EVIDENCE BASED PUBLIC HEALTH POLICY AND PRACTICE

Effect of area poverty rate on cancer screening across US communities

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Study objective: To analyse the contextual effect of area poverty rate on never having been screened for breast, cervical, and colorectal cancer by (1) describing the extent of the variation in screening behaviours among 98 US metropolitan areas; (2) determining if the variation in lack of screening can be explained by differences in the characteristics of the persons who resided in these areas; and (3) determining if living in a metropolitan area with a higher poverty rate increased the likelihood of never having been screened for cancer over and above individual characteristics.

Design: Cross sectional survey using data from the 2002 Behavioral Risk Factor Surveillance System. Multilevel logistic regression included both individual level factors as well as area poverty rate.

Setting: Ninety eight areas across the USA.

Participants: Over 118 000 persons residing in 98 areas; a sample aimed at estimating 48.3% of the US population age 18 or older.

Main results: After adjustment for individual level factors, increasing area level poverty rate (per 5%) remained associated with never having had a mammogram (odds ratio (OR) = 1.28, 95% confidence interval (CI): 1.03 to 1.37); clinical breast examination (OR = 1.28, 95% CI: 1.11 to 1.48), colonoscopy/sigmoidoscopy (OR = 1.10, 95% CI: 1.01 to 1.19), and a faecal occult blood test (OR = 1.19, 95% CI: 1.12 to 1.27). Poverty rate was not independently associated with never having had a Pap smear (OR = 1.12; 95% CI: 0.90 to 1.41). The size of the variance among metropolitan or micropolitan statistical areas (MMSAs) varied by type of screening test, with intraclass correlation coefficients ranging from 4.9% (never having had a Pap smear) to 1.2% (never having had a colonoscopy/sigmoidoscopy).

Conclusions: Area poverty rate was independently associated with never having been screened for breast and colorectal cancer, but not cervical cancer. The size of the variance among MMSAs was modest at best.

In 2004, 18% of the estimated 563 700 cancer deaths in the USA were the result of colorectal, breast, and cervical cancer.¹ Key to reducing mortality from these cancers is to identify them at an early, more treatable stage by means of screening. However, screening prevalence for these various cancers has been found to vary by age, income, and racial/ethnic groups among others.^{2–6} In addition, recent findings suggest that there may be geographical variation in screening. Using reweighted Behavioral Risk Factor Surveillance System (BRFSS) data, Nelson and colleagues⁷ showed that screening for breast, cervical, and colorectal cancer varied among metropolitan areas in the USA. However, it is unclear if this geographical variation in screening use was the result of differences in characteristics of the persons who resided in these areas, such as income or health insurance,⁸ or if there is variation that can instead be attributed to contextual level factors such as area level socioeconomic status (SES). Persons who reside in areas with more adverse socioeconomic conditions are more likely to be diagnosed with advanced breast and colorectal cancer and have a higher incidence of cervical cancer suggesting that lack of screening may play an important part.^{9–12}

An emerging body of literature has shown that persons who reside in socioeconomically deprived areas reported higher smoking level as well as lower physical activity and recommended eating patterns, after taking into account individual level factors in a multilevel approach.^{13,14} In these studies, some of the variation among geographical areas resulted from differences in individual characteristics of persons who resided in these areas, however an important contextual effect of area level SES remained. There is a paucity of similar research regarding the use of cancer

screening, especially for geographical areas smaller than at the state level. The results of such studies could be used to facilitate allocation of screening resources and interventions locally, identify concise geographical targets for intervention, monitor disparities among various population subgroups, and track progress toward Healthy People 2010 goals at the local level depending on the magnitude of the variation among areas. Targeting specific geographical areas becomes more feasible when larger variation is present among areas.^{15,16} Yet, the magnitude of the geographical variation in cancer screening is currently unclear.

