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National Information Platform for Nutrition

Ethiopian Public Health Institute

Progress in Water, Sanitation and Hygiene (WASH) Practices and Association with Changes in Diarrhea and Stunting in Children Aged 0-59 Months in Ethiopia (2000-2016)

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Addis Ababa
September 2021

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This report was prepared by the NIPN in Ethiopia, hosted by EPHI. Technical support to the NIPN is provided by IFPRI. The NIPN is a global initiative of the European Commission. The NIPN in Ethiopia is funded by the European Union (EU) Delegation for Ethiopia, the Foreign, Commonwealth and Development Office and the Bill and Melinda Gates Foundation.

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List of Acronyms

DALY	Disability-Adjusted Life Years
EDHS	Ethiopian Demographic and Health Survey
JMP	Joint Monitoring Program
HAZ	Height-for-age z-score
LAZ	Length-for-age z-score
LMIC	Low- and Middle-Income Countries
NNP II	National Nutrition Program II
SD	Standard Deviation
SDG	Sustainable Development Goals
SNNPR	Southern Nations Nationalities and Peoples Region
UNICEF	United Nations Children's Fund
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization

Abstract

Despite progress in the past decade, inadequate safe water supply and poor sanitation and hygiene continue to be important risk factors for diarrhea and stunting globally. We used data from the four rounds of the Ethiopian Demographic and Health Survey (EDHS) to investigate the progress made in Water, Sanitation and Hygiene (WASH) practices between 2000-2016. We used the new World Health Organization (WHO)/UNICEF Joint Monitoring Program (JMP) service standards to assess progress in WASH coverage. We performed an age-disaggregated pooled linear probability regression analysis to explore the relationship between WASH practices and diarrhea and stunting. This was followed by a decomposition analysis to determine whether any changes in WASH practices have contributed to the changing prevalence of diarrhea and stunting in children under five years of age. We observed a significant increase in the coverage of safe drinking water and adequate sanitation facilities over the period. At the national level, the use of a basic water source increased from 18% in 2000 to 50% in 2016. Open defecation declined from 82% to 32% over the same period. However, in 2016 only 6% of households had access to a basic sanitation facility, and 40% of households had no handwashing facilities. In children aged 0-5 months, surface water use was associated with an increased probability of diarrhea. In children aged 0-5 months, surface water use was associated with an increased probability of diarrhea. The reduction of surface water use between 2000-2016 explained 6% of the decline in diarrhea observed among children aged 0-5 months. Open defecation was significantly associated with an increased probability of diarrhea among children aged 0-5 months and 24-59 months and an increased probability of stunting among children aged 6-11, 12-23, and 24-59 months. In children aged 6-59 months, 7-9 % of the reduction in stunting between 2000 and 2016 was attributable to the reduction in open defecation over this period. Despite progress, improvements are still needed to increase the WASH standards and coverage in Ethiopia. Our findings showed that improvements in water and sanitation only modestly explained reductions in diarrhea and stunting.

1. Introduction

Inadequate safe water supply and poor sanitation and hygiene continue to be leading environmental causes of disability-adjusted life years (DALYs)[1] and important risk factors for diarrheal mortality globally[2]. Diarrhea is one the most frequent infections during childhood and is the result of a gastro-intestinal infection, spread through contaminated food or drinking water, or from person to person as a result of poor WASH practices[3]. In 2017, it was estimated that diarrhea accounts for approximately 8% of all deaths among children under five years worldwide[4], with a much higher burden of disease for those living in South Asia and sub-Sahara Africa[5]. In Ethiopia, diarrheal disease remains a major public health concern. In 2016, estimates revealed a prevalence of diarrheal disease of 12% and that 13% of child deaths were attributable to diarrhea[6]. A more recent systematic review of diarrheal prevalence studies (14 of the 31 studies published from 2016 onwards) in Ethiopia has however, revealed a prevalence of diarrheal disease of 22%[7], suggesting that the proportion of under-five mortality attributable to diarrhea may have increased.

The high burden of infectious diseases such as diarrhea is also a major contributor to the high rates of stunted growth observed in low-income settings[8]. Globally stunting (length/height-for-age z-score[LAZ/HAZ]< -2 standard deviations [SD]) is the most prevalent form of chronic undernutrition, with current estimates revealing that more than one in five children under five years of age worldwide are stunted, but with much higher rates in low-and middle-income countries (LMICs)[9]. Ethiopia, in particular, remains a country with a high burden of childhood undernutrition, with recent estimates revealing a stunting prevalence of 37%[10]. This is despite notable declines in the prevalence of stunting between 2000 (58%)[11] and 2016 (38%)[6]. The short- and long-term outcomes associated with stunting include higher mortality, lower educational attainment, and reduced adult economic output[12].

A positive reinforcement loop exists between childhood undernutrition and diarrheal disease[12,13]. Undernutrition is related to immunosuppression and an increased predisposition to infections such as diarrhea. In turn, diarrhea leads to undernutrition via reduced appetite, malabsorption and ultimately a reduced energy intake[14-16]. Indeed, findings from observational studies suggest that repeated diarrhea incidence in the first two years of life increases the risk of being stunted at two years of age [17-19]. Given the interrelationship between these two outcomes, identifying factors and appropriate interventions targeting stunting and/or diarrhea could potentially confer mutual benefits. The WHO conceptual framework on childhood stunting[20] postulates a multisectoral approach in order to achieve maximum benefit in tackling this form of malnutrition. The framework presents the proximal causes (poor quality diet and infections such as diarrhea) and the community and societal factors that contribute to these proximal causes including poor WASH practices.

The positive effect of improved WASH practices and a reduced diarrhea incidence in young children, especially in those residing in LMIC, is well known and has been reported in several meta-analyses[21-23]. These findings have led to the hypothesis that, via the positive effect on diarrhea risk, WASH may confer benefits to linear growth. Observational studies have shown support for an association between WASH practices and child height[24-28] and a meta-analysis of five WASH trials revealed a small but significant impact on HAZ at five years.[29] More recently however, the publication of the two large WASH Benefits trials[30,31] and the SHINE trial[32] have cast doubt on this association, with all three trials observing no effect on linear growth (LAZ) at 18-24 months of age, with the authors concluding that elementary household level WASH interventions are unlikely to improve child growth.[33]

While the evidence regarding the efficacy of WASH interventions on reducing childhood stunting is equivocal, the benefits of promoting improved WASH practices remains important for child nutrition (e.g., wasting and micronutrient deficiency), health and development. The Sustainable Development Goals (SDGs) recognize WASH as central to development with SDG 6 calling for universal access to safe and adequate water, sanitation, and hygiene for all by 2030[34]. Consequently, promoting appropriate WASH practices will help achieve sustainable development in general[35] and WASH coverage targets included in Ethiopia's Growth and Transformation Plan II[36] and the Ethiopian National Food and Nutrition Policy[37] in particular. Furthermore, the recent national level estimates of diarrhea (12%) and stunting (38%) reported in the EDHS 2016[6], highlight the fact that undernutrition and diarrhea still represent a significant burden for children under five years and that identification of risk factors to reduce this burden is warranted.

2. Objectives

Considering the importance of WASH to health and overall wellbeing and in alignment with the priorities within the national landscape, the study aimed to:

1. investigate the progress made in WASH practices between 2000-2016, and
2. determine whether any changes in WASH practices have contributed to the changing prevalence of diarrhea and stunting in children under five years of age in Ethiopia.

3. Methods

3.1 Data Source

This report uses data from the four rounds (2000, 2005, 2011, and 2016) of the EDHS [6,11,38,39]. These surveys are standardized and collect nationally and regionally representative cross-sectional data for households, children under five years of age, women of reproductive age, and men. The EDHS uses a stratified two-stage cluster sampling method to select participants. In the first stage, each region is stratified as urban or rural and within these strata, enumeration areas are selected using probability proportional to size sampling. Enumeration areas are geographic areas that cover an average of 181 households. In the second stage, households are randomly selected from each enumeration area. For this analysis, we used the household and child datasets of the EDHS. The household dataset provides information on household characteristics including the source of water, type of toilet facility, housing type, and asset ownership. The child dataset, for children aged 0-59 months, contains information on child health (diarrhea, acute respiratory tract infections, and vaccination history) and nutrition (stunting, wasting, underweight, and infant and young child feeding). The child dataset also provides information on maternal and paternal education attainment, occupation, employment status as well as maternal anthropometric data. Table 1 presents the number of households and children included in each round of the EDHS. We used the household dataset to determine trends in WASH practices and the child dataset to test associations between WASH practices and diarrhea and stunting.

