Food Insecurity and Early Childhood Development among Children 24-59 months in Nigeria: A Multilevel Mixed Effects Modelling of the Social Determinants of Health Inequities

Otobo I. Ujah[1,2], Omojo C. Adaji[3], Innocent A.O. Ujah[2], Russell S. Kirby[1]

[1] College of Public Health, University of South Florida, Tampa, Florida, USA

[2] Department of Obstetrics and Gynaecology, Federal University of Health Sciences, Otukpo, Nigeria

[3] Sightsavers, Abuja, Nigeria

* Correspondence: otobo@usf.edu; otoboujah@yahoo.com

Abstract

Prior studies have demonstrated the consequent impact of food insecurity (FI) for child development. Yet, there is paucity of evidence quantifying this association based on the recently designed Early Development Index 2030 (ECDI2030). Herein, we provide national estimates of early childhood development (ECD) risks using the ECDI2030, and examined to what extent FI was associated with ECD among children aged 24-59 months in Nigeria. This population based cross-sectional analyses used data from the UNICEF-supported 2021 Multiple Indicator Cluster Survey in Nigeria. The analytic sample comprised children aged 24-59 months (Unweighted N = 11494). We measured early childhood development for each child using the ECDI2030, measured across three domains: learning, psychosocial well-being and health. Food insecurity was assessed using the Food Insecurity Experience Scale (FIES), categorized as none, moderate and severe. We fitted mixed-effects multilevel logistic regression models, with random intercepts, to estimate the odds of association between FI status and ECD. A total of 11494 (weighted N = 12112) children aged 24-59 months (mean [SE] age, 43.1 [0.1] months), including 5797 boys (50.2%) and 5697 girls (49.9%), were included in the study. Approximately 46.4% of children were developmentally off track and about 76% of children lived in food-insecure households. The intercept-only model demonstrated statistically significant variation in the prevalence of ECD (τ_{00} = 0.94, intraclass correlation = 0.21, $p < 0.0001$), suggesting nonignorable variability in ECD across communities. Adjusting for confounders, we observed no significant association between FI and ECD. However, increasing child's age and disability status appeared as significant risk factors for higher odds of children being developmentally off track. While the findings from this study suggest that the association between FI and ECD in children aged 24-59 months in Nigeria remains inconclusive, they indicate that ECD in Nigeria is influenced by a combination of compositional and contextual factors.

Keywords: Social Determinants of Health, Early Childhood Development, ECDI2030, **Food Insecurity Experience Scale**, Multiple Indicator Cluster Survey (MICS)

Introduction

Food insecurity (FI), characterized by limitations or uncertainties in accessing food in adequate quantity and quality or, inability to access food in socially acceptable ways, is a growing and pervasive public health crises [1-4]. According to a recent report by the United Nations Food and Agriculture Organization (UN FAO), approximately 2.4 billion people globally experienced moderate or severe FI in 2022 [5]. Food insecurity is particularly acute and persistent in Sub-Saharan Africa (SSA). In 2022, approximately two out of three individuals in SSA countries experienced moderate to severe FI, and one in four experienced severe FI [5].

There is a growing concern about the detrimental impacts of FI on child performance and development [6-10]. For instance, one study in Canada showed that children from households experiencing very low FI had a 35% lower odds of meeting expectations for reading and 38% lower odds of meeting expectations for mathematics [11]. Furthermore, FI is intricately linked to poverty and malnutrition [9]. Evidence shows that approximately 250 million children under 5 years of age globally were not developmentally “on track” due to extreme poverty and stunting [12]. Notably, Nigeria, Ethiopia, DR Congo, and Tanzania were among the top 10 out of 28 Sub-Saharan African (SSA) countries in 2010 with the highest prevalence (> 60%) of children at risk of poor development [12]. More recently, a study in Ecuador found that preschool children experiencing marginal and moderate-severe FI had a 29% and 30% higher prevalence of reporting overall developmental delay, respectively [9]. This association also varied by the literacy-numeracy, social-emotional, physical and cognitive development ECD domains.

Aurino and colleagues have described several plausible interconnected pathways linking FI and ECD [13]. First, FI may result in poor dietary quality, leading to impaired cognitive and psychosocial well-being. Second, FI within contexts of financial hardships can result in limited investment in early childhood education resources, hindering child development. Furthermore, food-insecure caregivers experience higher stress levels, thereby reducing the quality and

quantity of interactions with children. Lastly, children experiencing FI may demonstrate signs of psychological distress, lowering interaction quality with parents, teachers, and peers.

Early childhood development forms the foundation for the development of cognitive, motor, and social-emotional skills and, thus, remains central to the ability of individuals to survive, thrive and flourish during adulthood [12, 14, 15]. Despite the pressing need for public health interventions to address FI in SSA and its potential implications for ECD, there is currently paucity of robust and high-quality evidence quantifying the impact of FI on ECD in many parts of SSA [13], particularly in the Nigerian context. The lack of such evidence precludes the design and implementation of programs and policies needed to support national efforts in attaining the benchmarks set in the Sustainable Development Goals 2.1 and 4.2 [5]. Moreover, with the recent launch of the early child development index 2030 (ECDI2030) and its implementation in population-based surveys [16], there is need to extend current evidence as it concerns the relationship of ECD with FI. Framed by the socio-ecological model [17], we used population level data from Nigeria to answer the following questions:

1. How much variation in ECD among children 24-59 months is attributable to socio-ecological factors in Nigeria?
2. Is food insecurity associated with ECD among children 24-59 months in Nigeria, after adjusting for adjusting for social-ecological factors?
3. What are the key social-ecological factors associated ECD among children 24-59 months in Nigeria?

By addressing these questions, we aim to contribute to extended current understanding of the mechanisms underlying the relationship between FI, socio-ecologic factors and children development, which ultimately could inform intervention efforts, such as early stimulation, responsive care and nutrition interventions, for children with poor developmental delay exposed to HFI [18]. In addition, considering that an important indicator for SDG 4.2 is measuring

developmental progress in health, learning, and psychosocial well-being specifically among children aged 24–59 months [19], the present study focused on children within this age group.

Theoretical framework

From a theoretical perspective, ECD, as with other health behaviors and outcomes, occurs within an ecological framework that is influenced by a complex interplay of individual, family and broader contextual variables. Based on this, we draw directly from the Ecological Systems Theory (EST) proposed by Bronfenbrenner to guide the conceptual and empirical aspects of our study. According to EST, human development occurs within a complex set of relationships influenced by multiple interacting environmental factors [17].

Generally and in the context of ECD, these factors could occur at one or more levels of the microsystem (age, sex, race/ethnicity, education), mesosystem (parental education, religion, household income), exosystem (community level socioeconomic status, availability of early childhood education and care programs) and the broad macrosystem (government policies and legislation) levels [20-22]. The EST has been used across a diverse range of health behaviors and outcomes including condom use [23], mental health [24], food insecurity [25], physical activity [26] and sleep [27]. For the purposes of this study, the EST provides a compelling framework with which we can conceptually and methodologically examine factors across multiple intersecting levels of influence associated with ECD. Importantly, this framework will guide our analytic strategy and as well provides a framework to aid the interpretation of our findings and inform how these findings can be applied to shape public health interventions aimed at optimizing development in early childhood.

