An extensive literature documents the profound influence of socioeconomic status on life expectancy. The notion that social conditions affect health is intuitive to policymakers and the public, but the magnitude of this effect may not be fully appreciated, and our previous work has sought to put it in perspective. For example, we have previously demonstrated on the basis of vital statistics that correcting mortality disparities by race and educational status would save 5 and 8 lives, respectively, for every 1 life saved by biomedical advances.

Social determinants exert influences on health through individual and household circumstances as well as through concurrent environmental conditions that exist in areas where people reside. People with good jobs, higher incomes, an advanced education, or historically favored racial or ethnic backgrounds experience better health not only because of these personal characteristics but also because of their surroundings. Access to safe neighborhoods, supermarkets with healthy foods, places to exercise, good schools, health care facilities, and clean air and water affects health outcomes. Area-based measures of economic status can act as a proxy for this package of interrelated social (individual and community) conditions.

Virginia offers an interesting setting for contrasting the health effects of disparate socioeconomic environments. Since 2000, 1 or more counties in northern Virginia have been among the 10 counties in the United States with the highest median household income. Conversely, Virginia also encompasses areas of deep poverty, such as the Appalachian region, and counties with large populations of minorities and adults with limited education. We took advantage of this setting to explore the association between health status and median area household income, the latter acting as a proxy for the combination of individual, household, and community conditions that exist in these areas.

We posed the following research question: How many deaths would be averted in Virginia if every county and city experienced the mortality rates of the most affluent areas? We estimated averted deaths in aggregate for the state, for each county and city, and for specific demographic subgroups.

METHODS

The years of analysis were 1990 through 2006, the most recent year for which analyzable data were available. Vital statistics were obtained in raw format (individual-level death data) from the Division of Health Statistics of the Virginia Department of Health and included data fields on decedents’ age, gender, race/ethnicity, place of residence, educational attainment, and year of death. Area-based population counts and demographic characteristics were obtained from the US Census Bureau for all 95 counties and 39 independent cities listed for Virginia. The US Census Bureau data were obtained in separate files for 1990 through 1999 and 2000 through 2006. All calculations were performed using SAS version 9.2 (SAS Institute, Cary, NC).

Reference Population

For each year from 1990 through 2006, we determined the aggregate mortality rate of the 5 areas (counties or cities; counties/cities hereafter) with the highest median household income. The median household income for counties/cities was obtained directly from the US Census Bureau Small Area Income and Poverty Estimates program, with the exception of the years 1990 through 1992, 1994, 1996, and 2006, for which the data were either inconsistent or not reported. We imputed median household income for these 6 calendar years, fitting a different model for each county with 3 explanatory variables using linear (year), quadratic (year squared), and cubic (year cubed) terms and choosing the model with the highest adjusted $R^2$ measure to derive the missing values.
income data. Counties/cities were ranked by the interpolated values for 1994 and 1996 (extrapolated for 1990 through 1992 and 2006), and the top 5 were designated as the reference population for that year.

The mortality rate for the reference population was determined for 12 age-gender subgroups: males aged 0 to 19 years, 20 to 34 years, 35 to 49 years, 50 to 64 years, 65 to 79 years, and 80 years and older, and the same age groups for females. The age-gender-specific mortality rates were calculated by dividing the number of deaths among persons with a place of residence in the reference population counties/cities by the population size of the age-gender-specific subgroup of the reference population. This procedure produced 12 age-gender-specific rates to apply as reference rates for subsequent calculations.

**Calculation of Avertable Deaths**

We determined avertable deaths for each calendar year for each county/city, and we aggregated them to arrive at the total number of avertable deaths for the state. The number of avertable deaths for a county/city was determined by applying the reference population mortality rate for each age-gender-specific subgroup to the population count of the corresponding age-gender-specific subgroup of the county/city and then subtracting this projected death count from the actual number of deaths for that age-gender-specific subgroup (deaths among persons with a place of residence in that county/city). The difference—the averted deaths for the age-gender-specific subgroup—were summed with the values for the remaining 11 age-gender-specific subgroups to determine the total number of avertable deaths for the county/city. The proportion of deaths that were avertable was the quotient of the number of avertable deaths divided by the actual number of deaths in the county/city. The total number of avertable deaths for the 95 counties and 39 cities was summed to determine the avertable deaths for the state.

