

The Development of a Summary Measure to Estimate the Relative Burden of Smoking in Wisconsin Counties

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ABSTRACT

Background: The rate of cigarette smoking among US adults has declined over the past 50 years. Yet smoking remains the leading cause of preventable death and marked disparities now exist in smoking rates based on education level, socioeconomic status, race/ethnicity, and geographic location. In order to target resources to reduce these disparities, a summary measure comparing the relative burden of smoking among smaller populations is needed.

Objective: To create a single summary measure that assesses the relative health burden from smoking in Wisconsin counties using age-adjusted mortality rates for smoking-attributable diseases, current adult smoking prevalence, and the current rate of mothers who smoked during pregnancy.

Results: Rates varied significantly between counties for smoking-attributable deaths (2-fold), adult smoking prevalence (5-fold), and smoking in pregnancy (5-fold). The summary measure of relative smoking burden was highest in rural counties and in counties with less education, higher rates of poverty, and more veterans. The ranking of a county's smoking burden was highly correlated with its overall health ranking from the County Health Rankings.

Discussion: The burden from smoking varied markedly across Wisconsin and was highest in the least advantaged counties in the state. Additional public health efforts must be directed toward the counties with the greater relative smoking burden in order to reduce these disparities.

INTRODUCTION

Even though smoking rates declined among US adults between 1965 (42.4%) and 2012 (18.1%), smoking remains the leading cause of preventable death in the United States.¹ Reductions in smoking rates did not occur evenly across society, resulting in health disparities by education levels, socioeconomic status, race/ethnicity, and geographic location.¹ Well-funded, comprehensive statewide tobacco campaigns have proven effective in other

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states,^{2,3} and additional resources spent on evidence-based tobacco control policies will increase demand to quit smoking⁴ and diminish the monetary and health costs due to smoking.⁵ However, reducing the disparate burden of smoking is also a priority and will require new approaches that specifically target those populations at highest risk of smoking. One approach to such targeting would be to focus on smaller geographic locations such as counties.

The County Health Rankings has already taken this approach and offers community leaders, county health departments, nonprofit hospitals, and nongovernmental organizations critical information for assessing the overall health of their county, relative to other counties in the state—information that is useful when developing a community health improvement plan.⁶ The prevalence of adult smoking was included

in the County Health Rankings but, similar to other metrics, provided only 1 aspect of smoking burden at a single point in time. The Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC), developed by the Centers for Disease Control and Prevention (CDC), is a good tool to measure the health and economic burden of tobacco, though it requires data that are rarely available in small communities (eg, age-specific smoking prevalence data or mortality due to uncommon smoking-related diseases). The objective of this study was to compare and contrast the relative burden of smoking among Wisconsin's 72 counties using a summary measure that combines existing data on age-adjusted mortality rates for smoking-attributable diseases, adult smoking prevalence rates, and the rates of mothers who smoke during pregnancy.

METHODS

Smoking-attributable mortality rates, adult smoking prevalence rates, and smoking during pregnancy rates for each Wisconsin

county were compiled from readily available epidemiologic databases. These rates were then combined into a single summary measure that estimated the relative burden of smoking among Wisconsin counties. Finally, this summary measure was compared to demographic information and the County Health Rankings. This study utilized secondary data of nonidentifiable, aggregate information and therefore did not need approval by an Institutional Review Board.

Smoking-attributable Mortality Rates

Smoking-attributable mortality rates were calculated for adults age 35 and older in all 72 Wisconsin counties from 2001 to 2010 using mortality data from Wide-ranging Online Data for Epidemiologic Research (WONDER), an online database at the CDC (<http://wonder.cdc.gov/>). These data were grouped into 4 categories of smoking-attributable diseases as done in previous research⁷—neoplasm of the lung, other tobacco-related neoplasm, heart disease and stroke, and respiratory disease.

Death rates for each county were age-adjusted to the 2000 United States population, the most recent available option. County smoking-attributable mortality rate for each disease category was estimated by multiplying the county's age-adjusted mortality rates by the category's respective statewide smoking-attributable fraction.⁷ This method is similar to the CDC's calculation of smoking-attributable mortality in larger populations.⁸ Neoplasm of the lung had the highest smoking-attributable fraction (79%) compared to other tobacco-related neoplasm (34%), heart disease and stroke (14%), and respiratory disease (57%).