Methods

Study design and data source

In this cross-sectional study, we performed a secondary analysis of nationally representative data drawn from Round 6 of the Multiple Indicator Cluster Survey (MICS6) conducted in 2021 in Nigeria which was sponsored by UNICEF and implemented by the

National Bureau of Statistics (NBS). The MICS is a population-based household survey which collects nationally representative data on social and health indicators in low- and middle-income countries (LMICs) from representative samples of households, men, women and children. The survey employed a multistage stratified cluster design.

In the first stage, 2076 primary sampling units (PSUs) were randomly selected from the 2006 Population and Housing Census of the Federal Republic of Nigeria (NPHC). In the second stage, 20 households were randomly selected from each PSU using a probability proportional-to-size sampling. Data collection was performed using Computer-Assisted Personal Interviewing (CAPI) technology, with face-to-face interviews conducted in the households of respondents. Documentation regarding the Nigerian MICS sampling design and data collection techniques can be found elsewhere [28]. For this study, we merged child dataset, which contained variables related to ECD outcomes with household dataset which contains data on HFI. The datasets used in this study are publicly available from the MICS website (https://mics.unicef.org/).

Ethical considerations

The MICS protocol was approved by the National Bureau of Statistics (NBS) and UNICEF. According to the 2021 MICS6 report [28], all participants provided verbal consent, including minors aged 15-17 years, who required prior adult consent. Participants were informed about the voluntary nature of participation, data confidentiality, anonymity, and their right to refuse questions or terminate the interview. Although this study involves human participants, IRB review and approval were not required as it is based on an analysis of secondary data, and prior ethical approval had been obtained by the primary data collectors.

Analytic sample

Among all children under 5 years of age participating in the MICS6, all boys and girls aged 24-59 months in MICS6 were eligible for inclusion in the analysis (19463/33103). We further restricted the analysis to participants with complete and valid data for sociodemographic characteristics, maternal characteristics, overall ECD2030 scores and FI. Thus, for this study, a

total of 11494 children aged between 29-59 months (weighted *N* = 12112) belonging to 9539 households nested within 1718 clusters were included in the study (**Fig 1**). The respondents for the information of these children were either their mothers or the caregivers.

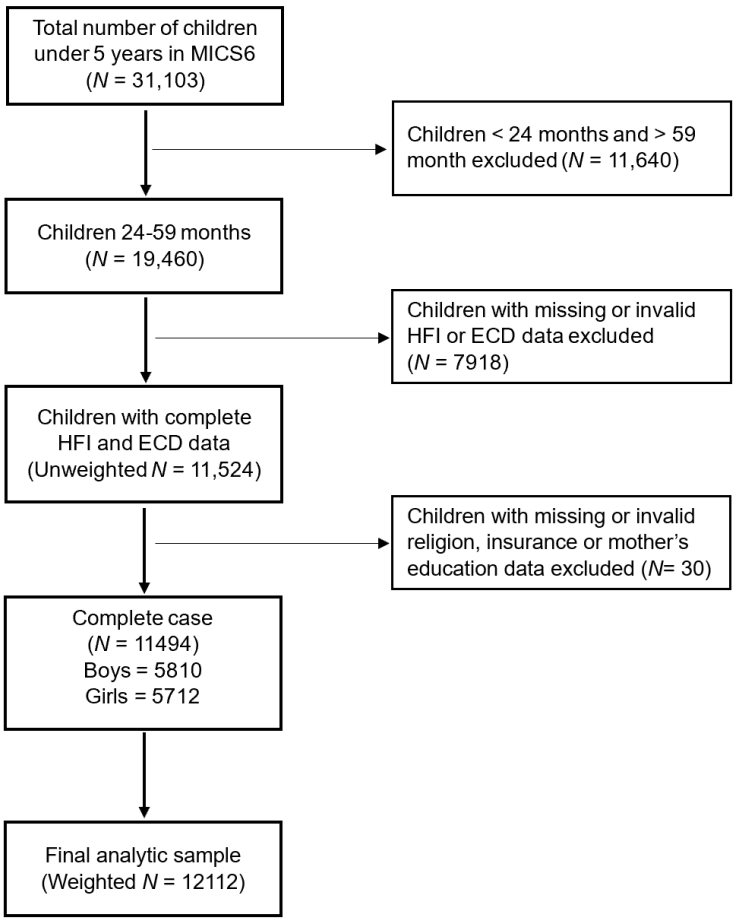

Fig 1: Flow chart depicting the selection of study participants for a study of the association between food insecurity and early children development (ECD) among children 24-59 months in Nigeria, Multiple Indicator Cluster Survey (MICS6), 2021.

Outcome assessment: Early Childhood Development (ECD)

We measured Early Childhood Development (ECD) outcomes using the 20-item Early Childhood Development Index (ECDI) 2030. The ECDI2030, launched in 2020, is a comprehensive caregiver-reported tool used to generate country-level estimates of the **percentage of children aged 24 to 59 years** who are developmentally on track, relative to their age, across the domains of health, learning, and psychosocial well-being [16]. The ECDI2030 consists of 20 questions, each designed to measure specific developmental constructs within each domain (**Table 1**). The ECDI2030 was recently included in the Nigeria MICS6 in 2021 and is useful for monitoring and reporting progress of SDG proxy indicator 4.2.1 – "*proportion of children aged 24–59 months who are developmentally on track in health, learning and psychosocial well-being, by sex*". Further details of the ECDI2030 have been published elsewhere [16]. Based on the single age-specific ECDI summary score generated, we defined a 2-category variable of ECD, classifying children as developmentally "on track" or "not on track" per the ECDI2030 guidelines.

Table 1. Domains, items and scoring of the ECDI2030 used in MICS6, Nigeria, 2021		
Domain	**Items**	**Scoring**
Learning	Can (name) say at least ten or more words like “Mama” or “ball”?	1
	Can (name) speak using sentences of three or more words that go together, for example, “I want water” or “The house is big”?	1
	Can (name) speak using sentences of five or more words that go together?	1
	If you show (name) an object he/she knows well, such as a cup or animal, can he/she consistently name it?	1
	Can (name) correctly use any of the words ‘I,’ ‘you,’ ‘she,’ or ‘he’, for example, “I go to the store,” or “He eats rice”?	1
	Can (name) recognize at least five letters of the alphabet?	1
	If you ask (name) to give you three objects, such as three stones or three beans, does (he/she) give you the correct amount?	1
	Can (name) count 10 objects, for example, 10 fingers or blocks, without mistakes?	1
	Does (name) know all numbers from 1 to 5?	1
	Can (name) write his/her own name?	1
	Can (name) do an activity such as colouring without repeatedly asking for help or giving up too quickly?	1
Psychosocial well-being	Does (name) get along well with other children?	1
	Does (name) ask about familiar people other than parents when they are not there, for example, “Where is Grandma?”?	1
	Does (name) offer to help someone who seems to need help?	1
	How often does (name) seem to be very sad or depressed?	1
	Compared with children of the same age, does (name) kick, bite or hit other children or adults?	1
Health	Can (name) dress him/herself, that is, put on pants and shirt without help?	1
	Can the child fasten and unfasten buttons without help?	1
	Can (name) jump up with both feet leaving the ground?	1
	Can (name) walk on an uneven surface, for example, a bumpy or steep road, without falling?	1

