Prevalence and correlates of stunting at hospital discharge among children 1-59 months in Western Kenya

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Abstract

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Background: The risk of mortality among recently hospitalized children in sub-Saharan Africa is 6 to 8-fold higher than similarly aged children in the community. Stunting (length/height-for-age z-score [LAZ/HAZ] <-2 SD) is associated with significant morbidity and mortality among children under the age of 5 in sub-Saharan Africa. Children who are stunted and recently hospitalized for acute illness may be at elevated risk for post-discharge morbidity and mortality. Few studies have examined predictors of stunting at hospital discharge among recently hospitalized children, who represent a population at high risk of poor outcomes and may benefit from targeted intervention.

Methods: We determined correlates of stunting among children 1-59 months at discharge from 4 hospitals in in the Nyanza Province of Western Kenya enrolled in the Toto Bora Trial (NCT02414399), using log-Poisson regression to estimate prevalence ratios (PRs), adjusted for child age and study site.

Results: Of the 1400 children enrolled in the parent trial (median age 18 months (IQR: 9-32)), 23% were stunted. Age over one year was associated with a higher prevalence of stunting at discharge ($aPR_{12\text{-}23m}$: 1.5 [95%CI: 1.1-2.1]; and 24-59 months $aPR_{24\text{-}59m}$: 1.5 [95% CI: 1.1-2.1]). Lack of exclusive breastfeeding in the first 6 months of life was associated with higher stunting prevalence as compared to exclusive breastfeeding (aPR_{never}: 2.6 [95% CI: 1.4-4.7]; $aPR_{partial}$: 1.3 [95% CI: 1.0-1.7]). Children who were HIV-infected or HIV-exposed, uninfected were more likely to be stunted than HIV-unexposed children ($aPR_{HIVinfect}$: 2.7 [95% CI: 1.4-5.0]); aPR_{HEU}: 1.9 [95% CI: 1.3-2.6]). Children whose caregivers reported having the equivalent of a primary school education or less were 2 times more likely to be stunted relative to those whose caregivers reported completing secondary school (aPR: 2.0 [95% CI: 1.6-2.5]). Having unimproved sanitation (pit latrine without slab floor or open defecation) was associated with a higher prevalence of stunting relative to having a flush toilet ($aPR_{\text{pit latrine without slab floor}}$: 2.0 [95% CI: 1.2-3.4]; $aPR_{\text{open defecation}}$: 3.5 [95% CI: 1.8-7.1]). Child sex, shared toilet facility, enteric pathogen exposure (*Salmonella, Shigella,* and *Campylobacter, Giardia and Cryptosporidium*), and number of previous hospitalizations in the last year were not associated with stunting at discharge in this population.

Conclusions: HIV exposure, poor sanitation, and lack of exclusive breastfeeding were important risk factors of stunting. Children hospitalized with an acute infectious illness who are stunted at discharge are at high risk for adverse health outcomes and death. Hospital discharge may represent an important opportunity for administering targeted interventions to prevent further growth faltering and post-discharge mortality in this highly vulnerable population.

INTRODUCTION

Over half of the world's 5.3 million under-5 deaths occurred in sub-Saharan Africa in 2018.[1] More than 45% of these deaths were due to infectious diseases, most commonly pneumonia, diarrhea, and malaria.[2] Hospitalized children represent a group at particularly high-risk of death, both in hospital (in-patient mortality ranging from 2-11%[3]) and following discharge (9%-25% post-discharge mortality).[4,5] Children who are stunted (length/height-for-age z-score <-2 SD) at presentation to hospital with an acute illness are at particularly high risk for both in-patient and post-discharge mortality.[3,6-9]

The increased risk of poor outcomes among stunted children may be the result of a number of host, environmental, and social risk factors. The causes of stunting are multifactorial and include not only food insecurity, but recurrent infection and unhygienic environmental conditions that lead to a chronic inflammatory state. Despite the elevated risk of mortality and morbidity among stunted children, particularly those recovering from an acute illness, and well-documented long-term sequelae of stunting among survivors [10-12], there is a limited evidence base available to inform interventions to mitigate poor outcomes among this population.

The majority of studies examining correlates of stunting have been conducted in community settings and often do not include children who are hospitalized.[13,14] Among the few studies from Sub-Saharan Africa that do report anthropometric status among hospitalized children, stunting prevalence varies from 14% to 40%.[15,16] Stunting status at discharge may be an informative marker of post-discharge vulnerability.

Within a large cohort of children aged 1-59 months in Western Kenya [17], we sought to measure the prevalence of stunting at discharge from hospital and to identify host, caregiver, and environmental correlates for stunting at hospital discharge.

METHODS

Study setting and population

We conducted a cross-sectional study nested within the Toto Bora Trial (NIH/NICHD-HD079695)[17], a double blind randomized, placebo-controlled trial of a 5-day course of azithromycin to reduce post-discharge re-hospitalizations and mortality among children age 1 to 59 months discharged from four hospitals in Western Kenya. Children were excluded from the parent study if they were admitted for injuries or congenital anomalies, if azithromycin was contraindicated (children taking or prescribed other macrolide antibiotics or the protease inhibitor lopinavir), those with a known macrolide allergy, who did not plan to remain in the study catchment area for at least 6 months, whose primary caregiver did not provide informed consent, or if a sibling was enrolled in the trial the same day of screening. Participants were recruited from in-patient wards of four hospitals (Kisii Teaching and Referral Hospital, Homa Bay District Hospital, Kendu Bay Hospital, St. Paul Mission Hospital,) in Kisii and Homa Bay counties in the Nyanza Province of Western Kenya between June 2016 and October 2019. Caregivers provided informed consent and children were enrolled when preparing to leave the hospital.

Data collection

At enrollment, a physical examination was performed to document the child's vital signs and measure anthropometry. A study nurse conducted an interview with the primary caregiver accompanying the child to obtain information on socio-demographic characteristics, water sanitation and hygiene conditions and practices, and breastfeeding status and history. Relevant clinical history was abstracted from the medical record. Whole stool and rectal swab samples were collected at baseline and bacterial culture was performed for detection of *Salmonella, Shigella,* and *Campylobacter,* and the rapid enzyme immunoassay test (QuikChek) for detection of *Giardia and Cryptosporidium*.

Anthropometric measurements

Length (if <24 months) or height (if ≥24 months) in centimeters was measured using a Shorr Board or stadiometer, respectively. Weight (kg) was obtained by weighing the child and caregiver together, then subtracting caregiver weight (if <24 months) or weighing the child alone (if ≥24 months). Standardization tests were performed on each scale daily. Mid-upper arm circumference (MUAC) was measured using standard MUAC tape. All measurements were obtained twice by trained study staff. A third measurement was taken if the initial two differed by more than 10% with the median used as final measure. Mean length/height and weight values were converted to length/height-for-age z-scores (LAZ/HAZ), weight-for-age z-scores (WAZ), and weight-for-length/height z-scores (WLZ/WHZ) using the WHO Anthro Software.[18] Children whose HAZ/LAZ scores were less than -2 were considered to be stunted. Here forth, height and length will be noted as height.