The relatively small number of deaths that occur in sparsely populated counties creates instability in temporal comparisons of county-level estimates of the proportion of avertable deaths over time. Therefore, we pooled results over 4 years (4-year “moving averages,” weighted by year-specific population counts) when presenting proportions for all individual counties and cities. For example, the proportion of avertable deaths for a county in 2006 was the average of pooled mortality data for 2003 through 2006 weighted by population counts in each of the 4 years. The proportion was a negative value in those counties/cities in which the mortality rate was lower than the average mortality rate of the reference population. As expected, this occurred commonly among individual counties/cities within the reference population, but it also occurred episodically among counties/cities elsewhere in the state with exceptionally low mortality rates.

**Stratification of Results**

Although we applied age-gender-specific rates to calculate avertable deaths, we did not adjust for race/ethnicity or socioeconomic status (e.g., income, education). The aim of the study was to estimate the number of deaths that are potentially avertable by manipulating the conditions that cause disparities in mortality. We adjusted for age and gender, because these influences on mortality are not generally amenable to change, but we did not do so for race/ethnicity because that would imply that minorities could not experience the lower mortality rates available to nonminorities in the reference population.

Although we did not adjust for these variables, we did apply the known distribution among actual deaths to characterize the distribution of averted deaths by race/ethnicity and education. Specifically, we applied the distribution of actual deaths to our estimate of averted deaths, stratified by 4 categories of race/ethnicity (non-Hispanic Whites, non-Hispanic Blacks, Hispanics, and other) and 4 categories of educational attainment (less than high school, high school graduate but no postsecondary education, 1 to 3 years of postsecondary education, 4 or more years of postsecondary education) for adults aged 20 years and older.

**RESULTS**

The reference population—the 5 Virginia counties/cities with the highest median household income—is listed for each year in Table A (available as a supplement to the online version of this article at http://www.ajph.org). The reference population always included some combination of the following counties/cities in or near northern Virginia: Loudoun County, Fairfax County, the city of Falls Church, Prince William County, the city of Fairfax, and Stafford County. Imputed income values generated the same list of counties/cities in the reference population.

If the mortality rates of the reference population had applied throughout Virginia in 1990 through 2006, almost one fourth (mean = 24.3%; range = 21.8%–28.1%) of the state’s deaths would not have occurred (Table 1). A total of 220,211 deaths would have been averted between 1990 and 2006 (annual mean = 12,954; range = 10,548–14,569 deaths) if the state population had experienced the mortality rates of the reference population. Approximately three fourths of the averted


<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Actual Deaths</th>
<th>No. of Avertable Deaths</th>
<th>Avertable Deaths as a Proportion of Actual Deaths, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>47,125</td>
<td>10,562</td>
<td>22.4</td>
</tr>
<tr>
<td>1991</td>
<td>48,443</td>
<td>10,548</td>
<td>21.8</td>
</tr>
<tr>
<td>1992</td>
<td>48,520</td>
<td>11,794</td>
<td>24.3</td>
</tr>
<tr>
<td>1993</td>
<td>50,361</td>
<td>11,052</td>
<td>21.9</td>
</tr>
<tr>
<td>1994</td>
<td>50,806</td>
<td>11,881</td>
<td>23.4</td>
</tr>
<tr>
<td>1995</td>
<td>51,836</td>
<td>14,569</td>
<td>28.1</td>
</tr>
<tr>
<td>1996</td>
<td>52,518</td>
<td>13,395</td>
<td>25.5</td>
</tr>
<tr>
<td>1997</td>
<td>53,004</td>
<td>12,858</td>
<td>24.3</td>
</tr>
<tr>
<td>1998</td>
<td>53,003</td>
<td>14,236</td>
<td>26.9</td>
</tr>
<tr>
<td>1999</td>
<td>54,383</td>
<td>14,282</td>
<td>26.3</td>
</tr>
<tr>
<td>2000</td>
<td>56,091</td>
<td>13,660</td>
<td>24.4</td>
</tr>
<tr>
<td>2001</td>
<td>55,845</td>
<td>13,852</td>
<td>24.8</td>
</tr>
<tr>
<td>2002</td>
<td>56,940</td>
<td>14,283</td>
<td>25.1</td>
</tr>
<tr>
<td>2003</td>
<td>57,007</td>
<td>13,051</td>
<td>22.6</td>
</tr>
<tr>
<td>2004</td>
<td>56,241</td>
<td>13,193</td>
<td>23.5</td>
</tr>
<tr>
<td>2005</td>
<td>57,618</td>
<td>14,217</td>
<td>24.7</td>
</tr>
<tr>
<td>2006</td>
<td>57,387</td>
<td>12,778</td>
<td>22.3</td>
</tr>
<tr>
<td>Total</td>
<td>907,928</td>
<td>220,211</td>
<td>24.3[^3]</td>
</tr>
</tbody>
</table>

