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## Changes in Diarrheal Disease and Treatment Among Brazilian Children from 1986 to 1996

Narayan Sastry · Sarah Burgard

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**Abstract** We examined changes in diarrhea prevalence and treatment in Brazil between 1986 and 1996. Over this 10-year period there was a small decline in diarrhea prevalence but treatment with oral rehydration therapy (ORT) increased greatly. Deaths due to dehydration were thus averted, although the costly burden of morbidity remained high. The decline in diarrhea prevalence was largely due to changes in the effects of several key covariates, such as breastfeeding, with only a modest role played by socioeconomic change, infrastructure improvements, and other behavioral factors. ORT treatment of diarrhea was essentially unrelated to child and family characteristics, suggesting that the large increase was due to the success of public health efforts to promote its use widely. Our results suggest that the most effective policies for reducing diarrhea prevalence are likely to be further increases in education and the promotion of breastfeeding. Persistent disparities in diarrhea prevalence mean that policies to prevent the disease should be targeted at disadvantaged socioeconomic groups.

**Keywords** Child health · Diarrhea · Brazil · ORT treatment

### Introduction

Despite dramatic declines in deaths due to diarrheal disease among infants and children in developing countries, diarrhea remains a significant cause of morbidity as well as mortality (Kosek et al. 2003; Keusch et al. 2006). Frequent or prolonged diarrhea can lead to poor nutritional status, and repeated episodes of diarrhea can also leave children susceptible to other infections (Mirza et al. 1997). Furthermore,

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N. Sastry (✉) · S. Burgard  
Population Studies Center, University of Michigan, 426 Thompson Street,  
Ann Arbor, MI 48106, USA  
e-mail: nsastry@umich.edu

malnutrition can increase the severity, duration, and frequency of bouts of diarrhea (Hirschhorn and Greenough 1991). High diarrhea prevalence is unfortunate because the disease is largely preventable, and prevention techniques, reviewed below, are often relatively simple.

Diarrhea leads to death through dehydration. Oral rehydration therapy (ORT) is a potentially effective treatment for dehydration due to diarrhea that has been promoted widely throughout the developing world since the late 1970s. Victora et al. (1996) suggest that a large increase in the use of ORT played a central role in reducing deaths due to diarrhea in Brazil and, moreover, that the reduction in diarrhea deaths accounted for a large part of the substantial increase in child survival from the mid-1980s to the mid-1990s.

In this paper, we investigate changes in the prevalence and treatment of diarrhea in Brazil between 1986 and 1996 and the role of demographic, socioeconomic, and behavioral factors in accounting for these changes. We use these results to assess whether the increase in ORT treatment and the decline in diarrhea deaths were associated with a reduction in diarrhea prevalence. We begin, in the next section, by providing some background on diarrheal disease and its treatment. We then review previous research on the relationship between diarrheal disease and infant mortality in Brazil. Next, we describe changes in diarrheal prevalence and treatment in Brazil and selected other developing countries between the mid-1980s and mid-1990s. This is followed by an outline of our conceptual framework and statistical modeling approach. The study draws on data from two Brazilian surveys, conducted in 1986 and 1996 as part of the Demographic and Health Surveys Program. In the subsequent two sections we describe these data and the covariates used in our analysis. Finally, we present our results and end the paper with a discussion of our findings.

Our results indicate that there was a very modest decline in diarrhea prevalence in Brazil between 1986 and 1996. However, treatment with ORT increased greatly. These two findings support the contention that ORT programs may indeed have reduced child mortality due to diarrhea. However, the focus on diarrhea management may have occurred at the cost of primary preventive care. Although deaths due to diarrhea were reduced, the high rates of diarrhea morbidity continued to place a large number of children at risk of adverse nutritional outcomes. Finally, there were disparities in diarrhea prevalence across socioeconomic groups that persisted over time; nonetheless, the large increase in ORT treatment was not driven by family factors but instead represented a secular change that was likely the result of programs and policies to promote ORT use. The persistence of high rates of diarrhea means that reducing the prevalence of the disease remains a major public health priority.

## Causes and Control of Diarrhea

Diarrhea is caused by a variety of bacterial, viral, and parasitic enteropathogens. Transmission occurs through the fecal-oral route as a result of direct person-to-person contact and exposure to contaminated food, water, and objects. Avoidance of contaminated water and attention to hygienic practices, such as sanitary waste

disposal, correct food-handling techniques, and washing one's hands, can help prevent illness. In addition, infants may derive some protection from breastfeeding, because breastmilk contains specific rotavirus-neutralizing antibodies (Yolken et al. 1978; Huttly et al. 1997).

The most effective interventions for diarrheal disease control are programs to prevent the transmission of infectious agents in the home (Black 1984). Public health efforts to reduce the prevalence of diarrhea in Brazil and elsewhere have focused on expanding water-supply and sanitation systems. The resulting improvements in access to clean water and a more plentiful supply of water—as well as reductions in the levels of environmental contamination—reduce the exposure to pathogens and lead to lower rates of diarrhea (Barreto et al. 2007). Infrastructure improvements may also lead to the diffusion of new behaviors that are introduced or supported by changes in the local community environment. For example, the improvements may help spread awareness of appropriate hygienic practices in the home, such as the correct preparation of weaning foods, the boiling of drinking water, or greater personal cleanliness. Simple actions, such as hand washing, are very effective in preventing diarrhea (Curtis and Cairncross 2003; Luby et al. 2004). Other approaches to reducing diarrheal disease include the promotion of breastfeeding, better weaning practices, improved supplemental feeding, and immunization against measles, as well as direct promotion of better hygienic practices (Black et al. 1984; Feachem 1986; Keusch et al. 2006; Victora et al. 2000). These approaches may also help to mitigate socioeconomic disparities in diarrhea prevalence.

