Original Article

Multiple anthropometric failures and early child development in 34 low- and middle-income countries

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Conflict of Interest

No potential conflict of interest relevant to this
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ABSTRACT

Background: Child stunting is negatively associated with early child development (ECD) outcomes. However, less is known regarding the associations between multiple co-occurring anthropometric failures and ECD. The objective of this study was to determine the association between categories of anthropometric failures (CAF)—disaggregating single, double, and triple failures—with ECD among children in low- and middle-income countries (LMICs).

Methods: We combined data from the Multiple Indicator Cluster Surveys for 98,189 children aged 36–59 months in 34 LMICs. Height-for-age, weight-for-height, and weight-for-age were calculated using the 2006 World Health Organization growth standards. Children were classified into 7 mutually exclusive categories: no deficits; stunted only; wasted only; underweight only; stunted and underweight but not wasted; wasted and underweight but not stunted; and stunted, wasted, and underweight. ECD was measured using the Early Childhood Development Index (ECDI), an index of cognitive, literacy-numeracy, socioemotional, and physical development milestones for preschool-aged children. We used multivariable linear regression models to estimate the association between CAF and ECDI z-scores.

Results: Overall, 20.4% of children had a single failure (17.9% stunted only, 1.0% wasted only, and 1.5% underweight only), 13.7% had double failures (12.0% stunted and underweight, 1.7% wasted and underweight), and 1.5% had triple failures. Compared to children with no deficits, children with a single failure of stunting only ($\beta = -0.08$; 95% confidence interval [CI], -0.10 to -0.07), double failure of stunting and underweight ($\beta = -0.17$; 95% CI, -0.19 to -0.15), and triple failure of stunting, wasting, and underweight ($\beta = -0.15$; 95% CI, -0.20 to -0.10) were associated with statistically significant lower ECDI z-scores.

Conclusion: We found a potentially additive relationship between multiple anthropometric failures and ECD. Findings highlight the importance of integrated interventions that support mild to severe malnutrition as a key component of nurturing care approaches to improve ECD in LMICs.

Keywords: Anthropometry; Malnutrition; Child development; Global health

INTRODUCTION

It is estimated that 250 million children under 5 years of age are not reaching their developmental potential in low- and middle-income countries (LMICs).¹ A variety of biological, psychosocial, and environmental risk factors have been identified as compromising children's early development.² Exposures to such risks during the early years of life have been shown to profoundly impact children's brain development,³ and in turn predict a host of outcomes over the life course, ranging from school readiness⁴ and adolescent mental health^{5,6} to adult economic earnings.^{7,8}

A robust body of evidence has underscored how linear growth faltering during the first few years of life can compromise children's development outcomes.^{9,11} A recent meta-analysis of 68 studies from 29 LMICs found that height-for-age during the first 2 years of life was positively associated with both concurrent and later cognitive ability.⁹ However, the association was found to be null in some countries, including Barbados, Lebanon, and Moldova.¹² The associations between growth and early childhood development (ECD) outcomes were found to also vary by age, with stronger associations for children ages 2 years or younger compared to older children.⁹ At the same time, less is known regarding the associations between other undernutrition indicators (i.e., wasting and underweight) and ECD outcomes.

Particularly of concern, many children in LMICs simultaneously experience multiple anthropometric failures.¹³ Anthropometric failures do not occur in isolation,^{14,15} and distinguishing children with single versus multiple co-occurring failures can more accurately capture cases of severe nutritional deprivation. Children who are categorized as stunted by the conventional indicator includes those who suffer from single (stunting only) and multiple failures (e.g., stunted *and* underweight or even suffering from all 3 failures simultaneously); alternatively, children who are classified as not stunted by conventional definition includes those with other forms of failure. Different combinations of single and multiple failures likely reflect distinct etiology that require different clinical interventions.¹⁶⁻¹⁸ However, only a few studies to date have jointly considered multiple and concurrent child anthropometric failures,^{15,19} and no study has assessed the unique associations between these various categories of anthropometric failures (CAF) and ECD.

To address this gap in the literature, we classify children by CAF to distinguish those with single, double and triple failures, and examine their associations with ECD outcomes among children 36–59 months of age in multi-country sample from 34 LMICs. We further explore sources of variability in these associations by country and by children's age. Finally, we compare our findings to the estimates using conventional anthropometric failure indicators to examine any additional insights gained from utilizing CAF.

