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Sustainable Development Goal indicator for measuring availability and affordability of medicines for children: a proof-of-concept study

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ABSTRACT

Objectives To complement Sustainable Development Goal (SDG) indicator 3.b.3 that monitors access to medicines for all, a corresponding child-specific methodology was developed tailored to the health needs of children. This methodology could aid countries in monitoring accessibility to paediatric medicines in a validated manner and on a longitudinal basis. We aimed to provide proof of concept of this adapted methodology by applying the method to historical datasets.

Method A core set of child-appropriate medicines was selected for two groups of children: children aged 1–59 months and children aged 5–12 years. To enable calculation of affordability of medicines for children, the *number of units needed for treatment* was created, incorporating the recommended dosage and duration of treatment for the specific age group. The adapted methodology was applied to health facility survey data from Burundi (2013), China (2012) and Haiti (2011) for one age group. SDG indicator 3.b.3 scores and (mean) individual facility scores were calculated per country and sector.

Results We were able to calculate SDG indicator 3.b.3 based on historical data from Burundi, China and Haiti with the adapted methodology. In this case study, all individual facilities failed to reach the 80% benchmark of accessible medicines, resulting in SDG indicator 3.b.3 scores of 0% for all 3 countries. Mean facility scores ranged from 22.2% in Haiti to 40.3% in Burundi for lowest-price generic medicines. Mean facility scores for originator brands were 0%, 16.5% and 9.9% for Burundi, China and Haiti, respectively. The low scores seemed to stem from the low availability of medicines.

Conclusion The child-specific methodology was successfully applied to historical data from Burundi, China and Haiti, providing proof of concept of this methodology. The proposed validation steps and sensitivity analyses will help determine its robustness and could lead to further improvements.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A strength of this study is the adaptation of an existing tool that was made appropriate for children.
⇒ In using an existing tool as starting point, the adapted methodology also inherits some of the limitations of this tool, such as the burden of disease weighting and the national poverty line in the calculation of affordability.
⇒ In providing proof of concept of this tool, we were limited to historical data that were already available, which are of little relevance to the current situation.
⇒ The historical datasets used are quality-assured through standardised data collection and through data validation and verification steps.
⇒ Only a modest sample of age-appropriate medicines were surveyed in the historical datasets, demanding further analyses on larger datasets.

INTRODUCTION

Despite considerable progress in recent decades, unacceptably high numbers of preventable child deaths remain an important challenge in resource-limited countries. The number of child deaths is unevenly distributed: in 2020, over 80% of the 5.0 million deaths in children under five years old occurred in just 2 regions—Sub-Saharan Africa and South Asia.[1] A similar geographic disparity is visible in children and youth over 5 years of age, although mortality rates are somewhat lower in this group.[1] The large child populations in these regions put a further strain on often fragile health systems.[1] A key element in reducing the number of children suffering and dying from preventable and treatable diseases is improving access to medicines, as outlined in targets 3.8 and 3.b of the United Nations (UN) Sustainable Development Goals (SDGs).[2]

In order to promote access to essential medicines, countries' current performance and their progress need to be assessed and monitored.[3] This will help programme managers and policy-makers in planning their activities and developing targeted policies. Although SDG indicator 3.b.3 has been developed precisely for this purpose,[4] it predominantly

targets adult medicines. As to not exclude children from access to medicines research, there is a need for an assessment method tailored to children.

SDG indicator 3.b.3 is a multidimensional index of medicines' access, reported as the proportion of health facilities that have a core set of essential medicines available at affordable prices relative to the total number of surveyed health facilities (at a national level).[4] Indicator 3.b.3 thus allows for a combined evaluation of two important dimensions of access to medicines—availability and affordability—while also permitting separate analysis of these dimensions if overall performance is poor. However, the core set of medicines used for this indicator targets diseases such as cardiovascular diseases and diabetes mellitus type 2, which are typically not prevalent among children. Moreover, age-appropriate formulations are not considered as part of this core set of medicines.[5] Yet, manipulation of adult formulations to obtain an appropriate dose for children risks administrating toxic or subtherapeutic doses through inaccurate dosing, as well as dosing errors.[6] The availability of age-appropriate formulations is thus required for safe and effective treatment of infants and young children. Finally, affordability of medicines in indicator 3.b.3 is based on defined daily dosages (DDDs), which are only applicable to adults. Hence, the current indicator fails to provide critical insight into access to paediatric medicines.

At present, there is no methodology for measuring accessibility of essential medicines specifically for children, but a number of studies have reported on the availability or price of medicines, or both.[7–35] The methodologies for measuring these two important dimensions of access varied greatly between studies, as did the medicines surveyed, covering different age groups of children (eg, children under 5, children under 12 or all children and adolescents), priority diseases (anticancer medicines, cardiovascular medicines or a range of diseases) and number of surveyed medicines. Results are therefore difficult to compare and may not reflect overall access to medicines for children in a country. This emphasises the need for a standardised and validated methodology for measuring access to medicines for children that will enable global comparison and eventually benchmarking of indicators.