Adapted Early Childhood Development Index 2030 (ECDI2030): Percentage of children aged 24 to 59 months who have achieved the minimum number of milestones expected for their age group (Children aged 24-29 months: 7 of the 20 items; Children aged 30-35 months: 9 of the 20 items; Children aged 36-41 months: 11 of the 20 items; Children aged 42-47 months: 13 of the 20 items; Children aged 48-59 months: 15 of the 20 item)
Source: The Early Childhood Development Index 2030: A New Measure of Early Childhood development, https://data.unicef.org/resources/early-childhood-development-index-2030-ecdi2030/

Exposure assessment: Food Insecurity

The primary independent variable of interest in this study was household FI within the past 12 months, assessed using the widely validated 8-item Household Food Insecurity Experience Scale (FIES) developed by the United Nations Food and Agriculture Organization (UN FAO). The FIES is a tool used to estimate the prevalence of moderate or severe food insecurity within populations, consistent with Sustainable Development Goal (SDG) indicator 2.1.2. Participants were asked questions regarding their household's food security status over the preceding 12 months. These questions covered whether there was a time when they or members of their household could not afford healthy and nutritious food due to financial constraints, if their household experienced food shortages due to limited financial resources, or if they or others in their household went without eating for an entire day in the past-year due to financial constraints (**Table 2**). Response options for each question in the FIES included "*Yes*", "*No*" or "*Don't know*". Composite household food insecurity scores were derived by summing the affirmative responses, yielding a score range from 0-8. In this study, FI was categorized based on the FIES score as none/mild, moderate or severe FI.

Table 2. Description Food Insecurity Experience Scale (FIES) used in the Multiple Indicator Cluster Survey (MICS), 2021

FIES Indicators	Short Reference	Description
Q1	WORRIED	During the last 1 year, was there a time when you or others in your household worried about not having enough food to eat because of a lack of money or other resources?
Q2	HEALTHY	During the last 1 year, was there a time when you or others in your household were unable to eat healthy and nutritious food because of a lack of money or other resources?
Q3	FEWFOODS	During the last 1 year, was there a time when you or others in your household ate only a few kinds of foods because of a lack of money or other resources?
Q4	SKIPPED	During the last 1 year, was there a time when you or others in your household had to skip a meal because there was not enough money or other resources to get food?
Q5	ATELESS	During the last 1 year, was there a time when you or others in your household ate less than you thought you should because of a lack of money or other resources?
Q6	RANOUT	During the last 1 year, was there a time when your household ran out of food because of a lack of money or other resources?
Q7	HUNGRY	During the last 1 year, was there a time when you or others in your household were hungry but did not eat because there was not enough money or other resources for food?
Q8	WHLDAY	During the last 1 year, was there a time when you or others in your household went without eating for a whole day because of a lack of money or other resources?

Confounding variables

The covariates used in this study were defined *a priori* based on previous studies [6, 7, 10, 29], selected based on their availability in the dataset, and organized according to three levels of the EST into: microsystem, mesosystem and exosystem. The microsystem variables included child level characteristics such as age in months (24-29, 30-35, 36-41, 42-47, 48-59), sex (boy or girls), disability status (no functional difficulty, functional difficulty), health insurance coverage (not covered, covered). Mesosystem variables included number of children in household (1, ≥2), religious affiliation (Christian or Non-Christian), mother's educational attainment (less than secondary, secondary and higher than secondary) and household wealth quintile (1,2,3,4 or 5). Contextual or exosystem level variables include place of residence (rural or urban) and geographic region of residence (North Central, North East, North West, South East, South South or South West).

Statistical analysis

Data analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC) and R software (version 4.3.0). We applied sampling weights to the survey data using the weights assigned to each child in the Nigeria MICS6 survey. We used the SAS PROC SURVEY commands to apply these weights by incorporating the effects of weights, clustering and stratification to calculate the means and standard errors (SE) as well as frequencies and percentages (%). We further examined between-group differences for categorical variables using the Rao-Scott Chi-squared test of association.

Multilevel Model building strategy

Given the hierarchical structure of the data from the MICS, with children (*i*) nested within communities (*j*) and considering the dichotomous nature of the outcome variable reporting developmentally on track or not, we specified several two-level logistic regression models with random intercepts. These models were adjusted for both microsystem, mesosystem and exosystem level characteristics. We used SAS PROC GLIMMIX with a binomial distribution and

the LOGIT link function. All models in this study were estimated using the maximum likelihood approach (METHOD = LAPLACE). We also employed the CONTAINMENT approximation option (DDFM = CONTAIN) to estimate the degrees of freedom for the fixed effects.

Our modeling approach began by specifying a null (unconditional) model, excluding any predictors, to assess between-community variation in ECD and to determine the appropriateness of a multilevel modeling approach. Subsequently, we developed more complex conditional models by sequentially including predictors. Model I included the main exposure variable – FI, Model II included Model I and adjusted for microsystem-level factors, while Model III incorporated Model II and adjusted for mesosystem-level variables. Lastly, Model IV was the fully adjusted model which included Model III with adjustments for exosystem-level factors. Fixed effects are represented as crude and adjusted odds ratios (ORs) along with their corresponding 95% confidence intervals (CIs). All tests were two-tailed and p-values < 0.05 were considered statistically significant.

We assessed random effects for ECD using three standard metrics – intraclass correlation coefficient (ICC), Median Odds Ratio (MOR), and Proportional Change in Variance (PCV). The ICC quantifies the proportion of total observed variability in ECD status that can be attributed to between-community variability (Austin & Merlo, 2017). The MOR, on the other hand, measures the variability between communities by comparing two individuals randomly selected from different communities while the **PCV** estimates the variation explained by the multilevel models. The calculate the PCV, the τ_{00} value for conditional models (Models I-IV) were compared to that of the previous model [$\tau_{00(n-1)}$ - $\tau_{00(n-2)}$/$\tau_{00(n-1)}$], where τ_{00} is the between-cluster variability. To assess the goodness of fit of the different models, we used the Akaike Information Criterion (AIC). Smaller AIC values indicated better-fitting models.

Results

Sample characteristics

Data were analyzed from a sample of 11494 children (weighted to represent 12112 children aged 24-59 months). The mean age (SE) was 43.1 [0.1] months. The child, maternal/family and contextual level characteristics of the study participants are shown in Table 1. Approximately 49.9% of the sample were girls while 50.1% were boys and nearly two-thirds of the children were between the ages of 24-48 months. Most children (> 95%) were not covered by health insurance and were not reported to have a functional difficulty.