METHODS

Data source

We used data from United Nations Children's Fund (UNICEF)'s Multiple Indicator Cluster Survey (MICS). The MICS is an international household survey program that collects information about health, nutrition, education, and early development and well-being of children and their families in LMICs. For this study, we combined national surveys from

MICS rounds 4 and 5 that included the ECD module or assessed anthropometry among children under aged 5 years ($n = 388,656$ children from 42 countries). As the ECD module in the MICS was only asked regarding children aged 36–59 months, we restricted our sample to 142,385 children aged 36–59 months. We further restricted the sample to children who had non-missing data for ECD and anthropometry ($n = 106,165$). Finally, we excluded children from Guinea Bissau and Ukraine because there was no variation in levels of maternal and paternal education, and Cuba and Sao Tome & Principe because these country surveys did not systematically collect the full set of sociodemographic characteristics. This resulted in an analytic sample size of 98,189 children with complete data on the exposure and outcome, and ultimately a final analytic sample size of 76,509 children with complete data on the exposure, outcome, and the full set of covariates across 34 LMICs.

ECD

ECD was measured using the Early Childhood Development Index (ECDI). Developed by UNICEF for the MICS household survey program, the ECDI is comprised of 10 caregiver-reported, dichotomously-scored questions that are relevant to children's cognitive, socioemotional, literacy-numeracy, and physical development. These 10 items were determined through multi-country field tests, validity, and reliability studies, and deliberation with experts.²⁰ This population measure of ECD has been used in other recent studies.^{12,21} A composite score for ECD was created by summing the number of positive responses across the literacy-numeracy, social-emotional, learning, and physical development domain items (total score ranging from 0 to 10), which was then normalized to a z-score (mean of 0 and standard deviation [SD] of 1).

CAF

In the MICS, children's height and weight were objectively measured by field assessment teams. Weight was measured using electronic scales, and height was measured using adjustable measuring boards. Standing height was obtained for children older than 24 months. In most existing studies on child undernutrition, children's anthropometric failures are conventionally assessed using binary indicators of stunting, wasting and/or underweight.²² In these studies, the raw height and weight measures are first transformed into age- and sex-specific z-scores using the World Health Organization child growth standards, and all children with height-for-age z-scores (HAZ) less than -2 SD are classified to have stunting; those with weight-for-age z-scores (WAZ) less than -2 SD as wasting; and those with weight-for-height z-scores (WHZ) less than -2 SD as underweight.²³ These 3 binary classifications of anthropometric failures ignore the cases of multiple and concurrent cases of failures. Instead, we define CAF as the primary predictor of this analysis, with the following 7 mutually exclusive categories: 1) no failure (children whose height and weight are above the age-specific norm, and hence do not suffer from any anthropometric failure); 2) stunted only (children with $HAZ < -2SD$, but who have acceptable weight both for their age and for their short height); 3) wasted only (children with acceptable weight and height for their age, but who have $WHZ < -2SD$); 4) underweight only (children with $WAZ < -2SD$, but who have acceptable HAZ and WHZ); 5) stunted and underweight (children with both HAZ and $WAZ < -2SD$, but who have acceptable WHZ); 6) wasted and underweight (children with above-norm heights, but whose WAZ and WHZ are $< -2SD$); and 7) stunted, wasted, and underweight (children who suffer from all anthropometric failures simultaneously). Another theoretical combination is children who experience wasting and stunting, but previous literature notes that it is not physically possible for a child to simultaneously experience stunting and wasting and not be underweight.¹⁴

Covariates

We adjusted for a variety of child-, caregiver-, and household-level covariates. Child characteristics included age (in months) and sex (male or female). Caregiver characteristics included maternal and paternal highest level of education (no formal education, primary, or secondary or higher), maternal age (5-year age categories from 15 to 49 years), and maternal and paternal stimulation (reported engagement in any of 6 cognitive and socioemotional caregiving activities with their child in the past 3 days). Household characteristics included household wealth index (quintiles within each country, calculated as a principal component of a group of assets owned by the household) and place of residency (urban or rural). Additionally, we controlled for whether or not the child attended an early education program.

