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Nutritional status of children living within institution-based care: a retrospective analysis with funnel plots and control charts for programme monitoring

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ABSTRACT

Objectives The aim of this study is to fill a key information gap on the nutrition-related epidemiology of orphaned and vulnerable children living within institution-based care (IBC) across six countries.

Design A retrospective analysis with Shewhart control charts and funnel plots to explore intersite and over time variations in nutritional status.

Setting We conducted a retrospective analysis of records from Holt International's Child Nutrition Programme from 35 sites in six countries; Mongolia, India, Ethiopia, Vietnam, China and the Philippines.

Participants Deidentified health records from Holt International's online nutrition screening database included records from 2926 children, 0–18 years old. Data were collected from 2013 to 2020 and included demographic and health information.

Results At initial screening, 717 (28.7%) children were anaemic, 788 (34.1%) underweight, 1048 (37.3%) stunted, 212 (12.6%) wasted, 135 (12%) overweight or obese and 339 (31%) had small head circumference. Many had underlying conditions: low birth weight, 514 (57.5%); prematurity, 294 (42.2%) and disabilities, 739 (25.3%). Children with disabilities had higher prevalence of malnutrition compared with counterparts without disabilities at baseline and 1-year screenings. There was marked intersite variation. Funnel plots highlight sites with malnutrition prevalence outside expected limits for this specific population taking into consideration natural variation at baseline and at 1 year. Control charts show changes in site mean z-scores over time in relation to site control limits.

Conclusions Malnutrition is prevalent among children living within IBC, notably different forms of undernutrition (stunting, underweight, wasting). Underlying risk factors are also common: prematurity, low birth weight and disability. Nutrition interventions should take into account the needs of this vulnerable population, especially for infants and those with disabilities. Using control charts to present data could be especially useful to programme managers as sites outside control limits could represent: problems to be investigated; good practices to be shared.

Strengths and limitations of this study

- The main strength of our study was the large sample size in both terms of individual children (including those with disabilities) and multiple centres across several countries.
- This study explored the utility of statistical process control charts and funnel plots to explore intersite and over time variations in malnutrition prevalence—these are established but under-used tools which might help managers monitor and ultimately improve programme outcomes.
- There were changes in the sample size over time.
- The sites included in this sample may not be representative of all similar institutions in all of the countries.

BACKGROUND

UNICEF estimates there are 140 million orphans worldwide who have lost either one or both parents.[1] Although most live with other family members, some live in institution-based care (IBC) or residential care facilities.[1] IBC is defined by the United Nations as residential care provided in any non-family-based group setting.[2] The UN Convention on the Rights of the Child requires that children in IBC are provided with standards of living that will support their full development. There are 3.18 million to 9.42 million children ages 18 years and younger who live in IBC globally.[3]

Malnutrition continues to affect many countries worldwide with millions of children having inadequate access to nutritious food.[4–6] Almost half of the deaths among children younger than 5 years old have undernutrition as an underlying factor.[4 6] Malnutrition also predisposes children to long-term impairments such as

diminished cognition, disability, non-communicable diseases and suboptimal performance at school and work.[4 6] Dramatic worsening is anticipated as a result of the COVID-19 pandemic.[7 8]

A recent systematic review exploring the nutritional status of children living in IBC found few studies directly documenting the problem.[9] Where publications were available, 'data quality was often poor: as well as suboptimal reporting of anthropometry, few looked for or described disabilities, despite disability being common in this population and having a large potential impact on nutrition status.'[9] Disabilities in particular can be both a cause and a result of malnutrition.[10] Interpreting data can be difficult due to limited information about children's lives prior to entering IBC.[9 11–13] Pre-existing needs and adversities, including disabilities, low birth weight (LBW) or premature birth, or exposure to alcohol or drugs can impact nutritional status.[9 11 13 14]

Once children enter into IBC, facilities might only be able to address their basic needs due to limited staffing, time and fiscal constraints.[11 15–17] Children's nutritional status could be impacted by inadequate dietary diversity; inappropriate types of food; poor feeding practices; inadequate attention or stimulation; suboptimal hygiene and sanitation. These can further exacerbate preadmission vulnerabilities, with the net result of: reduced nutrient utilisation, worsening malnutrition and a vicious cycle of increased vulnerability to illnesses and in turn further nutritional decline.[9 13 16 18]

In this paper, we seek to help contribute to the current small body of data on nutritional status of children in IBC by analysing data on 2926 children from 35 sites in six countries. Our objectives were to:

1. Describe children's nutritional status, focusing on core anthropometric measures of growth (underweight, wasting, stunting, overweight) and anaemia.
2. Explore intersite variations and potential factors underlying those, notably disability.
3. Explore any changes in nutritional status over time in IBC.

Cross-cutting these objectives, we also explored the utility of control charts and funnel plots to present key data in a way that may be used to track, monitor and evaluate nutritional status and programmes.

METHODS

We reported according to the Strengthening the Reporting of Observational Studies in Epidemiology statement (online supplemental file 1).[19] A data use agreement was signed with Holt International for use of routinely collected data.

Study design

A retrospective analysis of nutrition screenings from a large multicountry nutrition programme.

Setting/study size

We used secondary data from Holt International's Child Nutrition Programme nutrition screening database. Holt International is a 65-year-old child welfare nonprofit, which provides services to children and families in numerous countries around the world. Holt's Child Nutrition Programme currently supports 35 IBC sites in six countries: Mongolia, India, China, Philippines, Ethiopia and Vietnam. Study size was determined by the number of children and nutrition screenings at each site. Figure 1 is a flow chart of inclusion criteria leading to the final sample size.

Patient and public involvement

This study analysed secondary deidentified routine programme audit data and did not involve patients or public in development of the research. However, we intend to disseminate this research to the public and all relevant stakeholders on open access publication.

Participants

Screenings from children 0–18 years old residing in IBC between January 2013 and June 2020 were included. These health/nutrition screenings were routinely performed at each site based on age and specific health indicators (eg, anaemia). They are carried out monthly on children up to 2 years old; quarterly on children 2–5 years old and biannually thereafter. Each screening captures information on age, birth status, sex, disability status, time spent in care, episodes of illness, nutritional status as assessed by anthropometric measurements and anaemia as assessed by haemoglobin tests. Screenings and measurements were taken by trained staff using standardised equipment (Stadiometer (Seca 206 cm), standing scale (Seca model 469), baby scale (Health-O-metre model 553 kL), infant/child length/height measurement board (Shorrboard), Hb201 +Haemoglobin System (Hemocue)).

Variables

Health indicators analysed included prevalence of stunting (height-for-age z-score, HAZ), wasting (weight-for-height z-score, WHZ and mid-upper arm circumference-for-age z-score), underweight (weight-for-age z-score, WAZ), thinness/underweight (body mass index z-score, BMIZ), overweight (BMIZ), head circumference (head circumference-for-age z-score) and anaemia. Disabilities, as categorised by professionals in country, were grouped and tabulated by the primary disability listed. LBW and preterm birth were as noted in any preadmission health records.

Statistical analysis

Analysis was completed using Stata V.16.[20] Children's baseline and last screening within each 6-month period were selected for analysis. Child health characteristics are described in tables 1 and 2 with n (%) for categorical variables and means, SD, medians, and IQR for continuous variables. WHO diagnostic and data cleaning criteria for anthropometry and anaemia were used

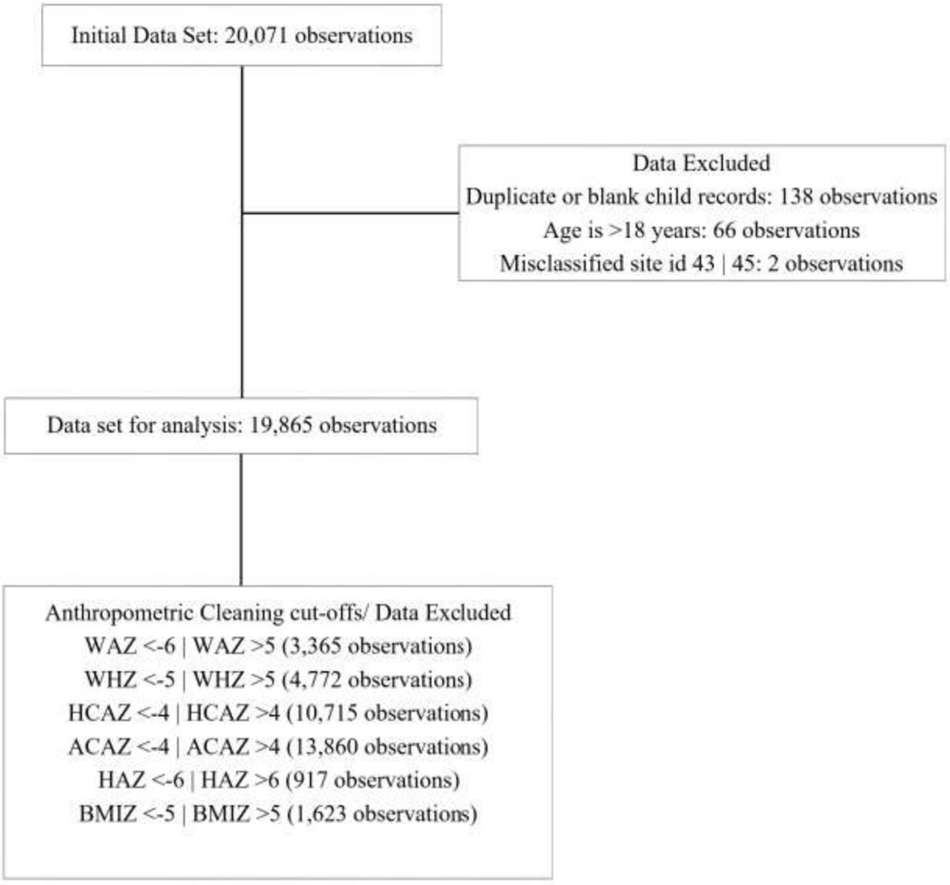

Figure 1 Data cleaning flow chart.[19] BMIZ, body mass index z-score; HAZ, height-for-age z-score; HCAZ, head circumference-for-age z-score; WAZ, weight-for-age z-score; WHZ, weight-for-height z-score; ACAZ, mid-upper arm circumference-for-age z-score.

(haemoglobin levels for ages 0–5 years: mild 10.0–10.9 g/dL, moderate 7.0–9.9 g/dL, severe, <7.0 g/dL; ages 5–11 years: mild 11.0–11.4 g/dL, moderate 8.0–10.9 g/dL, severe, <8.0 g/dL; ages 12–14 years: mild 11.0–11.9 g/dL, moderate 8.0–10.9 g/dL, severe, <8.0 g/dL; females aged 14+ years: mild 11.0–11.9 g/dL, moderate 8.0–10.9 g/dL, severe <8.0 g/dL and males aged 14+years: mild 11.0–12.9 g/dL, moderate 8.0–10.9 g/dL, severe <8.0 g/dL).[21–23] The time in programme is defined as the number of days from the registered admission date to exit and is censored at the date of the final observation for those remaining in care.