The development of water and sanitation systems and spread of hygienic practices provides a long-term solution for diarrheal disease. In the short term, the symptoms of diarrhea can be treated with ORT, by continuing adequate feeding during and after the diarrhea episode, and by the use of antibiotics in cases of dysentery caused by *Shigella*. ORT was developed in the late 1960s (Hirschhorn 1968; Pierce et al. 1968). It was adopted in 1979 as the cornerstone of the World Health Organization's program to control the consequences of diarrheal disease and, in particular, to reduce child mortality due to diarrhea (Victora et al. 2000). ORT involves the oral administration of an electrolyte solution composed of sodium, a carbohydrate, and water, which is designed to rehydrate a child or prevent dehydration by replacing fluids and vital ions lost through the bowel (Hirschhorn and Greenough 1991). Prior to the introduction of ORT, intravenous rehydration therapy was generally the only accepted treatment; although effective, intravenous rehydration was difficult or impossible to administer in many parts of the world.

The use of ORT in Brazil has been widely promoted since the beginning of the 1980s through programs of the Catholic Church (Finkam 1989) and the World Health Organization (Victora et al. 2000), as well as by the Brazilian Ministry of Health. Information about ORT has been disseminated in several ways: health workers from governmental and nongovernmental organization were trained in the preparation and use of oral rehydration solutions, a campaign to promote the use of homemade salt-and-sugar solutions for diarrhea treatment was launched, and instructions in preparing the solutions at home and advertisements for commercially prepared oral rehydration salts (ORS) were broadcast on television and radio (Barros et al. 1991).

## Diarrhea and Infant Mortality in Brazil

A major decline in infant mortality occurred in Brazil between 1970 and 1980, with the infant mortality rate falling from 100 per 1,000 births in 1970 to 62 per 1,000 births in 1980 (Simões 1992). This decline preceded the introduction of ORT and was, according to Merrick (1985), brought about by the significant infrastructure improvements that occurred over this decade. By 1991, the infant mortality rate had declined to 45 per 1,000 births and it fell to 35 per 1,000 births in 2000 (Simões 1992; Fundação IBGE 2001). Although the causes of infant mortality declines in the 1980s and 1990s are less clear, there was certainly a reduction in infectious and parasitic diseases. In particular, there was a large apparent decline in diarrhea-related deaths, especially in the poor and underdeveloped Northeast region. It was estimated that in 1980 diarrhea accounted for 41% of all infant deaths in the Northeast; by 1989, this had fallen to 25%, and by 1995–1997 it had dropped to 15% (Victora et al. 1996; Victora and Barros 2001). Victora et al. (1996) argued that ORT was responsible for about one-third of the decline during the 1980s in infant mortality attributable to diarrhea in Northeast Brazil. For Brazil as a whole, diarrhea was a leading cause of infant mortality in the mid-1980s, accounting for 17% of all infant deaths, but this was no longer the case by the mid-1990s, when diarrhea accounted for just 8% of infant deaths (Victora et al. 2000). These apparent trends suggest that, from a policy and public health perspective, resources should be shifted away from reducing diarrhea morbidity and mortality and toward reducing other, more important, causes of child illness and death.

It is important to note, however, that mortality data for Brazil—especially cause of death information—have some shortcomings. Vital statistics coverage of deaths is incomplete and information on cause of death is of low quality, especially in poorer areas where diarrhea prevalence is high. For example, in Northeast Brazil, 67% of infant deaths were unregistered in 1996 and, of those that were registered, 26% were attributed to ill-defined causes (Simões 1999; Victora and Barros 2001); thus, only 24% of deaths ( $0.33 \times 0.74 = 0.24$ ) had reliable information on cause of death. These gaps in the data make it difficult to draw firm conclusions about mortality patterns. Over time, there were major improvements in vital statistics coverage and in the quality of cause-of-death data that make earlier estimates more uncertain and influence the apparent trends in unknown ways.

In summary, deaths due to diarrhea appear to have declined substantially over the past 30 years. However, it is unclear how much of this decline is due to the substantial increases in ORT treatment and how much, if any, is due to reductions in diarrhea prevalence.

## Diarrhea Prevalence and Treatment in International Context

Over the 10-year period between 1986 and 1996, we estimate that diarrhea prevalence among children in Brazil under 5 years of age declined modestly, with the 2-week diarrhea prevalence falling from 17.8% in 1986 to 14.8% in 1996 (see Table 1). Although this change was modest, it was statistically significant.

