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Primary care, race, and mortality in US states

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Abstract

This study used US state-level data from 1985 to 1995 to examine the relationship of primary care resources and income inequality with all-cause mortality within the entire population, and in black and white populations. The study is a pooled ecological design with repeated measures using 11 years of state-level data ($n = 549$). Analyses controlled for socioeconomic and demographic characteristics. Contemporaneous and time-lagged covariates were modeled, and all analyses were stratified by race/ethnicity. In all models, primary care was associated with lower mortality. An increase of one primary care doctor per 10,000 population was associated with a reduction of 14.4 deaths per 100,000. The magnitude of primary care coefficients was higher for black mortality than for white mortality. Income inequality was not associated with mortality after controlling for state-level sociodemographic covariates. The study provides evidence that primary care resources are associated with population health and could aid in reducing socioeconomic disparities in health.

Keywords: USA; Primary care resources; Mortality; Ethnicity

Background

In the past decade, substantial literature suggested a significant association between income inequality and mortality both in the US and abroad (Blakely, Lochner, & Kawachi, 2002; Wilkinson, 1996; Kennedy, Kawachi, & Prothrow-Stith, 1996; Lochner, Pamuk, Makuc, Kennedy, & Kawachi, 2001; Lynch et al., 1998; McLaughlin & Stokes, 2002; Subramanian, Blakely, & Kawachi, 2003). The greater the gap in income distribution between the rich and poor in a given area, the higher the mortality rate for the population of that area. However, several recent studies have failed to find a similar relationship between income inequality and various manifestations of health (Mellor & Milyo, 2001; Wagstaff & van Doorslaer, 2000; Lynch et al., 2004).

Increasingly, studies have examined the pathways and mechanisms through which income inequality might affect health. Psychosocial theories give over-riding influence to psychological effects. These theories hold that phenomena such as alienation are the main path of the ill effect on health (Wilkinson, 1999; Everson et al., 1996; Miller, Smith, Turner, Guijarro, & Hallet, 1996). Social capital explanations hold that social relationships influence health either directly or through other phenomena. One postulated explanation is that more egalitarian areas are more socially cohesive, leading to less psychosocial stress and better health status. For

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example Kawachi et al. demonstrated that where income differences are smaller, people are more trusting of one another and more likely to participate in communal activities, and this social cohesiveness is linked to lower overall mortality (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997) and better self-rated health (Kawachi, Kennedy, & Glass, 1999). Other investigators have postulated that the political and policy context is itself a precursor to health inequalities (Kawachi et al., 1999; Dye, 1991; Navarro & Shi, 2001).

Another alternative explanation for the apparent relationship between income inequality and health is that the relationship, at least in the United States, is partially or wholly confounded by race (Deaton & Lubotsky, 2003). The authors argue that the association between income inequality and health in the US might be the result of confounding with race, since those areas with a higher proportion of black population also have higher income inequality and higher mortality—for whites as well as for the entire population (Deaton & Lubotsky, 2003). At the same time, McLaughlin and Stokes (2002) found that in an ecological study of US counties, income inequality *was* a significant predictor of mortality for both black and white populations even though racial concentration interacted with income inequality measures. Because of the possibility of confounding and evidence of differential patterns of access to and use of primary care services among different racial groups, the analyses presented here stratify for race (Shi, 1999).

Our previous published studies have suggested an important role for health system factors, especially the role of primary care resources, and showed the likely importance of primary care in reducing the apparent adverse effects of income inequality (Shi, Starfield, Kennedy, & Kawachi, 1999). Using 1990 US state-level data, we found a significant association between primary care physician supply and reduced mortality, increased life expectancy, and improved birth outcome, even after controlling for income inequality and population socio-demographic characteristics. Similar findings were noted using US metropolitan areas as the unit of analysis (Shi & Starfield, 2001) and in mixed-level analyses (Shi & Starfield, 2000; Shi, Starfield, Politzer, & Regan, 2002). Although results were consistent among units of analysis, our previous studies were limited to a single year's observation. The current study addresses limitations of previous studies by using 11 years of US state-level data.

We assess the impact of primary care by examining if there is an independent relationship between primary care and mortality and by determining whether primary care attenuates the impact of socioeconomic characteristics on mortality. The logic of the connection between primary care and reduced mortality is reflected in the goal of primary care (Starfield, 1994, 1992) and mounting evidence that links primary care with better health status (Starfield, 1998; Shi, 1994, 1997; Macinko, Starfield, & Shi, 2003).

Primary care addresses the most common problems in the community to maximize health and well-being. It integrates care where there is more than one health problem, and deals with the context in which illness exists and influences the responses of people to their health problems. It is care that organizes and rationalizes the deployment of all resources, basic as well as specialized, directed at promoting, maintaining, and improving health. Findings of an independent effect of primary care on reduced mortality would be particularly relevant as it would represent a specific mechanism for addressing at least some of the health impact of growing social inequalities in the Unites States.