Power calculation

We determined the minimal detectable prevalence ratios assuming the prevalence of stunting ranging from 15-35% based on previously published literature,[19-21] exposure prevalences between 1% and 45%, 80% statistical power, and an alpha level of 0.05 (see Supplemental Appendix Table 1). With a 25% prevalence of stunting and assuming a 5% prevalence of correlates, such as HIV-infection (as documented in a study of children 6-59 months with acute diarrhea conducted in the same two hospitals in Western Kenya),[19] we anticipated 80% power to detect a prevalence ratio (PR) of 1.6. For risk factors we expected to have a prevalence of 40%, such as exclusive breastfeeding documented in the same study in Western Kenya[19], we had 80% power to detect a PR of 1.3 given a 25% prevalence of stunting.

Statistical analysis

To estimate prevalence ratios (PR) and 95% confidence intervals of the association between host, caregiver, and environmental risk factors and stunting, we used Poisson regression with *a priori* adjustment for child age (months) and study site. We additionally adjusted for maternal height (cm) in secondary analyses to evaluate risk factors of stunting above and beyond height genetic potential. Because a subset of stunted children was wasted (defined by a weight-for-height z-score [WHZ] $<$-2 and/or MUAC $<$12.5 cm), another important marker of undernutrition, in secondary analyses we examined stunting correlates stratified by wasting status. Additionally, we conducted a secondary analysis stratifying by child age ($<$24 months and $\geq$24 months) as linear growth faltering in younger children may have different underlying etiologies and health consequences than those contributing to stunting in older children. All analyses were conducted using an alpha level of 0.05 in Stata 14.

Ethical considerations

All caregivers provided written informed consent or documented witnessed thumbprint confirming verbal consent. The parent trial was registered with ClinicalTrials.gov (NCT 02414399). All modifications to the study protocol or participant consent materials were approved by the Kenya Medical Research Institute Scientific Ethics Review Unit and the University of Washington Human Subjects Division (STUDY00002592).

RESULTS

A total of 1400 children aged 1-59 months were enrolled in the parent trial at hospital discharge, of whom 830 (59%) were male and had a median age of 18 months (interquartile range [IQR]: 9-32) (Table 1). The majority were enrolled from either Kisii Teaching and Referral (n=823, 59%) or Homa Bay District Hospitals (n=522, 37%). More than half (n=875, 63%) of accompanying primary caregivers reported a monthly income of less than 5000 Kenyan Shillings (~47 USD) and 46% (n=644) of caregivers reported a primary school education or less. Among enrolled children, 659 (47%) were exclusively breastfed in the first 6 months, or exclusively breastfed from birth to the date of enrollment if aged less than 6 months, and 635 (46%) reported partial breastfeeding in these timeframes. Seventy-nine (6%) enrolled children were wasted, defined as weight-for-height z-score (WHZ) <-2 SD, and 176 (13%) were underweight (weight-for-age z-score [WAZ] <-2 SD). The median MUAC, WAZ, WHZ, and HAZ was 14.3 (IQR: 13.2-15.3), -0.5 (IQR: -1.3-0.4), 0.09 (IQR: -0.8-0.9), -0.90 (IQR:-1.9-0.01), respectively.

Of the 1400 children enrolled in the parent study, 321 (23%) were stunted at hospital discharge, of whom 9% were severely stunted (HAZ <-3). There were several host factors associated with stunting at discharge. Older child age (12-23 months and 24-59 months) was associated with a higher prevalence of stunting at discharge ($aPR_{12\text{-}23m}$: 1.5 [95%CI: 1.1-2.1]; $aPR_{24\text{-}59m}$: 1.5 [95% CI: 1.1-2.1], respectively) (Table 2). Compared to children who were exclusively breastfeed in the first 6 months of life, children who were never or partially breastfed in the first 6 months of life had a 2.6- and 1.3-fold higher prevalence of stunting ($aPR_{neverbreastfeed}$: 2.6 [95% CI: 1.4-4.7]; $aPR_{partiallybreastfed}$: 1.3 [95% CI: 1.0-1.7]). Children who were HIV-infected (3%) or HIV-exposed and uninfected (14%) were more likely to be stunted than HIV-unexposed children (77%) ($aPR_{HIVinfect}$: 2.7 [95% CI: 1.4-5.0]); aPR_{HEU}: 1.9 [95% CI: 1.3-2.6]). Missing any age-appropriate vaccines (according to the Kenyan Ministry of Health vaccination schedule) was not significantly associated with stunting at discharge (aPR: 1.2 [95% CI: 1.0-1.5]). Certain hospital diagnoses were found to be associated with stunting. For example, there was a lower prevalence of stunting among children with a diagnosis of a lower respiratory tract infection compared to those without (aPR: 0.7 [95% CI: 0.6-0.9]), and a higher prevalence of stunting at discharge among children with a final diagnosis of tuberculosis (aPR: 2.4 [95% CI: 1.3-4.2]). Presence of any bacterial *(Salmonella, Shigella, Campylobacter)* or parasitic *(Giardia,* *Cryptosporidium)* enteric pathogen in stool, and number of previous hospitalizations in the last year were not associated with stunting at hospital discharge.

Caregiver age and education were significantly associated with stunting at discharge. There was a 61% higher stunting prevalence among children with younger caregivers (<20 years) relative children with older caregivers (aPR: 1.6 [95% CI: 1.1-2.3]). Children whose caregivers reported having the equivalent of a primary school education or less were 2 times more likely to be stunted relative to those whose caregivers reported at least some secondary education (aPR: 2.0 [95% CI: 1.6-2.5]). Children whose households had access to unimproved sanitation (pit latrine without slab floor or open defecation) were significantly more likely to be stunted at hospital discharge compared to those with access to a flush toilet ($aPR_{\text{pit latrine without slab}}$: 2.0 [95% CI: 1.2-3.4]; $aPR_{\text{open defecation}}$: 3.5 [95% CI: 1.8-7.1]). Crowding and safe drinking water source were not significant correlates of stunting at discharge in this study.

In subsets of children stratified by age (≥24 months and <24 months), toilet type, treated drinking water source, and the presence of more than 2 children under 5 years in the child's household appeared to be more strongly associated with stunting at discharge among the older group of children (Table 3). Among children younger than 24 months, severe and moderate acute malnutrition was more strongly associated with stunting at discharge than presence of severe or moderate acute malnutrition among older children. In subsets of children stratified by wasting status (presence or absence), we found no meaningful differences in correlates across wasting strata. Additional adjustment for maternal height did not meaningfully change estimates of association and was removed as a covariate in the final models.