**Table 1** Means (and standard deviations) for diarrhea prevalence and treatment in selected less developed countries in the mid-1980s and mid-1990s

Country	Mid-1980s			Mid-1990s		
	Diarrhea prevalence	Any treatment	ORT treatment	Diarrhea prevalence	Any treatment	ORT treatment
Brazil	0.178 (0.383)	0.762 (0.426)	0.150 (0.357)	0.148 (0.355)	0.867 (0.340)	0.544 (0.498)
Bolivia	0.320 (0.466)	0.771 (0.421)	0.369 (0.483)	0.186 (0.389)	0.976 (0.152)	0.511 (0.500)
Colombia	0.194 (0.395)	0.925 (0.263)	0.478 (0.500)	0.172 (0.377)	0.886 (0.318)	0.490 (0.500)
Dominica	0.253 (0.435)	0.779 (0.415)	0.412 (0.492)	0.169 (0.375)	0.934 (0.1270)	0.385 (0.385)
Guatemala	0.166 (0.372)	0.834 (0.372)	0.177 (0.382)	0.198 (0.398)	0.615 (0.487)	0.516 (0.500)
Peru	0.325 (0.469)	0.889 (0.314)	0.473 (0.500)	0.201 (0.400)	0.841 (0.366)	0.277 (0.447)
Ghana	0.266 (0.442)	0.888 (0.315)	0.367 (0.482)	0.193 (0.395)	0.941 (0.236)	0.325 (0.469)
Senegal	0.395 (0.489)	0.689 (0.463)	0.063 (0.244)	0.153 (0.360)	0.874 (0.332)	0.342 (0.475)
Uganda	0.246 (0.431)	0.715 (0.452)	0.180 (0.385)	0.237 <sup>a</sup> (0.425)	0.895 <sup>a</sup> (0.307)	0.492 <sup>a</sup> (0.500)

*Source:* Authors' calculations using data from DHS surveys of Brazil (1986 and 1996), Bolivia (1989 and 1998), Colombia (1986 and 1995), Dominican Republic (1986 and 1996), Guatemala (1987 and 1995), Peru (1986 and 1996), Ghana (1988 and 1998), Senegal (1986 and 1997), and Uganda (1988 and 1995)

<sup>a</sup> Only includes children up to 4 years of age

Treatment rates for Brazilian children with diarrhea increased over the same period. In 1996, 87% of child diarrhea cases were treated, up from 76% in 1986, a statistically significant change. There was a large increase in the likelihood of children with diarrhea being treated using ORT: in 1986 only 15% of children with diarrhea were treated with ORT, but this increased to 54% in 1996.

In order to understand the results for Brazil in their international context, we also present in Table 1 estimates of diarrhea prevalence and treatment for the mid-1980s and mid-1990s for other developing countries in which Demographic and Health Surveys were conducted for both periods. All of these surveys were based on similar samples of children and used closely comparable measures of diarrhea prevalence and treatment.

Brazil had the second lowest diarrhea prevalence rates among these countries in the mid-1980s and the lowest rate in the mid-1990s. There was a moderate decline in diarrhea prevalence rates for all countries except Guatemala. The decline in diarrhea prevalence of 17% for Brazil was less than the median decline of 27% for these nine countries.

Generally, there were small increases in any-treatment rates over this period, with the any-treatment rates for Brazil close to the median in both periods and with Brazil at the median for the percentage increase in any-treatment rates. However, there were major changes in ORT treatment between the mid-1980s and mid-1990s, with large divergence in the trend across these countries. ORT treatment increased in some countries and actually declined in others. The largest increases in ORT treatment were found in Senegal, Brazil, Guatemala, and Uganda. Over this period, Brazil went from having the second-lowest rate of ORT treatment to having the highest rate. There is no relationship between an increase in ORT use and a decline in diarrhea prevalence. However, there is a negative correlation between diarrhea prevalence and any-treatment rates. Finally, there was substantially less cross-country variation in ORT treatment rates in the mid-1990s than in the mid-1980s, although ORT treatment rates actually declined in Dominican Republic, Peru, and Ghana.

Overall these results suggest that diarrhea treatment—particularly treatment using ORT, which was the focus of public health efforts in the 1980s and 1990s—had very little effect on diarrhea prevalence rates, although use of ORT may have prevented child deaths. It is likely that other social and environmental changes that occurred over this period played a greater role in affecting diarrhea prevalence.

## Conceptual Framework and Modeling Approach

### Conceptual Framework

The conceptual framework that guides our analysis of children's diarrhea prevalence identifies four groups of biological and behavioral factors as the inputs that directly determine child health: maternal factors, environmental contamination, nutrient deficiency, and personal illness control (Mosley and Chen 1984). The specific health inputs within these four groups, such as the presence of an indoor

toilet or breastfeeding duration, are determined by the constraints and choices that parents face, as well as their background demographic and socioeconomic characteristics; attributes of the child may also influence these choices. Combining the two separate concepts—that children's health outcomes are produced by a set of inputs, and that the specific input levels reflect parental choices, parents' background, and child characteristics—we can derive simplified, reduced-form relationships that will be the focus of our analysis. We investigate how diarrhea prevalence is influenced by child characteristics such as age and sex; parents' characteristics such as socioeconomic status and family composition; and contextual factors such as region and rural–urban place of residence.

The child health inputs should not ordinarily appear in the reduced-form equation for child health. Rather, they usually either belong in the health production function or may be analyzed as outcomes separately if they are of interest. However, one reason for including these factors in the reduced-form equation for child health is to examine how the effects of background factors are changed by their inclusion. This approach provides insights into the ways in which the background factors operate to affect child health. In this hybrid production function/reduced-form model, the effects of background factors, such as mother's education, must be interpreted carefully. This is because in such models the effects of the background variables are changed to represent their net effects after accounting for many—but not all—of the pathways through which they work.<sup>1</sup>

Child health outcomes are determined not only by measured inputs classified within the four groups of inputs identified above, but also by unmeasured factors that reflect parents' abilities to promote the health of their children or unobservable aspects of the home or community environment.<sup>2</sup> Therefore, the effects of unobserved heterogeneity at the family and community levels are of substantive interest in this analysis. In particular, the variance of the distribution of unobserved heterogeneity provides us with an indication of the strength of unmeasured effects.