We used statistical process control (SPC) charts (Shewhart), which provide graphical representation of data and applies the statistical power of classical significance tests to analyse data chronologically while being easily interpreted and capable of identifying changes (figures 2 and 3, online supplemental annex 1–9).[24 25] The central line and upper and lower control limits (UCL and LCL) define the expected amount of variability assuming expected variability due to sampling. Historically, control charts were used to determine if manufacturing processes were within expected variability; however recently they've been used in healthcare and development settings to distinguish random variations from statistically significant variations which may require further exploration/analysis.[24 25] Here, we use the control charts to explore changes over time in key anthropometric indicators and monitor the health of children in individual sites. We hypothesise that ongoing use of control charts will enable sites to take action accordingly. Different types of control charts exist for different types of data. For our anthropometric data we use X-bar charts, plotting the mean anthropometric z-scores at each time point for an individual site along with the site UCL and LCL. These control charts were created using site level aggregated mean z-scores for the nutritional status indicators at different time points based on the children's last screening in each 6-month period after baseline. The central line is the arithmetic mean and our UCL and LCL were calculated based on the mean and SE of the mean (±3) of aggregated data from the site at baseline.

A funnel plot plots the outcome of interest against a measure of study precision with more data resulting in more precision and creating the funnel shape. We used funnel plots for outcomes measured as proportions, plotting IBC sites against the absolute number of occurrences of our health outcomes of interest (eg, stunting) while taking into account the amount of available data from each site and plotting sites by size (smallest to largest) against the proportion of interest. The plot's mean and limits of 2 and 3 SEs identify sites for whom the prevalence/

Table 1 Description of population at baseline screening of children living within IBC in six countries

Population at baseline	Total (n=2926)
Age (%)	
Exact date of birth unknown	2639 (90.2)
Estimated or known date of birth	(n=2926)
0–6 months	746 (25.5)
6–12 months	245 (8.4)
12–24 months	282 (9.6)
24–59 months	427 (14.6)
5–18 years	1226 (41.9)
Sex (%)	(n=2926)
Female	1435 (49.0)
Disability (%)	(n=2926)
With one or more disabilities	739 (25.3)
Common disabilities (%)	(n=547)
Autism spectrum disorder	9 (1.6)
Cerebral palsy	100 (18.2)
Cleft lip/cleft palate	7 (1.3)
Cognitive impairment	34 (6.2)
Down syndrome	15 (2.7)
Hearing loss/deafness	8 (1.5)
Heart disease/defect	35 (6.4)
HIV/AIDS	10 (1.8)
Hydrocephaly	16 (2.9)
Microcephaly	6 (1.1)
Vision impairment and blindness	13 (2.4)
Speech/language delays	3 (0.6)
Other	291 (53.2)
Birth weight (%)	(n=2926)
Birth weight unknown	2031 (69.4)
Where birth weight known	(n=895)
Birth weight >2.5 kg	381 (42.6)
Low birth weight <2.5 kg	452 (50.5)
Very low birth weight <1.5 kg	55 (6.2)
Extremely low birth weight <1.0 kg	7 (0.8)
Birth status (%)	(n=2926)
Unknown birth status	2229 (76.2)
Where birth status known	(n=697)
Where known full term	403 (57.8)
Where known premature	294 (42.2)
Age at admission	(n=2926)
Median age in months (IQR)	10 (0.4–71.8)
Time since admission	(n=2926)
Median time in months since admission (IQR)	20.7 (8.9–49.2)
Exit status	(n=2926)
Total no exited	1489
Active children	1437
Exit status reasons (%)	(n=1489)
Family reunification	315 (21)
Foster care placement	29 (2)
Adoption (domestic)	517 (34.7)
Adoption(international)	281 (18.9)
Aged out of care	82 (5.5)
Transfer to a different centre	103 (6.9)
Death	40 (2.7)
Other	57 (4.1)
Programme closed	65 (4.4)

IBC, institution-based care.

outcome is unusually high or low. Together, these charts will allow us to assess individual site performance over time and enable appropriate targeted support.

RESULTS

We analysed data from 19 865 nutrition records from 2926 children at 35 sites in six countries.

Demographic characteristics

Table 1 shows baseline characteristics of 2926 children living within IBC. The largest age groups were children 0–6 months 746 (25.5%) and children older than 5 years of age 1226 (41.9%); 1435 (49%) were female; 739 (25.3%) had one or more disabilities. A range of disabilities were reported. Cerebral palsy was the most common disability identified (100 (18.2%)). However, 291 (53.2%) children with disabilities had a disability which did not fall into established categories. Of those with a known birth weight, 514 (57.5%) were born LBW. Of those children with a known gestational age, 294 (42.2%) were born prematurely. Children came into IBC at a median age of 10 months (IQR: 0.4–71.8 months) and resided in IBC for a median time of 21.7 months (IQR: 9.7–50.9 months).

Anthropometric characteristics

Table 2 and online supplemental annex table 1 show details of anthropometric status. At baseline the mean weight-for-age z-score for those 0–10 years old was −1.48±1.54. The mean HAZ was −1.74±1.67 for those 0–18 years old. For children 0–5 years old, the mean WHZ at baseline was −0.42±1.49. BMI z-score for children 5–18 years old at baseline was −0.44 (±1.34).

At baseline 788 (34.1%) of children younger than 10 years of old were underweight and 1048 (37.3%) of children ages 0–18 years were stunted. Of those children younger than 5 years old, 212 (12.6%) were wasted. Of children 5–18 years of age, 114 (10.2%) were too thin/

Table 2 Total population mean anthropometric z-scores, malnutrition and anaemia prevalence at baseline

Mean anthropometric baseline z-scores	z-score (±SD)
Weight-for-age z-score (0–10 years) (n=2308)	−1.48±1.54
Height-for-age z-score (0–18 years) (n=1686)	−1.74±1.67
Weight-for-height z-score (0–5 years) (n=1678)	−0.42±1.49
BMI z-score (0–18 years) (n=2733)	−0.62±1.45
Mid upper arm circumference-for-age z-score (6 months to 5 years) (n=426)	−0.33±1.20
Head circumference-for-age z-score (0–5 years) (n=1095)	−1.26±1.37
Malnutrition prevalence	n (%)
Underweight (WAZ) (0–10 years) (n=2308)	
Normal (≥2)	1520 (65.9)
Moderate (≥3 to ≤2)	443 (19.2)
Severe (<-3)	345 (15)
Stunting (HAZ) (0–18 years) (n=2812)	
Normal (≥2)	1764 (62.7)
Moderate (≥3 to ≤2)	560 (19.9)
Severe (≤3)	488 (17.4)
Wasted (WHZ) (0–5 years) (n=1678)	
Normal (≥2)	1466 (87.4)
Moderate (≥3 to ≤2)	137 (8.2)
Severe (≤3)	75 (4.5)
Overweight/thinness (BMIZ) (5–18 years) (n=1123)	
Obese (≥2)	17 (1.5)
Overweight (≥1 to <2)	118 (10.5)
Normal (≥2 to <1)	874 (77.8)
Thinness (≥3 to ≤2)	80 (7.1)
Severe thinness (≤3)	34 (3)
Head circumference (HCAZ) (0–5 years) (n=1095)	
Severe large (≥3)	7 (0.6)
Large (≥2 to <3)	10 (0.9)
Normal (≥2 to <2)	739 (67.5)
Small (≥3 to ≤2)	214 (19.5)
Severe small (≤3)	125 (11.4)
Anaemia (0–18 years) (n=2494)	
Normal	1777 (71.3)
Mild	413 (16.6)
Moderate	287 (11.5)
Severe	17 (0.7)

ACAZ, mid-upper arm circumference-for-age z-score; BMI, body mass index; HAZ, height-for-age z-score; HCAZ, head circumference-for-age z-score; WAZ, weight-for-age z-score; WHZ, weight-for-height z-score.

underweight. For children ages 5–18 years old, 135 (12%) were overweight/obese. Of children ages 0–5 years old, 339 (31%) had a small head circumference.

Among those with disabilities who had anthropometric data available, at baseline 324 (57.6%) of those under 10 years old were underweight and 368 (56.3%) were stunted. Of children ages 5–18 years old, 38 (16.2%) were too thin/underweight and 38 (16.2%) were overweight/obese. For children with disabilities, 95 (53.7%) had a small head circumference.

At baseline, of the total population 717 (28.8%) had anaemia, with younger children more likely to have anaemia. Over time, anaemia severity and prevalence of anaemia reduced for most categories and age groups. Children younger than 5 years old and those younger than 5 years old with a disability had similar

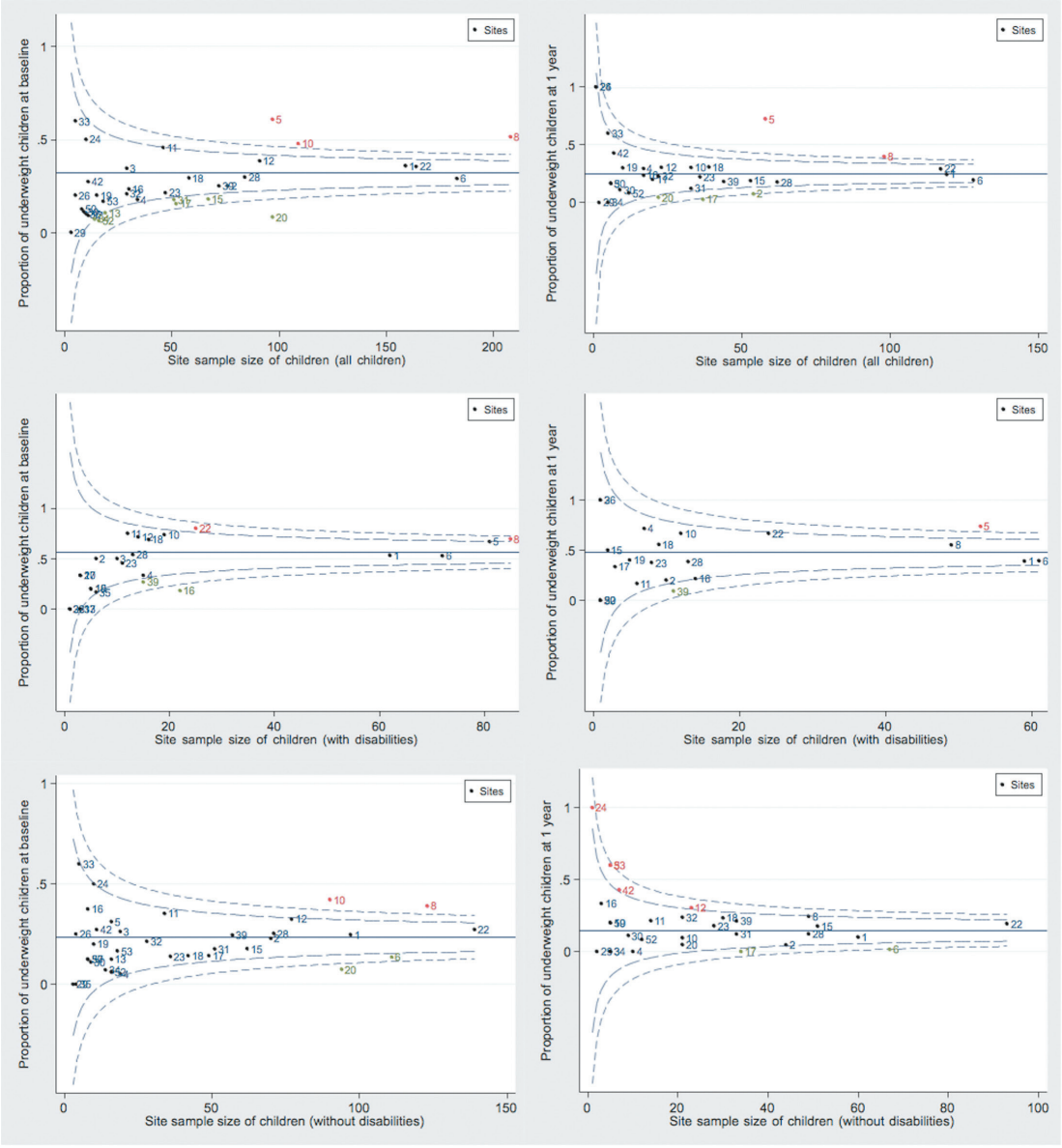

Figure 2 Funnel plots of the proportion of underweight children (WAZ), 0–10 years old at baseline screening (left side panels) and 1-year screening (right side panels). Top row includes all children, the middle row includes only those children with disabilities and the bottom row includes only those children without disabilities. Site identifiers above expected variation are in red, those within variation in black and those below expected variation in green. WAZ, weight-for-age z-score.

anaemia prevalence; 461 (34.4%) and 131 (34.5%), respectively.