This study is unique in that it seeks to examine the independent relationship between income inequality and population mortality, shed light on the still contentious issue of the impact of racial composition on the observed relationship between income inequality and health, and assess the extent to which primary care might mediates this association. By using 11 years of data, we are able to examine the relationship among the variables of interest in more than one period, thus improving the robustness of our findings to changes over time. By performing race-stratified analysis, we are able to examine the differential effects of income inequality and primary care on white and black mortality. As noted above, previous research has indicated that the effect of income inequality on health may be confounded by the inclusion of the fraction of African-Americans in the population (Deaton & Lubotsky, 2003).

Methods

Data and measures

Data for this study came from a variety of sources including the Compressed Mortality Files (US Department of Health and Human Services National Center for Health Statistics, 2000), the US Department of Commerce and the Census Bureau (1985–1996), and the National Center for Health Statistics (1985–1996). Physician data were obtained from the American Medical Association (1985–1996). Data were drawn from 1985, the earliest year data from which state-level household income intervals were readily available, to 1995, the year of the latest data availability at the time of the study.

The dependent variables *total mortality*, *white mortality*, and *black mortality*, were standardized for age to the 1990 US population and expressed as the number of deaths per 100,000. They were obtained from the compressed mortality files compiled by CDC using WONDER/PC software (Friede, Reid, & Ory, 1993). Age-adjusted total mortality has been used extensively as a health status indicator (Bergner, 1985; Donabedian, 1985; Rice, 1991) and may reflect social inequalities, including racial disparities. Socioeconomic disparities are often measured through differential mortality information (Sen, 1998).

For the purpose of this study, primary care resources include physicians in family practice and general practice, general internal medicine, and general pediatrics (Klein & Hawk, 1992; Starfield, 1986). Family and general practice are often combined into one group called family medicine. Thus, "primary care resources" refer to doctors of medicine per 10,000 civilian population who were in active office-based (including community health centers) patient care in family medicine, internal medicine, and pediatrics. Non-physician primary care providers (e.g. nurse practitioners) were not included for lack of consistent data over the time period. For the sake of brevity, this variable is called primary care throughout the paper.

Income distribution was measured by the Gini coefficient, a commonly used indicator of income inequality wherein higher values indicate greater inequality in income distribution. It is derived from the Lorenz curve, which is a mechanism to graphically represent the cumulative share of the total income accruing to successive income intervals. Data used to calculate Gini came from the US Census Bureau website which provides annual data on household income for 25 income intervals (US Census Bureau, 2003). Counts of the number of households that fall into each income interval along with the total aggregate income and the median household income were obtained for each state. The Gini coefficient was calculated using software developed by E. Welniak (unpublished software, US Census Bureau, 2003). We also used the Robin Hood index, another measure of income inequality. Since both measures provided similar results, we only present the Gini coefficient. We did not construct other income inequality measures since prior studies found that different measurers yield generally consistent results (Kawachi & Kennedy, 1997).

Additional sociodemographic variables known to be associated with population mortality were included in the analyses as covariates. They included percent of population age 25 and above with less than high school education (*Education*), percent of work-force population unemployed (*Unemployed*), percent of population that are identified as black or African-American (*Black*), and percent of urban population (*Metro*). The variable per capita income was included in the initial analysis but taken out in the final models due to its high correlation with other sociodemographic covariates. In the final models, socioeconomic status is measured only by state levels of education.

Design

The present study was a pooled ecological design with repeated measures. The unit of analysis was the 50 US states (not including Washington, DC) over an 11-year period. One data point (Delaware in 1991) was dropped due to missing values ($n = 549$ instead of 550). The covariates of interest (availability of primary care and income dispersion) were ecological measures: the study therefore examined relationships among variables at the state rather than the individual level. We avoided making inferences about individuals from grouped data in order to assure that no cross-level bias occurred (Susser, 1994; Schwartz, 1994). One advantage of such an approach is the lower likelihood of random fluctuations in mortality and other data through geographic aggregation at the state level. Using state-level aggregate data also had the advantage of attenuating the likely "cross-over" effect encountered when smaller units of analysis are used for measuring availability of medical care and mortality (Hadley, 1982; Klein & Hawk, 1992).

Analysis

In analyzing the data, we first examined the association between primary care, income inequality, sociodemographic covariates, and mortality using Pearson's correlation coefficients. For multivariate analyses, we used a pooled, ecological design with repeated measures. This design analyses a cross-section of ecologic units of observation (states) over a span of time (years). Ordinary Least Squares regression will not yield proper estimates on data containing repeated measures. For this reason, parameters were estimated using the SAS PROC MIXED procedure (SAS, 1999). This approach uses a maximum likelihood estimator to account for correlation among error terms due to the presence of repeated measures (each year) on the same unit (state). Moreover, this procedure provides estimates for both fixed and time-varying covariates, and models not only the means of the data but also the variances and covariances (Littell, Pendergast, & Natarajan, 2000). Examination of the data suggested use of the compound symmetry variance structure to appropriately adjust standard errors (SAS, 1999). States were treated as fixed effects, thus allowing the model to control for relatively stable inter-state differences, such as policy context and historical differences in technology, resources, and other determinants of population health (Hsiao, 1986).

