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## Examining the Association between Anemia and Early Childhood Development in 9 Low- and Middle-income Countries

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Countries**

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## ABSTRACT

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Anemia is a significant public health problem in many low- and middle-income countries (LMICs), with young children being especially vulnerable. Iron deficiency is a leading cause of anemia and prior studies have shown associations between low iron status/iron deficiency anemia and poor child development outcomes. In LMICs, 43% of children under the age of 5 years are at risk of not meeting their developmental potential. However, few studies have examined associations between anemia status and early childhood development (ECD) in large population-based surveys. We examined the associations between severe or moderate anemia and ECD domains (literacy-numeracy, physical, social-emotional, and learning) and an overall ECD index among children age 36–59 months. Demographic and Health Survey (DHS) data from the last phase of The DHS Program (DHS-7) that included the ECD module and hemoglobin testing in children under age 5 were used. Bivariate and multivariate logistic regressions were run for each of the five outcomes. Multivariate models controlled for early learning/interaction variables, child, maternal, and paternal characteristics, and socio-economic and household characteristics. Results showed almost no significant associations between anemia and ECD domains or the overall ECD index except for social-emotional development in Benin ( $AOR = 1.00$   $p < .05$ ) and physical development in Maldives ( $AORs = 0.97$   $p < .05$ ). Attendance at an early childhood education program was also significantly associated with the outcomes in many of the countries. Our findings reinforce the importance of the Nurturing Care Framework which describes a multi-sectoral approach to promote ECD in LMICs.

**Key words:** early childhood development, anemia, iron deficiency anemia



## ACRONYMS AND ABBREVIATIONS

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DHS	Demographic and Health Survey
ECD	early childhood development
ECDI	Early Childhood Development Index
LMIC	low- and middle-income country
MICS	Multiple Indicator Cluster Surveys
SDG	Sustainable Development Goal



# 1 INTRODUCTION

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## 1.1 Background

Early childhood is a critical time for the development of children, setting the foundation for their futures. The process of childhood development is complex. It begins at conception with rapid brain development through age three years and is shaped by stimulation and interaction with social and physical environments, the availability of good nutrition, and other genetic factors (Britto et al. 2017; Grantham-McGregor et al. 2007). During this process children build their motor, cognitive, social, emotional, language and self-regulation skills (Black et al. 2017; Grantham-McGregor et al. 2007). Children who meet their developmental potential, achieving key developmental milestones, are more likely to continue to increase their learning capacities, achieve academically, and in later life increase their economic productivity.

Global momentum on early childhood development (ECD) has expanded the need for appropriate metrics. The United Nations Children’s Fund (UNICEF) released one of the first sets of global indicators for ECD in 2006 to address the lack of population level indicators in low- and middle-income countries (LMICs) (Loizillon et al. 2017). The indicators have gone through several rounds of revision and in 2009 the 10-item Early Childhood Development Index (ECDI) was released. The ECDI covers four domains of development literacy-numeracy, physical, social-emotional, and learning (Loizillon et al. 2017). Since its release, the ECDI has been widely used in population-based surveys such the Multiple Indicator Cluster Surveys (MICS) and The Demographic and Health Surveys (DHS). Currently, in the Sustainable Development Goal (SDG) era, ECD is included as an SDG target and the ECDI was recently updated in 2021 as a primary tool for measuring progress towards the SDG target.

In 2010 43% of children under the age of 5 years in LMICs were estimated to be at risk of not meeting their developmental potential (Lu, Black, and Richter 2016). Further analyses show that almost one-third of pre-school aged children are not achieving key cognitive and or social and emotional developmental milestones (McCoy et al. 2016). Children in LMICs are often exposed to multiple risk factors for poor childhood development (Wachs and Rahman 2013). These include structural factors such as poverty and poor environmental conditions, physiological and social factors such as non-responsive parenting and poor parental mental health, and individual level risk factors such as infection and inflammation, stunting, and micronutrient deficiencies (Black et al. 2017; Bradley and Putnick 2012; Britto et al. 2017; Singla, Kumbakumba, and Aboud 2015; Walker et al. 2007; Walker et al. 2011).

Anemia, defined as a low concentration of hemoglobin, is a significant public health problem in several LMICs, especially among young children and women of reproductive age (Stevens et al. 2013). While anemia can be caused by a variety of factors including micronutrient deficiencies, malaria, infections, chronic inflammation, and genetic disorders, iron deficiency is a major cause (WHO 2017). Iron deficiency is estimated to be responsible for over one billion cases of anemia globally and iron deficiency anemia is a top contributor to morbidity in LMICs (GBD 2016 Disease and Injury Incidence and Prevalence Collaborators 2017). Young children in LMICs who are most vulnerable to anemia are also at greatest risk of developmental delays.

For young children, iron is important for tissue oxygen delivery, tissue growth, and brain development (John, Black, and Nelson 2017; Lozoff 2007). There are critical time points in the neonatal, infancy, and toddler periods during which there are higher iron demands to support brain development (Lozoff 2007; Wachs et al. 2014). From 6 months to 3 years of age, iron is needed for myelin, frontal cortex, and basal ganglia development and these brain areas play an important role in neurobehavioral development (Lozoff 2007; Wachs et al. 2014). Studies examining the links between ECD and iron deficiency anemia in infants and young children have reported that iron deficiency anemia is associated with poor neurodevelopment outcomes including decreased social-emotional, cognitive, and motor development (Britto et al. 2017; Grantham-McGregor and Ani 2001; Lozoff 2007). In addition, iron supplementation interventions among young children demonstrate mixed results with some reviews reporting benefits in cognitive, mental, and motor development among children of varying ages with and without anemia or iron deficiency anemia (De-Regil et al. 2011; Larson, Phiri, and Pasricha 2017; Sachdev, Gera, and Nestel 2005). However, most of these studies focused on children under age 2 years.

Studies using nationally representative surveys like the DHS found significant associations between suboptimal motor, cognitive, and social-emotional development and poor nutritional status (Kang et al. 2018; McCoy et al. 2016; Miller et al. 2016) and suboptimal literacy-numeracy development and poor dietary intake among children age 3–4 years (Bliznashka et al. 2021). However, few if any studies, have examined associations between anemia status and ECD in population-based surveys among children age 3–4 years. DHS surveys routinely collect hemoglobin data among children under 5 years and since 2011 have collected the ECDI in several LMICs (Pullum et al. 2017). Leveraging existing DHS surveys that include both ECDI and hemoglobin data, our analyses examine the association between anemia status and ECDI domains as well as the overall ECDI index.

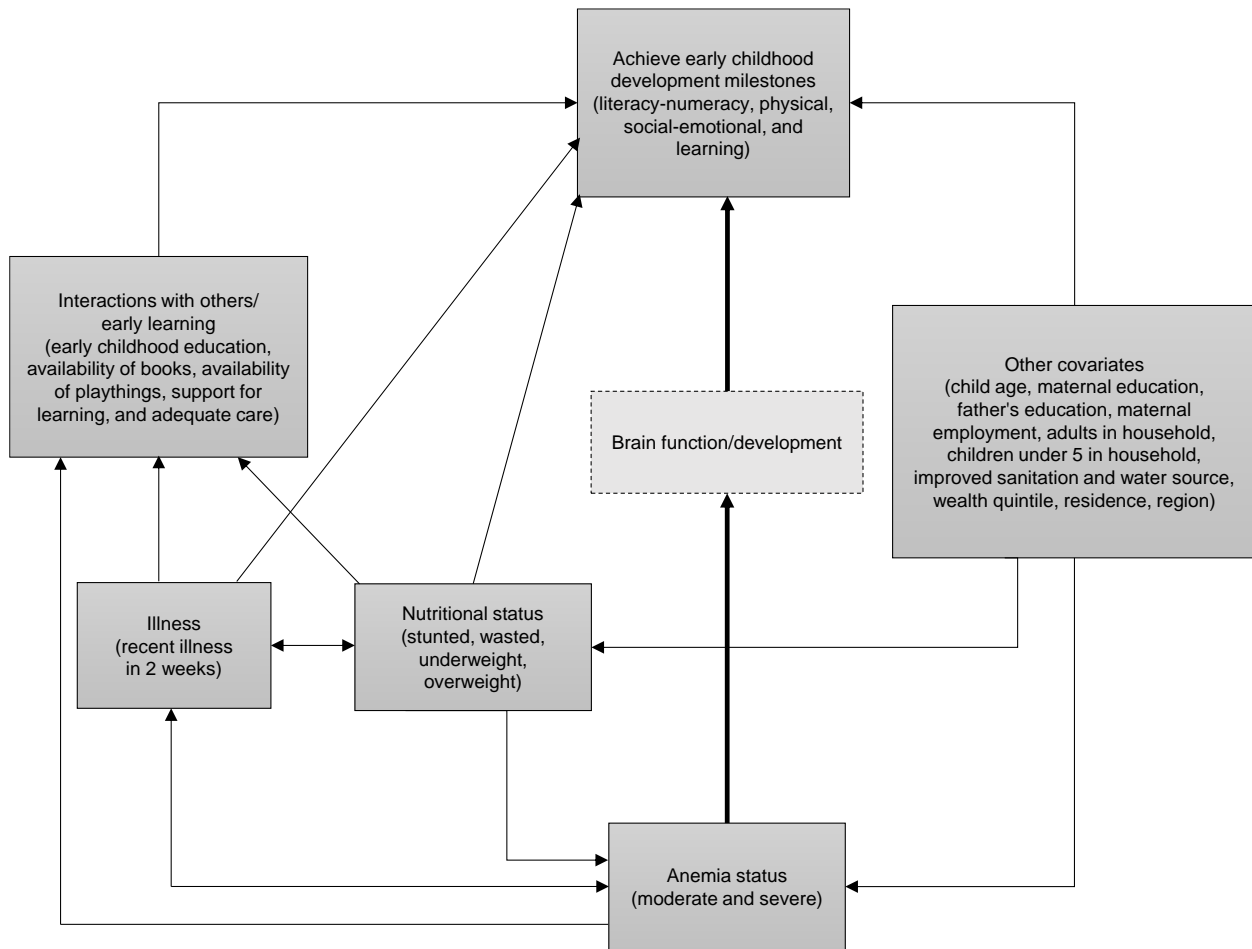
## 1.2 Conceptual Framework

The conceptual framework for this study is shown in **Figure 1**. It is informed by two existing frameworks. The Larson et al. 2017 framework describes a biological pathway linking anemia, diet, nutritional status, illness and interactions with others and the environment to ECD outcomes (Larson, Phiri, and Pasricha 2017). The Nurturing Care Framework takes a social ecological approach (Black et al. 2017). It describes the role of the social context in ECD, with the family environment at the center, and highlights knowledge, attitudes, and behaviors across health, nutrition, security and safety, responsive caregiving, and early learning sectors (Black et al. 2017; Britto et al. 2017).

Our conceptual framework shows potential pathways between anemia and ECD mediated by brain development as well as potential confounders. Early learning interventions and interactions with others are positively associated with ECD outcomes (Britto et al. 2017). Poor nutritional status and child illness directly and indirectly affect ECD and are negatively associated with ECD outcomes (Kang et al. 2018; Larson, Martorell, and Bauer 2018; McCoy et al. 2016; Miller et al. 2016; Olney et al. 2009; Prado et al. 2017; Sudfeld et al. 2015). Other important confounders include characteristics of the child, mother, father, household, and environment (Ngure et al. 2014; Prado et al. 2017).



**Figure 1 Conceptual framework of the relationship between anemia status and early childhood development**





## 2 DATA AND METHODS

### 2.1 Data

The study used data from recent DHS surveys in 10 countries: Benin 2017–18, Burundi 2016–17, Cambodia 2014, Haiti 2016–17, Jordan 2017–18, Maldives 2016–17, Myanmar 2015–17, Rwanda 2019–20, Senegal 2017, and Uganda 2016. These countries were selected based on the availability of the ECD questions and anemia testing for children as well as their recent implementation (in the seventh phase of The DHS Program). DHS surveys are population-based household surveys which use a two-stage cluster sampling design to draw a sample that is representative of the country as a whole, for the next administrative level (for example, regions, states, or provinces), and for urban and rural areas. In the first stage of sampling, clusters or enumeration areas are selected from the country’s most recent census sampling frame with probability proportional to the population size of clusters. In the second stage, a systematic sample of households is interviewed in each of the selected clusters. Within each household, eligible women age 15–49 answered questions about reproduction, maternal and child health and nutrition, and ECD, among other topics. For some surveys, within each or a sub-sample of households, eligible men answer similar questions to the women, but without a detailed reproductive history or questions on maternal and child health. Height and weight measurements and anemia testing are also collected from eligible men, women, and children. Since children age 6–59 months were tested for anemia and youngest children age 36–59 months were asked about in the ECD module, the analytical sample is therefore limited to children age 36–59 months.

Table 1 presents information about the sample sizes of children age 36–59 months included for anemia testing and ECD in each dataset.

