Practice of Epidemiology

Comparing Individual- and Area-based Socioeconomic Measures for the Surveillance of Health Disparities: A Multilevel Analysis of Massachusetts Births, 1989–1991

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The absence of individual-level socioeconomic information in most US health surveillance data necessitates using area-based socioeconomic measures (ABSMs) to monitor health inequalities. Using the 1989–1991 birth weight data from Massachusetts, the authors compared estimates of health disparities detected with census tract- and block group-level ABSMs pertaining to poverty and education, as well as parental education, both independently and together. In separate models, adjusted for infant's sex, mother's age, and parents' race/ethnicity, worst-off categories of census tract ABSMs and parental education had a comparable birth weight deficit of ~70 g. Similar results were observed for low birth weight (<2,500 g), with worst-off categories of census tract ABSMs and parental education having an odds ratio of ~1.37 ($p < 0.001$). In mutually adjusted models for birth weight and low birth weight, census tract ABSMs still detected an effect estimate nearly 50% of that detected by parental education. Additionally, census tract ABSMs detected socioeconomic gradients in birth weight among births to mothers aged less than 25 years, an age group in which educational attainment is unlikely to be completed. These results suggest that aptly chosen ABSMs can be used to monitor socioeconomic inequalities in health. The risk, if any, in the absence of individual-level socioeconomic information is a conservative estimate of socioeconomic inequalities in health.

education; infant, low birth weight; multilevel model; poverty; socioeconomic factors; United States

Abbreviations: ABSM, area-based socioeconomic measure; CI, confidence interval.

The absence of socioeconomic information at the individual level in most health surveillance data in the United States imposes severe restriction for quantifying socioeconomic inequalities in health (1, 2). Even when such information is available, from a public health monitoring perspective, validity of individual-based socioeconomic measures lim-

its the wider application of such information (3, 4). For instance, it is well known that educational information on older, less-educated, deceased individuals tends to be "inflated" (5, 6). Individual-based educational levels also tend to be less meaningful for quantifying health disparities for younger persons (e.g., aged <25 years) who have not necessarily completed their educational attainment. Under such circumstances, area-based socioeconomic measures (ABSMs) (7) can be uniquely relevant for monitoring population-level socioeconomic health inequities (1, 8). It is well known that ABSMs miss a substantial proportion of between-individual/within-area variation in education and

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income (9, 10), but there is evidence that the area-based measures capture other aspects of socioeconomic position that often cannot be captured by individual-based measures of socioeconomic position (11, 12). The aim of this study is to compare the performance of census tract ABSM estimates with individual-based education estimates in predicting birth weight, an outcome that is well known for its relevance for a range of outcomes (13–21), in addition to being sensitive to measures of socioeconomic position (22).

MATERIALS AND METHODS

Data

The study consisted of all births ($n = 267,531$) occurring in Massachusetts for the time period, 1989–1991. Birth certificate data were provided by the Massachusetts Department of Public Health. Geocoding of the birth certificates to block groups and census tracts was done by a commercial firm chosen on the basis of accuracy of geocoding and completeness (23). We excluded births to mothers aged less than 15 years or more than 55 years. Additional exclusions were on observations with missing birth weight, multiple births, "outlier" birth weights (either <150 or $>6,000$ g), and block groups/census tracts with missing socioeconomic data, resulting in a final analytical sample of 226,927 births. US Census Bureau data on ABSMs were obtained from the *1990 Census Summary Tape File 3A* (*STF 3A*) (http://www.census.gov/mp/www/90CD/msrom6ae.html) for census tracts and block groups. The block group, a subdivision of the census tract, is the smallest geographic census unit for which census socioeconomic data are tabulated and, on average, contains 1,000 people (24). Census tracts, meanwhile, on average, contain 4,000 persons and are defined as "small, relatively permanent statistical subdivisions of a county" (24, p. A-11) by the US Census Bureau and are "designed to be relatively homogeneous with respect to population characteristics, economic status, and living conditions" (24, p. A-11). Use of the data was approved by the Massachusetts Department of Public Health and the Human Subjects Committee of the Harvard School of Public Health.