DISCUSSION

In this cross-sectional analysis of 1400 children being discharged from Kenyan hospitals, we found nearly one quarter (23%) of children were stunted. Stunting was more common in older children, those with other indicators of undernutrition, exposure to HIV, and those who were not exclusively breastfed during their first 6 months of life. Caregiver factors, namely caregiver age, nutritional status, and education were also independently associated with stunting status, confirming that caregiver and child health and well-being are inextricably linked. Unlike many other studies of stunting risk factors, safe drinking water source and practices, and household crowding did not emerge as significant risk factors, perhaps because this recently hospitalized pediatric population has a unique set of vulnerabilities compared to stunted children who are not severely acutely ill. Additionally, children recovering from acute illness as a whole be more socially and biologically vulnerable; therefore, differences in risk factors between stunted and non-stunted children may be less pronounced.

The stunting prevalence among children enrolled in this trial was higher than that reported in other studies among African children seeking care for diarrhea (17%)[22] or those presenting to pediatric emergency unit and out-patient departments (19%).[23] Surprisingly, the prevalence of stunting in this study was slightly lower than the national prevalence reported in the 2015 Kenya Demographic and Health Survey (DHS) (26%).[24] However, the national DHS stunting prevalence may be driven by high burden regions, such as Northern Kenya, so the country-wide estimate may appear higher than what is expected in the study area. Because the parent trial enrolled children at hospital discharge, children who were admitted to the hospital with acute illness with the most severe forms of stunting may have died during hospitalization, as undernutrition is a well-documented risk factor for in-patient mortality.[3] This bias may have resulted in the lower prevalence of stunting in our population relative to the DHS. Alternatively, care seeking and willingness to participate in the trial may indicate higher household wealth and be related to better child nutritional status, which may have resulted in lower stunting among hospitalized children than would be expected.

Older child age, other forms of undernutrition, such as wasting or underweight, HIV-infection, and lack of exclusive breastfeeding were host characteristics most strongly associated with stunting at discharge. Older child age is a well-documented risk factor for stunting.[13,14,25,26] This association may be driven by the change in dietary composition that takes place after 1 year of age, during which breastfeeding often ceases and complementary foods such as porridge are introduced, whose composition may not adequately fulfil the protein, lipid, and micronutrient needs of the growing child.[27] During this period of early life, exposure to enteric pathogens is also common among those living in and near contaminated environments. Cumulative exposure can lead to environmental enteric dysfunction (EED), an acquired enteropathy affecting gut structure and function[28]. EED is thought to be an important contributor to growth failure in low and middle-income settings.[29,30]

Lack of exclusive breastfeeding was significantly associated with stunting at discharge. Breastfeeding has been shown across settings to prevent infections, improve immunity, and overall child survival, all of which may contribute to decreased risk of stunting. [31-33] In addition, children who were either HIV-exposed, uninfected, or known HIV-infected had a higher prevalence of stunting than their unexposed counterparts. HIV-infected mothers may have opted for formula feeding or early introduction of complementary foods instead of breastfeeding due to concerns about HIV transmission. HIV exposure and infection may also alter metabolic function and feeding patterns as a result of side effects associated with antiretroviral therapy or cotrimoxazole prophylaxis. These factors, along with elevated risk for opportunistic infections and higher diarrhea incidence, could contribute to undernutrition risk.[34-36] Child vaccination status has also been shown across studies to be an important indicator of nutritional status.[14,37] Vaccinations provide important protection against infectious diseases and may indirectly describe caregivers' general knowledge of guidelines and frequency of healthcare service engagement, which contribute to improved health status. While vaccination adherence was not significantly associated with stunting at discharge in this analysis, the directionality does suggest a possible elevated prevalence of stunting among children missing any age-appropriate vaccinations.

Low maternal education is a well-documented determinant of growth faltering and other adverse health outcomes.[26,37-39] Caregiver education is a strong predictor of earning potential, wealth status, and enhanced decision-making power in the household, which in turn impacts availability of and access to healthcare resources. Higher caregiver education attainment has also been shown to be associated with improved child health outcomes through increased ability to recognize early warning signs of illness and more immediate care seeking behaviors.[40,41]

Unlike community-based studies, which have found sanitation to be associated with stunting [42], in this population of recently discharged children, aside from toilet type, we did not find a significant association between drinking water source, drinking water treatment method, or shared toilet facility and stunting at discharge. This finding suggests that more proximate host factors that may have contributed to the child's likelihood of being hospitalized with an acute illness, such as HIV-exposure, may be more important indicators of stunting status for this population than distal environmental factors that impact overall health status. Additionally, water and sanitation characteristics are highly correlated with wealth status and may be acting as a surrogate for household socioeconomic status, which in the context of the parent trial, may have been incompletely ascertained by self-reported caregiver monthly income only.

Household crowding was not a significant correlate of stunting in this analysis, but having 2 or more children under the age of 5 in the child's household was found to be a significant predictor of stunting. This finding may be driven by availability and distribution of age-specific resources, such as breastfeeding and access to appropriate complementary foods. Alternatively, household exposure to enteric pathogens is likely to be more common when many young children reside in the same household where there are more children and where hygiene habits may be less closely monitored. These continuous exposures may lead to the development of EED.[29,30]

We did not observe an association between the presence of any bacterial or parasitic enteric pathogen in stool and stunting at discharge. Because of the cross-sectional nature of this data set, we were unable to evaluate the temporal relationship between enteric infection and linear growth faltering as was demonstrated in the multi-site longitudinal cohort study Etiology, Risk Factors, and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development Study (MAL-ED Study)[25]. In addition, this population of recently admitted children had a very high prevalence of recent exposure to antibiotics which may have limited our ability to detect a small subset of pre-specified enteric pathogens at discharge. Additionally, the culture and enzyme immunoassay methods used in this study to detect presence of bacterial or parasitic enteric pathogens are not as sensitive as molecular methods for enteric pathogen detection so may be underestimated the true prevalence of infection.[43]

Hospital diagnoses, including lower and upper respiratory tract infections and tuberculosis were shown to be associated with stunting at discharge. We would expect chronic conditions such as tuberculosis, sickle cell, and anemia to be associated with increased physiologic vulnerability due to the metabolic demands of prolonged illness and therefore elevated risk for stunting. While a significant association was observed between tuberculosis and stunting at discharge, sickle cell and anemia diagnoses were non-significant correlates. Due to limited clinical and laboratory capacity to facilitate early diagnosis, sickle cell may be underdiagnosed and hemoglobin levels that meet anemia criteria may not consistently be classified as an anemia diagnosis in this population, thus contributing to potential misclassification of disease statuses.[44]

Contrary to our hypothesis that children who were wasted would have different risk factors for stunting than non-wasted children, we did not detect meaningful differences in the magnitude of effect sizes across wasting strata. In the age-stratified analysis, having 2 or more children under 5 years appeared to be a stronger predictor of stunting at discharge among older children. This could be reflective of the shift in dietary composition that includes more complementary foods, which may be a scarce shared resource in some households as the result of food insecurity. Unimproved sanitation was more strongly associated with stunting at discharge among children 24 months or older. Once children are able to walk and move about households more freely, they be having increased interaction with sanitation facilities or other shared environments and be at a higher risk for more frequent oral-fecal contamination. Sociodemographic factors, such as caregiver age and education remained important determinants of stunting in both age strata, thus remain important predictors of stunting throughout the first 5 years of life.