In the present study, we propose a conceptual methodology for adapting the SDG indicator 3.b.3 that can be used to assess access to essential medicines for children. We apply the methodology to three case study countries (Burundi, China and Haiti) as proof of concept.

METHODOLOGY

SDG indicator 3.b.3 is a composite bidimensional indicator of access, that can be calculated as follows[4]:

$$SDG_{3.b.3.} = \frac{\text{Facilities with available and affordable basket of medicines (n)}}{\text{Surveyed Facilities (n)}} \quad (1)$$

The indicator includes three core concepts used to calculate access to medicines:

1. A core set of globally relevant (quality-assured) essential medicines—weighted for the regional burden of disease.
2. Availability of medicines.
3. Affordability of medicines—based on the price of a medicine, the daily dose of the medicine needed for treatment, the national poverty line (NPL) and the lowest-paid unskilled government worker (LPGW) wage.

As both availability and affordability are important dimensions of access, the combination of these core concepts into a single measure allows evaluation of overall access to medicines. As SDG indicator 3.b.3 was formally approved by the UN Statistics Division, we aimed for an adapted indicator 3.b.3 for children to resemble the original indicator as closely as possible. In this section, we discuss the critical steps of the original framework and describe how the core concepts have been adapted to allow calculation of access to paediatric medicines.

A core set of globally relevant essential medicines

The core set of medicines consists of tracer essential medicines, together indicative of overall access to medicines in primary healthcare. Over the years, several baskets of paediatric medicines have already been proposed. However, the list of medicines defined for the 2007 'Better medicines for children' project is not only dated, but also purposely excludes antiretroviral therapies for HIV.[3] Since HIV/AIDS is still prevalent among paediatric populations in low-income and middle-income countries, this selection of medicines is not suitable for the current purpose. In 2012, the WHO published a list of thirteen 'Priority life-saving medicines' for children under the age of 5, intended to help countries in prioritising those medicines that will have the biggest impact on reducing child morbidity and mortality.[36] We believe that an access indicator should serve a broader age group, especially since children aged 5–12 years may have different treatment requirements than the youngest. Additionally, the priority list only targets seven prevalent diseases, and is thus limited in its scope. With that, no existing basket of paediatric medicines was deemed suitable for the current purpose.

A new core set of medicines for children with ages 1 month to 12 years for treating acute and chronic, communicable and non-communicable diseases in the primary healthcare setting and including child-appropriate formulations was thus established. To cater to the unique needs of children with different ages, separate baskets for two age groups were created: young children (infants, toddlers and preschool children) aged 1 month to 59 months, and school-aged children 5–12 years of age. These groups will allow stakeholders to differentiate between health needs in terms of disease prevalence, required dosage strengths and preferred dosage forms. Children above the age of 12 often do not

require paediatric formulations[37] and their health needs may already be adequately covered in the original SDG indicator 3.b.3 methodology.

To enable use of this methodology in a global context, medicines used for treating diseases with a high global prevalence were selected. Starting point for establishing a universal set of paediatric medicines were the 2019 global burden of disease estimates in children (Global Health Estimates (GHEs)).[38] We selected 10 priority conditions causing the most mortality and morbidity in disability-adjusted life years (DALYs) per age group, which were treatable with medicines from the 2019 WHO Essential Medicines List for Children (EMLc).[39] This excluded for example congenital defects and malnutrition. And although not separately represented in the GHEs, pain and palliative care was included in the selection of diseases for each age group as these are considered essential in supportive care of many conditions.

Priority conditions were linked to first-choice medicines in primary healthcare using WHO and South African treatment guidelines.[40–44] Multiple medicines from the same therapeutic class of medicines could be selected and can be considered interchangeable (including antiepileptics, anthelminthics, antimalarials). Medicines requiring cold-chain management were excluded, as these may not be widely available in primary health facilities. Additionally, although vaccines are a key component in healthcare, vaccination coverage is already included within indicator 3.b.1 of the SDGs and will therefore not be covered in indicator 3.b.3 as well. To ensure that the proposed basket of medicines sufficiently addresses priority health needs in clinical practice, a primary expert validation of the core set of essential medicines has taken place through an online survey (see online supplemental annex 1 for details). The validated basket of medicines for children aged 1 month to 5 years can be found in table 1. Child-appropriate medicine formulations were selected pragmatically, based on formulations present on the WHO EMLc and the required dosage strengths in young children.

Availability of medicines

The second core concept in the SDG indicator 3.b.3 is the availability of medicines. Availability is a snapshot, binary variable: a medicine is considered available in a facility when found in the facility by the interviewer on the day of data collection.[4] The definition and analysis of availability in the original framework were deemed compatible with paediatric medicines and was applied without revisions.