**Table 1** Unweighted number of cases in the ten DHS surveys with measurement of combinations of anemia and ECD data for children age 36–59 months

Country	Year	Sample of children 36–59 months	Sample of children 36–59 months with anemia testing data	Sample of children 36–59 months with ECD index data	Sample of children 36–59 months with both anemia and ECD index data
Benin	2017–18	4,855	2,337	4,244	2,168
Burundi	2016–17	4,847	2,329	4,717	2,327
Cambodia	2014	2,679	1,636	2,610	1,627
Haiti	2016–17	2,403	2,128	1,433	1,412
Jordan	2017–18	4,184	3,877	2,137	1,996
Maldives	2016–17	1,285	907	1,264	906
Myanmar	2015–17	1,842	1,608	0	0
Rwanda	2019–20	3,067	1,449	2,926	1,448
Senegal	2017	4,594	4,079	4,268	4,044
Uganda	2016	5,781	1,628	5,049	1,610

The first data column of Table 1 shows the unweighted numbers of children age 36–59 months. This number ranges from 1,285 in Maldives to 5,781 in Uganda and largely reflects the overall survey sample size. The second column gives the number of children age 36–59 months for whom a valid measurement of hemoglobin concentration was obtained. This number is often substantially less than the number of children because of subsampling. In Benin, Burundi, and Rwanda, half of households were randomly selected for hemoglobin testing. In Cambodia and Uganda, a third of the households were selected. In the surveys with

subsampling, the hemoglobin testing was confined to the households selected for the men’s survey. The third column gives the number of children age 36–59 months for whom valid scores were obtained on the ECD index items. In Jordan there was subsampling of households for the ECD questions; for half of the women, one child per woman (the youngest child age 3–4 years) was selected for the ECD questions. In Haiti, one child age 0–4 years per woman was selected for the ECD questions. In addition, further reductions in the sample sizes for anemia data and ECD data are due to subsampling; these sample sizes are reduced due to the child not residing in the same household as the mother, which is a requirement for both hemoglobin testing and the ECD indicators.

As shown in Table 1, the Myanmar 2015–16 survey did not include the ten components necessary to construct the ECD domains or index and had to be dropped. Therefore, only nine countries were included in the analytic sample for this study.

## 2.2 Methods

### 2.2.1 Measures

Measures were selected for inclusion based on the conceptual framework above outlining the pathway between anemia status and ECD. Definitions and categorization of each measure included in the analysis are described below.

#### Outcome variables

The outcome variables were measured using the ECDI, a summary measure based on 10 items responded to by the mother or caregiver of children 36–59 months (Loizillon et al. 2017). The questions cover four domains of child development: physical, social-emotional, learning, and literacy-numeracy.

**Table 2 ECDI index domains, items, and scoring**

Domain	Items	On-track score
Physical	1. child can pick up small objects with two fingers, like a stick or a rock from the ground 2. child is not sometimes too sick to play.	2 of 2 items
Social-emotional	3. child gets along well with other children 4. child does not kick, bite or hit other children 5. child does not get distracted easily	1 of 3 items
Learning	6. child can follow simple directions on how to do something correctly 7. when given something to do, the child is able to do it independently	2 of 2 items
Literacy-numeracy	8. child can read at least four simple, popular words 9. can identify/name at least ten letters of the alphabet 10. knows the name and recognizes the symbols of all numbers 1–10.	1 of 2 items
Overall (ECDI)		3 of 4 domains

The ECDI was calculated by domain as a binary (yes/no) variable to indicate that a child is on-track in that domain, and overall as a binary (yes/no) variable to indicate that a child is on-track with their overall development.

#### Independent variables

The key independent variable of interest for this study was anemia, which was defined using the WHO recommended cutoffs for hemoglobin concentrations (WHO 2011). Children were defined as not anemic

when their hemoglobin level was at or above 11.0 grams per deciliter (g/dL), adjusted for altitude in enumeration areas that are above 1,000 meters. Anemia was then categorized into severe (hemoglobin level below 7.0 g/dL), moderate (hemoglobin level between 7.0–9.9 g/dL), and mild (hemoglobin level between 10.0–10.9 g/dL). Hemoglobin concentrations were measured using capillary blood in the HemoCue® machine (Pullum et al. 2017).

For the purposes of our study, we explored all categorizations of anemia, but for the analyses presented here, the classification is reduced to 1: severe or moderate; 0: mild or not anemic. Severe or moderate anemia were hypothesized to be more strongly associated with the outcomes based on evidence from studies linking severity of iron deficiency anemia and ECD (Lozoff 2007; Stoltzfus et al. 2001).

Other covariates included in the model are described in Table 3.

**Table 3 Variables used in analysis**

Variable	Definition	Categories	Binary variable constructed
<b>Early learning/interaction</b>			
Early childhood education	Youngest children age 3–4 years living with interviewed mother who attend any organized learning or early childhood education program, such as a private or government facility, including kindergarten or community child care	Yes/No	Yes/No
Availability of books	Number of children’s books or picture books available for youngest child age 0–4 years living with interviewed mother	- Continuous 0–9 - 10+	Child has 3 or more books available to them
Availability of playthings	Youngest children age 0–4 years living with interviewed mother who have toys available	- homemade toys or other toys made at home - toys from a shop or manufactured toys - household objects or objects found outside	Child has toys from at least 2 categories available to them
Support for learning	Youngest children age 0–4 years living with interviewed mother who engage in activities with household members over the age of 15 in the past 3 days	- read books to or looked at picture books with child - told stories to child - sang songs to or with child - took child outside the home, compound, yard, or enclosure - played with the child - named, counted, or drew things with child	Child engaged in any (1 or more) activities with an adult household member
Adequate care	Number of times youngest children age 0–4 years living with interviewed mother were left alone for more than an hour or left in the care of another child less than 10 years of age for more than an hour	Continuous 0–7	Child was not left alone or in the care of another child less than 10 years of age for more than an hour at any time in the past week

*Continued...*

**Table 3—Continued**

Variable	Definition	Categories	Binary variable constructed
<b>Physical growth</b>			
Nutritional status	Children under 5 in the household who were not any of the following: stunted, underweight, overweight, or wasted <sup>a</sup>	Yes/No	Yes/No
<b>Wellness</b>			
Wellness	Children under 5 in the household whose mothers report that the child had not had diarrhea, fever, or cough in the past 2 weeks	Yes/No	Yes/No
<b>Other covariates</b>			
Age of child	Age of child in months	Continuous	
Maternal height	Maternal height in cm	- Short maternal stature (<145 cm) - No short maternal stature (>145 cm)	Short maternal stature (Yes/No)
Maternal work status	Mother worked in the last 7 days	Yes/No	Yes/No
Maternal education	Highest educational level of the mother	- No education - Primary (ref) - Secondary - Higher	
Paternal education	Highest educational level of the father	- No education - Primary (ref) - Secondary - Higher	
Wealth index	Composite measure of a household's cumulative living standard divided into quintiles.	- Lowest - Second - Middle - Fourth - Highest	
Place of residence	Country census definitions were used to characterize rural and urban residence	Rural/urban	Rural/urban
Region	Country's first administrative level	First administrative level designations according to country	
Number of adults age 15 or above in the household	Number of adults age 15 or above in the household	- 2 or fewer de jure residents over age 15 - 3+ de jure residents over age 15	2 or fewer/3+ de jure residents over age 15
Number of children under 5 in the household	Number of children under 5 in the household	- 2 or fewer children under age 5 - 3+ children under age 5	2 or fewer/3+ children under age 5
Availability of improved sanitation and improved water source in the household	Improved sanitation includes: Include any non-shared toilet of the following types: flush/pour flush toilets to piped sewer systems and pit latrines, ventilated improved pit (VIP) latrines, and pit latrines with slabs.  Improved water source includes: piped water, protected springs, and rainwater. Households that use bottled water for drinking are classified as using an improved source only if the water they use for cooking and hand washing comes from an improved source	- No improved water source, no improved toilet - No improved water source, improved toilet - Improved water source, no improved toilet - Improved water source, improved toilet	

Note: Maternal height was not collected in Senegal 2017. Child nutritional status was not included in Jordan 2017–18 due to data quality concerns.

<sup>a</sup> Stunted, underweight, overweight, or wasted were categorized as follows: children under 5 in the household were categorized as underweight, or normal according to the weight-for-age *z* score, categorized as stunted or normal according to the height-for-age *z* score, and categorized as wasted, normal, or overweight according to the weight-for-height *z* score in comparison to the mean on the WHO Child Growth Standards scale.

### 2.2.2 Statistical analysis

We examined the association between anemia status, the overall ECDI, and individual ECDI domains among children age 36–59 months. The statistical analysis was performed in Stata, using the generalized linear models (*glm*) set of estimation commands. Each survey was analyzed separately and not pooled because the relationships appear to differ from one survey to another. The models were adjusted for the weights and sample design (with strata and clusters) of each survey. Statistical significance was indicated, using  $p < .05$ ,  $.01$ , and  $.001$  criteria. The sample sizes varied considerably across the selected surveys, so there was variation in the power of the surveys to detect associations that exist in the reference populations. If a test statistic is not statistically significant, we cannot conclude that there is no association.

Model 1 examines the effect of anemia on ECD outcomes with no other covariates. Model 2 adds to Model 1 several child, family, and household covariates: child's age, wellness, and nutritional status; the mother's work status, education, and height; the father's education; the household wealth quintile; improved water and sanitation; place of residence; and region (Table 3). This model is important for identifying the effects of anemia on ECD net of the control variables. Finally Model 3 adds to Model 2 covariates on early learning/interaction variables (Table 3). Model 2 and Model 3 are important for identifying the effects of anemia on ECD net of the control variables and control plus early learning/interaction variables. To make the results easier to review, the results for each model were limited to an adjusted odds ratio for the effect of anemia on the ECD domains and overall index.





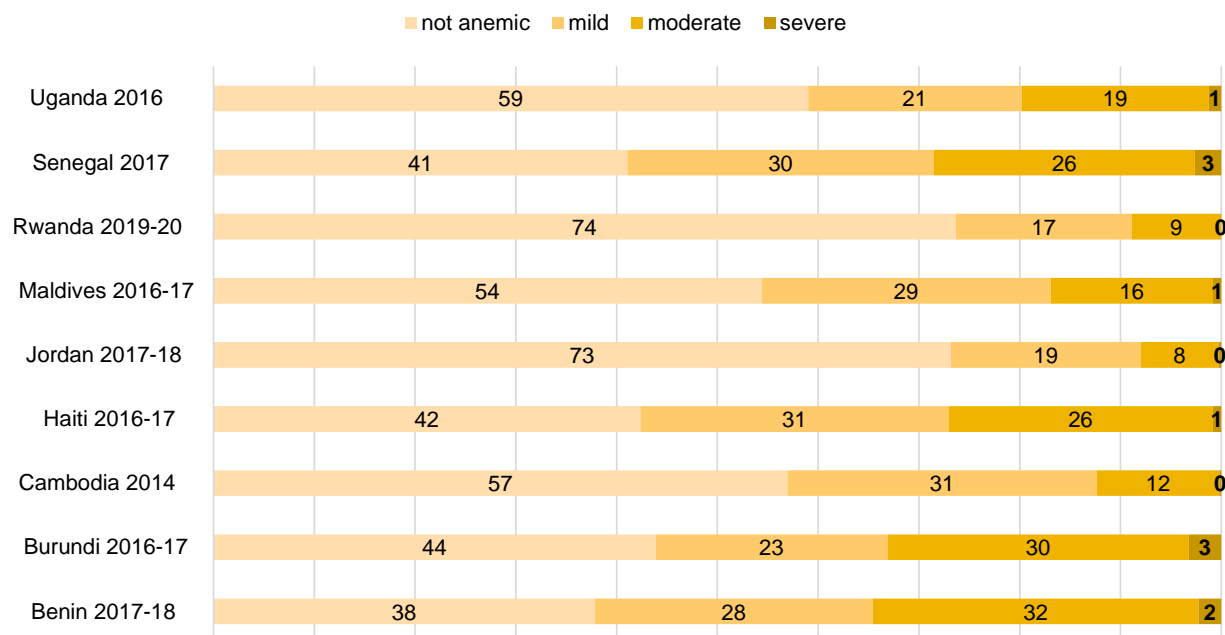
### 3 RESULTS

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#### 3.1 Percentage of Children with Anemia

More than 40% of children age 36–59 months had any anemia in 7 out of 9 countries and the prevalence of any anemia ranged from 26% in Rwanda to 62% in Benin (Figure 2). The percentage of children with mild anemia ranged from 17% in Rwanda to 31% in Haiti and Cambodia. The prevalence of moderate anemia ranged from 8% in Jordan to 32% in Benin, and the prevalence of severe anemia ranged from less than 1% in Cambodia, Jordan, and Rwanda to 3% in Burundi and Senegal (Figure 2).