[^3]: Derived by applying the reference population mortality rate to the state’s population counts for 12 age- and gender-specific subgroups.
Localized patterns were predictable, such as the high proportion of avertable deaths in cities (e.g., Richmond, Norfolk) and the lower rates in surrounding bedroom-community suburban counties. Rates were low in the campus towns (and counties) of the University of Virginia and James Madison University, and in Virginia Beach, where tourist destinations and military bases are located. More anomalous patterns were also observed (Figure 2).

For example, the data reveal a low proportion of avertable deaths for the county that is home to Colonial Williamsburg and the College of William and Mary, but higher rates within the city limits where these facilities are located. Rural counties east of Petersburg (Prince George County and Surry County) had distinctly lower rates than surrounding counties to the west and south, despite seemingly similar demographic characteristics (e.g., large Black populations).

**DISCUSSION**

This study demonstrated that approximately 1 out of 4 deaths in Virginia from 1990 through 2006 would have been averted if the entire state had experienced the mortality rates of the reference population, in which the median household income was high. The predicted effect was substantial: the average number of lives saved per year (approximately 13,000) rivals the number of cancer deaths in the state.

The policies that would enable every county and city in the state to achieve the health advantages of northern Virginia, the location of the reference population, are unclear. One choice would be to increase household income, the independent variable of the study. Regions of the state with deep poverty had high mortality rates. However, income is deeply interrelated with other social determinants of health, such as education, race, and ethnicity. In our study, adults with no education beyond high school accounted for 75% of the avertable deaths. A confluence of interrelated socioeconomic variables—poverty, low graduation rates, and large minority populations—affects the regions of Virginia where we observed the highest rates, such as the Southwest and Southside areas, whereas areas with lower rates of avertable mortality, such as campus towns and affluent suburbs, have populations with more education, higher incomes, and lower minority representation.

Furthermore, individual characteristics (e.g., age, gender, race/ethnicity, income, education) are confounded with characteristics of the communities in which people live. Some personal variables that have a direct influence on health—such as low income, limited education,
and occupation—may also act as proxies for adverse environmental factors that exert their own influence on health, such as onerous conditions in urban centers or distressed rural counties, where we observed high mortality rates. Northern Virginia may have low mortality rates not only because of its residents’ affluence or education but also because of the area’s health care infrastructure, built environment, supermarket access, social services, school systems, pollution control, and progressive policies (e.g., smoke-free buildings).

The extent to which each of these individual and environmental factors contributes to improved health is a subject of great interest to researchers and policymakers. Communities cannot act on the disparities reported here without knowing which aspects of the reference population are worth emulating or prioritizing. For a future study we are planning to conduct a regression analysis to identify which factors matter most. For many communities, however, the deepening recession and financial crisis have removed the question of whether economic stimulus is a priority or whether individuals or communities need assistance. Families, businesses, and surrounding neighborhoods are all likely to benefit—and sustain each other—when policies promote jobs, education, secure housing, commerce, and a stronger infrastructure.

The insight from this study is that such socioeconomic policies are of great importance to health. This conclusion can be accepted without necessarily knowing the causal inter-relationships among the component parts. The “package” of individual and environmental conditions associated with high household income exerts influence on health outcomes, perhaps more than health care itself. The projected effect we report here—reducing adult all-cause mortality rates by 25%—could not be achieved by any known medical intervention. This effect is of acute pertinence amid the current recession, underscoring the potentially large health implications of policies to improve socioeconomic well-being and the importance of examining the “health in all policies” strategy.