Table 1. Number of Households and Children (0-59 months) Included in Each Round of the EDHS

	2000	2005	2011	2016
Households	14,642	13,721	16,702	16,650
Children 0-59 months	10,449	4,586	10,282	10,552

3.2 Trends in WASH Practices: WASH Indicators

We used the new WHO/UNICEF JMP WASH service standards[40] to describe WASH practices in Ethiopia. These new WASH service standards (described in Table 2) build on the widely used improved/unimproved facility type classification and introduce additional indicators to reflect higher standards[40]. In Ethiopia, data were not available to construct 'safely managed water' and 'sanitation standards'. Consequently, the highest service standards used in this analysis are 'basic drinking water facilities' and 'basic sanitation facilities'. A 'basic drinking water source' refers to 'drinking water from an improved source, with collection time, not more than 30 minutes for a round trip'. A 'basic sanitation facility' is 'an improved toilet facility that is not shared with other households'. The highest hygiene service standard is 'basic' which requires 'the availability of a handwashing facility with soap and water on the premises'.

Table 2. WHO/UNICEF JMP WASH Standards

Drinking Water Standards	
Safely Managed	Drinking water from an improved water source that is located on premise, available when needed, and free from fecal and priority chemical contamination.
Basic	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing.
Limited	Drinking water from an improved source which collection time exceeds 30 minutes for a round trip, including queuing.
Unimproved	Drinking water from an unprotected dug well or unprotected spring
Surface Water	Drinking water directly from a river, dam lake, pond, stream, canal or irrigation canal.
Improved water sources include: piped water, boreholes or tube wells, protected dug wells, protected spring, rainwater, and packaged or delivered.	
Sanitation Standards	
Safely Managed	Use of improved facilities that are not shared with other households and where excreta are safely disposed of *in situ* or transported and treated off site.
Basic	Use of improved facilities that are not shared with other households.
Limited	Use of improved facilities shared between two or more households.
Unimproved	Use of pit latrines without slab or platform, hanging latrines or bucket latrines.
Open Defecation	Disposal of human feces in fields, forests, bushes, open bodies of water, other open spaces or with solid waste.
Improved facilities include: flush/pour flush piped to sewer system, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets or pit latrines with slab.	
Hygiene Standards	
Basic	Availability of a handwashing facility on premise with soap and water.
Limited	Availability of a handwashing facility on premise without soap and water.
No Facility	No handwashing facility on premise.

Handwashing facilities may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs of basins designated for handwashing. Soap includes bar soap, liquid soap, powder detergent and soapy water but does not include ash, soil, sand, or other handwashing agents.

3.3 Relationship Between WASH Practices and Stunting and Diarrhea

3.3.1 Exposures

As data pertaining to hygiene practices were only available in 2011 and 2016, the analysis to assess the association between WASH practices with stunting and diarrhea focused on drinking water and sanitation practices only. Specifically, the exposures of interest were the use of surface water as a drinking source and the practice of open defecation.

3.3.2 Outcomes

The outcomes of our regression analysis were diarrhea and stunting. Diarrhea was defined as the percentage of children with diarrhea (three or more loose stools per day) at any time in the two weeks preceding the survey. Stunting was defined as HAZ/LAZ below -2 SD of the median based on the WHO 2006 Child Growth Standards[41].

3.3.3 Covariates

The relationships between exposures and outcomes were adjusted for covariates which were selected based on the Lancet framework for action (Black et.al)[42] or previously reported associations with the outcome variables[7,8,13,43-49]. These included maternal and paternal education, household wealth, maternal employment, child age, child sex, residence, region and survey round (see Table A4 in the annex for a description of these variables).

3.4 Statistical Analysis

3.4.1 Trends in WASH Indicators and Diarrhea and Stunting

Trends in WASH practices, diarrhea and stunting were explored using data from the four rounds of the EDHS. To account for the cluster sampling used in the EDHS, sampling weights were applied to estimate the prevalence of WASH practices, stunting and diarrhea across survey rounds. To explore changes in WASH practices between 2000-2016, stacked area plots were produced at the national and regional level. Additionally, equity plots documenting the temporal changes in WASH practices by wealth quintile and place of residence (urban versus rural) were produced.

3.4.2 Relationship Between WASH Practices and Stunting and Diarrhea

To account for the timing of growth faltering in childhood [11], we made an *a priori* decision to investigate the relationship between WASH practices and stunting and diarrhea using an age-disaggregated approach. Accordingly, stratified analyses were performed in the following age ranges: 0-5 months, 6-11 months, 12-23 months, and 24-59 months. In addition, we made an *a priori* decision to include in the analysis, for households with more than one child below 59 months, only the youngest child with anthropometric data. Within the age groups listed above, we performed a regression decomposition analysis, which seeks to determine the contribution made by changes in the mean levels of exposures over time to changes in outcomes. Specifically, the decomposition analysis sought to reveal whether changes in surface water usage and open defecation practices identified in the previous step, contributed to observed reductions in diarrhea and stunting between 2000 and 2016. As has been done in other decomposition analyses, we initially examined the relationship between diarrhea and stunting with the exposures by pooling data from all rounds of the EDHS and performing a linear probability regression analysis (adjusted for the covariates listed above and with robust standard errors to account for clustering). A key assumption underpinning the use of a decomposition analysis which is based on a pooled regression model, is that coefficients are time invariant (i.e., the magnitude and direction of coefficients are stable over time). In order to test this assumption, we performed a series of Chow tests, which test whether coefficients differ significantly over time. We did not find support for the coefficients being time-varying and we therefore followed the approach by Headey[44,45,47] and performed a simple decomposition analysis for exposures that were associated with outcomes in the regression analysis at the 10% level of significance. The decomposition equation takes the form of

$$\Delta\overline{N}_{i,t} = \beta(\bar{X}_{t=k} - \bar{X}_{t=1})$$

where t=1 represents the EDHS 2000 sweep, t=k is the 2016 EDHS and β and $\bar{X}$ represent the regression coefficient and sample mean, respectively, for a given variable. The decomposition then entails multiplying observed changes in the means of each variable over time by its regression coefficient. Doing so gives the predicted change in the probability of stunting or diarrhea from each change in a selected variable and thus shows the estimated contributions of each variable to changes in stunting and diarrhea. For example, let's assume that the practice of open defecation decreased by 20% between 2000 and 2016 and that the regression coefficient, in a model with diarrhea as the outcome, comparing the practice of open defecation versus no open defecation is 0.05. If we multiply these two numbers, we will get 1%, indicating that the changes in the practice of open defecation accounts for 1% decline in diarrhea. If diarrhea declined by 5% over the same period, changes in the prevalence of basic toilet facilities would therefore represent a 20% contribution to the reduction in diarrhea prevalence. Data management and statistical analysis were conducted in Stata Version 14.0.

4. Results

Data from 61,715 households across the four rounds of the EDHS (2000-2016) were used to describe trends in WASH practices. A total of 6,373, 2,833, 6,832 and 6,323 children aged 0-59 months (n= 22,361) from the 2000 EDHS, 2005 EDHS, 2011 EDHS, and 2016 EDHS, respectively were included in the regression analysis. After exclusion of children with missing values for outcomes, exposures and covariates, 20,509 children were included in the diarrhea model and 20,408 were included in the stunting model. Figure A1 in the annex shows criteria used to include children in the regression analysis. The mean (SD) child age was 22(15) months, and 51% of the children were male. The mean (SD) maternal age was 29(7) years.

4.1 Progress in Drinking Water Coverage

Figure 1 below and Table A1 in the annex show the progress in water coverage between 2000 and 2016. In 2016, half (50%) of households in Ethiopia used a basic water source (an improved source that has a collection time of no more than 30 minutes for a round trip). This figure represents an increase from 2000, when only 18% of households used a basic water source. Despite this progress in 2016, 15% of households spent more than 30 minutes collecting water (limited drinking water ladder), 24% used an unimproved water source, and 11% used surface water. While improvements in water service standards were seen across all regions, regional differences in coverage were observed. For example, in 2016, the use of a basic water source was much larger than the national average in Addis Ababa (98%), Dire Dawa (81%), Harari (75%), and Gambela (75%). In contrast, in Somali, only 32% of households used a basic water source, and 22% used surface water. Surface water use was also high in Afar (22%).