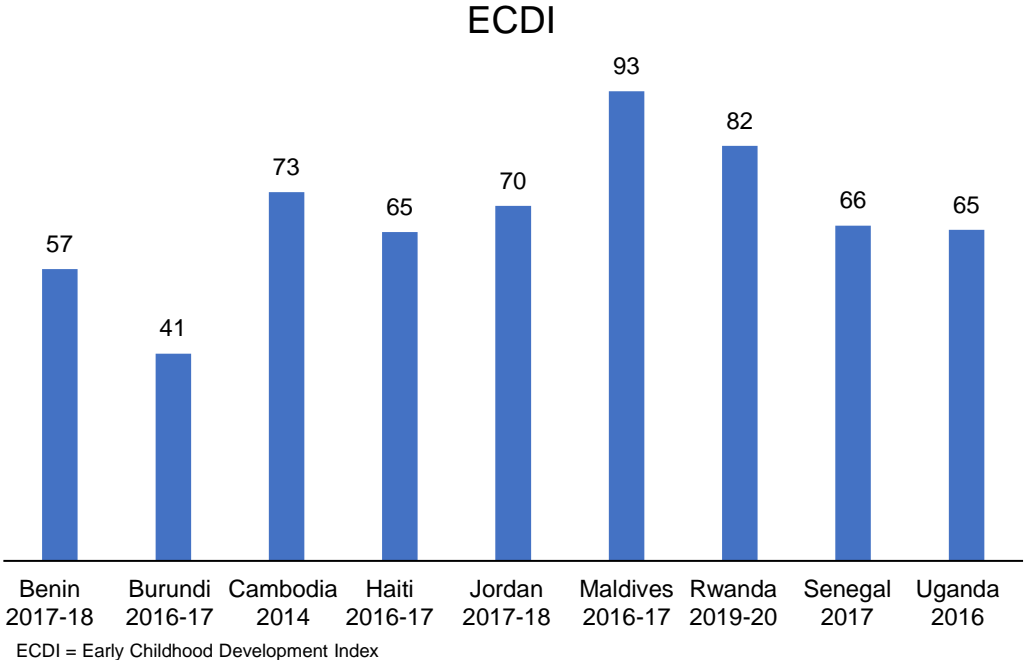
**Figure 2** Percentage of children age 36–59 months with anemia by severity



### 3.2 Early Childhood Development Index and Domain Scores

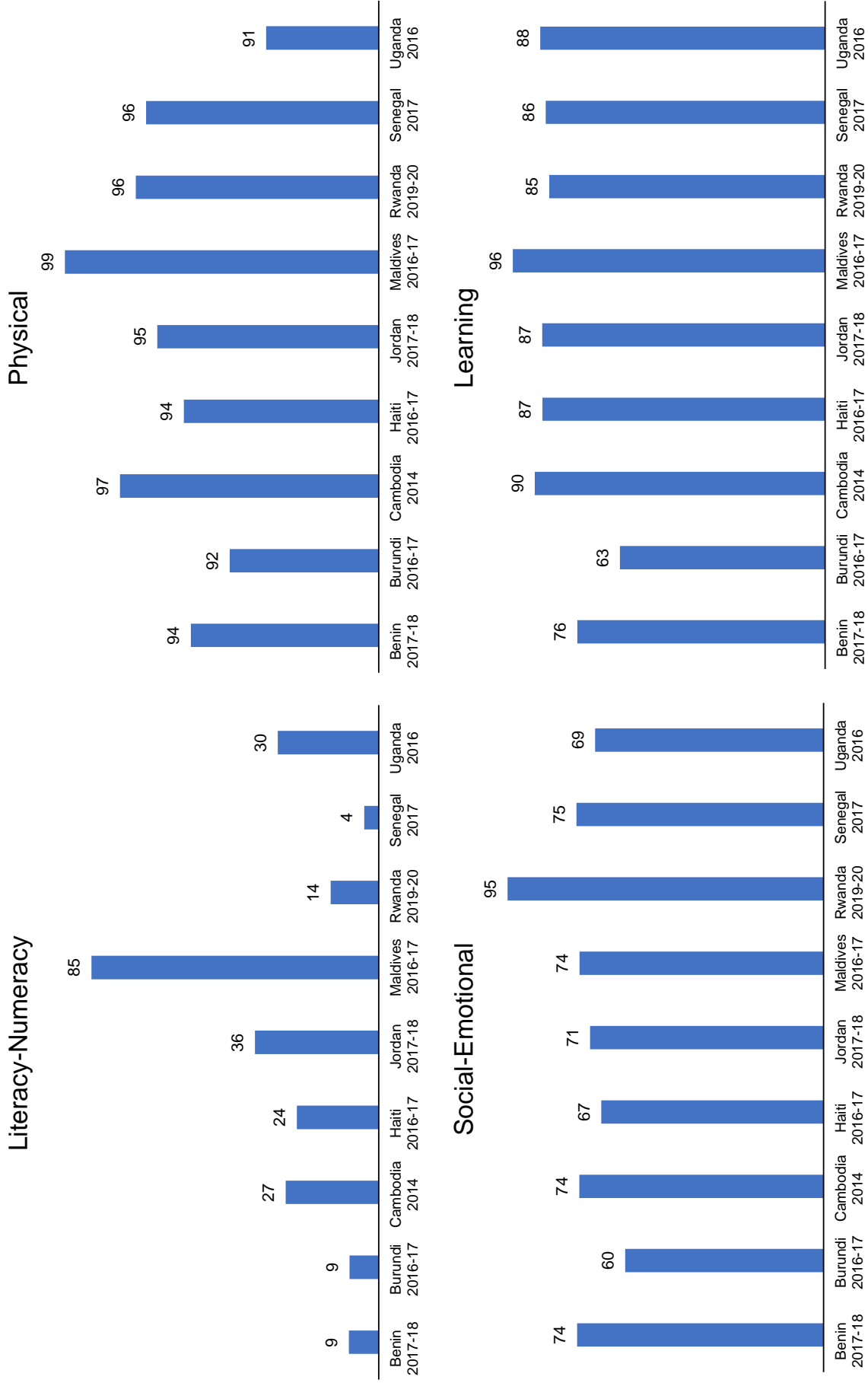
The percentage of children who were developmentally on-track for at least three of the four ECDI domains ranged from 41% in Burundi to 93% in Maldives (Figure 3).

**Figure 3** Percentage of children age 36–59 months developmentally on-track by country



Most children were developmentally on-track for the physical domain, ranging from 91% in Uganda to 99% in Maldives (Figure 4). For the social-emotional domain the percentage of children on-track ranged from 60% in Burundi to 95% in Rwanda, and for the learning domain the percentage of children on-track ranged from 63% in Burundi to 96% in Maldives. The literacy-numeracy domain had the lowest percentages of children developmentally on-track overall, with 8 out of 9 countries showing less than 36% of children on track. Percentages ranged from 4% in Senegal to 85% in Maldives (Figure 4).

**Figure 4 Percentage of children age 36–59 months on-track for the physical, social-emotional, learning, and literacy-numeracy ECDI domains by country**



### 3.3 Regression Results

In Model 1, having moderate or severe anemia was significantly associated with lower odds of being developmentally on-track for several domains and the overall index in many countries, but the magnitude of the associations were very small ranging from an odds ratio (*OR*) of 0.99 to 1.0, and thus may not be clinically meaningful (Table 4). In Benin, Burundi, Haiti, Senegal, and Uganda having moderate or severe anemia was associated with lower odds of on-track literacy-numeracy development (all *ORs* = 0.99  $p < .05$ ). In Benin, Burundi, Jordan, Rwanda, and Senegal, having moderate or severe anemia was associated with lower odds of on-track learning development (*ORs* = 0.99  $p < .05$  in Jordan and Rwanda and *ORs* = 1.00  $p < .05$  in Benin, Burundi, and Senegal). Having moderate or severe anemia was associated with lower odds of on-track physical development in Haiti and Uganda (*ORs* = 0.99  $p < .05$ ); and lower odds of on-track social-emotional development in Benin and Senegal (*ORs* = 1.00  $p < .05$ ). For the overall index, negative associations among children with moderate or severe anemia were found in Benin, Burundi, Rwanda and Senegal (*OR* = 0.99  $p < .05$  in Rwanda and *OR* = 1.00  $p < .05$  in Benin, Burundi and Senegal) (Table 4).

When adjusted with child, family, and household characteristics (Model 2) and early learning/interaction variables (Model 3), most of the significant findings disappeared (Table 4). In Model 2, there were significant associations between having moderate or severe anemia and lower odds of on-track physical development in Haiti (*AOR* = 0.99  $p < .05$ ), learning development in Jordan (*AOR* = 0.99  $p < .05$ ), and social-emotional development and overall index in Benin (*AORs* = 1.00  $p < .05$ ). With the addition of the early learning/interaction variables to the model (Model 3), having moderate or severe anemia was only associated with lower odds of on-track social-emotional development in Benin (*AOR* = 1.00  $p < .05$ ) and physical development in Maldives (*AORs* = 0.97  $p < .05$ ).

In the fully adjusted models (Model 3), several covariates were significantly associated with ECD domains and the overall index, but results varied by country (Appendix Tables A1–A5). Attendance at an early childhood education program was consistently associated with on-track development for the overall ECDI in six out of nine countries, literacy-numeracy in all nine countries, learning in six countries, and social-emotional and physical development in one country each. Small and mostly positive associations were observed between child's age and being on-track for the overall ECDI in five out of nine countries, literacy-numeracy development in eight countries, learning development in four countries, and physical development in two countries. Wealth was associated with being on-track for the overall ECDI, literacy-numeracy, social-emotional, and physical developments in four countries each, and learning development in two countries, but the direction of association varied across countries. For availability of books, playthings, support for learning, adequate care, mother's education, employment, father's education, child nutritional status, wellness, WASH, and residence, significant results were found with some ECD outcomes in fewer countries, but the direction of the associations were not consistent (Appendix Tables A1–A5).

**Table 4 Odds ratios for the effect of anemia on on-track early childhood development domains and overall index among children age 36–59 months across all countries**

Survey	ECD Domain/Index	Model 1 <sup>a</sup>						Model 2 <sup>b</sup>						Model 3 <sup>c</sup>					
		OR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value		
Benin 2017–18	Literacy-numeracy	0.99	0.99	1.00	.004	1.00	0.99	1.01	.880	1.00	0.99	1.01	.880	1.00	0.99	1.01	.924		
	Physical	1.00	1.00	1.00	.390	1.00	1.00	1.01	.354	1.00	1.00	1.01	.354	1.00	1.00	1.01	.358		
	Social-emotional	1.00	1.00	1.00	.042	1.00	0.99	1.00	.021	1.00	0.99	1.00	.023	1.00	0.99	1.00	.023		
Burundi 2016–17	Learning	1.00	0.99	1.00	.001	1.00	1.00	1.00	.507	1.00	1.00	1.00	.507	1.00	1.00	1.00	.637		
	ECDI	1.00	0.99	1.00	.000	1.00	1.00	1.00	.043	1.00	1.00	1.00	.043	1.00	1.00	1.00	.063		
	Literacy-numeracy	0.99	0.99	1.00	.005	1.00	0.99	1.00	.722	1.00	0.99	1.00	.722	1.00	0.99	1.00	.715		
Cambodia 2014	Physical	1.00	0.99	1.00	.165	1.00	0.99	1.00	.853	1.00	0.99	1.00	.853	1.00	0.99	1.00	.855		
	Social-emotional	1.00	1.00	1.00	.258	1.00	1.00	1.00	.549	1.00	1.00	1.00	.549	1.00	1.00	1.00	.469		
	Learning	1.00	1.00	1.00	.030	1.00	1.00	1.00	.360	1.00	1.00	1.00	.360	1.00	1.00	1.00	.482		
Haiti 2016–17	ECDI	1.00	1.00	1.00	.007	1.00	1.00	1.00	.175	1.00	1.00	1.00	.175	1.00	1.00	1.00	.353		
	Literacy-numeracy	1.00	0.99	1.00	.343	1.00	1.00	1.01	.723	1.00	1.00	1.01	.723	1.00	1.00	1.01	.487		
	Physical	0.99	0.99	1.00	.260	0.99	0.98	1.00	.100	0.99	0.98	1.00	.100	0.99	0.98	1.00	.099		
Jordan 2017–18	Social-emotional	1.00	0.99	1.00	.541	1.00	0.99	1.00	.227	1.00	0.99	1.00	.227	1.00	0.99	1.00	.261		
	Learning	1.00	0.99	1.01	.938	1.00	1.00	1.01	.751	1.00	1.00	1.01	.751	1.00	1.00	1.01	.662		
	ECDI	1.00	0.99	1.00	.337	1.00	0.99	1.00	.447	1.00	0.99	1.00	.447	1.00	0.99	1.00	.548		
Maldives 2016–17	Literacy-numeracy	0.99	0.99	1.00	.000	0.99	0.99	1.00	.101	0.99	0.99	1.00	.101	0.99	0.99	1.00	.133		
	Physical	0.99	0.98	1.00	.001	0.99	0.98	1.00	.038	0.99	0.98	1.00	.038	0.99	0.98	1.00	.052		
	Social-emotional	1.00	1.00	1.00	.796	1.00	1.00	1.01	.602	1.00	1.00	1.01	.602	1.00	1.00	1.01	.465		
Rwanda 2019–20	Learning	1.00	1.00	1.00	.832	1.00	1.00	1.01	.515	1.00	1.00	1.01	.515	1.00	1.00	1.01	.374		
	ECDI	1.00	0.99	1.00	.129	1.00	0.99	1.00	.543	1.00	0.99	1.00	.543	1.00	0.99	1.00	.393		
	Literacy-numeracy	1.00	0.99	1.00	.102	1.00	0.99	1.00	.490	1.00	0.99	1.00	.490	1.00	0.99	1.00	.547		
Senegal 2017	Physical	1.00	0.98	1.01	.745	1.00	0.98	1.01	.707	1.00	0.98	1.01	.707	1.00	0.98	1.01	.686		
	Social-emotional	1.00	1.00	1.01	.286	1.00	1.00	1.01	.480	1.00	1.00	1.01	.480	1.00	1.00	1.01	.428		
	Learning	0.99	0.99	1.00	.011	0.99	0.99	1.00	.041	0.99	0.99	1.00	.041	0.99	0.99	1.00	.100		
Uganda 2016	ECDI	1.00	0.99	1.00	.064	1.00	0.99	1.00	.155	1.00	0.99	1.00	.155	1.00	0.99	1.00	.215		
	Literacy-numeracy	1.00	0.99	1.00	.466	1.00	0.98	1.01	.603	1.00	0.98	1.01	.603	1.00	0.98	1.01	.532		
	Physical	0.99	0.98	1.00	.220	0.98	0.95	1.00	.095	0.97	0.95	1.00	.095	0.97	0.95	1.00	.001		
Senegal 2017	Social-emotional	1.00	0.99	1.01	.746	1.00	0.99	1.00	.281	1.00	0.99	1.01	.281	1.00	0.99	1.01	.565		
	Learning	1.01	1.00	1.02	.208	1.01	0.99	1.02	.436	1.01	0.99	1.02	.436	1.01	0.99	1.02	.422		
	ECDI	1.00	0.99	1.01	.996	1.00	0.99	1.02	.480	1.01	0.99	1.02	.480	1.01	0.99	1.02	.330		
Rwanda 2019–20	Literacy-numeracy	1.00	0.99	1.00	.541	1.00	0.99	1.01	.690	1.00	0.99	1.01	.690	1.00	0.99	1.01	.997		
	Physical	1.01	1.00	1.02	.140	1.01	1.00	1.03	.124	1.01	1.00	1.03	.124	1.01	1.00	1.03	.120		
	Social-emotional	1.00	0.99	1.00	.366	1.00	0.99	1.00	.829	1.00	0.99	1.01	.829	1.00	0.99	1.01	.741		
Senegal 2017	Learning	0.99	0.99	1.00	.007	1.00	0.99	1.00	.472	1.00	0.99	1.00	.472	1.00	0.99	1.00	.328		
	ECDI	0.99	0.99	1.00	.027	1.00	0.99	1.00	.913	1.00	0.99	1.00	.913	1.00	0.99	1.00	.889		
	Literacy-numeracy	0.99	0.98	0.99	.000	1.00	0.99	1.00	.146	1.00	0.99	1.00	.146	1.00	0.99	1.00	.419		
Uganda 2016	Physical	1.00	0.99	1.00	.254	1.00	0.99	1.00	.814	1.00	0.99	1.00	.814	1.00	0.99	1.00	.402		
	Social-emotional	1.00	1.00	1.00	.031	1.00	1.00	1.00	.744	1.00	1.00	1.00	.744	1.00	1.00	1.00	.421		
	Learning	1.00	0.99	1.00	.000	1.00	1.00	1.00	.567	1.00	1.00	1.00	.567	1.00	1.00	1.00	.649		
Uganda 2016	ECDI	1.00	0.99	1.00	.000	1.00	1.00	1.00	.441	1.00	1.00	1.00	.441	1.00	1.00	1.00	.297		
	Literacy-numeracy	0.99	0.99	1.00	.000	1.00	1.00	1.01	.578	1.00	1.00	1.01	.578	1.00	1.00	1.01	.316		
	Physical	0.99	0.99	1.00	.000	1.00	0.99	1.00	.400	1.00	0.99	1.00	.400	1.00	0.99	1.00	.294		
Uganda 2016	Social-emotional	1.00	1.00	1.00	.439	1.00	1.00	1.01	.154	1.00	1.00	1.01	.154	1.00	1.00	1.01	.173		
	Learning	1.00	0.99	1.00	.463	1.00	1.00	1.01	.229	1.00	1.00	1.01	.229	1.00	1.00	1.01	.242		
	ECDI	1.00	0.99	1.00	.091	1.00	1.00	1.01	.114	1.00	1.00	1.01	.114	1.00	1.00	1.01	.099		