Affordability of medicines

A medicine is considered affordable in SDG indicator 3.b.3 when no extra daily wages (EDW) are needed for the LPGW to purchase a monthly dose treatment of this medicine after fulfilling basic needs, represented by the NPL (formula 2):

$$\text{Extra daily wages (EDW)} = \frac{\text{NPL+price per treatment}}{\text{daily wage of LPGW}} \quad (2)$$

In which

$$\text{Price per treatment} = \frac{\text{Unit price} \times \text{number of units needed per treatment}}{365/12} \quad (3)$$

This measure indicates whether the LPGW wage is enough to cover the costs of daily expenditures for food and non-food items plus the cost of a medicine. The EDW is again transformed into a binary variable: a medicine is considered affordable when no EDW are required to purchase it (formula 4).

$$\begin{cases} \text{if EDW} \leq 1, \text{ affordability} = 1, \\ \text{otherwise, affordability} = 0 \end{cases} \quad (4)$$

Number of units needed for treatment (NUNT)

The price per monthly treatment of a medicine is calculated from (1) the price of a medicine unit (eg, tablet, millilitre, etc) and (2) the NUNT. In the original framework, the latter is based on DDDs that are not applicable to children. Hence, in order to calculate affordability for children, the NUNT was determined through the elements below:

1. The recommended dosing per age or weight group.
2. If applicable, the transformation of weight-based dosing (or based on body surface area (BSA)) to age-based dosing.
3. The duration of treatment.

Recommended (maintenance) doses per day in children—used for its main indication—were determined based on international treatment guidelines.[40–44] As many dosing regimens are based on the body weight of a child, weight-based dosing regimens were converted to age-based regimens using weight-for-age charts.[45–47] Median weights of boys and girls within an age group were averaged to obtain a single measure per group. Medicines dosed based on BSA were converted through an extra calculation step, using the Meeh type equation.[48] Of note, each of the two age groups represents a range of ages. In order to calculate a single outcome for each group, the NUNT is based on the average age and weight of a child within a group (ie, a 30-month-old child of 11 kg and an 8-year-old child with a weight of 25 kg). Some examples of how the NUNT was calculated are provided in figure 1. The NUNT was predetermined for all medicines in the core set of paediatric medicines (online supplemental annex 2).

Weighting for burden of disease

In the original framework, accessible medicines are weighted according to the regional burden of disease to address differences in demand between medicines (weighting for regional burden of disease is a different process than selecting medicines for the core set based on global burden of disease).[4] This concept was applied to paediatric medicines as well, based on the GHEs.[38] Each medicine in the basket was assigned a GHE code for one or several disease(s) that are treated/cured/controlled

Table 1 Proposed core set of essential medicines for children 1–59 months

Disease area (GHE code)	Medicine name	Acceptable formulations
Diarrhoeal diseases (110)	Oral rehydration salts	Powder sachet 200 mL, 500 mL or 1 L
	Zinc sulphate	Cap/tab 20 mg
Epilepsy (970)	Carbamazepine OR	Cap/tab 100 mg; oral liquid 100 mg/5 mL
	Phenobarbital OR	Cap/tab 30 mg or 100 mg; injection 100 mg/mL or 200 mg/mL; oral liquid 15 mg/5 mL
	Phenytoin OR	Cap/tab 25 mg, 50 mg or 100 mg; injection 50 mg/mL; oral liquid 25 or 30 mg/5 mL
	Lamotrigine	Cap/tab 25 mg, 50 mg or 100 mg
	Valproic acid	Cap/tab 100 mg, 150 mg, 200 mg or 500 mg; oral liquid 200 mg/5 mL
	Diazepam OR	Rectal solution 5 mg/mL; injection 5 mg/mL
	Lorazepam OR	Parenteral solution 2 mg/mL or 4 mg/mL
	Midazolam	Oromucosal solution 5 mg/mL or 10 mg/mL; ampoule 10 mg/mL
HIV/AIDS (100)	Abacavir+lamivudine+ dolutegravir OR	Cap/tab 120/60 mg (abacavir/lamivudine) AND cap/tab 10 mg (dolutegravir)
	Abacavir+lamivudine+ lopinavir/ritonavir	Cap/tab 120/60 mg (abacavir/lamivudine) AND cap/tab 40/10 mg or 100/25 mg (lopinavir/ritonavir)
Iron deficiency anaemia (580)	Ferrous salt	Cap/tab 60 mg or 200 mg; oral liquid 25 mg/mL
	Albendazole OR	Cap/tab 200 mg or 400 mg
	Mebendazole	Cap/tab 100 mg
Malaria (220)	Artemether+lumefantrine OR	Cap/tab 20/120 mg
	Artesunate+amodiaquine OR	Cap/tab 25/67.5 mg or 50/135 mg
	Artesunate+mefloquine OR	Cap/tab 25/55 mg
	Dihydroartemisinin+ piperaquine OR	Cap/tab 20/160 mg or 20/320 mg
	Artesunate+ sulfadoxine–pyrimethamine OR	Cap/tab 50/500/25 mg or cap/tab 50 mg (artesunate) AND cap/tab 500/25 mg (sulfadoxine–pyrimethamine)
	Chloroquine	Cap/tab 100 mg; oral liquid 50 mg/5 mL
	Artesunate	Cap/tab 50 mg; suppository 50 mg
Measles (150) Vitamin A deficiency (570)	Retinol	Cap/tab 25 000 IU, 100 000 IU or 200 000 IU
Pain and palliative care (weight=1/T*)	Paracetamol	Cap/tab 100 mg; suppository 100 mg; suspension 120 or 125 mg/5 mL
	Morphine	Cap/tab (slow release) 10 mg; injection 10 mg/ampoule; oral liquid 10 mg/5 mL
	Ibuprofen	Cap/tab 200 mg; oral liquid 200 mg/5 mL
Tuberculosis (30)	Ethambutol+isoniazid+ pyrazinamide+rifampicin	Cap/tab 100 mg or 400 mg or oral liquid 25 mg/mL (ethambutol) AND cap/tab 50/150/75 mg (isoniazid+pyrazinamide+rifampicin)
Lower respiratory infections (390) Other infectious diseases (370)	Amoxicillin OR	Cap/tab 250 mg or 500 mg; powder for injection 250 mg/vial, 500 mg/vial or 1 g/vial; suspension 125 mg/5 mL or 250 mg/5 mL
	Amoxicillin+clavulanic acid	Cap/tab 100/125 mg, 250/125 mg or 500/125 mg; powder for injection 500/100 mg/vial; oral liquid 125/53.25 mg/5 mL or 250/62.5 mg/5 mL
	Ampicillin	Cap/tab 250 mg or 500 mg; injection 500 mg/vial or 1 g/vial
	Benzylpenicillin	Injection 1 MIU/vial
	Gentamicin	Injection 10 mg/mL or 40 mg/mL

