ELSEVIER

Social Science & Medicine 65 (2007) 2070–2080

SOCIAL SCIENCE & MEDICINE

www.elsevier.com/locate/socscimed

Going to scale with community-based primary care: An analysis of the family health program and infant mortality in Brazil, 1999–2004

James Macinko[a,*], Maria de Fátima Marinho de Souza[b], Frederico C. Guanais[c], Celso Cardoso da Silva Simões[d]

[a]*University of Pennsylvania, RWJF Health and Society Scholars program, 3641 Locust Walk, Philadelphia, PA 19104, USA*
[b]*Secretariat of Health Surveillance, Ministry of Health, Brasília, Brazil*
[c]*Ministry of Social Development and the Fight against Hunger, Brasília, Brazil*
[d]*Institute of Geography and Statistics (IBGE), Rio de Janeiro, Brazil*

Available online 8 August 2007

Abstract

This article assesses the effects of an integrated community-based primary care program (Brazil's Family Health Program, known as the PSF) on microregional variations in infant mortality (IMR), neonatal mortality, and post-neonatal mortality rates from 1999 to 2004. The study utilized a pooled cross-sectional ecological analysis using panel data from Brazilian microregions, and controlled for measures of physicians and hospital beds per 1000 population, Hepatitis B coverage, the proportion of women without prenatal care and with no formal education, low birth weight births, population size, and poverty rates. The data covered all the 557 Brazilian microregions over a 6-year period (1999–2004).

Results show that IMR declined about 13 percent from 1999 to 2004, while Family Health Program coverage increased from an average of about 14 to nearly 60 percent. Controlling for other health determinants, a 10 percent increase in Family Health Program coverage was associated with a 0.45 percent decrease in IMR, a 0.6 percent decline in post-neonatal mortality, and a 1 percent decline in diarrhea mortality ($p<0.05$). PSF program coverage was not associated with neonatal mortality rates. Lessons learned from the Brazilian experience may be helpful as other countries consider adopting community-based primary care approaches.

Keywords: Primary health care; Family health program; Brazil; Health services evaluation; Infant mortality

Introduction

There is renewed worldwide interest in primary health care and its potential for improving human health (Pan American Health Organization, 2007). But there have been few peer-reviewed studies that assess the effectiveness of national primary health care strategies on improving population health in the developing world. This study attempts to fill this gap by analyzing the effects of the Brazilian Family Health Program (*Programa Saúde da Família* or PSF in Portuguese) on child health. Child health outcomes are particularly important to examine because of the higher-than-expected rates of infant

*Corresponding author. Tel.: +1 2129985592.
E-mail addresses: jmj5@nyu.edu (J. Macinko), mfmsouza@usp.br (M. de Fátima Marinho de Souza).

0277-9536/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.socscimed.2007.06.028

and child mortality in Brazil as compared to other countries of similar gross national income, the PSF's emphasis on improving infant and child health, and the possibility of observing rapid changes in these outcomes over a relatively short period of time.

The PSF is the main approach to provide primary care services within Brazil's national health system, known as the *Sistema Única de Saúde* or SUS (Almeida & Pêgo, 2002). The PSF has its roots in the community health agents program begun in the state of Ceará in the early 1990s (Cufino Svitone, Garfield, Vasconcelos, & Araujo Craveiro, 2000). Since it was adopted as a national strategy in 1994, the program had grown by 2007 to encompass 26,730 community-based teams responsible for providing care to about 85 million people, making it one of the world's largest systems of community-based primary care (Brazilian Ministry of Health Department of Primary Care, 2007).

The PSF is a decentralized approach to providing core primary care functions, including first-contact access for each new health need, comprehensive and person-focused care over the lifecourse, coordination of care between different providers and types of health services, and family and community-oriented health promotion activities (Ministry of Health of Brazil, 2003). These functions are achieved through the program's organization (municipalities manage the program with national supervision and each PSF team is assigned to a geographical area with responsibility for enrolling and monitoring the health status of about 3500 people), its financing (services are delivered free of charge, are financed on a capitation basis, and municipalities have incentives for increasing the number of neighborhoods with access to the program), and delivery mechanisms (multidisciplinary teams are composed of, at minimum, a physician and nurse who deliver clinic-based care and most teams include community health workers who make regular home visits and perform community-based health promotion activities) (Ministry of Health of Brazil, 2003). Family Health Program teams in many areas also include dental and social work professionals.

Despite the ambitious scope of this undertaking there have been only a few evaluations of the program (Conill, 2002; Escorel et al., 2002; Ministério da Saúde, 2004; Serra, 2005; Viana & Pierantoni, 2002) although several more are underway. To date, only one peer-reviewed article has assessed the relationship between PSF coverage and changes in health outcomes at the national level (Macinko, Guanais, & Marinho de Souza, 2006). The present article expands and strengthens earlier work by employing local-level analyses, examining several different outcomes, and by assessing the effects of the rapid expansions in PSF coverage over the past few years.

Methods

This study follows a quasi-experimental design since each municipality in Brazil adopted the PSF at different times and coverage in each municipality grew at different rates. To take advantage of this heterogeneity, we use a pooled, cross-sectional, time series approach to assess the relationships between dependent and independent variables over a 6-year period. This technique pools together 6 years (1999–2004) of cross-sections (composed of all 557 Brazilian microregions for each year) for a maximum sample size of 3342 observations. The approach provides an estimate of the health effects of program expansion by testing the association between differences in coverage in each microregion with differences in infant mortality outcomes, while controlling for potential confounders (Hsiao, 2003).