### Modeling Approach

We use multilevel logistic regression to model a child's risk of having diarrhea. The probability of a child having diarrhea is defined as  $p_{ijk} = \Pr(y_{ijk} = 1)$ , where  $y_{ijk} = 1$  indicates that the  $i$ th child of the  $j$ th family living in the  $k$ th community had diarrhea in the past 2 weeks, and a logit transformation of  $p_{ijk}$  is modeled as a linear function of the covariates in the model:

$$\log\left[\frac{p_{ijk}}{1 - p_{ijk}}\right] = X'_{ijk}\beta_1 + X'_{jk}\beta_2 + X'_k\beta_3 + u_{jk} + v_k. \quad (1)$$

Here,  $u_{jk}$  represents a family-level random effect and  $v_k$  a community-level random effect that are each normally distributed with a zero mean and variance  $\sigma_u^2$  and  $\sigma_v^2$ ,

<sup>1</sup> One concern in applying this model is the endogenous nature of the intermediate factors, which may be reflected in the correlation between these covariates and the error components. However, the cross-sectional structure of the data and the absence of any plausible instrumental variables mean that there is no convincing approach to correct for endogeneity.

<sup>2</sup> Unmeasured child-specific factors may be present, but are unidentifiable with the single observation we have for each child.

respectively. We assume that the observations are independent once we condition on  $u_{jk}$  and  $v_k$ , which capture any unobserved effects common to children from the same family and the same community. We can summarize the strength of unobserved family and community effects with the intra-class correlation coefficients for families ( $\rho_f$ ) and communities ( $\rho_c$ ).

We first estimate the reduced form model shown in Eq. 1 that includes only the background child ( $X_{ijk}$ ), family ( $X_{jk}$ ), and community ( $X_k$ ) covariates. We next add intermediate child ( $W_{ijk}$ ) and family ( $W_{jk}$ ) covariates to the model:

$$\log[p_{ijk}/(1 - p_{ijk})] = W'_{ijk}\gamma_1 + W'_{jk}\gamma_2 + X'_{ijk}\beta_1 + X'_{jk}\beta_2 + X'_k\beta_3 + u_{jk} + v_k. \quad (2)$$

By comparing the estimates obtained from Eqs. 1 and 2, we can examine how background factors affect diarrhea prevalence directly and indirectly. In particular, results based on Eq. 1 shows the total effect of each background factor on diarrhea prevalence (net of other background factors in the model). Comparing these results with those from Eq. 2 shows how the background factors operate through the intermediate variables that are added to the model.

Our analysis of diarrhea treatment focuses on the estimation of models based on Eq. 1 alone because this outcome represents one of the input factors in our conceptual framework. These models of the demand for diarrhea treatment are estimated only for children who were reported to have had diarrhea in the past 2-weeks. Because there were few cases of multiple children in a family with diarrhea in the past 2 weeks, the models control only for correlation among observations at the community level.

## Data

We use data from two nationally-representative surveys from Brazil conducted in 1986 and 1996 as part of the Demographic and Health Survey (DHS) Program. Each survey collected information on child health, as well as other topics related to fertility and reproductive health, from women of childbearing age. The two surveys were based on multistage, clustered sampling plans. The quality of the DHS data from Brazil is generally quite high.

The 1986 Brazil Demographic and Health Survey (DHS-1) completed interviews with 5,692 women aged 15–44 years from 337 primary sampling units across all of Brazil except for sparsely populated rural areas in the Brazilian Amazon. Information on diarrhea was obtained for 3,183 children under 5 years of age. The 1996 Brazil Demographic and Health Survey interviewed 12,612 women aged 15–49 years from 842 primary sampling units, again with the exception of rural areas in the Brazilian Amazon. Information on diarrhea in 1996 covered 4,617 children under age 5 years.

We use information from questions in the two DHS surveys that asked mothers about their children's diarrhea in the 2-weeks preceding the interview. Mothers were asked what treatments, if any, were provided for children with diarrhea. For more details about the questions in these two surveys on diarrhea prevalence and its treatment and a discussion about data quality issues, see Sastry and Burgard (2005).

## Model Covariates

The child, family, and community variables we include in our models are based on the conceptual framework outlined above. We present summary statistics for these variables in Table 2. Child-level background variables include age and sex. There is a strong relationship between a child's age and his or her probability of having diarrhea, much of which is due to changes in feeding and mobility. We discuss breastfeeding below; here we note that as children learn to crawl, they are much more likely to be exposed to pathogens in their environment and, through hand-to-mouth contact, to contract diarrhea. A child's sex may be related to diarrhea prevalence through sex-selective reporting or due to genuine differences in diarrhea relating to patterns of care or treatment that differ by children's sex.

Family-level background variables include the mother's and father's education, parents' marital status, and household wealth; community-level variables include rural–urban place of residence and region. Mother's education is a key factor relating to child health and has been the topic of much research over the past 20 years.<sup>3</sup> Accumulating evidence suggests that the most important role of maternal education in improving child health is to provide women with the ability to acquire, understand, and act on information about how to raise healthy children (Levine et al. 1994; Rosenzweig and Schultz 1982; Thomas et al. 1991; Glewwe 1999). In 1986, mothers averaged 4.7 years of schooling in Brazil, a figure that increased to 5.5 years a decade later—a statistically significant change.