Adult Smoking Prevalence Rates

The prevalence of cigarette smoking among adults (18 years of age and older) in each Wisconsin county was compiled previously and reported by the University of Wisconsin Population Health Institute for its County Health Rankings and accessed on that web page (<http://www.countyhealthrankings.org>). These rates were based on a 7-year average of data from the CDC's Behavioral Risk Factor Surveillance System, for the years 2006 to 2012.

Smoking During Pregnancy Rates

The prevalence of smoking during pregnancy was included to capture some of the future costs that will result from smoking today, such as the cost of adverse health effects of babies born to mothers who smoke during pregnancy⁹ or increased risk of future smoking by the mother's child.¹⁰ These data were obtained for all counties for the years 2001 to 2010 from the Wisconsin Department of Health Services' clinical information database Wisconsin Interactive Statistics on Health (WISH) from its web page (<https://www.dhs.wisconsin.gov/WISH/>). Using 10-year averages provided more stable estimates for smaller counties.

Smoking Summary Measure

A single summary measure estimating relative smoking burden was calculated for each county by combining the 3 rates above, and weighting smoking-attributable mortality (50%), adult prevalence (25%), and smoking during pregnancy (25%). Greater weight was given to the smoking-related mortality rates given the burden from this health outcome. This calculated z-score encapsulated an estimate of the burden of smoking due to smoking in the past (smoking-attributable mortality), an estimate of the current burden of smoking (adult smoking prevalence), and an indication of the future burden of smoking (smoking during pregnancy). This method of using weighted z-scores to assess the relative health of counties was similar to the approach used in the County Health Rankings¹¹. Z-scores were calculated for each county in the following manner:

$$\left[\begin{array}{l} \text{Smoking} \\ \text{Burden} \\ \text{z-score} \end{array} \right] = [50\%] * \left[\frac{(\text{County SAM}) - (\text{Mean SAM})}{(\text{St Dev SAM})} \right] + [25\%] * \left[\frac{(\text{County Prev}) - (\text{Mean Prev})}{(\text{St Dev Prev})} \right] + [25\%] * \left[\frac{(\text{County SDP}) - (\text{Mean SDP})}{(\text{St Dev SDP})} \right]$$

SAM = Smoking Attributable Mortality
 Prev = Adult Smoking Prevalence
 SDP = Smoking During Pregnancy

A z-score provided an estimate of how many standard deviations a particular data point lay from the mean (negative z-scores indicated lower burden and positive z-scores indicated higher burden). The counties then were ranked according to these smoking burden z-scores.

Demographic and Health Characteristics of Counties

County demographic data including percent living in poverty, veterans, and who had a bachelor's degree or higher were gathered from the US Census Bureau's QuickFacts on its web page (<http://www.census.gov>) using data from 2008 to 2012. The overall health outcome ranking for each county was taken from the County Health Rankings (www.countyhealthrankings.com) for 2014.

These county demographics and health outcomes measures were correlated with the smoking burden z-score. Using US Census Bureau definitions,¹² differences between the smoking burden of rural counties (with no urban center of 10,000 people or more), micropolitan counties (with an urban center of at least 10,000 people but fewer than 50,000 people), and metropolitan counties (with an urban center of 50,000 people or more) were compared using between-samples *t* tests. Correlations between counties' summary measure burden of smoking and overall health outcome were calculated using Spearman rank correlation.

Table. Smoking-Related Burden for Wisconsin's 72 Counties. Ranked from Lowest (1) to Highest (72) Relative Burden

