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KEY WORDS

primary health care, family health program, Brazil, health services evaluation, under-5 mortality, diarrhea, lower respiratory infections

ABBREVIATIONS

PHC—primary health care
FHP—Family Health Program
BR—Brazilian reais

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WHAT'S KNOWN ON THIS SUBJECT: The FHP, one of largest PHC programs in the world, was created in Brazil in 1994 and experienced a dramatic expansion, but few studies have analyzed its general impact, and none has analyzed specific causes of preventable mortality.

WHAT THIS STUDY ADDS: The FHP succeeded in reducing mortality rates for children younger than 5 years in Brazil; it had a stronger effect on diarrheal diseases and lower respiratory infections, even after controlling for environmental, social, and economic variables.

abstract

OBJECTIVE: To evaluate the effects of the Family Health Program (FHP), a strategy for reorganization of primary health care in Brazil, on mortality of children younger than 5 years, particularly from diarrheal diseases and lower respiratory tract infections.

METHODS: Mortality rates and the extent of FHP coverage from 2000 to 2005 was evaluated from the 2601 (of 5507) Brazilian municipalities with an adequate quality of vital information. A multivariable regression analysis for panel data was conducted by using a negative binomial model with fixed effects, adjusted for relevant demographic and socioeconomic covariates.

RESULTS: A statistically significant negative association was observed between FHP coverage levels, classified as none (the reference category), low (<30%), intermediate (≥30% and <70%), or high (≥70%), and all analyzed mortality rates, with a reduction of 4% (95% confidence interval [CI]: 2%–6%), 9% (95% CI: 7%–12%), and 13% (95% CI: 10%–15%), respectively, on mortality rates or children younger than 5. The greatest effect was on postneonatal mortality. Reductions of 31% (95% CI: 20%–40%) and 19% (95% CI: 8%–28%) in mortality rates from diarrheal diseases and lower respiratory infections, respectively, were found in the group of municipalities with the highest FHP coverage.

CONCLUSIONS: The FHP, one of the largest comprehensive primary health care programs in the world, was effective in reducing overall mortality of children younger than 5, and particularly deaths related to diarrheal diseases and lower respiratory tract infections. *Pediatrics* 2010;126:e000

Primary health care (PHC) is considered one of the main pathways to improving a population's health and reducing maternal and child mortality, especially in developing countries.[1] The current PHC approach officially came into being at the Alma-Ata conference in 1978 and is on the basis of the principles of person-centeredness, continuity, comprehensiveness, and integration of care.[2]

In the last 30 years, PHC programs have been widely developed in Africa, Asia, and Latin America, but also in developed countries. However, the translation of values into tangible reforms has been uneven, and programs have been undertaken using a variety of principles and organizational approaches.[3] Recently renewed interest has been focused on PHC as a way of reducing growing health inequalities and of constructing more cost-effective health systems.[1,4]

In 1994, the Brazilian Minister of Health adopted the Family Health Program (FHP) as the national strategy for PHC. Since then the FHP has experienced a dramatic expansion, and by the end of 2008 it had been implemented in 94% of Brazilian municipalities, with coverage of almost 50% of the population.[5] The FHP aims to broaden access to public health services, especially in a context of limited resources, and is connected to secondary and tertiary levels of care so that patients can be referred between levels if necessary. According to Brazilian law, all this care must be free. The FHP is strongly decentralized and, in accordance with national regulations, is managed at municipal level. Each multiprofessional team, made up of a minimum of 1 physician, 1 graduate nurse, 1 auxiliary nurse, and from 4 to 6 community health workers, operates within a designated geographic area with a population of ~3450. Child health-related FHP activities include the promotion of breastfeeding, prenatal care, immunization, and the prevention and treatment of infectious diseases.[6] Brazil is experiencing a steep reduction in rates of mortality of infants and children younger than 5; even if these are still high when compared with countries with similar economic conditions. Reductions have mainly been because of a decrease in mortality related to communicable diseases, which has led to a relative increase in deaths from perinatal causes.[7]

Although the FHP represents one of the major structural changes in the national health system in recent years, few studies have analyzed its effect on population health outcomes.[8,9] In a recent study that used a multivariate binomial negative modeling of panel data from selected Brazilian municipalities from 1996 to 2004, a decrease of 22% in the infant mortality rate was reported for municipalities with a consolidated FHP service compared with municipalities without the FHP; specific causes of death, however, were not analyzed.[10] The objective of our study was to evaluate the impact of the FHP on mortality rates for children younger than 5 in Brazilian municipalities from 2000 to 2005, focusing on its effect on the major preventable causes of mortality in this age group: diarrheal diseases and lower respiratory infections.