The parents' marital status indicator distinguishes among women who were married, cohabiting, formerly married, or never married. Unmarried mothers may have fewer household resources than married women. The proportion of mothers married at the time of the survey decreased between 1986 and 1996, from 75 to 59%, and there was an accompanying large rise in the percentage of mothers who were cohabiting, from 16% in 1986 to 25% a decade later. All of these changes in marital status between 1986 and 1996 were statistically significant. Father's education is likely to have effects similar to those of mother's education, as well as reflecting the effects of socioeconomic status. Table 2 shows that children in 1996 were slightly less likely to have a father with at least a primary education, due to the increases in the fraction of women who did not have a partner or did not know their partner's schooling level (these latter two groups were combined based on a preliminary analysis that indicated they were very similar).

We created an index of household wealth based on a principal components analysis of household assets (Filmer and Pritchett 2001) that considered the ownership of a car, television, radio, vacuum cleaner, and a maid in 1986 and the same items plus a refrigerator, washing machine, and videocassette recorder as well as the number of rooms in the house, house construction material, and electrical connection in 1996. We used the household wealth index to distinguish children in households in the top wealth quartile from those in the bottom three quartiles. Region and rural–urban place of residence are important factors in the Brazilian context. Rural areas have poorer water and sanitation infrastructure and score

<sup>3</sup> For reviews, see Cleland and van Ginneken (1988) and Strauss and Thomas (1995).

**Table 2** Means (and standard deviations) or percent by category for independent variables by survey year for children under age 5 years in Brazil

Variable	Survey year	
	1986 DHS-1	1996 DHS-3
Child age (months)	30.1 (17.3)	29.3 (17.2)
Child sex		
Female	48.6%	49.2%
Male	51.4	50.8
Mother's education (years)	4.70 (3.96)	5.53 (3.73)
Marital status		
Married	75.0%	59.3%
Cohabiting	16.3	25.4
Never married	2.8	6.2
Previously married	5.9	9.1
Father's education		
None	17.3%	18.8%
Primary or more	82.4	76.4
Don't know/missing	0.3	4.8
Household wealth index		
Bottom 75%	75.8%	74.1%
Top 25%	24.2	25.9
Place of residence		
Urban	68.6%	74.7%
Rural	31.4	25.3
Region		
Northeast	38.9%	43.5%
Rest of Brazil	61.1	56.5
Birth order		
First born	28.7%	34.6%
Order 2–4	48.0	51.5
Order 5+	23.3	13.9
Child still breastfeeding		
No	83.4%	78.6%
Yes	16.6	21.4
Household water supply		
Piped	51.8%	64.3%
Well/undeveloped	48.2	35.7
Household sanitation		
Developed	46.2%	60.7%
Undeveloped	53.8	39.3
Number of observations	3,183	4,617

Source: Authors' calculations

lower on many level-of-living indicators. However, a polluted environment and unhygienic behaviors are likely to have a greater effect on diarrheal disease in high-density urban areas because of greater exposure to contaminants and easier

transmission of infectious agents (Cairncross and Valdmanis 2006; Moraes et al. 2003). The proportion of the sample living in urban areas increased between 1986 and 1996, from 69 to 75%.

Child- and family-level intermediate factors included in the models were the child's breastfeeding status, the child's birth-order, and household sanitation and water supply. We also examined the effects of breastfeeding duration, measles immunization, mother's age, and preceding and succeeding birth intervals. However, none of these latter variables had statistically significant effects and their inclusion did not alter the effects of other covariates; hence, they were excluded from the models we present.

Breastmilk provides protection against pathogens that cause diarrhea, and exclusive breastfeeding lowers the chances that children will be exposed to contaminated water or food. We expect the likelihood of diarrhea to increase greatly when a child first receives supplementary liquids or solids, which was likely to occur at early ages in Brazil because breastfeeding durations were brief. In 1986, the average duration of breastfeeding was 6.8 months and 17% of children were still breastfeeding at the time of the interview. These figures changed significantly by 1996, with breastfeeding durations increasing to 8.2 months and the percentage of children currently being breastfed rising to 21%.

Birth order may be related to diarrhea prevalence through its effects on the family environment. First-born children have mothers who are generally less experienced in looking after children, whereas high-order births (the fifth or later child born in a family) are associated with a larger number of siblings and increased opportunities for transmission of pathogens causing diarrhea. Larger families may also have more competition among siblings for limited resources. Due to declining fertility, there were significantly more first-born children and fewer children of fifth or higher birth order in 1996 than in 1986.

Improved household sanitation and water supply are expected to be the key factors associated with the decline of diarrheal disease in the long term. Sanitation and water supply have a direct effect in reducing exposure to pathogens. Previous studies have found that certain aspects of sanitation and water supply, such as the quantity of water available and whether the water was supplied inside or away from the home, are more important than other aspects, such as water quality (Esrey and Habicht 1986; Esrey et al. 1991; Fewtrell et al. 2005). Indirect effects may occur as the increased diffusion of sanitation and water supply in a community changes standard household hygienic practices. There was an increase in the availability of household piped water and sanitation over the decade under study. The proportion of families in our samples with piped water in their homes increased from 52% in 1986 to 64% in 1996, and the proportion with developed sanitation (a connection to the sewage network or a septic tank) increased from 46 to 61%.