This study has several limitations. First, due to the study's cross-sectional design, we are unable to draw conclusions about causality or the temporal relationship between the correlates of interest and the outcome. The parent trial enrolled participants at hospital discharge thus excluding children who died in hospital, a population whose stunting status may be higher than among survivors. This discharge timepoint also meant that we did not obtain important information at the point of admission, such as enteric pathogens, nor before. Because this was a facility-based study of children recovering from acute illness, the results of this study cannot be generalized to children residing in the community who represent a population at lower-risk for morbidity and mortality, or community children who may have been acutely ill but did not seek care at a facility.

Despite the noted limitations, this study is the first to identify correlates of stunting at hospital discharge among children 1-59 months recently hospitalized for infectious conditions in Kenya. The high prevalence of stunting at hospital discharge reinforces the need for anthropometry (including length/height) to be collected throughout the course of a child's hospitalization to help assess vulnerability and direct follow up care as well as indicate a need for additional nutritional and hygiene counseling or service provision for the caregiver. The burden of stunting among this population also reinforces the need for upstream community-based stunting interventions.

To date, randomized trials of behavioral, therapeutic, and nutritional interventions to improve linear growth have yielded inconsistent results. [45-49] The relative impact of stunting interventions appears to be highly dependent on factors such as child age, setting, disease burden, singular or combined interventions, and intervention fidelity. [50,51] However, despite the growing body of evidence-based stunting interventions and evidence of high risk during the post-discharge period, few trials have specifically targeted stunted and acutely ill populations.

CONCLUSION

A combination of social and biologic vulnerabilities among place hospitalized and stunted children at particularly high risk of poor outcomes.[4,7,52-55] Among 1400 children recently hospitalized with multiple diagnoses, nearly 1 in 4 were stunted at discharge. Older child age, young caregiver age and low education, lack of exclusive breastfeeding, and HIV exposure were important determinants of stunting at hospital discharge. Hospital discharge represents an accessible point within the care cascade to identify highly vulnerable children prior to discharge for targeted interventions to improve survival and optimize growth. The high prevalence of stunting at discharge reinforces the need for the scale up of both community- and facility-based nutrition-specific and nutrition-sensitive programs that target growth faltering in the period following hospital discharge to prevent post-discharge morbidity and mortality among children under 5.

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Table 1. Characteristics of children 1-59 months recently discharged from hospital enrolled in the Toto Bora Trial (N=1400)

	n **Median**	**(%)** **IQR**
Child age category (months)		
1-6	239	17.1
7-11	229	16.4
12-23	406	20.0
24-59	526	37.5
Female	570	40.1
Study hospital		
Kisii Teaching & Referral Hospital	823	58.8
Homa Bay District Hospital	522	37.3
St. Paul Mission Hospital	19	1.3
Kendu Bay Hospital	36	2.6
Caregiver age (<20 years)	105	7.7
Maternal height (cm)	160.7	156.7-165.0
Caregiver BMI		
Underweight (<18.5)	66	4.7
Normal (18.5-24.9)	779	55.8
Overweight or obese (25.0-34.9)	551	39.5
Caregiver education (primary school or less)	644	46.1
Caregiver monthly income (<5000 Kenyan Shillings) [i]	875	62.5
Crowding (≥2 persons per room in household)	629	45.0
Two or more children <5 years in household	561	40.3
Safe water source[ii]	1156	82.7
Treats drinking water[iii]	691	50.5
Toilet type		
Flush toilet	136	9.7
Pit latrine	1209	86.5
Other	53	3.8
Shared toilet facility[iv]	633	47.3
Acute malnutrition[v]		
None	1264	90.4
Moderate	74	5.3
Severe	60	4.3
Underweight[vi]		
None	1223	87.4
Moderate	100	7.1
Severe	76	5.4
HIV status[vii]		
Unexposed	1191	85.1
HEU	139	9.9
HIV-infected	18	1.3
Length of exclusive breastfeeding (months, all ages)	6	6-6
Breastfeeding status (in first 6 months)[viii]		
Exclusively breastfed	659	47.2
Partially breastfed	635	45.5
Never breastfed	24	1.7
Unknown	78	5.6
Missing any age-appropriate vaccinations[ix]	747	53.6

Length of hospitalization (days)	3	2-5
Number of previous hospitalizations in last 12 months		
0	1080	77.8
1	187	13.5
2+	121	8.7
Final diagnosis		
Anemia	178	12.8
Gastroenteritis/diarrhea	251	18.0
Lower respiratory tract infection	437	31.3
Upper respiratory tract infection	136	9.8
Malaria	333	23.9
Malnutrition	88	6.3
Meningitis	68	4.9
Sepsis	52	3.7
Sickle cell	108	7.7
Tuberculosis	23	1.6
Other discharge[x]	394	28.3

[i] Refused to answer (n=70)

[ii] Safe water source defined as piped household or community water connection, protected spring water, borehole or tube well, dug well, rainwater, and bottled water

[iii] Treated drinking water defined as drinking water that is boiled, treated with chlorine, or passed through a ceramic/ sand/ composite/ LifeStraw filter

[iv] Shared toilet facility defined as toilet for household located outside child's house and used by multiple households

[v] Moderate acute malnutrition defined as weight-for-height z-score (WHZ) between -3 and -2 SD below WHO child growth standards median, and/or 11.5 $\leq$ mid-upper arm circumference (MUAC) $<$12.5 cm if $>$6 months; severe acute malnutrition defined as WHZ $<$ -3 SD below WHO child growth standards median, and/or MUAC $<$11.5 cm if $>$6 months, and/or presence of nutritional edema, and/or presence of kwashiorkor

[vi] Moderately underweight defined as weight-for-age z-score (WAZ) between -3 and -2 SD below WHO child growth standards median; severely underweight defined as WAZ $<$ -3 SD below WHO child growth standards median

[vii] Unknown HIV-infection status (n=52)

[viii] Exclusive breastfed defined as no other food or drink (including water) except for breastmilk in first 6 months; partially breastfed defined as child received breastmilk in addition to other food (including formula) and/or drink in first 6 months; never breastfed defined as no breastmilk in first 6 months