It is also important to note that while regular screening has increased quite substantially over time, there remains a significant proportion of people who meet criteria for routine screening but who never have been screened. Moreover, disparities remain among persons of differing SES and among persons with varying access to medical care in terms of the prevalence of never having been screened,^{4,17} making the examination of persons who never had been screened of substantial importance. Targeting this population to increase screening will reduce the risk of late stage diagnosis or even prevent cancer, and may subsequently reduce the population burden from these cancer more than when focused on regular screening.

The purpose of this study was to model the proportion of persons who had never been screened for breast, cervical, and colorectal cancer, examining the magnitude of the geographical variation in each of five cancer screening behaviours

Abbreviations: MMSA, metropolitan or micropolitan statistical area; SES, socioeconomic status; FOBT, faecal occult blood test; CBE, clinical breast examination; BRFSS, Behavioral Risk Factor Surveillance System

(mammography, clinical breast examination (CBE), Pap smear, colonoscopy/sigmoidoscopy, and faecal occult blood test (FOBT)) and 98 areas, and their relation to area level SES using multilevel models. The main objectives were to: (1) describe the extent of the variation in five cancer screening behaviours among 98 US metropolitan areas; (2) determine if the variation in lack of screening can be explained by differences in the characteristics of the persons who resided in these areas; and (3) determine if living in a metropolitan area with a higher poverty rate increased the likelihood of never having been screened for cancer over and above individual characteristics.

METHODS

Data and population

Rewighted data from the 2002 BRFSS were used to assess the relations of interest.¹⁸ A respondent was associated with a particular metropolitan or micropolitan statistical area (MMSA) on the basis of their self reported county code. Missing county codes were imputed from a value included in the purchased telephone sample that represents the county most probably associated with the telephone number.

A metropolitan statistical area is defined as having at least one urbanised area of 50 000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. A micropolitan statistical area has at least one urban cluster of at least 10 000 but less than 50 000 population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. MMSAs are defined in terms of whole counties (or equivalent entities), including in the six New England States. Of 3142 counties in the USA, 1090 are in the 362 metropolitan statistical areas in the USA and 674 counties are in micropolitan statistical areas, while 1378 counties remained outside the classification.

MMSA level estimates have been produced from the 2002 BRFSS data for 98 of the 1036 MMSAs in the USA that met CDC's analysis criteria, namely containing at least 500 respondents per MMSA age 18 or older. The 98 MMSAs consisted of 740 counties (23.6% of all US counties) and contained an estimated 48.3% of the US population age 18 or older. As a result, we were able to construct a two level model consisting of persons at level 1 and MMSAs at level 2. The CASRO rate, developed by the Council of American Survey Research Organizations, reflects telephone sampling efficiency as well as the degree of cooperation among eligible people contacted, with higher percentages indicating lower potential for bias in the data. The median CASRO rate for the state based BRFSS was 58.3% in 2002 (state based range: 42.2%–82.6%).

Screening assessment

Self reported use of screening for breast, cervical, and colorectal cancers was obtained from the 2002 BRFSS data. For breast cancer screening, never having had a mammogram was assessed by: "A mammogram is an x ray of each breast to look for breast cancer. Have you ever had a mammogram?" Women were considered to have never had a mammogram if they answered "no" to this question. Similar questions were asked of the respondents for screening for CBE for breast cancer, Pap smear for cervical cancer, and FOBT and sigmoidoscopy/colonoscopy for colorectal cancer. In the analysis, women 40 years of age or older who never had a mammogram were contrasted with those who ever had a mammogram. Similarly, women aged 40 or older were included in the analysis for CBE. For cervical cancer screening, women age 18 or older were included in the analysis.

Data were analysed for men and women age 50 or older for colorectal cancer screening.