Outcome

We modeled birth weight as both a continuous response variable (measured in grams) and a binary outcome, low birth weight ($<2,500$ g) or not. Given our focus on evaluating the change in effect of ABSMs under different model specifications, modeling birth weight as a continuous outcome allows interpretation of the resultant differences in absolute terms (i.e., actual birth weight) and, as such, is not sensitive to transformations (e.g., log of the odds, probability, odds ratio, or relative risk). Given the clinical and policy relevance of low birth weight, we additionally conducted analysis with low birth weight as an outcome.

Predictors

Table 1 presents the individual-based and area-based predictors (or independent variables) considered for the statis-

tical models. At the individual level, we considered infant's sex, mother's age, mother's and father's race/ethnicity, and mother's and father's educational status. Missingness on parental race/ethnicity and education was modeled as a separate category given their potential social patterning (25, 26). At the block group and census tract levels, we considered three ABSM categories: 1) fraction of the population aged 25 or more years with less than a high school education; 2) fraction of the population aged 25 or more years with a college education or greater; and 3) fraction of the population living below the federal poverty line. Although the fraction of the population living in poverty has been shown to be consistent and useful for monitoring health disparities (27), the two area-based education measures reflect the area analogs of individual-level education. The a priori cutpoints for all three ABSMs were informed by prior research on estimating the burden of socioeconomic inequalities in health (8, 27–29).

Statistical analysis

Multilevel linear regression techniques (30, 31) were utilized to model the variation in birth weight with a four-level hierarchical structure of 226,927 singleton births (level 1) nested within 5,458 block groups (level 2), 1,295 census tracts (level 3), and 14 counties (level 4). Low birth weight, meanwhile, was modeled by a multilevel logistic regression approach with the above structure. Given the multilevel structure of the data and our interest in estimating the effects of area-level variables, a multilevel modeling approach was appropriate (32–34). The regression estimates from the linear models are maximum likelihood based, using the iterative generalized least-squares algorithm, while the estimates for the logistic models are based on penalized/predictive quasi-likelihood estimates with second-order Taylor series linearization procedures (30, 35).

Modeling strategy

We calibrated two types of models. We separately modeled birth weight and low birth weight as a function of either census tract or block group ABSM or parental education, adjusting for individual demographic variables (model A). This model allowed quantification of disparities in birth weight and low birth weight by census tract and block group ABSMs and by individual-based socioeconomic measure, each in the absence of the other. Model B considered census tract and block group ABSMs and parental education simultaneously, in addition to individual-level demographic variables, thus quantifying socioeconomic disparities that are uniquely attributable to ABSMs and parental education. All models considered each ABSM separately. Because prior studies suggest age-specific trends in prevalence of (low) birth weight (36, 37), we also repeated model B across three maternal age strata: 15–19, 20–24, and 25 or more years. Our motivation was that the use of ABSMs for quantifying socioeconomic inequalities in birth weight would be even more relevant in ages less than 25 years, where individual-level education is less informative.

RESULTS

The kernel density plot of the birth weight distribution by categories of census tract ABSM (figure 1) suggests a downward shift in the entire birth weight distribution associated with each of the categories of the three census tract ABSMs, with worst-off census tracts having lower mean birth weight. The crude birth weight deficits in the worst-off census tracts (compared with the best off) were 213 g for the fraction of the population living below the poverty level, 199 g for the fraction of the population with less than a high school education, and 130 g for the fraction of the population with a college-level education or greater. Census tracts that were worst off had a far greater proportion of low birth weight infants compared with the best-off census tracts. The crude birth weight deficit translated to an approximately twofold increase in low birth weight prevalence. In census tracts with more than 20 percent poverty, the low birth weight prevalence was 7.5 percent compared with 3.5 percent in the census tracts with less than 5 percent poverty. Similarly, the range (across extreme categories) in low birth weight prevalence in the other educational census tract ABSMs was 7.0–3.6 percent for the fraction of the population with less than a high school education and 6.0–3.7 percent for the fraction of the population with a college education or greater.