OR = odds ratio; AOR = adjusted odds ratio; LB = lower bound of confidence interval; UB = upper bound of confidence interval

<sup>a</sup>Model 1: bivariate model with child anemia (moderate or severe)

<sup>b</sup>Model 2: adjusted for child nutritional status, child wellness, age of child, maternal height, education, employment, paternal education, number of adults age 15+ in household, number of children under age 5 in household, improved sanitation, improved water source, wealth index, residence, region. In Jordan, child nutritional status was not included and in Senegal, maternal height was not included.

<sup>c</sup>Model 3: same as Model 2 covariates plus early childhood education attendance, availability of books, availability of playthings, support for learning, and adequate care



## 4 DISCUSSION

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This study examined associations between child anemia and ECD outcomes in population-based surveys in nine low- and middle-income countries. In most of the countries, anemia was a serious public health problem, and more than half of children were developmentally on-track, but there was variation across countries. Significant associations with several developmental outcomes were observed in bivariate analyses, but ORs were very close to 1. In adjusted analyses, most associations were attenuated. There were only two statistically significant findings with social-emotional and physical development in Benin and Maldives, respectively. Both associations were small.

The unadjusted association between having anemia and early childhood development showed that children with moderate or severe anemia were less likely to be on-track developmentally for literacy-numeracy, physical, social emotional, learning, and the overall index in several countries. However, these associations were very small and have limited clinical significance, and it is also plausible that some could be spurious. Nevertheless, the direction of the associations were consistent for all developmental domains and the index across all countries. Our finding agrees with our hypothesized pathway between anemia and early childhood development and is supported by studies showing poorer cognitive, motor, and social-emotional development associated with iron deficiency anemia in young children under age 2 years in LMICs (Lozoff 2007). Further, other studies have reported significant associations with modest effect sizes between higher hemoglobin concentrations and better language, motor, and cognitive development in children under two years in LMICs (Larson, Martorell, and Bauer 2018; Prado et al. 2017). Given that we used moderate or severe anemia status as a proxy for iron deficiency anemia in our study, the limited significant associations and ORs very close to 1 are not surprising. Furthermore, it is possible for children to be iron deficient without anemia and this may also account for the small associations observed.

In adjusted regressions, we found a lack of association between anemia and ECD outcomes except for small associations with social-emotional and physical development in two countries. Our finding is contrary to other literature from baseline or endline assessments of micronutrient and lipid supplement interventions that show a complex relationship between anemia and ECD (Larson, Martorell, and Bauer 2018; Olney et al. 2009; Prado et al. 2017). In Ghana and Malawi, authors reported weak but direct associations between hemoglobin/iron status and language development among children 6–18 months, and stronger (direct) associations between hemoglobin/iron status and motor development among children 9–18 months in Burkina Faso (Prado et al. 2017). Among Zanzibari children age 15–19 months, direct associations were reported between hemoglobin concentration and motor development, and in India, weak direct and indirect associations between hemoglobin concentration, language, social and cognitive development were reported among children 12–18 months (Larson, Martorell, and Bauer 2018; Olney et al. 2009). There are a few explanations for our findings. Compared to our study, researchers in previous studies used different and more direct and specific measures of childhood development such as the Developmental Milestones Checklist-II, vocabulary checklists, and task tests which may partly explain our null results (Larson, Martorell, and Bauer 2018; Olney et al. 2009; Prado et al. 2017). Such assessments involve interviews and direct observations for a variety of domains based on age-specific milestones (Abubakar et al. 2008; Diamond 1985; Fenson et al. 2007; Prado et al. 2014). In addition, the prior studies used data from supplement trials and children who received the interventions may be more likely to show associations with ECD outcomes. Another reason is that anemia generally peaks around 12–24 months of age, a critical time

for brain development, and most studies examining the effects of iron deficiency anemia have focused on children under 2 years (Larson, Martorell, and Bauer 2018; Lozoff 2007; Olney et al. 2009; Prado et al. 2017). Most brain development also takes place before age three years and therefore, assessing children 36–59 months may not represent the most sensitive period to find associations (Grantham-McGregor et al. 2007). By exploring relationships among older children, we may have potentially missed the biologically relevant window and thus our analyses find no associations. Another potential explanation is that we assessed current anemia status which may not reflect chronicity. The duration of anemia/iron deficiency anemia has been associated with worse cognitive and motor development in young children in Chile and Guatemala (Lozoff 2007). The effects of anemia on ECD may not be immediate and these cross-sectional analyses do not allow for understanding whether anemia was experienced before developmental delays.

Our analyses also controlled for several covariates highlighting the importance of early childhood education, age in months, and wealth status on early childhood development. Our finding that in most countries, attendance of an early childhood education program was strongly associated with on-track early childhood development outcomes is consistent with other reports among young children in LMICs (Appendix A1–5). Two reviews found positive effects of early childhood education programs on literacy, psychosocial and other cognitive development measures among preschool aged children and children under age 2 in LMICs (Engle et al. 2011; Rao et al. 2014) and recent studies found similar results for language, psychosocial, and motor development among young children ranging from age 12 to 59 months in LMICs (Bliznashka et al. 2021; Larson, Martorell, and Bauer 2018; Prado et al. 2017). We also observed small positive associations with age and in general children from wealthier households were more likely to be on-track developmentally (Appendix A1–5). Both variables likely have some interaction with early childhood education, but findings for wealth are consistent with others showing disparities in early childhood development by socioeconomic status (Engle et al. 2011; Prado et al. 2017). Overall, as evidenced by the Nurturing Care Framework, many factors contribute to a child’s development and anemia is only one potential adverse exposure a child could have.

## **4.1 Strengths and Limitations**

To our knowledge this was the first study to examine the association between anemia and ECD using population-based survey data in LMICs. Although our results did not show strong or consistent results across countries, they are representative of entire populations. Further, the adjusted models reinforce the importance of the multi-sectoral Nurturing Care Framework for policy and programmatic approaches that address country-specific social and environmental contexts.

Our study is not without limitations. The cross-sectional nature of the data means we cannot infer causality and thus the direction of associations is not certain. However, given the consistency of our few results with other studies on the direction of association, provides some reassurance. We already discussed several challenges related to the key variable of interest—that is, anemia as a proxy representing current status, and temporality and how this may have contributed to the null findings and weak associations. In addition, anemia was calculated as a binary variable. We could have used hemoglobin concentration as a continuous variable, but the effect is unlikely linear. Additionally, we considered using only severe anemia, but that would have limited our sample size. Inclusion of markers of iron deficiency could have strengthened the analysis, but these are not collected in DHS surveys. We controlled for several confounders based on conceptual relevance because we wanted to examine the effect of anemia in context, but these variables



likely attenuated our already weak associations. Path or mediation analyses could be conducted to better understand the pathways and examine direct and indirect contributions of anemia. Another limitation is our outcome. Although we analyzed each development domain and the overall index separately, the literacy-numeracy and physical domains have been criticized (Bliznashka et al. 2021; Grantham-McGregor et al. 2007; McCoy et al. 2016). The literacy-numeracy domain includes items that are too advanced for children age 36–59 months, and the physical domain includes items that are basic functionalities for most children age 36–59 months (McCoy et al. 2016). Another criticism is that the ECDI is missing domains or items that capture other relevant cognitive functions which develop between 36–59 months such as increased attention span and processing speed (Bliznashka et al. 2021; Grantham-McGregor et al. 2007). The ECDI was also not intended to be used for domain-specific analyses. The new ECDI 2030 overcomes many of the challenges with the ECDI, but at the time of these surveys was not available. The ECDI is also based on caregiver recall and therefore is subject to recall bias and not as rigorous as direct child observations.

## **4.2 Conclusions**

Our study found virtually no associations between severe or moderate anemia and ECD domains and the overall ECD index among children age 36–59 months. Positive associations were observed for early learning/interaction variables and a few demographic variables. Multi-sectoral interventions that target children early and address disparities are important to promote ECD in LMICs. Future research could replicate these analyses with the new ECDI 2030 or direct developmental assessments which address some of the limitations of the ECDI, and longitudinal studies with younger children could also address temporality issues. Additionally, studies unpacking the complex pathways between nutrition indicators and all domains of nurturing care, and early childhood development outcomes in different contexts could inform targeted ECD policies and programs. Alone, effects of nutrition and health interventions on early childhood development can be modest, but in tandem with interventions from other sectors, they can contribute to promoting ECD.



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# APPENDIX

Appendix Table A1 Adjusted odds ratios for on-track early childhood development among children age 36–59 months across all countries