In order to strengthen the study design, we analyze two types of outcomes. Based on previous literature, we hypothesize that the PSF will have a strong association with outcomes most sensitive to primary care: post-neonatal mortality (deaths of children from 30 days to 1 year per 1000 live births) and deaths from diarrheal diseases (deaths of children under 1 year from diarrhea per 1000 live births) (Caldeira, França, & Goulart, 2001; Caldeira, França, Perpetuo, & Goulart, 2005). It should have a modest impact on IMR (all deaths of children under 1 year per 1000 live births in the same year) that will depend on the proportion of IMR that is composed of post-neonatal mortality (Moore, Castillo, Richardson, & Reid, 2003). We hypothesize that there should be little or no relation between PSF coverage and neonatal mortality rates (deaths of children within their first month of life per 1000 live births), since these outcomes are most sensitive to care provided primarily by specialist and hospital services outside the scope of the PSF (Lansky, França, & Leal Mdo, 2002).

The unit of analysis is the microregion. Each of the 557 microregions contains several of Brazil's 5564 municipalities that have been grouped together to be geographically contiguous and homogeneous in terms of demography, agriculture, and transportation. Microregions represent smaller units of analysis and thus capture greater variation than would analysis of the 27 Brazilian states. Microregions also have a larger population size than individual municipalities, thus allowing for more stable mortality estimates over time.

Data on PSF coverage, health resources, and outcomes are from the Brazilian Ministry of Health (Ministry of Health of Brazil, 2007). In this study, we use official estimates of IMR that have been adjusted for underreporting of child deaths (Rede Interagencial de informações para a saúde (RIPSA), 2002; Szwarcwald, Leal Medo, de Andrade, & Souza, 2002). All other outcomes (neonatal, post-neonatal, and diarrhea mortality rates) are constructed directly from observed counts.

Independent variables known to influence infant mortality include poverty (proportion of the population in the lowest income quintile), women's health and development (proportion of women over 15 with no formal schooling, and proportion of women with no prenatal care), child health (proportion of children with Hepatitis B immunizations, low birth weight defined as percent of births under 2500 g), and health services (physicians and hospital beds per 1000) (Moore et al., 2003; Wang, 2003). Data on these variables are based on population surveys conducted by the Brazilian Institute of Geography and Statistics (IGBE) and developed for state-level representativity by the Institute of Applied Economic Research (IPEA) (Brazilian Institute of Geography and Statistics, 2005; Instituto de Pesquisa Econômica Aplicada (IPEA), May 2005).

Some independent variable data were missing for some years. Missing data were imputed using non-linear interpolation methods that modeled within-municipal changes as a function of prior values at the municipal level and contemporaneous values at the state level (Allison, 2002; Guanais, 2006). All values were then summed up to the microregional level.

Statistical analyses

The study uses a fixed-effects specification in order to correct for serial correlation of repeated measures and to control for time-invariant unobserved or unobservable microregional characteristics. An alternative approach, the random effects model, was rejected due to results of the Hausman test ($p < .0001$) that tested correlation between the regressors and error terms. (Wooldridge, 2002) All analyses were conducted using Stata 9 software and use robust standard errors to correct for heteroskedasticity (Statacorp, 2005).

Advantages of the fixed-effects model over cross-sectional analyses include the fact that it is able establish temporal ordering between exposures and outcomes and it can control for unmeasured time-invariant characteristics of the microregion (such as geography, historical disadvantages, urban/rural location, and local cultural practices) that might influence health outcomes (Hsiao, 2003). One disadvantage of the fixed-effects approach is that the results obtained are conditional on the data used to estimate them; that is, results cannot be generalized to other years or microregions not included in the study (Hsiao, 2003).

In order to compare how variables changed over time, we calculate the mean values and standard deviations for 1999 and 2004 and the percent change during this time. Differences in mean values between time periods were assessed using *t*-tests. Regression analyses are presented as a series of nested models. The *F*-test is used to assess whether the inclusion of an additional set of independent variables improved regression models. In order to compare the magnitude of the effects of the main explanatory variables on the outcomes, we calculated their marginal effects. This statistic represents the percent change in the outcome given a one-percent change in the independent variable, when all other values are set at their mean (Greene, 2003).

We also assessed several pathways by which the PSF might influence IMR. Primary care access is associated with lower post-neonatal mortality and fewer deaths from diarrhea (UNICEF, 2002). In order to test potential mechanisms of the health effects of PSF expansion we developed a set of dummy variables representing microregions in the highest 75th percentile of under-five deaths from both of these conditions (called "high diarrhea deaths" and "high postneonatal deaths," respectively). We then created interaction terms between these binary variables and PSF coverage to test if the PSF effect was higher in those microregions where a greater share of infant and child mortality was amenable to primary care. Other interactions of the PSF term (with physicians per 1000 population and Hepatitis B coverage) were not significant and therefore not included in the final models.

Because there are great differences in health and economic development between the poorer north and northeastern regions of Brazil, as compared with the south, southeast, and central-west regions, we present analyses stratified by region.

In order to test if there might be a threshold effect for certain levels of PSF coverage, we transformed PSF coverage into quartiles of coverage and included these in regression models.

Finally, we performed a number of sensitivity tests, including using statistical models to control for potential panel-level autocorrelation and using Poisson regression to directly model count data for each outcome (Greene, 2003). None of these alternative specifications significantly affected the sign, significance, or main conclusions reached with the fixed effects models, suggesting that the results presented here are robust.

Results

Table 1 presents descriptive statistics. Between 1999 and 2004 some measures of infant mortality declined: IMR was reduced by 13 percent, post-neonatal mortality by 16 percent and diarrhea-specific mortality by 44 percent. However, neonatal mortality increased by 5 percent and the percentage of births that were low birth weight increased 10 percent. By 2004, the PSF covered about 60 percent of the population in the microregions, ranging from a low of 6 percent to over 100 percent for the top 90th percentile. Access to some forms of healthcare appeared to increase: Physician availability increased by 87 percent, Hepatitis B coverage increased by 20 percent, and access to prenatal care increased by 50 percent. Hospital beds per 1000 declined slightly. Average population size for microregions increased by nearly a quarter and most of this increase occurred in large metropolitan areas. The proportion of the population in the lowest income quintile increased slightly, while the proportion of mothers with no education declined by nearly one-third from 1999 levels.

