Reducing Child Mortality in Sudan by Preventing Diarrheal Disease

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Sudan's rate of child mortality, measured as the number of deaths per 1,000 live births, decreased from 106 in 2000 to 73 in 2012. However, child mortality in Sudan far exceeds the global rate of child mortality, which was 48 in 2012. Contributing to this disparity is diarrheal disease, which is a leading cause of preventable death in Sudan. In this paper, we will examine diarrheal disease among children under five in Sudan through an analysis of the 2000 Sudan Household Health Survey. We conduct a retrospective investigation of the region now officially known as the Republic of Sudan, focused on possible factors related to diarrheal disease in the year 2000. We hypothesize that having access to clean water, improved sanitation facilities—defined here as any kind of latrine—and improved nutritional status through nutrient supplementation would, while controlling for confounding variables, lead to a dramatic decrease in the disease susceptibility of Sudanese children. Additionally, we tested whether maternal education level could alter the effectiveness of clean water and sanitation access.

Our results indicate that availability of household sanitation facilities, access to clean water and better nutrition were all associated with a lower incidence of diarrhea. Maternal education level had an ambiguous effect. Somewhat surprisingly, we found that communities with relatively better levels of sanitation access had higher levels of diarrhea incidence. We conjecture that this finding is due to individuals acting in self-interest as people do not adequately care for communal facilities. These behaviors may have a damaging effect on shared resources and, consequently, turn communal facilities from being beneficial to detrimental.[1]

INTRODUCTION

Our Focus

Straddling North and Sub-Saharan Africa, Sudan has remained in the headlines over the past decade primarily due to its civil war, the crisis in Darfur and the recent secession of South Sudan in 2011. However, beyond the armed conflict, a profound tragedy is Sudan's child mortality rate, which was 73 per 1,000 live births in 2012 (Table 1), with roughly two-thirds of the overall mortality affecting infants (Table 2). In addition to diarrheal disease, common communicable diseases, such as malaria and tuberculosis, comprise the largest share of the disease burden in Sudan.[2] In this paper, we focus on diarrheal disease because it is generally preventable by simple, low-cost methods at the community and household level.[3]

It is important to note that we made our decision to conduct a retrospective study after we had selected our region and formed our hypothesis regarding diarrheal disease. This was largely driven by a lack of publicly-available, contemporary datasets. Given that we used a dataset from 2000, our findings may lack external validity over time. However, factors we found to have an impact on diarrhea in that point in time were quite surprising and might lead to new research directions. Additionally, a historical analysis can serve as a useful benchmark for future studies utilizing more recent datasets. One can investigate if similar effects are found in newer datasets and, if not, what factors changed.

Diarrheal Disease

A leading cause of morbidity and mortality among children in Sudan in 2000 was, and continues to be, diarrheal disease, which occurs when the intestinal tract becomes infected by a viral, bacterial, toxic or parasitic agent. Rotavirus and *Escherichia coli* are the most common causes of diarrhea among infants and children globally, and there are approximately 1.7 billion cases of diarrhea each year. Unfortunately, young children are most affected.[4] For children under five, diarrheal disease was the second leading cause of death worldwide in 2013.[4] According to the Multiple Indicator Cluster Survey Report of 2000, 28% of children under the age of five in Sudan had experienced a diarrhea episode within the two weeks preceding the survey.[5] This is significant since under-five mortality in the Republic of Sudan is relatively high compared to neighboring countries (Table 1), and the World Health Organization estimated that diarrhea accounted for 13.1% of deaths among children under five in Sudan in a 2009 report.[6]

Diarrheal disease can spread easily and has serious physiological effects. It can be spread from person-to-person due to poor hygiene habits, but is more commonly spread through food and water sources that are contaminated with human feces. Areas that have open sewage drains and latrines are of high concern since people are more likely to be exposed to a pathogenic agent in the absence of suitable sanitation facilities.

Diarrheal disease often causes an intestinal infection in which the invading agent prevents intestinal cells from absorbing fluid and nutrients, thereby causing severe dehydration and malnutrition.[7] Treatment within 24 to 48 hours is critical for children because they are particularly susceptible to dehydration. Furthermore, a negative feedback cycle exists whereby malnourished children are more susceptible to an infection, and the illness itself causes severe malnutrition once the infection develops into diarrheal disease.