4.2 Progress in Sanitation Coverage

Figure 2 below and Table A2 in the annex show national and regional trends in sanitation. While some progress has been made since 2000, large gaps remain in coverage of sanitation facilities. In 2016, only 6% of Ethiopian households used a basic sanitation facility, compared to no households in 2000. Additionally, 9% of households used an improved toilet facility that is shared with two or more households (limited sanitation ladder). Open defecation showed a significant decline between 2000 and 2016. In 2000, 82% of households practiced open defecation compared to 32% in 2016. Similar to water coverage, regional differences in the type of sanitation facilities used were observed. The largest percentages of households that used basic and limited sanitation facilities were in Addis Ababa (basic: 23%, limited: 56%) and Dire Dawa (basic:24%, limited: 38%), both city administrations. The percentage of households that still practiced open defecation was highest in Afar (64%), Somali (61%), and Tigray (52%). By contrast, in Southern Nations Nationalities and Peoples Region (SNNPR), open defecation declined from 81% in 2000 to 19% in 2016.

Figure 1. Changes in Water Coverage in Ethiopia Between 2000 and 2016: National and Regional Levels

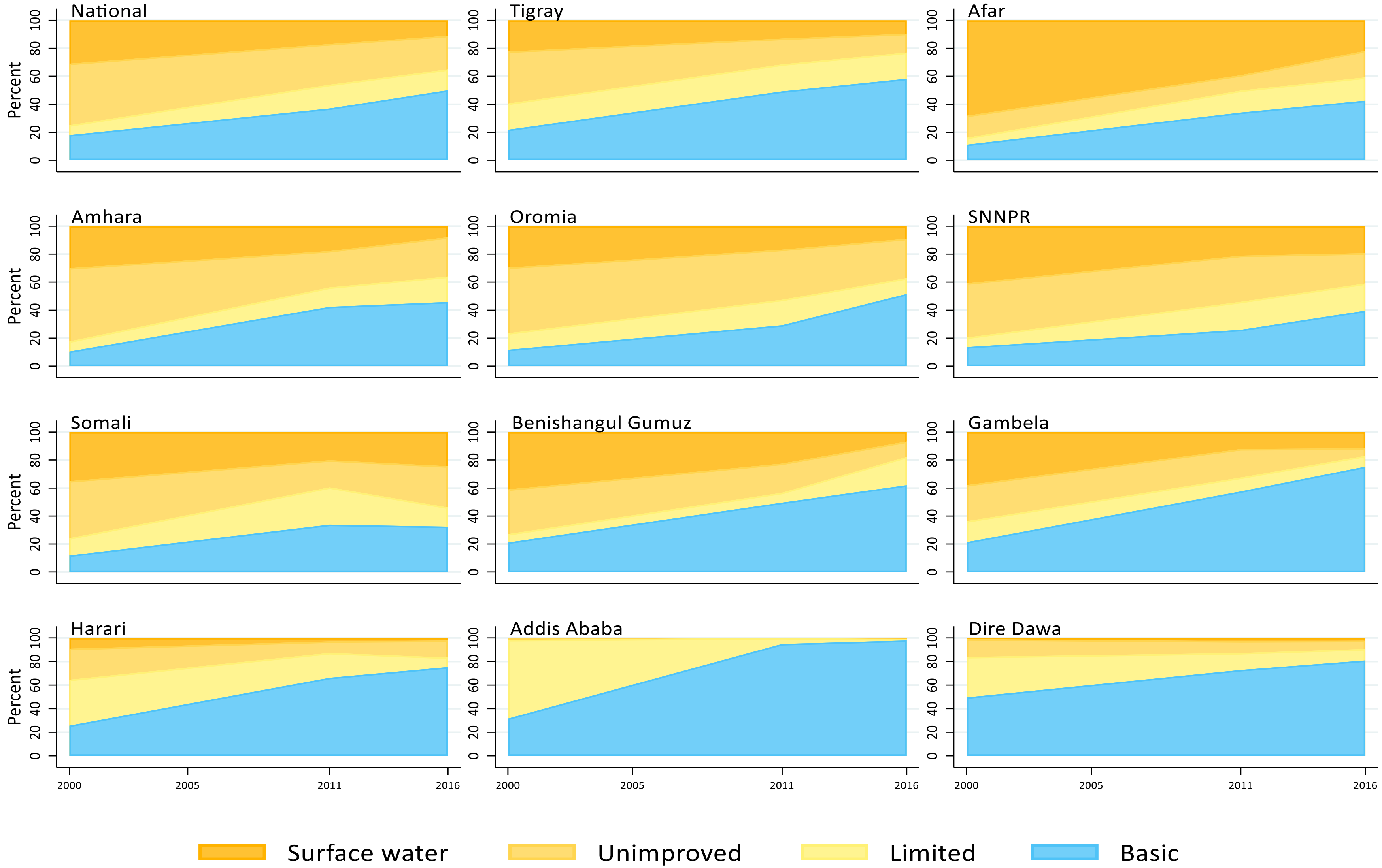


Figure 2. Changes in Sanitation Coverage in Ethiopia Between 2000 and 2016: National and Regional Levels

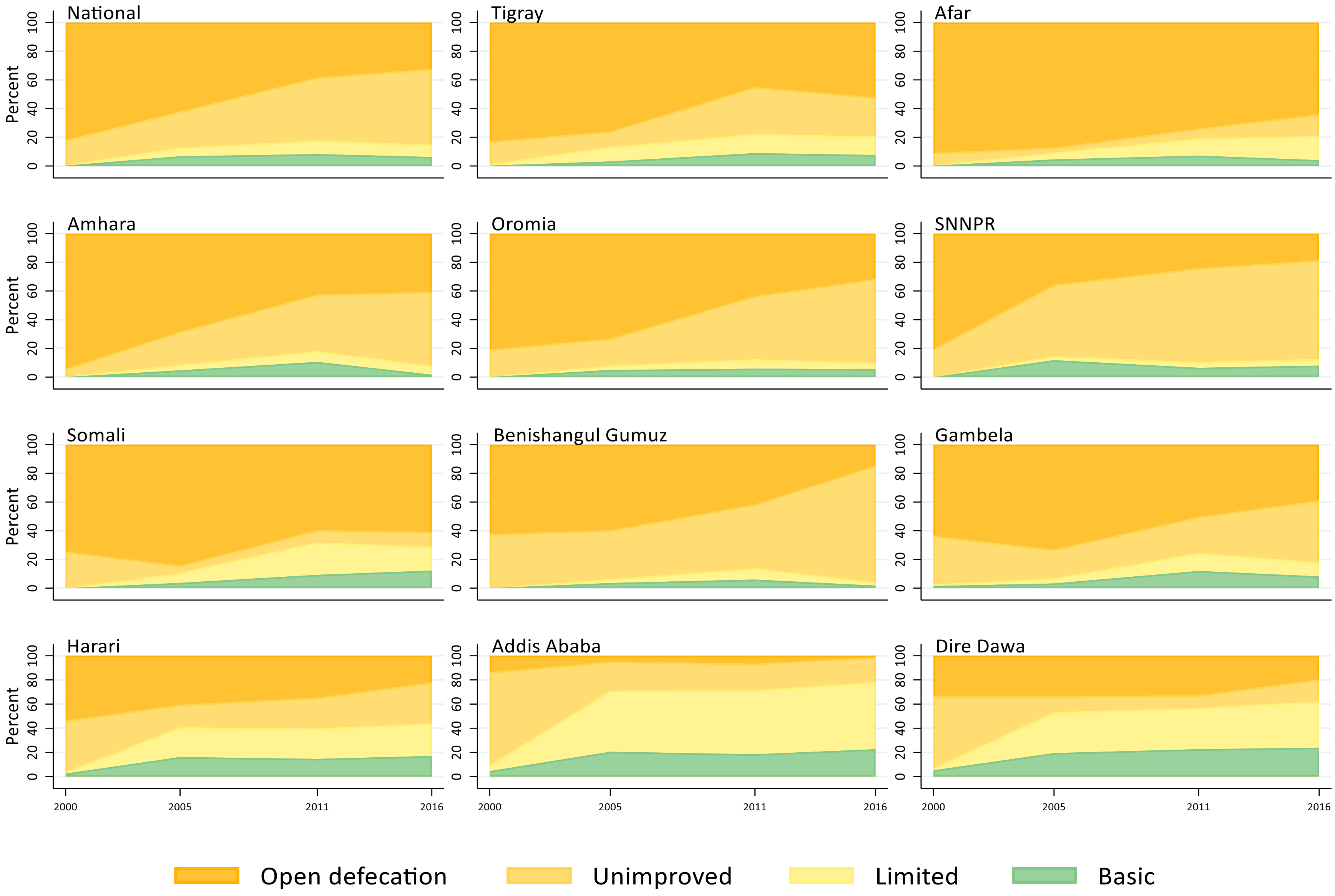
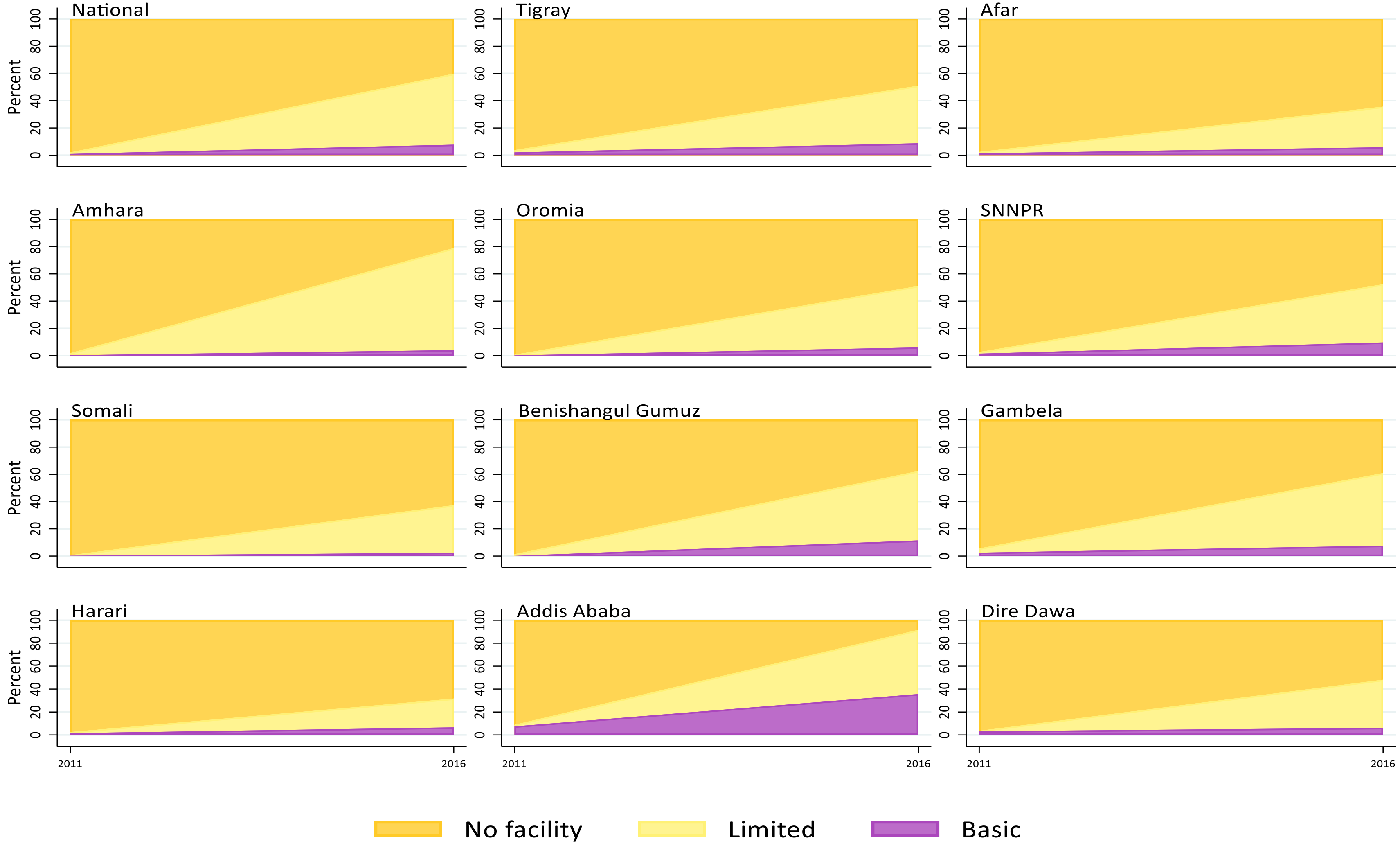


