based on 24-hour recall of the mother and child's consumption of food groups within the past 24 hours. Foods were categorized into nine groups, plus two additional groups were added based on UNICEF recommendations of breastmilk and formula milk being added as food groups. The food groups based on the Food and Agriculture Organisation's (FAO) infant and young child feeding (IYCF) recommendations include (*i*) starchy foods; (*ii*) vitamin A-rich vegetables and fruits; (*iii*) other fruits and vegetables; (*iv*) meat and flesh foods; (*v*) egg; (*vi*) legumes; nuts and seeds, (*vii*) milk and milk products; (*viii*) oil and fats, (*ix*) breastmilk, (*x*) formula milk and (*xi*) non-nutritional food. The consumption of each food group was transformed into binary variables to indicate whether food items from a particular group were consumed (1) or not (0). The DDS was obtained by summing the number of food and food items consumed in each group, with a total score ranging from 0 - 11.[22]

Individual DDS: Qualitative recall of the child's food consumption during the previous 24 hours was used to calculate the individual DDS when the children were 7 and 17 months old. The total score was used to classify the DDS as either adequate (≥5) or inadequate (<5).[10] Miscellaneous foods, defined as any food with little dietary fibre, protein, vitamins or minerals, and lacking essential nutritional value, were not included in the DDS calculation. For children <24 months, breastmilk was also considered a food group in the DDS assessment.

Maternal DDS: The mothers' 24-hour food recall at enrolment was used to calculate their DDS. Maternal dietary diversity consists of a simple count of food groups that a household has consumed over the preceding 24 hours, reflecting the household's dietary nutrient adequacy. The Food and Agricultural Organization (FAO)/International Fund for Agricultural Development (IFAD)/World Food Program (WFP) notes that there are no established cut-off points for low, medium or high DDS.[23] However, there is a consensus that higher DDS is desirable, as consuming a larger variety of foods or food groups helps meet daily nutrient requirements.[24] Based on this, the total DDS was classified as either adequate (≥5) or inadequate (<5).[10]

Data analysis

First, to describe the study population, we summarised the child and mother demographic characteristics at birth (0M). Next, we compared the characteristics by HIV exposure using the Student's *t*-test for parametric or normally distributed data, the Kruskal-Wallis test for non-parametric or data non-normally distributed, and the χ^2 or Fisher's exact test for proportions.

Third, to determine the association between characteristics at enrolment and HIV exposure, we used a log-binomial regression model to estimate the crude relative risk (RR) with the corresponding 95% confidence interval (95% CI).

Fourth, to compare growth outcomes and the proportion of children with inadequate DD at 7 and 17 months by HIV exposure status, we used the Student's *t*-test for parametric or normally distributed data, the Kruskal-Wallis test for non-parametric or non-normally distributed, and the χ^2 or Fisher's exact test for proportions.

Finally, to identify participant characteristics associated with poor outcomes, including inadequate household DD at enrolment, inadequate child DD at 7 and 17 months of age, and stunting at 17 months, we used log-binomial regression models to estimate the RR. We present the crude and adjusted RR and 95%CI. We used a purposeful selection of variables to reduce the full model to a more parsimonious final model. Variables with a *p*-value of <0.25 and other variables of known clinical relevance (e.g. SES and age)[25] were included in the multivariable analysis. A cut-off value of $p<0.25$ has been widely used.[26] Data were collected and imported into Stata version 14 (StataCorp, USA) and SAS version 9.3 (SAS Institute, USA) for analysis.

Results

Baseline data were collected from 317 mother-child dyads who attended the first three study visits—immediately after birth, at 7 months, and at 17 months of age. After excluding dyads that did not meet the criteria, only 305 dyads were included in the final analysis. Nine caregiver-child dyads were excluded as we needed the mother's HIV status to determine HIV exposure in children. Caregivers who were not mothers were unable to provide this information. We excluded any HIV-positive children. Three of the children had an unknown HIV status; hence, they were excluded from the analysis.