Diarrheal disease is preventable and treatable, but it continues to affect developing countries on a large scale for a multitude of reasons. Lack of access to safe drinking water, hand washing without soap and not receiving the rotavirus vaccine can all contribute to diarrheal disease in developing countries.[4] The most common treatment for diarrhea is an oral rehydration salts (ORS) solution, which is a simple combination of salt, sugar and clean water that aids in rehydration. Zinc supplementation is also a preferred treatment method that has been proven to reduce stool volume and duration of diarrheal episodes.[4]

There is evidence that preventative products are inexpensive and have high returns in mortality reduction for diarrheal disease.[8] Investing in household-level interventions will also help reduce the costs incurred by both individuals and healthcare systems for treating diarrheal disease.[9] As a concrete example, a randomized, controlled trial of children from over 300 households in squatter settlements in Karachi, Pakistan, found that hand washing with soap has the potential to reduce episodes of diarrhea by thirty to fifty percent.[10] Furthermore, in a review covering 14 randomized controlled trials, the Cochrane Infectious Diseases Group determined that hand washing with soap also led to a 30% reduction in diarrhea for children and adults in low- and middle-income countries.[11] Preventing malnutrition is also a key component to fighting these diseases, as studies have shown that underweight children have an increased risk of dying from diarrheal disease.[12] The biggest challenge to large-scale adoption of these healthy practices is often lack of awareness.[13, 14] People might be unaware of the potential benefits of following such routines and making such investments, not know how to implement them effectively, or simply lack the necessary resources to put into practice the prevention strategies mentioned above.

Another promising prevention strategy involves sanitation. This effort requires greater investment in infrastructure and may have additional long-run costs such as educating people on how to best use and care for the infrastructure, but the benefits promise to be substantial. However, taking fiscal realities into account may mean that this kind of infrastructure project can only be implemented in high-population areas and with the aid of humanitarian organizations.

Based upon the existing literature surrounding diarrhea prevention, we hypothesized that our data would show that the most important elements in reducing diarrhea prevalence would be access to sanitation facilities, water cleanliness, nutrition and maternal education level. In the following section we use survey data and logistic regressions to determine the relative importance of these variables.

METHODS

Data Source: MICS2

Our dataset comes from the UNICEF-sponsored Sudan Household Health Survey (SHHS) conducted in 2000, the Multiple Indicator Cluster Survey-Round 2.[15] The MICS2 measures disease incidence, specifically the rates of diarrhea and fever incidence among children in the two weeks prior to the interview. This survey was conducted across fourteen regions of what was then Northern Sudan, now the Republic of Sudan, and each region was broken into 45 clusters. About 35 households were interviewed in each cluster, for a total of 25,200 household observations. From these households, data were gathered on 23,295 children under the age of five who will form the basis of our analysis.

Regression Model

$$Pr(Y_{i,d}=1) = \alpha+\beta_1 * X_{i,d} + \beta_2 * H_{i,d} + \beta_3 * I_{i,d} + \beta_4 * Cl_{c,d} + \beta_5 * R_{i,region}$$

For brevity, the above model has been compressed: each lettered covariate represents several covariates grouped by type. For example, $X_{i,d}$ is a group of variables that account for individual characteristics like age and gender, while $H_{i,d}$ groups household-level data such as access to a latrine and household socioeconomic status (strictly speaking, each represents a matrix of coefficients, while $X_{i,d}$, $H_{i,d}$, $Cl_{c,d}$, $I_{i,d}$, and $R_{i,region}$ are matrices of covariates). The full list of covariates has been reproduced in Table 4, and some of the more complicated covariates will be discussed in detail below.

The dependent variable in this model is whether a child under the age of five has had an episode of diarrhea within the last two weeks. Since the outcome variable is binary (0 for no diarrhea, 1 for a recent diarrhea episode), the type of regression we can use is somewhat constrained. Rather than using ordinary-least squares, we used a logistic regression analysis, which accounts for the lack of a continuous dependent variable.