Area socioeconomic position

We used the percentage of the population living below the US federal poverty line from the 2000 census as measure of area socioeconomic position. The poverty rate seems to be a measure that is robust across various diseases and levels of geography; it has a link to possible policy implications, and is comparable over time.^{11 19}

Individual characteristics

Andersen's behavioural model of access to care was used to identify characteristics previously associated with self reported screening.²⁰ It is one of the most widely used and accepted models of access in the health services research literature. In this model, five sets of underlying characteristics contribute to the use of health related services: (1) predisposing characteristics, which reflect preferences, styles of healthcare use, and other non-health related factors that affect the demand for care; (2) enabling factors, which allow persons to satisfy a need for care; (3) need for healthcare as indicated by the presence of illness or symptoms; (4) personal health practices, which interact with the use of health services to influence health outcomes; and (5) external environment, which includes physical, political, and economic components. These characteristics guided the identification of variables for multilevel analysis. The external environment, operationalised by the area poverty rate is the primary focus of the conceptual model in the proposed study. We and others have previously used this model to describe various aspects of the provision of medical care, including primary care, medical check ups, rural behavioural health services, and breast cancer screening.^{21 22} These characteristics were used as independent individual level covariates and some also as part of cross level interaction terms. However, our main focus is not on the comprehensive assessment of this model, but to focus on aspects that have been heretofore less well explored.

The individual level characteristics were obtained from the 2002 BRFSS data. Household income was categorised into five groups: less than \$25 000; \$25 000–\$49 999; \$50 000–\$74 999; \$75 000 or more; and Unknown. Unfortunately, the BRFSS did not include the number of family members this income supported, and therefore we were unable to determine the percentage of the federal poverty level this income represented. Educational attainment was categorised as having less than a high school education, high school graduate/GED, or more than high school. Employment was categorised as employed or not employed (unemployed, retired, homemaker/student, or unable to work). Insurance coverage was categorised as having or not having health insurance at the time of the interview. Race/Hispanic ethnicity was categorised as white non-Hispanic, African American non-Hispanic, Other race non-Hispanic (Asian, Pacific Islander, American Indian, Alaska Native, other race), or Hispanic. Self perceived health, five age groups (18–39, 40–49, 50–59, 60–69, and 70+), sex (for colorectal cancer screening), and having trouble getting medical care in the last year regardless of the reason (yes compared with no) were also included. Persons who reported to have ever smoked at least 100 cigarettes and smoked at least one cigarette per day or smoked some days were considered to be smokers. They were contrasted with all other persons who were non-smokers.

Statistical analysis

The multilevel logistic models reported in this paper were all two level models in which persons (level 1) were nested

Table 1 Characteristics of persons age 18 or older residing in the 98 MMSAs by MMSA level poverty rate, USA, 2002

MMSA characteristics	ICC	MMSA level poverty rate	
		5.0–9.9	10.0+
Number of MMSAs		47	51
Number of persons		59336	59301
Median (min–max) number of person in the MMSAs		1098 (501–4024)	881 (505–4598)
Individual level characteristics			
Age (years)			
18–29	0.7	15.3	15.5
30–39	0.3	20.8	19.3
40–49	0.2	22.2	21.0
50–59	0.1	17.8	17.4
60–69	0.4	11.0	12.2
70+	1.9	13.0	14.4
Household income			
Less than \$25000	4.0	18.3	24.7
\$25000–\$49999	0.8	26.7	27.5
\$50000–\$74999	1.0	17.1	14.4
\$75000 or more	3.3	23.9	17.4
Unknown	2.4	13.9	16.1
Educational attainment			
Less than high school	6.8	7.0	10.7
High school graduate/GED	1.5	27.6	30.3
More than high school	2.0	65.4	59.0
Employment			
Employed	0.7	65.5	60.2
Unemployed	2.4	4.3	4.9
Retired	1.6	17.6	19.5
Homemaker/student	0.9	10.0	10.6
Unable to work	3.2	3.0	4.6
Race/Hispanic ethnicity			
White, non-Hispanic	20.1	80.8	73.1
African American non-Hispanic	24.8	7.2	11.1
Other race, non-Hispanic	10.2	7.5	7.8
Hispanic	29.5	4.6	8.0
% Female	0.0	58.9	60.4
% Having trouble getting medical care	2.7	4.8	6.4
% Uninsured	5.6	9.1	12.5
% Current smoker	0.9	20.2	22.5

MMSA, metropolitan or micropolitan statistical areas; ICC, intraclass correlation (expressed as percentage).

within MMSAs (level 2). We used restricted iterative generalised least squares²³ and second order penalised quasilielihood estimation in all models.²⁴ These methods are approximations to full maximum likelihood estimation that produce accurate estimates of the random part (level 1 and 2 variances) and fixed part (regression coefficients) of the models.²³ Thus, using this method allows us to ascertain the unique and combined contribution of individual and area level factors on screening behaviour.