Slightly more than one-half (55.7%) had less than secondary education and at least two out of three children resided in households with 2 or more children under 5 years of age (66.1%) and in households whose religious affiliation was Christianity (60.3%). About 44% of children residence in households with poor wealth index. About two-thirds (62.5%) of the children resided in households located in the rural areas while 34.7% resided in households located in the North West region. A total of 2629 children (23.5%) were in food secure households, while 3567 (31.9%) and 5298 (44.6%) were living in households experiencing moderate and severe FI, respectively.

In our sample, the mean ECDI2030 score was 11.98 (range 2-20, SD 3.54). Based on individual ECD domain, the mean learning score was 5.77 (range 1-11, SD 2.25), the mean health score was 2.53 (range 0-4, SD 1.18) while the mean psychosocial well-being score was 3.68 (range 1-5, SD 1.01). For children who were developmentally on track, the mean ECDI2030 score was 13.77 (SD 3.31) and 10.04 (SD 2.65) for children who were developmentally off track.

Table 1 also shows the univariate associations between ECD and the characteristics of the study participants. In this study, 6498 (53.6%) children were developmentally on track, and 5614 (46.4%) were not on track ($p < 0.0001$). Children who were developmentally on track were more likely to live in food secure households, while those who were not developmentally on track were slightly more likely to live in households experiencing severe FI (Table 1). **Fig 2** shows the weighted prevalence of affirmative responses to each items of the FIES based on

ECD status among children in the sample. There were statistically significant differences between the ECD categories and each item of the FIES ($p < 0.05$) except for “ATELESS”, “RANOUT” and “HUNGRY”. In addition, **Fig 3** depicts the prevalence of ECD status according to HFI status among children 24-59 months in Nigeria.

All the confounding variables exhibited differential distribution regarding the outcome variable – early childhood development (Table 1). When comparing across early child development categories, children who were not developmentally on track were more likely to be older, face functional difficulties, have mothers with less than a higher level of education, reside in households with two or more children under 5 years of age, be affiliated with a religion other than Christianity, reside in poor households, and live in rural areas and in the Northern region ($p < 0.001$; Table 1).

Table 2: Characteristics among children aged 24-59 months old by early childhood development status, Multiple Indicator Cluster Survey, 2021 (N = 11494).

	Overall		Early Childhood Development (ECD) status				
			On Track *N* = 6498 53.6%		Not On Track *N* = 5614 46.4%		*p* value
Characteristics	Unweighted *N*	Weighted %	*N*	%	*N*	%	
Household food insecurity							
None	2629	23.5	1626	25.0	1175	21.7	**0.0297**
Moderate	3567	31.9	2038	31.4	1827	32.5	
Severe	5298	44.6	2834	43.6	2569	45.8	
Sex							
Boy	5797	50.2	3226	49.6	2848	50.7	0.43
Girl	5697	49.8	3272	50.4	2766	49.3	
Age, months							
24-29	1381	12.3	1242	19.1	249	4.2	**<0.0001**
30-35	1308	11.5	935	14.4	460	8.2	
36-41	2208	19.9	1429	21.9	976	17.3	
42-47	1759	15.5	866	13.3	1005	17.9	
48-59	4838	40.9	2026	31.2	2925	52.2	
Disability status							
No functional difficulty	11188	97.4	6394	98.4	5402	93.2	**<0.0001**
Functional difficulty	306	2.6	104	1.6	212	3.8	
Health insurance coverage							
No	11177	96.6	5532	95.2	6189	98.5	**<0.0001**
Yes	317	3.2	309	4.8	82	1.5	
Mother's education level							
Less than secondary	6707	55.7	2785	42.9	3963	70.5	**<0.0001**
Secondary	3707	32.6	2580	39.7	1370	24.5	
Higher secondary	1080	11.7	1133	17.4	281	5.0	
Number of children < 5 years in household							
1	3726	33.9	250	38.7	1596	28.4	**<0.0001**
2 or more	7796	66.1	3988	61.3	4018	71.6	
Religious affiliation							
Christianity	4809	39.7	3251	50.1	1558	27.8	**<0.0001**
Other	6896	60.3	3247	49.9	4056	72.2	
Household wealth index							
1 (Poorest)	3112	23.2	1005	15.5	1875	33.4	**<0.0001**
2	2766	21.7	1137	17.5	1486	26.5	
3	2443	19.9	1296	19.9	1121	19.9	
4	1837	17.6	1414	21.8	718	12.8	
5 (Richest)	1336	16.9	1646	25.3	413	7.4	
Place of residence							
Rural	7566	62.5	3387	52.1	4188	74.6	**<0.0001**
Urban	4546	37.5	3120	47.9	1426	25.4	
Geographic region							
North Central	2144	12.9	800	12.3	770	13.7	**<0.0001**

North East	2799	16.1	838	12.9	1106	19.7
North West	3119	34.7	1689	25.9	2517	44.8
South East	1082	10.1	825	12.7	395	7.0
South South	1183	11.3	963	14.8	407	7.2
South West	1167	14.9	1382	21.3	418	7.5
Number of observations (unweighted sample)			11494			
Population size (weighted sample)			12112			
No. of primary sampling units (PSUs)			1718			
No. of strata			37			

Notes: Percentages (%) and 95% confidence intervals (CIs) are weighted to adjusted for the complex design of the survey

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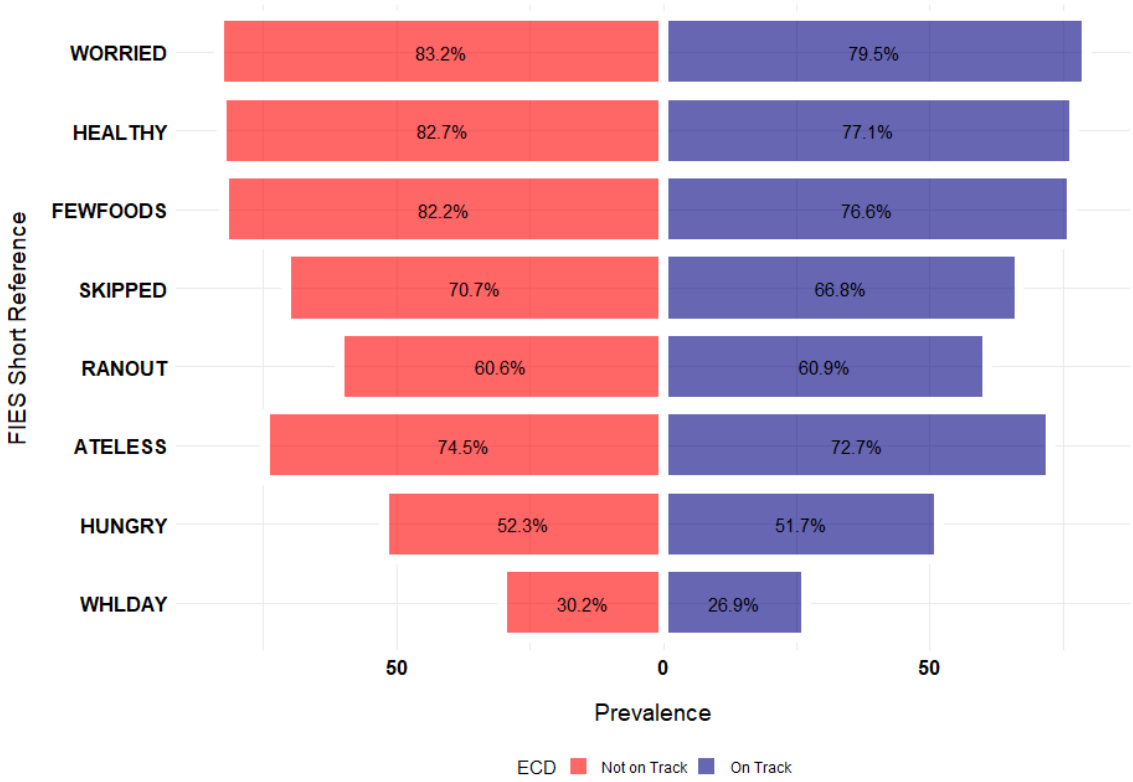