Funnel plots

Funnel plots (figure 2, online supplemental annex 1–5) show prevalence of anthropometric deficit in different sites over time and by disability status, identifying those sites which are outside of expected limits. Figure 2 shows weight-for-age prevalence. Sites 5 and 8 are outside the control limits with higher than expected prevalence of underweight children both baseline and 1 year. At 1 year, site 10 seems to have a higher proportion of underweight than would be expected compared with other sites. The mean prevalence of underweight is higher among children with disabilities than in those without. Online supplemental annex 1–5 show the same for other key anthropometric indicators—broad patterns are similar to underweight.

SPC charts

Figure 3 and online supplemental annex 6–9 show control charts for tracking site-level changes in anthropometric z-scores over time compared with total population UCL and LCL. Figure 3 shows mean WAZ change over time. Sites 1 and 6 illustrate sites with average (generally within the UCL and LCL) performance, respectively. Both sites have individual points outside of expected variation for children with disabilities, with a suggestion of a slight improvement in weight-for-age at 1 year for both sites, with site six maintaining the improvement over time.

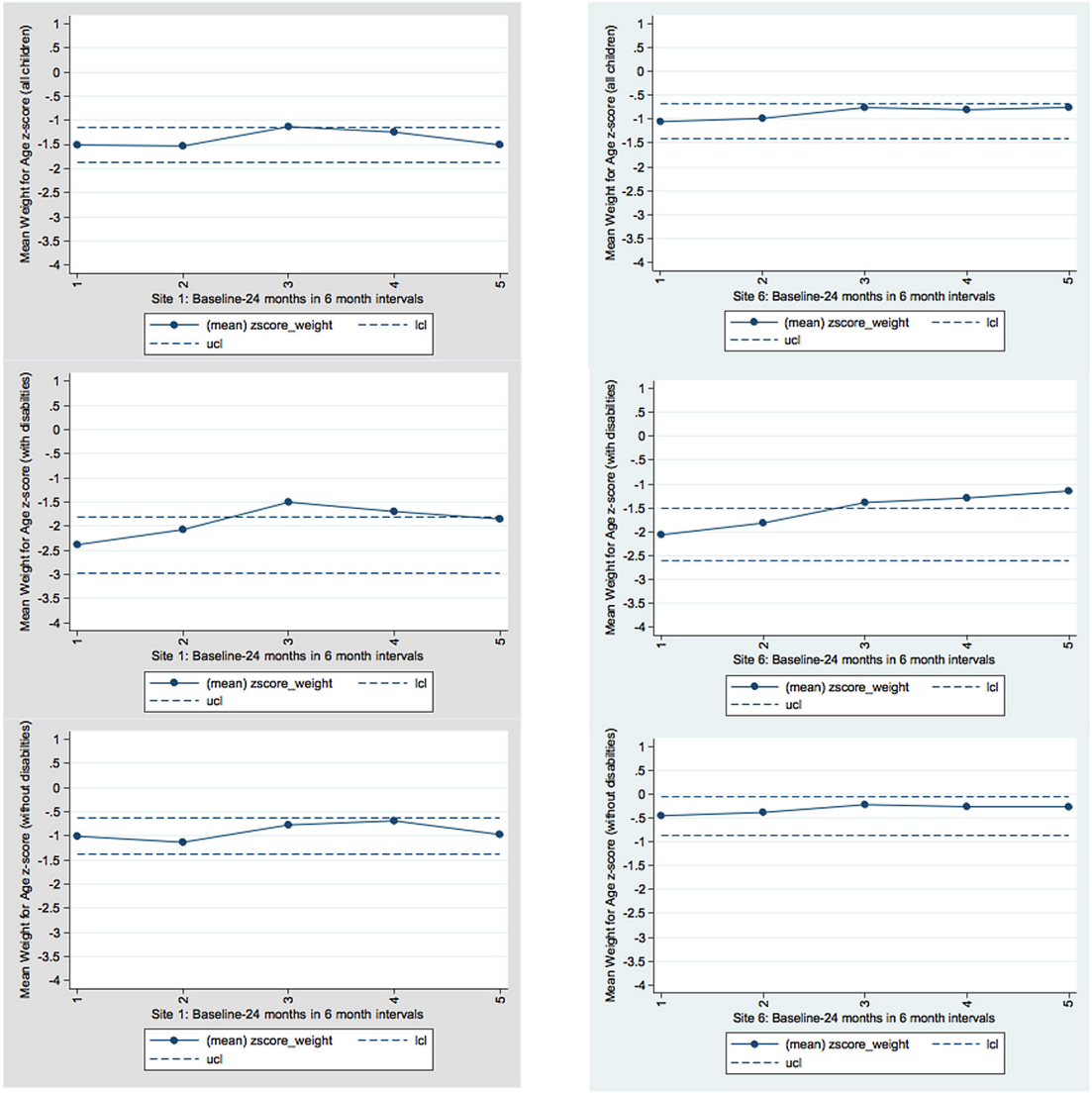

Figure 3 Individual site control charts showing the mean WAZ for children 0–10 years of age over time from baseline screening to 24-month screening. The top row includes all children; the middle row includes only those children with disabilities and bottom row includes only those children without disabilities. Upper control limits (UCL) and lower control limits (LCL) are indicated by the dashed lines; WAZ, weight-for-age z-score.

DISCUSSION

Our study presents comprehensive data on the nutritional status of children living within IBC and uses funnel plots and control charts to visualise intersite variations and progress over time in individual centres. Overall, children were at high risk of malnutrition, especially for those with disabilities.

Date of birth, birth weight, prematurity, age and length of stay

There is a paucity of information on children's birth history and this requires healthcare professionals or site staff to estimate date of birth which can lead to inaccuracies for other indicators (eg, WAZ). Such data gaps can occur when children are abandoned without connections to birth family, when records are not forwarded from hospitals or other healthcare facilities or when unavailable.[12] Aiming to receive available information is important and might be helped by improving transfer processes and by decreasing stigma for families placing children. Medical history matters because being born LBW or prematurely can increase children's risk of mortality, being stunted, wasted or developmentally delayed.[4] For those with records available, we found a notably high prevalence of LBW, 514 (57.5%) compared with the global prevalence of 14.6% and premature, 294 (42.2%) vs the global prevalence of prematurity 10.6% (table 1).[26 27] The high proportion of young children and the median age of admission means that a large proportion of children are entering IBC early in life, within the developmentally sensitive 'first 1000 days' of life.[4] The median length of stay indicates that children stay in care for around 2 years although some had lived within IBC for more than 13 years. This could indicate faster placement into families for young children or the challenge of finding homes for older children or those with the severest disabilities. This

is important because the longer children stay within IBC, the more at risk they are for delayed development and malnutrition.[12 17]

Disability status

Over a quarter of this population had one or more disabilities (table 1). This is markedly higher than the global prevalence of 5.1% of children younger than 15 years of age and for those older than 15 years of age (14.9%).[28] Children with disabilities were significantly smaller than their peers without disability over multiple anthropometric indices and this continued over 2 years (table 2 and online supplemental annex table 1). Nutritional status of children with disabilities seems to improve for younger children over time but older children do not appear to improve, and in some cases worsen. It could be that children with more severe disabilities stay in IBC longer because of their high needs.

Anaemia

Almost a quarter of all children entered into the programme with anaemia, which was below the anaemia prevalence in low-income and middle income countries (LMICs) of 42.9% for children younger than 5 years old (table 2 and online supplemental annex table 1).[5] Anaemia can impact brain development, cognition and growth.[4] Children 0–6 months had the highest prevalence of anaemia, which is expected with the high prevalence of LBW and premature births in the population. Throughout the 2-year period, the prevalence of anaemia reduced and moderate and severe anaemia eliminated for some age groups. This could be a reflection of access to health services or routine meals that children can experience in IBC, which may not be accessible to all community families.[15 29]

Anthropometry

Being underweight, wasted, stunted or thin can increase children's risk of infectious diseases, delayed development, mortality and non-communicable diseases.[4] This can be especially serious for children with disabilities.[4 10] We found for most anthropometric measurements, the total population of children have mean z-scores below the WHO mean for age (table 2, online supplemental annex table 1).[22] Compared with the prevalence in LMIC there was a higher prevalence of malnutrition indicators, such as stunting, wasting and thin/underweight, with the one exception being overweight/obese children which was below global figures.[5] Children with disabilities had more severe anthropometric deficits than their peers without disabilities and their prevalence of malnutrition overall was higher. The high prevalence of stunting for young children is especially concerning. For those younger than 5 years of age, 725 (43%) and specifically those with a disability, 260 (61.5%) were stunted. Catch-up from early-life stunting can be limited, especially for those outside of the developmentally sensitive 'first 1000 days'.[4] Although children with some disabling conditions may be smaller or slighter than their peers without disabilities, stunting relevant to the normal growth potential of adequately nourished children with the same disabling conditions should not be overlooked.[30] Wasting among children with disabilities was also higher than their peers without disabilities (without disability: 100 (8%) vs children with disabilities: 112 (26.7%) vs 2020 prevalence in LMIC: 6.8%).[5] This could be related to a number of issues including difficulties swallowing/dysphagia, inadequate or poor nutrition, poor feeding practices, biological needs or caregiver practices or beliefs.[10 30] Children with disabilities who are wasted are at high risk of mortality and require specific care and inclusion in malnutrition treatment programmes.[31] It is also notable that nearly a third of children younger than 5 years and over half of those with disabilities had a small head circumference, which although associated with preterm birth or some disabilities, could be an indicator of impacted brain development.

Utility of control charts and funnel plots

Funnel plots capture all of the sites at a specific time point, allowing easy visualisation of a particular indicator (eg, prevalence of underweight children) and comparing sites with each other to highlight those inside versus outside of control limits. In the control charts, we see individual sites trends over time in comparison to the site's limits. Using these charts is an easy way of distinguishing normal inter-site variations from statistically significant variations which warrant site visits and in-depth consultations to explore possible reasons and potential extra need for support.

Together these charts could help healthcare providers better track and monitor the nutritional needs of their individual sites with tools that provide expected limits and take into account the existence of natural variation. These charts will be added to Holt International's nutrition screening database to allow programme staff to evaluate the impact of programmes in a way that is easily understandable, interpretable and provides up-to-date information. These automated charts in tandem with tools and training provided by Holt's Child Nutrition Programme, will support sites to appropriately conduct targeted nutrition interventions when needed.