Adjusting for infants's sex, mother's age, and parental race/ethnicity, we observed an independent association between census tract ABSMs and birth weight (table 2). Infants in census tract ABSM categories associated with the population having the highest fraction of less than a high school education and poverty weighed ~70 g less than did those in the lowest fraction of these two census tract ABSMs. The census tract gradient in the fraction of the population with a college education was smaller, with a birth weight deficit of ~45 g in areas with the lowest fraction. A similar pattern was observed with block group ABSMs, with the best/worst birth weight differential being smaller compared with similar census tract ABSMs (table 2). Parental education was a strong predictor of birth weight (even after adjustment for parental race/ethnicity and mother's age) (table 2). Infants whose mothers or fathers had less than a high school education weighed ~80 g and ~60 g less compared with those whose mothers or fathers had a college education or greater. Of note, infants whose fathers did not report their education had the largest birth weight deficit of 93 g.

The model B columns in table 2 present the mutually adjusted effect estimates for each ABSM and parental education on birth weight. With adjustment for parental education, infants in census tract categories associated with the highest population fraction of less than a high school education and poverty continued to experience statistically significant birth weight deficits (27 and 38 g, respectively). The socioeconomic differentials in birth weight by census tract fraction population with a college education or greater were, however, substantially smaller. The birth weight differentials by block group ABSMs were also weak, compared with those observed at the census tract level. Parental education remained a strong predictor of birth weight in models that

mutually adjust for census tract and block group ABSM, with infants born to mothers and fathers with less than a high school education weighing 74 and 55 g less compared with those whose parents have a college education or greater.

Generally, in models that mutually adjusted for ABSMs and parental education (compared with models that did not mutually adjust for each other, i.e., model A), the attenuation in effect estimates was substantially greater for ABSMs than it was for parental education, with larger attenuation observed for block group compared with census tract ABSMs. Importantly, even after adjustment for parental education, the ABSM effects remained significant, and the birth weight deficit among infants born to mothers in the poorest census tracts (compared with the least poorest) was ~37 g, a quantity slightly over half the deficit for infants born to mothers with the least compared with most education (~70 g).

Area- and individual-level socioeconomic patterning in birth weight remained in models with low birth weight as the outcome (table 3). Because the socioeconomic birth weight disparities detected by the population fraction with a college education were not marked, the results in table 3 are presented for the ABSMs percent poverty and percent population with less than a high school education. In models that did not mutually adjust for area- and individual-level socioeconomic measures, the odds associated with low birth weight for mothers and fathers with less than a high school education were 1.37 (95 percent confidence interval (CI): 1.26, 1.49) and 1.41 (95 percent CI: 1.29, 1.54), respectively, compared with those with a college education or greater. Compared with that in census tracts having the least population fraction with less than a high school education, the odds ratio for low birth weight for census tracts with the greatest population fraction with less than a high school education was 1.43 (95 percent CI: 1.34, 1.54). Similarly, compared with that in census tracts having the least poverty, the low birth weight prevalence was substantially greater in census tracts having the most poverty (odds ratio = 1.41, 95 percent CI: 1.31, 1.51). In models that mutually adjust for parental education and block group ABSM, the low birth weight differential-associated census tract ABSM was attenuated but remained substantial. The odds ratios for low birth weight were 1.14 (95 percent CI: 1.01, 1.27) for the ABSM associated with percent less than a high school education and 1.17 (95 percent CI: 1.06, 1.29) for the ABSM associated with percent poor.