Figure 3. Changes in Hygiene Coverage in Ethiopia Between 2011 and 2016: National and Regional Levels



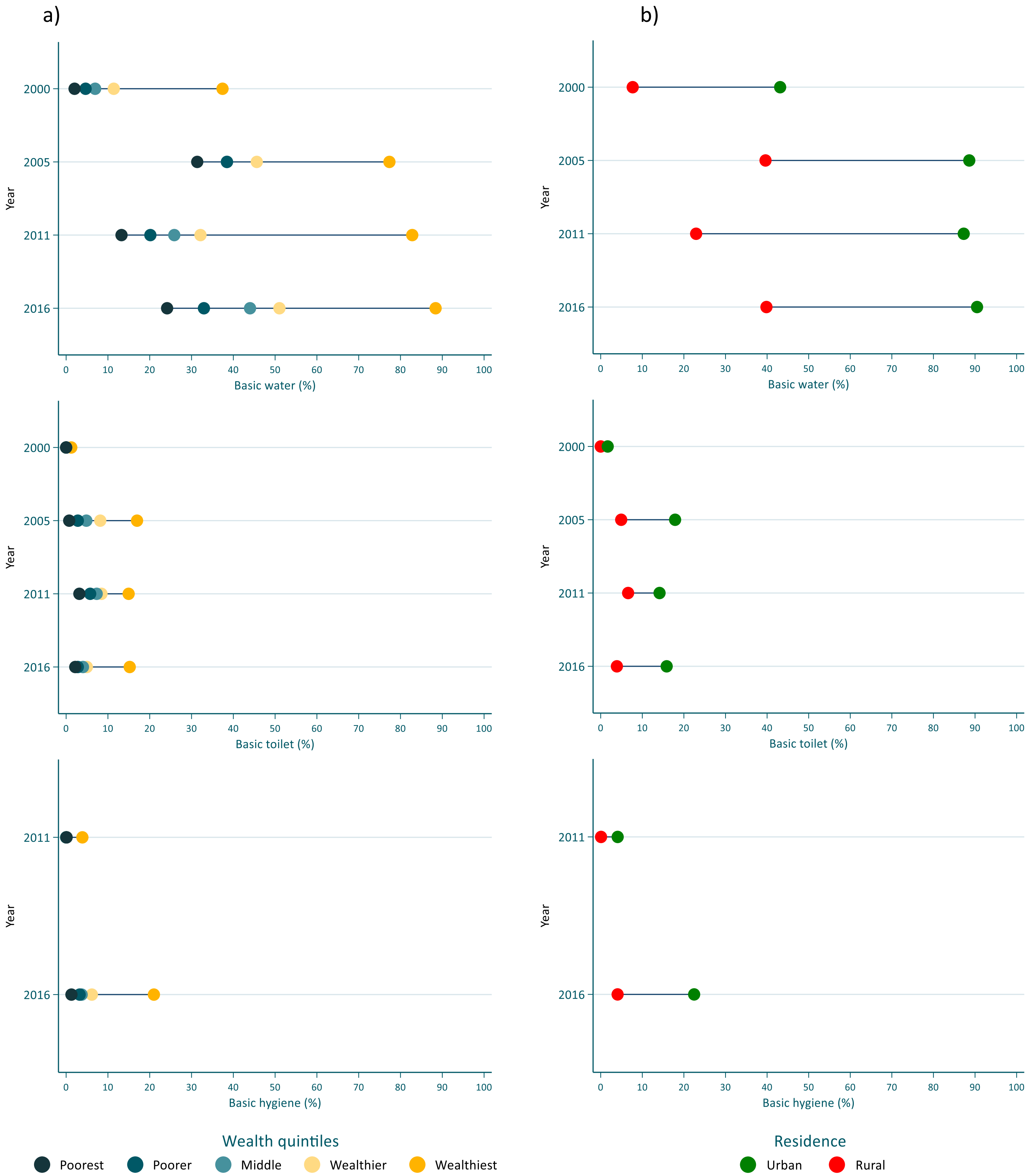
4.3 Progress in Hygiene Coverage

The use of basic handwashing facilities is low in Ethiopia. In 2016, only 8% of households had a handwashing facility with soap and water available on the premises (Figure 3 above and Table A3 in the annex). Additionally, 52% of the households used a limited hand washing facility, and 40% had no handwashing facility on the premises. In some regions, close to 70% of households did not have any handwashing facilities (Harari 68%, Somalia 63%, Dire Dawa 52 %, Tigray 49 %, Afar 64%, Oromia 49%). In all regions except Addis Ababa and Benishangul Gumuz, less than 10% of the households had a handwashing facility with soap and water. Addis Ababa had the highest proportion of households with basic hygiene facilities, at 36%. Percentages used to construct Figures 1-3 are included in Tables A1-A3 in the annex.