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289 **Fig 2.** Single items of the FIES among children 24-59 months who were developmentally on
290 track and not on track

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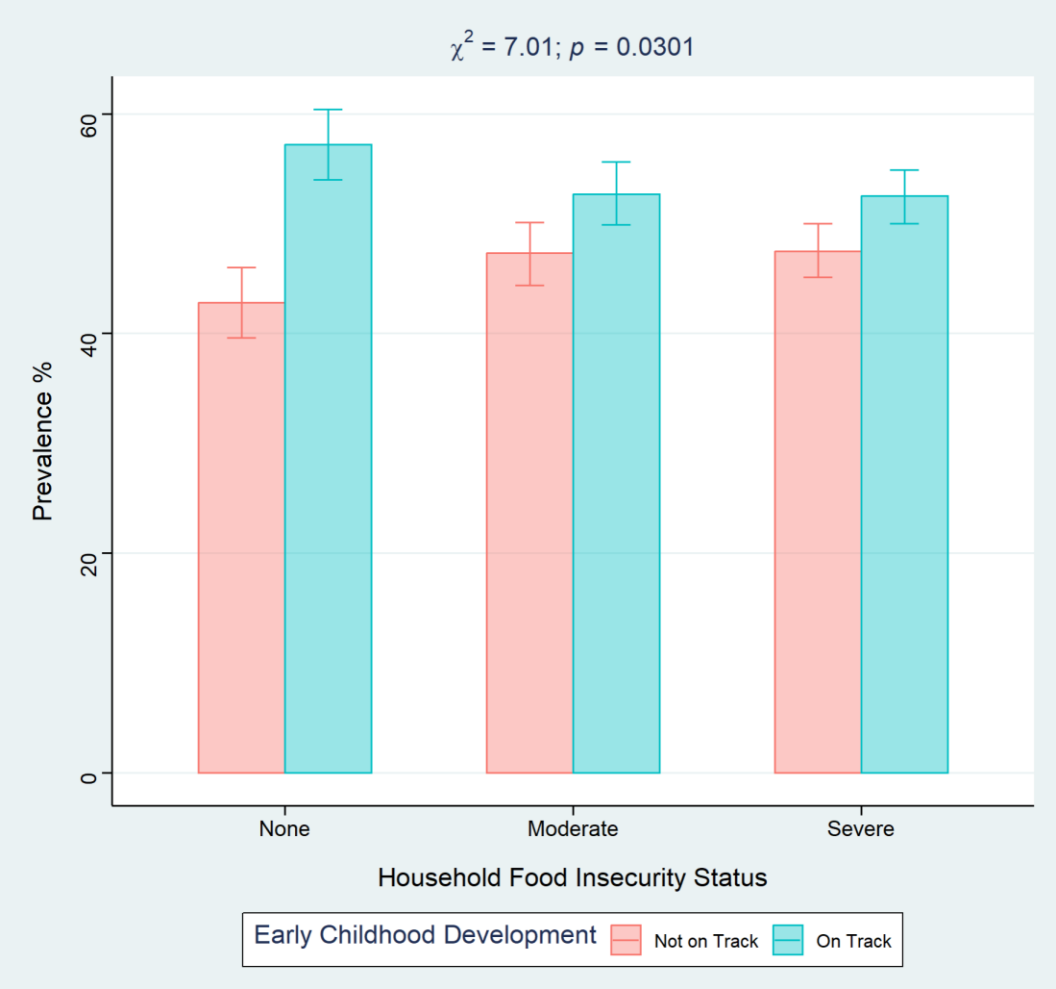

Fig 3. Weighted prevalence of early childhood development status according to household food insecurity status among children 24-59 months in Nigeria. Error bars represent 95% confidence intervals

Multilevel analysis

Measures of association (fixed effects)

Table 3 presents the estimated intercept for the empty model, which was 0.22. This suggests that in a typical community, where the random effect on the logit scale is zero, the odds of children aged 24-59 months being developmentally off track were 1.25, corresponding to a probability of 0.56. Table 3 presents the results of the multilevel logistic regression analysis for HFI and ECD. The crude model (Model I) shows that increasing HFI status was associated with increasingly higher odds of being developmentally off track. Specifically, children who lived in households experiencing moderate FI vs No FI had a 22% higher odds of being developmentally off track (OR = 1.22; 95% CI: 1.07-1.39) while those who lived in households experiencing severe FI vs No FI had a 26% higher odds of being developmentally off track (OR = 1.26; 95% CI: 1.11-1.42). However, after accounting for child, maternal/family and contextual level factors (Table 3, Model IV), these associations between HFI status and ECD status were no longer statistically significant.

From Table 3, Model IV (the fully adjusted model) was the model which had the best fit for the data based on the AIC (13383.82) and BIC (13520.04) values, and therefore will be used to answer the remaining research questions. In the final model which fully adjusted for the effects of child, maternal/family and contextual level characteristics, child's age, disability status, mother's level of educational attainment, religious affiliation, household wealth index, place of residence and region of residence were significantly associated with the odds of children being developmentally off track. At the child level, the odds of being developmentally off track increased with each age category. Specifically, the odds were 2.78 times higher among those aged 30-35 months (aOR = 2.78, 95% CI = 2.25-3.43), 3.47 times higher among those aged 36-41 months (aOR = 3.47, 95% CI = 2.85-4.22), 8.38 times higher among those aged 42-47 months (aOR = 8.38, 95% CI = 6.84-10.27), and 8.28 times higher among those aged 48-59 months (aOR = 8.28, 95% CI = 6.90-9.94). Furthermore, children who had functional difficulty

were 2.5 times (aOR = 2.54; 95% CI = 1.88-3.43) more likely to be developmentally off track compared to children with no functional difficulty.