While many of the covariates included in the model are straightforward, the inclusion of some variables might be confusing. We will review them and give explanations where necessary. The first group, $X_{i,d}$, includes dummy variables capturing gender, maternal education level (educated is considered anything beyond primary), nutrition quality and a categorical variable for age, while $H_{i,d}$ captures dummies for water quality, sanitation access, living in an urban environment, wealth index

Table 1: Child Mortality Comparison for 2012[29]

	Total Child Mortality *Thousands*	Mortality Rate *Per 1,000 live births*
Sudan	89	73
Egypt	40	21
Chad	82	150
Middle East & North Africa	306	30
Sub-Saharan Africa	3,245	98
Developing Countries	6,463	53
Developed Countries	90	6
Developed Countries	90	6

Table 2: Child and Infant Mortality in Sudan for 2012[2]

	Total Mortality *Thousands*	Mortality Rate *Per 1,000 live births*	Male Mortality Rate *Per 1,000 live births*	Female Mortality Rate *Per 1,000 live births*
Children *Under 5 Yrs. Old*	89	73	79	67
Infants	60	49	-	-

Table 3: Summary Statistics

Characteristics	Had Diarrhea in the Past Two Weeks	Did NOT Have Diarrhea in the Past Two Weeks
Rural	29.19	70.81
Urban	26.61	73.39
Female	27.59	72.41
Male	28.98	71.02
Mother Is Not Educated	28.64	71.36
Mother Has Education	27.68	72.32
Top 60% of Wealth Index	28.32	71.68
Bottom 40% of Wealth Index	28.15	71.85
Access to contained water	26.96	73.04
No contained water	30.22	69.78

and a categorical variable for household size. We included maternal education rather than paternal, as studies have shown that mothers are more likely to be the child's primary caregiver.[16] We hypothesized that more educated mothers are likely better able to utilize resources and be more aware of how diseases are transmitted and so be better equipped to protect their children from diarrhea.

Additionally, we classified water quality in three ways: open, partially-covered and fully-covered. An open water source is typically a river, stream or pond, while partially-covered means a specific rain catchment or sand filtration system. A fully-covered water source means either water piped from a central authority or borehole. For sanitation, having improved sanitation is when the child has access to either a dug, covered latrine or a flush toilet.

Next, the matrix $I_{i,d}$ has relevant interaction terms that incorporate interactions between maternal education level and water quality, and again between maternal education level and sanitation access. This variable tells us the differential impact that maternal education level has on the effectiveness of clean water usage and sanitation access, under the assumption that education level has some impact on how facilities and water are used and cleaned. For example, a mother that is educated may be more likely to understand the need to keep a clean toilet to avoid disease transmittance than a mother that has not been educated.

Variable $Cl_{c,d}$ measures cluster level averages rather than simple individual levels. For example, a cluster level sanitation average of 0.8 means that eighty percent of the respondents in that cluster have access to improved sanitation facilities. Our rationale is that disease incidence is related not only to an individual's access to water or sanitation, but also to the aggregate levels in a cluster. Diarrhea is predominantly caused by communicable diseases passed between people, so there may be spillover effects from having a high or low level of sanitation in a cluster.

Finally, $R_{i,region}$ is a matrix of dummies that tells which region the child lives in. In the regions of North Sudan there are substantial systematic differences, primarily geographic (i.e. lush vs. arid) and political (some areas have been exposed to more conflict than others). Adding these covariates allows us to see which regions seem to be hardest hit by diarrhea.

We ran four versions of the model when running our regressions: Model 1 has only individual level and household covariates; Model 2 adds in interaction terms; Model 3 incorporates spillover effects; and Model 4 finally adds in regional differences.

RESULTS

Below we have reproduced the results from all four regression models for diarrhea incidence (Table 4). Across all four models, we found several covariates with significant effects: child's age, urban environment, regular use of any milk, whether the child is male and the size of the household. Interestingly, male children show higher levels of diarrhea incidence than female children. Though this difference is puzzling, determining the answer goes beyond the scope of this paper.