[ix] Per Kenyan Ministry of Health childhood vaccination schedule

[x] Urinary tract infection(n=11), fever of unknown origin(n=0), acutely unwell, unknown cause(n=4), poisoning/ herbal intoxication(n=6), asthma(n=30), convulsions(n=82), blood dyscrasia(n=4), congenital/acquired heart disease(n=8), cerebral palsy(n=10), diabetic ketoacidosis(n=4), skin/soft tissue infection(n=16), skin disease(n=7), hernia(n=5), helminth infection(n=2), burn/trauma(n=3), liver disease(n=3), congenital malformation(n=2), neurological disease(n=6), kidney disease(n=2), intestinal obstruction(n=3), CVA(n=1), trisomy 21(n=2)

Table 2. Characteristics of stunted (LAZ/HAZ <-2) and non-stunted Kenyan children 1-59 months and host, caregiver, and environmental correlates of stunting (N=1400)

	Stunted children (n=321)		**Non-stunted children (n= 1078)**		**Site- and child age-adjusted PR**[i]	**95% CI**	**p-value**
	n Median	**(%) IQR**	**n Median**	**(%) IQR**			
Age (months)							
1-6	42	13.1	197	18.3	Ref	-	-
7-11	45	14.0	184	17.1	1.16[ii]	0.76-1.76	0.495
12-23	103	32.1	303	28.1	1.50[ii]	1.05-2.14	0.027
24-59	131	40.8	394	36.5	1.49[ii]	1.05-2.11	0.026
Female	115	35.1	455	42.2	0.82	0.65-1.03	0.095
Caregiver age (<20 years)	36	11.7	69	6.6	1.61	1.13-2.30	0.008
Maternal height (cm)	154.9	154.6-161.9	161.7	157.5-165.5	0.94	0.92-0.95	<0.001
Paternal height (cm)	157.9	157.6-161.9	161.7	157.4-165.5	1.03	0.95-1.11	0.491
Caregiver BMI	22.9	20.9-27.0	24.0	21.3-27.4	0.97	0.95-1.00	0.020
Caregiver BMI							
Normal (18.5-24.9)	194	60.4	585	54.4	Ref	-	-
Underweight (<18.5)	14	4.4	52	4.8	0.88	0.51-1.52	0.650
Overweight (25.0-34.9)	113	35.2	438	40.7	0.81	0.51-1.52	0.079
Caregiver education (primary school or less)	196	61.4	448	41.6	1.95	1.55-2.45	<0.001
Caregiver monthly income (Kenyan Shillings)[iii]							
≥5,000	91	28.4	364	33.8	Ref	-	-
<5,000	220	68.5	654	60.7	1.13	0.92-1.39	0.234
Crowding (≥2 persons per room in household)	141	43.9	488	45.3	1.00	0.80-1.26	0.985
More than 2 children <5 years in household	144	45.1	471	38.8	1.27	1.02-1.59	0.033
Safe water source[iv]	261	81.3	895	83.1	0.89	0.67-1.18	0.402
Treated drinking water[v]	136	43.2	555	53.7	0.81	0.64-1.03	0.091
Toilet type							
Flush toilet	16	5.00	120	11.1	Ref	-	-
Pit latrine	286	89.4	923	85.6	2.02	1.22-3.36	0.006
Other[vi]	18	5.6	35	3.3	3.53	1.75-7.12	<0.001
Shared toilet facility[vii]	137	45.4	496	47.9	1.03	0.82-1.30	0.816
Child weight (kg)	9.0	7.0	11.3	8.2-13.2	0.60	0.56-0.64	<0.001
Acute malnutrition[viii]							
None	246	76.9	1018	94.4	Ref	-	-
Moderate	32	10.0	42	3.9	2.27	1.16-3.28	<0.001
Severe	42	13.1	18	1.7	3.89	2.78-5.44	<0.001
Underweight[ix]							
None	179	55.8	1044	96.8	Ref	-	-
Moderate	70	21.8	30	2.8	4.74	3.59-6.25	<0.001
Severe	72	22.4	4	0.4	6.82	5.15-9.03	<0.001

HIV status[x]							
Unexposed	246	76.6	945	87.6	Ref	-	-
HEU	46	14.3	93	8.6	1.85	1.33-2.58	<0.001
HIV-infected	10	3.1	8	0.7	2.67	1.42-5.04	0.002
Breastfeeding status in first 6 months[xi]							
Exclusively breastfed	122	38.2	537	49.9	Ref	-	-
Partially breastfed	161	50.5	474	44.0	1.29	1.00-1.65	0.047
Never breastfed	12	3.8	12	1.1	2.57	1.42-4.67	0.002
Missing any age-appropriate vaccinations[xii]	185	58.0	561	52.2	1.22	0.97-1.53	0.083
Number of previous hospitalizations in last 12 months							
0	240	75.0	839	78.6	Ref	-	-
1	45	14.1	142	13.3	1.08	0.79-1.49	0.626
2+	35	10.9	86	8.1	1.27	0.89-1.83	0.189
Final diagnosis							
Anemia	42	13.2	136	12.7	1.09	0.78-1.52	0.621
Gastroenteritis/diarrhea	54	16.9	197	18.3	0.95	0.71-1.23	0.735
Lower respiratory tract infection	81	25.4	356	33.1	0.71	0.55-0.93	0.012
Upper respiratory tract infection	22	6.9	114	10.6	0.64	0.41-1.00	0.050
Malaria	73	22.9	260	24.2	0.97	0.74-1.27	0.808
Malnutrition	64	20.1	24	2.2	4.16	3.13-5.54	<0.001
Meningitis	17	5.3	51	4.7	1.02	0.62-1.66	0.951
Sepsis	8	2.5	44	4.1	0.81	0.40-1.64	0.553
Sickle cell	18	5.6	90	8.4	0.74	0.45-1.21	0.235
Tuberculosis	12	3.7	11	1.0	2.35	1.32-4.20	0.004
Other discharge[xiii]	86	27.0	308	28.6	0.87	0.63-1.21	0.407
Presence of any bacterial or parasitic enteric pathogen in stool (*Salmonella, Shigella, Campylobacter, Cryptosporidium, Giardia)*	19	5.9	52	4.8	1.16	0.73-1.85	0.524