METHODS

This study has an ecological design and adopts the municipality (county) as the unit of analysis. We used a longitudinal-data, or panel-data, model, and created a data set from several databases for the years 2000–2005.

From the 5507 Brazilian municipalities in 2000, we selected a subgroup that had adequate vital information for at least 3 consecutive years within the 6-year period. The quality of vital information was evaluated according to previously published criteria[11]: for municipalities with <50 000 inhabitants, the age-standardized mortality rate had to be ≥5.0 deaths per 1000 inhabitants, the ratio between registered and estimated birth rates ≥0.8, the percentage of ill-defined deaths ("symptoms, signs, and abnormal clinical and laboratory findings, not classified elsewhere," corresponding to codes R00–R98 from the *International Classification of Diseases, 10th Revision*) ≤20.7%, the mean deviation for birth rate ≤17.1%, and the mean deviation for age-standardized mortality rate ≤20.9%. For municipalities with >50 000 inhabitants, the age-standardized mortality rate had to be ≤6.3 deaths per 1000 inhabitants, the ratio between registered and estimated birth rate ≥0.8, the percentage of ill-defined deaths ≤16.2%, the mean deviation for the birth rate ≤8.1%, and the mean deviation for the age-standardized mortality rate ≤6.1%.

Mortality rates (neonatal, postneonatal, children younger than 5, and for specific causes) were obtained by direct calculation, using the Brazilian death certificates database for each year of the study, selecting deaths per age and/or cause, and aggregating them per municipality. For selected causes we used the following categories from the *International Classification of Diseases, 10th Revision*:[12] diarrheal diseases (A00, A01, A03, A04, A06–A09), lower respiratory infections (J10–J18, J20–J22), and injuries (V01–Y98). Mortality from injuries was included as a control, because there is no evidence for a main effect of FHP on this cause of mortality. The yearly coverage of the FHP was calculated as the ratio of the population covered by the program, represented by the sum of the persons registered and assisted by each FHP unit in the county, over the total population of the same municipality, and was classified according to

4 different categories: without FHP, low coverage (<30.0% of population), intermediate coverage (from 30.0% to 69.9%), and high coverage (≥70.0%).

We selected a set of variables, which are recognized in the literature as determinants for the mortalities studied and available in the source data sets, as covariates for the various models: total fertility rate (stratified as ≤2.32 and >2.32 children per childbearing-aged woman, median of the distribution), per capita income (monthly, in Brazilian reais [BR], stratified as ≤120 BR and >120 BR, the national poverty threshold, corresponding to 65 US dollars), percentage of individuals without basic literacy among the population over age 15 (stratified as ≤11.1% and >11.1%, median of the distribution), percentage of individuals living in households with running water (stratified as ≤96.9% and >96.9%, median of the distribution), percentage of individuals living in households with sewerage systems (stratified as ≤71.0% and >71.0%, median of the distribution), and local hospitals (stratified in present or absent in the municipality).

Data Sources

The data used in this study were collected from different information systems. We obtained vital statistics made available by the Brazilian Ministry of Health from the Mortality Information System, Primary Care Information System, Information System on Live Births and Outpatient Information System.[13] For socioeconomic and demographic variables, we used data from the Brazilian Institute of Geography and Statistics[14] and from the Human Development Atlas of the United Nations Development Program.[15] Because these covariates were obtained from the 1991 and 2000 national censuses databases, the annual values from 2001–2005 were calculated by linear extrapolation.[16]

Statistical Analyses

We used multivariable negative binomial regression models for panel data with fixed-effects specification. Negative binomial regression is used when the outcome to be analyzed is a count and when the Poisson model assumption that the mean is equal to variance is not met, usually because the data presents greater dispersion.[17] Longitudinal or panel data models include, besides the disturbance or error term, a second term to control for unobserved time-invariant characteristics of each subject, such geographical, historical, or sociocultural characteristics of each county. The choice of fixed-effect or random-effect models was based on the method by which the sample was drawn and on the Hausman specification test.[18] According to these criteria, fixed effects was the most appropriate specification for all the models.

