Article

Mapping child growth failure across low- and middle-income countries

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Local Burden of Disease Child Growth Failure Collaborators*

Childhood malnutrition is associated with high morbidity and mortality globally[1]. Undernourished children are more likely to experience cognitive, physical, and metabolic developmental impairments that can lead to later cardiovascular disease, reduced intellectual ability and school attainment, and reduced economic productivity in adulthood[2]. Child growth failure (CGF), expressed as stunting, wasting, and underweight in children under five years of age (0–59 months), is a specific subset of undernutrition characterized by insufficient height or weight against age-specific growth reference standards[3–5]. The prevalence of stunting, wasting, or underweight in children under five is the proportion of children with a height-for-age, weight-for-height, or weight-for-age *z*-score, respectively, that is more than two standard deviations below the World Health Organization's median growth reference standards for a healthy population[6]. Subnational estimates of CGF report substantial heterogeneity within countries, but are available primarily at the first administrative level (for example, states or provinces)[7]; the uneven geographical distribution of CGF has motivated further calls for assessments that can match the local scale of many public health programmes[8]. Building from our previous work mapping CGF in Africa[9], here we provide the first, to our knowledge, mapped high-spatial-resolution estimates of CGF indicators from 2000 to 2017 across 105 low- and middle-income countries (LMICs), where 99% of affected children live[1], aggregated to policy-relevant first and second (for example, districts or counties) administrative-level units and national levels. Despite remarkable declines over the study period, many LMICs remain far from the ambitious World Health Organization Global Nutrition Targets to reduce stunting by 40% and wasting to less than 5% by 2025. Large disparities in prevalence and progress exist across and within countries; our maps identify high-prevalence areas even within nations otherwise succeeding in reducing overall CGF prevalence. By highlighting where the highest-need populations reside, these geospatial estimates can support policy-makers in planning interventions that are adapted locally and in efficiently directing resources towards reducing CGF and its health implications.

Despite improvements in nearly all LMICs, stunting remained the most widespread and prevalent indicator of CGF throughout the study period. Overall, estimated childhood stunting prevalence across LMICs decreased from 36.9% (95% uncertainty interval, 32.8–41.4%) in 2000 to 26.6% (21.5–32.4%) in 2017. Progress was particularly noticeable in Central America and the Caribbean, Andean South America, North Africa, and East Asia regions, and in some coastal central and western sub-Saharan African (SSA) countries, where most areas with estimated stunting prevalence of at least 50% in 2000 had reduced to 30% or less by 2017 (Fig. 1a, b). By 2017, zones with the highest prevalence of stunting primarily persisted throughout much of the SSA, Central and South Asia, and Oceania regions, where large areas had estimated levels of at least 40%, such as in the first administrative-level units of Nigeria's Jigawa state (60.6% (51.5–69.7%)), Burundi's Karuzi province (60.0% (51.4–67.5%)), India's Uttar Pradesh state (49.0% (48.5–49.5%)), and Laos's Houaphan province (58.3% (50.7–66.8%)) (Extended Data Fig. 1). In 2017, Guatemala (47.0% (40.2–54.6%)), Niger (47.5% (42.2–53.9%)), Burundi (54.2% (46.3–61.2%)), Madagascar (49.8% (43.2–57.2%)), Timor-Leste (49.8% (43.4–56.2%)), and Yemen (45.4% (38.8–51.5%)) had the highest national-level stunting prevalence.

Even within the aforementioned regions where reductions were most evident, local-level estimates revealed communities in which levels still approached those seen in SSA and South Asia; areas in southern Mexico and central Ecuador had estimated stunting prevalence of at least 40%, and areas in western Mongolia reached at least 30%. Wide within-country disparities were apparent in several instances, indicating large areas left behind by the general pace of progress that require attention (Fig. 1a, b). Although most countries successfully reduced