Statistical analysis

We conducted a pooled, complete case analysis and specified 2 linear regression models to estimate the associations between CAF and ECDI z-scores. The CAF exposure variable was dummy coded such that each failure category (e.g., stunted only; stunted and underweight; stunted, wasted, and underweight) was compared to the reference category of 'no failure'. Model 1 adjusted for child age, sex, and country fixed effects. Model 2 further adjusted for the full set of covariates. After determining the main associations between CAF and ECDI z-scores, we conducted 3 supplementary analyses. First, we explored whether the associations differed by child's age by conducting stratified analyses by 6-month child age groups (i.e., 36–41, 42–47, 48–53, and 54–59 months). Second, we explored the degree to which main associations between CAF and ECDI z-scores varied in country-specific analyses. Finally, we conducted a comparative analysis replacing the CAF with the conventional indicators of stunting, underweight, and wasting as independent predictors in separate multivariate regression models with the full set of covariates. Standard errors across all models were clustered at the primary sampling unit-level to account for the complex MICS survey design. All analyses were conducted using Stata version 15 (StataCorp LLC, College Station, TX, USA).

RESULTS

Table 1 presents descriptive statistics of the full sample of 98,189 children aged 36–59 months from 34 LMICs. The average child age was 47.2 months and approximately half (49.3%) of the sample was female. The majority of households (66.5%) resided in rural areas. In the pooled sample, 31.4% of children were stunted, 4.7% were wasted, and 16.1% were underweight (**Fig. 1**). However, when disaggregated by CAF, results revealed that 64.5% of children experienced no anthropometric failure, 17.9% were stunted only, 1.0% were wasted only, 1.5% were underweight only, 12.0% were stunted and underweight, 1.7% were wasted and underweight, and 1.5% were stunted, wasted, and underweight. Overall, the average ECDI total score was 5.6 out of 10 developmental milestones. Results indicated clear patterning of sociodemographic distributions by CAF (**Table 1**). For example, maternal and paternal education and household wealth quintile were worse for children who experienced double and triple anthropometric failures.

Table 2 presents minimally adjusted and fully adjusted associations between CAF and ECDI z-score. In the fully adjusted models that controlled for child sex, age, maternal age, maternal and paternal education, stimulation, wealth quintile, number of household members, rural residence, and early child education attendance, results revealed a statistically significant negative association between stunting only and ECDI z-score ($\beta = -0.08$, 95% confidence

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Table 1. Distribution of study sample characteristics by the 7 CAF