To evaluate the association between specific mortality rates and FHP coverage levels, we calculated mortality rate ratios, both crude and adjusted for a set of demographic, social, and economic determinants as covariates, using municipalities without FHP as a reference category. An analysis of the same models with an additional covariate, the proportion of ill-defined deaths, was undertaken to evaluate the effect of quality of cause of death information on FHP impact for diarrheal diseases and lower respiratory infections. To understand the possible mechanism of FHP activity, models of bivariate associations between process variables and FHP coverage were fitted. The number of basic medical activities per inhabitant per year, intended as the total medical consultations and curative treatments at the primary care level, and the number of nurse or physician domiciliary visits per family per year, which are complementary to the routine community health worker visits, were selected as dependent variables.

RESULTS

The selection criteria were met by 2601 (47%) of the 5507 Brazilian municipalities in the year 2000.

In the period from 2000–2005, in the set of municipalities studied, mortality rates of children younger than 5 decreased from 22.6 to 18.1 per 1000 live births (Table 1). Neonatal mortality, which in percentage terms represents the greatest proportion of total mortality of children younger than 5, decreased (from 13.1 to 10.7 per 1000 live births), whereas postneonatal mortality had the greatest reduction (from 6.4 to 4.8 per 1000 live births, corresponding to a 25% reduction). Among the causes of mortality for children younger than 5, mortality rates for diarrheal diseases decreased from 0.81 to 0.46 per 1000 live births (a 43% reduction), as did mortality from lower respiratory infections (from 1.39 to 0.96 per 1000 live births, a 31% reduction); a slight decrease was observed in mortality because of injuries (from 1.13 to 1.03 per 1000 live births).

Socioeconomic conditions improved globally: there was a reduction in the total fertility rate and in the percentage of illiterate persons 15 or older, whereas increases were observed in monthly per capita income, the percentage of individuals who live in houses with running water, and the percentage of individuals who live in households with sewerage systems.

Table 2 shows the relationship of FHP coverage levels to mortality rate ratios, both crude and adjusted for covariates. In the adjusted model of mortality rates of children younger than 5, reductions of 4%, 9%, and 13% (all statistically significant) were found for

TABLE 1 Mortality Rates and Covariate Medians of Selected Municipalities ($N = 2601$): Brazil, 2000–2005

Variable	2000	2001	2002	2003	2004	2005
Mortality rates (per 1000 live births)						
<5 y	22.6	21.7	20.5	20.2	19.1	18.1
Infant	19.5	18.6	17.5	17.2	16.4	15.6
Neonatal	13.1	12.6	12.0	11.6	11.2	10.7
Postneonatal	6.37	6.01	5.51	5.57	5.20	4.85
1–4 y	3.09	3.12	2.97	3.02	2.72	2.52
Diarrheal diseases[a]	0.81	0.74	0.66	0.62	0.56	0.46
Lower respiratory infections[a]	1.39	1.24	1.16	1.17	1.11	0.96
Injuries[a]	1.13	1.09	1.09	1.11	1.06	1.03
Covariates						
Total fertility rate, No. of children per childbearing-aged woman	2.44	2.39	2.34	2.28	2.24	2.20
Percentage of illiterates among individuals >15 y	12.8	12.1	11.4	10.7	10.0	9.3
Per capita income (monthly, in BR)	216.9	223.6	231.4	238.4	243.4	250.0
Percentage of individuals living in households with running water	93.5	95.0	96.5	97.8	99.0	99.8
Percentage of individuals living in households with sewerage	20.3	21.8	23.3	25.1	26.6	27.5

[a] Mortality rates of children younger than 5.