Table 2 presents the results of the fixed effects analyses. Model 1 shows the bivariate relationship between PSF and IMR: the larger the proportion of the state's population served by the PSF, the lower the expected infant mortality rate. Model 2 adds health system covariates to model 1. PSF coverage remains significant and negatively associated with IMR. In terms of covariates, physician supply and Hepatitis B coverage were negatively associated with IMR, while hospital beds were positively associated with it. The *F*-test is statistically significant, suggesting that addition of these covariates improves the explanatory power of model 2 over model 1.

Model 3 adds a set of social and economic variables. Population size was negatively associated with IMR, suggesting that IMR is lower in microregions with larger populations. Both the proportion of women with no formal education and the proportion of the population in the lowest income quintile were positively associated with IMR. The PSF coefficient remains significant and negative (although slightly reduced in magnitude),

Table 1
Descriptive statistics for Brazilian microregions 1999–2004 ($n = 557$)

Indicator	Statistic	1999	2004	Difference	% Change
Adjusted infant mortality rate[a] (per 1000 live births)	Mean (s. dev)	30.155 (13.776)	26.096 (12.429)	−4.059***	−13.46
Neonatal mortality rate (per 1000 live births)	Mean (s. dev)	4.581 (0.108)	4.844 (0.087)	0.263*	5.74
Post-neonatal mortality rate (per 1000 live births)	Mean (s. dev)	16.961 (8.286)	14.177 (4.670)	−2.784***	−16.41
Neonatal mortality (as % of IMR)	Mean (s. dev)	21.591 (9.532)	25.783 (9.480)	4.192***	19.41
Proportionate mortality from diarrhea (as % of IMR)	Mean (s. dev)	3.215 (0 .271)	1.782 (0.149)	−1.432***	−44.54
Coverage of family health program (%)	Mean (s. dev)	13.714 (15.862)	59.883 (31.137)	46.169***	336.66
Physicians per 1000 population[b]	Mean (s. dev)	1.647 (1.141)	3.079 (1.983)	1.432***	86.97
Hospital beds per 1000 population[b]	Mean (s. dev)	2.992 (1.867)	2.591 (1.662)	−0.401***	−13.40
Children immunized against Hepatitis B (%)	Mean (s. dev)	74.088 (33.192)	93.215 (12.098)	19.127***	25.81
Population (1000s)	Mean (s. dev)	294.953 (772.812)	318.211 (828.998)	23.259***	7.88
Population in poorest income quintile (%)[b]	Mean (s. dev)	20.703 (88.715)	23.756 (97.122)	3.053***	14.74
Mothers with no formal education (%)	Mean (s. dev)	5.722 (7.659)	4.015 (4.605)	−1.707***	−29.83
Mothers with no prenatal care (%)	Mean (s. dev)	6.247 (7.262)	2.855 (4.382)	−3.392***	−54.30
Low birth weight (% of all births)	Mean (s. dev)	6.765 (1.502)	7.423 (1.546)	0.658***	9.73

Sources: IBGE, SIM/SINASC, IPEA, MAS.* $p<0.05$; ** $p<0.01$; *** $p<0.001$; from paired *t*-test.
[a]Adjusted infant mortality rate takes into account underreporting of infant deaths in some municipalities.
[b]Missing values for 2001 and 2003–2004 calculated through interpolation.

Table 2
Fixed effects regression models of infant mortality rates[a] for the microregions of Brazil, 1999–2004

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Family health program (% population covered)	−0.057** (0.001)	−0.042** (0.003)	−0.038** (0.002)	−0.030** (0.002)	−0.028** (0.002)	–
Family health program (Coverage quartile 2)	–	–	–	–	–	−0.715** (0.066)
Family health program (Coverage quartile 3)	–	–	–	–	–	−1.346** (0.105)
Family health program (Coverage quartile 4)	–	–	–	–	–	−2.188** (0.147)
Physicians (per 1000 population)	–	−0.385** (0.139)	−0.333** (0.128)	−0.296** (0.113)	−0.299** (0.112)	−0.353** (0.117)
Hospital beds (per 1000 population)	–	0.478** (0.063)	0.343** (0.056)	0.350** (0.055)	0.366** (0.055)	0.365** (0.056)
Hepatitis B vaccination (% children covered)	–	−0.013** (0.001)	−0.014** (0.001)	−0.012** (0.001)	−0.011** (0.001)	−0.012** (0.001)
Population (1000s)	–	–	−0.012** (0.002)	−0.009** (0.001)	−0.009** (0.001)	−0.009** (0.001)
Population in poverty (% in lowest income quintile)	–	–	0.035** (0.009)	0.027** (0.007)	0.025** (0.007)	0.025** (0.007)
No formal education (% of all mothers)	–	–	0.158** (0.017)	0.098** (0.015)	0.097** (0.014)	0.104** (0.015)
No prenatal care (% of all mothers)	–	–	–	0.160** (0.016)	0.149** (0.015)	0.160** (0.015)
LBW births (% of all births)	–	–	–	−0.214** (0.028)	−0.217** (0.028)	−0.213** (0.028)
High diarrhea deaths (75th percentile)	–	–	–	–	0.452** (0.096)	–
Interaction: (PSF* high diarrhea deaths)	–	–	–	–	−0.007** (0.002)	–
High post-neonatal mortality (75th percentile)	–	–	–	–	0.333** (0.092)	–
Interaction: PSF* high post-neonatal mortality	–	–	–	–	−0.003* (0.001)	–
Constant	30.200** (0.059)	30.340** (0.393)	32.530** (0.574)	32.531** (0.516)	32.277** (0.512)	32.059** (0.526)
Observations	3342	3337	3337	3337	3337	3337
Number of microregions	557	557	557	557	557	557
R-squared (within)	0.567	0.625	0.688	0.733	0.725	0.74
F-test (model 2 v 1)	–	71.49**	–	–	–	–
F-test (model 3 v 2)	–	–	55.52**	–	–	–
F-test (model 4 v 3)	–	–	–	78.25**	–	–