A set of nested models was designed to examine the independent effect of primary care and income inequality on mortality and the extent to which the addition of primary care to the statistical model attenuates the association between income inequality and mortality. In Model 1, only income inequality was used as a predictor of mortality. In Model 2, mortality is predicted by both income inequality and sociodemographic characteristics of the population. Model 3 includes primary care along with the other covariates included in Model 2. Regression coefficients and standard errors of the measures are presented along with tests of statistical significance. Changes in the regression coefficients of income inequality between models one and two indicate the extent to which sociodemographic characteristics mediate the association between income inequality on mortality. Changes in the regression coefficients of sociodemographic characteristics between models two and three indicate the extent to which primary care mediates the association between sociodemographic characteristics on mortality.

Since the effects of the predictors on mortality are expected to materialize over time, we also conducted analyses with time-lags. Three time-lagged models are presented. A 1-year lag model shows total mortality as a function of the independent measures of the previous year. A 3-year lag model shows total mortality as a function of the independent measures 3 years prior, and 5-year lag model shows mortality as a function of the independent measures 5 years prior. The time-lag models are meant to test the hypothesis that if covariates are truly associated with health outcomes, then this association is likely to be the result of prior exposure. Although the time-lagged models cannot establish causality, they do provide stronger evidence that the relationships observed in the contemporaneous models are valid.

In addition to total (all races) mortality analyses, we also performed race-specific (i.e. black mortality and white mortality, respectively) analyses to examine if the magnitude and significance of predictors of mortality vary according to race.

Results

During 1985–1995, there was a decline in all-cause mortality. The mean state age-adjusted mortality rate dropped from 821 to 762 per 100,000 population (Fig. 1, Panel 1). In the same period, there was a steady increase in primary care physicians, from 5.02 to 6.04 per 10,000 population (Fig. 1, Panel 2). Income inequality within states fluctuated during the period with an overall worsening trend: the mean of the Gini coefficient among states increased from 0.41 to 0.43 during the period (Fig. 1, Panel 3).

Table 1 presents the correlation matrix range (1985–1995) among total mortality, income inequality,

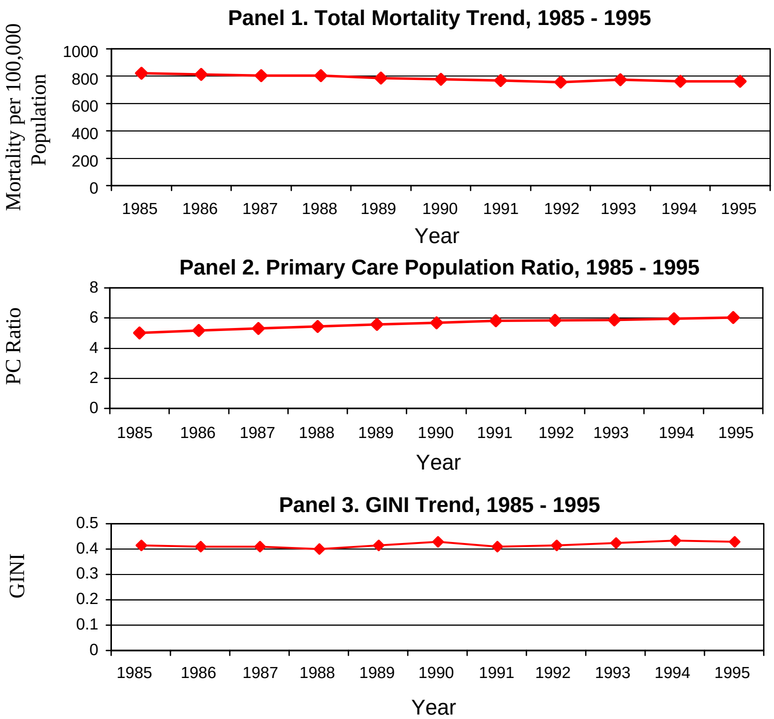

Fig. 1. (Panels 1–3) Trend of total mortality, primary care, and income inequality in US states (1985–1995).

Table 1
Range of Pearson correlation matrix, 1985–1995[a]

$n = 549$	Mortality	Gini	PC	Black	Metro	Unemployed	Education
Total mortality per 100,000 population (Mortality)	1.00						
Income inequality (GINI)	0.23–0.63*	1.00					
Office-based patient care primary care doctor per 10,000 population (PC)	−0.42 to −0.49***	−0.01 to 0.11	1.00				
Percent of population that is black (Black)	0.70–0.78***	0.28–0.69*	−0.16–0.38*	1.00			
Percent of population that is metropolitan (Metro)	−0.05–0.07	0.01–0.43	0.24, 0.35*	0.21–0.29*	1.00		
Percent of population that is unemployed (Unemployed)	0.29–0.52**	0.15–0.60	−0.03 to −0.51	0.17–0.26	−0.05 to 0.33	1.00	
Percent population ⩾25 that has completed high school education (Education)	−0.64 to −0.77***	−0.37 to −0.66***	0.27–0.47*	−0.67 to −0.70***	0.03–0.07	−0.16 to −0.43	1.00
Mean[b]	757.3–821.1	0.40–0.43	5.02–6.04	9.40–10.01	63.4–67.0	5.2–7.1	67.5–78.5