We additionally calibrated models for the continuous measure of birth weight stratified by three age categories: teenaged mothers aged 15–19 years, young adults aged 20–24 years, and adults aged 25 or more years. We found that, in the age stratum 15–19 years, the ABSM-based socioeconomic disparities in birth weight were imprecisely estimated, while infants born to mothers or fathers with less than a high school education weighed 24 or 36 g less than did those born to parents with a high school education, respectively. Among births to mothers aged 20–24 years, the ABSM associated with census tract poverty detected a birth weight differential (a deficit of 42 g for infants in the poorest census tracts) similar to those observed using mother's and father's educational levels (birth weight deficits of 57 g and

TABLE 1.   Frequency of variables, along with mean birth weight, standard deviation, and low birth weight births, Massachusetts, 1989–1991

Predictor variables	Frequency		Mean birth weight (g)	Standard deviation (g)	Low birth weight births (<2,500 g)	
	No.	%			No.	%
Infant's sex						
Male	116,355	51.3	3,480	582	5,100	4.4
Female	110,572	48.7	3,350	551	5,689	5.1
Mother's age (years)						
15–19	15,654	6.9	3,250	578	1,148	7.3
20–24	43,655	19.2	3,340	561	2,390	5.5
25–29	69,272	30.5	3,430	559	2,943	4.2
30–34	65,234	28.7	3,460	564	2,652	4.1
≥35	33,112	14.6	3,460	590	1,656	5.0
Mother's race/ethnicity						
White, non-Hispanic	174,563	76.9	3,460	556	6,885	3.9
Black, non-Hispanic	18,171	8.0	3,190	640	1,821	10.0
Asian, Pacific Islander, non-Hispanic	5,899	2.6	3,190	495	374	6.3
American Indian, non-Hispanic	368	0.2	3,310	604	28	7.6
Other, non-Hispanic	2,105	1.5	3,310	566	136	6.5
Hispanic	24,934	11.0	3,300	559	1,488	6.0
Missing	887	0.4	3,360	685	57	6.4
Father's race/ethnicity						
White, non-Hispanic	160,391	70.7	3,480	547	5,702	3.6
Black, non-Hispanic	11,280	5.0	3,290	615	846	7.5
Asian, Pacific Islander, non-Hispanic	4,201	1.9	3,210	483	248	5.9
American Indian, non-Hispanic	328	0.1	3,360	649	24	7.3
Other, non-Hispanic	1,719	0.8	3,330	568	108	6.3
Hispanic	19,359	8.5	3,320	539	984	5.1
Missing	29,649	13.1	3,210	631	2,877	9.7
Mother's education						
Less than high school	39,383	17.3	3,270	577	2,863	7.3
High school	71,904	31.7	3,390	577	3,723	5.2
Some college	53,036	23.4	3,460	562	2,087	3.9
College or greater	61,426	27.1	3,500	540	2,035	3.3
Missing	1,178	0.5	3,320	675	81	6.9
Father's education						
Less than high school	25,624	11.3	3,330	558	1,405	5.5
High school	67,250	29.6	3,420	559	2,941	4.4
Some college	36,796	16.2	3,470	556	1,398	3.8
College or greater	66,457	29.3	3,500	538	2,105	3.2
Missing	30,800	13.6	3,210	627	2,940	9.5

Table continues

45 g for mother's and father's having less than a high school education, respectively). In the age stratum of 25 or more years, the results are approximately similar to those reported for age-adjusted models, except that the socioeconomic inequalities for both parental education and ABSMs were systematically smaller.