For each screening procedure, we first computed the association between never having been screened and MMSA level poverty rate. Next, we added the individual level characteristics to the model to assess whether they explained differences in area prevalence of never having been screened. Next, we examined cross level interaction of poverty rate with individual characteristics. Because the interaction effects were small in magnitude and did not add

to the interpretation of the outcomes of interest, we did not include them in the remainder of the analysis. In all multilevel models, the random components were assessed at the individual and the MMSA level. We found no evidence of extra binomial variation for each of the screening tests using χ^2 tests in an empty model.

To determine the geographical variation in screening rates between MMSAs, we calculated the intraclass correlation (ICC), which is the percentage of the total variance between MMSAs, namely $ICC = [V_n]/[V_n + V_i] \times 100$, where V_n = MMSA variance and $V_i = \pi^2/3$.²⁵ A high ICC indicates large geographical differences between MMSAs.

Models were developed and fitted using the multilevel modeling software MLwiN, beta version 2.0 (Multilevel Models Project, Institute of Education, University of London, London, 2003). Parameters in the fixed part and the random part were tested with the Wald test.²⁶ All analyses

Table 2 Predicted MMSA prevalence (%) of never having a screening test by type among 98 MMSAs, USA 2002

	Minimum	Maximum	Median	Mean	Range
Mammography	5.7	14.9	9.2	9.5	9.2
Clinical breast examination	4.3	13.2	7.4	7.7	8.9
Pap smear	2.8	8.1	4.2	4.3	5.3
FOBT	37.8	67.3	52.1	51.6	29.5
Sigmoidoscopy/colonoscopy	33.0	66.0	49.1	49.2	33.0

FOBT, faecal occult blood test.

Table 3 Odds ratios (95% CI) for a 5% increase in MMSA level poverty rate for each type of screening test; crude and adjusted for individual level factors

Screening test	Crude	Adjusted*
Mammography	1.22 (1.04 to 1.43)	1.28 (1.03 to 1.37)
Clinical breast examination	1.47 (1.33 to 1.64)	1.28 (1.11 to 1.48)
Pap smear	1.33 (1.09 to 1.61)	1.12 (0.90 to 1.41)
FOBT	1.32 (1.22 to 1.41)	1.19 (1.12 to 1.27)
Colonoscopy/sigmoidoscopy	1.15 (1.08 to 1.25)	1.10 (1.01 to 1.19)

MMSA, metropolitan or micropolitan statistical areas; CI, confidence interval. *Adjusted for income, education, employment, insurance, race/Hispanic ethnicity, age, sex (for FOBT and colonoscopy/sigmoidoscopy), self perceived health, having trouble getting medical care, smoking status.

involved weighted estimation of the model parameters. Individual level weights were those provided by the CDC and were adjusted for probability of inclusion in the sample and representativeness of the sample by sex, age, and race/ethnicity.

RESULTS

Population characteristics

Table 1 shows individual level characteristics for MMSA level poverty rate categorised as either 5.0%–9.9% or 10.0%–18.3% based on the range of poverty rates. Persons who resided in MMSAs with poverty rates of at least 10% were more likely to have lower incomes, less education, to be African American or Hispanic, and to have trouble getting medical care relative to those residing in MMSAs with lower poverty rates. This table also shows the degree to which individual level factors were similar within MMSAs (intraclass correlation). We found considerable clustering of persons within MMSAs for each racial/ethnic category, and, to a lesser extent, for persons with household incomes of \$25 000 or less and for persons with less than a high school education.