County	SAM per 100,000 People 2001-2010 Average (Rank)	Adult Smoking Prevalence 2006-2012 Average (Rank)	Smoking During Pregnancy 2001-2010 Average (Rank)	Total Smoking Burden Z-score (Rank)	County	SAM per 100,000 People 2001-2010 Average (Rank)	Adult Smoking Prevalence 2006-2012 Average (Rank)	Smoking During Pregnancy 2001-2010 Average (Rank)	Total Smoking Burden Z-score (Rank)
Calumet	176 (1)	11% (2)	8.9% (3)	-1.64 (1)	Walworth	233 (46)	19% (41)	14.8% (24)	-0.07 (37)
Ozaukee	192 (2)	12% (3)	6.9% (1)	-1.39 (2)	Bayfield	220 (33)	16% (18)	25.7% (59)	-0.03 (38)
Lafayette	204 (13)	8% (1)	11.9% (9)	-1.23 (3)	Oconto	225 (38)	19% (36)	20.5% (47)	-0.01 (39)
Dane	199 (10)	14% (6)	8.9% (4)	-1.13 (4)	Sauk	230 (42)	17% (26)	21.3% (51)	0.04 (40)
Pierce	193 (5)	14% (7)	11.1% (6)	-1.11 (5)	Shawano	220 (32)	21% (49)	21.6% (53)	0.05 (41)
Waukesha	204 (14)	16% (20)	7.7% (2)	-0.96 (6)	Rusk	233 (45)	16% (17)	22.2% (55)	0.05 (42)
Washington	203 (12)	14% (7)	11.2% (7)	-0.94 (7)	Green Lake	234 (48)	19% (42)	18.5% (39)	0.08 (43)
Portage	197 (9)	15% (13)	12.7% (14)	-0.94 (8)	Racine	234 (49)	23% (59)	14.2% (18)	0.12 (44)
Door	194 (6)	16% (15)	14.2% (19)	-0.92 (9)	Milwaukee	247 (58)	21% (50)	11.6% (8)	0.13 (45)
Kewaunee	192 (3)	18% (32)	12.5% (13)	-0.88 (10)	Lincoln	213 (24)	23% (57)	24.6% (57)	0.16 (46)
Taylor	193 (4)	17% (23)	15.9% (28)	-0.81 (11)	Vilas	225 (37)	18% (34)	26.0% (62)	0.19 (47)
St. Croix	213 (23)	15% (12)	9.4% (5)	-0.79 (12)	Columbia	235 (50)	23% (54)	17.2% (35)	0.23 (48)
Dunn	195 (8)	16% (16)	17.0% (33)	-0.79 (13)	Waushara	235 (51)	21% (51)	20.7% (49)	0.28 (49)
Green	206 (17)	12% (4)	16.5% (30)	-0.78 (14)	Chippewa	228 (40)	24% (65)	20.5% (48)	0.29 (50)
Marathon	195 (7)	18% (28)	16.8% (31)	-0.70 (15)	Oneida	238 (54)	20% (45)	21.5% (52)	0.29 (51)
Outagamie	205 (15)	18% (30)	12.5% (12)	-0.68 (16)	Barron	233 (44)	24% (66)	19.7% (44)	0.36 (52)
Pepin	219 (31)	14% (5)	12.8% (15)	-0.65 (17)	Burnett	232 (43)	15% (11)	33.5% (71)	0.39 (53)
Clark	205 (16)	21% (52)	12.2% (10)	-0.51 (18)	Crawford	242 (56)	23% (57)	18.1% (38)	0.40 (54)
Brown	211 (19)	19% (39)	13.0% (16)	-0.51 (19)	Jackson	241 (55)	20% (47)	25.9% (61)	0.55 (55)
Jefferson	212 (20)	16% (18)	17.1% (34)	-0.50 (20)	Monroe	250 (59)	23% (54)	19.5% (43)	0.57 (56)
Manitowoc	201 (11)	18% (31)	19.9% (45)	-0.46 (21)	Florence	226 (39)	26% (69)	26.3% (63)	0.59 (57)
Fond du Lac	212 (21)	18% (34)	14.5% (21)	-0.45 (22)	Washburn	236 (53)	23% (61)	25.7% (60)	0.60 (58)
Sheboygan	216 (28)	17% (25)	14.8% (25)	-0.45 (23)	Kenosha	268 (68)	21% (52)	14.6% (23)	0.63 (59)
La Crosse	225 (36)	15% (14)	14.6% (22)	-0.39 (24)	Rock	259 (65)	23% (63)	18.7% (40)	0.73 (60)
Buffalo	214 (25)	19% (36)	15.8% (26)	-0.37 (25)	Iron	255 (63)	19% (43)	28.0% (66)	0.82 (61)
Wood	207 (18)	18% (32)	19.4% (42)	-0.36 (26)	Waupaca	273 (70)	20% (46)	20.1% (46)	0.84 (62)
Winnebago	217 (29)	18% (28)	16.1% (29)	-0.35 (27)	Douglas	260 (66)	23% (63)	22.0% (54)	0.87 (63)
Trempealeau	215 (26)	19% (38)	15.9% (27)	-0.35 (28)	Marquette	255 (62)	24% (67)	23.5% (56)	0.89 (64)
Richland	219 (30)	16% (21)	17.5% (36)	-0.34 (29)	Langlade	251 (60)	23% (62)	27.6% (64)	0.92 (65)
Iowa	213 (22)	21% (48)	14.4% (20)	-0.34 (30)	Marinette	246 (57)	27% (70)	25.5% (58)	0.93 (66)
Eau Claire	223 (35)	17% (24)	16.9% (32)	-0.27 (31)	Forest	261 (67)	19% (43)	31.9% (70)	1.06 (67)
Grant	234 (47)	17% (27)	13.3% (17)	-0.20 (32)	Juneau	257 (64)	26% (68)	27.7% (65)	1.15 (68)
Price	229 (41)	15% (10)	19.3% (41)	-0.18 (33)	Sawyer	254 (61)	27% (71)	28.7% (67)	1.20 (69)
Vernon	221 (34)	23% (56)	12.3% (11)	-0.17 (34)	Ashland	285 (71)	16% (21)	31.5% (68)	1.30 (70)
Polk	216 (27)	19% (40)	21.0% (50)	-0.14 (35)	Adams	270 (69)	23% (60)	31.6% (69)	1.38 (71)
Dodge	236 (52)	15% (9)	18.0% (37)	-0.12 (36)	Menominee	387 (72)	46% (72)	40.6% (72)	4.24 (72)