Variable	Benin 2017–18					Burundi 2016–17					Cambodia 2014					Haiti 2016–17					Jordan 2017–18					
	AOR	LB	UB	p value		AOR	LB	UB	p value		AOR	LB	UB	p value		AOR	LB	UB	p value		AOR	LB	UB	p value		
Severe or moderate anemia	1.00	1.00	1.00	.063		1.00	1.00	1.00	.353		1.00	0.99	1.00	.548		1.00	1.00	1.01	.392		1.00	0.99	1.00	.392		
Early child education	1.57	1.06	2.33	.024		2.96	1.74	5.05	.000		2.17	1.24	3.81	.007		1.46	0.93	2.32	.102		1.36	0.63	2.94	.432		
Availability of books	1.57	0.53	4.63	.417		0.40	0.07	2.29	.300		0.63	0.28	1.43	.273		1.55	0.81	3.00	.187		2.23	1.26	3.94	.006		
Availability of playthings	1.29	1.00	1.65	.048		0.88	0.67	1.15	.344		1.22	0.88	1.70	.238		1.04	0.72	1.51	.826		1.18	0.82	1.68	.373		
Adequate care	1.23	0.96	1.59	.104		1.09	0.86	1.39	.463		1.35	0.83	2.18	.224		1.54	0.99	2.40	.056		0.79	0.51	1.21	.278		
Support for learning	1.10	1.03	1.18	.005		1.02	0.95	1.10	.593		1.11	1.03	1.21	.010		1.06	1.02	1.07	.307		1.03	0.88	1.20	.710		
Age in months (36–59)	1.03	1.02	1.05	.000		1.03	1.01	1.05	.002		1.02	1.00	1.05	.032		1.04	1.02	1.07	.001		1.01	0.98	1.03	.490		
No illness past 2 weeks	1.31	1.02	1.68	.036		1.03	0.82	1.30	.794		1.01	0.69	1.48	.953		1.22	0.82	1.81	.328		0.86	0.59	1.27	.455		
Not malnourished <sup>a</sup>	1.21	0.96	1.53	.102		1.18	0.92	1.52	.191		1.37	1.02	1.84	.035		1.01	0.64	1.58	.969							
Mother's education level																										
None	0.77	0.53	1.11	.156		0.94	0.73	1.21	.618		1.41	0.92	2.16	.118		1.32	0.76	2.30	.317		0.63	0.21	1.88	.408		
Primary	1.00					1.00					1.00					1.00					1.00					
Secondary	0.87	0.53	1.43	.582		2.07	1.05	4.06	.035		1.41	0.93	2.14	.103		0.66	0.37	1.15	.142		1.29	0.64	2.57	.477		
Higher	1.49	0.30	7.42	.624		2.45	0.49	12.27	.275		3.56	0.52	24.33	.195		0.68	0.07	6.56	.739		1.39	0.63	3.07	.410		
Mother working	1.28	0.91	1.78	.151		1.24	0.85	1.82	.256		0.88	0.61	1.27	.493		0.81	0.55	1.20	.287		0.71	0.39	1.28	.254		
Mother's height <145 cm	0.71	0.24	2.13	.546		0.61	0.35	1.09	.098		1.00	0.53	1.89	.995		0.39	0.05	2.79	.346		1.78	0.38	8.30	.464		
Father's education level																										
None	0.97	0.69	1.34	.838		1.13	0.89	1.44	.330		0.98	0.59	1.61	.926		0.90	0.55	1.46	.662		1.32	0.42	4.20	.635		
Primary	1.00					1.00					1.00					1.00					1.00					
Secondary	1.20	0.82	1.74	.354		0.77	0.47	1.27	.302		1.01	0.68	1.51	.963		1.37	0.79	2.36	.264		1.66	0.99	2.79	.056		
Higher	1.92	0.89	4.16	.097		1.22	0.33	4.43	.765		0.99	0.33	2.97	.985		4.50	1.42	14.23	.011		2.85	1.44	5.64	.003		
3+ adults in household	1.04	0.81	1.33	.759		1.03	0.80	1.33	.804		0.78	0.56	1.09	.142		1.06	0.73	1.54	.750		1.39	0.90	2.14	.142		
household	0.97	0.73	1.29	.847		0.58	0.43	0.78	.000		1.01	0.54	1.88	.985		1.44	0.83	2.51	.194		0.76	0.50	1.17	.212		
WASH																										
Water-, toilet-	1.00					1.00					1.00					1.00										
Water-, toilet+	1.09	0.55	2.15	.804		1.38	0.81	2.38	.239		1.35	0.67	2.72	.393		1.01	0.49	2.08	.978							
Water+, toilet-	0.94	0.69	1.29	.705		0.96	0.62	1.47	.837		1.29	0.83	1.99	.258		0.99	0.58	1.67	.958							
Water+, toilet+	1.44	0.94	2.20	.096		1.19	0.75	1.90	.456		1.43	0.83	2.46	.192		0.97	0.51	1.85	.936							
Wealth quintile																										
Poorest	1.00					1.00					1.00					1.00										
Poorer	1.01	0.71	1.43	.947		0.84	0.59	1.20	.334		1.29	0.82	2.02	.267		0.95	0.57	1.61	.857		0.86	0.56	1.32	.486		
Middle	0.99	0.70	1.40	.959		1.09	0.76	1.56	.625		1.31	0.77	2.22	.319		1.04	0.48	2.22	.928		0.78	0.48	1.25	.302		
Richer	0.71	0.46	1.09	.116		1.14	0.78	1.67	.491		0.68	0.37	1.26	.224		1.21	0.53	2.74	.649		0.48	0.27	0.86	.013		
Richest	0.46	0.26	0.82	.009		1.06	0.62	1.80	.831		0.59	0.26	1.34	.210		1.34	0.47	3.85	.581		0.60	0.24	1.46	.259		
Residence																										
Urban	1.00					1.00					1.00					1.00										
Rural	1.23	0.92	1.65	.158		1.47	0.74	2.93	.270		0.75	0.44	1.28	.293		0.94	0.51	1.74	.842		0.82	0.55	1.22	.334		

Continued...

Appendix Table A1—Continued

Variable	Maldives 2016–17				Rwanda 2019–20				Senegal 2017				Uganda 2016			
	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value
	Severe or moderate anemia	1.01	0.99	1.02	.330	1.00	0.99	1.00	.889	1.00	1.00	1.00	.297	1.00	1.00	1.01
Early child education	2.60	0.97	6.99	.059	2.18	1.43	3.33	.000	2.02	1.37	2.98	.000	3.37	2.19	5.19	.000
Availability of books	0.95	0.36	2.53	.925	1.56	0.29	8.27	.603	4.64	0.98	21.96	.053	3.98	0.72	22.02	.113
Availability of playthings	0.38	0.15	1.01	.051	1.08	0.75	1.57	.675	0.83	0.62	1.12	.225	0.99	0.70	1.41	.973
Adequate care	2.20	0.77	6.32	.140	1.22	0.84	1.78	.301	0.75	0.59	0.95	.017	1.12	0.82	1.53	.487
Support for learning	0.56	0.17	1.87	.344	0.99	0.89	1.10	.883	0.86	0.80	0.93	.000	1.06	0.96	1.16	.239
Age in months (36–59)	1.08	1.00	1.16	.050	1.02	1.00	1.04	.106	1.02	1.01	1.04	.007	0.99	0.97	1.02	.612
No illness past 2 weeks	0.38	0.12	1.13	.081	1.25	0.87	1.79	.237	0.92	0.72	1.18	.535	1.07	0.77	1.48	.706
Not malnourished <sup>a</sup>	0.46	0.18	1.13	.089	1.05	0.75	1.48	.765	1.02	0.80	1.29	.881	0.99	0.72	1.38	.973
Mother's education level																
None	2.72	0.22	33.26	.432	0.73	0.45	1.20	.219	0.74	0.56	0.98	.034	1.25	0.80	1.95	.335
Primary	1.00				1.00				1.00				1.00			
Secondary	5.71	1.80	18.12	.003	1.67	0.86	3.25	.128	0.64	0.38	1.09	.100	1.19	0.70	2.03	.509
Higher	8.09	1.86	35.23	.006	1.16	0.30	4.57	.826	4.48	1.20	16.78	.026	1.04	0.33	3.28	.950
Mother working	1.12	0.41	3.04	.823	1.45	0.96	2.18	.078	1.09	0.85	1.41	.484	1.06	0.69	1.64	.789
Mother's height <145 cm	0.58	0.15	2.18	.419	1.20	0.42	3.40	.733					0.34	0.08	1.45	.144
Father's education level																
None	1.19	0.23	6.20	.839	0.96	0.57	1.61	.866	0.78	0.58	1.06	.111	1.19	0.63	2.23	.594
Primary	1.00				1.00				1.00				1.00			
Secondary	1.33	0.39	4.59	.646	0.84	0.44	1.58	.582	1.04	0.64	1.68	.874	1.09	0.69	1.71	.706
Higher	1.71	0.40	7.32	.468	0.77	0.20	2.95	.705	1.38	0.61	3.11	.437	1.27	0.61	2.65	.521
3+ adults in household	1.55	0.50	4.77	.444	0.80	0.55	1.16	.247	0.90	0.61	1.31	.577	1.02	0.72	1.45	.909
3+ children under 5 in household	0.26	0.06	1.01	.051	0.61	0.34	1.07	.086	0.77	0.59	1.01	.056	1.38	0.86	2.22	.186
WASH																
Water, toilet-					1.00				1.00				1.00			
Water, toilet+					1.29	0.71	2.34	.410	1.00	0.60	1.68	.991	1.93	0.72	5.15	.188
Water+, toilet-					1.54	0.88	2.72	.132	1.04	0.71	1.51	.857	0.82	0.50	1.35	.432
Water+, toilet+					1.64	0.94	2.85	.079	1.60	1.06	2.43	.026	1.31	0.73	2.34	.364
Wealth quintile																
Poorest	1.00				1.00				1.00				1.00			
Poorer	2.98	0.89	9.96	.076	1.51	0.96	2.36	.071	0.81	0.59	1.12	.201	1.11	0.69	1.78	.666
Middle	1.70	0.53	5.51	.373	2.31	1.35	3.97	.002	0.60	0.39	0.93	.021	1.65	1.00	2.72	.049
Richer	0.99	0.25	3.91	.989	2.92	1.60	5.34	.001	0.74	0.44	1.24	.258	0.85	0.48	1.50	.575
Richest	1.00				1.82	0.85	3.89	.124	0.69	0.33	1.44	.324	1.41	0.65	3.04	.380
Residence																
Urban	1.00				1.00				1.00				1.00			
Rural	0.40	0.08	2.08	.272	1.34	0.77	2.33	.297	1.20	0.84	1.73	.316	0.71	0.41	1.24	.231

AOR = adjusted odds ratio; LB = lower bound of confidence interval; UB = upper bound of confidence interval

<sup>a</sup> Malnourished refers to children who are not stunted, underweight, overweight, or wasted.

Note: Models were adjusted for region. In Jordan child nutritional status was not included and in Senegal maternal height was not included. Blank cells indicate that no coefficients were produced in the model because of small sample sizes.



Appendix Table A2 Adjusted odds ratios for on-track literacy-numeracy development among children age 36–59 months across all countries

Variable	Benin 2017–18					Burundi 2016–17					Cambodia 2014					Haiti 2016–17					Jordan 2017–18				
	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	
Severe or moderate anemia	1.00	0.99	1.01	.924	1.00	1.00	1.01	.715	1.00	1.00	1.01	.487	0.99	0.99	1.00	.133	1.00	0.99	1.00	1.00	0.99	1.00	1.00	.547	
Early child education	7.92	4.55	13.77	.000	5.24	2.77	9.91	.000	4.34	2.60	7.26	.000	2.54	1.36	4.75	.004	3.10	1.71	5.61	1.00	1.71	1.71	5.61	.000	
Availability of books	2.50	0.98	6.40	.055	4.06	0.68	24.23	.124	1.09	0.43	2.74	.854	3.72	1.70	8.14	.001	2.31	1.42	3.76	1.00	1.42	1.42	3.76	.001	
Availability of playthings	1.92	1.05	3.49	.034	1.34	0.82	2.19	.236	1.24	0.80	1.92	.328	0.90	0.52	1.55	.712	1.68	1.11	2.53	1.00	1.11	1.11	2.53	.014	
Adequate care	0.86	0.49	1.51	.603	1.00	0.60	1.66	.992	1.12	0.65	1.91	.686	1.00	0.54	1.88	.988	1.02	0.69	1.50	1.00	0.69	1.50	.938		
Support for learning	0.97	0.84	1.12	.651	0.98	0.84	1.14	.778	1.12	1.01	1.26	.038	1.00	0.98	1.33	.095	1.02	0.89	1.18	1.00	0.89	1.18	.775		
Age in months (36–59)	1.10	1.06	1.14	.000	1.04	1.01	1.07	.009	1.05	1.03	1.08	.000	1.12	1.08	1.17	.000	1.04	1.02	1.06	1.00	1.02	1.06	.000		
No illness past 2 weeks	0.87	0.48	1.57	.637	1.04	0.68	1.60	.848	1.31	0.85	2.01	.226	1.05	0.62	1.77	.870	0.93	0.60	1.47	1.00	0.60	1.47	.767		
Not malnourished <sup>a</sup>	1.41	0.74	2.68	.300	1.43	0.92	2.21	.112	1.14	0.80	1.62	.466	2.08	0.94	4.60	.071	0.93	0.60	1.47	1.00	0.60	1.47	.767		
Mother's education level																									
None	0.63	0.32	1.25	.186	0.46	0.28	0.75	.002	0.62	0.32	1.20	.155	0.61	0.27	1.37	.228	0.28	0.09	0.82	1.00	0.09	0.82	.021		
Primary	1.00				1.00				1.00				1.00				1.00			1.00					
Secondary	0.83	0.44	1.58	.570	3.61	1.52	8.58	.004	1.49	0.99	2.25	.055	0.72	0.37	1.40	.329	0.55	0.27	1.13	1.00	0.27	1.13	.102		
Higher	1.02	0.14	7.57	.983	2.34	0.23	23.21	.468	2.14	0.58	7.85	.251	0.30	0.06	1.47	.136	0.70	0.32	1.54	1.00	0.32	1.54	.375		
Mother working	1.53	0.70	3.32	.286	0.67	0.38	1.20	.178	1.35	0.91	2.01	.138	1.09	0.65	1.84	.736	1.10	0.63	1.95	1.00	0.63	1.95	.731		
Mother's height <145 cm	2.72	0.58	12.87	.206	1.00				0.88	0.44	1.75	.712	1.48	0.10	22.09	.774	1.03	0.32	3.25	1.00	0.32	3.25	.965		
Father's education level																									
None	0.56	0.25	1.24	.152	0.75	0.43	1.29	.295	1.28	0.69	2.35	.433	1.14	0.55	2.34	.725	0.38	0.13	1.11	1.00	0.13	1.11	.076		
Primary	1.00				1.00				1.00				1.00				1.00			1.00					
Secondary	1.11	0.54	2.30	.777	0.59	0.24	1.46	.252	1.18	0.76	1.85	.458	1.96	0.96	3.99	.064	1.05	0.58	1.89	1.00	0.58	1.89	.865		
Higher	2.48	0.90	6.80	.078	0.62	0.13	2.98	.547	2.19	0.94	5.08	.069	2.92	0.97	8.83	.057	1.33	0.65	2.70	1.00	0.65	2.70	.437		
3+ adults in household	0.97	0.57	1.64	.902	1.28	0.78	2.13	.329	0.86	0.61	1.21	.382	1.00	0.61	1.66	.988	1.34	0.87	2.05	1.00	0.87	2.05	.180		
3+ children under 5 in household	1.15	0.57	2.32	.698	0.52	0.26	1.06	.070	0.73	0.39	1.36	.320	1.79	0.81	3.95	.146	1.20	0.80	1.81	1.00	0.80	1.81	.381		
WASH																									
Water, toilet-	1.00				1.00				1.00				1.00				1.00			1.00					
Water+, toilet+	0.91	0.28	3.04	.884	0.55	0.16	1.91	.343	1.34	0.58	3.12	.492	1.02	0.30	3.43	.974	1.00			1.00					
Water+, toilet-	0.69	0.29	1.65	.408	0.82	0.35	1.89	.636	1.02	0.49	2.11	.964	0.85	0.38	1.93	.698	1.00			1.00					
Water+, toilet+	0.92	0.36	2.34	.866	0.71	0.27	1.85	.486	1.82	0.83	3.96	.132	0.52	1.21	1.31	.131	1.00			1.00					
Wealth quintile																									
Poorest	1.00				1.00				1.00				1.00				1.00			1.00					
Poorer	1.25	0.30	5.14	.756	0.71	0.32	1.59	.404	0.92	0.50	1.70	.786	1.95	0.75	5.07	.171	1.51	0.96	2.36	1.00	0.96	2.36	.075		
Middle	2.06	0.46	9.18	.344	1.06	0.50	2.23	.880	1.15	0.61	2.17	.668	3.01	1.24	7.30	.015	1.03	0.61	1.76	1.00	0.61	1.76	.909		
Richer	2.60	0.63	10.79	.188	1.08	0.51	2.28	.839	1.04	0.54	1.97	.916	3.20	1.11	9.28	.032	0.95	0.51	1.75	1.00	0.51	1.75	.866		
Richest	5.18	1.13	23.84	.035	0.73	0.20	2.68	.637	0.88	0.38	2.04	.759	5.44	1.61	18.32	.006	1.17	0.53	2.59	1.00	0.53	2.59	.697		
Residence																									
Urban	1.00				1.00				1.00				1.00				1.00			1.00					
Rural	0.85	0.49	1.47	.558	0.75	0.30	1.82	.520	1.33	0.81	2.18	.261	1.03	0.55	1.94	.921	0.72	0.46	1.11	1.00	0.46	1.11	.133		

Continued...