[i] PR: Prevalence ratio adjusted for study site and child age (months)
[ii] Adjusted for study site
[iii] Unknown or refused to answer (n=70)
[iv] Safe water source defined as piped household or community water connection, protected spring water, borehole or tube well, dug well, rainwater, and bottled water
[v] Treated drinking water defined as drinking water that is boiled, treated with chlorine, or passed through a ceramic/sand/composite/LifeStraw filter
[vi] Other includes bush, cat, other
[vii] Shared toilet facility defined as toilet for household located outside child's house and used by multiple households
[viii] Moderate acute malnutrition defined as weight-for-height z-score between -3 and -2 SD, and/or 11.5 ≤ MUAC <12.5 cm if >6 months; severe acute malnutrition defined as WHZ < -3 SD, and/or MUAC <11.5 cm if >6 months, and/or presence of nutritional edema, and/or presence of kwashiorkor
[ix] Moderately underweight defined as WAZ between -3 and -2 SD; severely underweight defined as WAZ < -3 SD
[x] Unknown HIV-infection status (n=52)
[xi] Exclusive breastfed defined as no other food or drink (including water) except for breastmilk in first 6 months; partially breastfed defined as child received breastmilk in addition to other food (including formula) and/or drink in first 6 months; never breastfed defined as no breastmilk in first 6 months
[xii] Per Kenyan Ministry of Health childhood vaccination schedule
[xiii] Urinary tract infection(n=11), fever of unknown origin(n=0), acutely unwell, unknown cause(n=4), poisoning/ herbal intoxication(n=6), asthma(n=30), convulsions(n=82), blood dyscrasia(n=4), congenital/acquired heart disease(n=8), cerebral palsy(n=10), diabetic ketoacidosis(n=4), skin/soft tissue infection(n=16), skin disease(n=7), hernia(n=5), helminth infection(n=2), burn/trauma(n=3), liver disease(n=3), congenital malformation(n=2), neurological disease(n=6), kidney disease(n=2), intestinal obstruction(n=3), CVA(n=1), trisomy 21(n=2)

Table 3. Correlates of stunting among Kenyan children 1-59 months stratified by child age (months) (N=1400).

	Children < =24 months (n=874)			Children ≥24 months (n=526)		
	Site- and child age-adjusted PR[i]	95% CI	p-value	Site- and child age-adjusted PR[i]	95% CI	p-value
Female	0.80	0.59-1.07	0.136	0.86	0.60-1.22	0.401
Caregiver age (<20 y)	1.79	1.22-2.65	0.003	1.27	0.52-3.12	0.12
Maternal height (cm)	0.94	0.92-0.96	<0.001	0.93	0.90-0.96	<0.001
Caregiver BMI						
Normal (18.5-24.9)	Ref	-	-	Ref	-	-
Underweight (<18.5)	1.01	0.49-2.07	0.983	0.70	0.30-1.61	0.404
Overweight (25.0-34.9)	0.81	0.60-1.10	0.178	0.85	0.59-1.22	0.380
Caregiver education (primary school or less)	1.83	1.36-2.46	<0.001	2.09	1.45-3.00	<0.001
Caregiver income (<5,000 Kenyan Shillings)	1.13	0.86-1.49	0.376	1.18	0.87-1.61	0.292
Crowding (≥2 persons per room in household)	0.89	0.66-1.20	0.439	1.21	0.84-1.74	0.294
More than 2 children <5 y in household	1.10	0.82-1.47	0.518	1.63	1.15-2.30	0.006
Safe water source[ii]	0.96	0.66-1.41	0.849	0.80	0.52-1.22	0.301
Treated drinking water[iii]	0.74	0.54-1.02	0.063	0.95	0.65-1.38	0.781
Toilet type						
Flush toilet	Ref	-	-	Ref	-	-
Pit latrine	1.83	0.95-3.58	0.078	2.27	1.06-4.88	0.036
Other[iv]	2.62	0.98-7.05	0.056	4.50	164012.3	0.004
Shared toilet facility[v]	1.00	0.75-1.34	0.998	1.05	0.72-1.53	0.802
Acute malnutrition[vi]						
None	Ref	-	-	Ref	-	-
Moderate	2.85	1.84-4.42	<0.001	1.54	0.75-3.16	0.236
Severe	4.54	3.14-6.58	<0.001	2.61	1.05-6.41	0.037
Underweight[vii]						
None	Ref	-	-	Ref	-	-
Moderate	5.95	4.16-8.51	<0.001	3.58	2.26-5.67	<0.001
Severe	8.53	6.10-11.95	<0.001	4.50	2.52-8.06	<0.001
HIV status[viii]						
Unexposed	Ref	-	-	Ref	-	-
HIV-exposed, uninfected	2.10	1.40-3.17	<0.001	1.58	0.89-2.80	0.121
HIV-infected	1.88	0.60-5.89	<0.001	3.26	1.51-7.03	0.003
Breastfeeding status (in first 6 m)[ix]						
Exclusively breastfed	Ref	-	-	Ref	-	-
Partially breastfed	1.31	0.95-1.79	0.100	1.29	0.86-1.93	0.222
Never breastfed	2.63	1.20-5.73	0.015	2.44	0.97-6.13	0.058
Missing any age-appropriate vaccinations	1.28	0.96-1.73	0.093	1.07	0.75-1.52	0.719
Number of previous hospitalizations in last 12 months						
0	Ref	-	-	Ref	-	-

1	1.44	0.98-2.12	0.061	0.63	0.35-1.12	0.115
2+	1.21	0.66-2.17	0.545	1.24	0.78-1.96	0.352
Final diagnosis						
Anemia	0.81	0.50-1.33	0.413	1.41	0.89-2.23	0.139
Gastroenteritis/diarrhea	0.89	0.63-1.27	0.532	0.94	0.54-1.64	0.824
Lower respiratory tract infection	0.54	0.39-0.76	<0.001	1.35	0.90-2.03	0.150
Malaria	0.83	0.56-1.23	0.355	1.03	0.71-1.50	0.881
Malnutrition	4.39	3.21-5.98	<0.001	3.19	1.30-7.82	0.011
Meningitis	0.92	0.43-1.96	0.823	0.97	0.51-1.86	0.932
Sepsis	0.97	0.39-2.40	0.946	0.71	0.22-2.24	0.557
Sickle cell	0.58	0.23-1.43	0.237	0.90	0.50-1.62	0.715
Tuberculosis	2.48	1.26-4.88	0.008	2.39	0.76-7.56	0.138
Other discharge[xi]	0.90	0.56-1.44	0.661	0.83	0.53-1.31	0.430

[i] PR: Prevalence ratio adjusted for study site and child age (months)

[ii] Safe water source defined as piped household or community water connection, protected spring water, borehole or tube well, dug well, rainwater, and bottled water

[iii] Treated drinking water defined as drinking water that is boiled, treated with chlorine, or passed through a ceramic/sand/composite/LifeStraw filter

[iv] Other includes bush, cat, other

[v] Shared toilet facility defined as toilet for household located outside child's house and used by multiple households