Child and mother sociodemographic characteristics

Of the 305 children included in the analysis, 50.3% were female, with a median birthweight of 3.1 kg (IQR 2.9 - 3.4) and a median birthlength of 50 cm (IQR 49 - 51). Additionally, 29.7% had no siblings. Of the total, 71 (23.2%) were HEU and 234 (76.8%) were HUU children.

HUU children had a smaller head circumference at birth (median 34 v. 35 cm; p=0.039) and were more likely to not have any siblings (33.3% v. 16.9%; RR 2.0 95% CI 1.15 - 3.44) compared with their HEU counterparts. Birth weightand birthlength were similar between HEU and HUU children (p=0.290 and p=0.926, respectively).

Over half of the mothers (median age 30, IQR 25 - 36 years) in this study were married, the majority (87%) had completed secondary or tertiary education, and only 11.8% were employed at enrolment (median 58 days, IQR 29 - 83 days after birth). Over half of the women had a low SES, 46% of households reported no income, 32% were receiving a child grant, 10.5% reported food insecurity, and 37.3% had an inadequate women's dietary diversity score (WDDS) (Table 1).

Mothers who were HIV positive (n=71; 95.6% on ART) were slightly older than uninfected mothers (median age 33, IQR 28 - 38 years v. 29, IQR 24 - 35; p=0.003). At enrolment, HIV-infected and uninfected mothers were similar in terms of employment status (10.0% v. 12.4%), marital status (being single, divorced, separated or widowed) (36.8% v. 44.3%), receiving a government grant in the past month (26.8% v. 33.8%), reporting no source of household income (51.4% v. 44.2%) and having a low WDDS (38% v. 37.3%). Compared with uninfected mothers, mothers who were HIV positive were less likely to have completed secondary or tertiary education (76.1% v. 90.8%; RR 0.84 95% CI 0.73 - 0.96) and more likely to report food insecurity (21.3% v. 7.3%; RR 2.91 95% CI 1.47 - 5.78).

Food group consumption

Dairy products, eggs, meat, legumes and fruits were the least consumed food groups, while starches were the most consumed food group among both mothers and children.

At enrolment, the WDDS obtained from the mothers' 24-hour food recall showed that more HIV-positive mothers (80%) consumed flesh and flesh foods compared with HIV-negative mothers (62%). In other words, HIV-positive mothers were 1.2 times more likely to have consumed flesh foods. Additionally, 22% of HIV-positive mothers consumed eggs compared with 10% of HIV-negative mothers, making HIV-positive mothers three times more likely to consume eggs. Consumption of other food groups was similar between HIV-positive and negative mothers ($p>0.05$). The mothers' 24-hour food recall at enrolment showed that 37.3% of households in the study had inadequate household dietary diversity.

At 7 months of age, 79.2% of HUU were still consuming breastmilk, compared with 59.2% of HEU children (p=0.001). On the other hand, 50.7% of HEU children were consuming formula milk, compared with 36.0% of HUU children (p=0.022). At 7 months, 22.5% of HEU were consuming some form of non-nutritionally dense food (classified as junk food), compared with 28.6% in HUU children (p=0.286). The consumption of other food groups was similar between HEU and HUU children ($p>0.05$).

At 17 months of age, 42.0% of HUU children were still consuming breastmilk compared with 21.3% of HEU children (p=0.003). Formula milk at 17 months was consumed by 37.7% of children in the HEU group and 22.0% of those in the HUU group (p=0.013). A third of HUU and HEU children were consuming non-nutritionally dense foods at 17 months of age, with a 10% increase in consumption among HEU children compared with their intake at 7 months.

At 7 months of age, 1 (1.5%) HEU child and 6 (2.6%) HUU children were underweight for age (p=0.562). The prevalence of stunting at 7 months was similar between the two groups, n=4 (5.6%) in the HEU group and 14 (6.0%) in the HUU group. The individual DDS at 7 months ranged from 1 - 10 over 12 possible range groups, with a median DDS of 2.0 (IQR 1 - 3). The majority (90.1%) of the children had inadequate DDS (Table 2).