TABLE 2 Fixed-Effect Negative Binomial Models for Crude and Adjusted Association Between Mortality Groups of Children Younger Than 5 and FHP Coverage: Brazil, 2000–2005

Variables	Mortality of Children Younger Than 5 y, RR (95% CI)		Neonatal Mortality RR (95% CI)	Postneonatal Mortality RR (95% CI)	Mortality of 1- to 4-y-Old Children, RR (95% CI)
	Crude	Adjusted			
FHP coverage					
No FHP[a]	1	1	1	1	1
Low[b]	0.94 (0.92–0.96)	0.96 (0.94–0.98)	0.97 (0.95–1.00)	0.93 (0.90–0.97)	0.98 (0.93–1.03)
Intermediate[c]	0.87 (0.85–0.89)	0.91 (0.88–0.93)	0.92 (0.89–0.95)	0.88 (0.84–0.91)	0.91 (0.86–0.97)
High[d]	0.82 (0.80–0.84)	0.87 (0.85–0.90)	0.89 (0.86–0.93)	0.83 (0.78–0.87)	0.88 (0.81–0.94)
Total fertility rate >2.32 children per woman of childbearing age	—	1.11 (1.08–1.14)	1.09 (1.05–1.14)	1.17 (1.11–1.23)	1.11 (1.03–1.18)
Percentage of illiterates among individuals >15 > 11.1%	—	1.03 (1.00–1.06)	1.00 (0.96–1.04)	1.08 (1.02–1.14)	1.08 (1.01–1.16)
Per-capita income (monthly) >120 BRD	—	0.90 (0.83–0.96)	0.95 (0.86–1.05)	0.82 (0.72–0.93)	0.90 (0.76–1.07)
Percentage of individuals living in households with running water >96.9%	—	0.92 (0.90–0.94)	0.91 (0.88–0.93)	0.92 (0.89–0.96)	0.93 (0.89–0.98)
Percentage of individuals living in households with sewerage >71.0%	—	0.91 (0.88–0.95)	0.93 (0.89–0.97)	0.87 (0.82–0.93)	0.92 (0.85–1.01)
Presence of local hospitalizations	—	1.00 (0.94–1.07)	1.05 (0.96–1.15)	0.94 (0.84–1.05)	1.07 (0.91–1.26)
No. of observations	15 570	15 570	15 450	14 694	13 848
No. of municipalities	2595	2595	2575	2449	2308

CI indicates confidence interval; RR, rate ratio.
[a] Coverage equal to 0% of the population.
[b] Coverage of <30% of the municipal population.
[c] Coverage of 30% to 69.9% of the municipal population.
[d] Coverage of ≥70% of the municipal population.

low, intermediate, and high levels of coverage, respectively.

Comparing the effect of the FHP on neonatal, postneonatal, and 1- to 4-year-old mortality, the greatest reduction was found in postneonatal mortality rates, at 7%, 12%, and 17% for increasing levels of coverage. The smallest effect was observed on neonatal mortality, reaching a maximum reduction of 11%. Among the mortality rates for 1- to 4 year-olds, the effect of the FHP was similar to that seen in the younger-than-5 period (2%, 9%, and 12%).

Table 3 presents the effect of the FHP on the selected causes of mortality of children younger than 5. We found the strongest reduction in diarrheal diseases, with a higher dose-effect slope, reaching 11%, 18%, and 31%, according to FHP coverage level, whereas a smaller effect was observed on lower respiratory infections (13%, 20%, and 19%). The FHP had no effect on mortality from injuries, because the mortality rate ratios did not vary with level of FHP coverage.

An analysis of the same models using the proportion of ill-defined deaths as an additional covariate revealed no significant modification of FHP effect.

The selected PHC process indicators demonstrated a relevant improvement

TABLE 3 Fixed-Effect Negative Binomial Models for Association Between Causes of Mortality of Children Younger Than 5 Years and FHP Coverage: Brazil, 2000–2005