The coefficients on access to partially-covered water (-0.174) and fully-covered water (-0.164) show that better water quality decreases the likelihood of having diarrhea. Both coefficients are significant (p<.001) in the first two models. In Model 3, with the inclusion of community-level averages, these variables lose statistical significance. Instead, the same effect from Models 1 and 2 seems to be captured by community-level averages. This is a plausible outcome, as water quality is likely very homogenous at the community level, and so incorporating this variable decreases the significance of individual-level water quality by drastically reducing heterogeneity. Similarly, in Model 4, we lose any significance among all the water quality variables, as water quality is also strongly tied to regional differences.

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The variable that captures the education level of the child's mother shows no statistically significant effect across all four models. However, the interaction term between maternal education level and having access to partially covered water is positive and significant (p<.05) in Models 2 (0.274), 3 (0.269) and 4 (0.255). Literature exists showing that more educated mothers are able to better protect their children from diseases, which makes this result confusing. This will be discussed further below.

Interestingly, we find no statistically significant effect from having access to a latrine or toilet in the first two models. However, the coefficients in Models 3 (-0.135) and 4 (-0.128) are negative and significant with p<.05. In contrast, the variable for community-average level of sanitation in Models 3 (0.273) and 4 (0.189) are positive and highly significant with p<.001. This surprising outcome, that the household-level and community-level sanitation effects are in opposite directions, will be discussed in depth in the next section.

Finally, Model 4 shows some interesting results with regards to regional differences. In particular, the coefficients on the regions of River Nile (0.574), Kassala (0.395), Blue Nile (0.77), Khartoum (0.594) and South Darfur (0.383) are strongly positive and significant with p<0.001, suggesting that children in these regions are particularly susceptible to diarrhea.

DISCUSSION

Sanitation

One of the most striking results is that community- and individual-level sanitation usage seem to operate in different directions: a high community average of sanitation access is correlated with higher rates of diarrhea, while a high individual level of access is tied to lower incidence of diarrhea when compared to no access to sanitation facilities. We take this as an indication that individual access to sanitation is beneficial, but community-level access is detrimental. That is, if many people in a community are sharing sanitation facilities, this can actually increase rates of diarrheal disease. We hypothesize two possible mechanisms for this occurrence. First, having many people share the same sanitation resources can facilitate the transfer of bacteria and parasites between hosts. With communal facilities, we conjecture that people are more likely to come into contact with bacteria or parasites due to poor management of the facility.[17] Second, individuals may not be invested in the upkeep of communal facilities due to lack of ownership, leading to the degradation of communal sanitation areas—a phenomenon known as the tragedy of the commons.[1] Regardless of the reason, this difference between the individual and community levels of sanitation will play a major role in our recommendations.

Our results indicate that the number of individual level facilities in Sudan should be scaled up, so that people can rely less on communal latrines and toilets. Since it is possible that communal facilities increase the danger of contamination, another possible strategy for reducing child diarrhea rates is increasing the presence of hand washing stations equipped with soap. Given the ongoing conflict in Sudan and lack of involvement by the central government in peripheral regions, much of this work would likely need to be implemented by non-governmental organizations.

Where the only available facilities are those for public use, it is critical that proper hygiene is maintained through hand washing with soap. To encourage this practice we suggest subsidies for soap so that it is made available at every sanitation facility. However, soap availability should be combined with education on proper hand washing techniques as well as hand washing stations, which are a key part of soap use.[18, 19, 20] These stations can be built with locally available products to reduce costs and increase implementation. UNICEF has implemented programs to educate and teach communities how to construct the stations through Community-Led Total Sanitation Programs (CLTS).[21] The feasibility of these programs depends on various factors, such as government support and a coordinated national strategy to improve sanitation. For example, the national governments of Zambia and Sierra Leone are actively scaling-up CLTS programs and including them in district health plans.[21] The CLTS model, which requires communities to design and build their own latrines using materials available locally in the hopes that this will maximize accountability and maintenance of the facilities, could be another effective strategy for reducing child diarrhea rates in the Republic of Sudan.