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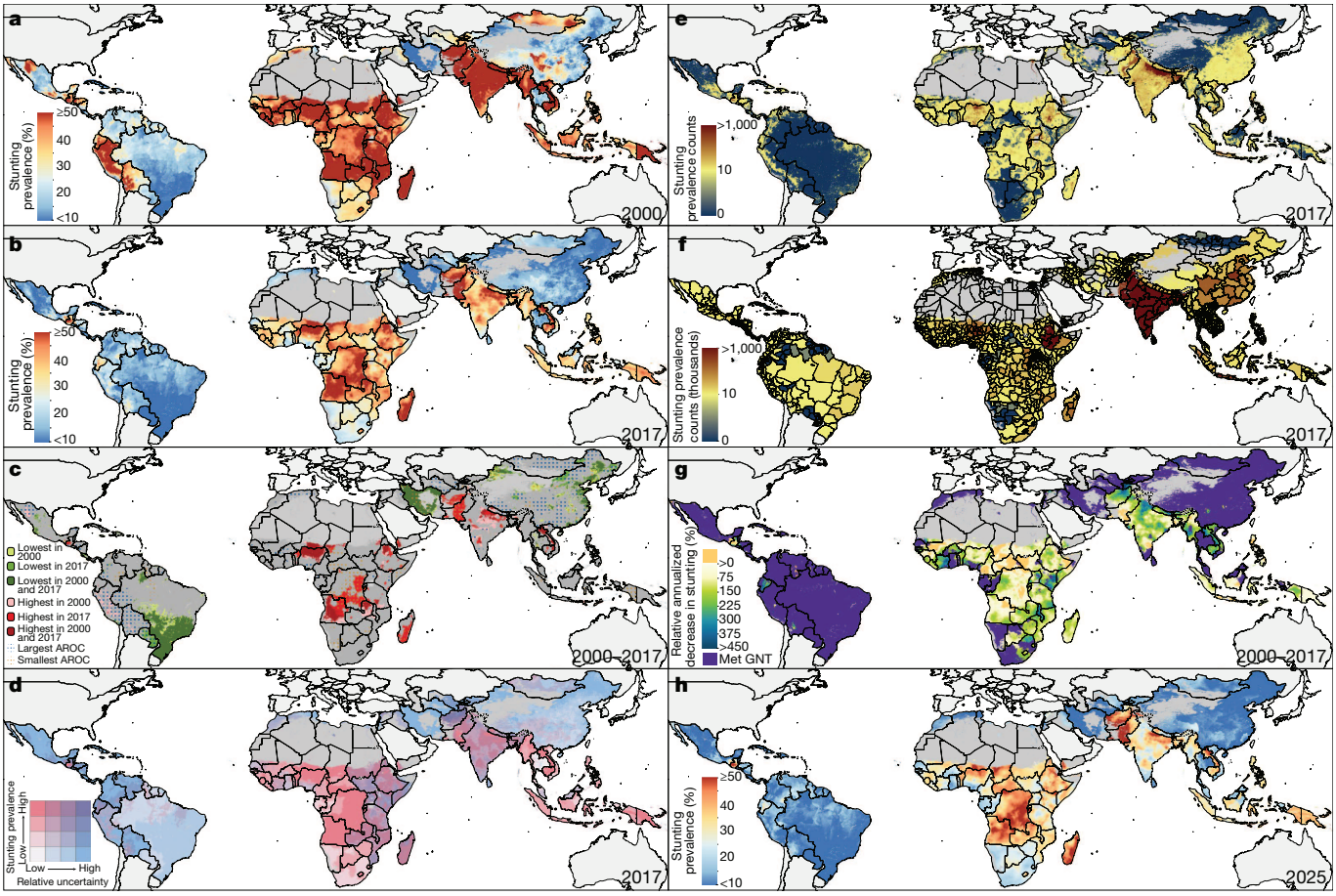

Fig. 1 | Prevalence of stunting in children under five in LMICs (2000–2017) and progress towards 2025. a, **b**, Prevalence of stunting in children under five at the 5 × 5-km resolution in 2000 (**a**) and 2017 (**b**). **c**, Overlapping population-weighted tenth and ninetieth percentiles (lowest and highest) of 5 × 5-km grid cells and AROC in stunting, 2000–2017. **d**, Overlapping population-weighted quartiles of stunting prevalence and relative 95% uncertainty in 2017. **e**, **f**, Number of children under five who were stunted, at the 5 × 5-km (**e**) and first-administrative-unit (**f**) levels. **g**, 2000–2017 annualized decrease in stunting prevalence relative to rates needed during 2017–2025 to meet the WHO GNT. **h**, Grid-cell-level predicted stunting prevalence in 2025. Maps were produced using ArcGIS Desktop 10.6. Interactive visualization tools are available at https://vizhub.healthdata.org/lbd/cgf.