Robust standard errors in parentheses. Microregion fixed effects not shown.
*$p<0.01$; ** $p<0.001$,
[a]Infant mortality rate expressed as per 1000 live births and adjusted for underreporting of infant deaths in some municipalities.

and socioeconomic variables remain stable. Based on the results of the *F*-test, Model 3 is considered superior to the previous models.

Model 4 includes additional maternal and child health indicators. The proportion of women with no prenatal care is positively associated with IMR while the percentage of births that are low weight is negatively associated with IMR. The PSF variable is lightly reduced in magnitude, but remains similar in direction and statistical significance. Results of the *F*-test indicate that Model 4 is superior to any previous models. The *R*-squared value suggests that the model explains up to 73 percent of the within-microregion variation in IMR from 1999 to 2004.

Model 5 further explores the relationship between PSF and IMR by including interaction terms between PSF coverage and microregions with high proportionate mortality from diarrhea and high post-neonatal mortality. The coefficients for high diarrhea mortality and for high post-neonatal mortality are positive and significant, suggesting that IMR is higher in those microregions with very high levels of diarrhea-related and post-neonatal deaths. The interaction variable for PSF*diarrhea and PSF*post-neonatal deaths is significant and negative, suggesting that increases in PSF coverage have a particularly strong impact on lowering IMR by reducing diarrhea and post-neonatal deaths in areas where these rates are high.

Model 6 tests a transformation of the PSF variables to reflect quartiles of coverage. The results show that as PSF coverage increases, the magnitude of the regression coefficient likewise increases, suggesting a dose–response relationship.

Table 3 presents results for neonatal, post-neonatal, and diarrhea mortality rates. All covariates are the same as in the full model (Model 4 from Table 2). Family health program coverage was not associated with neonatal mortality, although it was negatively associated with both post-neonatal and diarrhea mortality rates.

Table 4 presents analyses stratified by geographic region. The main finding is that the PSF has a consistently significant negative association with IMR in each region. Covariates are generally similar to the full sample analysis, although in the regional analyses poverty is significant only for the north region, physicians are not significant in the southeast, and low birth weight is not significant for the south.

Table 5 presents the marginal effects of the main explanatory variables included in the final model (Model 4 in Table 2). Marginal effects have been multiplied by 10 to give a measure of the percent change in infant mortality associated with a 10 percent increase in the independent variable. Controlling for all other covariates, a ten percent increase in PSF coverage was associated, on average, with a 0.45 percent decrease in IMR, a 0.6 percent decrease in post-neonatal mortality, and a 1 percent decrease in diarrhea-related mortality. The largest contributor to reductions in all outcomes was the size of the microregion's population, suggesting an important urban advantage. For mortality from diarrhea, a ten percent increase in Hepatitis B coverage was associated with a 3.7 percent decline. Most other covariates had marginal effects near or less than that of PSF coverage.

Discussion

The analyses presented here suggest that PSF coverage is independently associated with better primary care-sensitive child health outcomes, including IMR, post-neonatal mortality, and deaths from diarrhea. As hypothesized, PSF coverage was not associated with neonatal mortality, which is strongly influenced by the availability and quality of care during and post-delivery, special care for low birth weight babies, and some aspects of prenatal care (Martines et al., 2005).

Table 3
Fixed effects regression of unadjusted infant mortality rates[a], Brazilian microregions 1999–2004

Variable	Neonatal mortality rate	Post-neonatal mortality rate	Diarrhea mortality rate
Family health program (% covered)	−0.004 (0.003)	−0.022** (0.006)	−0.012* (0.006)
Physicians (per 1000 population)	−0.008 (0.069)	−0.264 (0.14)	−0.216 (0.182)
Hospital beds (per 1000 population)	0.084 (0.103)	−0.297 (0.225)	−0.176 (0.217)
Hepatitis B coverage (% of children covered)	0.016** (0.002)	0.006 (0.005)	−0.020** (0.006)
Population (1000s)	−0.003 (0.002)	−0.015** (0.003)	−0.007** (0.002)
Population in poorest income quintile (%)	0.011 (0.007)	0.035* (0.017)	0.017 (0.011)
Mothers with no formal education (%)	−0.024 (0.024)	0.027 (0.082)	0.164** (0.056)
Mothers with no prenatal care (%)	0.046 (0.026)	0.279** (0.066)	−0.066 (0.052)
LBW births (% of all births)	0.192** (0.063)	0.214 (0.156)	−0.104 (0.124)
Constant	2.919** (0.77)	18.256** (1.775)	9.969** (1.479)
Observations	3336	3336	3228
Number of microregions	556	556	538
R-squared (within)	0.335	0.545	0.407

Robust standard errors in parentheses; microregion fixed effects not shown.
* $p<0.05$; ** $p<0.01$.
[a]All rates expressed as per 1000 live births and are based observed counts that have not been adjusted for underreporting of infant deaths in some municipalities.