Appendix Table A2—Continued

Variable	Maldives 2016–17				Rwanda 2019–20				Senegal 2017				Uganda 2016			
	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value
Severe or moderate anemia	1.00	0.98	1.01	.532	1.00	0.99	1.01	.997	1.00	0.99	1.00	.419	1.00	1.00	1.01	.316
Early child education	3.61	1.69	7.69	.001	3.32	2.14	5.15	.000	1.96	1.02	3.75	.042	21.58	13.33	34.96	.000
Availability of books	1.09	0.51	2.35	.823	1.87	0.63	5.51	.258	8.40	2.86	24.64	.000	1.92	0.62	5.94	.257
Availability of playthings	0.45	0.19	1.06	.069	1.05	0.68	1.63	.816	1.49	0.77	2.88	.231	1.72	1.02	2.93	.044
Adequate care	0.51	0.07	3.88	.516	0.91	0.57	1.46	.702	0.64	0.27	1.55	.324	1.32	0.83	2.09	.237
Support for learning	0.85	0.44	1.66	.639	1.10	0.97	1.25	.123	1.73	1.41	2.13	.000	1.05	0.95	1.17	.352
Age in months (36–59)	1.09	1.05	1.13	.000	1.06	1.03	1.09	.000	1.10	1.04	1.15	.000	1.03	1.00	1.06	.093
No illness past 2 weeks	1.21	0.45	3.23	.706	1.26	0.79	2.01	.323	1.15	0.59	2.24	.691	1.03	0.64	1.65	.914
Not malnourished <sup>a</sup>	0.96	0.50	1.87	.911	1.79	1.08	2.97	.023	1.81	0.78	4.19	.168	1.47	0.91	2.36	.116
Mother's education level																
None	3.63	0.12	114.20	.461	0.63	0.32	1.22	.169	0.32	0.13	0.80	.015	0.47	0.19	1.14	.096
Primary	1.00				1.00				1.00				1.00			
Secondary	2.94	1.10	7.84	.032	1.47	0.88	2.46	.138	0.80	0.34	1.86	.599	0.96	0.52	1.77	.898
Higher	12.02	1.85	78.15	.009	1.68	0.60	4.69	.324	11.14	2.35	52.87	.003	1.30	0.36	4.63	.687
Mother working	1.00	0.53	1.89	.994	0.79	0.48	1.32	.376	1.01	0.47	2.18	.975	0.68	0.34	1.36	.270
Mother's height <145 cm	1.22	0.44	3.40	.699	1.51	0.38	6.01	.555					0.97	0.17	5.39	.971
Father's education level																
None	8.76	2.04	37.57	.004	0.98	0.45	2.16	.964	0.29	0.11	0.78	.015	0.50	0.19	1.30	.153
Primary	1.00				1.00				1.00				1.00			
Secondary	1.11	0.48	2.56	.806	0.66	0.34	1.28	.218	0.49	0.22	1.12	.090	1.25	0.69	2.26	.465
Higher	1.05	0.30	3.67	.943	0.80	0.29	2.23	.672	0.62	0.18	2.20	.462	1.14	0.48	2.69	.765
3+ adults in household	1.36	0.57	3.23	.480	1.17	0.72	1.91	.528	2.82	0.96	8.30	.059	1.01	0.60	1.70	.977
3+ children under 5 in household	0.94	0.40	2.21	.879	0.69	0.30	1.59	.386	0.76	0.37	1.56	.448	0.84	0.46	1.55	.587
WASH																
Water-, toilet-					1.00				1.00				1.00			
Water-, toilet+					0.88	0.30	2.59	.813	2.96	0.45	19.38	.256	1.12	0.40	3.12	.835
Water+, toilet-					2.54	0.87	7.41	.087	1.32	0.17	10.49	.793	1.54	0.76	3.13	.231
Water+, toilet+					1.74	0.63	4.81	.282	3.16	0.39	25.45	.279	1.19	0.52	2.70	.679
Wealth quintile																
Poorest	1.00				1.00				1.00				1.00			
Poorer	3.37	1.33	8.49	.010	1.63	0.77	3.46	.199	1.49	0.22	10.28	.687	2.32	1.00	5.34	.049
Middle	3.86	1.71	8.73	.001	1.85	0.83	4.10	.132	1.75	0.28	11.00	.548	5.39	2.35	12.35	.000
Richer	0.83	0.25	2.69	.749	1.26	0.54	2.93	.588	1.30	0.14	12.08	.818	4.28	1.70	10.77	.002
Richest	0.20	0.02	2.42	.203	3.09	1.27	7.52	.013	2.70	0.32	23.16	.363	5.38	1.81	15.99	.003
Residence																
Urban	1.00				1.00				1.00				1.00			
Rural	0.43	0.07	2.49	.342	1.01	0.50	2.01	.986	0.87	0.37	2.05	.754	0.73	0.40	1.34	.309

AOR = adjusted odds ratio; LB = lower bound of confidence interval; UB = upper bound of confidence interval

<sup>a</sup> Malnourished refers to children who are not stunted, underweight, overweight, or wasted.

Note: Models were adjusted for region. In Jordan child nutritional status was not included and in Senegal maternal height was not included.

Blank cells indicate that no coefficients were produced in the model because of small sample sizes.

Appendix Table A3 Adjusted odds ratios for on-track physical development among children age 36–59 months across all countries

Variable	Benin 2017-18					Burundi 2016-17					Cambodia 2014					Haiti 2016-17					Jordan 2017-18				
	AOR	LB	UB	P value		AOR	LB	UB	P value		AOR	LB	UB	P value		AOR	LB	UB	P value		AOR	LB	UB	P value	
Severe or moderate anemia	1.00	1.00	1.01	.358		1.00	0.99	1.00	.855		0.99	0.98	1.00	.099		0.99	0.98	1.00	.052		1.00	0.98	1.01	.686	
Early child education	1.74	0.75	4.08	.198		1.64	0.60	4.47	.334		0.87	0.15	5.09	.876		1.47	0.75	2.89	.258		1.34	0.26	6.90	.726	
Availability of books	1.00				1.00					1.22	0.17	8.82	8.43	.843		0.44	0.17	1.14	.090		1.54	0.62	3.84	.349	
Availability of playthings	1.23	0.75	2.02	.418		2.31	1.31	4.07	.004		0.83	0.38	1.83	.650		0.95	0.54	1.70	.874		0.74	0.33	1.68	.478	
Adequate care	0.93	0.58	1.50	.766		1.20	0.73	1.98	.469		0.55	0.11	2.74	.465		0.84	0.41	1.73	.644		0.26	0.11	0.58	.001	
Support for learning	1.22	1.07	1.40	.003		1.03	0.90	1.19	.651		0.87	0.70	1.08	.194		1.19	0.97	1.47	.095		0.68	0.47	0.99	.046	
Age in months (36–59)	1.02	0.99	1.05	.206		1.03	1.00	1.06	.059		1.02	0.95	1.08	.620		1.00	0.93	1.06	.896		0.97	0.93	1.02	.295	
No illness past 2 weeks	1.81	1.12	2.95	.016		1.06	0.68	1.67	.785		1.47	0.58	3.76	.418		2.18	0.84	5.65	.110		1.11	0.43	2.87	.829	
Not malnourished <sup>a</sup>	1.64	1.06	2.55	.027		0.87	0.55	1.38	.555		1.00	0.45	2.22	1.000		1.04	0.49	2.20	.923						
Mother's education level																									
None	1.28	0.64	2.57	.485		1.21	0.73	2.00	.471		1.56	0.52	4.65	.424		1.46	0.39	5.48	.572		0.82	0.11	5.89	.845	
Primary	1.00				1.00					1.00					1.00					1.00					
Secondary	2.30	0.66	8.08	.192		1.26	0.27	5.80	.770		0.83	0.33	2.10	.696		3.52	0.92	13.47	.065		2.29	0.78	6.71	.130	
Higher	0.19	0.03	1.34	.095		1.00				1.48	0.10	21.47	.772		1.00					1.89	0.61	5.85	2.66		
Mother working	1.50	0.81	2.75	.194		0.85	0.38	1.88	.682		0.88	0.34	2.27	.792		1.14	0.54	2.40	.725		0.41	0.17	1.03	.058	
Mother's height <145 cm	0.49	0.09	2.60	.402		1.08	0.41	2.82	.875		2.10	0.24	18.46	.504											
Father's education level																									
None	1.29	0.64	2.60	.482		0.96	0.61	1.52	.869		1.69	0.53	5.36	.374		1.02	0.48	2.17	.952		0.18	0.04	0.92	.040	
Primary	1.00				1.00					1.00					1.00					1.00					
Secondary	1.04	0.48	2.27	.917		1.20	0.39	3.76	.749		1.72	0.61	4.87	.307		1.54	0.46	5.14	.483		0.69	0.23	2.11	.519	
Higher	1.32	0.21	8.47	.768		3.58	0.24	53.95	.356		2.51	0.47	13.56	.284		1.00				1.89	0.45	8.00	.388		
3+ adults in household	0.57	0.34	0.96	.034		0.68	0.43	1.09	.113		0.61	0.26	1.44	.255		0.61	0.30	1.24	.170		0.98	0.41	2.35	.960	
3+ children under 5 in household	0.84	0.48	1.47	.535		0.71	0.41	1.24	.229		1.00				1.22	0.42	3.52	.710		0.66	0.25	1.75	.401		
WASH																									
Water-, toilet-	1.00				1.00					1.00					1.00										
Water-, toilet+	3.14	0.36	27.45	.301		1.50	0.54	4.19	.434		2.32	0.38	14.10	.360		5.42	0.40	73.73	.204		0.44	0.17	1.13	.088	
Water+, toilet-	0.85	0.47	1.54	.589		0.53	0.26	1.11	.091		0.98	0.34	2.86	.974		0.86	0.32	2.36	.772		0.55	0.24	1.25	.152	
Water+, toilet+	1.20	0.51	2.81	.678		0.87	0.38	1.99	.747		3.72	0.56	24.65	.173		1.94	0.56	6.75	.295		0.58	0.14	2.47	.459	
Wealth quintile																									
Poorest	1.00				1.00					1.00					1.00					1.00					
Poorer	0.65	0.26	1.62	.353		1.14	0.60	2.18	.691		3.47	1.16	10.41	.027		0.78	0.32	1.89	.582		0.44	0.17	1.13	.088	
Middle	0.64	0.25	1.63	.353		0.81	0.45	1.49	.505		14.33	3.93	52.22	.000		0.34	0.11	1.03	.056		0.55	0.24	1.25	.152	
Richer	0.43	0.16	1.14	.091		1.68	0.85	3.32	.132		3.12	0.34	28.86	.316		0.38	0.07	2.11	.265		0.58	0.14	2.47	.459	
Richest	0.14	0.04	0.46	.001		1.03	0.36	2.93	.953		1.23	0.17	9.15	.838		0.52	0.06	4.19	.537		27.28	2.18	342.03	.010	
Residence																									
Urban	1.00				1.00					1.00					1.00					1.00					
Rural	0.52	0.26	1.04	.064		2.17	0.87	5.42	.096		2.67	0.48	14.81	.259		0.26	0.06	1.17	.079		0.78	0.29	2.14	.633	

Continued...