*$p<0.05$ for each but 1 year between 1985 and 1995. **$p<0.05$ for each year between 1985 and 1995. ***$p<0.01$ for each year between 1985 and 1995.
[a]Range of correlation coefficients reflects the lowest and the highest correlations for the period 1985–1995.
[b]Range of means reflects the smallest and the largest means for the period 1985–1995.

primary care, and sociodemographic indicators. Both primary care (inversely) and income inequality (positively) were significantly associated with total mortality ($p<0.01$ for primary care and $p<0.05$ for income inequality). Among sociodemographic indicators, blacks ($p<0.01$), and unemployment ($p<0.05$) are significantly and positively related to mortality; education ($p<0.01$) is significantly and inversely related to mortality. Metro is not significantly related to mortality. In addition, primary care is positively and significantly related to metro and education. Income inequality is significantly and positively related to black ($p<0.05$) but inversely related to education ($p<0.01$).

Table 2 presents the regression coefficients and their significance of the mixed model procedure examining the extent to which income inequality and primary care affect population mortality. In Model 1 under the same year analysis, the effect of income inequality on mortality is examined. A significant effect of income inequality on mortality was noted ($p<0.01$). In Model 2, the effects of both income inequality and sociodemographics on mortality are examined. Inclusion of sociodemographics, particularly *Percent of Black* reduces the regression coefficient of income inequality to insignificance. In Model 3, the effect of primary care on mortality is examined, while controlling for income inequality and sociodemographics. The inclusion of primary care reduces the magnitude of all sociodemographic regression coefficients, although only metro loses statistical significance. In model 3, primary care is independently and inversely associated with mortality. An increase of one primary care doctor per 10,000 population is associated with a reduction of 14.4 deaths per 100,000 population, or 1.44 deaths per 10,000 population, after taking into account the effects of income inequality and the sociodemographic correlates of mortality.

Results of the same year analysis were essentially replicated in time-lagged models (also in Table 2). A careful examination of the time-lagged models indicates that the magnitude of the association between primary care and mortality remains stable over time, suggesting a lagged effect of primary care on mortality. The association between income inequality and mortality remains insignificant in time-lagged analysis after controlling for sociodemographic characteristics.

Table 3 presents the regression coefficients and their significance from the mixed model procedure examining all-cause mortality stratified by race. The stratified analyses yield similar results to those observed in the total mortality analysis. Income inequality was significantly associated with mortality only in model 1, where neither sociodemographic characteristics nor primary care were included in the model (model 1) ($p<0.001$). The magnitude of the income inequality coefficient was significantly higher for black mortality than for white

Table 2
Primary care, income inequality, and total mortality, 1985–1995 US states: results of same-year and time-lagged mixed models

Model	Same year[a]			1-year lag[a]			3-year lag[a]			5-year lag[a]		
	1	2	3	1	2	3	1	2	3	1	2	3
Intercept	409.3 (39.3)	1000.1 (36.7)	1023.6 (34.1)	384.1 (40.3)	954.2 (36.1)	977.0 (33.4)	359.3 (42.6)	886.0 (43.5)	927.1 (42.3)	383.8 (46.5)	887.5 (46.1)	931.9 (45.6)
Gini	901.1** (91.7)	−110.1 (65.1)	−52.4 (62.3)	956.0** (94.7)	−62.0 (66.9)	−3.6 (63.9)	1007** (102.0)	5.2 (73.5)	42.6 (70.7)	930.5** (112)	−29.3 (77.6)	19.4 (75.8)
Black		370.1** (24.0)	343.9** (23.2)		376.9** (24.9)	350.9** (24.0)		385.0** (28.3)	358.2** (27.5)		369.7** (32.4)	343.2** (31.8)
Metro		−0.3* (0.1)	−0.1 (0.1)		−0.3** (0.1)	−0.1 (0.1)		−0.3** (0.1)	−0.1 (0.1)		−0.2* (0.1)	−0.1 (0.1)
Unemployed		7.8** (1.0)	6.4** (1.0)		8.2* (1.0)	6.9** (1.0)		8.9** (1.1)	7.4** (1.1)		9.6** (1.2)	7.5** (1.2)
Education		−3.2** (0.3)	−2.8** (0.3)		−3.0** (0.3)	−2.5** (0.3)		−2.6** (0.4)	−2.3** (0.3)		−2.7** (0.4)	−2.4** (0.4)
PC			−14.4** (2.1)			−14.8** (2.2)			−14.8** (2.5)			−14.6** (3.1)
χ^2	—	136.18	118.66	—	124.38	108.68	—	103.35	90.2	—	83.075	71.58

*$p<0.05$; **$p<0.01$.
[a]Estimated coefficients and standard errors (in parenthesis) were provided from the MIXED models.