Table 4
Determinants of infant mortality rate by region, 1999–2004

Variable	North	Northeast	Southeast	South	Central-west
Coverage of family health program (%)	−0.037** (0.006)	−0.023** (0.003)	−0.038** (0.003)	−0.014** (0.002)	−0.013** (0.002)
Physicians (per 1000 population)	−1.401** (0.232)	−1.140** (0.111)	−0.048 (0.055)	−0.603** (0.065)	−0.853** (0.091)
Hospital beds (per 1000 population)	0.338** (0.113)	0.222* (0.09)	0.371** (0.07)	0.433** (0.124)	0.255** (0.059)
Hepatitis B immunization (% of children covered)	−0.016** (0.003)	−0.011** (0.002)	−0.006* (0.002)	0.003* (0.001)	−0.007* (0.003)
Population (1000s)	−0.006* (0.003)	−0.010** (0.003)	−0.005** (0.001)	−0.004 (0.004)	−0.011** (0.001)
Population in poorest income quintile (%)	0.046* (0.022)	−0.01 (0.036)	0.017 (0.009)	−0.01 (0.017)	−0.005 (0.005)
Mothers with no formal education (%)	0.060** (0.02)	0.147** (0.025)	0.062* (0.03)	0.071* (0.03)	0.088** (0.026)
Mothers with no prenatal care (%)	0.065** (0.023)	0.106** (0.021)	0.329** (0.04)	0.243** (0.048)	0.125** (0.043)
LBW births (% of all births)	−0.106* (0.052)	−0.194** (0.055)	−0.212** (0.033)	−0.066 (0.035)	−0.107** (0.029)
Constant	31.888** (0.670)	47.913** (0.845)	22.874** (0.614)	19.754** (1.098)	26.871** (0.544)
Observations	378	1122	957	564	312
Number of microregions	63	187	160	94	52
R-squared (within)	0.76	0.84	0.74	0.76	0.90
Mean values for selected variables (1999–2004)					
Infant mortality rate (IMR)	27.12	42.37	19.18	17.81	21.47
PSF coverage (%)	30.82	53.73	32.30	34.44	47.44
Physicians	1.22	1.83	3.34	2.67	2.16
Hospital beds	2.00	2.15	3.29	3.17	3.56
Hepatitis B coverage	80.69	85.49	96.98	97.02	92.41
Mothers with no prenatal care	7.48	10.24	1.97	1.77	2.34

Robust standard errors in parentheses; microregion fixed effects not shown.
* $p<0.05$; ** $p<0.01$.
Infant mortality rate expressed as per 1000 live births and adjusted for underreporting of infant deaths in some municipalities.

Table 5
Marginal effects[a] by outcome, Brazilian microregions 1999–2004

Variable	Infant mortality rate	Post-neonatal mortality rate[b]	Diarrhea mortality[b]
Coverage of family health program	−0.447** (−0.506, −0.387)	−0.591** (−0.909, −0.273)	−1.034* (−2.030, −0.037)
Physicians per 1000 population	−0.251** (−0.439, −0.064)	−0.401* (−0.816, 0.015)	−1.088 (−2.880, 0.704)
Hospital beds per 1000 population	0.348** (0.242, 0.455)	−0.526 (−1.310, 0.257)	−1.038 (−3.536, 1.459)
Hepatitis B coverage (%)	−0.376** (−0.452, −0.300)	0.359 (−0.252, 0.971)	−3.770** (−5.951, −1.589)
Population (1000s)	−1.048** (−1.340, −0.755)	−2.873** (−4.154, −1.593)	−4.715** (−7.439, −1.991)
Population in poorest income quintile (%)	0.213** (0.102, 0.323)	0.497* (0.035, 0.958)	0.801 (−0.229, 1.831)
Mothers with no formal education (%)	0.190** (0.134, 0.245)	0.093 (−0.459, 0.644)	1.879** (−0.628, 3.130)
Mothers with no prenatal care (%)	0.252** (0.204, 0.300)	0.784** (0.420, 1.147)	−0.619 (−1.570, 0.332)
LBW births (% of all births)	−0.546** (−0.686, −0.406)	0.973 (−0.414, 2.360)	−1.572 (−5.245, 2.101)

Robust 95% confidence intervals in parentheses; microregion fixed effects not shown.
* $p<0.05$; ** $p<0.01$.
[a]Marginal effects represent percent change in the outcome associated with a 10 percent change in the independent variable. All marginal effects were calculated in terms of elasticities evaluated at the means of all other independent variables.
[b]Rates expressed as per 1000 live births and are based on observed counts that have not been adjusted for underreporting of infant deaths in some municipalities.

Our results are consistent with evidence of potential mechanisms through which the PSF might work to lower primary care-sensitive infant mortality. For example, higher PSF coverage has been found to be associated with higher population rates of breastfeeding, oral rehydration therapy, immunizations, and treatment of respiratory and other infections—interventions that address the leading causes of post-neonatal mortality (Emond, Pollock, Da Costa, Maranhão, & Macedo, 2002; Escorel et al., 2002; Shi et al., 2004; Starfield, 1985).

The magnitude of the PSF effect was significant, albeit of lesser magnitude than observed in previous studies. This is likely to be due to the fact that IMR has experienced a dramatic decline throughout Brazil as a function of a range of interventions, including PSF coverage, improved water and sanitation, and better women's health and development (Macinko et al., 2006). Moreover, as noted above, as IMR declines a greater proportion of infant deaths tend to happen within the first month of life due to conditions that are less amenable to primary care. Neonatal mortality has been linked to increased preterm and low birth weight births and has become a more significant contributor to IMR in Brazil as post-neonatal mortality declined (Barros et al., 2005; Caldeira et al., 2001).

There were also important regional differences in the effects of PSF coverage. In the region-stratified analyses, the effect of the PSF program was reduced for the more developed southern regions where IMR has been lower relative to the north and northeast. The apparent protective effect of population size may represent either an urban advantage or the fact that since 1998, PSF expansion has focused on municipalities with populations greater than 100,000 people.