Education

The results of the mother's education variable seem to run counter to the literature and our expectations. Considerable research has been done linking levels of maternal education to a decreased diarrhea incidence but our findings show either no correlation or, in the interaction term, a positive correlation (Models 2, 3 and 4 in Table 4).[22, 23, 24] This seems to imply that a child with an educated mother and a partially covered water source will be more likely to experience diarrhea than a similar child with an uneducated mother. We would expect that a more educated mother would have both more information on prevention strategies and would be able to more effectively implement them. However, other studies such as Dargent-Molina, James, Strogatz and Savitz, have shown that the effect of maternal education on child diarrhea incidence is dependent on the mother's socioeconomic environment.[25] That is, while maternal education has a protective effect on infant diarrhea in economically advantaged households, there is no effect on child diarrhea incidence in socially and economically disadvantaged communities. In the study by Dargent-Moline et al., advantaged and disadvantaged communities were designated by access to community economic resources, level of household assets and availability of social mothers' groups, defined in this study as organized social gatherings that provide informal education on a variety of topics including health-related issues.[25]

It is possible that this type of economic advantage could be confounding our results. The variable we used to measure mother's education level was binary, with mothers broken into two groups, one of which had not attended secondary, while the other group had spent at least some time in secondary school. This lack of granularity makes it difficult to disentangle the effect of years of education from access to education, which itself could be tied to other factors (e.g. urban women are more likely to have access to secondary schools). Without a stronger education variable, we cannot make any strong assertions about the channel through which a mother's education affects a child's diarrhea risk.

Additionally, most of the evidence in support of mother's education as diarrhea prevention is associated with targeted programs rather than general education. In North Sudan, it is possible that implementing targeted education programs rather than increasing formal education might be a more effective policy in reducing incidence of diarrhea. For example, a community education program may help to teach community members how to prevent and treat diarrhea. To target mothers, education programs or workshops could be implemented that specifically address practices pertaining to food safety and strategies to prevent diarrhea in the household. Programs with topics such as hand washing with soap could target school-age children, while workshops on the proper use of ORS could target households and communities where diarrhea incidence is high.[26] Another possible recommendation is to include UNICEF Water, Sanitation and Hygiene (WASH) programs into the school curriculum.[27] In this way, children can learn about the causes of diarrhea and how to prevent the disease through formal education.

Regional Differences

In all four models, the negative and statistically significant coefficients on the urban environment variable suggest that children in urban settings are less likely to suffer from diarrhea than those in rural settings (see Table 4). The assumption we make is that urban environments tend to have more sophisticated and comprehensive water and sanitation infrastructure in place that reduce disease burden in the cities. At the same time, one would expect that since cities are more crowded, there should be an increased probability of transmission. It could be that we found a statistically-significant negative coefficient in all four models because either the effect from the improved infrastructure outweighs the increased likelihood of transmission or because the infrastructure is different. As explained above, we also found that latrines or toilets at a household level correlated with reduced incidence of diarrhea, while communal facilities were correlated with an increased risk. It could be that urban areas have a greater proportion of household-level facilities than rural areas.

The negative coefficients we found on the water quality variables in our models align with our expectations that higher water quality should be correlated with a reduced incidence of diarrhea. However, they are only significant in Models 1 and 2. It seems that the effect of water quality is subsumed by the aggregate coefficients added in Models 3 and 4 (community averages). These variables measure the average level of water quality in a community. In Model 3, these coefficients are in accord with the literature, as higher water quality is strongly associated with reduced rates of diarrhea.[28] However, water quality coefficients are no longer significant in Model 4, which incorporates dummy variables for regions. We assume this is because water quality is highly correlated with regional differences such as water infrastructure as well as access to well water or open water sources. More precisely, we expect that regions with better water delivery infrastructure, for example, would help deliver clean water to households, which would in turn have lower rates of diarrhea.

After comparing regional differences between the incidence of diarrhea and correlated factors, it is clear that certain regions fare much worse than others. Kassala, Al-Gadafir, the Blue Nile Region, Northern Kordufan, Southern Darfur and Western Darfur have among the highest levels of diarrhea as well as the lowest ratios of educated mothers, contained water and sanitation facilities. Interventions might be prioritized for these regions specifically. Programs targeting these regions must also take into account the pervasive conflict as well as the resulting displacement of people. For example, it might simply be too risky, both in terms of human lives as well as investment, to build large-scale sanitation infrastructure in areas where armed conflict continues.