Continued

Table 1 Continued

Disease area (GHE code)	Medicine name	Acceptable formulations
Other infectious diseases (370) Meningitis (170)	Ceftriaxone	Injection 250 mg/vial, 500 mg/vial or 1 g/vial
	Cefotaxime	Injection 1 g/vial
Syphilis (50)	Procaine benzylpenicillin	Injection 1 MIU/vial

*T is the total number of surveyed medicines.
Cap/tab, capsule/tablet; GHE, Global Health Estimates; MIU, milli-international units.

by that medicine. Indications of the medicines were determined according to their uses as described in the WHO EMLc (see table 1).[39] Some antibacterial medicines were also assigned the additional code (370), as a proxy for the broad use of these medicines in a variety of bacterial diseases.

The weight that each medicine is given in the calculation was computed as the proportion of associated DALYs for a medicine compared with the total sum of DALYs for all medicines surveyed. Of note, the GHEs include data for children 1–59 months and children 5–14 years. The weighting of children up to 12 years of age based on data for children up to 14 years old does not have a significant impact on the results as assigned weights are proportional weights.

Calculating SDG indicator 3.b.3

The age-specific SDG indicator 3.b.3 can be calculated with formula 1. Assessing availability and affordability of medicines, and subsequent weighting for regional disease burden, was done at the facility level, meaning that a separate score is calculated for each health facility surveyed. Facilities with at least 80% of medicines in the basket available and affordable were considered to have accessible medicines. This threshold was adopted by the WHO Global Action Plan on Non-Communicable Diseases and used as a reference.[49] Table 2 presents a full summary of the adaptations to the original SDG 3.b.3 methodology to make it child appropriate. A hypothetical working example is provided in online supplemental annex 3.

Proof of concept

As proof of concept, the methodology described above was applied to three historical WHO/Health Action International (HAI) datasets for the young children age group (1 month to 5 years) (see figure 2 for an explanation of the WHO/HAI standardised methodology[50]).

Data on medicines' availability and price for Burundi (2013), China (2012) and Haiti (2011) was obtained from HAI. These datasets were selected because the highest absolute number of age-appropriate medicines that are listed in the proposed core set of medicines was included in these surveys (11, 10 and 12 out of 22 medicines, respectively).[51] Additionally, this selection represents countries with different income levels (eg, Burundi and Haiti low-income countries, China an upper-middle income country) and from different geographical regions. To make the datasets appropriate for analysis, only the age-appropriate medicines as listed in table 1 were selected. A selection in participating health facilities was not made.

Data on NPLs were obtained from World Bank reports on poverty.[52–54] NPLs were adjusted for inflation and deflation between the year data was reported and the survey year using the Consumer Price Index.[55] Monthly poverty lines were converted to daily time periods. LPGW wages were directly obtained from the datasets provided by HAI and thus required no corrections for the year of survey.

Because regional data on burden of disease in DALYs is available for every 5 years only, the year closest in time

Paracetamol 100 mg cap/tab
The recommended dosage for a child below five is 10-15 mg/kg 4-6 times daily. Assuming pain treatment is continuous (every day of the month), the number of unites needed for treatment (NUNT) is then calculated as:

$$Required\ units\ per\ intake\ moment = 12.5\,mg/kg * 11\,kg = 138\,mg \approx 1\,unit$$

$$NUNT = 1\,unit * 5\,daily\ intake\ moments * 30\,days = 150\,units$$

Amoxicillin 50 mg/ml suspension
The recommended dosage for a child below five is 40 mg/kg twice daily. Assuming the duration of treatment is 5 days, the NUNT is then calculated as:

$$Required\ units\ per\ intake\ moment = {}^{40\,mg/kg * 11\,kg}\Big/_{50\,mg/ml} = 9\,ml$$

$$NUNT = 9\,ml * 2\,daily\ intake\ moments * 5\,days = 90\,units$$

Figure 1 Two example calculations of the number of units needed for treatment (NUNT).