Limitations

There were several limitations in our study. First, though our sample was large both in terms of individual children and different centres across several countries, those may not be representative of all similar institutions within all of the countries. As a large global non-governmental organisation, Holt International offers support and resources that many locally-funded centres may not have and the nutritional status of the wider group of children in IBC is likely to be worse than our data suggest. The uniqueness of the children who come into IBC and the environments in IBC are also likely not reflective of wider local community populations. This is concerning since children arrive

malnourished and high quality (and costly) nutrition and care is needed to optimise their chances of catch-up growth.

Other limitations included unknown prior history, stage of entry into care and length of stay in the programme—all of which could impact growth. For some, their first screening was their first day into IBC but for others, it occurred multiple years into living in IBC. Changes over time may be more impactful for different children depending on how long they are in IBC prior to their first screening. Potential biases include measurement error which could have occurred during anthropometric assessment as measurements can be especially difficult for children with disabilities.[30] Disabilities also, though diagnosed by qualified health professionals in all countries were not assessed by a standardised method, such as the 'Washington Group' questionnaire, which would enable a more comparative analysis.[31 32] Future analysis should include additional categorisation of many other disabilities, including physical disabilities. Although grouping those with and without disabilities does help understand intercentre variations, this simple split does not address the individual needs of children. Children with some types of disabilities may be small or underweight for age based on clinical sequelae related to their specific disability. These disabilities may impede their ability to feed themselves, digest food or be associated with conditions that would reflect in lower height or weight. Another limitation was a decrease in sample sizes over time and some small site sample sizes. This decrease may introduce biases as some children exit the programme, such as those who are healthier being placed into family-based care at a higher rate and those needing more support staying in care longer.

CONCLUSION

Malnourished children in IBC are at risk of not fulfilling their growth potential and are thus more vulnerable to serious illness, becoming disabled or exacerbating existing disabilities. We found a high prevalence of children who are malnourished or at risk for malnutrition. Many were born LBW, prematurely or have an underlying disability. Those with disabilities were found to have a higher prevalence of malnutrition than children without disabilities. Control charts could be a valuable tool to track and monitor children's growth and inter-centre variations. Future research should aim to understand the reasons for intercentre variations in more detail and also formally explore the utility of control charts over more standard methods of presenting key data. The nutritional needs of close to 10 million children in IBC around the world are likely high and worthy of greater global attention. Children have a basic human right to grow and fully develop regardless of where they received care early in their lives.

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Contributors ED, MK, EA and CJT designed the study. ED, MK, EH, MQ, CJT, NEG, EA, MD-A, HTD, JV and EB contributed to specific areas of the methods, data analysis, statistics and quality control. ED, MK, MQ and EH had access and verified the data. ED led the data analysis and writing of the first draft of the manuscript. ED, MK, EH, MQ, CJT, EA, NEG, MD-A, HTD, JV and EB contributed to the writing of the manuscript and agree with the manuscript's results and conclusions. All of the authors read and approve of the submitted manuscript. ED is the guarantor of this study.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Ethical approval was obtained from the London School of Hygiene and Tropical Medicine's Ethics Committee (ref: 17808).

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Data availability statement Data may be obtained from a third party and are not publicly available. Data may be obtained from a third party and are not publicly available. Relevant research and data information has been stored in the London School of Hygiene and Tropical Medicine's Data Compass. DeLacey, E (2020). Data for: 'The nutritional status of children living within institutionalised care: a retrospective analysis with control charts for program monitoring'. (Data Collection). London School of Hygiene and Tropical Medicine, London, UK. https://doi.org/10.17037/DATA.00001994. Requests for access to this data need to be directed to Holt International. The data will be shared only on a contingent approval basis with interested parties. Additional related study protocols can be requested. Approval of a proposal, a data management protocol and a signed data access agreement will be required. To be addressed by: Holt International, info@holtinternational.org; 250 Country Club Road, Eugene, OR 97401; tel: 541.687.2202

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Supplement 1:

STROBE Checklist

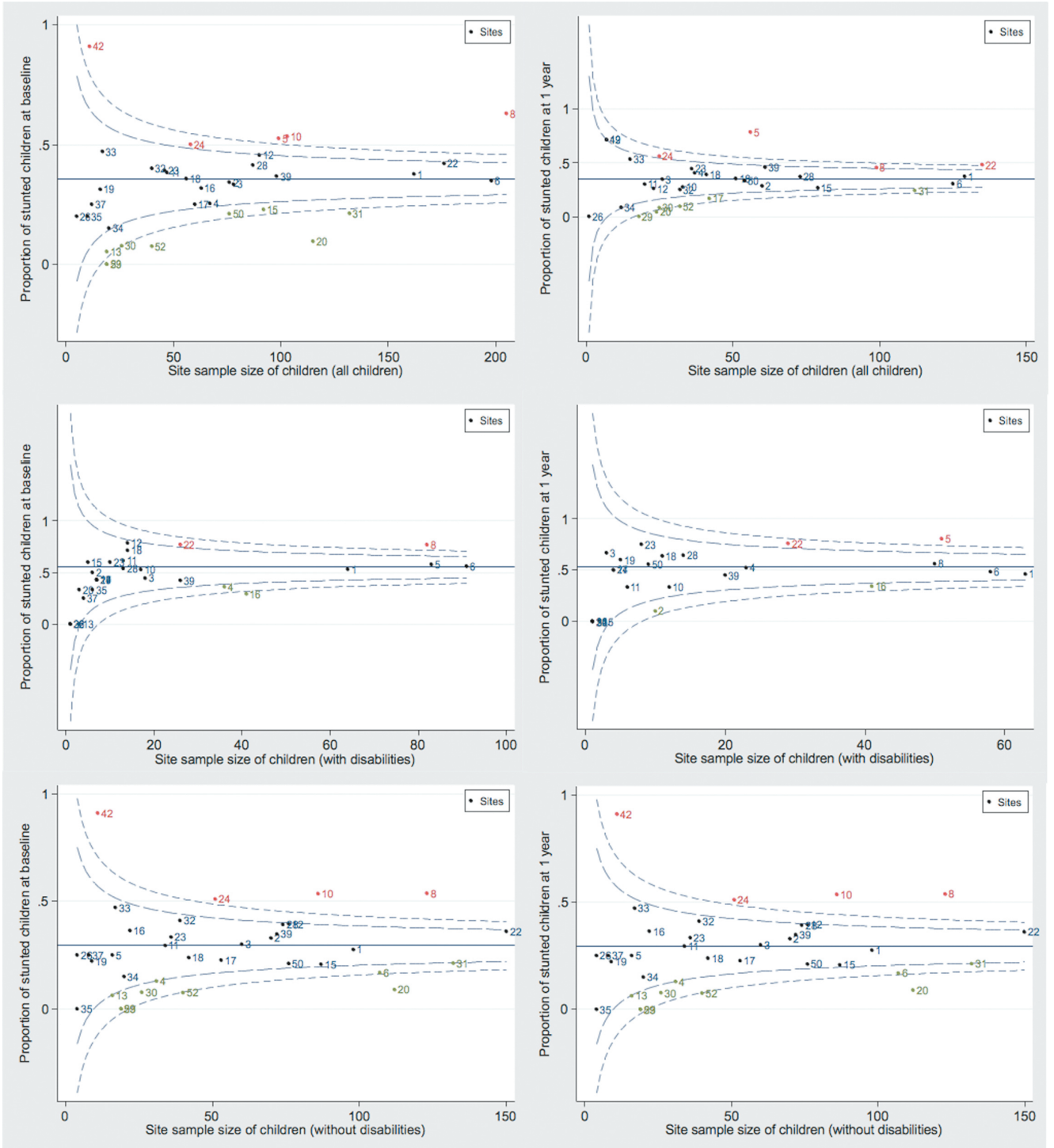
STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page located
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6

		(*b*) Describe any methods used to examine subgroups and interactions	5-6
		(*c*) Explain how missing data were addressed	5, 11
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	5-6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed	7, Figure 1
		(b) Give reasons for non-participation at each stage	7, Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-16, Table 1 & 2, Annex Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Tables 1 & 2
		(c) Summarize follow-up time (e.g., average and total amount)	Figures 2, 3 and Annex Figures 1-9
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-16, Tables 1, 2 and Figures 2,3 and Annex Table 1, Annex Figures 1-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6, Tables 1, 2 and Figures 2,3 and Annex Figures 1-9
		(*b*) Report category boundaries when continuous variables were categorized	Tables 1, 2 and Figures 2,3 and Annex Table 1, Annex Figures 1-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses	Tables 1, 2 and Figures 2,3 and Annex Table 1, Annex Figures 1-9
Discussion			

Key results	18	Summarize key results with reference to study objectives	17-19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17-19
Generalizability	21	Discuss the generalizability (external validity) of the study results	17-19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2, 20