Appendix Table A3—Continued

Variable	Maldives 2016–17				Rwanda 2019–20				Senegal 2017				Uganda 2016			
	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value
Severe or moderate anemia	0.97	0.95	0.98	.001	1.01	1.00	1.03	.120	1.00	0.99	1.00	.402	1.00	0.99	1.00	.294
Early child education	0.01	0.00	1.60	.073	1.09	0.50	2.36	.833	1.78	0.85	3.73	.126	2.40	1.07	5.41	.034
Availability of books	2.66	0.40	17.90	.309	0.67	0.32	1.39	.282	0.58	0.33	1.00	.049	1.51	0.82	2.48	.336
Adequate care	55.67	4.45	697.19	.002	0.75	0.32	1.75	.509	0.70	0.44	1.12	.139	0.95	0.57	1.58	.841
Support for learning	9.14	1.52	55.07	.016	0.95	0.78	1.16	.627	0.76	0.67	0.87	.000	0.89	0.77	1.04	.153
Age in months (36–59)	0.88	0.78	0.99	.037	1.05	1.00	1.09	.057	1.01	0.98	1.04	.641	0.96	0.93	1.00	.047
No illness past 2 weeks	0.01	0.00	1.33	.065	1.15	0.57	2.30	.694	0.72	0.43	1.22	.223	0.75	0.44	1.29	.301
Not mainourished <sup>a</sup>					1.09	0.55	2.17	.806	1.24	0.73	2.11	.430	1.10	0.62	1.96	.750
Mother's education level																
None	0.00	0.00	1.49	.060	0.53	0.21	1.35	.181	0.26	0.13	0.53	.000	1.43	0.65	3.17	.377
Primary	1.00				1.00				1.00				1.00			
Secondary	54.84	0.69	4,328.96	.072	1.25	0.35	4.51	.733	0.85	0.23	3.13	.804	3.76	1.28	11.06	.016
Higher	10.54	0.20	558.71	.241	0.63	0.03	13.31	.765	0.09	0.02	0.34	.001	1.03	0.22	4.87	.971
Mother working	36.35	1.50	883.62	.028	0.70	0.25	1.95	.489	1.26	0.72	2.21	.408	2.11	1.09	4.08	.028
Mother's height <145 cm	0.00	0.00	4.23	.109									1.44	0.21	9.84	.707
Father's education level																
None	0.22	0.01	3.67	.287	0.92	0.38	2.21	.845	1.08	0.52	2.24	.839	0.63	0.31	1.28	.200
Primary	1.00				1.00				1.00				1.00			
Secondary	0.00	0.00	20.65	.173	0.59	0.15	2.28	.445	5.11	0.13	1.98	.332	0.93	0.44	1.95	.842
Higher	0.01	0.00	39.26	.274	1.00	0.36	1.35	.285	0.92	0.38	2.19	.845	1.06	0.62	2.00	.478
3+ adults in household					0.70				0.93				1.06		1.80	.830
3+ children under 5 in household	0.91	0.17	4.88	.915	1.56	0.40	6.12	.524	0.93	0.54	1.58	.775	0.79	0.38	1.66	.532
WASH																
Water+, toilet-	1.00				1.00				1.00				1.00			
Water+, toilet+	0.00	0.00	1.12	.055	1.05	0.45	2.47	.910	1.12	0.64	1.96	.684	1.28	0.61	2.69	.515
Water+, toilet+	0.01	0.00	0.66	.033	3.82	1.15	12.74	.029	0.67	0.33	1.34	.257	2.03	0.93	4.44	.075
Water+, toilet+	0.00	0.00	0.09	.017	2.84	0.92	8.79	.070	0.65	0.27	1.58	.342	1.73	0.70	4.27	.236
Wealth quintile					2.87	0.76	10.76	.118	2.52	0.55	11.57	.232	1.92	0.59	6.31	.279
Poorest	1.00				1.00				1.00				1.00			
Poorer	0.00	0.00	1.12	.055	1.05	0.45	2.47	.910	1.12	0.64	1.96	.684	1.28	0.61	2.69	.515
Middle	0.01	0.00	0.66	.033	3.82	1.15	12.74	.029	0.67	0.33	1.34	.257	2.03	0.93	4.44	.075
Richer	0.00	0.00	0.09	.017	2.84	0.92	8.79	.070	0.65	0.27	1.58	.342	1.73	0.70	4.27	.236
Richest	0.00	0.00	0.09	.017	2.87	0.76	10.76	.118	2.52	0.55	11.57	.232	1.92	0.59	6.31	.279
Residence																
Urban	1.00				1.00				1.00				1.00			
Rural	1.00				1.40	0.43	4.55	.570	1.09	0.63	1.89	.764	0.25	0.07	0.86	.029

AOR = adjusted odds ratio; LB = lower bound of confidence interval; UB = upper bound of confidence interval

<sup>a</sup> Mainourished refers to children who are not stunted, underweight, overweight, or wasted.

Note: Models were adjusted for region. In Jordan child nutritional status was not included and in Senegal maternal height was not included. Blank cells indicate that no coefficients were produced in the model because of small sample sizes.

**Appendix Table A4 Adjusted odds ratios for on-track for social-emotional development among children age 36–59 months across all countries**

Variable	Benin 2017–18				Burundi 2016–17				Cambodia 2014				Haiti 2016–17				Jordan 2017–18			
	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value
Severe or moderate anemia	1.00	0.99	1.00	.023	1.00	1.00	1.00	.469	1.00	0.99	1.00	.261	1.00	1.00	1.01	.465	1.00	1.00	1.01	.428
Early child education	0.89	0.60	1.32	.578	1.20	0.70	2.04	.504	0.85	0.53	1.37	.507	0.83	0.51	1.36	.468	0.70	0.39	1.27	.245
Availability of books	0.43	0.20	0.95	.036	0.27	0.06	1.23	.090	0.76	0.38	1.53	.445	1.28	0.67	2.46	.458	1.66	1.00	2.74	.050
Availability of playthings	1.00	0.75	1.33	.997	0.78	0.60	1.02	.070	1.12	0.82	1.53	.478	1.16	0.79	1.70	.458	0.72	0.44	1.17	.186
Adequate care	1.33	1.01	1.76	.044	1.31	1.03	1.66	.025	1.45	0.92	2.28	.107	1.75	1.13	2.72	.013	0.62	0.42	0.92	.018
Support for learning	1.08	1.01	1.16	.032	1.04	0.97	1.13	.258	1.07	0.98	1.16	.114	1.14	0.97	1.10	.667	0.99	0.86	1.14	.909
Age in months (36–59)	1.01	0.99	1.03	.397	1.01	0.99	1.03	.187	1.00	0.98	1.02	.793	1.00	0.98	1.03	.915	0.99	0.96	1.01	.343
No illness past 2 weeks	1.19	0.91	1.55	.194	1.18	0.93	1.49	.174	0.87	0.63	1.22	.423	1.22	0.83	1.79	.301	1.01	0.70	1.47	.938
Not malnourished <sup>a</sup>	1.05	0.80	1.37	.717	1.02	0.78	1.33	.910	1.50	1.11	2.02	.008	0.90	0.57	1.44	.666				
Mother's education level																				
None	0.80	0.55	1.17	.251	0.98	0.76	1.27	.894	1.52	1.00	2.33	.051	1.76	1.02	3.04	.041	1.09	0.37	3.21	.872
Primary	1.00				1.00				1.00				1.00				1.00			
Secondary	0.83	0.49	1.38	.469	1.21	0.68	2.15	.512	1.26	0.86	1.85	.235	1.08	0.63	1.84	.784	0.80	0.37	1.72	.560
Higher	18.55	2.05	168.25	.010	5.42	1.19	24.81	.029	1.05	0.30	3.58	.944	2.12	0.28	15.90	.464	0.76	0.33	1.76	.527
Mother working	0.81	0.53	1.24	.331	1.36	0.91	2.05	.133	0.91	0.61	1.36	.645	0.98	0.65	1.46	.916	1.31	0.73	2.35	.361
Mother's height <145 cm	1.95	0.52	7.23	.318	0.69	0.41	1.15	.158	1.38	0.71	2.68	.342	0.57	0.06	5.09	.612	0.46	0.12	1.76	.255
Father's education level																				
None	1.07	0.75	1.53	.716	1.34	1.05	1.71	.021	1.02	0.59	1.77	.940	0.66	0.40	1.07	.093	1.63	0.61	4.36	.329
Primary	1.00				1.00				1.00				1.00				1.00			
Secondary	1.18	0.81	1.71	.397	0.99	0.60	1.62	.956	1.12	0.77	1.61	.552	0.77	0.44	1.35	.361	1.79	1.00	3.19	.050
Higher	1.10	0.50	2.40	.811	0.64	0.21	1.88	.411	1.08	0.44	2.63	.870	1.55	0.59	4.11	.374	2.09	1.08	4.03	.028
3+ adults in household	1.30	0.97	1.74	.083	1.18	0.92	1.51	.202	0.96	0.70	1.32	.813	1.18	0.78	1.77	.431	1.40	0.93	2.09	.104
3+ children under 5 in household	0.81	0.60	1.08	.149	0.62	0.46	0.82	.001	1.30	0.68	2.48	.420	1.42	0.75	2.70	.281	1.07	0.66	1.74	.783
WASH																				
Water-, toilet-	1.00				1.00				1.00				1.00				1.00			
Water-, toilet+	0.80	0.38	1.72	.574	1.07	0.61	1.86	.825	1.14	0.61	2.14	.671	1.17	0.48	2.89	.726	0.70	0.46	1.07	.103
Water+, toilet-	1.04	0.75	1.44	.807	0.78	0.51	1.21	.270	1.16	0.74	1.82	.512	0.84	0.48	1.44	.516	0.52	0.33	0.84	.007
Water+, toilet+	1.78	1.11	2.85	.017	1.02	0.65	1.61	.924	0.90	0.55	1.47	.679	1.41	0.69	2.87	.342	0.44	0.23	0.82	.009
Wealth quintile																				
Poorest	1.00				1.00				1.00				1.00				1.00			
Poorer	1.14	0.76	1.70	.524	0.93	0.63	1.36	.693	1.19	0.76	1.87	.437	1.13	0.64	1.98	.673	0.70	0.46	1.07	.103
Middle	0.89	0.59	1.35	.585	0.74	0.51	1.06	.103	0.69	0.41	1.17	.168	0.86	0.41	1.81	.683	0.52	0.33	0.84	.007
Richer	0.94	0.59	1.50	.793	0.82	0.55	1.21	.307	0.51	0.28	0.94	.031	0.78	0.31	1.93	.588	0.44	0.23	0.82	.009
Richest	0.47	0.25	0.89	.020	0.72	0.42	1.23	.232	0.70	0.32	1.51	.364	0.74	0.25	2.23	.596	0.57	0.28	1.15	.117
Residence																				
Urban	1.00				1.00				1.00				1.00				1.00			
Rural	1.12	0.78	1.62	.544	1.37	0.83	2.29	.221	0.74	0.45	1.20	.218	0.93	0.49	1.74	.816	0.99	0.64	1.53	.958

Continued...

Appendix Table A4—Continued

Variable	Maldives 2016–17					Rwanda 2019–20					Senegal 2017					Uganda 2016					
	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	
	Severe or moderate anemia	1.00	0.99	1.01	.565	1.00	0.99	1.01	.741	1.00	1.00	1.00	.421	1.00	1.00	1.01	.173	1.00	1.00	1.01	.173
Early child education	1.16	0.61	2.22	.653	0.59	0.30	1.16	.126	1.62	1.07	2.45	.022	1.12	0.78	1.61	.554	1.12	0.78	1.61	.554	
Availability of books	1.26	0.67	2.40	.471	0.41	0.06	2.71	.356	2.10	0.59	7.44	.250	0.90	0.32	2.53	.840	0.90	0.32	2.53	.840	
Availability of playthings	1.18	0.62	2.26	.605	1.44	0.76	2.74	.260	0.68	0.74	0.94	.019	0.70	0.49	1.00	.052	0.70	0.49	1.00	.052	
Adequate care	0.71	0.29	1.74	.457	3.26	1.65	6.44	.001	0.75	0.58	0.96	.023	1.28	0.91	1.81	.156	1.28	0.91	1.81	.156	
Support for learning	0.99	0.65	1.49	.946	0.90	0.70	1.16	.424	0.77	0.70	0.84	.000	1.10	1.01	1.20	.032	1.10	1.01	1.20	.032	
Age in months (36–59)	0.97	0.93	1.02	.267	1.01	0.97	1.06	.513	1.01	1.00	1.03	.132	0.99	0.97	1.01	.416	0.99	0.97	1.01	.416	
No illness past 2 weeks	0.67	0.32	1.41	.286	2.16	1.13	4.09	.019	1.03	0.80	1.32	.819	1.55	1.12	2.14	.008	1.55	1.12	2.14	.008	
Not malnourished <sup>a</sup>	0.55	0.26	1.14	.107	0.67	0.34	1.32	.247	1.11	0.87	1.40	.401	1.01	0.70	1.45	.972	1.01	0.70	1.45	.972	
Mother's education level																					
None	3.35	0.47	24.08	.227	1.66	0.80	3.42	.173	0.76	0.54	1.09	.140	1.33	0.82	2.15	.241	1.33	0.82	2.15	.241	
Primary	1.00				1.00				1.00				1.00				1.00				
Secondary	1.93	0.77	4.85	.162	1.90	0.51	7.08	.338	0.58	0.30	1.15	.117	0.93	0.59	1.49	.771	0.93	0.59	1.49	.771	
Higher	0.78	0.18	3.39	.745	1.00	0.58	3.11	.485	1.26	0.38	4.15	.702	2.78	1.01	7.68	.049	2.78	1.01	7.68	.049	
Mother working	1.17	0.63	2.16	.616	1.35	0.58	3.11	.485	1.06	0.82	1.38	.631	1.09	0.69	1.71	.718	1.09	0.69	1.71	.718	
Mother's height <145 cm	2.17	0.83	5.66	.114	2.32	0.28	19.03	.432	2.32	0.28	19.03	.432	0.46	0.12	1.76	.259	0.46	0.12	1.76	.259	
Father's education level																					
None	0.61	0.18	2.06	.427	0.58	0.26	1.26	.168	0.93	0.66	1.30	.662	1.76	0.76	4.04	.186	1.76	0.76	4.04	.186	
Primary	1.00				1.00				1.00				1.00				1.00				
Secondary	1.02	0.40	2.60	.970					0.89	0.54	1.47	.653	1.34	0.86	2.08	.191	1.34	0.86	2.08	.191	
Higher	1.25	0.46	3.38	.656					1.59	0.65	3.87	.310	1.38	0.76	2.49	.292	1.38	0.76	2.49	.292	
3+ adults in household	0.99	0.51	1.95	.985	0.88	0.43	1.82	.735	0.87	0.55	1.38	.556	1.01	0.72	1.42	.945	1.01	0.72	1.42	.945	
3+ children under 5 in household	0.58	0.28	1.19	.136	1.01	0.35	2.97	.982	0.89	0.66	1.21	.463	1.33	0.88	2.01	.178	1.33	0.88	2.01	.178	
WASH																					
Water-, toilet-					1.00				1.00				1.00				1.00				
Water-, toilet+					0.70	0.15	3.32	.653	0.64	0.37	1.11	.115	2.52	0.95	6.67	.063	2.52	0.95	6.67	.063	
Water+, toilet-					0.58	0.15	2.27	.435	0.85	0.57	1.28	.430	1.43	0.86	2.38	.163	1.43	0.86	2.38	.163	
Water+, toilet+					0.47	0.13	1.73	.256	1.02	0.66	1.57	.925	2.00	0.97	4.11	.059	2.00	0.97	4.11	.059	
Wealth quintile																					
Poorest	1.00				1.00				1.00				1.00				1.00				
Poorer	1.39	0.66	2.97	.386	0.83	0.37	1.85	.642	1.02	0.74	1.41	.883	0.79	0.49	1.29	.355	1.02	0.74	1.41	.883	
Middle	1.01	0.48	2.14	.974	2.74	0.92	8.17	.070	0.86	0.56	1.34	.510	0.81	0.50	1.31	.384	0.86	0.56	1.34	.510	
Richer	1.84	0.47	7.20	.381	1.14	0.46	2.82	.771	0.86	0.49	1.51	.598	0.49	0.28	0.88	.016	0.86	0.49	1.51	.598	
Richest	0.42	0.06	3.10	.396	3.17	0.74	13.50	.118	3.17	0.69	3.30	.399	0.51	0.23	1.15	.107	3.17	0.69	3.30	.399	
Residence																					
Urban	1.00				1.00				1.00				1.00				1.00				
Rural	0.88	0.18	4.30	.873	0.42	0.14	1.30	.134	1.05	0.74	1.51	.769	0.81	0.45	1.45	.472	1.05	0.74	1.51	.769	