Table 3
Race-specific primary care, income inequality, and total mortality, 1985–1995 US states results of same-year and time-lagged mixed models

Model	White mortality						Black mortality					
	Same year[a]			5-year lag[a]			Same year[a]			5-year lag[a]		
	1	2	3	1	2	3	1	2	3	1	2	3
Intercept	604.2 (36.9)	1202.6 (44.2)	1217.0 (42.0)	576.0 (43.9)	1100.8 (56.3)	1137.2 (55.3)	328.2 (92.7)	1024.7 (119.7)	1042.9 (113.9)	331.4 (116.9)	1044.7 (166.9)	1129.3 (165.8)
Gini	684.5** (85.3)	−39.5 (77.5)	11.3 (74.5)	709.1** (105.6)	20.9 (96.2)	68.0 (94.0)	1103.7** (221.6)	51.8 (218.4)	203.9 (211.2)	1076.0** (283.2)	-95.2 (290.7)	26.2 (286.7)
Metro		0.1 (0.1)	0.2* (0.1)		0.1 (0.1)	0.2 (0.1)		2.4** (0.3)	2.8** (0.3)		2.8** (0.4)	3.0** (0.4)
Unemployed		8.8** (1.2)	7.2** (1.2)		10.4** (1.5)	7.9** (1.5)		12.1** (3.5)	8.2* (3.5)		19.0** (4.5)	12.8** (4.8)
Education		−4.8** (0.3)	−4.1** (0.3)		−4.5** (0.4)	−3.9** (0.4)		−6.6** (0.8)	−4.7** (0.8)		−7.6** (1.2)	−6.0** (1.2)
PC			−15.8** (2.5)			−16.5** (3.8)			−39.7** (7.4)			−40.0** (12.0)
χ^2	—	85.4666	74.75	—	51.6666	44.425	—	46.3333	43.175	—	31.3666	27.95

*$p<0.05$; **$p<0.01$.
[a]Estimated coefficients and standard errors (in parenthesis) were provided from the mixed models.

mortality. However, for both races, inclusion of sociodemographics rendered income inequality statistically insignificant.

Primary care exhibited a similar relationship between black and white mortality, although the magnitude of the association was higher for black mortality. In the complete model (model 3), primary care is significantly and inversely associated with mortality, after controlling for income inequality and sociodemographic correlates of mortality. In the white population, an increase of one primary care doctor per 10,000 population is associated with a reduction of 1.58 deaths per 10,000 population. In the black population, primary care was associated with a reduction of 3.97 deaths per 10,000 population. For both populations, the inclusion of primary care reduces the magnitude of other sociodemographic variables. These results were replicated in time-lagged models (also in Table 3). The effect of primary care on white and black mortality remains relatively stable over time (see 5-year lag models). The effect of income inequality on mortality remains insignificant in time-lagged analysis after controlling for sociodemographic characteristics.

Discussion

This study confirmed earlier findings that primary care was associated with lower mortality and partially mediated the association between socioeconomic variables and mortality (Shi et al., 1999, 2002; Shi & Starfield, 2000, 2001). These findings are significant because they provide more robust evidence of a relationship between primary care physicians and lower state mortality than was possible by previous cross-sectional analyses. That primary care remained significant after including income inequality and sociodemographic covariates of mortality indicates primary care is likely to be independently associated with lower population mortality. An increase of one primary care doctor is independently associated, on average, with a reduction of 14.4 deaths, per 100,000 population—about a 2 percent decline over current levels.

Race-specific stratified analyses demonstrated that the relationship between primary care and mortality was not confounded by race. Primary care is significantly and inversely associated with white and black mortality, after controlling for sociodemographics and income inequality. However, primary care exerted a greater impact on black mortality than white mortality (2.5 times or 3.97/1.58). These findings are consistent with previous studies demonstrating that an increase in primary care resources in areas of high social inequality would result in greater health improvements (lower mortality) than would the same increase of primary care resources in areas of lower social inequalities (Shi et al., 2002).

Results of time-lagged models demonstrate that in addition to a contemporaneous association, primary care also has a latent relationship on mortality. These findings are consistent with prior postulated benefits specific to primary care adequacy at the population level (Starfield, 1992, 1994, 1998; Shi, 1994, 1997; Macinko et al., 2003). According to the results of this study, primary care is associated with improvements in health—reductions in mortality over time—while other risk factors (e.g. unemployment, education) are positively associated with eroding health status over time. This result points to a longer-term contextual impact of primary care resources at the state-level and increasing primary care resources might represent one strategy to at least partially offset the effects of "accumulated disadvantage" on population health. There is evidence that (at least in Europe) differential access to primary care and other preventive services over the period of several decades may be partially responsible for current inequalities in health (Mackenbach, Stronks, & Kunst, 1989; Paterson & Judge, 2002).

These findings are also consistent with other research that attributes a significant percentage of the increase in life expectancy in the developed world over the past 50 years to advances in health care (Bunker, 2001). In all, clinical services, composed of preventive services as well as therapeutic intervention, were credited with approximately five of the 30 years of increase in life expectancy since 1950 (Bunker, Frazier, & Mosteller, 1995). One postulated mechanism for the impact of primary care is that access to a regular source of primary care may improve prevention and early detection of chronic diseases (Shea, Misra, Ehrlich, Field, & Francis, 1992). Primary care makes its contribution to the health by providing comprehensive, coordinated, and longitudinal care upon first contact with the health system (Starfield, 1998). There is evidence that high-quality primary care can also lead to more efficient secondary and tertiary care (Casanova, Colomer, & Starfield, 1996; Casanova & Starfield, 1995). We hypothesize that the unique features of primary care such as continuous, longitudinal, and person-focused care, may also work to reverse some of the negative health effects of social inequalities by "short-circuiting" the ability of long-term stressors to produce chronic ailments.