CONCLUSION

In our analysis of diarrheal disease in the Republic of Sudan in 2000, we found some surprising correlations between access to community sanitation systems, education and regional differences in the incidence of diarrheal disease among children under five years of age.

Table 4: Diarrhea Incidence Among Male and Female Children
Dependent Variable: *Had Diarrhea in Past Two Weeks*

Diarrhea	Model I	Model II	Model III	Model IV
Age	-0.139*** (-12.89)	-0.139*** (-12.88)	-0.139*** (-12.88)	-0.139*** (-12.77)
Male	0.0652* (2.13)	0.0650* (2.13)	0.0638* (2.09)	0.0665* (2.16)
Household size	0.0143** (2.62)	0.0148** (2.70)	0.0123* (2.22)	0.00865 (1.54)
Lives in a city	-0.118** (-3.07)	-0.122** (-3.16)	-0.132*** (-3.34)	-0.148*** (-3.62)
First (Top) Wealth Quintile	0.0536 (0.73)	0.0561 (0.75)	0.0867 (1.15)	0.176* (2.23)
Second Wealth Quintile	0.110 (1.70)	0.109 (1.65)	0.127 (1.91)	0.229*** (3.31)
Third Wealth Quintile	0.152* (2.49)	0.152* (2.43)	0.163** (2.60)	0.252*** (3.86)
Fourth Wealth Quintile	0.135* (2.25)	0.136* (2.24)	0.142* (2.33)	0.180** (2.92)
Mother is educated	0.0166 (0.46)	-0.122 (-1.45)	-0.144 (-1.70)	-0.101 (-1.18)
Water source is partially covered	-0.174*** (-3.37)	-0.247*** (-4.16)	-0.0596 (-0.69)	-0.0608 (-0.70)
Water source is fully covered	-0.164*** (-3.98)	-0.162*** (-3.43)	0.0357 (0.46)	0.0376 (0.48)
Eats meat regularly	-0.0148 (-0.34)	-0.0108 (-0.25)	-0.0233 (-0.53)	-0.00886 (-0.20)
Drinks milk regularly	-0.284*** (-7.01)	-0.285*** (-7.01)	-0.283*** (-6.95)	-0.269*** (-6.46)
Has improved sanitation facilities	0.0137 (0.37)	-0.0241 (-0.55)	-0.135** (-2.61)	-0.128* (-2.44)
Educated Mother and Partially covered water		0.274* (2.47)	0.269* (2.42)	0.255* (2.27)
Ed. Mother and contained water		0.0314 (0.37)	0.0348 (0.41)	0.0341 (0.40)
Ed. Mother and improved sanitation		0.119 (1.62)	0.138 (1.88)	0.125 (1.68)
'Village average for partially covered water			-0.296** (-2.93)	0.0636 (0.59)
Village average for fully covered water			-0.304*** (-3.51)	-0.0524 (-0.58)
Village average for improved sanitation			0.273*** (4.03)	0.189** (2.65)
Lives in River Nile Region				0.574*** (5.35)
Lives in Red Sea region				-0.0344 (-0.28)
Lives in Kassala region				0.395*** (4.30)
Lives in Al Gazira region				0.154 (1.47)
Lives in White Nile region				0.214* (2.15)
Lives in Blue Nile region				0.770*** (8.37)
Lives in Khartoum region				0.594*** (5.89)
Lives in North Kordufan region				0.148 (1.32)
Lives in South Kordufan region				-0.191 (-1.83)
Lives in West Kordufan region				0.0307 (0.30)
Lives in North Darfur region				0.0900 (0.86)
Lives in South Darfur region				0.383*** (3.82)
Lives in West Darfur region				0.212 (1.95)
Constant term	-0.507*** (-5.33)	-0.484*** (-5.08)	-0.475*** (-4.82)	-1.029*** (-7.91)
N	21466	21466	21466	21466

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Possible explanations for these results were proposed as well as policies and interventions that might lead to reduced rates of diarrheal disease in the Republic of Sudan. However, it is clear that there is a need for further investigation to establish or reject causality and gain a further understanding of the detailed dynamics underlying these results. To this end, we hope to extend our research to a more contemporary dataset.

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