Variables	Mortality From Diarrheal Diseases, RR (95% CI)	Mortality From Lower Respiratory Infections, RR (95% CI)	Mortality From Injuries, RR (95% CI)
Crude			
FHP coverage			
No FHP[a]	1.00	1.00	1.00
Low[b]	0.84 (0.75–0.94)	0.84 (0.78–0.91)	1.04 (0.96–1.13)
Intermediate[c]	0.75 (0.66–0.85)	0.75 (0.68–0.82)	0.91 (0.83–1.00)
High[d]	0.61 (0.53–0.70)	0.74 (0.66–0.83)	0.99 (0.89–1.11)
Adjusted[e]			
FHP coverage			
No FHP[a]	1.00	1.00	1.00
Low[b]	0.89 (0.79–1.00)	0.87 (0.80–0.94)	1.05 (0.97–1.13)
Intermediate[c]	0.82 (0.73–0.94)	0.80 (0.72–0.88)	0.92 (0.84–1.01)
High[d]	0.69 (0.60–0.80)	0.81 (0.72–0.92)	1.01 (0.89–1.14)
No. of observations	8130	10 074	10 998
No. of municipalities	1355	1679	1833

CI indicates confidence interval; RR, rate ratio.
[a] Coverage equal to 0% of the population.
[b] Coverage of <30% of the municipal population.
[c] Coverage of 30% to 69.9% of the municipal population.
[d] Coverage of ≥70% of the municipal population.
[e] Models adjusted for total fertility rate, per capita income (monthly), percentage of functional illiterates among individuals older than 15, percentage of individuals living in households with running water, percentage of individuals living in households with sewerage, and local hospitalizations.

TABLE 4 Fixed-Effect Negative Binomial Models for the Bivariate Association Between PHC Indicators and FHP Coverage: Brazil, 2000–2005

Variables	Basic Medical Activities per Inhabitant per Year, RR (95% CI)	Domiciliary Visits per Family per Year, RR (95% CI)
FHP coverage		
No FHP[a]	1.00	1.00
Low[b]	1.00 (0.98–1.02)	1.00 (0.91–1.10)
Intermediate[c]	1.03 (1.01–1.05)	1.45 (1.30–1.60)
High[d]	1.22 (1.20–1.25)	2.66 (2.41–2.94)
No. of observations	15 606	8634
No. of municipalities	2601	1439

CI indicates confidence interval; RR, rate ratio.
[a] Coverage equal to 0% of the population.
[b] Coverage of <30% of the municipal population.
[c] Coverage of 30% to 69.9% of the municipal population.
[d] Coverage of ≥70% of the municipal population.

(Table 4): the number of annual basic medical activities per inhabitant per year increased by 22% at the highest coverage, and the number of domiciliary visits per family per year reached a maximum increase of 166%.

DISCUSSION

Our study results reveal that the FHP succeeded in reducing child mortality rates in Brazilian municipalities, with a strong effect on diarrheal diseases and lower respiratory infections, even after controlling for environmental, social, and economic variables. Among children younger than 5, postneonatal mortality was the most vulnerable to FHP intervention, as demonstrated in previous studies.[9,10] It has to be considered that no major changes occurred in the national therapy guidelines on child health care during this time period.[19]

The program demonstrated the least effect on neonatal mortality. The majority of neonatal deaths were because of perinatal causes (83% in 2005), and although prenatal care represents an important protection factor for perinatal deaths, mortality depends heavily on the quality of delivery care.[20,21] It should be noted that in Brazil >96% of births occur in hospitals.[13]

The strong effect of the FHP on postneonatal mortality could be explained by its capacity to increase access to medical care, which, together with environmental and socioeconomic conditions, is one of the main determinants of this mortality.[22] Moreover, in comparison with mortality patterns in other groups, a larger proportion of postneonatal deaths were because of infectious diseases, in particular to diarrheal diseases (11.3% in 2000), which are more preventable through FHP interventions. Early childhood mortality (mortality between 1 and 4 years) is also strongly related to socioeconomic conditions,[23] but the proportion of deaths caused by diarrheal diseases was lower (5.1% in 2000).

As suggested in previous studies,[9] we demonstrated that the FHP succeeds in strongly reducing diarrhea mortality, a mortality that is still high in several areas of Brazil. In fact, the FHP adopts and promotes the use of oral rehydration therapy, which is recognized as one of the most effective therapeutic interventions in reducing diarrhea mortality worldwide.[24] At the community level, the program implements various activities that have a demonstrated impact on diarrhea morbidity and mortality: promotion of exclusive breastfeeding and of correct weaning practices (that have been seen to be among the most effective), education of mothers in appropriate feeding during and after diarrhea episodes, personal hygiene, and food preparation practices.[25,26] Preventive actions for diarrhea mortality are particularly necessary because, with a few exceptions, the data suggest that the pronounced decline in diarrheal mortality rate in Brazil as a whole has followed only a modest decrease in diarrhea prevalence.[27,28]