At 17 months of age, three children from the HEU group were underweight, while one child from the HUU group was underweight (p=0.013). Regarding stunting, 10 children from the HEU group were stunted, while 40 children from the HUU group were stunted, but no significant differences were noted between the groups ($p>0.05$). The individual DDS at 17 months ranged from 1 - 9 over 12 possible groups, with a median DDS of 3.0 (IQR 2.0 – 4.0). Approximately two-thirds of the children had an inadequate DDS, indicating a less than adequate diverse diet.

Factors associated with poor outcomes

Inadequate maternal DDS at enrolment

Mothers with secondary or tertiary education were significantly less likely to have inadequate women's DD (RR 0.62 95% CI 0.51 - 0.77). Similarly, those with the highest SES were less likely to experience inadequate women's DD (RR 0.71 95% CI 0.55 - 0.93) compared

Table 1. Participant characteristics at birth, stratified by exposure to HIV (*N*=305)

	HUU (*n*=234), *n*(%)	HEU (*n*=71), *n*(%)	Total (*N*=305), *n*(%)	*p*-value
Child's characteristics				
Head circumference at birth, median (Q1 - Q3)	34.0 (33.0 - 35.0)	35.0 (34.0 - 36.0)	34.0 (33.0 - 35.0)	0.039*†
Birthweight, median (Q1 - Q3)	3.1 (2.9 - 3.4)	3.0 (2.9 - 3.3)	3.1 (2.9 - 3.4)	0.290†
Birthlength, median (Q1 - Q3)	50.0 (49.0 - 51.0)	50.0 (49.0 - 52.0)	50.0 (49.0 - 51.0)	0.926†
Siblings				
None	78 (33.3)	12 (16.9)	91 (29.7)	0.036*‡
One or more	154 (65.8)	59 (83.1)	213 (69.6)	
Sex§				
Boy	117 (50.9)	32 (45.1)	150 (49.7)	0.393‡
Girl	113 (49.1)	39 (54.9)	152 (50.3)	
Mother's characteristics				
Marital status				
Married	126 (53.9)	43 (60.6)	169 (55.4)	0.274‡
Not in a relationship	100 (42.7)	25 (35.2)	125 (41.0)	
Other/unknown	8 (3.4)	3 (4.2)	11 (3.6)	
Education (highest grade completed)				
Primary or lower	21 (9.2)	17 (23.9)	39 (13.0)	0.001*†
Secondary/tertiary	208 (90.8)	54 (76.1)	262 (87.0)	
Employment				
Not employed	204 (87.6)	63 (90.0)	268 (88.2)	0.579‡
Employed	29 (12.4)	7 (10.0)	36 (11.8)	
Social welfare				
No child grant	155 (66.2)	52 (73.2)	208 (68.0)	0.269‡
Receiving child grant	79 (33.8)	19 (26.8)	98 (32.0)	
Socioeconomic status				
Low	118 (50.4)	47 (66.2)	166 (54.3)	0.065‡
Medium	33 (14.1)	7 (9.9)	40 (13.0)	
High	83 (35.5)	17 (23.9)	99 (32.7)	
Food security				
Secure	190 (92.7)	48 (78.7)	238 (89.5)	0.002*‡
Insecure	15 (7.3)	13 (21.3)	28 (10.5)	
Source of household income				
No income	102 (44.2)	36 (51.4)	139 (46.0)	0.285‡
Income from employment	129 (55.8)	34 (48.6)	163 (54.0)	
Mother's age, median (Q1-Q3)	29.0 (24.0 - 35.0)	33.0 (28.0 - 38.0)	30.0 (25.0 - 36.0)	0.003*†
18 - 34	173 (74.9)	43 (60.6)	216 (71.5)	0.019‡
35+	58 (25.1)	28 (39.4)	86 (28.4)	
Missing	3 (1.3)	0 (0.0)	3.0 (1.0)	
WDDS, median (Q1 - Q3)	4.0 (3.0 - 5.0)	4.0 (3.0 - 5.0)	4.0 (3.0 - 5.0)	0.908†
Inadequate WDDS	87 (37.2)	27 (38.0)	114 (37.3)	0.736‡
Adequate WDDS	147 (62.8)	44 (62.0)	89 (29.1)	
Missing	38 (16.2)	16 (22.5)	54 (17.7)	
Depressive symptoms, median (Q1 - Q3)	1.0 (0.0 -3.0)	1.0 (0.0 - 3.0)	1.0 (0.0 - 3.0)	0.052†
Yes	19 (8.1)	4 (5.6)	23 (7.5)	0.487‡
No	215 (91.9)	67 (94.4)	282 (92.5)	
Household size, median (Q1 - Q3)	6 (5 -8)	5 (4 - 7)	6.0 (5.0 - 8.0)	0.358†
<6 persons	83 (35.5)	39 (54.9)	122 (40.0)	0.003‡
≥6 persons	151 (64.5)	32 (45.1)	183 (60.0)	
Household head				
Yes	34 (14.3)	19 (43.2)	53 (18.9)	0.284‡
No	203 (86.7)	25 (56.8)	228 (81.1)	