## Results

In this section, we present the results from estimating multilevel logistic regression models for 2-week diarrhea prevalence. We also present results from models of

diarrhea treatment. Our regression results are presented in Tables 3 and 4. We show the estimated parameters and standard errors and indicate the level of statistical significance. The coefficients in the tables are odds ratios, which represent the change in the probability of the outcome associated with a one-unit increase for a continuous covariate or with a shift from the baseline category for a categorical covariate. As an example, the first coefficient in Table 3 shows that the 2-week probability of diarrhea increased by 1.36, or 36%, with each month of age during a child's first 5 months of life. The asterisks indicate that this effect was statistically significant at the 0.01 level. When an interaction with year is included, the covariate effect for the later period (1996) is the product of the direct effect and the interaction. For instance, the effect of having a father with primary or more education in Model I in Table 3 is to reduce diarrhea prevalence by .907, or 9%, in 1986 but by  $0.907 \times 0.618 = 0.560$ , or 44%, in 1996. The effect of father's education is not statistically significant in 1986 but is significant at the 0.01 level in 1996.<sup>4</sup>

### Models of Diarrhea Prevalence

The results from estimating models of 2-week diarrhea prevalence for children under age five are presented in Table 3. We estimated models that pooled the data from 1986 and 1996 to maximize the efficiency of the parameter estimates, although we included all statistically significant interactions with survey year to allow covariate effects to change over time.

Both the family and the community random effects are statistically significant in Model I (which includes background factors) and Model II (which adds intermediate factors to Model I). There is little difference in the random effects results between the two models, so we focus our discussion of the random effects on the findings from Model I. The variance of the family random effect (2.33) is more than six times larger than the variance for the community random effect (0.35), indicating that unobserved family effects were far more important than unobserved community effects. The intra-family correlation is 0.45 while the intra-community correlation was only 0.06. The large family-level effect indicates that there was a strong correlation in the chances of siblings having diarrhea that may be the result of important unmeasured maternal characteristics and household environmental factors (Sastry 1997), which is apparent despite the fact that there were, on average, only 1.33 children per family and 71% of families contributed a single child to the sample. In contrast, there was an average of 7.4 children and 5.6 women per sample community. Our results indicate that correcting for correlation among siblings and among children living in the same community is important for obtaining accurate parameter estimates and standard errors and making appropriate statistical inferences.

Model I in Table 3 fits the data well. There are statistically significant effects on diarrhea prevalence of child age, mother's education, father's education, parents' marital status, rural–urban place of residence, and region of residence. Several of these effects changed over time as revealed by their statistically significant

<sup>4</sup> For covariate effects based on the product of main and interaction effects, we report the statistical significance of this total effect in the text, not in the tables.

**Table 3** Multilevel logistic regression models of 2-week diarrhea prevalence for children under age 5 years in Brazil, 1986–1996

Variable	Model I	Model II
Child age (spline)		
0–5 months	1.364*** (0.061)	1.334*** (0.063)
6–59 months	0.955*** (0.003)	0.953*** (0.003)
Child sex		
Female <sup>a</sup>	–	–
Male	1.024 (0.086)	1.021 (0.086)
Mother's education (years)	0.919*** (0.015)	0.926*** (0.016)
Marital status		
Married <sup>a</sup>	–	–
Cohabiting	1.347*** (0.154)	1.329** (0.153)
Never married	0.796 (0.191)	0.745 (0.186)
Previously married	1.342* (0.231)	1.303 (0.225)
Father's education		
None <sup>a</sup>	–	–
Primary or more (additive effect)	0.907 (0.170)	0.994 (0.189)
Primary or more ( $\times 1996$ )	0.618** (0.145)	0.530*** (0.127)
Don't know/missing	0.604* (0.180)	0.593* (0.178)
Household wealth index		
Bottom 75% <sup>a</sup>	–	–
Top 25%	0.824 (0.109)	0.884 (0.120)
Place of residence		
Urban <sup>a</sup>	–	–
Rural (additive effect)	1.277 (0.230)	0.958 (0.185)
Rural ( $\times 1996$ )	0.506*** (0.120)	0.746 (0.194)
Year		
1986 <sup>a</sup>	–	–
1996	1.025 (0.259)	1.784** (0.503)
Region		
Rest of Brazil <sup>a</sup>	–	–
Northeast (additive effect)	1.284 (0.223)	1.081 (0.194)
Northeast ( $\times 1996$ )	1.481* (0.326)	1.773** (0.403)
Birth order		
First-born	–	1.125 (0.112)
Order 2–4 <sup>a</sup>	–	–
Order 5+	–	1.096 (0.138)
Child still breastfeeding		
No <sup>a</sup>	–	–
Yes (additive effect)	–	1.046 (0.181)
Yes ( $\times 1996$ )	–	0.601** (0.124)
Household water supply		
Piped <sup>a</sup>	–	–

**Table 3** continued

Variable	Model I	Model II
Well/undeveloped (additive effect)	–	1.485** (0.296)
Well/undeveloped ( $\times 1996$ )	–	0.618* (0.154)
Household sanitation		
Developed <sup>a</sup>	–	–
Undeveloped (additive effect)	–	1.527** (0.307)
Undeveloped ( $\times 1996$ )	–	0.622** (0.151)
Variance of random effects		
Family	2.330*** (0.441)	2.362*** (0.446)
Community	0.346*** (0.107)	0.333*** (0.107)