Physician supply was also associated with lower infant mortality: a finding that is consistent with other studies (Anand & Barnighausen, 2004). Sensitivity tests using nurses per 1000 instead of physicians found similar results, although both variables could not be included in the analyses due to their high correlation ($\rho = 0.74$; $p<0.001$). This results suggests that the PSF has made progress in expanding primary care physician supply in underserved regions (such as the northeast) (Ministério da Saúde, 2004). This argument is supported by the observation that the physician supply effect was significant in all regions except the southeast where there has historically been less of a physician deficit than in other regions and where most physicians are specialists (rather than family practitioners or other primary care providers).

Not surprisingly, measures such as poverty, female illiteracy, lack of prenatal care, and low levels of Hepatitis B immunization were all found to be associated with higher mortality. Although earlier studies found no relationship between immunization rates and IMR (Macinko et al., 2006), they used measures of all immunization schedules which are already over 90 percent in most states. Hepatitis B vaccination is a more recent initiative and coverage varies substantially between microregions, making it potentially a more sensitive indicator of primary care access.

Availability of hospital beds was positively associated with outcomes—a result that was not expected. One possible explanation is that in recent years hospitals may have experienced declines in accessibility, quality, or both. This hypothesis is partially supported by the results in Table 3 which show that hospital beds were not associated with neonatal mortality, the outcome that should be most highly correlated with indicators of hospital care. Lansky, França, and Kawachi (2007) suggest that there is considerable variation in hospital quality and this variation is associated with elevated perinatal mortality from potentially avoidable conditions such as intrapartum asphyxia. Potentially avoidable infant mortality was found to be especially high for normal birth weight babies born in government-contracted private hospitals in large urban areas, which were found to have lower quality care (Lansky et al., 2007).

Finally, low birth weight births were found to be negatively associated with IMR in this study. This "low birth weight paradox" has been observed elsewhere and may be explained by the fact that low birth weight infants from population groups in which LBW is most frequent often have a lower risk of death than low birth weight infants from the general population (Hernandez-Dıaz, Schisterman, & Hernan, 2006). Our ecological analysis might be more prone to picking up this phenomenon than would an individual-level study. Removing LBW from the analyses does not significantly change any of our conclusions.

Limitations

This is an ecologic study, so it is not possible to test whether the reductions in IMR and other outcomes occurred within families that actually visited the Family Health Program. Ideally, we would conduct a multi-level analysis but there are currently no nationally representative data on individual PSF users and non-users. Nevertheless, there is evidence that improving PSF coverage leads to improvements in determinants of child health. For example, PSF clients regularly receive health education about breastfeeding, use of oral rehydration therapy, immunization, and infant growth monitoring (Emond et al., 2002; Escorel et al., 2002). In a study of several large urban centers, more than three-quarters of PSF clients interviewed believed that child health services were of good quality and that the PSF was responsible for improvements in the health of the neighborhood and their family (Escorel et al., 2002). There is also evidence to suggest that the PSF program decreases financial barriers to access (Goldbaum, Gianini, Novaes, & Cesar, 2005). Finally, other studies have confirmed that in areas where the PSF or similar programs have been implemented, infant mortality has actually declined (Cufino Svitone et al., 2000; Macinko et al., 2006; Serra, 2005).

Ecological analyses are vulnerable to omitted variable problems. That is, there could be some latent, unmeasured variable confounding the apparent relationship between PSF and IMR. In this case, the existence of such a variable is unlikely given that we employed a comprehensive model of health determinants, included fixed effects to control for time-invariant unobserved characteristics of microregions, and tested several pathways and alternative explanations. The high R-squared values of the main regression models suggest that they explain a large proportion of the variation in infant mortality.

Finally, conclusions about outcomes based on unadjusted rates (post-neonatal, neonatal, and diarrhea deaths) need to be interpreted with caution since there is evidence of undercounting of child mortality in Brazil. Note that this undercounting has improved in recent years, so each year's data should be closer to real values. In this study, adjusted IMR values corresponded with observed IMR rates 85 percent of the time with an average difference of 4.7 deaths/1000 live births. Most of this variation was in the Northeast region of the country (60 percent agreement in the northeast, 84 percent agreement in the north, 90 percent agreement in the central-west, 99 percent agreement in the south and southeast). In sensitivity tests that excluded the 982 (out of 3337) data points with outcome data that was one or more standard deviation above or below the adjusted IMR rates for any year, there was no change in the main conclusions of the relationship between PSF coverage and IMR, neonatal mortality, or post-neonatal mortality. However, several covariates did become non-significant as did the relationship between PSF coverage and diarrhea mortality. This may be due to that fact that the microregions excluded due to poor quality data were also those with the highest rates of diarrheal deaths and underscores the importance of using adjusted rates when available.

Conclusions

The study has shown that expanding coverage of a community-based primary care program, hand-in-hand with other socioeconomic developments, was consistently associated with reductions in primary care-sensitive measures of infant mortality. Despite the consistency of these findings, several issues need to be addressed in order to assess the program's overall effectiveness and potential relevance to other countries.

First, there is little data on the contribution of the PSF to health inequalities within Brazil. This study provides some evidence that due to its expansion in the north and northeast regions of the country, the PSF may have contributed to reducing inter-regional inequalities in primary care-sensitive infant mortality. But within regions, expanded PSF coverage has not always occurred in the most deprived municipalities (Morsch, Chavannes, van den Akker, Sa, & Dinant, 2001). In order to maximize the equity-enhancing potential of the program, national efforts should be directed at encouraging adoption of the program in the poorest municipalities. Within municipalities, program expansion should be encouraged within the most underserved neighborhoods. Such a strategy is likely to improve equity in outcomes since the greatest impact is likely to occur where infant mortality is still the highest, especially once outcomes have already improved for higher income groups (Victora, Vaughan, Barros, Silva, & Tomasi, 2000).