*p-value<0.05
HUU = HIV-unexposed uninfected; HEU = HIV-exposed uninfected; WDDS = women's dietary diversity score; Q1= quartile 1; Q3 = quartile 3.
†Student's *t*-test was used for parametric or normally distributed data.
‡Kruskal-Wallis, χ^2 or Fisher's exact tests were used for non-parametric data or data that are not normally distributed.
§HIV exposure was not known for four children.

Table 2. Anthropometric and dietary diversity at 7 and 17 months by HIV exposure

Variables	Total (*N*=305), *n*(%)	HUU (*n*=234), *n*(%)	HEU (*n*=71), *n*(%)	*p*-value
7 months				
WAZ, median (IQR)	0.4 (−0.5 - 1.2)	0.5 (−0.3 - 1.2)	−0.7 (−1.0 - 1.0)	0.018*
Underweight	7 (2.3)	6 (2.6)	1 (1.5)	0.562†
Normal	284 (92.8)	216 (92.3)	67 (98.5)	-
Missing	15 (4.9)	12 (5.1)	3 (4.2)	-
HAZ, median (IQR)	−0.12 (−1.0 - 0.7)	−0.1 (−0.8 - 1.0)	−0.5 (−1.2 - 0.1)	0.001**
Stunted	18 (5.9)	14 (6.0)	4 (5.6)	0.907†
Normal	270 (88.2)	206 (88.0)	63 (88.7)	-
Missing	18 (5.9)	14 (6.0)	4 (5.6)	-
DD, median (IQR)	2.0 (1.0 - 3.0)	2.0 (1.0 - 3.0)	2.0 (1.0 - 3.0)	0.840
Adequate	28 (9.2)	21 (9.0)	7 (9.9)	0.951†
Inadequate	276 (90.2)	211 (90.2)	64 (90.1)	-
Missing	2 (0.6)	2 (0.8)	-	-
17 months				
WAZ, median (IQR)	0.2 (−0.6 - 0.8)	0.1 (−0.6 - 0.8)	0.2 (−0.5 - 0.9)	0.923
Underweight	4 (1.3)	1 (0.5)	3 (4.2)	0.013*
Normal	261 (85.3)	203 (86.8)	58 (81.7)	0.04†
Missing	41 (13.4)	30 (12.8)	10 (14.1)	
HAZ, median (IQR)	−0.8 (−1.6 - 0.1)	−0.6 (−1.6 - 0.1)	−0.9 (−1.6 - −0.2)	0.776
Stunted	50 (16.3)	40 (17.1)	10 (14.1)	0.573†
Normal	215 (70.3)	164 (70.1)	51 (71.8)	-
Missing	41 (13.4)	30 (12.8)	10 (14.1)	-
DD, median (IQR)	3.0 (2.0 - 4.0)	3.0 (2.0 - 4.0)	3.0 (2.0 - 4.0)	0.329
Adequate	62 (20.3)	48 (20.5)	14 (19.7)	0.146†
Inadequate	204 (66.7)	157 (67.1)	47 (66.2)	
Missing	39 (12.7)	29 (12.4)	10 (9.3)	