Table 2 Comparison of the original and child-specific $SDG_{3.b.3}$ methodology

Input	Original $SDG_{3.b.3}$ methodology[4]	Child-specific $SDG_{3.b.3}$ methodology
SDG indicator 3.b.3		
Calculation	► Based on individual facility scores. ► Facilities considered as having accessible medicines when reaching an 80% threshold.	► Based on individual facility scores. ► Facilities considered as having accessible medicines when reaching an 80% threshold.
Core set of globally relevant essential medicines		
Selection of medicines	► Defined on a global level. ► Selected from 2017 WHO EML. ► Selection process not described.	► Defined on a global level. ► Selected from 2019 WHO EMLc. ► Selection based on global burden of disease (top 10 conditions causing disability/mortality that can be treated with medicines), international treatment guidelines and expert consultation.
The basket	► One basket for all.	► Baskets defined for two age groups (young children; school-aged children).
	► 32 tracer essential medicines for acute and chronic, communicable and non-communicable diseases.	► 22 tracer essential medicines for acute and chronic, communicable and non-communicable diseases for both young and school-aged children.
		► Age-appropriate formulations selected per age group.
Burden of disease	► Weighting according to regional burden of disease (in DALYs). ► Based on WHO GHEs. ► Pre-defined GHE codes, with overarching GHE code for 'infectious and parasitic diseases' for antibacterials. ► Equal weights assigned to medicines that are used to treat the same disease.	► Weighting according to regional burden of disease (in DALYs). ► Based on WHO GHEs, from period closest to year of survey. ► Affiliated GHE codes determined according to the uses as described in EMLc. GHE codes for antibacterials determined according to uses as described in EMLc plus code for 'other infectious diseases'. ► Equal weights assigned to medicines that are used to treat the same disease.
Availability of medicines		
Availability	► Captured as binary variable. ► As surveyed.	► Captured as binary variable. ► As surveyed.
Affordability of medicines		
Required inputs	► Captured as binary variable. ► Calculated from the price of a medicine, the number of units needed for treatment, the NPL and the wage of the LPGW.	► Captured as binary variable. ► Calculated from the price of a medicine, the NUNT, the NPL and the wage of the LPGW.
Number of units needed for treatment	► Total number of units needed per month or treatment course based on DDDs. ► Process for defining duration of treatment not described.	► NUNT based on duration of treatment and recommended daily dosages per age or weight group. Weight-based dosing transformed to age-based dosing. ► Recommended daily dosages and duration of treatment derived from international treatment guidelines.

DALY, disability-adjusted life year; DDD, defined daily dosage; EML, Essential Medicines List; EMLc, Essential Medicines List for Children; GHE, Global Health Estimates; LPGW, lowest-paid unskilled government worker; NPL, national poverty line; NUNT, number of units needed for treatment; SDG, Sustainable Development Goal.

to the year of survey was used (eg, 2010 publication for China and Haiti and 2015 publication for Burundi) to weight for burden of disease.[38]

In addition to estimating the overall SDG 3.b.3 indicator, mean individual facility scores were also calculated per country and sector. Results were disaggregated per medicine to investigate drivers of inaccessibility.

Patient and public involvement

There was no patient or public involvement in the design or conduct of this study.

RESULTS

Access to medicines for children aged 1 month to 5 years was calculated for each of the three case study countries for its different health sectors. Analysis of data from Burundi showed a stark contrast between lowest-price generic medicines (LPM) and the originator brand (OB), with a mean facility score of 40.3% for LPMs vs 0.0% for the OB. The public and mission sector provided more accessible medicines than the private sector. The difference between LPMs and the OB was not as pronounced in China with mean facilities scores of 22.3% and 16.5% respectively, with LPMs more accessible in the public

The World Health Organization/Health Action International methodology

The World health Organization (WHO)/Health Action International (HAI) methodology is considered the gold standard for the collection of evidence on the availability and prices of medicines. This standardized methodology outlines the steps needed to plan and conduct a survey to generate reliable information on medicines' prices and availability.

Key elements of the methodology include:

- Data is collected in six geographical survey areas: a country's main urban center and five other areas.
- Health facilities – or medicine outlets – from the public, private and up to two other sectors are selected through a systematic approach. In each survey area, data are collected in at least five medicine outlets per sector.
- Up to 50 medicines are surveyed, including 14 core medicines that allow for global comparison.
- Data on the price and availability of medicines are gathered by data collectors during visits to the selected health facilities.
- For each medicine, data are collected on the originator brand and the lowest-priced generic equivalent found at each medicine outlet.