*Give information separately for exposed and unexposed groups.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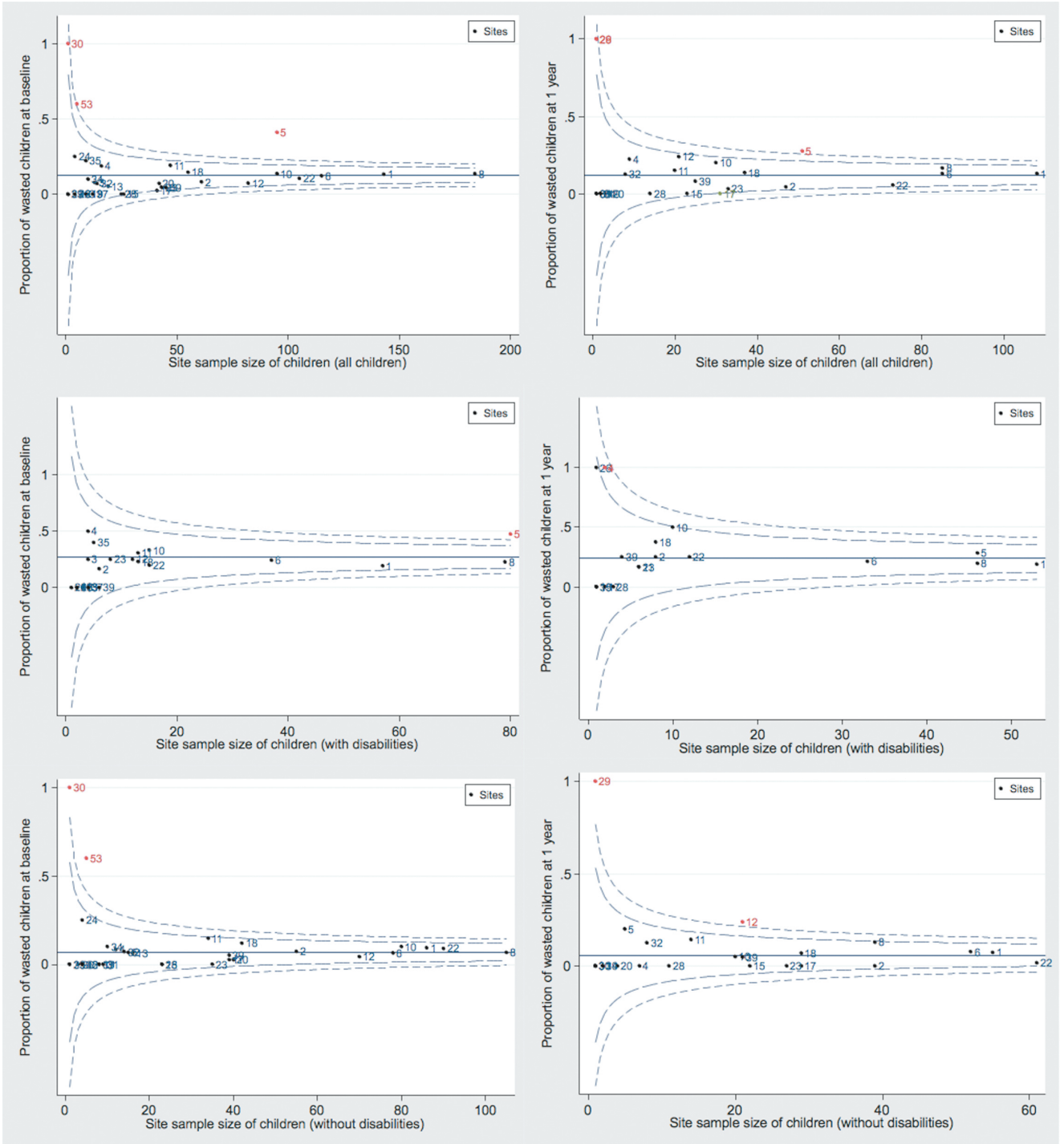
Site sample size of children (all children)
Proportion of stunted children at baseline
Site sample size of children (with disabilities)
Proportion of stunted children at 1 year
Site sample size of children (with disabilities)
Proportion of stunted children at baseline
Site sample size of children (without disabilities)
Proportion of stunted children at 1 year
Site sample size of children (without disabilities)
Sites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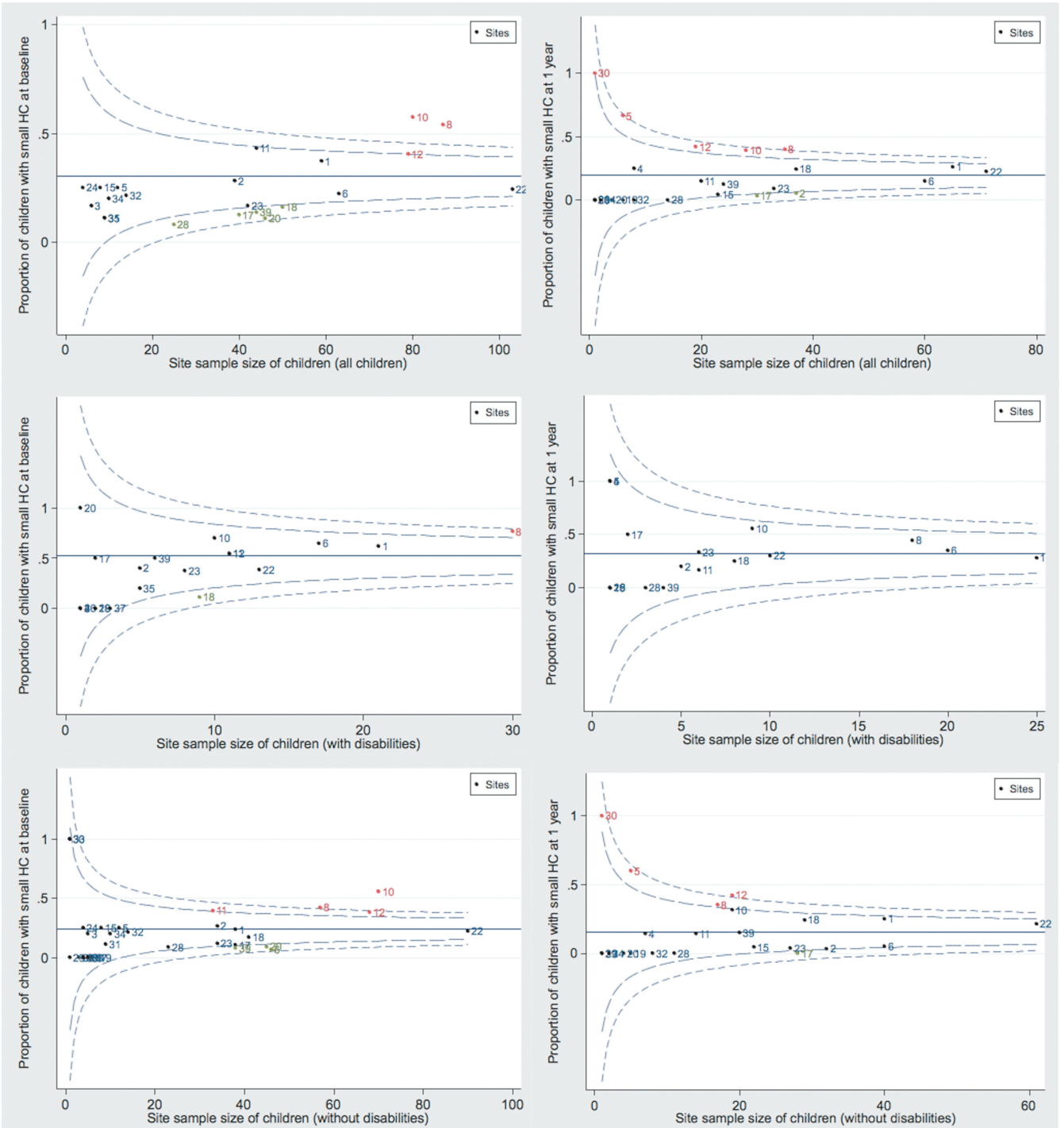
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Proportion of children with small HC at baseline
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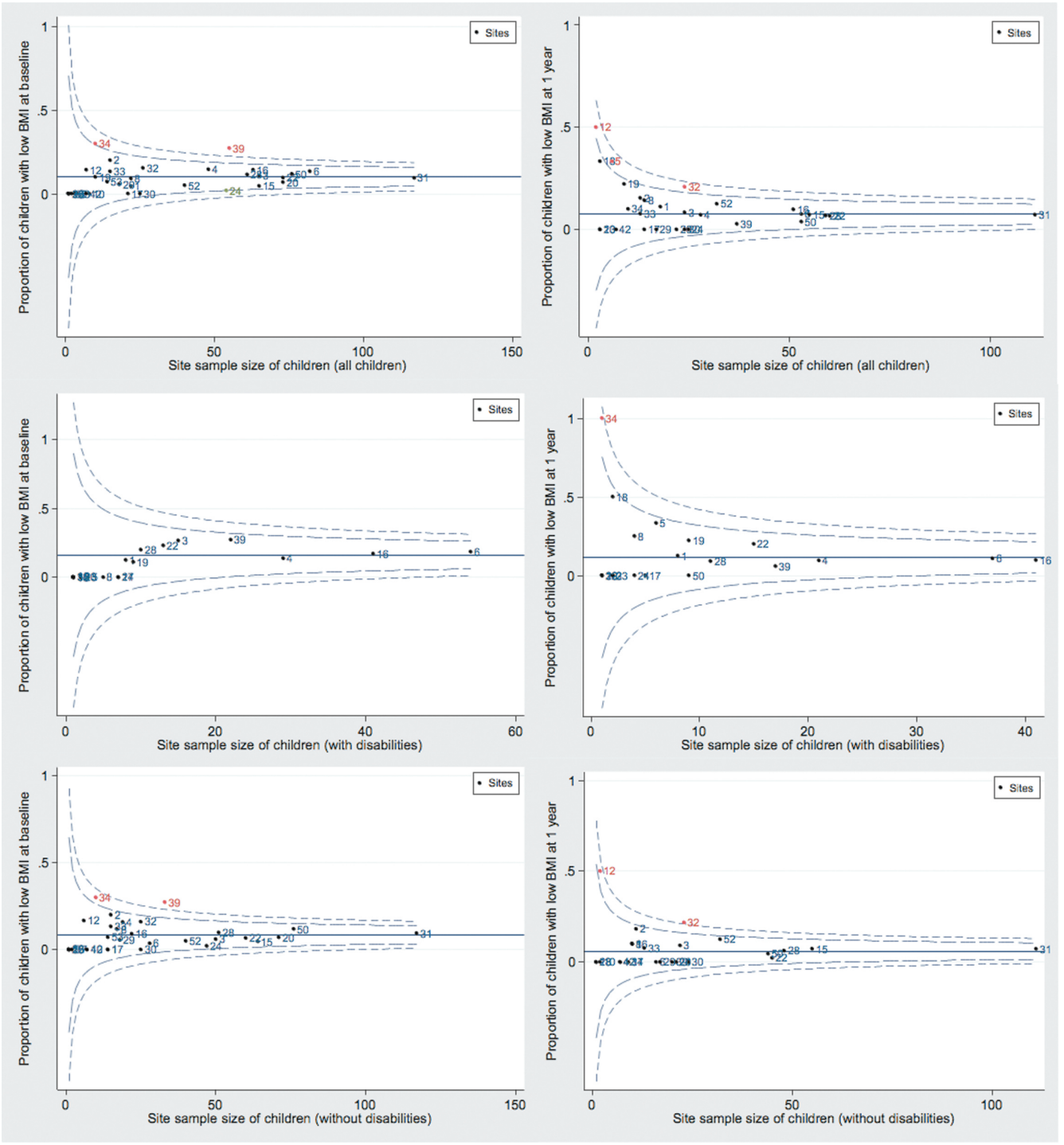
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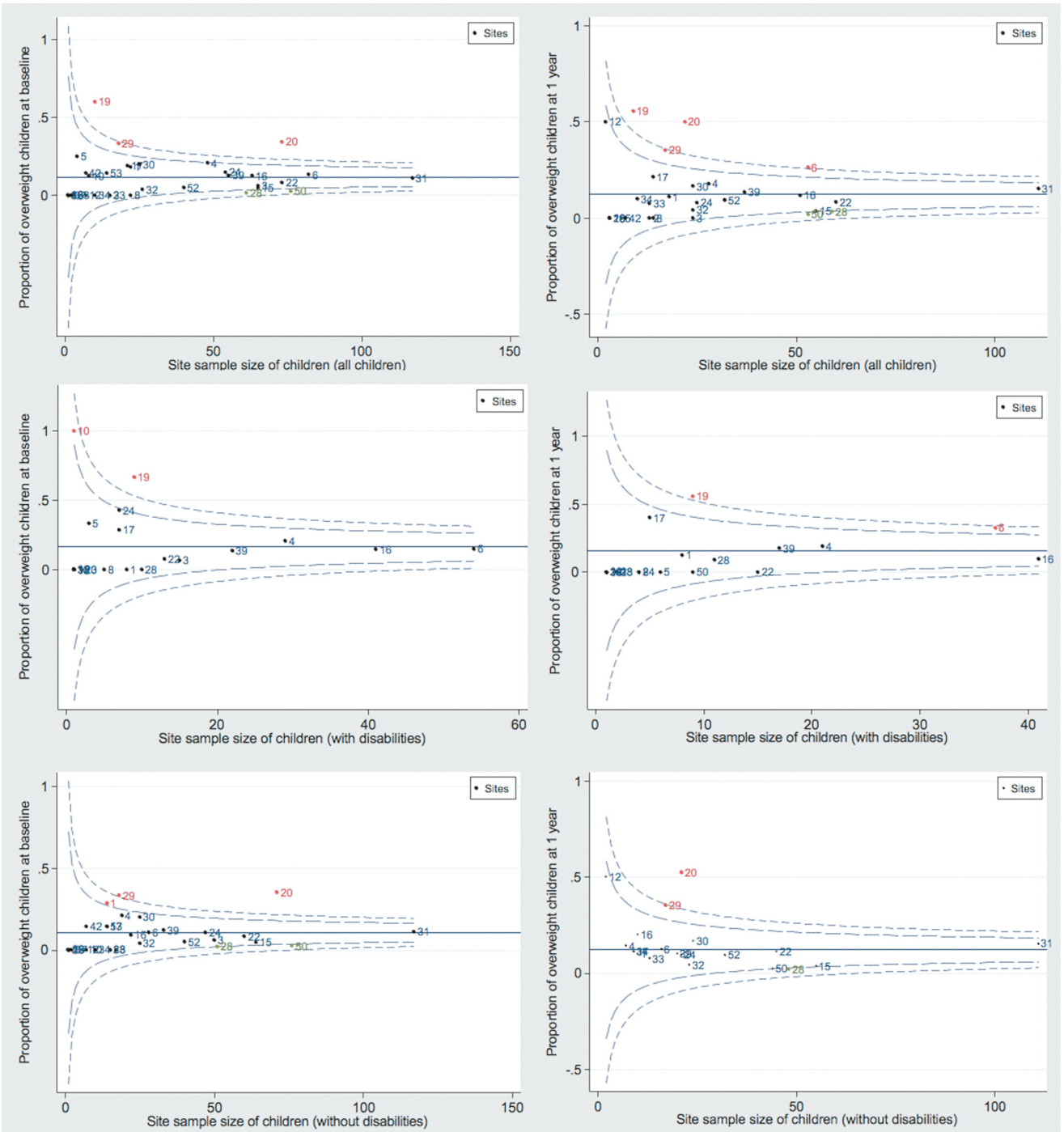
Site sample size of children (without disabilities)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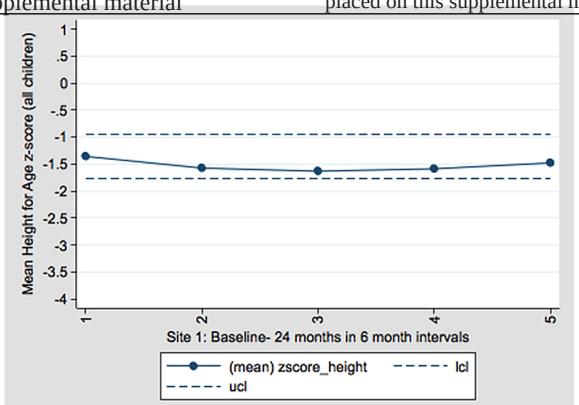
Site sample size of children (with disabilities)
Site sample size of children (without disabilities)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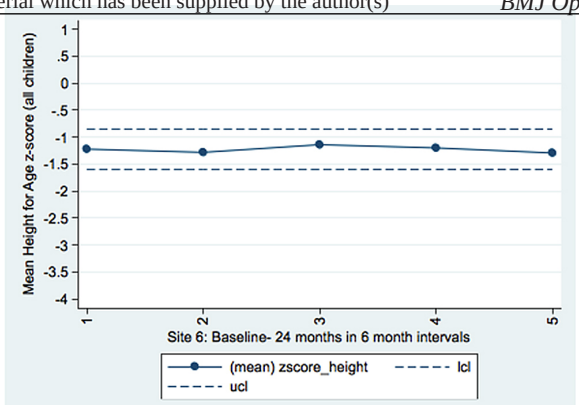
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Site 6: Baseline- 24 months in 6 month intervals
(mean) zscore_height
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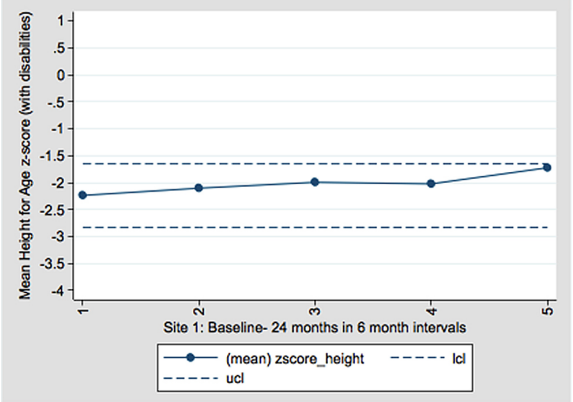
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Site 1: Baseline- 24 months in 6 month intervals