4.4 Trends in Inequalities in Basic WASH Standard Coverage

Figure 4 shows trends in coverage of basic water, basic sanitation, and basic hygiene facilities by wealth and residence. In general, the use of a basic water facility increased over time across all wealth quintiles. However, the change was much greater in the wealthiest quintile, increasing from less than 40% of households in 2000 to just under 90% in 2016. As such, the gap between the poorest and the richest households (represented by the width of the bars shown in Figure 4) increased between 2000-2016. When disaggregated by place of residence, the proportion of households using a basic water facility was consistently greater in urban areas and this difference increased between 2000-2016. In both urban and rural settings, the proportion of households using a basic water facility increased markedly between 2000-2005, with little change observed thereafter. Access to basic sanitary facilities was consistently higher among the wealthiest households compared to the poorest households, though these differences were small compared to differences seen for access to basic water facilities. As was observed for basic water facilities, the greatest increases in the proportion of households, across the quintiles, was observed between 2000-2005, with a plateauing thereafter. As expected, wealthier households and households in urban areas had more access to basic hygiene facilities compared to poorer households and households located in rural areas, respectively and this difference increased between 2011-2016.

Figure 4. Change Over Time in Basic Water, Basic Sanitation and Basic Hygiene Coverage by Wealth and Residence



4.5 Trends in Diarrhea and Stunting

Table 3 presents age-disaggregated changes in the prevalence of diarrhea and stunting between 2000 and 2016. Overall, the prevalence of both diarrhea and stunting declined during this period. Across all EDHS rounds, the prevalence of diarrhea was lowest in the youngest infants (0-5 months). In all children aged 0-59 months, stunting declined by 22% between 2000 (55%) and 2016 (33%). The prevalence of stunting was lowest in infants aged 0-5 months and increased with age; with the highest prevalence in children aged 24-59 months.

Table 3. Age-Disaggregated Change in the Prevalence of Diarrhea and Stunting (%)

Age	Diarrhea[1]					Stunting[2]				
	2000	2005	2011	2016	Change (2016-2000)	2000	2005	2011	2016	Change (2016-2000)
0-5 months	15	17	11	6	-9	21	17	13	13	-8
6-11 months	39	31	25	23	-16	35	31	23	17	-18
12-23 months	38	30	23	19	-19	61	54	45	39	-22
24-59 months	23	17	13	12	-11	70	62	57	49	-21
0-59 months	29	22	17	15	-14	55	48	42	33	-22

[1]Percentage of children with diarrhea (three or more loose stools per day) at any time in the two weeks preceding the survey.

[2]Percentage of children with HAZ/LAZ below -2 SD of the median based on the WHO 2006 Child Growth Standards.

4.6 Relationship Between WASH Practices and Diarrhea and Stunting

Table 4 presents estimates for the age-disaggregated association between WASH practices, diarrhea, and stunting, obtained from the pooled regression models. We also present estimates from the model with all children aged 0-59 months. Trends in the modifiable predictors included in our decomposition analyses are shown in Tables A5 to A9 in the annex.

4.6.1 Children Aged 0-5 Months

Among children aged 0-5 months, the use of surface water was associated with a 4% (95% CI: 1%, 7%, p=0.018) increase in the probability of diarrhea (Table 4). Similarly, children who lived in households that practice open defecation had a 3% (95% CI: 0, 6%, p=0.087) higher probability of diarrhea. In contrast, neither household surface water use nor open defecation was associated with the probability of stunting. Decomposition analysis showed that the reduction of surface water use and open defecation between 2000 and 2016 respectively explained 6% and 7% of the decline in diarrhea in this age group (Figure 5).

Table 4. Water, Sanitation and Child Stunting and Diarrhea in Pooled Regression Models (n=20,141)[1]

	N	Surface Water Beta [95% CI]	*p*	Open Defecation Beta [95% CI]	*p*
Diarrhea					
0-5 months	2996	0.04 [0.01,0.07]	0.018	0.03 [-0.00,0.06]	0.087
6-11 months	3054	-0.01 [-0.05,0.03]	0.707	-0.01 [-0.05,0.03]	0.700
12-23 months	5562	0 [-0.03,0.03]	0.857	0 [-0.04,0.03]	0.869
24-59 months	8897	-0.01 [-0.03,0.01]	0.220	0.03 [0.01,0.05]	0.012
0-59 months	20509	0 [-0.02,0.01]	0.816	0.02 [-0.00,0.03]	0.063
Stunting					
0-5 months	2988	0.02 [-0.01,0.05]	0.206	0.01 [-0.02,0.04]	0.489
6-11 months	3045	-0.01 [-0.04,0.03]	0.631	0.04 [-0.00,0.07]	0.057
12-23 months	5534	0.01 [-0.03,0.04]	0.709	0.03 [-0.00,0.07]	0.056
24-59 months	8841	0.01 [-0.02,0.03]	0.663	0.03 [-0.00,0.06]	0.064
0-59 months	20408	0 [-0.01,0.02]	0.729	0.03 [0.01,0.05]	< 0.001

[1] Beta coefficients (95% CI) are estimated using linear probability regression model with a robust variance estimator. Models were adjusted for maternal education, paternal education, maternal employment, wealth, region, residence, age, sex and survey round.

4.6.2 Children Aged 6-11 Months

In children aged 6-11 months, use of surface water and open defecation were not significantly associated with diarrhea. However, use of open defecation was associated with a 4% (95% CI: 0%, 7%, p=0.057) increase in the probability of stunting and the reduction of open defecation between 2000-2016 explained 9% of the total decline in stunting between 2000 and 2016 (Figure 6).

4.6.3 Children Aged 12-23 Months

Similarly, in children aged 12-23 months, both surface water use and open defecation were not associated with the probability of diarrhea. Open defecation was associated with an increase in the probability of stunting (β: 3%, 95% CI: -0%, 7%, p=0.056). The decline in open defecation between 2000-2016 explained 7% of the overall decline in stunting (Figure 6).

4.6.4 Children Aged 24-59 Months

In children aged 24-59 months, surface water use was not associated with the probability of diarrhea or stunting. However, the practice of open defecation was associated with a 3% (95% CI: 1%, 5%, p=0.012) increase in the probability of diarrhea and stunting (β: 3%, 95% CI:0%, 6%, p=0.064). The decline in open defecation between 2000-2016 explained 8% and 7% of the decline seen in diarrhea and stunting respectively.

4.6.5 Children Aged 0-59 Months

In the model that included all children (aged 0-59 months), surface water use was not associated with diarrhea or stunting at the 10% level of significance. However, open defecation was associated with a decreased probability of stunting (β: 3%, 95% CI:1%, 1%, $p<0.001$). A decline in open defecation explained 7% of the decline in stunting (between 2000 and 2016) among children aged 0-59 months.

Figure 5. Estimated contribution of the decline in surface water use and the practice of open defecation between 2000-2016 to the decline in diarrhea observed over the same period