Our study adds to a growing literature that examines disparities in mortality by county, zip code, or census tract. For example, Ezzati et al. contrasted disparities in life expectancy from 1961 through 1999 across all counties in the United States.25 Krieger et al. examined the relationship between family income and county mortality rates from 1960 through 2002.26 Since 2003, the University of Wisconsin Population Health Institute has issued annual reports that rank each county in Wisconsin by its health status and the prevalence of various health determinants,27,28 and the institute is now doing the same for every county in the nation.
However, we are aware of no study that has used our approach to measure the proportion of deaths associated with geographic disparities in area-based income.

The limitations of our study bear examination. The analysis was cross-sectional rather than longitudinal; examined data for 1 state rather than the nation; relied on area-based (rather than individual) income data (which are interpolated and extrapolated for some years) and on raw vital statistics provided by the state registrar (which differ slightly from those reported by the National Center for Health Statistics); incorporated contextual data from death certificates, which can be incomplete and biased²⁹,³⁰, made comparisons by county rather than by census tract, which may be more predictive and economically homogeneous³¹; and conducted analyses only through 2006, after which dramatic economic events occurred.

The study can be criticized for not calculating specific mortality rates by race and ethnicity, given that Blacks and Hispanics have higher mortality rates than non-Hispanic Whites. We reasoned that doing so to calculate avertable deaths would imply that minorities in Virginia could aspire only to the mortality rates of minorities in the reference population, not to the lower mortality rates of non-Hispanic Whites in the reference population. In theory, the low mortality rates that others experience should be equally attainable by minorities, in the reference population and elsewhere, if the social conditions responsible for the disparity are rectified. We did produce a demographic profile of the race, ethnicity, and educational status of the adults whose deaths would be averted (Table 2), but we relied on the distribution of these variables among actual deaths and thereby made the contestable assumption that the same distribution would apply to averted deaths. It is more likely that the relative reduction in mortality conferred upon areas of economic disadvantage with improved economic conditions would be affected at the national level if the mortality rates of the most affluent areas (or those of another country) were applied. Regression analyses and other methods can help quantify the individual contribution of different causal factors and may explain the anomalous findings we observed. However, our research and other studies already provide sufficient evidence for policymakers to recognize the powerful interrelationships between social conditions and public health and to leverage the important opportunities they provide.■

About the Authors
Steven H. Woolf is with the Center on Human Needs and the Department of Family Medicine, Virginia Commonwealth University, Richmond. Rena M. Jones is with the Department of Epidemiology and Community Health and the Massaging Cancer Center, Virginia Commonwealth University. Robert E. Johnson is with the Department of Biostatistics, Virginia Commonwealth University. Robert L. Phillips Jr. and Andrew Bazemore are with the Robert Graham Center, American Academy of Family Physicians, Washington, DC. M. Norman Oliver is with the Department of Family Medicine, University of Virginia, Charlottesville. Anushree Vichare is with the Virginia Department of Health, Richmond.

Correspondence should be sent to Steven H. Woolf, MD, MPH, VCU Center on Human Needs, Virginia Commonwealth University, 1200 East Broad St, PO Box 980251, Richmond, VA 23229-0251 (e-mail: swoolf@vcu.edu). Reprints can be ordered at http://www.ajph.org by clicking the “Reprints/Eprints” link. This article was accepted August 15, 2009.

Contributors
S.H. Woolf conceptualized the study, obtained funding, led design and execution of the analysis, and drafted the article. R.M. Jones was chiefly responsible for designing and executing the statistical calculations, with guidance from R.E. Johnson, who personally performed advanced programming, calculations, and statistical consultation for the project. R.L. Phillips Jr. N.M. Oliver, and A. Bazemore served on a project team that designed the study, vetted methodological problems, edited the article, and arranged for geographic information system mapping. A. Vichare assisted R.M. Jones with initial statistical calculations.

Acknowledgments
This study was funded by the Robert Wood Johnson Foundation (grant 63408).

The authors thank Calvin Reynolds, director, Virginia Department of Health, Division of Health Statistics, for providing the vital statistics used in this study, and Imam Xierali, PhD, research scientist and health geographer at the Robert Graham Center, for assistance with mapping.

Human Participation Protection
This study was approved by the Virginia Commonwealth University institutional review board.

References