stunting prevalence, subnational inequalities (disparities between second administrative-level units (henceforth 'units')) remained widespread globally—especially evident in Vietnam, Honduras, Nigeria, and India (Extended Data Fig. 2). Among the top quintile of widest disparities, Indonesia experienced a twofold difference in stunting levels in 2017, ranging from 21.0% (16.2–27.0%) in Kota Yogyakarta regency (Yogyakarta province) to 51.5% (40.6–62.3%) in Sumba Barat regency (Nusa Tenggara Timur province). Stunting levels varied fourfold in Nigeria, ranging from 14.7% (9.1–21.0%) in Surulere Local Government Area (Lagos state) to 64.2% (54.2–74.6%) in Gagarawa Local Government Area (Jigawa state) in 2017.

Evaluated from estimates of population-weighted prevalence for areas with the highest and lowest estimated prevalence of stunting (ninetieth and tenth percentiles, respectively), locations in central Chad, Pakistan, and Afghanistan, in northeastern Angola, and throughout the Democratic Republic of the Congo and Madagascar had among the lowest annualized rates of change (AROC), indicating stagnation or increase over the study period (Fig. 1c); in 2017, these countries also had large geographical areas among the most highly prevalent for stunting. By contrast, areas scattered throughout Peru, northwestern Mexico, and eastern Nepal had among the highest stunting levels in 2000, but also the highest rates of decline; by 2017, many of these areas were subsequently no longer in the highest-prevalence decile.

The absolute number of children under five who were stunted was also unequally distributed (Fig. 1e, f), with a large proportion concentrated in a few nations in 2017; overall, 85.1% (84.4–85.7%) of all stunted children under five lived in Africa or Asia. Of the 176.1 million (151.6–203.3 million) children who were stunted in 2017, just over half (50.1% (48.5–52.0%)) lived in only four countries: India (51.5 million (47.7–55.3 million) children; 28.6% (27.1–30.4%) of global stunting), Pakistan (10.7 million (9.3–12.1 million); 6.8% (6.7–6.9%)), Nigeria (11.8 million (10.7–13.0 million); 6.6% (6.4–6.8%)), and China (16.2 million (14.0–18.5 million); 9.0% (9.1–8.9%)). Although China had a low prevalence of national stunting (10.8% (9.1–12.6%)) in 2017, the prevalence was high in India (39.3% (39.1–39.6%)), Pakistan (44.0% (38.4–49.9%)), and Nigeria (38.2% (34.5–42.0%)). Even with moderate levels of stunting (10 to <20%)[10], these highly populous countries would substantially contribute to the global share owing to their population size, and reducing their levels would markedly decrease the number of stunted children.

Childhood wasting was less widespread than stunting (Fig. 2a, b), affecting 8.4% (7.9–9.9%) of children under five in LMICs in 2000, and 6.4% (4.9–7.9%) by 2017. Wasting reached critical levels (at least 15%)[11] nationally in 13 LMICs in 2000 and 7 LMICs in 2017, although only in Mauritania (20.7% (16.5–25.6%)) did all units exceed these levels (Extended Data Fig. 3). Critical wasting prevalence was concentrated in few areas across the globe in 2017, including the peri-Sahelian areas of countries stretching from Mauritania to Sudan, as well as areas in South Sudan, Ethiopia, Kenya, Somalia, Yemen, India, Pakistan, Bhutan, and Indonesia. Most LMICs reduced within-country disparities between