Notes: \*  $p < 0.10$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ ; standard errors in parentheses

Source: Authors' calculations based on 7,800 children from 1986 DHS-1 and 1996 DHS-2

<sup>a</sup> Omitted category

interactions with year. We found the expected age pattern of diarrhea prevalence, which was modeled as a two-part linear spline with a knot at 6 months on the basis of a detailed preliminary analysis (results not shown). We observe a large initial increase in diarrhea during the first 6 months of life, followed by a slow decline. There was a strong, negative linear effect of mother's years of education on a child's probability of having diarrhea. With every additional year of education for a woman, the probability of her child having diarrhea declined by 8%. Children of couples who were either cohabiting or previously married had diarrhea rates more than 34% higher than children of married couples. Having a father with primary or more schooling was associated with diarrhea rates in 1996 that were 44% lower than having a father with no schooling (as shown above); in 1986, however, father's education had only a small and statistically insignificant effect on diarrhea rates. Two other effects only emerged in 1996: rural–urban place of residence and region. We found that households in rural areas had marginally higher diarrhea rates in 1986; by 1996, however, rural areas enjoyed rates that were substantially and significantly lower than those in urban areas. In particular, by multiplying the additive effect for rural residence (1.277) by the interaction effect between rural residence and year (0.506), we see that rural residence in 1996 was associated with an effect of 0.646 that corresponds to 35% lower rates of diarrhea and was statistically significant at the 0.01 level. After controlling for other covariates in the model, diarrhea prevalence for the Northeast region in 1986 was not significantly different from the prevalence in the rest of Brazil (although the observed unadjusted difference was statistically significant). While the observed diarrhea prevalence declined between 1986 and 1996 in both the Northeast region and the rest of Brazil, by 1996 children in the Northeast region had a diarrhea prevalence that was almost twice as high as that in the rest of Brazil ( $1.284 \times 1.481 = 1.902$ ) and this difference was statistically significant at the 0.01 level.

There was an important period effect on diarrhea prevalence, although the presence of year interactions makes it impossible to read the period effect directly

from Table 3. Rather, the period effect needs to be calculated while taking into account the year main effect and all year interaction effects. Based on our calculations (not shown) using the results in Model I, the probability that a child had diarrhea in the past 2 weeks declined 29% between 1986 and 1996, an effect statistically significant at the 0.01 level.

Model II in Table 3 adds the intermediate factors identified above, together with all statistically significant interactions with year. The intermediate factors were jointly significant at the 0.01 level, and there are a number of interesting results from this analysis. However, these intermediate factors together did not perform especially well in revealing the pathways through which the background factors operate. This is possibly because of poor measurement of these variables—or of diarrhea prevalence itself—or because important intermediate factors were omitted. In particular, there was no change in the statistical significance for the effects of the background factors between Model I and Model II, with two exceptions: rural place of residence (in 1996) and the total effect of year after accounting for all interactions, both of which were only significant in Model II at the .10 level. In Model II, after taking into account all year interaction effects, the probability of a child having diarrhea in the later period (1996) was 18% lower than in the baseline period (1986) compared to 29% lower in Model I. Apparently, changes in the distributions of the intermediate variables that we added to Model II (breastfeeding, water supply, and sanitation), and, in particular, changes in the parameter estimates that relate these factors to diarrhea risk, together accounted for about one-third of the decline in diarrhea rates between 1986 and 1996.

Turning to the effects of the intermediate variables in Model II, we found that breastfeeding had a large beneficial effect on preventing diarrhea—but only in 1996. There were insignificant effects of breastfeeding in 1986. In contrast, better water supply and sanitation were associated with lower rates of diarrhea, but only in 1986; these effects were not statistically significant in 1996. This shift may be explained by the increase between 1986 and 1996 in the reach of the sanitation system and the piped water supply. The proportion of households in Brazil with a developed sanitation system or with piped water each exceeded 60% by the end of this period. At these high levels of penetration, the public health benefits from better hygienic behaviors were likely to accrue to almost everyone, regardless of whether they had a piped water connection or developed sanitation in their homes (Sastry 1996). By contrast, certain individual behaviors, such as breastfeeding, better capture heterogeneity in children's exposure to pathogens in their local environments. Breastfeeding became more important in the later period—after broad-based improvements in infrastructure had influenced most Brazilians. Furthermore, there was an increase in breastfeeding rates over the study period, and the evidence is that this increase was greater among advantaged women (Sastry and Burgard 2005).

### Analysis of Diarrhea Treatment

Next, we investigated treatment for diarrhea among children who were reported to have had an episode of diarrhea in the 2 weeks preceding the survey. The sample sizes for this analysis were much smaller than in the previous analysis of diarrhea

prevalence because less than one-fifth of children in the sample had diarrhea in the past 2 weeks. We examined two outcomes: first, the probability of a child receiving any treatment for diarrhea and, second, the probability of a child receiving ORT treatment. The two models included all the background covariates identified previously and the results are presented in Table 4.