Second, financial incentives for municipalities to adopt the program are currently linked to increasing population coverage, but there are few systematic monitoring and evaluation processes in place to assess municipal or service-level performance. Surveys show that clients are generally satisfied with the quality of care delivered, but sustaining this level of satisfaction will be a critical challenge in maintaining popular and political support for the program (Trad et al., 2002). New initiatives have been proposed that would provide financial incentives for municipalities that reach or exceed certain health targets as a means to enhance access and quality of care. For these reasons, a major challenge will be to develop and use systems to monitor and improve the quality of care delivered in order to maximize the potential health gains of this innovative approach to integrated primary care delivery.

Third, there is little data available on the cost-effectiveness of the PSF. In 2005, Federal government transfers to municipalities totaled $5.7 billion Brazilian *Reais* (approximately $US 2.6 billion), which represents about $US 14 per person covered. This figure does not include the municipal contribution (which varies from zero to nearly 100 percent). Thus we estimate that the true costs of the program may be as much as $US 30 per capita. While this is still a modest amount, there is, as yet, no national data to compare how well this program performs vis-à-vis the status quo. Such information will become increasingly important to mobilize the additional political and financial capital needed to reach the rest of the Brazilian population not currently covered and then to maintain adequate coverage in light of Brazil's rapid epidemiologic and demographic transition.

Fourth, Brazil has a large supply of health workers, which might make it different from most other developing countries. So far, the PSF strategy has been successful in hiring more than 26,000 physicians and nurses and over 220,000 community health workers. In principle, any trained health professional may apply to the program and competitive salaries have made it an increasingly attractive option. On-going training in primary care is an additional benefit of PSF affiliation, but there is not yet enough known on how well this in-service training prepares formerly specialty-trained physicians to function as primary care providers. As the program continues to expand, health authorities will need to develop longer-term plans for maintaining and expanding the health workforce, with particular attention to improving the stability of physician contracting mechanisms, and more concerted efforts to enhance provider skills in community-based primary care.

Finally, because it serves as part of the Brazilian national health system, the PSF is vulnerable to health system level factors that could undermine its potential impact, such as access to pharmaceuticals; the quality and supply of needed specialty, diagnostic, or hospital care; or the availability, training, and salaries of health workers (Chiesa & Batista, 2004; Franco, Bastos, & Alves, 2005). Key challenges as the program moves forward include ensuring coordination between different types of health services and vertically focused disease control programs, improving quality of care, and maximizing community-based health promotion. Taken together these actions may help to assure that the PSF becomes more than just another program, but fulfills its promise as a central organizing feature of a more accessible, effective, and equitable national health system.

Acknowledgments

This study was partially supported by the Brazilian Ministry of Health. Frederico Guanais was supported by the National Council for Research and Development (CNPq). The conclusions presented in this paper represent the opinion of the authors alone.

References

Allison, P. (2002). *Missing data*. Thousand Oaks, CA: Sage Publications.

Almeida, C., & Pêgo, R. A. (2002). Theory and practice in health systems reform in Brazil and Mexico. *Cad Saúde Pública*, *18*(4), 971–989.

Anand, S., & Barnighausen, T. (2004). Human resources and health outcomes: Cross-country econometric study. *Lancet*, *364*(9445), 1603–1609.

Barros, F. C., Victora, C. G., Barros, A. J., Santos, I. S., Albernaz, E., Matijasevich, A., et al. (2005). The challenge of reducing neonatal mortality in middle-income countries: Findings from three Brazilian birth cohorts in 1982, 1993, and 2004. *Lancet*, *365*(9462), 847–854.

Brazilian Institute of Geography and Statistics. (2005). Banco multidimensional de estatísticas. Available: 〈http://www.ibge.gov.br/〉.

Brazilian Ministry of Health Department of Primary Care (2007). Atenção Básica e a Saúde da Família [Primary Care and Family Health]. Available: 〈http://dtr2004.saude.gov.br/dab/abnumeros.php〉; Accessed May 24, 2007.

Caldeira, A. P., França, E., & Goulart, E. M. (2001). Postneonatal infant mortality and quality of medical care: A case-control study. *Journal of Pediatr (Rio de Janeiro)*, *77*(6), 461–468.

Caldeira, A. P., França, E., Perpetuo, I. H., & Goulart, E. M. (2005). Trends in avoidable causes of infant mortality in Belo Horizonte, Brazil, 1984 to 1998. *Rev Saude Publica*, *39*(1), 67–74.

Chiesa, A. M., & Batista, K. B. C. (2004). Desafios da implantaç ão do Programa Saúde da Família em uma grande cidade: Reflexões acerca da experiência de São Paulo/challenges on the implementation of the family health program in a great city: Reflections on the experience São Paulo city. *Mundo saúde (1995)*, *28*(1), 42–48.

Conill, E. M. (2002). Primary care policies and health reforms: An evaluative approach based on an analysis of the family health program in Florianopolis, Santa Catarina, Brazil, 1994–2000. *Cad Saude Publica*, *18*(Suppl), 191–202.

Cufino Svitone, E., Garfield, R., Vasconcelos, M. I., & Araujo Craveiro, V. (2000). Primary health care lessons from the northeast of Brazil: The Agentes de Saúde Program. *Rev Panam Salud Publica*, *7*(5), 293–302.

Emond, A., Pollock, J., Da Costa, N., Maranhão, T., & Macedo, A. (2002). The effectiveness of community-based interventions to improve maternal and infant health in the Northeast of Brazil. *Rev Panam Salud Publica*, *12*(2), 101–110.