To ensure data quality of datasets, the collection of data is validated and all data is checked for any incomplete, erroneous or illegible data.

Figure 2 Core elements of the WHO/HAI methodology (adapted from World Health Organization (WHO) and Health Action International (HAI)[50]).

sector and the OBs more in the private sector. In Haiti, access was calculated for the public sector, the private sector, the non-profit sector and the mixed sector (health facilities managed by the government and non-profit organisation together). Mean facility scores for LPMs were similar across the sectors, with an overall mean of 22.2%. For OB medicines, scores varied between 0.6% in the private sector and 15.1% in the public sector. Results on SDG indicator 3.b.3 and mean facility scores across health facilities from different sectors are summarised in table 3.

None of the facilities in either of the three countries were categorised as providing sufficient access to medicines, as all facilities failed to reach the 80% threshold. This resulted in SDG indicator 3.b.3 outcomes of 0% in all three countries. The main driver for the low scores was the low availability of medicines, as illustrated in figure 3. Notably, those medicines that were available on the day of survey were generally also affordable, with a few exceptions (four cefotaxime injections, six ceftriaxone injections, two ibuprofen tablets, one phenobarbital tablet). Age-appropriate dosage forms such as oral suspension or liquids were not associated with unaffordable prices in these case studies.

DISCUSSION

This paper proposes an adapted methodology that can be used to measure access to paediatric medicines, based on the principles embedded in SDG indicator 3.b.3. This novel methodology could be an important tool for policymakers and programme managers in identifying major barriers to access and developing appropriate policies to improve access to medicines for children. In adapting the methodology, two proposed core sets of paediatric medicines were established for children of different ages, taking into account their specific health needs and age-appropriate formulations. Careful approaches were taken to create the NUNT—a novel parameter—which enables affordability calculations across ages. The adapted methodology was successfully applied to data from three individual countries, providing proof of concept of this methodology.

With no reliable method for measuring access to paediatric medicines having been established yet, the child-specific methodology presented in this paper can provide guidance to others aiming to study access to medicines for children. The use of a single methodology and core set of medicines to express access to medicines will allow for intercountry comparability of the SDG indicator. Another important advantage of such a standardised tool is its ease of use. By predetermining which medicines and formulations should be surveyed, by providing the typical NUNT, and demonstrating how accessibility should be calculated, this method only requires countries to collect the facility data and some additional inputs. Yet, standardisation can also be viewed as rigidity, which is

Table 3 Facility scores for access to paediatric medicines for children aged 1–59 months of originator brand and lowest-price generic medicines in Burundi, China and Haiti

			Lowest-price generic		Originator brand	
	Sector	Facilities surveyed, n	Mean facility score (%), range		Mean facility score (%), range	
Burundi (2013)	SDG indicator 3.b.3		0%			
	Public	23	49.1	(12.1–76.0)	0.0	(0.0–0.0)
	Private	27	29.1	(8.3–57.3)	0.0	(0.0–0.0)
	Mission	23	44.6	(11.5–76.0)	0.0	(0.0–0.0)
	Overall	73	40.3	(8.3–76.0)	0.0	(0.0–0.0)
China (2012)	SDG indicator 3.b.3		0%			
	Public	60	34.5	(0.0–54.7)	10.2	(0.0–32.4)
	Private	60	10.1	(0.0–58.6)	22.6	(0.0–32.4)
	Overall	120	22.3	(0.0–58.6)	16.5	(0.0–32.4)
Haiti (2011)	SDG indicator 3.b.3		0%			
	Public	54	20.4	(0.0–60.3)	15.1	(0.0–22.0)
	Private	35	25.9	(13.3–34.9)	0.6	(0.0–22.0)
	Non-profit	39	19.6	(0.0–41.6)	9.6	(0.0–22.0)
	Mixed	35	24.4	(0.0–44.0)	11.3	(0.0–22.0)
	Overall	163	22.2	(0.0–60.3)	9.9	(0.0–22.0)

SDG, Sustainable Development Goal.

inherent to any tool that uses a single core set for global reference. Local guidelines that recommend use of other active ingredients or formulations than those in the core set could lead to skewed outcomes. Therefore, this standardised method incorporates some flexibilities, allowing for several formulations or active ingredients from the same therapeutic class to be interchanged (ie, antiepileptics, antimalarials, etc). This allows countries to apply this method to their national situation. Additionally, we recognise that the proposed core set should be subject to regular updates, in accordance with updates to the WHO EMLc and international treatment guidelines.