From a policy perspective, the promotion of primary care may serve as a more feasible and less expensive strategy for combating mortality and for reducing socioeconomic disparities in health, compared with either social policy that addresses sociodemographic determinants of health or behavioral modifications. Such a hypothesis at least deserves consideration in the face of declining health levels of the US relative to comparably industrialized nations (Starfield & Shi, 2002).

Numerous ecological studies, mostly cross-sectional, have provided support for the hypothesis that unequal distributions of income are associated with high mortality in populations (Blakely et al., 2002; Wilkinson, 1996; Kennedy et al., 1996; Lochner et al., 2001; Lynch et al., 1998; McLaughlin & Stokes, 2002; Subramanian et al., 2003). Other studies, however, have challenged this finding (Mellor & Milyo, 2001; Wagstaff & van Doorslaer, 2000; Lynch et al., 2004). Our analysis indicates that income inequality is significantly associated with mortality only in analyses where it is the only variable. This effect becomes insignificant after taking into account population sociodemographic characteristics. This finding supports recent studies that claim income inequality has an apparent effect only because it is associated with other variables related to mortality. It reaffirms the significant association between population sociodemographic characteristics and mortality and implies that studies of the impact of income inequality on health need to include other determinants of health. From a policy perspective, improvement in population health is likely to require a multi-pronged approach that addresses sociodemographic determinants of health as well as strengthening primary care.

In interpreting the results of this study, several limitations require consideration. First, the finding of a relationship between primary care physicians and lower population mortality does not necessarily imply that the mere presence of more primary care physicians assures either that more individuals in the population are exposed to primary care or that the delivery of primary care will produce better health outcomes at the individual level. More particularly, primary care physician to population ratio is a structural feature of health systems; such characteristics can only operate through behavioral (process) characteristics such as the strength and quality of actual primary care practice. Only studies performed at the practice or individual level would test these hypotheses. Unfortunately, there are no data that make it possible to adequately characterize receipt of good primary care (as distinguished from receipt of ambulatory care services, which also include specialty care) at either national or other levels.

Another limitation is that models using ecological data may be more prone to model misspecification due to a greater likelihood of unmeasured confounding variables at the individual level. However, we cannot understand or improve patterns of population health without also considering structural determinants at the societal level (Lynch & Kaplan, 1997; Diez-Roux, 1998). Because the study was performed at the state level, the findings reported are not necessarily generalizable to other types of geographic areas (such as metropolitan areas or counties).

There exists the possibility that there were other unmeasured, latent characteristics of states also associated with increased primary care and that these confounding variables (rather than primary care) are the true source of changes in mortality rates at the state level. As a sensitivity test, we included state fixed effects in the models in order to control for unobserved, time-invariant state characteristics. These fixed effects represent relatively stable features of each state and might include characteristics such as culture, historical patterns of racism, and historical differences in resources. Inclusion of fixed effects did not alter any of the results reported previously. Nevertheless, it is still possible that time-varying state characteristics such as policies to improve environmental quality or safety, availability of new medications or improved technology, or even reimbursement policies that encourage more effective primary care practice, might influence mortality and also be associated with policies to increase the number of primary care physicians. As we found increasing explanatory power of primary care physicians with the passage of time, it is also possible that primary care itself is improving in quality either due to better organization and delivery or to more effective interventions.

A final limitation is that the primary care measure used could also have been improved upon. For example other providers such as doctors of osteopathy, nurse practitioners, and other professionals also practice primary care and were not captured. Therefore, it is likely that the study underestimated the overall impact of primary care on population health.

References

American Medical Association. (1985). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1986). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1987). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1988). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1989). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1990). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1991). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1992). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1993). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1994). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1995). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

American Medical Association. (1996). *Physician characteristics and distribution in the United States*. Chicago, IL: American Medical Association.

Bergner, M. (1985). Measurement of health status. *Medical Care*, *23*, 696–704.

Blakely, T. A., Lochner, K., & Kawachi, I. (2002). Metropolitan area income inequality and self-rated health—a multi-level study. *Social Science & Medicine*, *54*, 65–77.

Bunker, J. (2001). *Medicine matters after all: measuring the benefits of medical care, a healthy lifestyle and a just social environment*. London, UK: Nuffield Trust.

Bunker, J. P., Frazier, H. S., & Mosteller, F. (1995). The role of medical care in determining health: creating an inventory of benefits. In B. C. Amick III, S. Levine, A. R. Tarlov, & D. C. Walsh (Eds.), *Society and health*. New York, NY: Oxford University Press.

Casanova, C., Colomer, C., & Starfield, B. (1996). Pediatric hospitalization due to ambulatory care-sensitive conditions in Valencia (Spain). *International Journal for Quality in Health Care*, *8*, 51–59.