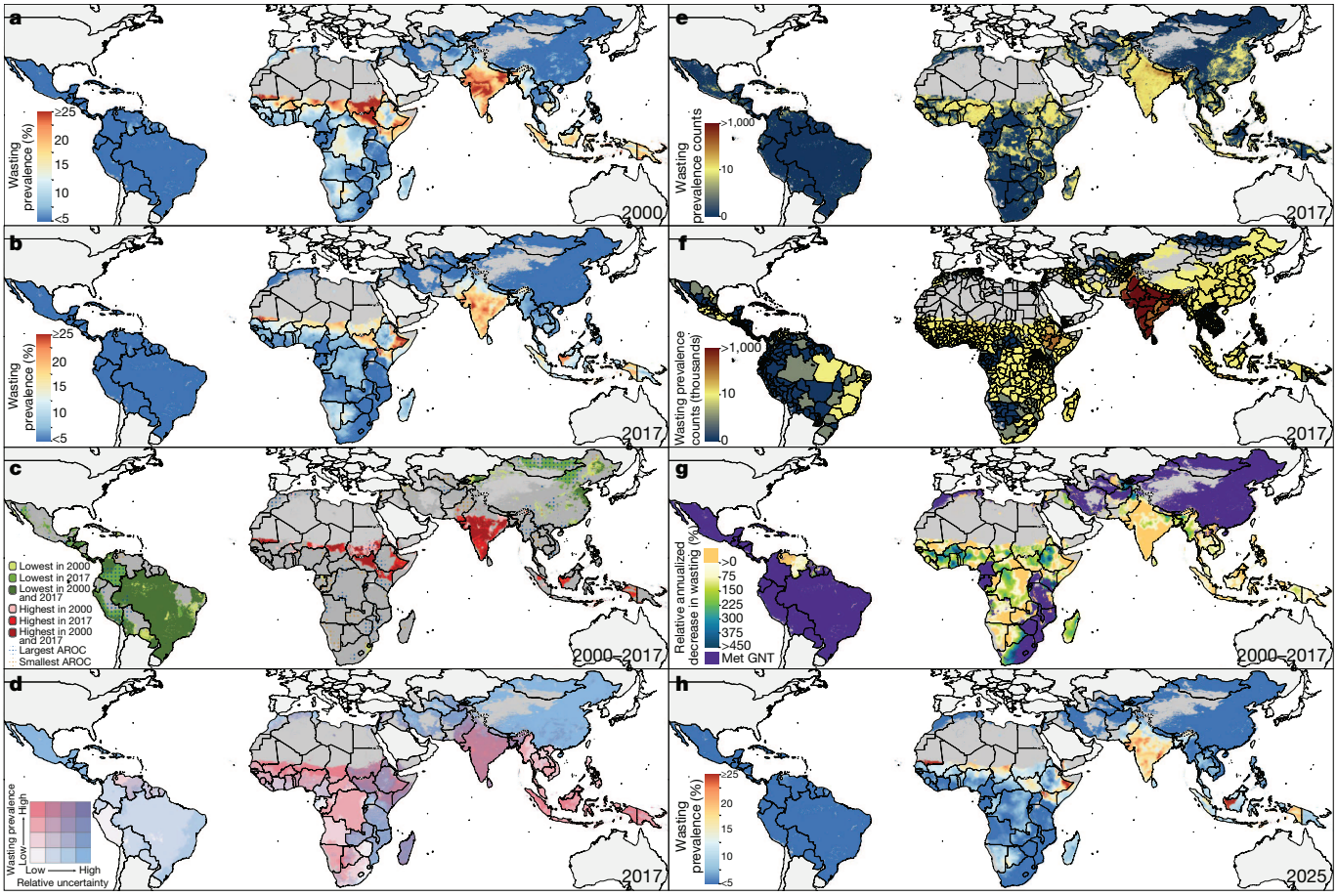

Fig. 2 | Prevalence of wasting in children under five in LMICs (2000–2017) and progress towards 2025. a, **b**, Prevalence of child wasting in children under five at the 5 × 5-km resolution in 2000 (**a**) and 2017 (**b**). **c**, Overlapping population-weighted tenth and ninetieth percentiles (lowest and highest) of 5 × 5-km grid cells and AROC in wasting, 2000–2017. **d**, Overlapping population-weighted quartiles of wasting prevalence and relative 95% uncertainty in 2017. **e**, **f**, Number of children under five affected by wasting, at the 5 × 5-km (**e**) and first-administrative-unit (**f**) levels. **g**, 2000–2017 annualized decrease in wasting prevalence relative to rates needed during 2017–2025 to meet the WHO GNT. **h**, Grid-cell-level predicted wasting prevalence in 2025. Maps were produced using ArcGIS Desktop 10.6. Interactive visualization tools are available at https://vizhub.healthdata.org/lbd/cgf.