The FHP also had a strong effect on mortality from lower respiratory infections. FHP activities enhance the most effective interventions in reducing lower respiratory infection mortality: early case diagnosis, treatment with antibiotics, and vaccination for pertussis and measles.[29] In addition, it can play an important role in the prevention of low birth weight, improvements in child nutrition, and breastfeeding practices, which are recognized as protective factors.[6,30]

Rates of mortality from injuries were used here as a control because FHP activities do not include actions related to injury prevention,[6] and we could not expect any major effect on this cause of mortality with increased FHP coverage.

As described in a previous study, we demonstrated that the FHP succeeded in increasing PHC actions in municipalities,[10] as the number of basic medical activities and of domiciliary visits per family per year.

From a methodologic point of view, the application of previously defined quality criteria for the vital information to select the municipalities to be analyzed enabled the direct calculation of reliable mortality rates, avoiding the common drawbacks of indirect estimates.[31]

Negative binomial regression of panel data, widely used in econometric literature, has recently been introduced in health studies[10,32,33] and represents a more appropriate model for the analysis of overdispersed count and rates data (such as mortality data sets).[17] It also enables an estimation of mortality rate ratios, an important measurement both in epidemiologic reasoning and for the evaluation of effectiveness in public health interventions.

One of the main limitations of this study was the possibility of ecological fallacy: it is impossible to exactly determine the exposure of those people who experienced the outcome because the only information available is at an aggregate level. However, the use of the municipality, a smaller unit of analysis than those used in certain previous studies,[8,9] could contribute to the minimization of this bias.

Another potential limitation was the selection of municipalities that was conditional on the quality of vital information, which reduced the number of analyzed panels. Moreover, the number of observations varied in different models, because of the presence of municipalities with 0 death counts for the whole 6-year period. For statistical reasons linked to the fixed-effects model computation, these municipalities are not included in the model fitting.

Comparing the covariate values of the municipalities included in each model to those that were excluded (obtained by subtracting the former from the total number of Brazilian counties), we generally found better values of the socioeconomic variables in the former, suggesting that counties with inadequate vital information are also poorer and have worse health conditions. A sensitivity test, conducted by fitting the models with data from all the Brazilian municipalities, showed similar, statistically significant, but slightly inferior (probably because of death underreporting) FHP effects. The selection undertaken may have limited the generalization of the results but improves the study's internal validity, because the reliability of the vital information is an essential prerequisite in evaluating the effect of different levels of FHP coverage on the mortality rates.

The use of extrapolation techniques to estimate the annual value of some covariates could represent another limitation of the study. In fact, the only measured values of these variables were from the 1991–2000 census; values for 2001–2005 were obtained by extrapolation. Possible bias, introduced by the use of crude extrapolation rather than more complex estimation techniques, is limited by variable categorization, which is able to level out the sharp fluctuations artificially introduced by this method. Moreover, comparisons of the covariate values obtained by extrapolation at state level with values from the National Household Sample Survey, which provides yearly estimates of these variables for each Brazilian state,[34] demonstrated great similarities. A time-representing variable was not included in the model because the use of mortality rate ratios with a comparison group (municipalities without FHP) allowed for control of unknown effects linked to mortality time trends.[10]

CONCLUSIONS

Our results reveal the effectiveness of a comprehensive and community-based PHC program on reduction of childhood mortality in a heterogeneous country like Brazil. These results suggest that a PHC program with these features is particularly effective in areas in which there is a high incidence of infectious diseases (and, for the most part, in precarious socioeconomic conditions); therefore, it is in the Brazilian context that the FHP is able to contribute to reduction of severe, within-country health inequalities.[10] At the same time, the FHP, like PHC programs in others countries,[35,36] needs to be refined to cope with the changing health needs of its communities. Today, 30 years after Alma-Ata, there is growing evidence that PHC programs that are appropriately implemented, economically supported, and adapted to the specific epidemiologic profiles and socioeconomic conditions of the population, can significantly contribute to improving child health across the world.

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