Casanova, C., & Starfield, B. (1995). Hospitalizations of children and access to primary care: a cross-national comparison. *International Journal of Health Services*, *25*, 283–294.

Deaton, A., & Lubotsky, D. (2003). Mortality, inequality and race in American cities and states. *Social Science & Medicine*, *56*, 1139–1153.

Diez-Roux, A. V. (1998). Bringing context back into epidemiology: variables and fallacies in multilevel analysis. *American Journal of Public Health*, *88*, 216–222.

Donabedian, A. (1985). Twenty years of research on the quality of medical care: 1964–1984. *Evaluation and the Health Professions*, *8*, 243–265.

Dye, T. R. (1991). *Politics in states and communities* (7th ed.). Englewood Cliffs, NJ: Prentice-Hall.

Everson, S. A., Goldberg, D. E., Kaplan, G. A., Cohen, R. D., Pukkala, E., Tuomilehto, J., & Salonen, J. T. (1996). Hopelessness and risk of mortality and incidence of myocardial infarction and cancer. *Psychosomatic Medicine*, *58*, 113–121.

Friede, A., Reid, J. A., & Ory, H. W. (1993). CDC WONDER: a comprehensive on-line public health information system of the Centers for Disease Control and Prevention. *American Journal of Public Health*, *83*, 1289–1294.

Hadley, J. (1982). *More medical care, better health?*. Washington, DC: Urban Institute Press.

Hsiao, C. (1986). *Analysis of panel data*. Cambridge, UK: Cambridge University Press.

Kawachi, I., & Kennedy, B. P. (1997). The relationship of income inequality to mortality: does the choice of indicator matter? *Social Science & Medicine*, *45*, 1121–1127.

Kawachi, I., Kennedy, B. P., & Glass, R. (1999). Social capital and self-rated health: a contextual analysis. *American Journal of Public Health*, *89*, 1187–1193.

Kawachi, I., Kennedy, B. P., Lochner, K., & Prothrow-Stith, D. (1997). Social capital, income inequality, and mortality. *American Journal of Public Health*, *87*, 1491–1498.

Kennedy, B. P., Kawachi, I., & Prothrow-Stith, D. (1996). Income distribution and mortality: cross sectional ecological study of the Robin Hood index in the United States. *British Medical Journal*, *312*, 1004–1007 (Erratum: *British Medical Journal 312*(7040), 1996, p. 1194).

Klein, R. J., & Hawk, S. A. (1992). Health status indicators: definitions and national data. *Healthy people 2000 statistical notes*, *1*, 1–7.

Littell, R. C., Pendergast, J., & Natarajan, R. (2000). Modelling covariance structure in the analysis of repeated measures data. *Statistics in Medicine*, *19*, 1793–1819.

Lochner, K., Pamuk, E., Makuc, D., Kennedy, B. P., & Kawachi, I. (2001). State-level income inequality and individual mortality risk: a prospective, multilevel study. *American Journal of Public Health*, *91*, 385–391.

Lynch, J. W., & Kaplan, G. A. (1997). Understanding how inequality in the distribution of income affects health. *Journal of Health Psychology*, *2*, 297–314.

Lynch, J. W., Kaplan, G. A., Pamuk, E. R., Cohen, R. D., Heck, K. E., Balfour, J. L., & Yen, I. H. (1998). Income inequality and mortality in metropolitan areas of the United States. *American Journal of Public Health*, *88*, 1074–1080.

Lynch, J., Smith, G. D., Harper, S., Hillemeier, M., Ross, N., Kaplan, G. A., & Wolfson, M. (2004). Is income inequality a determinant of population health? Part 1. A systematic review. *Milbank Quarterly*, *82*, 5–99.

Macinko, J., Starfield, B., & Shi, L. (2003). The contribution of primary care systems to health outcomes within Organization for Economic Cooperation and Development (OECD) countries, 1970–1998. *Health Services Research*, *38*, 831–865.

Mackenbach, J. P., Stronks, K., & Kunst, A. E. (1989). The contribution of medical care to inequalities in health: differences between socio-economic groups in decline of mortality from conditions amenable to medical intervention. *Social Science & Medicine*, *29*, 369–376.

McLaughlin, D. K., & Stokes, C. S. (2002). Income inequality and mortality in US counties: does minority racial concentration matter? *American Journal of Public Health*, *92*, 99–104.

Mellor, J. M., & Milyo, J. (2001). Reexamining the evidence of an ecological association between income inequality and health. *Journal of Health Politics, Policy and Law*, *26*, 487–522.

Miller, T. Q., Smith, T. W., Turner, C. W., Guijarro, M. L., & Hallet, A. J. (1996). A meta-analytic review of research on hostility and physical health. *Psychological Bulletin*, *119*, 322–348.

National Center for Health Statistics (NCHS). (1985). *Health, United States 1985*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1986). *Health, United States 1986*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1987). *Health, United States 1987*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1988). *Health, United States 1988*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1989). *Health, United States 1989*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1990). *Health, United States 1990*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1991). *Health, United States 1991*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1992). *Health, United States 1992*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1993). *Health, United States 1993*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1994). *Health, United States 1994*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1995). *Health, United States 1995*. Hyattsville, MD: CDC/NCHS.