their highest- and lowest-prevalence units between 2000 and 2017, most notably in Algeria, Uzbekistan, and Egypt (Extended Data Fig. 4). Even against a backdrop of national-level declines, however, broad within-country disparities in wasting remained in countries such as Indonesia, Ethiopia, Nigeria, and Kenya. An estimated ninefold difference in wasting prevalence occurred among Kenya's units in 2017, ranging from 2.9% (1.6–4.9%) in Tetu constituency (Nyeri county) to 28.3% (20.2–37.3%) in Turkana East constituency (Turkana county); higher-resolution estimates reveal areas with a wasting prevalence of at least 25%. High-prevalence areas in 2000 typically remained within the highest population-weighted decile for wasting in 2017, including the units of Rabkona county (Unity state) in northern South Sudan (27.8% (19.8–37.6%) in 2000; 17.3% (8.8–21.9%) in 2017), the Tanout department (Zinder region) in southern Niger (21.6% (17.3–26.7%) in 2000; 16.5% (11.3–23.3%) in 2017), and Alor regency (Nusa Tenggara Timur province) in southeastern Indonesia (16.4% (9.6–25.8%) in 2000; 20.7% (12.8–30.3%) in 2017) (Fig. 2c).

The absolute number of children affected by wasting was unequal both across and within countries (Fig. 2e, f). Of the 58.3 million (47.6–70.7 million) children affected by wasting in 2017, 57.1% (52.7–61.6%) occurred in four of the most populous countries: India (26.1 million (23.1–29.0 million); 44.7% (41.0–48.6%) of global wasting), Pakistan (3.5 million (2.8–4.3 million); 6.0% (5.8–6.1%)), Bangladesh (1.8 million (1.2–2.4 million); 3.0% (2.6–3.4%)), and Indonesia (2.0 million (1.7–2.3 million); 3.4% (3.3–3.5%)). On the basis of standard thresholds[11], these countries had serious levels of national wasting prevalence (10 to <15%), ranging from 12.2% (9.7–14.9%) in Pakistan to 15.7% (15.5–15.9%) in India, and all but Bangladesh had areas with estimated wasting levels above 20%; increased efforts, especially in densely populated areas with high prevalence and absolute numbers, could immensely reduce global child wasting.

The prevalence of underweight—a composite indicator of stunting and wasting—followed the scattered pattern of high-stunting areas in SSA and spanning Central Asia to Oceania, and the high prevalence belt of wasting along the African Sahel (Extended Data Fig. 5a, b). Affecting 19.8% (17.3–22.7%) of children under five across LMICs in 2000 and 13.0% (10.4–16.0%) in 2017, reductions in underweight prevalence were most notable for countries in Central and South America, southern SSA, North Africa, and Southeast Asia. For example, by 2017, estimated underweight prevalence had decreased to less than or equal to 20% for nearly all areas in Namibia. By contrast, peri-Sahelian countries stretching from Mauritania to Somalia maintained an estimated underweight prevalence of at least 30% in many areas. Large geographical areas across Central and South Asia also maintained high prevalence of underweight during the study period; in particular, India, Pakistan, and Bangladesh sustained estimated prevalence of at least 30% in most locations. Although levels of child underweight had largely reduced since 2000, within-country disparities remained widespread; 71.4% (75 out of 105) of LMICs experienced at least a twofold difference across units in 2017 (Extended Data Fig. 6).