*$p<0.05$
**$p<0.01$
HUU = HIV-unexposed and uninfected; HEU = HIV-exposed uninfected; HAZ = height-for-age Z-score; IQR = interquartile range; WAZ = weight-for-age z-score; DD = dietary diversity.
†Calculated using χ2 or Fisher's exact tests.

with households with low or medium SES. In contrast, older mothers (>35 years) were more likely to have an inadequate women's DD (RR 1.50 95% CI 1.23 - 1.84) compared with younger mothers (18 - 35 years). However, after adjusting for other variables, younger mothers, those from high SES, and mothers reporting depressive symptoms shortly after birth were more likely to experience inadequate women's DD (Table 2).

Inadequate child DD at 7 months of age

Employed mothers were more likely than unemployed mothers to have children with inadequate DDs (RR 1.18 95% CI 1.03 - 1.30). Additionally, children not receiving any milk feeds at 7 months were more likely to have inadequate DD (RR 1.11 95% CI 1.07 - 1.16). After adjusting for *a priori* variables, only the lack of milk feeds at 7 months remained significantly associated with inadequate DD (RR 14.83 95% CI 13.99 - 15.68) (Table 2).

Inadequate child DD at 17 months of age

Employed mothers were less likely to have children with inadequate DD at 17 months (RR 0.73 95% CI 0.53 - 0.98). Similarly, children from households with the highest SES were less likely to have inadequate DD (RR 0.82 95% CI 0.69 - 0.97). In the adjusted analysis, children from households where mothers were not the head were also less likely to have inadequate DD at 17 months (RR 0.20 95% CI 0.05 - 0.86).

Stunting at 17 months of age

Children whose mothers reported being food secure were likely to be stunted at 17 months, as were children with adequate DD 118 (76%) v. 23 (68%) ($p=0.471$). However, these associations became non-significant after adjusting for other variables.

Bivariate analysis showed that maternal education, occupation, family income, and wealth score were positively associated with DD scores (Table 2). Every 1-year increase in maternal age was associated with decreased household DD (RR 1.50 95% 1.23 - 1.84; $p<0.001$). At 7 months, no significant differences in DD were observed. Wealthier households at baseline had more diverse diets for both mother and children at 17 months. Interestingly, children with more siblings also had more diverse diets at 17 months. No single food was identified as increasing the risk of stunting or being underweight at 7 months. Maternal depressive symptoms did not appear to influence children's DD.

Discussion

This study examined whether household DD and individual DD in children are associated with growth patterns among HEU v. HUU children in rural Limpopo. The analysis aimed to assess growth and explore how factors such as SES, household size, caregiver depression, and nutritional adequacy (measured through DD) might affect HEU and HUU children differently. The results showed that HEU and HUU households were generally similar in DD and maternal and child characteristics, likely owing to their shared community context. Higher SES and increased maternal education were associated with greater DD. However, no significant associations were found between DD and stunting or being underweight among children based on their HIV exposure status *in utero*.