Variable	Total sample (n = 98,189)	No failure (n = 63,283)	Stunted only (n = 17,574)	Underweight only (n = 931)	Wasted only (n = 1,512)	Stunted and underweight (n = 11,779)	Wasted and underweight (n = 1,628)	Stunted, wasted, and underweight (n = 1,482)
Covariates								
Child sex								
Male	49,734 (50.7)	32,019 (50.6)	9,049 (51.5)	419 (45.0)	775 (51.3)	5,772 (49.0)	840 (51.6)	860 (58.0)
Female	48,455 (49.3)	31,264 (49.4)	8,525 (48.5)	512 (55.0)	737 (48.7)	6,007 (51.0)	788 (48.4)	622 (42.0)
Child age in months	47.2 ± 6.9	47.3 ± 6.9	47.3 ± 6.9	48.8 ± 6.8	47.4 ± 7.1	47.6 ± 6.9	47.8 ± 6.9	47.6 ± 6.8
Maternal age								
15–19	1,390 (1.5)	666 (1.1)	330 (2.0)	18 (2.1)	17 (1.2)	285 (2.6)	30 (2.0)	44 (3.2)
20–24	15,219 (16.6)	9,015 (15.2)	3,068 (18.9)	167 (19.3)	213 (15.1)	2,206 (20.3)	262 (17.2)	288 (20.8)
25–29	25,717 (28.1)	16,525 (27.9)	4,621 (28.4)	256 (29.6)	383 (27.1)	3,099 (28.5)	445 (29.2)	388 (28.0)
30–34	21,915 (23.9)	14,766 (24.9)	3,602 (22.1)	186 (21.5)	364 (25.8)	2,341 (21.5)	377 (24.8)	279 (20.1)
35–39	15,482 (16.9)	10,458 (17.7)	2,594 (15.9)	119 (13.7)	224 (15.9)	1,662 (15.3)	212 (13.9)	213 (15.4)
40–44	8,295 (9.1)	5,537 (9.3)	1,415 (8.7)	78 (9.0)	158 (11.2)	849 (7.8)	131 (8.6)	127 (9.2)
45–49	3,539 (3.9)	2,262 (3.8)	639 (3.9)	42 (4.8)	54 (3.8)	430 (4.0)	65 (4.3)	47 (3.4)
Maternal education								
None	31,348 (32.1)	16,025 (25.5)	7,138 (40.8)	316 (34.0)	503 (33.5)	5,968 (50.7)	632 (39.0)	766 (51.7)
Primary	31,888 (32.7)	20,154 (32.1)	6,334 (36.2)	320 (34.4)	448 (29.8)	3,804 (32.3)	436 (26.9)	392 (26.5)
Secondary	29,852 (30.6)	22,649 (36.1)	3,723 (21.3)	274 (29.5)	480 (32.0)	1,908 (16.2)	506 (31.2)	312 (21.1)
Tertiary	4,510 (4.6)	3,961 (6.3)	321 (1.8)	19 (2.0)	71 (4.7)	80 (0.7)	47 (2.9)	11 (0.7)
Paternal education								
None	18,434 (23.2)	9,021 (17.6)	4,228 (30.3)	207 (28.5)	334 (26.6)	3,671 (38.3)	446 (34.0)	527 (43.5)
Primary	24,153 (30.4)	14,938 (29.1)	4,793 (34.4)	242 (33.3)	328 (26.2)	3,193 (33.4)	317 (24.2)	342 (28.2)
Secondary	32,856 (41.4)	24,075 (46.9)	4,594 (32.9)	249 (34.3)	530 (42.3)	2,585 (27.0)	501 (38.2)	322 (26.6)
Tertiary	3,888 (4.9)	3,278 (6.4)	329 (2.4)	28 (3.9)	62 (4.9)	124 (1.3)	46 (3.5)	21 (1.7)
Maternal stimulation	2.1 ± 1.9	2.2 ± 2.0	1.8 ± 1.8	2.0 ± 1.9	2.1 ± 2.0	1.7 ± 1.7	2.1 ± 1.9	1.7 ± 1.7
Paternal stimulation	1.0 ± 1.5	1.1 ± 1.6	0.9 ± 1.3	0.9 ± 1.4	1.1 ± 1.6	0.8 ± 1.3	1.0 ± 1.4	0.8 ± 1.3
Child attending early education program								
No	73,001 (74.5)	44,133 (69.9)	14,464 (82.5)	696 (74.9)	1,098 (72.8)	10,101 (86.0)	1,251 (76.9)	1,258 (85.2)
Yes	24,988 (25.5)	19,036 (30.1)	3,073 (17.5)	233 (25.1)	410 (27.2)	1,643 (14.0)	375 (23.1)	218 (14.8)
No. of household members	6.7 ± 3.4	6.6 ± 3.3	7.0 ± 3.4	6.5 ± 3.2	6.6 ± 3.4	7.0 ± 3.6	6.5 ± 3.2	6.9 ± 3.8
Wealth quintile								
Poorest	20,671 (21.1)	11,752 (18.6)	4,433 (25.2)	178 (19.1)	320 (21.2)	3,266 (27.7)	350 (21.5)	372 (25.1)
Poor	20,375 (20.8)	12,139 (19.2)	4,029 (22.9)	214 (23.0)	268 (17.7)	3,000 (25.5)	349 (21.4)	376 (25.4)
Middle	19,264 (19.6)	12,067 (19.1)	3,653 (20.8)	189 (20.3)	287 (19.0)	2,457 (20.9)	320 (19.7)	291 (19.6)
Rich	18,079 (18.4)	12,356 (19.5)	2,975 (16.9)	179 (19.2)	299 (19.8)	1,736 (14.7)	286 (17.6)	248 (16.7)
Richest	19,800 (20.2)	14,969 (23.7)	2,484 (14.1)	171 (18.4)	338 (22.4)	1,320 (11.2)	323 (19.8)	195 (13.2)
Place of residence								
Urban	32,939 (33.5)	24,712 (39.0)	4,372 (24.9)	231 (24.8)	602 (39.8)	2,162 (18.4)	523 (32.1)	337 (22.7)
Rural	65,250 (66.5)	38,571 (61.0)	13,202 (75.1)	700 (75.2)	910 (60.2)	9,617 (81.6)	1,105 (67.9)	1,145 (77.3)
Outcome variable								
Early Child Development Index, total score	5.6 (1.9)	5.9 (1.9)	5.2 (1.8)	5.6 (1.8)	5.9 (2.0)	5.0 (1.7)	5.5 (1.9)	5.0 (1.8)

Values are presented as number (%) and mean ± standard deviation.

interval [CI], −0.10, −0.07), compared to the reference category of children who did not experience any anthropometric failure. Furthermore, the magnitude of the association was approximately 2 times greater for children who experienced double anthropometric failure for stunting and underweight ($\beta = -0.17$, 95% CI, −0.19, −0.15) and children who experience triple failure for stunting, wasting, and underweight ($\beta = -0.15$, 95% CI, −0.20, −0.10), compared to the reference category of children who did not experience any anthropometric failure.