Predicted screening prevalence

The average percentage of persons who reported that they never had a specific screening test across among the 98 MMSAs varied from a low of 7.7% for CBE to a high of 51.6% for FOBT (table 2). The mean and median were similar within each screening test. The range of the percentage of women who reported that never had a Pap smear was the lowest of any of the five screening tests. In contrast, the range of the percentage of persons who reported that they never had a FOBT or sigmoidoscopy/colonoscopy was larger than for any other screening tests.

What this paper adds

This paper is the first to: (1) describe the extent of the variation in five cancer screening behaviours among 98 US metropolitan areas; (2) determine if the variation in lack of screening can be explained by differences in the characteristics of the persons who resided in these areas; and (3) determine if living in a metropolitan area with a higher poverty rate increased the likelihood of never having been screened for cancer over and above individual characteristics. in the USA. The magnitude of the variation in cancer screening among communities was limited to no more than 5% of the total variance, suggesting that most of the variation in screening is within communities. Except for Pap smear use, persons who resided in communities with higher poverty rates were more likely to never having been screened for breast and for colorectal cancer over and above the individual level factors considered.

Compositional and contextual effects

The variation (ICC) between MMSAs varied by screening test: Pap smear: 4.9; CBE: 4.4; FOBT: 2.7; mammography: 2.5; and colonoscopy/sigmoidoscopy: 1.2 (all $p < 0.05$). The low values of the ICCs for each screening test suggest much greater heterogeneity within MMSAs than between MMSAs.

As table 3 shows, the crude odds ratios per 5% increase in MMSA level poverty rate were attenuated by the inclusion of the individual level factors, but remained associated with never having had a CBE (OR = 1.28) and FOBT (OR = 1.19) as shown in the adjusted odds ratio. There was an association between MMSA level poverty and Pap smear use in bivariate analyses (OR = 1.33), but the association was reduced and 95% confidence interval for the odds ratio included the null when including the individual level factors in the model (OR = 1.12). Adding the individual level factors to the model did not affect the crude odds ratios for a 5% increase in MMSA level poverty rate in never having had a mammogram and never having had a colonoscopy/sigmoidoscopy as shown in their adjusted odds ratios. For all five screening tests, significant MMSA level variance remained after including only the individual level factors, and after adding MMSA level poverty rate (all $p < 0.05$).

DISCUSSION

This study simultaneously estimated the variance in the lack of several cancer screening tests apportioned at the individual and MMSA level. The size of the variance among MMSAs was modest and varied by type of screening test, with ICCs ranging from 4.9% (never having had a Pap smear) to 1.2% (never having had a colonoscopy/sigmoidoscopy). This suggests much greater heterogeneity within MMSAs than between MMSAs. Future research could examine the magnitude of the variation within MMSAs at the county level or even smaller geographical areas such as census tracts as the intra-MMSA variation is large. Although there have been many studies using multilevel methods in the USA,²⁷ most have quantified the association between area level factors and individual level outcomes in terms of odds ratios and have neglected to examine the variance apportioned to individual and area levels as shown to be distinctly different and important.^{15 16} This study shows that contextual effects exist and are important even in the presence of low area level variance.

Increasing MMSA level poverty rate was associated with higher prevalence of never having been screened for all tests. After adjustment for the individual level factors, the association between poverty rate and screening using CBE, FOBT, and Pap smear was attenuated, but did not affect the results for mammogram, and colonoscopy/sigmoidoscopy. The compositional effect of the individual level factors for CBE and Pap smear may not be attributable to confounding, but such factors could actually be in the pathway between area level factors and health outcomes. Controlling for these factors in the analysis is considered to be overadjustment.^{28 29}

However, based on the similarities between the crude and adjusted odds ratios for the association between MMSA level poverty rate with mammogram, CBE, colonoscopy/sigmoidoscopy, and FOBT use, there is little evidence that the included individual level factors are mediators. Other individual level factors, not included in the models, may exert residual confounding or be mediators between MMSA level poverty and screening use. This lack of screening seen in our study in areas with higher poverty rates may result in lower rates of early stage cancer, as well as higher rates of advanced stage cancer and mortality.^{10–11}