At the maternal/family level, children born to mothers with secondary education had a 33% lower likelihood of being developmentally off track compared to those born to mothers with less than secondary education (aOR = 0.67; 95% CI = 0.60-0.76). Additionally, children born to mothers with higher than secondary education had a 55% lower likelihood of being developmentally off track than those born to mothers with less than secondary education (aOR = 0.45; 95% CI = 0.37-0.56). Furthermore, children residing in households affiliated with Christianity were 26% lower odds of being developmentally off track compared to children in non-Christian households (aOR = 0.74; 95% CI = 0.64-0.86). The odds of being developmentally off track decreased with increasing household wealth index. The odds of being developmentally off track among children from the poorer households were 16% lower higher (aOR = 0.84; 95% CI = 0.74-0.96), from middle income households 33% lower (aOR = 0.67; 95% CI = 0.58-0.78), from the richer households 46% lower (aOR = 0.54; 95% CI = 0.45-0.65) and from richest households 69% (aOR = 0.31, 95%CI = 0.25-0.39) compared to children from the poorest households.

At the contextual level, the odds of being developmentally off track were 20% lower for children residing in urban areas compared to their counterparts residing in rural areas (aOR = 0.80; 95% CI = 0.69-0.92). Furthermore, the odds of being developmentally off track differed by region. Children residing in the North East had 16% lower odds (adjusted odds ratio [aOR] = 0.84; 95% CI = 0.71-0.99), those in the South East had 33% lower odds (aOR = 0.67; 95% CI = 0.53-0.85), those in the South South had 42% lower odds (aOR = 0.58; 95% CI = 0.47-0.72), and those in the South West had 69% lower odds (aOR = 0.45, 95% CI = 0.36-0.56), all compared to children in the North Central.

Measures of variation (random effects)

Table 4 presents estimates of the random effects from the multilevel analysis. The probability of children 24-59 months being developmentally off track varied across communities, as indicated by the statistically significant variability in the likelihood of being developmentally on track across communities [$\tau 00 = 0.8595$, $z(1717) = 12.51$, $p < 0.0001$]. Approximately 21% of the total variability in the odds of children being developmentally on track was attributed to systematic differences across communities (ICC = 0.21), leaving 79% of the variability to be accounted for by individual differences or other unknown factors. The between-cluster variability declined across successive models, from 21% in the unconditional model to 22.6% in the child-level only model, 10.9% in the maternal/family-level only model, and 10.1% in the fully adjusted model. In the null model, the MOR was estimated to be 2.42. This implies that children residing in a community characterized by being developmentally on track had 2.42 times higher odds of being developmentally on track compared to a child residing in a community where children were not developmentally on track. After including child, maternal/family, and contextual level characteristics in the model, the median odds ratio (MOR) decreased to 1.79. This indicates that the effect of clustering remains statistically significant in the fully adjusted model. Notably, the PCV indicated that the addition of child, maternal/family and contextual level characteristics to the empty model explained approximately 7.9% of the variability in the early childhood development in Nigeria.

Table 3: Results from the two-level logistic regression models investigating the association between household food insecurity and development in early childhood, adjusting for child, maternal/family and contextual level factors among children 24-59 months in Nigeria, *N* = 11494

Outcome variable: Early Childhood Development (Reference = On Track)										
	Null Model[a]		**Model I[b]**		**Model II[c]**		**Model III[d]**		**Model IV[e]**	
Variables	Odds		OR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Fixed effects										
Intercept[†]	**0.79**	**0.75-0.85*** **	**0.68**	**0.60-0.76*** **	**0.14**	**0.11-0.17*** **	**0.41**	**0.33-0.51*** **	**0.43**	**0.34-0.55*** **
Food insecurity status										
None			1.00		1.00		1.00		1.00	
Moderate FI			**1.22**	**1.07-1.39****	**1.18**	**1.03-1.35***	1.04	0.91-1.19	1.05	0.91-1.20
Severe FI			**1.26**	**1.11-1.42****	**1.22**	**1.07-1.39****	0.98	0.86-1.12	1.00	0.88-1.14
Child characteristics										
Age, months										
24-29					1.00		1.00		1.00	
30-35					**2.66**	**2.15-3.27*** **	**2.74**	**2.22-3.37*** **	**2.78**	**2.25-3.43*** **
36-41					**3.61**	**2.96-4.41*** **	**3.45**	**2.83-4.20*** **	**3.47**	**2.85-4.22*** **
42-47					**8.12**	**6.62-9.98*** **	**8.29**	**6.77-10.15*** **	**8.38**	**6.84-10.27*** **
48-59					**8.49**	**7.06-10.21*** **	**8.12**	**6.77-9.75*** **	**8.28**	**6.90-9.94*** **
Sex										
Boy					1.00		1.00		1.00	
Girl					0.97	0.89-1.05	0.97	0.89-1.06	0.97	0.89-1.06
Disability status										
No functional difficulty					1.00		1.00		1.00	
Functional difficulty					**3.08**	**2.27-4.18*** **	**2.66**	**1.97-3.59*** **	**2.54**	**1.88-3.43*** **
Health insurance coverage										
No					**1.00**		1.00		1.00	
Yes					**0.38**	**0.27-0.53*** **	0.80	0.56-1.13	0.80	0.57-1.12
Maternal/family characteristics										
Mother's education level										
Less than secondary							1.00		1.00	
Secondary							**0.64**	**0.57-0.72*** **	**0.67**	**0.60-0.76*** **

Higher secondary	**0.44**	**0.36-0.54*** **	**0.45**	**0.37-0.56*** **
Number of children < 5 years in household				
1	1.00		1.00	
≥ 2	**1.11**	**1.01-1.23***	1.07	0.96-1.18
Religious affiliation				
Other	1.00		1.00	
Christian	**0.60**	**0.54-0.68*** **	**0.74**	**0.64-0.86*** **
Household wealth index				
1 (Poorest)	1.00		1.00	
2	**0.81**	**0.71-0.92****	**0.84**	**0.74-0.96***
3	**0.58**	**0.50-0.67*** **	**0.67**	**0.58-0.78*** **
4	**0.43**	**0.36-0.51*** **	**0.54**	**0.45-0.65*** **
5 (Richest)	**0.23**	**0.18-0.28*** **	**0.31**	**0.25-0.39*** **
Contextual level characteristics				
Place of residence				
Rural			1.00	
Urban			**0.80**	**0.69-0.92****
Geographic region				
North Central			1.00	
North East			**0.84**	**0.71-0.99***
North West			1.11	0.94-1.31
South East			**0.67**	**0.53-0.85****
South South			**0.58**	**0.47-0.72*** **
South West			**0.45**	**0.36-0.56*** **

Notes: Estimation method = Maximum likelihood; Containment degrees of freedom; All estimates are weighted for the survey's complex sampling design. Boldface indicates statistically significant results at the 0·05 level.
Abbreviations: OR – odds ratio, aOR – adjusted odds ratio CI–confidence interval.
[a] Null model unconditional model, baseline model without any predictor variables
[b] Model I – includes the main explanatory variable (HFI)
[c] Model II – Model I adjusted for only child-level characteristics
[d] Model III – Model II adjusted for only maternal/family-level characteristics
[e] Model IV – Model III adjusted for contextual-level characteristics (full model)
[†] Estimates presented as odds
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Table 4. Results from the random intercept model (measure of variation) for early childhood development at cluster level by multilevel logistic regression analysis