Supplementary analyses suggested that these associations were generally stronger among older versus younger aged children (**Supplementary Table 1**). For example, associations for 1) single failure of stunting only; 2) double failure of stunting and underweight; and 3) triple failure of stunting, wasting, and underweight were greater among children aged 54–59

Fig. 1. Prevalence of child undernutrition by (A) conventional indicators of anthropometric failures and (B) CAF disaggregating single, double, and triple failures. CAF = categories of anthropometric failures.

Table 2. Associations between different CAF and ECDI z-scores

CAF ('no failure' as reference group)	Model 1 (n = 98,189)		Model 2 (n = 76,509)	
	B	95% CI	B	95% CI
Stunted only	-0.19*	-0.21, -0.17	-0.08*	-0.10, -0.07
Wasted only	-0.11*	-0.17, -0.06	-0.04	-0.10, 0.03
Underweight only	-0.02	-0.02, 0.07	0.03	-0.02, 0.08
Stunted and underweight	-0.33*	-0.35, -0.31	-0.17*	-0.19, -0.15
Wasted and underweight	-0.09*	-0.14, -0.05	-0.04	-0.09, 0.01
Stunted, wasted, and underweight	-0.30*	-0.35, -0.26	-0.15*	-0.20, -0.10

Model 1 adjusted for child age and sex. Model 2 adjusted for child age, sex, maternal age, maternal and paternal education, stimulation, early child education attendance, number of household members, wealth quintile, and rural residence. Both models include country fixed-effects and standard errors are clustered at the PSU-level.

CAF = categories of anthropometric failures; ECDI = Early Childhood Development Index; CI = confidence interval; PSU = primary sampling unit.

* $P < 0.001$.

months ($\beta = -0.11$, 95% CI, -0.15 , -0.07 ; $\beta = -0.18$, 95% CI, -0.22 , -0.13 ; and $\beta = -0.21$, 95% CI, -0.31 , 0.11 ; respectively), compared to children aged 36–41 months ($\beta = -0.07$, 95% CI, -0.10 , -0.03 ; $\beta = -0.14$, 95% CI, -0.18 , -0.10 ; and $\beta = -0.04$, 95% CI, -0.15 , 0.06 ; respectively).

Country-specific analyses uncovered substantial variations in these associations across the 34 sampled LMICs (**Supplementary Table 2**). Significant negative associations were detected for a single failure of stunting only, compared to no anthropometric failure, in 6 LMICs (i.e., Bangladesh, Central African Republic, Chad, Laos, Nigeria, and Vietnam, with effect sizes ranging from -0.25 to -0.07); double failure of stunting and underweight in 9 LMICs (i.e., Bangladesh, Chad, Democratic Republic of Congo, Iraq, Kazakhstan, Laos, Nepal, Nigeria, and Vietnam, with effect sizes ranging from -0.68 to -0.11); and triple failure of stunting, wasting, and underweight in 9 LMICs (i.e., Bangladesh, Central African Republic, Guinea Bissau, Iraq, Kosovo, Macedonia, Nepal, Serbia, and Swaziland, with effect sizes ranging from -1.86 to -0.21). Of note, although the country-specific regression results corresponding to a single failure of stunting only, double failure of stunting and underweight, and triple failure of stunting, wasting, and underweight were negative in the majority of countries, positive associations were detected for some of these coefficients in a few countries (e.g., Barbados, Guinea Bissau).

Finally, results from the multivariate regression models with the conventional indicators of anthropometric failures as independent predictors of ECDI z-scores showed statistically significant associations for stunting ($\beta = -0.09$, 95% CI, -0.10 , -0.07) and underweight ($\beta = -0.08$, 95% CI, -0.10 , -0.06) (**Supplementary Table 3**). However, when interpreted in light of the findings from our main analysis of CAF, the significant association between the conventional indicator of underweight and ECDI z-scores appeared to be mostly driven by children who suffer from double failure of stunting and underweight and triple failure rather than those who suffer from a single failure of underweight only.

DISCUSSION

In this study, we examined the population-level associations between different CAF and ECD across 34 LMICs. We found that 35.5% of children experienced some form of undernutrition, with the greatest burden for a single failure of stunting only for nearly one in 5 children, followed by concurrent stunting and underweight for one in 8 children. We found statistically significant negative associations between a single failure of stunting and ECD, even after adjusting for covariates. Additionally, our results suggested that the negative associations were even greater for double and triple failures. These associations were generally stronger among older versus younger aged children, and substantial variations were found across the 34 sampled LMICs. Our findings highlight the importance of integrated interventions that support mild to severe malnutrition as a key component of nurturing care approaches to promoting optimal ECD in LMICs.