Our study found that only 20% of children aged 7 months, and 36.9% of those aged 17 months in rural Limpopo achieved the recommended minimum DD. There were no significant differences between HEU and HUU children. At 7 months, DD is often low as children are still learning to eat and may not yet be able to consume solid foods.[27] The continuation of breastfeeding is supported beyond the 6 months during the complementary feeding period, as breastmilk provides high-fat content compared with most complementary foods. It remains an essential source of energy, as well as essential fatty acids and micronutrients.[9] For children aged 12 - 23 months, breastmilk can supply 35 - 40% of daily energy requirements, which is particularly beneficial in low-income settings.[28]

This study highlighted important differences in breastfeeding practices between HEU and HUU children, which warrant further research. In particular, a higher percentage of HUU children consumed breastmilk compared with HEU children at both 7 and 17 months, with a gap of ~20% between the groups. This discrepancy may stem from HIV-positive mothers' fear of transmitting the virus through breastfeeding, leading to its avoidance. In food-insecure families, breastfeeding remains the most economical infant feeding strategy.[5] Breastmilk supplies the ideal nutrition and protects against common childhood infections such as diarrhoea and pneumonia. Therefore, early cessation of breastfeeding poses significant risks for infants in resource-poor settings.[29]

Our findings align with other studies that showed a positive association between DDS, maternal education, and SES indicators.[30] However, we found no association between DDS and household income or food security. This may be because of the uniformly low-income levels among participants and the potential reliance on local food production rather than purchased foods. Additionally, educated mothers likely possess greater nutritional knowledge and better caregiving practices, leading to improved nutrition outcomes. Our study observed higher DDS among those with more education, aligning with findings from another study.[31]

Animal-source foods such as meat, milk, eggs, and poultry are rich in essential micronutrients, including vitamin A, vitamin B12, riboflavin, calcium, iron, and zinc—nutrients that are challenging to obtain in adequate quantities from grain, tubers, and vegetables.[32] In our study, about half of the participants consumed flesh foods or eggs the day before the survey. Additionally, HIV-positive mothers were significantly more likely to consume flesh foods and eggs than HIV-negative mothers in this study.

After adjusting for other variables, none of the associations remained significant. This may indicate collinearity and confounding within the population, suggesting that the groups were highly similar, making it difficult to detect differences. These findings highlight that, regardless of HIV exposure at birth, nutrition education is crucial to promote DD and encourage improved nutritional practices among mothers.

Strengths and limitations

We used well-validated and rigorously developed questionnaires in our study, which controlled for potential bias. Data from the 24-hour recall may not represent the long-term dietary habits of the caregivers and their children and only estimate intake. Recall bias was mostly avoided by the short recall period. However, it may still have contributed to an underestimation of dietary intake. Using a food frequency questionnaire or a weighted 24-hour recall could have provided a better understanding of dietary intake and allowed for the calculation of nutrient intakes.

Conclusion

This study revealed that the dietary diversity in the first 2 years of life is still a point of concern; this population might not well understand the implications of the cessation of breastfeeding by HIV-exposed mothers. Ending breastfeeding prematurely limits the energy available to the child and abruptly weaned children might suffer from malnutrition and hunger if families/households are food insecure. The South African Department of Health should ensure that community health workers and health promoters emphasise key messages about breastfeeding and weaning foods for HIV-positive mothers. Additionally, interventions to improve the growth of HEU children should target both pregnant women and their children.

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Author contributions. NM conceived and designed the analysis, analysed the data and wrote the manuscript with support from DE. RP, AT, DH, AY, GF and DE conceived the trial and sub-study, and were in charge of overall direction and planning. LC supervised the implementation of the research and data collection. AR and MG contributed to review and editing. All authors discussed the results and contributed to the final manuscript.

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Data availability statement. The datasets generated and/or analysed during the current study are not publicly available as the data are owned by the study sites (universities) and the National Department of Health (South Africa) and governed by the Human Research Ethics Committee (University of the Witwatersrand, Johannesburg, South Africa). All relevant data are included in the paper, but the full data are available from the Health Economics and Epidemiology Research Office for researchers who meet the criteria for access to confidential data and with permission from the custodians of the data. Contact the organisation at information@heroza.org for additional information regarding data access.

Conflicts of interest. None.

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