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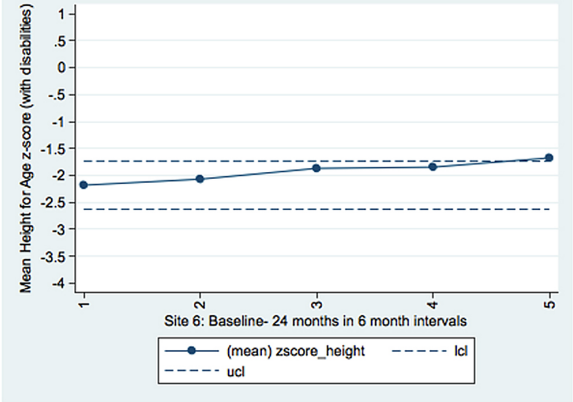
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Site 6: Baseline- 24 months in 6 month intervals
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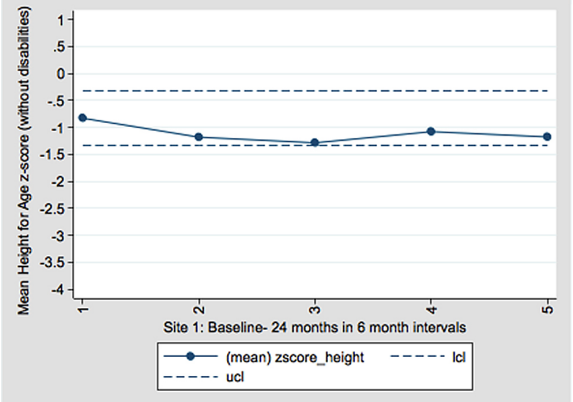
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Site 1: Baseline- 24 months in 6 month intervals
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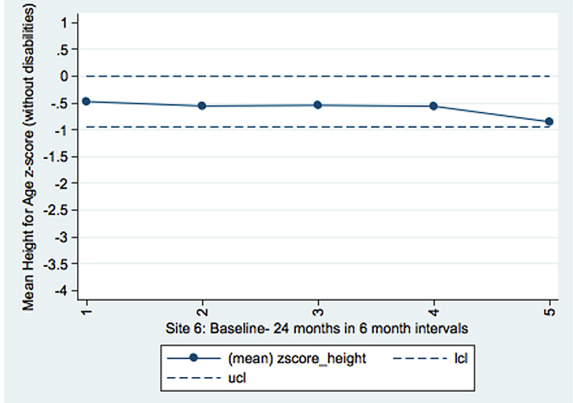
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Site 6: Baseline- 24 months in 6 month intervals
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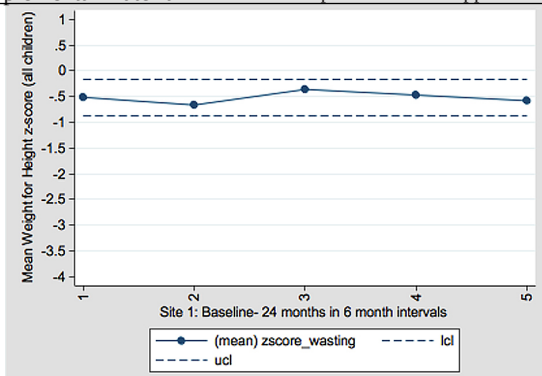
Mean Weight for Height z-score (all children)
Site 1: Baseline- 24 months in 6 month intervals
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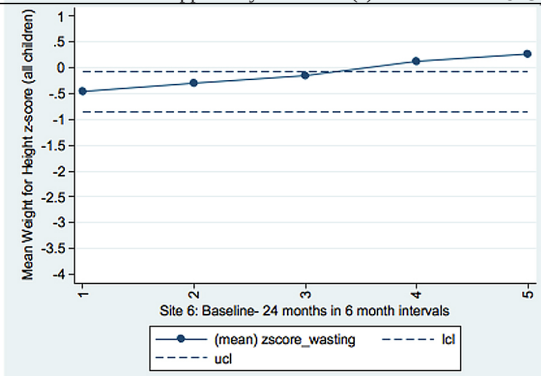
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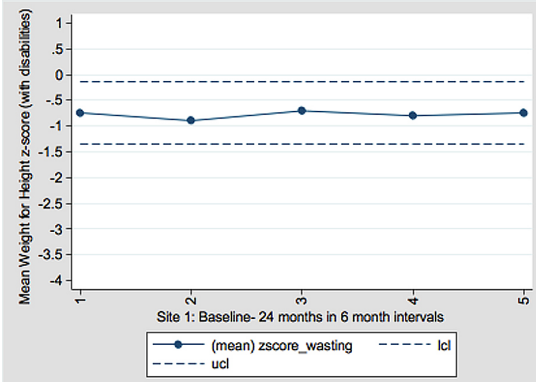
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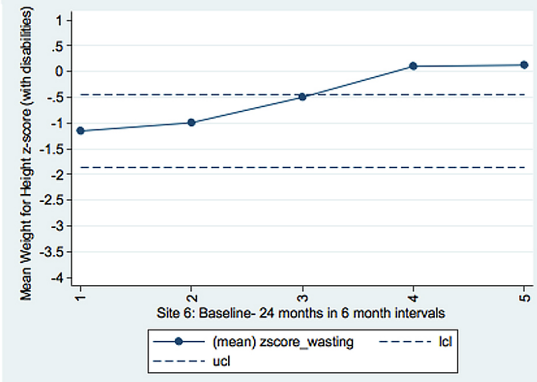
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Site 6: Baseline- 24 months in 6 month intervals
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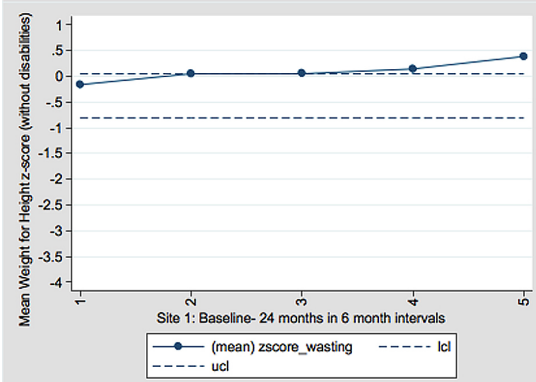
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Site 1: Baseline- 24 months in 6 month intervals
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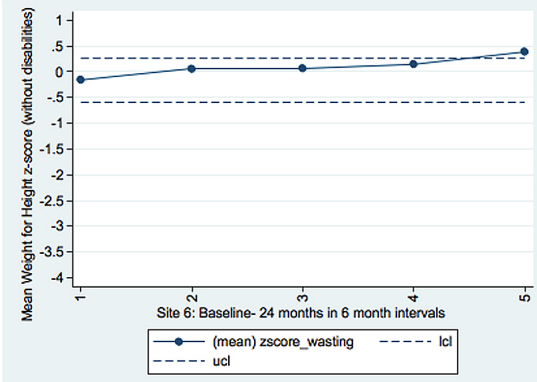
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Site 6: Baseline- 24 months in 6 month intervals