National Center for Health Statistics (NCHS). (1996). *Health, United States 1996*. Hyattsville, MD: CDC/NCHS.

Navarro, V., & Shi, L. (2001). The political context of social inequalities and health. *Social Science & Medicine*, *52*, 481–491.

Paterson, I., & Judge, K. (2002). Equality of access to healthcare. In J. P. Mackenbach, & M. Bakker (Eds.), *Reducing inequalities in health* (pp. 169–187). London: Routledge.

Rice, D. P. (1991). Health status and national health priorities. *Western Journal of Medicine*, *154*, 294–302.

SAS. (1999). *SAS/STAT user's guide, v8*. Cary, NC: SAS Institute, Inc. pp. 2083–2226.

Schwartz, S. (1994). The fallacy of the ecological fallacy: the potential misuse of a concept and the consequences. *American Journal of Public Health*, *84*, 819–824.

Sen, A. (1998). Mortality as an indicator of economic success and failure. *Economic Journal*, *108*, 1–25.

Shea, S., Misra, D., Ehrlich, M. H., Field, L., & Francis, C. K. (1992). Predisposing factors for severe, uncontrolled hypertension in an inner-city minority population. *New England Journal of Medicine*, *327*, 776–781.

Shi, L. (1994). Primary care, specialty care, and life chances. *International Journal of Health Services*, *24*, 431–458.

Shi, L. (1997). Health care spending, delivery, and outcome in developed countries: a cross-national comparison. *American Journal of Medical Quality*, *12*, 83–93.

Shi, L. (1999). Experience of primary care by racial and ethnic groups in the United States. *Medical Care*, *37*, 1068–1077.

Shi, L., & Starfield, B. (2000). Primary care, income inequality, and self-rated health in the United States: a mixed-level analysis. *International Journal of Health Services*, *30*, 541–555.

Shi, L., & Starfield, B. (2001). The effect of primary care physician supply and income inequality on mortality among blacks and whites in US metropolitan areas. *American Journal of Public Health*, *91*, 1246–1250.

Shi, L., Starfield, B., Kennedy, B. P., & Kawachi, I. (1999). Income inequality, primary care, and health indicators. *Journal of Family Practice*, *48*, 275–284.

Shi, L., Starfield, B., Politzer, R., & Regan, J. (2002). Primary care, self-rated health, and reductions in social disparities in health. *Health Services Research*, *37*, 529–550.

Starfield, B. (1986). Primary care in the United States. *International Journal of Health Services*, *16*, 179–198.

Starfield, B. (1992). *Primary care: concept, evaluation, and policy*. New York, NY: Oxford University Press.

Starfield, B. (1994). Is primary care essential? *Lancet*, *344*, 1129–1133.

Starfield, B. (1998). *Primary care: balancing health needs, services, and technology*. New York: Oxford University Press.

Starfield, B., & Shi, L. (2002). Policy relevant determinants of health: an international perspective. *Health Policy*, *60*, 201–218.

Subramanian, S. V., Blakely, T., & Kawachi, I. (2003). Income inequality as a public health concern: where do we stand? Commentary on "Is exposure to income inequality a public health concern?". *Health Services Research*, *38*, 153–167.

Susser, M. (1994). The logic in ecological: I. The logic of analysis. *American Journal of Public Health*, *84*, 825–829.

US Census Bureau. (2003). *Small area income and poverty estimates: state and county estimates*. Washington, DC: US Census Bureau http://www.census.gov/hhes/www/saipe/estimatetoc.html (accessed 12/03).

US Department of Commerce and the Census Bureau. (1985). *Statistical abstracts of the United States, 1985*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1986). *Statistical abstracts of the United States, 1986*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1987). *Statistical abstracts of the United States, 1987*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1988). *Statistical abstracts of the United States, 1988*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1989). *Statistical abstracts of the United States, 1989*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1990). *Statistical abstracts of the United States, 1990*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1991). *Statistical abstracts of the United States, 1991*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1992). *Statistical abstracts of the United States, 1992*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1993). *Statistical abstracts of the United States, 1993*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1994). *Statistical abstracts of the United States, 1994*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1995). *Statistical abstracts of the United States, 1995*. Washington, DC: US Government Printing Office.

US Department of Commerce and the Census Bureau. (1996). *Statistical abstracts of the United States, 1996*. Washington, DC: US Government Printing Office.

US Department of Health and Human Services National Center for Health Statistics. (2000). *Compressed mortality files*. Washington, DC: US Department of Health and Human Services.

Wagstaff, A., & van Doorslaer, E. (2000). Income inequality and health: what does the literature tell us? *Annual Review of Public Health*, *21*, 543–567.

Wilkinson, R. G. (1996). *Unhealthy societies: the afflictions of inequality*. London: Routledge.

Wilkinson, R. G. (1999). Income inequality, social cohesion, and health: clarifying the theory—a reply to Muntaner and Lynch. *International Journal of Health Services*, *29*, 525–543.