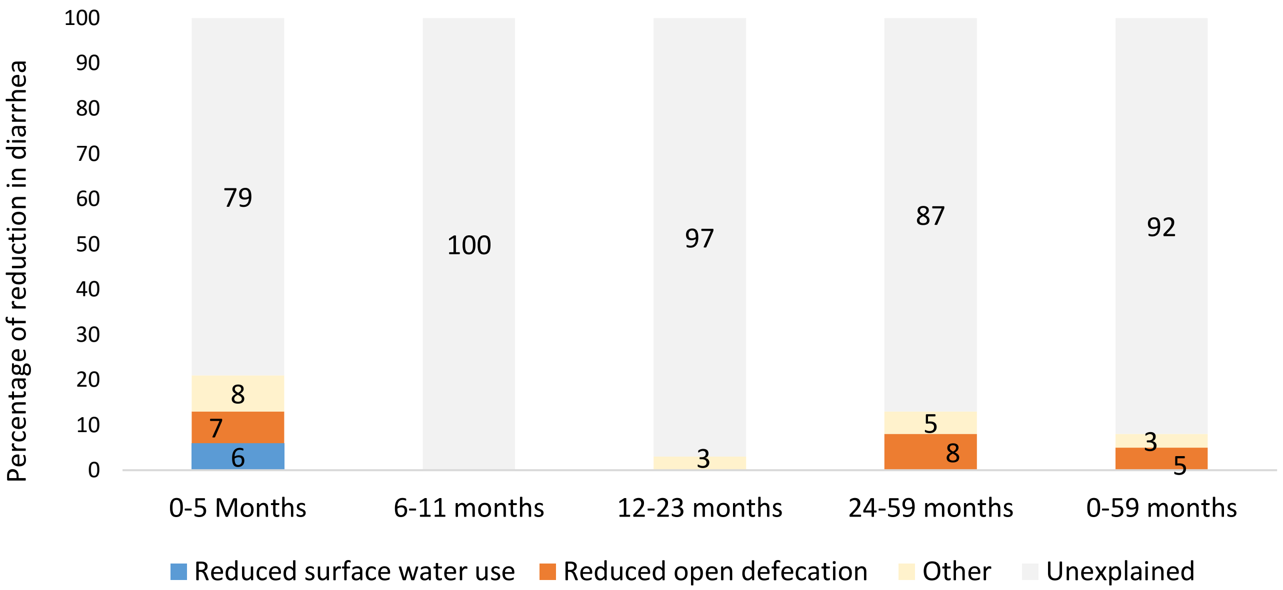
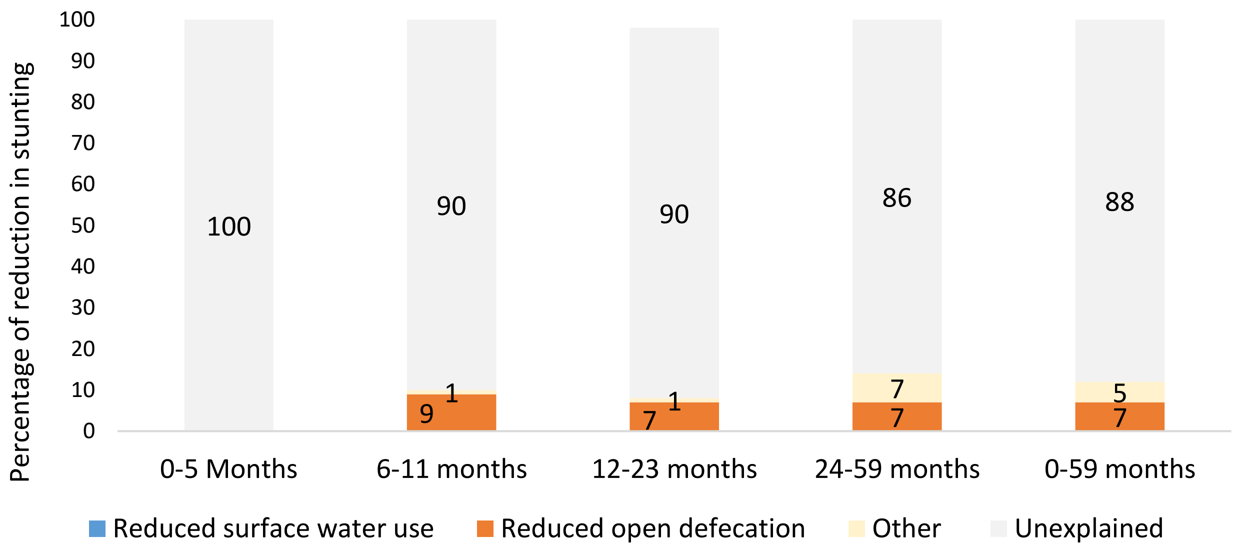


Figure 6. Estimated contribution of the decline in surface water use and the practice of open defecation between 2000-2016 to the decline in stunting observed over the same period



5. Conclusion and Recommendations

Summary of the Findings

This report utilized data from multiple rounds of the EDHS to derive trends in WASH practices between 2000-2016 and relate these trends to changes in the prevalence of stunting and diarrhea among Ethiopian children aged 0-59 months. Between 2000-2016, the prevalence of stunting in children under five years of age (included in our analysis) decreased from 55% to 33%, with the biggest reduction in prevalence observed in children aged 12-23 months (61% in 2000 to 39% in 2016; a 22% change). Reductions in the prevalence of diarrhea were also observed, declining from 29% to 15% in children under five years of age, again with the largest reduction observed in children aged 12-23 months (38% in 2000 to 19% in 2016; a 19% change). We observed a significant increase in the coverage of safe and adequate drinking water and sanitation facilities over the period. To illustrate, at the national level, the use of a basic water source increased from 18% to 50% between 2000 and 2016, while open defecation declined from 82% to 32%. These improvements in WASH practices contributed to some of the observed reductions in the probability of experiencing diarrhea and stunting. The reduction of surface water use over this period explained 6% of the decline in diarrhea observed among children aged 0-5 months. In children aged 0-59 months, 7% of the reduction in stunting between 2000 and 2016 was attributable to the reduction in open defecation over this period. Despite these positive results, the finding that only 6% of households had access to basic sanitation facilities and 40% of households had no handwashing facilities at all, means that more efforts are still required to improve WASH coverage in Ethiopia.

Interpretation of the Findings

We present original findings regarding the change in age-disaggregated diarrhea prevalence in children under five years of age. A recent systematic review of 31 studies published between 2003-2017 estimated the prevalence of diarrhea in children under five years at 22%[7]. Our analysis, by estimating the prevalence in age-disaggregated groups, provides greater insight into the burden of, and risk factors associated with diarrhea in early childhood. We observed the lowest prevalence of diarrhea in those aged 0-5 months. Thereafter, we reveal a pattern of an increasing burden of diarrhea around the time of the introduction of complementary feeding at six months and a subsequent reduction after 12 months. Taken together, these findings highlight the benefits of exclusive breastfeeding and the increased risk of diarrhea associated with the transition to complementary feeding, likely a consequence of the consumption of contaminated food and water as a result of poor WASH conditions. This finding of an increasing burden of diarrhea at this age has been reported in Ethiopia [6,11,50] and in other LMIC settings[51]. In light of the above, we observed an unexpected association with the probability of diarrhea and the type of water source (surface water) among children aged 0-5 months. This finding is surprising since we would expect the use of surface water to increase the risk of diarrhea once complementary feeding starts after 6 months. The lack of association between diarrhea and surface water use in older children seen in this analysis supports findings from recent WASH trials conducted in Bangladesh[52], Zimbabwe,[32] and Kenya[31] which observed little effect of water treatment interventions on diarrhea incidence in children. In terms of sanitation practices, we observed that 7% and 8% of the estimated decline in diarrhea among children aged 0-5 months and 24-59 months respectively, was attributed to the reduction in open defecation. This observed stronger association between sanitation and diarrheal incidence compared to water usage has also been reported in an analysis of data from 217 Demographic and Health Surveys[53].

Our finding of an overall reduction in the stunting prevalence in children under five years of age in Ethiopia has been reported elsewhere[50,54,55]. However, the age-disaggregated analysis has enabled us to also identify a changing dynamic of age-related stunting prevalence over time. For example, in 2000, the prevalence of stunting increased immediately after birth (0-5 months) and continued to increase thereafter. In 2016 however, in addition to numbers being lower overall, the time at which the stunting prevalence increased rapidly appears to be later than in 2000, with little change in stunting prevalence in infants aged 0-5 months (13%) and 6-11 months (17%), followed by a rapid rise between 12-23 months (39%). This delay in growth faltering may be attributable to improved breastfeeding practices in the first six months and improved complementary feeding practices at six to 12 months which may have reduced the exposure to infections as a result of poor WASH conditions.

In our analysis we did not find an association between surface water use and stunting. However, open defecation was associated with an increased probability of stunting across the age groups. A lower risk of stunting with improved sanitation but not improved water has been reported for Ethiopian children elsewhere[48]. The mixed findings between WASH practices and stunting observed in our study are mirrored in the mixed evidence reported in the literature. Whilst observational studies have reported positive associations between WASH practices and linear growth in childhood[24-27], results from three recent randomized control trials observed no effect of WASH interventions on LAZ-scores at 18-24 months of age[30-32]. As mentioned earlier, large improvements have been made in sanitation coverage in Ethiopia (Figure 2), with a reduction in the practice of open defecation from 82% in 2000, to 32% in 2016. Our findings showed that this reduction contributed to 9% and 7% of the decline in stunting seen among children aged 6 to 11 months, and 12 to 59 months, respectively. Since one proposed pathway between poor WASH practices and stunting is via increase in the incidence of diarrhea, our findings of increased probability of diarrhea and stunting with open defecation are expected.