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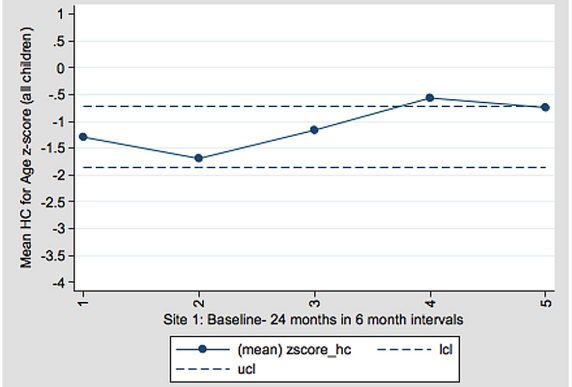
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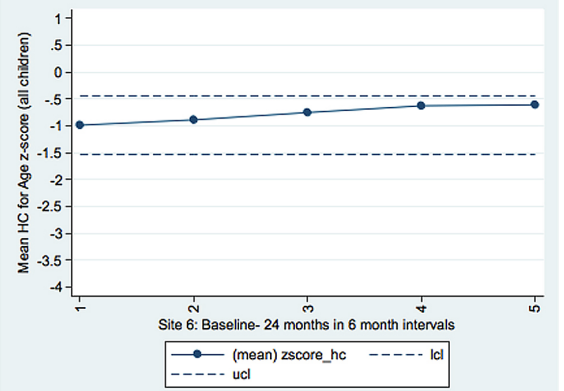
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Site 6: Baseline- 24 months in 6 month intervals
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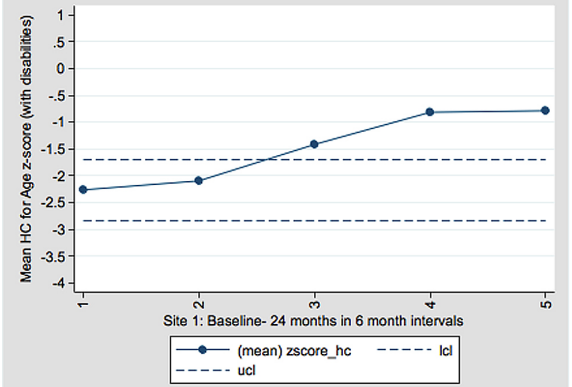
Mean HC for Age z-score (with disabilities)
Site 1: Baseline- 24 months in 6 month intervals
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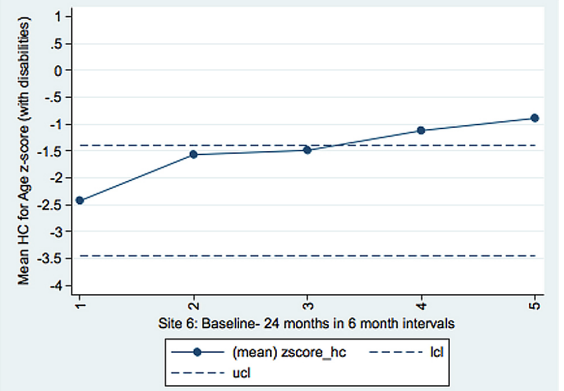
Mean HC for Age z-score (with disabilities)
Site 6: Baseline- 24 months in 6 month intervals
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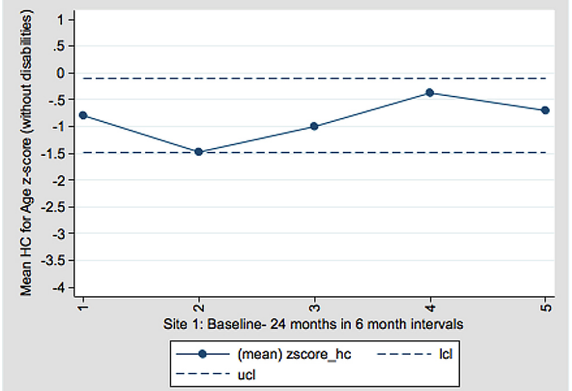
Mean HC for Age z-score (without disabilities)
Site 1: Baseline- 24 months in 6 month intervals
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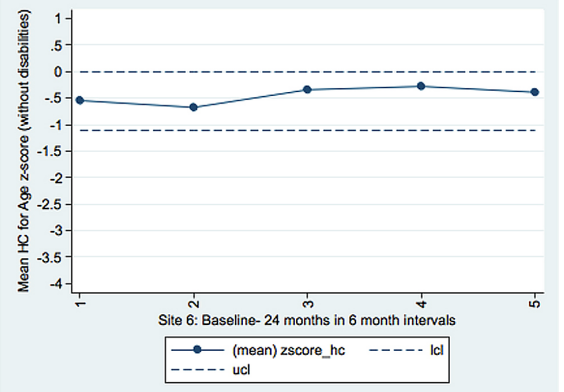
Mean HC for Age z-score (without disabilities)
Site 6: Baseline- 24 months in 6 month intervals
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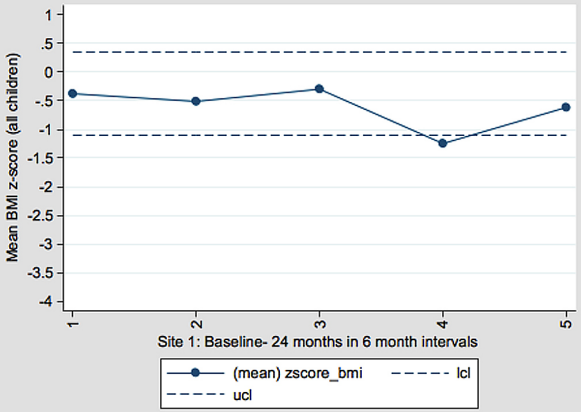
Mean BMI z-score (all children)
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Site 1: Baseline- 24 months in 6 month intervals
(mean) zscore_bmi
lcl
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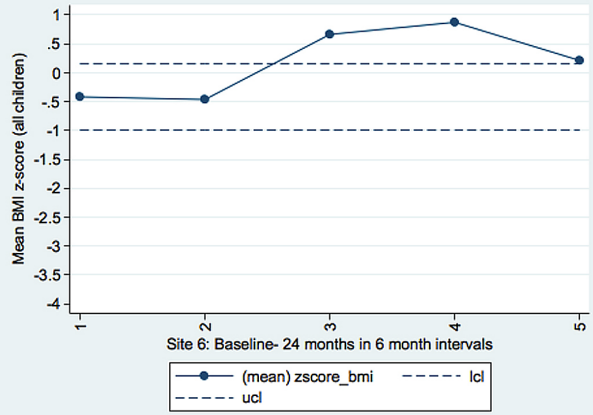
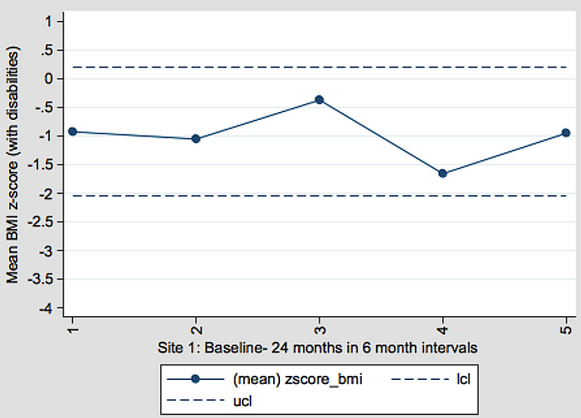
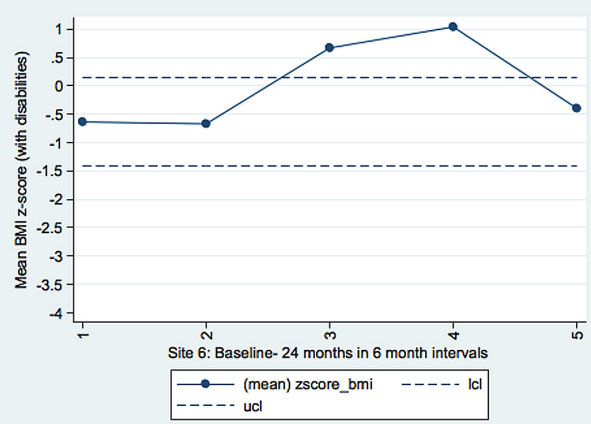
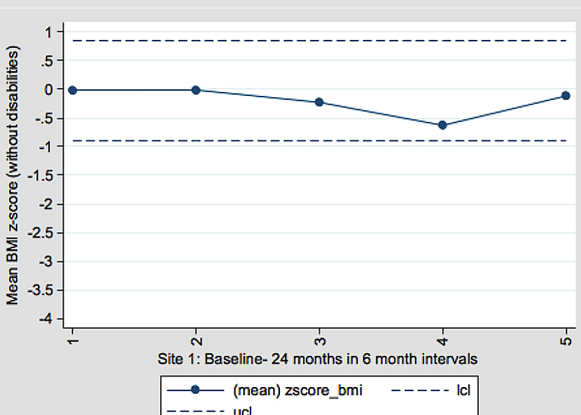
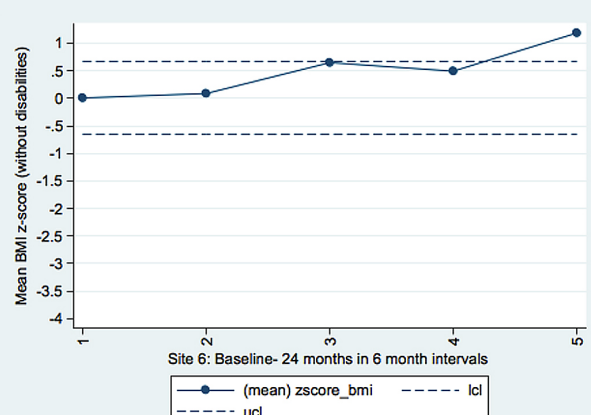