Of the different CAF, the most prevalent form was stunting alone (17.9%). The relatively large burden of stunting is consistent with several other multi-country population-level studies that have documented stunting as the greatest form of global child undernutrition, due to compounded socioeconomic, biological, and environmental risk factors.^{13,24} Compared to prior studies that have used the conventional definitions of anthropometric failures, a novel finding of our study was in quantifying that nearly half of children who experienced some

form of anthropometric failure experienced multiple concurrent failures. Specifically, 12.0% of children experienced both stunting and underweight. Given the common co-occurrence and overlap, our results suggest the importance of simultaneously considering these multiple anthropometric indicators to distinguish children's undernutrition classifications and associations with child outcomes.

Compared to children without any anthropometric failure, we found that children with a single failure of stunting were associated with lower ECD scores. This is consistent with a robust body of evidence that has shown negative associations between stunting and early child cognitive, language, and motor development outcomes in LMICs.^{9,25,26} On the other hand, we did not find any associations between underweight or wasting—neither alone as single failures or together as double failures—and ECD scores. Relatively fewer studies in the literature have examined the relationship between underweight and wasting and ECD and the evidence to date has been mixed. Some studies have shown that child underweight status²⁷ and wasting^{27,28} predict ECD, whereas other studies have shown no associations between underweight or wasting and ECD.^{29,30} More research is needed to understand whether and how underweight and wasting may impact ECD outcomes.

In addition to the negative association between a single failure of stunting and ECD, we found greater associations among children who experienced double and triple anthropometric failures. Specifically, we found that the association was the greatest for the double failure of stunting and underweight, followed by the triple failure of stunting, underweight, and wasting. These findings suggest a potentially additive effect between multiple anthropometric failures on ECD—such that the negative consequences of being stunted are even greater when children are also underweight or both underweight and wasted.

Although a few recent studies have underscored the prevalence and burden of children concurrently stunted and wasted,³¹ our study is one of the first to document differing associations between these classifications of multiple anthropometric failures and ECD. Our findings are consistent with and extend prior studies that demonstrated that children with multiple anthropometric deficits are at a heightened risk of mortality³³ and morbidities³³ during the first 5 years of life. Our results documenting greater associations for double and triple anthropometric failures and ECD suggest complex mechanisms underlying the experiences of multiple failures for child development.³⁴ Future research should investigate and compare the underlying biological, developmental, and behavioral processes by which multiple anthropometric failures and their unique combinations may affect ECD outcomes. Such results will contribute to the broader global understanding of whether the relationships between child malnutrition and ECD are causal or a co-occurrence of common risk factors.¹²

There are several limitations to this study. First, the MICS data are cross-sectional, and therefore causality in the observed associations cannot be established. Second, the measure of ECD used in the MICS survey is a brief and caregiver-reported index of general milestones. Third, the MICS survey is limited in terms of available covariates. We were not able to control for other important factors such as child dietary intake, parental nutritional status, and biological risk factors that are known determinants of child growth and development. Fourth, the small sample sizes in select countries (e.g., Barbados and St. Lucia) limited our power to detect differences in the country-specific regression models, and may partially explain the considerable variation in country-specific results, including the positive associations detected between CAF and ECD in a few countries. Finally, the study was restricted to

children aged 36–59 months for whom the ECDI was asked in the MICS survey, and results are not generalizable to older or younger children during the developmental period of the first 1,000 days.

In conclusion, our findings reveal a significant negative association between stunting and ECD, and stronger associations between multiple anthropometric failures and ECD. Future research on child undernutrition should explore CAF to better understand the potential additive effects of co-occurring failures and their unique predictors and developmental consequences. In addition to enhancing early child learning opportunities and supporting parenting skills and practices, early integrated interventions that also aim to improve multiple aspects of child nutrition are critically needed to ensure that all children reach their developmental potential in LMICs.^{35,36}

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Fully-adjusted associations between different CAF and ECDI z-scores, stratified by child age (6-month age groups)

[Click here to view](#)

Supplementary Table 2

Country-specific fully-adjusted associations between different CAF and ECDI z-scores, with 'no failure' as reference group

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Supplementary Table 3

Fully-adjusted associations between conventional indicators of child anthropometric failures and ECDI z-scores

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