[vi] Moderate acute malnutrition defined as weight-for-height z-score between -3 and -2 SD below WHO child growth standards median, and/or 11.5 ≤ MUAC <12.5 cm if >6 months; severe acute malnutrition defined as WHZ < -3 SD below WHO child growth standards median, and/or MUAC <11.5 cm if >6 months, and/or presence of nutritional edema, and/or presence of kwashiorkor

[vii] Moderately underweight defined as WAZ between -3 and -2 SD below WHO child growth standards median; severely underweight defined as WAZ < -3 SD below WHO child growth standards median

[viii] 52 participants had unknown HIV-infection status

[ix] Exclusive breastfed defined as no other food or drink (including water) except for breastmilk in first 6 months; partially breastfed defined as child received breastmilk in addition to other food (including formula) and/or drink in first 6 months; never breastfed defined as no breastmilk in first 6 months

[x] Per Kenyan Ministry of Health childhood vaccination schedule with 4 week window

[xi] Urinary tract infection(n=11), fever of unknown origin(n=0), acutely unwell, unknown cause(n=4), poisoning/ herbal intoxication(n=6), asthma(n=30), convulsions(n=82), blood dyscrasia(n=4), congenital/acquired heart disease(n=8), cerebral palsy(n=10), diabetic ketoacidosis(n=4), skin/soft tissue infection(n=16), skin disease(n=7), hernia(n=5), helminth infection(n=2), burn/trauma(n=3), liver disease(n=3), congenital malformation(n=2), neurological disease(n=6), kidney disease(n=2), intestinal obstruction(n=3), CVA(n=1), trisomy 21(n=2)

APPENDIX

Supplemental Table 1. Estimations of minimum detectable risk assuming α(two-sided) = 0.05, power (1-β) = 0.80 and sample size (n=1400).

	Prevalence of stunting among unexposed children		
	0.15	0.25	0.35
Prevalence of exposure			
0.01	3.01	2.41	2.05
0.05	1.92	1.64	1.48
0.10	1.67	1.47	1.36
0.15	1.57	1.40	1.31
0.20	1.56	1.36	1.28
0.25	1.48	1.34	1.26
0.30	1.45	1.32	1.25
0.35	1.43	1.31	1.24
0.40	1.42	1.30	1.23
0.45	1.41	1.29	1.22

REFERENCES

1. UNICEF. Levels and Trends in Child Mortality. 2019.
2. Institute for Health Metrics and Evaluation. GHDx [Internet]. 2019. (Accessed October 24, 2019); Available from: http://ghdx.healthdata.org/gbd-results-tool.
3. Gathara D, Malla L, Ayieko P, et al. Variation in and risk factors for paediatric inpatient all-cause mortality in a low income setting: data from an emerging clinical information network. BMC Pediatr 2017;17:99.
4. Chisti MJ, Graham SM, Duke T, et al. Post-discharge mortality in children with severe malnutrition and pneumonia in Bangladesh. PLoS One 2014;9:e107663.
5. Kerac M, Bunn J, Chagaluka G, et al. Follow-up of post-discharge growth and mortality after treatment for severe acute malnutrition (FuSAM study): a prospective cohort study. PLoS One 2014;9:e96030.
6. Caulfield LE dOM, Blössner M, Black RE. Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria, and measles. Am J Clin Nutr 2004;80:193-8.
7. Moisi JC, Gatakaa H, Berkley JA, et al. Excess child mortality after discharge from hospital in Kilifi, Kenya: a retrospective cohort analysis. Bull World Health Organ 2011;89:725-32, 32A.
8. Talbert A, Ngari M, Bauni E, et al. Mortality after inpatient treatment for diarrhea in children: a cohort study. BMC Med 2019;17:20.
9. Kotloff KL, Nataro JP, Blackwelder WC, et al. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. The Lancet 2013;382:209-22.
10. Victora CG, Adair L, Fall C, et al. Maternal and child undernutrition: consequences for adult health and human capital. The Lancet 2008;371:340-57.

11. Dewey KG, Begum K. Long-term consequences of stunting in early life. Matern Child Nutr 2011;7 Suppl 3:5-18.
12. Prendergast AJ, Humphrey JH. The stunting syndrome in developing countries. Paediatr Int Child Health 2014;34:250-65.
13. Shinsugi C, Matsumura M, Karama M, Tanaka J, Changoma M, Kaneko S. Factors associated with stunting among children according to the level of food insecurity in the household: a cross-sectional study in a rural community of Southeastern Kenya. BMC Public Health 2015;15:441.
14. De Vita MV, Scolfaro C, Santini B, et al. Malnutrition, morbidity and infection in the informal settlements of Nairobi, Kenya: an epidemiological study. Ital J Pediatr 2019;45:12.
15. Onchiri FM, Pavlinac PB, Singa BO, et al. Low Bacteremia Prevalence Among Febrile Children in Areas of Differing Malaria Transmission in Rural Kenya: A Cross-Sectional Study. J Pediatric Infect Dis Soc 2016;5:385-94.
16. Brink J, Pettifor JM, Lala SG. The prevalence of malnutrition in children admitted to a general paediatric ward at the Chris Hani Baragwanath Academic Hospital: A cross-sectional survey. South African Journal of Child Health 2014;8.
17. Pavlinac PB, Singa BO, John-Stewart GC, et al. Azithromycin to prevent post-discharge morbidity and mortality in Kenyan children: a protocol for a randomised, double-blind, placebo-controlled trial (the Toto Bora trial). BMJ Open 2017;7:e019170.
18. World Health Organization. WHO AnthroPlus Software. Geneva: World Health Organization; 2009.
19. Pavlinac PB, Denno DM, John-Stewart GC, et al. Failure of Syndrome-Based Diarrhea Management Guidelines to Detect Shigella Infections in Kenyan Children. J Pediatric Infect Dis Soc 2016;5:366-74.
20. Matanda DJ, Mittelmark M.B., Kigaru DMD. Child undernutrition in Kenya: trend analysesfrom 1993 to 2008–09. BMC Pediatr 2014;15.