DISCUSSION

Our analysis has three key findings. First, the census tract ABSMs related to the categories of the population fraction below poverty and the population fraction with less than a high school education are equally predictive of birth

TABLE 1. Continued

Predictor variables	Frequency		Mean birth weight (g)	Standard deviation (g)	Low birth weight births (<2,500 g)	
	No.	%			No.	%
Census tract adult population fraction aged ≥25 years with less than a high school education (%)						
0.0–14.9	475	36.7	3,490	80	2,653	3.6
15.0–24.9	402	31.0	3,440	77.5	3,077	4.3
25.0–39.9	267	20.6	3,360	98.9	3,160	5.8
40.0–100	151	11.7	3,310	137	1,899	6.9
Block group adult population fraction aged ≥25 years with less than a high school education (%)						
0.0–14.9	2,279	41.8	3,480	154	3,034	3.6
15.0–24.9	1,450	26.6	3,450	133	2,570	4.3
25.0–39.9	1,109	20.3	3,380	151	2,925	5.7
40.0–100	620	11.4	3,310	148	2,260	6.9
Census tract adult population fraction aged ≥25 years with college education or greater (%)						
0.0–14.9	383	29.6	3,360	121	4,579	6.1
15.0–24.9	357	27.6	3,430	78.7	2,956	4.5
25.0–39.9	305	23.6	3,470	86.8	1,993	3.9
40.0–100	250	19.3	3,470	105	1,261	3.7
Block group adult population fraction aged ≥25 years with college education or greater (%)						
0.0–14.9	1,691	31.0	3,370	162	4,818	6.0
15.0–24.9	1,371	25.1	3,440	137	2,668	4.5
25.0–39.9	1,286	23.6	3,470	142	1,969	3.9
40.0–100	1,110	20.3	3,480	162	1,334	3.6
Census tract population fraction below poverty line (%)						
0.0–4.9	486	37.5	3,490	64.7	2,914	3.5
5.0–9.9	384	29.7	3,440	77.2	2,737	4.3
10.0–19.9	225	17.4	3,390	117	2,180	5.4
20.0–100	200	15.4	3,280	99.0	2,958	7.5
Block group population fraction below poverty line (%)						
0.0–4.9	2,518	46.1	3,480	153	3,446	3.7
5.0–9.9	1,262	23.1	3,440	131	2,180	4.2
10.0–19.9	953	17.5	3,400	152	2,180	5.3
20.0–100	725	13.3	3,300	145	2,983	7.4

weight, after adjustment for demographic factors, as are the mother's and father's educational levels in models. The birth weight deficit between the census tracts with the most and least poverty, without adjustment for parental education, is ~70 g, which is about the deficit (78 g) for mothers with less than a high school education (compared with mothers with a college education), without adjustment for ABSM. In the absence of individual-level data on parental education, the census tract ABSM also detected a similar differential in low