Escorel, S., Giovanella, L., Mendonça, M. H., Magalhães, R., de Castro, M., & Senna, M. (2002). *Avaliação da Implementação do Programa Saúde da Família em Dez Grande Centros Urbanos. Síntese dos Principais Resultados*. Brasília: Ministério da Saúde, Secretaria de Políticas de Saúde.

Franco, A. L., Bastos, A. C., & Alves, V. S. (2005). The physician–patient relationship under the family health program in three municipalities in Bahia State, Brazil. *Cad Saúde Pública*, *21*(2), 246–255.

Goldbaum, M., Gianini, R. J., Novaes, H. M., & Cesar, C. L. (2005). Health services utilization in areas covered by the family health program (Qualis) in São Paulo City, Brazil. *Rev Saude Publica*, *39*(1), 90–99.

Greene, W. H. (2003). *Econometric analysis*. Upper Saddle River, NJ: Prentice-Hall.

Guanais, F. C. (2006). *Evaluating the health impacts of primary care decentralization in the context of a developing country. Robert F. Wagner Graduate School of Public Service*. New York, NY: Robert F. Wagner Graduate School of Public Service, New York University.

Hernandez-Dıaz, S., Schisterman, E., & Hernan, M. (2006). The birth weight "paradox" uncovered? *American Journal of Epidemiology*, *164*(11), 1115–1120.

Hsiao, C. (2003). *Analysis of panel data*. Cambridge: Cambridge University Press.

Instituto de Pesquisa Econômica Aplicada (IPEA). (2005). Dados macroeconômicos e regionais. Available: 〈www.ipeadata.gov.br〉; Accessed May 2005.

Lansky, S., França, E., & Kawachi, I. (2007). Social inequalities in perinatal mortality in Belo Horizonte, Brazil: The role of hospital care. *American Journal of Public Health*, *97*(5), 867–873.

Lansky, S., França, E., & Leal Mdo, C. (2002). Perinatal mortality and evitability: A review. *Rev Saude Publica*, *36*(6), 759–772.

Macinko, J., Guanais, F. C., & Marinho de Souza, M. F. (2006). Evaluation of the impact of the family health program on infant mortality in Brazil, 1990–2002. *Journal of Epidemiology and Community Health*, *60*(1), 13–19.

Martines, J., Paul, V. K., Bhutta, Z. A., Koblinsky, M., Soucat, A., Walker, N., et al. (2005). Neonatal survival: A call for action. *Lancet*, *365*(9465), 1189–1197.

Ministério da Saúde. (2004). *Avaliação normativa do Programa Saúde da Família no Brasil*. Brasília: Sectária de Assistência à Saúde, Departamento de Atenção Básica.

Ministry of Health of Brazil. (2003). The family health program: Broadening coverage to consolidate the change in the primary care model. *Revista Brasileira de Saúde Materno-Infantil*, *3*(1), 113–125.

Ministry of Health of Brazil. (2007). Informações de Saúde. Available: 〈http://tabnet.datasus.gov.br/tabnet/tabnet.htm〉.

Moore, D., Castillo, E., Richardson, C., & Reid, R. J. (2003). Determinants of health status and the influence of primary health care services in Latin America, 1990–98. *International Journal of Health Planning and Management*, *18*(4), 279–292.

Morsch, E., Chavannes, N., van den Akker, M., Sa, H., & Dinant, G. J. (2001). The effects of the family health program in Ceará state, northeastern Brazil. *Archives of Public Health*, *59*, 151–165.

Pan American Health Organization. (2007). *Renewing primary health care in the Americas: Declaration of montevideo*. Washington, DC: Pan American Health Organization Available http://www.paho.org/English/AD/THS/primaryHealthCare.pdf.

Rede Interagencial de informações para a saúde (RIPSA). (2002). *Indicadores básicos para a saúde no Brasil*. Brasília, Brasil: Organização Panamericana da Saúde/OMS.

Serra, R. (2005). Uma avaliação empírica do impacto saúde da família sobre a saúde infantil no estado de São Paulo. Trabalho submetido ao Prêmio Economia da Saúde, IPEA. Brasília, DF.

Shi, L., Macinko, J., Starfield, B., Xu, J., Regan, J., Politzer, R., et al. (2004). Primary care, infant mortality, and low birth weight in the states of the USA. *Journal of Epidemiology and Community Health*, *58*(5), 374–380.

Starfield, B. (1985). Postneonatal mortality. *Annual Review of Public Health*, *6*, 21–40.

Statacorp. (2005). *Stata statistical software: Release 9.0*. College Station, TX: Stata Corporation.

Szwarcwald, C. L., Leal Medo, C., de Andrade, C. L., & Souza, P. R., Jr. (2002). Infant mortality estimation in Brazil: What do Ministry of Health data on deaths and live births say? *Cad Saúde Pública*, *18*(6), 1725–1736.

Trad, L. A. B., Bastos, A. C. S., Santana, E. M., et al. (2002). Estudo etnográfico da satisfação do usuário do Programa de Saúde da Família (PSF) na Bahia. *Ciênc Saúde Coletiva*, *7*(3), 581–589.

UNICEF. (2002). *Facts for life*. New York: United Nations Children's Fund.

Viana, A. L., & Pierantoni, C. R. (2002). *Indicadores de Monitoramento da Implementação do PSF em Grandes Centros Urbanos*. Brasilia: Brazilian Ministry of Health, Department of Primary Care.

Victora, C. G., Vaughan, J. P., Barros, F. C., Silva, A. C., & Tomasi, E. (2000). Explaining trends in inequities: Evidence from Brazilian child health studies. *Lancet*, *356*(9235), 1093–1098.

Wang, L. (2003). Determinants of child mortality in LDCs. Empirical findings from demographic and health surveys. *Health Policy*, *65*, 277–299.

Wooldridge, J. (2002). *Econometric analysis of cross section and panel data*. Cambridge, Massachusetts: The MIT Press.