In this study, we investigated the compositional effect of access to medical care and socioeconomic position as possible mediators of the association between area level poverty rates and cancer screening. This mechanism is not intended to replace other mechanisms but rather to complement and add to existing understanding of the factors that influence screening. This is by no means the only pathway by which persons who reside in socioeconomically deprived areas may be less likely to be screened for cancer. Other pathways include availability of the existing medical infrastructure (for example, physicians and mammography facilities), social capital and collective efficacy, and “compositional” confounding by psychosocial characteristics.^{30–33}

A separate issue is whether or not we can or should identify specific MMSAs to direct additional resources aimed at increasing screening. As the variation among MMSAs is much smaller than the intra-MMSA level variation, it is not efficient to target specific MMSAs and allocate screening resources locally to reduce the prevalence of never having been screened.¹⁶ Therefore, if MMSAs were selected based on high poverty rates, then a large low income population would be missed because they reside in MMSAs with low poverty rates.

The results of this study need to be considered in light of its limitations. Firstly, self reported screening use may overestimate actual cancer screening.³⁴ However, most discrepancies in self reported screening use have been attributable to inaccurate recall of the interval because the procedure, which was not an issue in this study. The overall accuracy of the BRFSS and similar surveys has been reported in previous studies.^{35–36} Secondly, generalisability of the findings is limited to persons with telephones. Telephone coverage (households with telephones) varies by state and also by sub-population. Telephone coverage averages 97.6% for US states as a whole in 2002, but non-coverage ranges from 1.1% to 6.6% across states. Although persons without telephones are more likely to be of lower income and therefore not included in the analysis, this fact is unlikely to have affected the findings because the variation among MMSAs is much smaller than the intra-MMSA level variation and a large low income population resided in MMSAs with low poverty rates.

Policy implications

Area level poverty rate was associated with never having been screened for breast and colorectal cancer, but not associated with screening for cervical cancer. As the variation among communities is much smaller than the intra-community level variation, it is not efficient to target specific communities and allocate screening resources locally to reduce the prevalence of never having been screened. While poverty rate was associated with screening independent of individual level factors, if communities were selected based on high poverty rates, then a large low income population would be missed because they reside in communities with low poverty rates.

Thirdly, one of the frequent criticisms of multilevel models using geographical areas at the second level is that in some cases the choice of the geographical areas is somewhat arbitrary and may not reflect communities. In our study, we used MMSAs, which have a high degree of social and economic integration as measured by commuting ties and, as such, may represent communities. Nevertheless, it is understood that for some MMSAs, substantial intra-MMSA variation may still exist as was evidenced by the modest ICCs.

Note that because our response variable is dichotomous, level 2 (MMSA level) variation is normally distributed, but level 1 (individual level) variation follows a logistic distribution, where the variance depends on the probability of screening.^{25–37} Our ICC estimates assume that the observed response variable reflects a threshold effect on an underlying continuous variable,³⁷ in this case, propensity to undergo cancer screening. Depending on how they are estimated, ICCs in multilevel logistic regression models may not accurately represent the partitioning of variance between level 1 and level 2.³⁷ In general, such measures of variance explained in logistic regression models tend to be low relative to those seen in normal response models.³⁸ Other approaches to quantifying the variation at level 2 are described by Goldstein and colleagues³⁷ and Larsen and Merlo.³⁹

Fourthly, selective residential mobility (for example, low income persons move to MMSAs with higher poverty rates where there is availability of cheap and affordable housing) may, in part, drive the compositional effects of the individual level factors. Although this may be true in some cases, it may be more likely that more affluent persons move from urban areas, leaving low income persons behind.⁴⁰ Regardless of the mechanism, some compositional effect of individual level factors was present in the study.

In conclusion, persons who resided in MMSAs with higher poverty rates were more likely never to have been screened for breast and for colorectal cancer over and above the individual level factors considered. The magnitude of the geographical variation in cancer screening between MMSAs was limited to no more than 5% of the total variance, suggesting that most of the variation in screening is within MMSAs. Future research should examine the pathways by which poverty rate exerts its influence on screening for various cancers.

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