Despite significant improvements in water and sanitation coverage, our study revealed that these were only associated with modest reductions in diarrhea and stunting in Ethiopian children age 0-59 months. Results from other decomposition analyses have also reported only modest benefits[44,45]. Furthermore, other studies such as the Malnutrition and the Consequences for Child Health and Development (MAL-ED) birth cohort[56] and WASH Benefit and SHINE trials [33] have found little to no effects of improved WASH and environmental enteric dysfunction and on stunting and diarrhea. A possible reason for the lack of relationship is that neighborhood WASH practices are more important than household practices for the reduction of environmental fecal contamination[57]. However, in a supplementary analysis replacing household WASH practices with community practices, this lack of association persisted (data not shown). In light of the modest results of improvements in WASH on diarrhea and stunting, there have been calls for research to identify interventions, labeled 'Transformative WASH', that radically reduce fecal contamination in the household environment in LMIC[33]. Proposed interventions may include: high community coverage of improved sanitation facilities[58], complete separation of animal feces from people's living environments[59,60], continuous and convenient access to uncontaminated water[61] and reductions in fecal contamination on surfaces where young children crawl and play[62]. Given that in 2016, 40% of households had no hygiene facilities, 53% rely on unimproved sanitation facilities, and about 35% of households rely on unimproved water sources or surface water, much more work is needed to increase coverage of even basic WASH services across Ethiopia.

Strengths and Weaknesses

We have utilized nationally representative data to identify the contributions made by WASH practices to reductions observed in diarrhea and stunting. We constructed age-disaggregated regression models which have several benefits. Firstly, such an approach has the benefit of being able to identify differential contributions made by variables in specific age periods and thus periods in which intervening on a particular variable may be more advantageous. For example, infants under two years represent an age group of particular interest, as most growth faltering takes places in the first 1000 days of life. Secondly, because age-disaggregated models respect the changing age dynamics of growth faltering observed across childhood[63], they are less likely to underestimate the effects of any factor on stunting. In terms of limitations, the EDHS relies predominantly on self- or proxy report, which is therefore subject to recall bias and which may affect older children to a greater extent than younger ones. A reliance on recall may have also led to the underestimation of diarrhea prevalence, if for example, respondents omit to mention episodes of diarrhea that did not result in the utilization of medical care or medicines.

Conclusion

In conclusion, the current analysis has highlighted the progress made in WASH practices between 2000-2016 in Ethiopia and their contribution to the reduction in diarrhea and stunting in children under five years of age. While progress has been made, improvements are still needed to increase the WASH standards and to address pro-wealthy and pro-urban inequalities in WASH coverage. Our findings showed that improvements in water and sanitation only modestly explained reductions in diarrhea and stunting. More research is needed to identify other unexplored drivers of diarrhea and stunting in Ethiopia.

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Annex: Additional Tables

Table A1. Changes in Water Coverage in Ethiopia Between 2000 and 2016: National and Regional Levels (%)

	2000	2005	2011	2016
	National			
Basic	18	46	37	50
Limited	7	15	17	15
Unimproved	44	13	29	24
Surface water	31	26	17	11
	Tigray			
Basic	22	47	49	58
Limited	19	23	19	19
Unimproved	37	15	18	13
Surface water	22	13	13	9
	Afar			
Basic	11	21	34	43
Limited	5	22	16	17
Unimproved	16	9	11	19
Surface water	64	47	39	22
	Amhara			
Basic	10	44	42	46
Limited	7	18	14	18
Unimproved	52	12	26	28
Surface water	30	25	17	7
	Oromia			
Basic	12	47	29	52
Limited	12	14	18	11
Unimproved	47	9	36	28
Surface water	30	30	17	9
	Somali			
Basic	12	19	34	32
Limited	12	14	27	14
Unimproved	41	30	19	29
Surface water	35	36	18	22

	2000	2005	2011	2016
	Benishangul Gumuz			
Basic	21	43	50	62
Limited	6	14	7	20
Unimproved	32	7	21	11
Surface water	41	35	22	7
	SNNPR			
Basic	14	45	26	40
Limited	7	11	20	19
Unimproved	39	17	33	22
Surface water	41	26	20	19
	Gambela			
Basic	21	49	58	75
Limited	15	9	10	8
Unimproved	26	15	20	5
Surface water	38	27	12	10
	Harari			
Basic	26	67	66	75
Limited	39	17	21	8
Unimproved	26	9	10	14
Surface water	9	6	3	2
	Addis Ababa			
Basic	32	96	95	98
Limited	67	3	5	1
Unimproved	1	0	0	0
Surface water	0	0	0	0
	Dire Dawa			
Basic	50	74	73	81
Limited	34	19	14	10
Unimproved	15	1	10	7
Surface water	1	5	2	2

Table A2. Changes in Sanitation Coverage in Ethiopia Between 2000 and 2016: National and Regional Levels (%)

	2000	2005	2011	2016
	National			
Basic	0	7	8	6
Limited	0	6	10	9
Unimproved	17	25	44	53
Open defecation	82	62	38	32
	Tigray			
Basic	0	3	9	8
Limited	1	10	13	13
Unimproved	16	11	33	27
Open defecation	83	76	45	52
	Afar			
Basic	0	5	7	4
Limited	0	5	12	17
Unimproved	9	4	7	15
Open defecation	91	87	74	64
	Amhara			
Basic	0	5	11	2
Limited	0	4	8	6
Unimproved	5	23	39	52
Open defecation	94	68	43	41
	Oromia			
Basic	0	5	6	6
Limited	0	3	7	4
Unimproved	19	19	44	59
Open defecation	81	73	44	32
	Somali			
Basic	0	4	9	12
Limited	0	7	23	17
Unimproved	26	5	9	10
Open defecation	74	84	60	61

	2000	2005	2011	2016
	Benishangul Gumuz			
Basic	0	4	6	2
Limited	0	3	8	3
Unimproved	38	34	45	81
Open defecation	62	60	42	15
	SNNPR			
Basic	0	12	7	8
Limited	0	3	4	5
Unimproved	19	50	66	69
Open defecation	81	36	24	19
	Gambela			
Basic	2	3	12	8
Limited	1	4	13	10
Unimproved	34	20	25	43
Open defecation	64	73	50	39
	Harari			
Basic	3	16	15	17
Limited	1	25	25	27
Unimproved	42	19	26	34
Open defecation	54	41	35	22
	Addis Ababa			
Basic	5	21	19	23
Limited	5	50	53	56
Unimproved	77	24	22	20
Open defecation	14	5	7	1
	Dire Dawa			
Basic	5	20	23	24
Limited	2	34	34	38
Unimproved	60	13	10	18
Open defecation	34	34	33	20

Table A3. Changes in Hygiene Coverage in Ethiopia Between 2011 and 2016: National and Regional Levels (%)

	2011	2016
	National	
Basic	1	8
Limited	1	52
No facility	98	40
	Tigray	
Basic	2	9
Limited	2	42
No facility	96	49
	Afar	
Basic	1	6
Limited	1	30
No facility	98	64
	Amhara	
Basic	0	4
Limited	2	75
No facility	98	21
	Oromia	
Basic	0	6
Limited	1	45
No facility	99	49
	Somali	
Basic	0	3
Limited	0	35
No facility	99	63

	2011	2016
	Benishangul Gumuz	
Basic	0	12
Limited	1	51
No facility	99	38
	SNNPR	
Basic	2	10
Limited	1	43
No facility	97	48
	Gambela	
Basic	3	8
Limited	3	53
No facility	94	39
	Harari	
Basic	2	7
Limited	1	25
No facility	98	68
	Addis Ababa	
Basic	8	36
Limited	1	56
No facility	91	8
	Dire Dawa	
Basic	3	6
Limited	1	42
No facility	96	52

Table A4. **Description of Variables Used in the Analysis**

Variables	Definition
Diarrhea	Percentage of living children (0-59 months) with diarrhea (three or more loose stools per day) at any time in the two weeks preceding the survey.
Stunting	Percentage of children (0-59 months) with height/length-for-age z score below -2 SD of the median based on the WHO 2006 Child Growth Standards.
Type of drinking water	Percentage of households whose main source of drinking water is basic, limited, unimproved or surface water.
Type of sanitation	Percentage of households who use toilet facilities that are basic, limited, unimproved or open defecation.
Household Wealth	EDHS calculated Wealth quintiles: Lowest, Second, Middle, Fourth, and Highest.
Maternal education	Percentage of women who attended any level of education. Categorized as no education, some primary education, some secondary education and higher education.
Fathers education	Percentage of men who attended any level of education. Categorized as no education, some primary education, some secondary education and higher education.
Maternal employment	Percentage of women who worked in the 12 months preceding the survey or are currently working.
Child age	Child age in months. (Dummy coded to include in the model)
Child Sex	Sex of child
Residence	Urban vs rural
Region	Region of residence
Survey round	Year of EDHS survey

Figure A1. Flow Diagram Showing Criteria Used to Include Children in Regression Analysis