Prospects for reaching 2025 targets

We estimate that broad areas across Central America and the Caribbean, South America, North Africa, and East Asia had high probability (>95%) of having already achieved targets for both stunting and wasting in 2017 (Extended Data Fig. 7). Exceptions to these regional patterns exist; areas with stagnated progress and less than 50% probability of having achieved the World Health Organization's Global Nutrition Targets for 2025 (WHO GNTs) in 2017 were found throughout much of Guatemala and Ecuador for stunting and in southern Venezuela for wasting (Figs. 1g, 2g, Extended Data Fig. 7). Even within countries that had achieved targets, there remain areas with slow progress; locations in central Peru for stunting and southwestern South Africa for wasting had not achieved targets in 2017 (less than 5% probability)—nuances otherwise hidden by aggregated estimates. Owing to stagnation or increases in prevalence, broad areas in SSA and substantial portions across Central Asia, South Asia, and Oceania (for example, in the Democratic Republic of the Congo and Pakistan for stunting; in Yemen and Indonesia for wasting) require reversal of trends or acceleration of declines in order to meet international targets (Figs. 1g, 2g).

Despite predicted improvements in AROC for 2017–2025, many highly affected countries are predicted to have areas that maintain estimated stunting levels of at least 40% or wasting levels of at least 15% in 2025 (Figs. 1h, 2h). Accounting for uncertainty in 2000–2017 AROC estimates, and with 2010 national-level estimates as a baseline for the 40% stunting reduction target, 44.8% (47 out of 105) of LMICs are estimated to nationally meet WHO GNT (>95% probability) for stunting by 2025 (Supplementary Table 13). At finer scales, 17.1% (n = 18) and 7.6% (n = 8) of LMICs will meet the stunting target in all first and second administrative-level units in 2025, respectively (Extended Data Fig. 8a, d, Supplementary Table 13). Similarly, 35.2% (n = 37) of LMICs are estimated to reduce to or maintain less than 5% wasting prevalence by 2025 (>95% probability) based on current trajectories (Supplementary Table 13). Fewer countries were estimated to meet wasting targets in all first administrative-level (16.2% (n = 17)) or second administrative-level (9.5% (n = 10)) units (Extended Data Fig. 8b, e, Supplementary Table 13). Only 26.7% (n = 28) of LMICs will meet national-level targets for both stunting and wasting by 2025, and only 4.8% (n = 5) will achieve both targets in all units (Supplementary Table 13).

Discussion

Although commendable declines in CGF have occurred globally, this progress measured at a coarse scale conceals subnational and local underachievement and variation in achieving the WHO GNTs. Supporting conclusions in the Global Nutrition Report[12], our results show that most LMICs will not reach WHO GNTs nationally, and even fewer will meet targets across subnational units. Our mapped results show broad heterogeneity across areas, and reveal hotspots of persistent CGF even within well-performing regions and countries, where increased and targeted efforts are needed. In 2017, one in four children under five across LMICs still suffered at least one dimension of CGF, and the largest numbers of affected children were often in specific within-country locations. Although the national prevalence of CGF was generally lower in Central America and the Caribbean, South American, and East Asian countries, there are communities in these regions in which levels of CGF remain as high as those in SSA and South Asia. Regardless of overall declines, many subnational areas across LMICs maintained high levels of CGF and require substantial acceleration of progress or reversal of increasing trends to meet nutrition targets and leave no populations behind.

To our knowledge, this study is the first to estimate CGF comprehensively across LMICs at a fine geospatial scale, providing a precision public health tool to support efficient targeting of local-level interventions to vulnerable populations. Although densely populated areas may have relatively low prevalence of CGF, the absolute number of affected children may still be high; thus, both relative and absolute estimates are important to determine where additional attention is needed. To achieve international goals, more concerted efforts are needed in areas with decreasing or stagnating trends, without diminishing support in areas that demonstrate progress nor contributing to increases in obesity. In future work, we plan to determine how to stratify our estimates of CGF by sex and age, assess the double burden of child undernutrition and overweight, analyse important maternal indicators that affect child nutritional status outcomes (such as anaemia), and continue to monitor progress towards the 2025 WHO GNTs. These mapped estimates enable decision-makers to visualize and compare subnational CGF and nutritional inequalities, and identify populations most in need of interventions[13].

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41586-019-1878-8.

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