Random effects	**Null model**	**Model I**	**Model II**	**Model III**	**Model IV**
Cluster-level variance (SE)	0.86 (0.07)	0.86 (0.07)	0.96 (0.08)	0.40 (0.05)	0.37 (0.05)
p value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
ICC (%)	20.71	20.77	22.64	10.90	10.12
MOR	2.42	2.42	2.55	1.83	1.79
PCV (%)	-	-33.74%	-11.65	58.22	7.93
Model fit statistics					
AIC	15277.08	15264.23	14191.51	13470.29	13383.82
BIC	15287.98	15286.03	14251.44	13573.82	13520.04

Abbreviations: ICC-Intraclass correlation coefficient, MOR–Median Odds Ratio, PCV– Proportional Change in Variance, AIC–Akaike Information Criteria; BIC–Bayesian Information Criteria
[a] Null model unconditional model, baseline model without any predictor variables
[b]Model I – includes the main explanatory variable (HFI)
[c]Model II – Model I adjusted for only child-level characteristics
[d]Model III – Model II adjusted for only maternal/family-level characteristics
[e]Model IV – Model III adjusted for contextual-level characteristics (full model)

Discussion

In many parts of SSA, including Nigeria, both HFI and suboptimal child development outcomes pose substantial risks. The results presented in this paper represent, to our knowledge, one of the earliest nationally representative population-based studies to use the newly designed ECDI2030 measure to empirically investigate the association between HFI and ECD. Additionally, this study tests a multilevel model predicting ECD based on various factors across socio-ecological systems. Approximately 46% of children in the sample were developmentally off track. This estimate is higher than the 37.9% prevalence of developmental delay among children in Nigeria reported in a previous study [30]. Our estimate appears to be consistent with estimates reported in previous studies. For instance, a recent multi-country study utilizing data from the Demography and Health Survey (DHS) across 9 low and middle-income countries (LMICs), which measured ECD using the original ECDI, found that the prevalence of children who were developmentally off track ranged from 7% in the Maldives to 59% in Burundi [10]. In Bangladesh, a recent studies showed at least 25% of children 3-4 years were not developmentally in track [31, 32].

Notably, we found that the child, maternal/family and contextual level factors play an important role in explaining the variations in ECD in children 24-59 months in Nigeria. Our results indicate one-fifth of the variation in ECD was attributable to contextual-level factors. This variation, although slightly lower, is fairly consistent with that reported in a previous population-based study in Nigeria showing significant clustering at the state level, with nearly one-third (29%) of the variation in ECD accounted for by differences across states [33]. Similarly, a study in Nepal showed that about 19% of the variation in ECD status was due to systematic differences between communities [34]. It is, however, important to note that the variations in estimates of the prevalence and the degree of geographic clustering in the measures of ECD outcomes in these studies compared with the results of our analysis are likely due to the population included in the analytic sample (i.e., children 36-59 months) as well as the measures

of ECDI used. Nevertheless, these findings align with Bronfenbrenner's EST, which posits that proximal contexts, within which individuals' behaviors are nested, play a crucial role in determining outcomes [17, 35]. Hence the need to carefully consider the role of context during the design of policies and interventions to improve ECD outcomes in Nigeria.

While the effect estimates from the unadjusted model showed children aged 24-59 months living in households experiencing moderate and severe FI were more likely to have higher odds of being developmentally off track, Controlling for all other multilevel factors, we found a null association between HFI and ECD. A previous study among children <36 months in Brazil also showed no association between FI and ECD (aOR = 0.79, 95% CI = 0.56-1.11) [36]. Although these findings contrast with the results of other studies, several conceptual and methodological limitations in these previous study could explain the disparities in the results. These limitations include variations in the study design, the composition and size of the analytic sample, methods of measuring and defining HFI and ECD, data structure, analytical approaches, and whether data were collected at the population or individual level. For example, a recent study in Ecuador reported strong and significantly higher associations between marginal and moderate-severe FI and global (overall) developmental delay among children age 36-59 months [9]. Several studies in Bangladesh, Ghana and Kenya employing longitudinal study designs have also reported statistically significant associations between HFI and children's development [13, 37, 38]. However, the diversity of the study samples in terms of age, as well as the inclusion of varied aspects/domains of child development not included in commonly used population based surveys in these prior studies, limits the extent to which their findings can be directly compared to the results of our study. This suggests that individual domains of early childhood development may be more strongly linked to HFI rather than the overall broad ECDI.

A plausible explanation for the lack of an association between HFI and ECD could be attributed to variations in the measures of ECDI utilized. Compared to our study which used the

newer ECDI2030 measure of ECD, researchers in previous studies using data from population-based surveys employed the ECDI utilized a 10-item scale across four domains. The ECDI2030 expanded the number of items in the original ECDI, thereby capturing more constructs across different, albeit interrelated, domains from the original ECDI. This observation has been noted in the study by [10]. Moreover, opinions are divided on the accurate definition and timing of early childhood [39].

Another reason could be that measures of HFI may not adequately capture the extent of FI or the level of hunger experienced specifically by children, potentially leading to an overestimation of FI among this demographic and consequently, a null association with ECD and ultimately misleading inferences. Moreover, FI is measured as a household condition while hunger is an individual experience [40]. Therefore, while children who are hungry are likely to be food insecure, not all children living in food insecure households experience hunger [40]. Indeed, within food insecure households, parents are likely to shield children from experiencing FI [41]. Thus, it remains a concern whether emphasis should be placed on household or individual levels of food deprivation. Regardless of whichever construct is used, there is need for valid and reliable instruments that better capture food deprivation during childhood, as these will further our understanding of which better predicts ECD outcomes especially in SSA.

Our results also depict a relatively homogeneous sample, with a substantial portion experiencing moderate or severe FI. This homogeneity may contribute to the lack of association observed between HFI and ECD and thereby reflecting the high prevalence rates of HFI across Nigeria. Furthermore, it is plausible that the impact of food insecurity on ECD may vary depending on the child's age. For younger children, the effect of past-year FI on ECD might be evolving, whereas for older children, past-year FI may not adequately capture deviations in ECD. Thus, age-related differences in the timing and measurement of food insecurity could influence its association with ECD outcomes.

Shifting our focus to factors associated with ECD, our results indicate that several factors across within and across multiple level of the ecological model were independently associated with ECD among this population. At the child/individual level our results showed significant positive associations of not being developmentally on track with increasing child's age and those with functional difficulty. This finding is consistent with other population-level studies conducted in different contexts. For example, a study among children in Ghana, Costa Rica and Bangladesh has shown that older children were less likely to achieve their developmental potential compared to their younger counterparts [42]. These findings are in contrast with the results in published studies showing children being developmentally on track with increasing age [43]. This is puzzling as evidence suggests that brain development occurs with increasing age [43]. However, a recent study showed children 4-5 years old in the UK were less likely to achieve their development potential in 2021 compared to the pre-pandemic period [44]. It is therefore likely that the disruptions associated with the COVID-19 pandemic could have had unintended consequences for ECD outcomes in Nigeria. Interestingly, our findings did not reveal sex differences in ECD and this has also been reported in a previous study [13].