Mean BMI z-score (all children)
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
3
4
5
Site 6: Baseline- 24 months in 6 month intervals
(mean) zscore_bmi
lcl
ucl


Mean BMI z-score (with disabilities)
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
3
4
5
Site 1: Baseline- 24 months in 6 month intervals
(mean) zscore_bmi
lcl
ucl


Mean BMI z-score (with disabilities)
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
3
4
5
Site 6: Baseline- 24 months in 6 month intervals
(mean) zscore_bmi
lcl
ucl


Mean BMI z-score (without disabilities)
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
3
4
5
Site 1: Baseline- 24 months in 6 month intervals
(mean) zscore_bmi
lcl
ucl


Mean BMI z-score (without disabilities)
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
3
4
5
Site 6: Baseline- 24 months in 6 month intervals
(mean) zscore_bmi
lcl
ucl

Annex Table 1: Total population mean anthropometric z-scores and anemia prevalence at baseline, 6 months, 12 months, 18 months and 24 months by age category and disability status.

All countries (Mean z-score, (± SD))																					
	Baseline Screening					6 month screening					12 month screening				18 month screening			24 month screening		
Age at screening	**0-≤6 months**	**>6-≤12 months**	**>12-≤24 months**	**>24-≤59 months**	**>5-≤18 years**	**0-≤6 months**	**>6-≤12 months**	**>12-≤24 months**	**>24-≤59 months**	**>5-≤18yrs**	**>6-≤12 months**	**>12-≤24 months**	**>24-≤59 months**	**>5-≤18 years**	**>12-≤24 months**	**>24-≤59 months**	**>5-≤18 years**	**>12-≤24 months**	**>24-≤59 months**	**>5-≤18 years**
Children without disabilities																				
N:	727	108	142	307	469	294	322	133	218	263	81	250	170	282	180	125	178	39	165	170
Weight for age z-score (0-10 years)	-1·48 ± 1·46	-1·04 ± 1·27	-0·69 ± 1·26	-1·09 ± 1·17	-0·99 ± 1·36	-1·48 ± 1·14	-1·13 ± 1·31	-0·76 ± 1·08	-1·12 ± 1·34	-1·07 ± 1·22	-0·77 ± 1·35	-0·79 ± 1·19	-1·02 ± 0·99	-0·97 ± 1·22	-0·67 ± 1·08	-0·96 1·05	-0·88 ± 1·25	-050 ± 0·98	-1·19 ± 1·40	-0·90 ± 1·34
N:	713	105	142	303	895	294	320	133	218	447	80	249	170	599	181	125	373	39	164	300
Height for age z-score (0-18 years)	-1·54 ± 1·73	-1·04 ± 1·62	-1·38 ± 1·46	-1·60 ± 1·29	-1·23 ± 1·24	-1·58 ± 1·48	-1·13 ± 1·46	-1·45 ± 1·34	-1·66 ± 1·19	-1·31 ± 1·25	-0·84 ± 1·41	-1·41 ± 1·36	-1·51 ± 1·11	-1·24 ± 1·21	-1·15 ± 1·42	- 1·51 ± 1·16	-1·06 ± 1·19	-1·10 ± 1·00	-1·57 ± 1·25	-1·05 ± 1·22
N:	707	105	142	303	286	295	321	133	218	170	80	249	170	168	180	124	98	39	165	79
Weight for height z-score (0-5 years)	-0·20 ± 1·51	-0·48 ± 1·34	-0·03 ± 1·24	-0·25 ± 1·19	-0·47 ± 1·23	-0·19 ± 1·58	-0·54 ± 1·23	-0·78 ± 1·08	-0·26 ± 1·09	-0·45 ± 1·14	-0·36 ± 1·26	-0·13 ± 1·21	-0·24 ± 0·99	-0·41 ±1·10	-0·10 ± 1·21	-0·12 ± 1·00	-0·40 ± 1·20	0·05 ± 1·07	-0·54 ± 1·34	-0·39 ± 1·16
N:	643	102	137	287	888	248	288	128	209	447	69	225	159	599	164	121	375	37	161	304
BMI z-score (0-18 years)	-0·84 ± 1·39	-0·56 ± 1·38	0·21 ± 1·25	-0·05 ± 1·22	-0·41 ± 1·23	-0·70 ± 1·33	-0·58 ± 1·26	0·17 ± 1·13	-0·06 ± 1·10	-0·38 ± 1·16	-0·23 ± 1·20	0·14 ± 1·21	-0·09 ± 1·01	-0·28 ± 1·14	0·16 ± 1·21	0·03 ± 1·03	-0·46 ± 1·157	0·23 ± 1·10	-0·35 ± 1·27	-0·43 ±1·24
N:	N/A	60	88	223	N/A	N/A	196	87	155	N/A	53	160	119	N/A	113	93	N/A	21	83	N/A
Mid upper arm circumference for age z-score (6 months- 5 years)	N/A	-0·20 ± 1·19	-0·16 ± 1·21	-0·37 ± 1·14	N/A	N/A	-0·61 ± 1·05	0·11 ± 1·07	-0·29 ± 1·06	N/A	-0·41 ± 0·97	-0·04 ± 1·11	-0·29 ± 1·06	N/A	0·06 ± 0·98	-0·14 ± 1·08	N/A	0·19 ± 0·85	-0·10 ± 1·04	N/A
N:	483	77	111	247	N/A	206	264	115	190	N/A	67	217	148	N/A	157	102	N/A	N/A	143	N/A
Head circumference for age z-score (0-5 years)	-1·41 ± 1·41	-0·75 ± 1·33	-0·65 ± 1·12	-0·92 ± 1·23	N/A	-1·74 ± 1·24	-1·30 ± 1·26	-0·48 ± 1·27	-0·72 ± 1·09	N/A	-1·31 ± 1·19	-0·71 ± 1·21	-0·71 ± 1·09	N/A	-0·53 ± 1·19	-0·69 ± 1·25	N/A	-0·69 ± 1·29	-0·69 ± 1·32	N/A
Anemia (N)	467	89	125	281	897	201	153	77	200	376	37	113	154	580	86	103	312	18	112	306
Normal Absolute (%)	264 (56·5)	59 (66·3)	90 (72)	219 (77·9)	709 (79)	155 (77·1)	124 (81·1)	61 (79·2)	164 (82·0)	280 (74·5)	32 (86·5)	96 (85·0)	133 (86·4)	502 (86·6)	76 (88·4)	90 (87·4)	274 (87·8)	13 (72·2)	101 (90·2)	273 (89·2)
Mild Absolute (%)	125 (26·8)	23 (25·8)	26 (20·8)	50 (17·8)	97 (10·8)	32 (15·9)	26 (17·0)	12 (15·6)	30 (15·0)	65 (17·3)	4 (10·8)	11 (9·7)	19 (12·3)	57 (9·8)	8 (9·3)	12 (11·7)	27 (8·7)	4 (22·2)	11 (9·8)	24 (7·8)
Moderate Absolute (%)	78 (16·7)	7 (7·9)	9 (7·2)	11 (3·9)	87 (9·7)	14 (7·0)	3 (2·0)	4 (5·2)	6 (3·0)	31 (8·2)	1 (2·7)	6 (5·3)	2 (1·3)	21 (3·62)	2 (2·3)	1 (1·0)	11 (3·5)	1 (5·6)	0	9 (2·9)
Severe Absolute (%)	0	0	0	1 (0·4)	4 (0·5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Children with disabilities																				
N:	199	43	55	132	138	50	152	59	112	106	25	135	100	110	102	74	104	17	85	82
Weight for age z-score (0-10 years)	-2·82 ± 1·57	-2·45 ± 1·66	-2·03 ± 1·44	-2·26 ± 1·57	-1·96 ± 1·57	-2·60 ± 1·27	-2·07 ± 1·58	-2·25 ± 1·30	-2·45 ± 1·56	-1·96 ± 1·57	-2·00 ± 1·22	-1·52 ± 1·60	-2·48 ± 1·45	-1·79 ± 1·50	-1·42 ± 1·51	-2·61 1·58	-2·18 ± 1·54	-0·55 ± 1·79	-1·79 ± 1·81	2·02 ± 1·44
N:	192	45	54	132	231	47	152	58	112	172	26	136	99	186	104	75	151	17	82	135
Height for age z-score (0-18 years)	-2·68 ± 1·73	-2·34 ± 1·85	-2·18 ± 1·31	-2·43 ± 1· 62	-1·98 ± 1·47	-3·00 ± 1·35	-1·87 ± 1·57	-2·72 ± 1·18	-2·60 ± 1·41	-2·13 ± 1·47	-2·38 ± 1·51	-1·84 ± 1·66	-2·73 ± 1·48	-2·07 ± 1·38	-1·86 ± 1·64	-3·03 ± 1·39	-2·16 ± 1·41	-1·14 ± 1·88	-2·15 ± 1·57	-2·02 ± 1·53
N:	189	46	55	130	114	49	152	59	112	94	26	137	98	82	105	71	82	17	79	64
Weight for height z-score (0-5 years)	-0·66 ± 1·61	-1·35 ± 1·72	-1·32 ± 1·33	-1·26 ± 1·58	-0·79 ± 1·63	0·03 ± 1·75	-1·06 ± 1·33	-1·17 ± 1·38	-1·43 ± 1·51	-0·91 ± 1·61	-1·06 ± 1·28	-0·87 ± 1·47	-1·21 ± 1·36	-0·78 ± 1·58	-0·80 ± 1·46	-1·41 ± 1·50	-1·05 ± 1·59	0·51 ± 1·65	-0·86 ± 1·57	-0·84 ± 1·71
N:	210	46	55	129	235	50	142	57	111	177	21	131	96	202	98	67	161	14	77	134
BMI z-score (0-18 years)	-1·79 ± 1·51	-1·63 ± 1·74	-1·04 ± 1·34	-0·92 ± 1·62	-0·56 ± 1·69	-0·94 ± 1·69	-1·23 ± 1·32	-0·82 ± 1·46	-1·10 ± 1·50	-0·67 ± 1·75	-0·67 ± 1·00	-0·60 ± 1·44	-0·95 ± 1·44	0·16 ± 1·85	-0·45 ± 1·44	-1·05 ± 1·51	-0·45 ± 1·91	0·33 ± 1·56	-0·59 ± 1·57	-0·52 ± 1·48
N:	N/A	9	11	34	N/A	N/A	52	11	22	N/A	14	58	28	N/A	54	18	N/A	9	47	N/A
Mid upper arm circumference for age z-score (6 months- 5 years)	N/A	-0·35 ± 1·58	-0·70 ± 1·74	-0·73 ± 1·18	N/A	N/A	-0·93 ± 1·17	-0·59 ± 1·48	-1·10 ± 1·07	N/A	-1·04 ± 0·90	-0·46 ± 1·23	-0·77 ± 1·19	N/A	- 0·53 ± 1·37	-0·80 ± 1·40	N/A	-0·11 ± 1·31	-0·68 ± 1·35	N/A
N:	102	18	13	44	N/A	24	85	16	28	N/A	17	81	33	N/A	75	17	N/A	13	64	N/A
Head circumference for age z-score (0-5 years)	-2·36 ± 1·22	-2·09 ± 1·24	-0·82 ± 1·22	-1·18 ± 1·43	N/A	-2·58 ± 0·77	-1·86 ± 1·16	-1·50 ± 1·19	-1·70 ± 1·22	N/A	-1·89 ± 0·92	-1·39 ± 1·22	-1·41 ± 1·20	N/A	-1·18 ± 1·41	-1·42 ± 0·96	N/A	0·06 ± 1·47	-1·34 ± 1·39	N/A
Anemia (N)	156	39	53	132	255	38	94	50	110	180	14	77	95	222	48	75	172	8	57	152
Normal Absolute (%)	79 (50·6)	29 (74·4)	41 (77·4)	100 (75·8)	187 (73·3)	22 (57·9)	71 (75·5)	40 (80·0)	93 (84·6)	136 (75·6)	11 (78·6)	69 (89·6)	79 (83·2)	182 (82·0)	36 (75)	64 (85·3)	140 (81·4)	7 (87·5)	52 (91·2)	127 (83·6)
Mild Absolute (%)	34 (21·8)	6 (15·4)	8 (15·1)	22 (16·7)	22 (8·6)	11 (29·0)	16 (17·0)	4 (8·0)	9 (8·2)	18 (10·0)	2 (14·3)	6 (7·8)	9 (9·5)	18 (8·1)	5 (10·4)	8 (10·7)	16 (9·3)	1 (12·5)	3 (5·3)	12 (7·9)
Moderate Absolute (%)	40 (25·6)	3 (7·7)	4 (7·6)	7 (5·3)	41 (16·1)	5 (13·2)	7 (7·5)	6 (12·0)	6 (5·5)	25 (13·9)	1 (7·1)	2 (2·6)	6 (6·3)	21 (9·5)	7 (14·6)	1 (1·3)	16 (9·3)	0	2 (3·5)	11 (7·2)
Severe Absolute (%)	3 (1·9)	1 (2·6)	0	3 (2·3)	5 (2·0)	0	0	0	2 (1·8)	1 (0·6)	0	0	1 (1·1)	1 (0·5)	0	2 (2·7)	0	0	0	2 (1·3)