Abbreviation: SAM, smoking-attributable mortality.

RESULTS

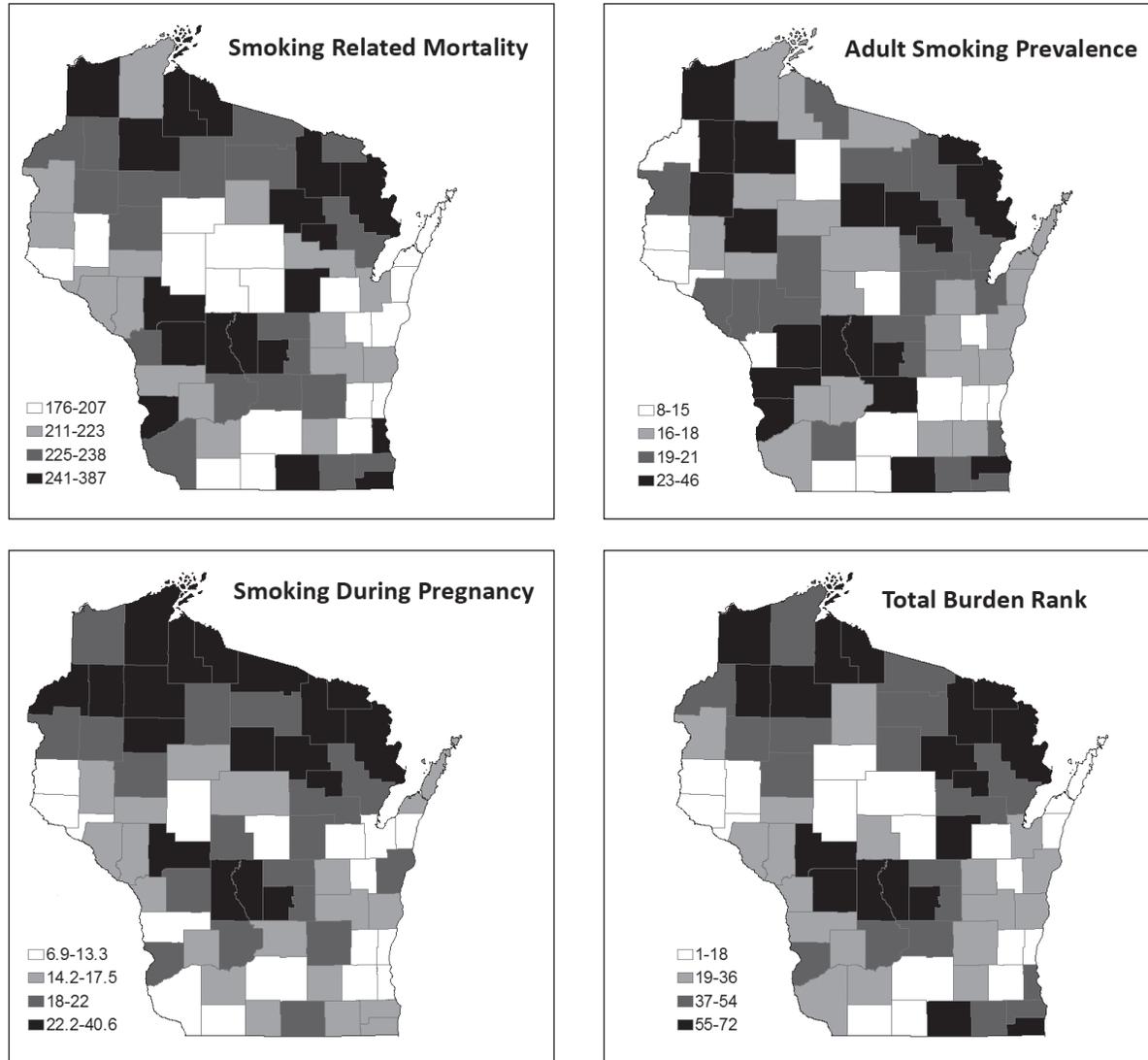
The median smoking-attributable mortality rate among Wisconsin counties during 2001 to 2010 was 225 deaths per 100,000 people, ranging over 2-fold, from a low of 176 in Calumet County to a high of 387 in Menominee County. Median adult smoking prevalence among Wisconsin counties during 2006-2012 was 19%, ranging over 5-fold, from a low of 8% in Lafayette County to a high of 46% in Menominee County. Menominee County had a significantly higher prevalence of adult smoking with the next highest prevalence of 27% seen in Marinette County. The median rate of women who smoked during pregnancy among Wisconsin counties during 2001-010 was 17.8%, ranging over 5-fold from a low of 6.9% in Ozaukee County to a high of 40.6% in Menominee County.