At the maternal/family/household level our results indicate increasing levels of education attainment as a significant predictor of ECD. Similar findings have been documented prior studies literature [29, 45-47]. One hypothesized mechanism explaining the relationship between maternal education and ECD, based findings from a study in Uganda, suggests that increase in the years of maternal education is likely to improve investments and engagement of mothers in stimulating activities, thereby reducing their application of harsh corporal punishment and non-home discharge [45]. Furthermore, another study which attempted to examine the differential effect of paternal versus maternal education on ECD showed that, after adjusting for child and household factors, both maternal and paternal education were positively and significantly associated with children's ECDI scores through their personal or partners efforts to support children's early learning [48]. Moreover, maternal education may exert a synergistic effect with

household wealth index to improve ECD, as evidence suggests that wealthier and well educated mothers were more likely to seek early engagement of their children in early child education programs, which in turn is associated with a improved ECD [49].

We observed that children in households affiliated with other regions other than Christianity were less likely to be developmentally on track. Evidence comparing differences in ECD by religious affiliation is lacking. However, it has been argued that children, particularly those from Muslim-affiliated households, may experience dietary restrictions during their early years and may also be exposed to fasting in utero during periods of Holy observances. These factors, coupled with women's limited autonomy and control of household resources, may contribute to the high rate of childhood malnutrition [50, 51], consequently adversely impacting Early Childhood Development (ECD). Moreover, a study in India has shown that Christian children under 5 years of age were less likely to be stunted relative to their non-Christian counterparts, an effect which was more evident among girls than for boys [52]. Further analysis would be needed to understand the underlying reasons behind the effect of religion and ECD.

A major contribution of this study is also the simultaneous examination of broader contextual (neighborhood) influences on ECD. We also found that neighborhood factors such as living in households in urban areas appear to be protective against developmental delays in early childhood, findings which have also been echoed in prior studies documenting rural residence was associated with lower ECD outcomes in Nigeria [33], Ghana [53], Vietnam [47] and China [54]. Furthermore, the reasons behind why residing in the Northern region is associated with higher odds of being developmentally off track are not fully understood, as reported also by another study in Ghana [55], although it is possible that sub-national disparities in early childhood education and care could explain this finding. More broadly, it could also reflect a higher unmet need (in terms of accessibility and affordability) for programs that could enhance development in early childhood. These stated mechanisms are, however, at best, speculative and therefore warrant further investigation.

Taken together, our study's results underscore the complex interaction of micro-, meso- and macro-level factors which shape ECD in Nigeria and again, are consistent with the propositions of the Bronfenbrenner's Ecological Systems Theory. As studies examining development in early childhood using the SDG ECDI2030 are currently lacking globally, the results presented in this paper signal an important contribution to the existing but scant body of knowledge. By elucidating the role of several factors across multiple levels of influence on ECD, we extend current knowledge that could help address disparities in ECD outcomes for children in Nigeria.

Strengths and limitations

The multilevel approach employed in our investigation enabled us to simultaneously examine intra-, interpersonal, and broader contextual influences that could predict the likelihood of children being developmentally off track. Furthermore, our statistical approach allowed us to address the non-independence and inherent clustering in our data, thereby avoiding the generation of spurious estimates. By doing so, we were able to disentangle the contextual and compositional determinants of ECD, which more or less would not be accounted for in more conventional single-level approaches. Also, our study benefited from a large sample size, which provided substantial statistical power to detect group-level differences. With exposure and outcome variables ascertained using standardized and well-validated measures, our analysis offers reliable estimates that are robust and can be generalized to the population of children aged 24-59 months in Nigeria.

Several limitations of our study threaten the validity of our results. We did not examine whether and to what extent HFI was associated with the individual ECDI2030 domains. Therefore, whether the inferences drawn from our study can be extended to the association between HFI and the learning, health, and psychosocial well-being domains of the ECDI2030 remains open for future lines of research. Relatedly, the ECDI2030, though measuring an array of constructs, is limited to three domains, hence the findings may not be generalizable in the

context of other facets of child development not captured by this measure. Our inability to account for unmeasured variables in our analysis could have confounded our estimates of the association between HFI and ECD, thus potentially influencing the inferences drawn from our study. Additionally, it is important to note child anthropometric measures were expunged during the MICS6 [28], therefore we lacked data on important variables such as stunting, wasting and undernutrition which could have improved the robustness of our findings. Furthermore, as our study's results are derived from population level data, the extent to which our findings may be valid and useful in clinical and community settings remains uncertain. Considering the cross-sectional nature of our data, we are unable to account for the effect of timing and duration of FI on ECD. Therefore, together with the exploratory approach employed to identify ecological correlates, it is important to interpret the effect estimates from the model outputs as mutually adjusted associations rather than as causal relationships to avoid "*Table 2 fallacy*" [56].

Implications for public health

Although the dichotomous measure of ECDI2030 enables comparability with the SDG benchmark, there is need for future research to explore the varied effects of FI on the multidimensional domains of ECD. These domains, as well as the overall ECDI2030 scores, are measured on a continuous scale. Importantly, it may also be worthwhile to determine whether the vector means of ECD outcome domains vary based on the severity of HFI, thereby providing insights into the potential impact of HFI on various aspects of early childhood development. There is an urgent need to create age-appropriate multilevel multicomponent interventions aimed at enhancing ECD in Nigeria.

Given the evidence of geographical clustering, it is essential for the design and implementation of such interventions to consider both generalized and specific contextual effects. Further, Also, our results highlight the need for early clinical evaluation and interventions to support children's physical health of children in Nigeria with or at risk of functional limitation. This approach ensures the effectiveness of interventions targeted towards improving ECD.

Furthermore, there is need for the evaluation of innovative approaches to screen for and address FI within clinical and community settings in children with or at risk of developmental delays.

Notwithstanding the null association between HFI and ECD in our study, FI is intricately related to inadequate dietary quantity and quality which could influence child growth and development. Therefore, urgent national policy interventions, such as nutrition and early childhood development programs and social protection programs, as well as collaboration and partnerships between the private and public sectors, are needed to enable families to meet their food needs and effectively address food insecurity. Given that efforts to improve early childhood development requires a multisectoral approach, there is a need for an interministerial committee to coordinate and facilitate national efforts that would employ data-driven approaches to ensure progress toward meeting the SDG target on ECD.

Conclusion

A significant proportion of children 24-59 months in Nigeria were developmentally off track. Our results indicate that the association of ECD, as measured by the ECDI2030, with HFI remains inconclusive. As the ECDI2030 is a relatively new measure of ECD, there is definitely need for further studies to validate the results of our analysis. However, our study identified several factors across multiple levels of the socio-ecological system that were associated with ECD (either as protective or risk factors), indicating that ECD among children aged 24-59 months in Nigeria is influenced by both compositional and contextual factors. To mitigate the negative consequences of suboptimal development in early childhood on subsequent health, cognitive, and behavioral outcomes, efforts to address delays in early childhood development should focus on designing and implementing multilevel, multicomponent interventions that consider both generalized and specific contextual influences.

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Declarations

Conflict of interest: The authors declare that they have no conflict of interest.

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