On closer examination of the case studies of Burundi, China and Haiti, the widespread inaccessibility seen in the results seemed to stem from unavailable rather than unaffordable medicines, for both LPMs and OBs. A recent systematic review on children's medicines identified 14 studies that reported on the availability of children's medicines and found a median availability of 38.1% and 24.2% for LPMs and OBs in the public sectors and of 35.9% and 21.1% in the private sectors, respectively.[56] With that, the unavailability of child medicines detected in the present case studies is in line with the results of the systematic review. The same systematic review identified 11 studies that reported on the affordability of medicines, based on the number of days' wages of the LPGW. In the public sector, affordability was 83.6% and 48.5% for LPMs and OBs, with 72.2% and 68.8% in the private sector. The results of this systematic review emphasise the need for a method that combines the two dimensions into a single indicator, as separate evaluation of these elements overestimates actual access to medicines for the patient. Beyond that, some of the studies included in the systematic review included unrepresentative samples of medicines (eg, studies focused on a single disease area or studies simply failing to consider child-appropriate formulations such as oral liquids or appropriate medicine strengths), again confirming the need for a standardised methodology to measure access to child medicines.

Before this methodology can, however, be applied on a widespread scale, several steps must be undertaken to further validate the methodology and examine the uncertainties introduced through our adaptations of the tool. First, the proposed core sets of medicines for school-aged children (not shown) should be validated through expert consultation. Additionally, the robustness of the adapted methodology with regard to the NUNT will need to be tested as it is an important variable when calculating affordability. The NUNT was determined based on recommended dosages and duration of treatment prescribed in international guidelines, which were often expressed as ranges. This generates some uncertainty when converting to a single NUNT. Also, determining an NUNT in many cases involved transformation of weight-based to age-based dosing through weight-to-age charts, introducing further uncertainties. The WHO provides international weight-for-age charts for boys and girls until the age of 5[45] and ages 5–10 years,[46] but no international charts are available for children above the age of 10. Therefore, Dutch growth diagrams were used to approximate median weights of children 10–12 years.[47] Initial comparison of international and Dutch growth charts shows that differences, if any, are small and will likely have had no significant impact on the NUNT. Furthermore,

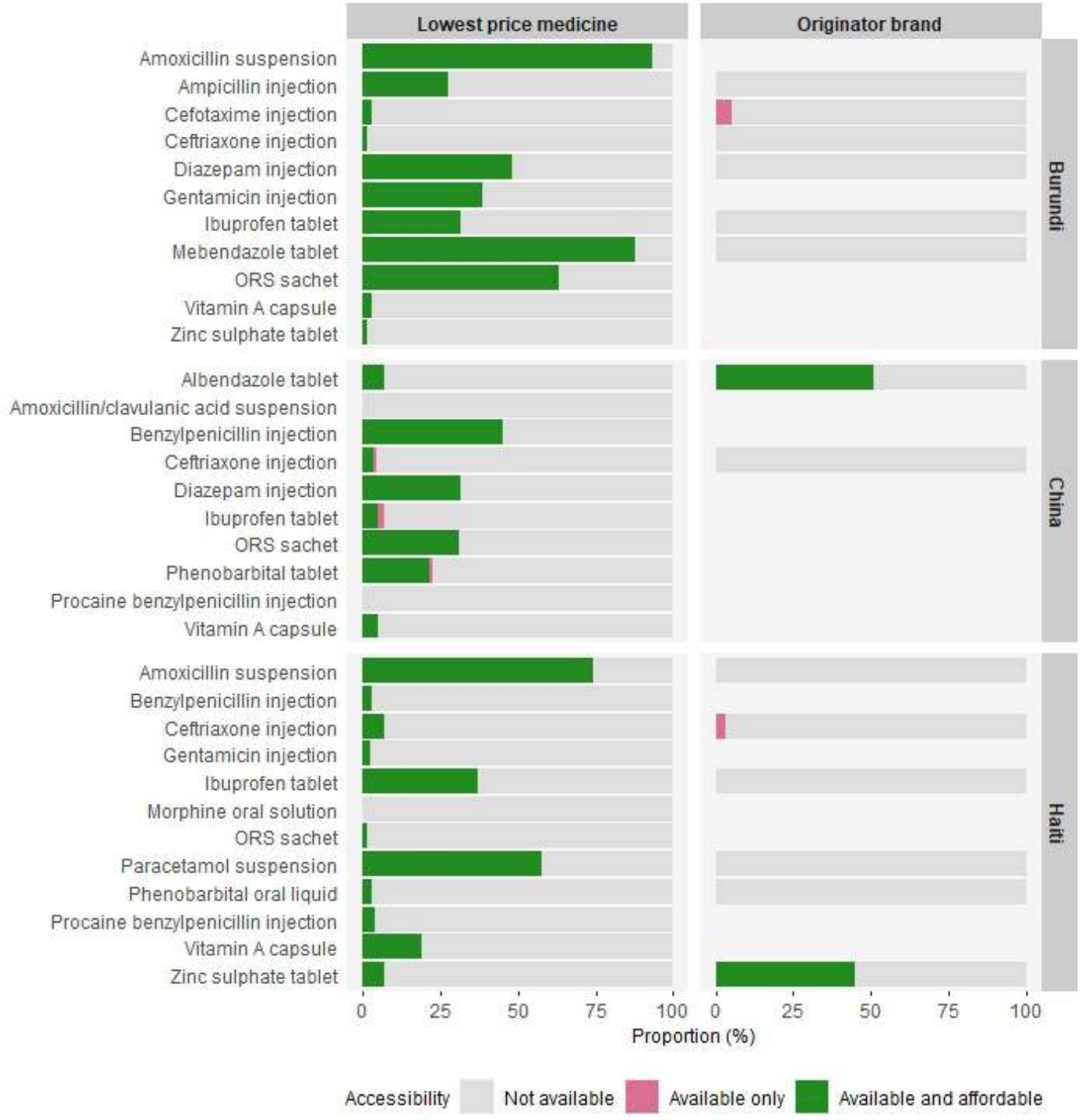

Figure 3 Proportion of medicines accessible in Burundi, China and Haiti. Since the originator brand was not surveyed for all active ingredients, findings in the private sectors of all three countries are based on a very small number of medicines only. ORS, oral rehydration salts.