The summary smoking burden z-scores for each county ranged from a low of -1.64 in Calumet County to a high of +4.24 in Menominee County (Table). All 3 measures that comprised the burden of smoking were highly correlated with one another. The highest correlation was seen between mortality and adult smoking ($r=0.75, P<0.001$), followed by mortality and smoking during pregnancy ($r=0.71, P<0.001$), and adult smoking and smoking during pregnancy ($r=0.58, P<0.001$).

County Characteristics and County Smoking Burden

Statewide, smoking burden was generally highest in counties in the northern, central, and southeastern regions of the state, with lower rates generally seen in the western, north-central, northeastern, and Milwaukee suburban counties (Figure). While high rates

Figure. Wisconsin's 72 Counties Grouped Into Quartiles Based on Smoking-attributable Mortality (Deaths/100,000 Population); Adult Smoking Prevalence (%); Smoking Rates Among Pregnant Women (%), and Summary Rank of Relative Smoking Burden.



of smoking-attributable mortality were seen distributed throughout the state, including metropolitan areas, it appeared that adult prevalence and smoking during pregnancy were more confined to the northern counties and excluded larger metropolitan areas.

The overall smoking burden was greatest for the 34 rural counties (mean z-score = +0.35, range -1.23 Lafayette to +4.24 Menominee); was less in the 13 micropolitan counties (mean z-score = -0.19, range = -0.94 Portage to +0.93 Marinette); and lowest for the 25 metropolitan counties (mean z-score = -0.40, range -1.64 Calumet to +0.87 Douglas). The only statistically significant difference existed between metropolitan counties (M = -0.40, SD = 0.65) and rural counties (M = +0.35, SD = 0.95; $t(57) = -3.38$, 2-tailed), $P < 0.05$. This significant difference remained when Menominee County (a potential outlier) was

removed from the rural group.

Separate simple linear regression analyses showed that the smoking burden was greatest in those counties with more adult poverty ($r = 0.61$, $P < 0.001$), lower levels of education ($r = 0.50$, $P < 0.001$), and a higher percent of adult veterans ($r = 0.49$, $P < 0.001$). These 3 variables were then included in a multiple regression model to identify interactions. All 3 independent variables continued to significantly predict a portion of total smoking burden z-scores ($r^2 = 0.55$, $P < 0.001$). The counties' summary measure of smoking burden rank was highly correlated with the overall health outcome rank, obtained from the County Health Rankings (Spearman rank order correlation = 0.78). Of the 10 counties with the highest smoking burden, 5 were ranked as the 10 least healthy counties in the state. Similarly, of the 10 counties

with the lowest smoking burden, 7 were ranked as the healthiest 10 counties in the state.