21. Ettyang GAK, Sawe CJ. Factors Associated with Stunting in Children under Age 2 in the Cambodia and Kenya 2014 Demographic and Health Surveys DHS Working Papers 2016.
22. Tickell KD, Pavlinac PB, John-Stewart GC, et al. Impact of Childhood Nutritional Status on Pathogen Prevalence and Severity of Acute Diarrhea. Am J Trop Med Hyg 2017;97:1337-44.
23. Ocheke IE, John C, Pouane T. Factors influencing the pattern of malnutrition among acutely ill children presenting in a tertiary hospital in Nigeria. Nigerian Journal of Paediatrics 2014;14:326-30.
24. Kenya National Bureau of Statistics. National AIDS Control Council/Kenya, Kenya Medical Research Institute, and National Council for Population and Development/Kenya. Kenya Demographic and Health Survey 2014. Rockville, MD, USA2015.
25. MAL-ED Network Investigators. Childhood stunting in relation to the pre- and postnatal environment during the first 2 years of life: The MAL-ED longitudinal birth cohort study. PLoS Med 2017;14:e1002408.
26. Nshimyiryo A, Hedt-Gauthier B, Mutaganzwa C, et al. Risk factors for stunting among children under five years: a cross-sectional population-based study in Rwanda using the 2015 Demographic and Health Survey. BMC Public Health 2019;19:175.
27. Kulwa KB, Mamiro PS, Kimanya ME, et al. Feeding practices and nutrient content of complementary meals in rural central Tanzania: implications for dietary adequacy and nutritional status. BMC Pediatr 2015;15:171.
28. Keusch GT, Denno DM, Black RE, et al. Environmental enteric dysfunction: pathogenesis, diagnosis, and clinical consequences. Clin Infect Dis 2014;59 Suppl 4:S207-12.
29. Kosek M, Haque R, Lima A, et al. Fecal markers of intestinal inflammation and permeability associated with the subsequent acquisition of linear growth deficits in infants. Am J Trop Med Hyg 2013;88:390-6.

30. Guerrant RL, Leite AM, Pinkerton R, et al. Biomarkers of Environmental Enteropathy, Inflammation, Stunting, and Impaired Growth in Children in Northeast Brazil. PLoS One 2016;11:e0158772.
31. Lamberti LM, Fischer Walker CL, Noiman A, et al. Breastfeeding and the risk for diarrhea morbidity and mortality. BMC Public Health 2011;11.
32. Sankar MJ, Sinha B, Chowdhury R, et al. Optimal breastfeeding practices and infant and child mortality: a systematic review and meta-analysis. Acta Paediatr 2015;104:3-13.
33. Scherbaum V SM, Srour ML. The Role of Breastfeeding in the Prevention of Childhood Malnutrition. In: Hidden Hunger: Malnutrition and the First 1,000 Days of Life: Causes, Consequences, and Solutions. Basel, New York: Karger; 2016:82-97.
34. Sint TT, Lovich R, Hammond W, et al. Challenges in infant and young child nutrition in the context of HIV. AIDS 2013;27 Suppl 2:S169-77.
35. Pavlinac PB, John-Stewart GC, Naulikha JM, et al. High-risk enteric pathogens associated with HIV infection and HIV exposure in Kenyan children with acute diarrhoea. AIDS 2014;28:2287-96.
36. Acacio S, Nhampossa T, Quinto L, et al. The role of HIV infection in the etiology and epidemiology of diarrheal disease among children aged 0-59 months in Manhica District, Rural Mozambique. Int J Infect Dis 2018;73:10-7.
37. Kim R, Mejia-Guevara I, Corsi DJ, et al. Relative importance of 13 correlates of child stunting in South Asia: Insights from nationally representative data from Afghanistan, Bangladesh, India, Nepal, and Pakistan. Soc Sci Med 2017;187:144-54.
38. Akombi BJ, Agho KE, Hall JJ, et al. Stunting and severe stunting among children under-5 years in Nigeria: A multilevel analysis. BMC Pediatr 2017;17:15.
39. Sultana P, Rahman MM, Akter J. Correlates of stunting among under-five children in Bangladesh: a multilevel approach. BMC Nutr 2019;5:41.

40. Bornstein MH, Putnick DL, Bradley RH, et al. Pathways among Caregiver Education, Household Resources, and Infant Growth in 39 Low- and Middle-Income Countries. Infancy 2015;20:353-76.
41. Wambui WM, Kimani S, Odhiambo E. Determinants of Health Seeking Behavior among Caregivers of Infants Admitted with Acute Childhood Illnesses at Kenyatta National Hospital, Nairobi, Kenya. Int J Pediatr 2018;2018:5190287.
42. Danaei G, Andrews KG, Sudfeld CR, et al. Risk Factors for Childhood Stunting in 137 Developing Countries: A Comparative Risk Assessment Analysis at Global, Regional, and Country Levels. PLoS Med 2016;13:e1002164.
43. Liu J, Platts-Mills JA, Juma J, et al. Use of quantitative molecular diagnostic methods to identify causes of diarrhoea in children: a reanalysis of the GEMS case-control study. The Lancet 2016;388:1291-301.
44. Tickell KD, Mangale DI, Tornberg-Belanger SN, et al. A mixed method multi-country assessment of barriers to implementing pediatric inpatient care guidelines. PLoS One 2019;14:e0212395.
45. Imdad A, Yakoob MY, Bhutta ZA. Effect of preventive zinc supplementation on linear growth in children under 5 years of age in developing countries: a meta-analysis of studies for input to the lives saved tool. BMC Public Health 2011;11.
46. Wang AZ, Shulman RJ, Crocker AH, et al. A Combined Intervention of Zinc, Multiple Micronutrients, and Albendazole Does Not Ameliorate Environmental Enteric Dysfunction or Stunting in Rural Malawian Children in a Double-Blind Randomized Controlled Trial. J Nutr 2017;147:97-103.
47. Stephenson KB, Agapova SE, Divala O, et al. Complementary feeding with cowpea reduces growth faltering in rural Malawian infants: a blind, randomized controlled clinical trial. Am J Clin Nutr 2017;106:1500-7.

48. Rogawski ET, Platts-Mills JA, Seidman JC, et al. Early Antibiotic Exposure in Low-resource Settings Is Associated With Increased Weight in the First Two Years of Life. J Pediatr Gastroenterol Nutr 2017;65:350-6.
49. Humphrey JH, Mbuya MNN, Ntozini R, et al. Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: a cluster-randomised trial. The Lancet Global Health 2019;7:e132-e47.
50. Bhutta ZA, Ahmed T, Black RE, et al. What works? Interventions for maternal and child undernutrition and survival. The Lancet 2008;371:417-40.
51. Hossain M, Choudhury N, Abdullah KAB, et al. Evidence-based approaches to childhood stunting in low and middle income countries: a systematic review. Arch Dis Child 2017;102:903-9.
52. Islam MA, Rhaman MM, Mahalanabis D, et al. Death in a diarrhoeal cohort of infants and young children soon after discharge from hospital: risk factors and causes by verbal autopsy. J Trop Pediatr 1996;46:342-7.
53. Opoka RO, Hamre KES, Brand N, et al. High Postdischarge Morbidity in Ugandan Children With Severe Malarial Anemia or Cerebral Malaria. J Pediatric Infect Dis Soc 2017;6:e41-e8.
54. Wiens MO, Kumbakumba E, Larson CP, et al. Postdischarge mortality in children with acute infectious diseases: derivation of postdischarge mortality prediction models. BMJ Open 2015;5:e009449.
55. Nemetchek B, English L, Kissoon N, et al. Paediatric postdischarge mortality in developing countries: a systematic review. BMJ Open 2018;8:e023445.