A single consistent finding emerged from this analysis—namely, that the probability of a child receiving any treatment or ORT treatment for diarrhea was substantially higher in 1996 than in 1986. This represented a secular increase in treatment, with no consistent effects of any other covariate. There was an 85% increase between 1986 and 1996 in the probability of a child with diarrhea receiving any form of treatment. For ORT treatment, there was an enormous tenfold increase

**Table 4** Multilevel logistic regression models of diarrhea treatment for children under 5 years of age in Brazil, 1986–1996: any treatment and ORT treatment

Variable	Any treatment	ORT treatment
Child age (spline)		
0–5 months	0.974 (0.087)	1.178* (0.106)
6–59 months	0.995 (0.006)	0.983*** (0.005)
Child sex		
Female <sup>a</sup>	–	–
Male	0.790 (0.130)	0.923 (0.145)
Mother's education (years)	1.064** (0.033)	1.022 (0.029)
Marital status		
Married <sup>a</sup>	–	–
Cohabiting	1.334 (0.624)	1.334 (0.522)
Never married	1.147 (0.239)	1.293 (0.254)
Previously married	0.916 (0.283)	1.254 (0.370)
Father's education		
None <sup>a</sup>	–	–
Primary or more	1.009 (0.227)	1.218 (0.276)
Don't know/missing	1.513 (0.877)	1.364 (0.643)
Household wealth index		
Bottom 75% <sup>a</sup>	–	–
Top 25%	0.938 (0.260)	0.817 (0.202)
Place of residence		
Urban <sup>a</sup>	–	–
Rural	0.744 (0.159)	0.816 (0.202)
Year		
1986 <sup>a</sup>	–	–
1996	1.852*** (0.359)	10.006*** (2.349)
Region		
Rest of Brazil <sup>a</sup>	–	–
Northeast	0.960 (0.190)	0.732 (0.146)
Variance of random effects		
Community	0.727*** (0.176)	1.407*** (0.196)

Notes: \*  $p < 0.10$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ ; standard errors in parentheses

Source: Authors' calculations based on 1,252 children from 1986 DHS-1 and 1996 DHS-2 who had diarrhea in the previous 2-weeks

<sup>a</sup> Omitted category

in the likelihood of treatment between 1986 and 1996. There were only two other statistically significant results: mother's education was associated with a higher likelihood of any treatment and child's age was associated with ORT treatment. These findings suggest that there was a strong independent increase in diarrhea treatment—and, especially, ORT treatment—over this period that operated entirely separately from changes in child and family characteristics.

## Conclusions

The prevalence of diarrhea among young Brazilian children declined modestly over a 10-year period from the mid-1980s to the mid-1990s, similar to findings from other settings over this period (see Keusch et al. 2006). In Brazil in 1986, 17.8% of children had diarrhea in the past 2 weeks, while by 1996 this had declined to 14.8% of children. The modest nature of the decline in diarrhea prevalence is at least partly due to the absence of strong public health efforts to prevent children from getting the disease. From a policy perspective, efforts should be made to reduce diarrhea prevalence in Brazil because as many as one-in-seven children under 5 years of age suffered from the disease over a 2-week period. This high level of disease likely imposes a substantial burden on children's physical and cognitive development (Guerrant et al. 2003).

Family characteristics associated with lower diarrhea prevalence became more common over the study period. For example, the average number of years of schooling increased and the proportion of children who were breastfed also increased; other major changes included increases in the proportion of households with more hygienic types of water supply and sanitation. However, results from our regression analysis suggest that it was largely changes in the *relationships* between these family characteristics and diarrhea risk that accounted for the observed decline in prevalence between 1986 and 1996, rather than the improvements in these family characteristics themselves. Nevertheless, our results suggest that diarrhea prevalence rates in Brazil could be reduced through improvements in mother's education, father's education, and breastfeeding rates.

The potential for reducing diarrheal disease prevalence and its harmful consequences via state-led, broad-scale investments appears mixed. Improvements in household water supply and sanitation are unlikely to contribute to further lowering of diarrhea rates in Brazil. This is because current levels of infrastructure may have already generated their maximum public health benefit, which appears to have accrued to all households—not just those that received piped water or a flush toilet. In particular, improvements in infrastructure have apparently led to widespread adoption of hygienic behavior and a cleaner environment. By contrast, the rise in the use of ORT for children with diarrhea from 15% in 1986 to 54% in 1996 represents a major achievement for the Brazilian public health system. Especially noteworthy is the fact that ORT use is not associated with family socioeconomic characteristics, suggesting that public education and outreach efforts by health care providers were successful in broadly disseminating information about ORT.

Diarrhea is clearly an extremely important public health issue in Brazil and elsewhere in the developing world. There are, however, some serious difficulties in studying the disease. Although information on diarrhea has been collected in dozens of DHS surveys, it has not been widely used. We suspect this is principally because of perceived problems with data quality. However, given the important policy goal of reducing diarrhea prevalence, it is essential that researchers try to exploit data on diarrhea prevalence from DHS and other surveys as best they can. Alternative approaches to gathering data on diarrhea, featured in most epidemiological studies, are to collect objective measures and obtain detailed reports from mothers at frequent intervals. These prospective methods virtually guarantee that much more complete and accurate information is obtained, but these methods are feasible only for relatively small community studies. To understand regional, national, or global trends in diarrheal disease, information on diarrhea must also be collected in large-scale demographic and health surveys. Our study has shown that the information in DHS surveys can be used effectively and does shed some light on the nature of the changes and disparities in diarrhea prevalence and treatment. However, it remains important to improve the collection of information on diarrhea in large surveys. In particular, validation studies would be useful for assessing the accuracy and completeness of reported information.

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