AOR = adjusted odds ratio; LB = lower bound of confidence interval; UB = upper bound of confidence interval  
<sup>a</sup> Malnourished refers to children who are not stunted, underweight, overweight, or wasted.

Note: Models were adjusted for region. In Jordan child nutritional status was not included and in Senegal maternal height was not included. Blank cells indicate that no coefficients were produced in the model because of small sample sizes.

Appendix Table A5 Adjusted odds ratios for on-track learning development among children age 36–59 months across all countries

Variable	Benin 2017–18				Burundi 2016–17				Cambodia 2014				Haiti 2016–17				Jordan 2017–18			
	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value	AOR	LB	UB	P value
Severe or moderate anemia	1.00	1.00	1.00	.637	1.00	1.00	1.00	.482	1.00	1.00	1.01	.661	1.00	1.00	1.01	.374	0.99	1.00	1.00	.099
Early child education	1.48	0.86	2.53	.153	2.91	1.35	6.26	.006	4.20	1.69	10.42	.002	2.64	1.30	5.36	.007	1.16	0.50	2.69	.731
Availability of books	0.85	0.32	2.30	.752	0.14	0.02	1.30	.083	0.28	0.09	0.83	.022	2.69	0.76	9.56	.125	3.51	1.70	7.26	.001
Availability of playthings	1.46	1.07	2.00	.017	1.17	0.87	1.57	.306	1.91	1.11	3.28	.020	0.86	0.49	1.49	.586	1.71	1.09	2.67	.020
Adequate care	1.22	0.91	1.63	.182	0.92	0.72	1.17	.482	1.22	0.57	2.59	.607	2.03	1.15	3.59	.015	1.31	0.73	2.33	.362
Support for learning	1.10	1.01	1.19	.028	0.94	0.87	1.03	.196	1.23	0.99	1.39	.001	1.05	0.90	1.22	.562	1.17	0.97	1.42	.095
Age in months (36–59)	1.04	1.02	1.06	.000	1.02	1.01	1.04	.004	1.03	0.99	1.06	.105	1.04	1.01	1.08	.025	0.99	0.97	1.02	.635
No illness past 2 weeks	1.17	0.84	1.61	.349	0.83	0.65	1.04	.110	1.08	0.65	1.78	.779	1.17	0.66	2.08	.588	0.72	0.42	1.21	.210
Not malnourished <sup>a</sup>	1.34	1.01	1.78	.045	1.11	0.83	1.48	.468	1.23	0.75	2.00	.409	1.06	0.59	1.91	.849				
Mother's education level																				
None	0.72	0.44	1.19	.199	0.99	0.76	1.29	.947	2.13	1.12	4.04	.022	1.20	0.56	2.59	.634	0.84	0.30	2.32	.732
Primary	1.00				1.00				1.00				1.00				1.00			
Secondary	1.08	0.54	2.17	.820	1.63	0.72	3.66	.238	1.04	0.63	1.74	.867	0.92	0.43	1.98	.833	2.74	1.25	6.04	.012
Higher	1.00				1.67	0.29	9.67	.565	2.51	0.18	34.80	.491	1.00				2.14	0.84	5.41	.109
Mother working	1.88	1.33	2.67	.000	1.37	0.89	2.10	.148	0.86	0.52	1.42	.567	0.85	0.50	1.46	.566	0.82	0.44	1.54	.539
Mother's height <145 cm	0.61	0.19	1.98	.406	0.74	0.44	1.25	.259	0.45	0.22	0.90	.024	0.08	0.01	1.05	.055	1.00			
Father's education level																				
None	0.94	0.65	1.36	.741	0.96	0.74	1.25	.786	0.94	0.50	1.76	.847	1.20	0.60	2.43	.603	2.15	0.85	5.42	.106
Primary	1.00				1.00				1.00				1.00				1.00			
Secondary	1.13	0.67	1.91	.645	0.94	0.54	1.67	.845	0.90	0.47	1.71	.738	1.58	0.77	3.25	.212	1.22	0.62	2.43	.563
Higher	1.55	0.46	5.27	.483	3.44	0.52	22.84	.201	0.78	0.07	9.43	.848	2.21	0.38	12.93	.378	1.34	0.55	3.27	.518
3+ adult in household	0.82	0.60	1.12	.209	0.97	0.73	1.28	.820	0.69	0.45	1.05	.086	1.23	0.71	2.11	.460	1.06	0.61	1.84	.830
3+ children under 5 in household	1.25	0.90	1.72	.182	0.88	0.63	1.22	.441	0.60	0.27	1.36	.224	2.15	0.94	4.93	.070	0.76	0.45	1.28	.296
WASH																				
Water-, toilet-	1.00				1.00				1.00				1.00							
Water-, toilet+	2.20	0.97	5.02	.060	1.34	0.76	2.37	.314	1.18	0.41	3.42	.754	0.58	0.19	1.75	.334				
Water+, toilet-	1.16	0.86	1.58	.333	0.98	0.64	1.51	.932	1.06	0.60	1.90	.835	1.87	0.77	4.54	.166				
Water+, toilet+	1.75	1.01	3.01	.045	1.59	1.00	2.54	.052	1.07	0.46	2.52	.875	0.95	0.37	2.43	.906				
Wealth quintile																				
Poorest	1.00				1.00				1.00				1.00				1.00			
Poorer	0.93	0.62	1.41	.739	0.99	0.69	1.41	.945	1.83	0.92	3.65	.084	0.98	0.45	2.17	.969	1.00	0.57	1.77	.987
Middle	1.11	0.74	1.66	.612	1.61	1.13	2.30	.008	1.65	0.74	3.68	.222	1.05	0.36	3.05	.923	0.96	0.52	1.75	.891
Richer	0.63	0.38	1.02	.062	0.96	0.63	1.45	.840	1.38	0.58	3.28	.465	0.38	0.11	1.24	.109	1.02	0.50	2.09	.946
Richest	0.57	0.27	1.20	.137	0.98	0.57	1.67	.928	1.30	0.38	4.44	.671	0.91	0.20	4.08	.901	0.91	0.27	3.08	.876
Residence																				
Urban	1.00				1.00				1.00				1.00				1.00			
Rural	1.30	0.92	1.84	.137	0.60	0.36	1.01	.054	0.49	0.23	1.03	.060	1.11	0.49	2.50	.806	1.09	0.69	1.73	.704

Continued...

Appendix Table A5—Continued

Variable	Maldives 2016–17				Rwanda 2019–20				Senegal 2017				Uganda 2016			
	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value	AOR	LB	UB	p value
Severe or moderate anemia	1.01	0.99	1.02	.422	1.00	0.99	1.00	.328	1.00	1.00	1.00	.649	1.00	1.00	1.01	.242
Early child education	1.02	0.36	2.91	.963	1.91	1.22	3.00	.005	3.06	1.44	6.48	.004	3.08	1.57	6.05	.001
Availability of books	2.07	0.79	5.42	.137	1.27	0.20	8.22	.799	1.15	0.68	1.93	.603	0.98	0.59	1.60	.925
Availability of playthings	1.01	0.33	3.09	.991	0.91	0.61	1.34	.623	0.77	0.55	1.07	.122	0.52	0.34	0.81	.004
Adequate care	4.12	1.00	16.96	.050	0.86	0.59	1.27	.461	1.11	0.99	1.25	.081	1.03	0.91	1.17	.607
Support for learning	0.68	0.27	1.69	.404	1.02	0.91	1.14	.765	1.03	1.01	1.05	.008	1.00	0.97	1.03	.984
Age in months (36–59)	1.06	1.01	1.12	.026	1.01	0.98	1.04	.425	0.67	0.45	0.99	.044	0.89	0.58	1.37	.587
No illness past 2 weeks	0.64	0.18	2.32	.494	1.05	0.72	1.53	.794	1.30	0.96	1.76	.087	1.29	0.80	2.07	.292
Not malnourished <sup>a</sup>	0.73	0.25	2.12	.562	1.13	0.77	1.65	.526	1.30	0.96	1.76	.087	1.29	0.80	2.07	.292
Mother's education level																
None					0.69	0.42	1.14	.147	0.74	0.46	1.17	.197	1.19	0.64	2.22	.587
Primary	1.00				1.00				1.00				1.00			
Secondary	2.43	0.59	9.98	.216	1.48	0.75	2.91	.261	0.87	0.36	2.09	.751	2.91	1.19	7.12	.019
Higher	2.48	0.49	12.61	.273	1.29	0.31	5.37	.727	1.00	0.85	1.62	.342	0.68	0.12	3.84	.664
Mother working	1.07	0.39	2.88	.900	1.54	1.01	2.36	.047	1.17	0.85	1.62	.342	0.66	0.34	1.28	.217
Mother's height <145 cm	0.49	0.12	1.90	.298	1.20	0.39	3.73	.753	1.17	0.85	1.62	.342	1.04	0.24	4.45	.958
Father's education level																
None	0.47	0.06	3.67	.467	0.99	0.58	1.69	.967	0.59	0.37	0.94	.028	1.13	0.46	2.73	.792
Primary	1.00				1.00				1.00				1.00			
Secondary	0.99	0.19	5.17	.994	0.86	0.40	1.84	.699	0.99	0.43	2.26	.975	1.10	0.60	2.01	.755
Higher	1.48	0.20	10.76	.699	0.64	0.16	2.60	.531	1.18	0.23	5.99	.839	1.29	0.34	4.84	.709
3+ adults in household	1.01	0.24	4.28	.984	0.68	0.46	1.02	.061	0.88	0.50	1.54	.644	0.92	0.57	1.49	.733
3+ children under 5 in household	0.36	0.10	1.36	.131	0.49	0.27	0.89	.019	0.87	0.59	1.28	.464	1.47	0.75	2.87	.259
WASH																
Water, toilet-	1.00				1.00				1.00				1.00			
Water-, toilet+	1.68	0.93	3.04	.085	2.87	1.27	6.48	.011	2.87	1.27	6.48	.011	1.99	0.25	16.07	.520
Water+, toilet-	1.80	0.97	3.34	.062	1.55	0.95	2.53	.077	1.55	0.95	2.53	.077	0.81	0.39	1.66	.561
Water+, toilet+	2.25	1.24	4.06	.008	2.98	1.60	5.54	.001	2.98	1.60	5.54	.001	1.53	0.61	3.80	.361
Wealth quintile																
Poorest	1.00				1.00				1.00				1.00			
Poorer	2.17	0.61	7.71	.228	1.51	0.86	2.65	.155	0.65	0.40	1.05	.078	1.07	0.59	1.94	.815
Middle	1.30	0.35	4.78	.695	1.88	1.04	3.39	.037	0.38	0.22	0.65	.000	1.64	0.79	3.43	.185
Richer	0.55	0.12	2.57	.441	3.66	1.79	7.48	.000	0.63	0.27	1.49	.291	1.88	0.77	4.58	.164
Richest	1.00				1.47	0.64	3.35	.361	0.84	0.31	2.32	.739	1.23	0.31	4.83	.768
Residence																
Urban	1.00				1.00				1.00				1.00			
Rural	1.00				1.41	0.77	2.56	.266	1.32	0.90	1.93	.155	1.09	0.52	2.27	.823

AOR = adjusted odds ratio; LB = lower bound of confidence interval; UB = upper bound of confidence interval

<sup>a</sup> Malnourished refers to children who are not stunted, underweight, overweight, or wasted.

Note: Models were adjusted for region. In Jordan child nutritional status was not included and in Senegal maternal height was not included. Blank cells indicate that no coefficients were produced in the model because of small sample sizes.