the NUNT is a single number used to represent an entire age group. How big the uncertainties with regard to the NUNT are and whether a single NUNT is indeed sufficiently representative for an entire age group should become clear in sensitivity analyses. Additionally, the case studies now performed were on a subset of the complete core set for young children, limited by the small number of age-appropriate medicines that had been surveyed in the three case study countries. Sensitivity analyses should also be performed to determine the minimum number of medicines required for a reliable measure of accessibility. To perform meaningful sensitivity analyses, more data on child medicines is needed than was available for the present case studies.

An important strength of this child-specific methodology is the use of an existing, formally approved tool as starting point which was adapted to suit the needs of children. Core concepts used in the adapted

methodology and its data requirements are therefore in line with conventional methods and data collection tools. However, through this approach our methodology also inherits some of the limitations of the original 3.b.3 indicator methodology. Particularly, weighting for regional burden of disease when calculating access at the facility level as done in the original methodology raises several concerns. For one, the methodology assigns equal weights to medicines that are used to treat the same disease and thus counts the burden of this disease multiple times. To illustrate, the basket of medicines includes both oral rehydration salts and zinc sulphate for diarrheal diseases, whereas only retinol was selected for measles/vitamin A deficiency. This leads to disproportionate weighting for actual burden of disease when calculating access at the facility level. Disproportionality is also a concern for antibacterial medicines, which use may be overrepresented by using GHE code 20, a code that is linked to all infectious and parasitic diseases. Although a proxy for this GHE code was used in the present study (GHE code 370 for 'other infectious diseases'), additional analyses should demonstrate how different weighting approaches affect the results. Additionally, the quality of the underlying GHEs data is unclear, especially because these data may be more difficult to obtain for children than for adults. Lastly, arguments can be made that the current approach of weighting for burden of disease is undesirable because it implies that some medicines are more important than others, even though all medicines in the basket are essential medicines and should always be accessible.

On a similar note, expressing affordability as a function of a poverty line instead of the LPGW wage has been used previously,[57] but a measure combining the NPL and LPGW wage as is used in the original 3.b.3 indicator has yet to prove itself. This is particularly relevant because it seems that somewhat less medicines were unaffordable in the present case studies than what was observed using the LPGW wage alone.[56] Further testing of the proposed child-specific methodology should include several scenarios for weighting for burden of disease and calculating affordability, which could lead to further adaptations of the methodology.

Since no facilities met the benchmark of 80% in our case study countries, the overall SDG indicator 3.b.3 was by definition 0% in all countries. Through this benchmarking approach relevant differences in access between countries and sectors were lost (eg, access in Burundi was better with a mean facility score of 40.3% vs 22.3% and 22.2% in China and Haiti, respectively). Additionally, the detail required for identifying the major obstacles in accessibility is also missing when the SDG indicator is reported as a single outcome. This highlights that disaggregated data on a facility and medicine level is vital in understanding the drivers of inaccessibility to medicines, particularly when the indicator value reflects a suboptimal level of access. We recommend that the indicator should therefore be reported in both a composite and disaggregated form.

To provide first evidence of the child-specific tool that we developed, we were limited to the use of historical datasets. In selecting suitable datasets for the case studies it was observed that only a small number of age-appropriate medicines are being surveyed in low-income and middle-income countries.[58] The WHO/HAI datasets used for the present case studies were selected for their quality of data and relatively high inclusivity of age-appropriate medicines, yet they still included a modest sample of child-appropriate medicines. Further analyses on a dataset with a higher number of age-appropriate medicines are thus required, which may need to be collected prospectively. Although the relevance of the findings to the current situation of Burundi, China and Haiti is limited because of the older data, the aim of providing proof of concept of the adapted methodology was achieved nonetheless. Finally, the individual facility data that support the findings of this study are not publicly available, but aggregated data per medicine and country can be obtained from the HAI website.[51] The aggregated data are sufficient to allow initial comparison of our methodology to previously existing tools.

CONCLUSION

This paper proposes a standardised methodology for measuring access to medicines for children that could complement the existing SDG indicator 3.b.3. This standardised method—once validated—can aid countries in assessing national accessibility to paediatric medicines in a validated manner and on a regular basis. The proposed validation steps of this method will help identify critical steps in the calculation and will determine its robustness, which could lead to further improvements of the method.

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