DISCUSSION

Significant disparities between Wisconsin counties were observed for smoking-attributable death rates (2-fold), adult smoking prevalence rates (5-fold), and smoking in pregnancy rates (5-fold). These measures of the burden of smoking encapsulated problems due to smoking in the past (mortality data), current health concerns (adult smoking prevalence), and future anticipated smoking-related health problems (smoking during pregnancy). When combined, these factors provided a single summary measure of the relative smoking burden in each county that includes current health and economic burden from smoking-related diseases, as well as future health and economic burden related to higher smoking prevalence rates among adults and pregnant women.

Several demographic factors explained most of the variation in the overall burden from smoking, with the greatest burden occurring in rural counties and in counties with the highest rates of poverty, lowest rates of education, and a higher percent of a county's population that were veterans. These findings were consistent with previous research, and similar to the factors that were associated with higher rates of smoking among individuals.^{1,13-15} These disparities have increased over time, as the effects of tobacco control interventions have been most effective among persons with more education and living in wealthier communities.^{1,16}

The burden from smoking was greatest in Menominee County—with the highest rates in the state for smoking-attributable deaths, smoking among adults, and smoking among pregnant women. This finding is not unique to Wisconsin, as the prevalence of smoking and smoking-related diseases is higher in many American Indian communities across the nation.¹⁷ Some of this burden can be explained by the factors that have been associated with smoking throughout Wisconsin, as Menominee County is a rural community with high rates of poverty and lower rates of education. However, additional factors including the culture of tobacco use, availability of low-cost cigarettes, and differences in tobacco policies may explain this greater burden.

Limitations

Several limitations should be considered when interpreting the results from this study. First, only limited demographic data were examined for each county, and other factors—including current levels of tobacco control and prevention efforts—may explain the observed differences in smoking prevalence and smoking-attributable mortality. Second, the time period of data collected for smoking prevalence did not align with the data collected for smoking-attributable mortality and smoking during pregnancy. This was purposefully done to obtain an average after smoking prevalence rates stabilized statewide in the mid-2000s. The slight

differences in timeframe for data collection likely had little impact since the objective of this study was to create a practical tool to compare the relative burden of smoking using existing data. Third, measures of smoking among youth, such as data from the Wisconsin Youth Risk Behavior Survey (YRBS) are available only at the state level and therefore were not available to include in our analysis of individual counties. Fourth, when calculating the summary measure z-score, changing the weights for each of the factors may change the overall county rank (though these changes would be minor since the individual measures were highly correlated). Finally, this study used rates to identify whether smoking burden was equitably distributed among counties, though the absolute smoking burden is greatest in counties with larger populations.

CONCLUSION

The burden from smoking varies markedly across Wisconsin and is highest in the least advantaged counties in the state. Given the health effects from smoking, it is not surprising that counties with the highest burden from smoking are also those counties that rank as some of the least healthy in the County Health Rankings. Although it is likely that other social, cultural, and environmental factors contribute to these differences, much of the variability in smoking burden among Wisconsin counties can be attributed to rates of poverty, less education, and the number of veterans living in a county. Ultimately, this model of calculating relative smoking burden among counties can be used as a single measure to help identify counties with successful tobacco control and prevention programs and policies, as well as identifying counties in need of investments for improvement.

Acknowledgments: The authors wish to thank Elizabeth Pollock for creating the maps. Both Elizabeth Pollock and Randall Glysch provided helpful comments on the manuscript.

Funding/Support: This work was supported by a summer research grant from the Herman and Gwendolyn Shapiro Foundation; a grant from the Health Resources Services Administration (HRSA) through the Training in Primary Care Medicine Interdisciplinary and Interprofessional Graduate Joint Degree Program (grant # T85HP24472); and by a grant (#69835) from the Robert Wood Johnson Foundation for the development of the County Health Rankings.

Financial Disclosures: None declared.

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