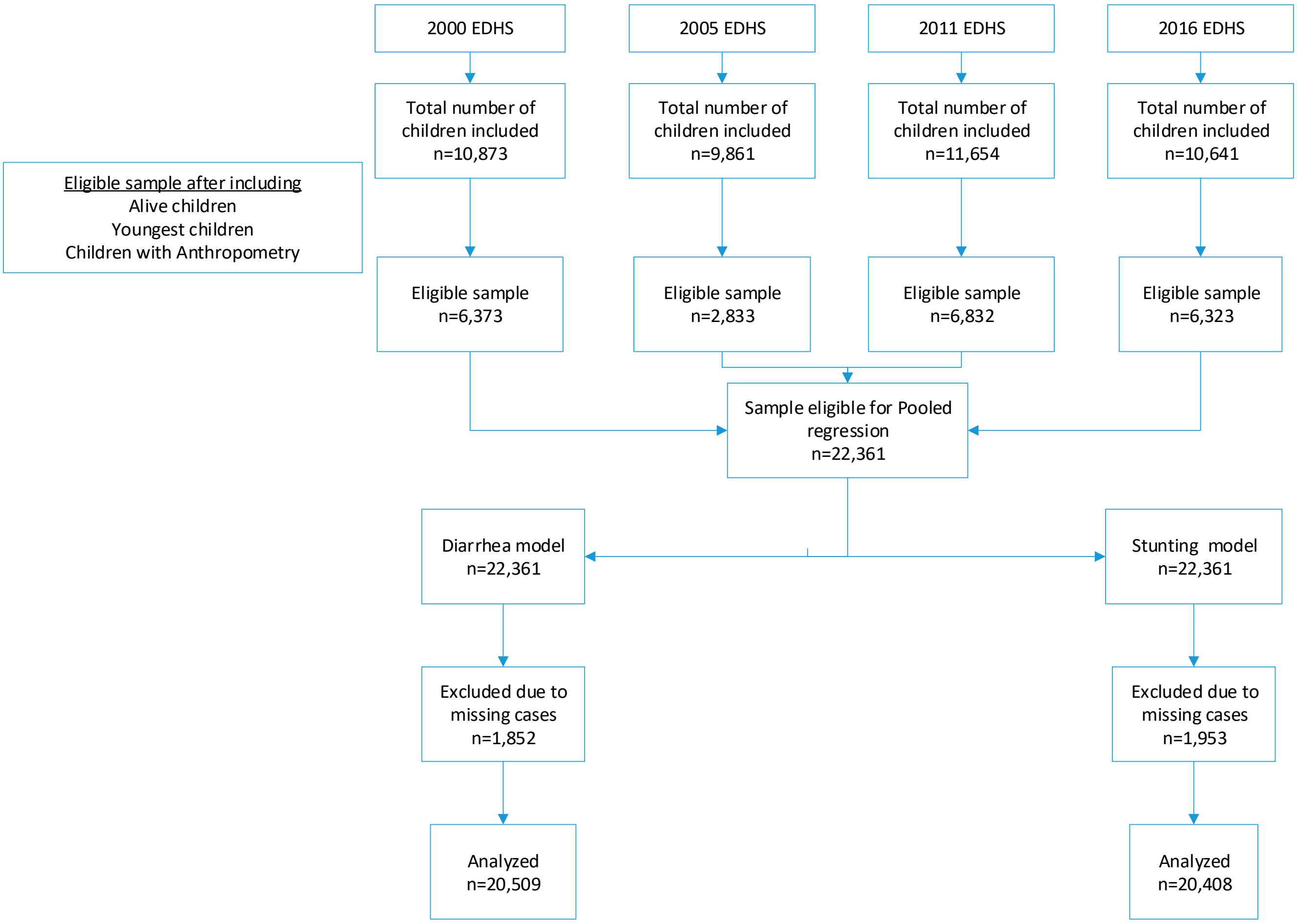

Table A5. **Change in Exposures and Covariates Between 2000 and 2016 Among Children Aged 0-6 Months**

Variables	2000	2005	2011	2016	Change (2016-2000)
Type of drinking water					
Surface water	41	29	20	13	-28
Unimproved	43	11	38	33	-10
Limited	7	13	17	14	7
Basic	9	47	25	40	31
Type of sanitation facilities					
Open defecation	85	71	42	38	-47
Unimproved toilet	15	24	46	53	38
Limited	0	3	5	4	4
Basic	0	2	7	5	5
Maternal education					
No formal education	82	77	65	59	-23
Formal education	19	23	36	40	21
Wealth					
Poorest	19	22	23	24	5
Poorer	20	19	22	23	3
Middle	25	22	24	19	-6
Richer	22	25	18	19	-3
Richest	15	12	15	15	0
Fathers education categorized					
No formal education	60	58	46	48	-12
Formal education	41	42	55	52	11
Maternal employment	60	18	47	36	-24

Table A6. **Change in Exposures and Covariates Between 2000 and 2016 Among Children Aged 6-11 Months**

Variables	2000	2005	2011	2016	Change (2016-2000)
Type of drinking water					
Surface water	40	30	19	10	-30
Unimproved	43	12	32	31	-12
Limited	6	15	20	16	10
Basic	11	44	29	44	33
Type of sanitation facilities					
Open defecation	86	64	45	34	-52
Unimproved toilet	13	29	43	55	42
Limited	0	2	6	7	7
Basic	0	5	6	5	5
Maternal education					
No formal education	83	78	67	56	-27
Formal education	17	22	33	44	27
Wealth					
Poorest	21	20	25	20	-1
Poorer	24	22	23	25	1
Middle	19	23	20	22	3
Richer	24	19	16	17	-7
Richest	13	15	16	17	4
Fathers education					
No education	63	55	48	38	-25
Primary	36	45	52	62	26
Maternal employment	59	35	47	39	-20

Table A7. **Change in Exposures and Covariates Between 2000 and 2016 Among Children Aged 12-23 Months**

Variables	2000	2005	2011	2016	Change (2000-2016)
Type of drinking water					
Surface water	35	32	19	12	-23
Unimproved	46	13	33	29	-17
Limited	7	13	17	17	10
Basic	12	42	31	42	30
Type of sanitation facilities					
Open defecation	86	66	43	37	-49
Unimproved toilet	14	27	44	54	40
Limited	0	3	5	4	4
Basic	0	4	8	5	5
Maternal education					
No formal education	80	77	68	63	-17
Formal education	21	23	32	38	17
Wealth					
Poorest	22	24	23	24	2
Poorer	21	22	22	20	-1
Middle	22	21	20	23	1
Richer	20	18	19	19	-1
Richest	17	15	16	14	-3
Fathers education					
No formal education	63	58	49	47	-16
Formal education	37	42	51	53	16
Maternal employment	63	34	55	45	-18

Table A8. **Change in Exposures and Covariates Between 2000 and 2016 Among Children Aged 24-59 Months**

Variables	2000	2005	2011	2016	Change (2016-2000)
Type of drinking water					
Surface water	36	28	17	13	-23
Unimproved	45	12	31	26	-19
Limited	8	14	19	16	8
Basic	12	45	33	45	-33
Type of sanitation facilities					
Open defecation	85	65	41	34	-51
Unimproved	14	28	45	54	40
Limited	1	2	5	6	5
Basic	0	5	9	6	6
Maternal education					
No formal education	84	79	67	67	-17
Formal education	17	21	33	33	16
Wealth					
Poorest	23	23	21	20	-3
Poorer	21	22	20	23	2
Middle	19	19	21	20	1
Richer	19	19	21	19	0
Richest	18	18	17	18	0
Fathers education					
No formal education	69	60	52	50	-19
Formal education	31	40	48	50	19
Maternal employment	71	41	63	53	-18

Table A9. **Change in Exposures and Covariates Between 2000 and 2016 Among Children Aged 0-59 Months**

Variables	2000	2005	2011	2016	Change (2016-2000)
Type of drinking water					
Surface water	37	29	18	12	-25
Unimproved	45	12	33	29	-16
Limited	7	14	18	16	9
Basic	11	45	30	43	32
Type of sanitation facilities					
Open defecation	86	66	42	35	-51
Unimproved	14	27	44	54	40
Limited	0	3	5	5	5
Basic	0	4	8	5	5
Maternal education					
No formal education	82	78	67	63	-19
Formal education	17	22	23	36	19
Wealth					
Poorest	21	22	22	21	0
Poorer	21	21	21	22	1
Middle	21	21	21	21	0
Richer	20	20	19	19	-1
Richest	16	16	16	16	0
Fathers education					
No formal education	65	58	50	47	-18
Formal education	35	41	50	53	18
Maternal employment	65	35	56	46	-19