birth weight. The prevalence of low birth weight was 41 percent higher in census tracts with the most poverty compared with census tracts having the least poverty, while mothers with less than a high school education were 37 percent more likely to have low birth weight babies compared with those with a college education. Second, in models that mutually adjust for ABSMs and parental education, the attenuation in effect sizes was greater for the census tract ABSM compared with parental education. Importantly,
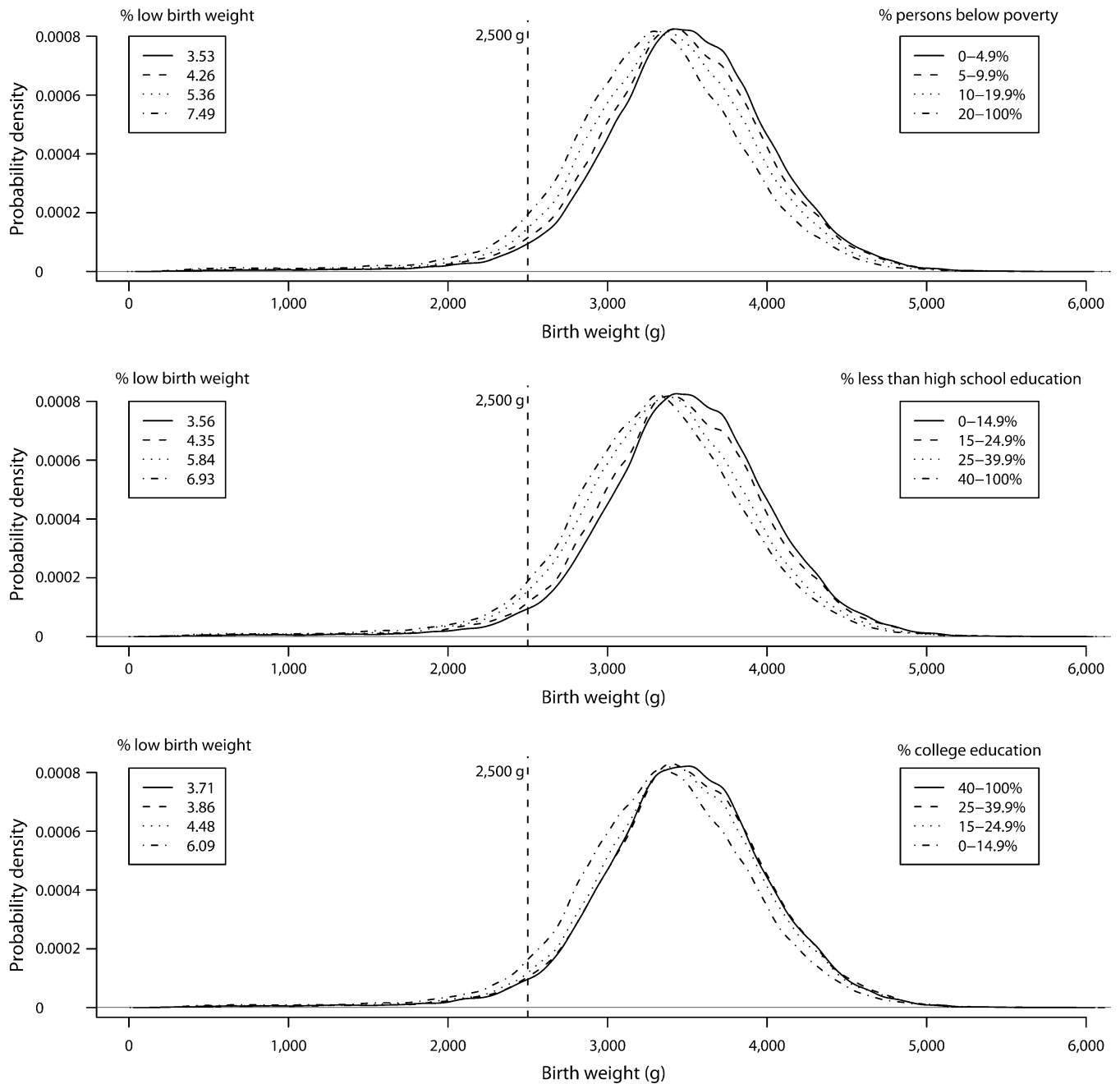
FIGURE 1. Birth weight distribution for categories of census tract population fractions below the poverty line (top), with less than a high school education (middle), and with a college education or greater (bottom), Massachusetts, 1989–1991.

however, the census tract ABSM still detected an effect estimate equivalent to almost 50 percent of that detected by the mother's education. Third, in the age group 20–24 years, census tract poverty was able to detect more than three fourths of the effects detected by the mother's education.

Do the findings suggest that ABSMs meaningfully estimate the socioeconomic disparities in birth weight? We believe that they do. In the absence of individual-based socioeconomic information, census tract ABSM-based socioeconomic inequalities in birth weight are likely to approximate or provide conservative estimates of the socioeconomic inequalities detected using parental measures of educational status. The discordance between census tract ABSM and mother's education is even smaller when quantifying socioeconomic inequalities in birth weight among young mothers aged less than 25 years. Given that in

younger age groups educational attainment is typically not completed (and other socioeconomic position variables such as occupation and income are even less applicable), individual-based measures are likely to be less informative of the mother's socioeconomic position in this age group.

The availability of educational status and residential address of the parents in birth weight data provided a unique opportunity to evaluate the relative importance of the individual-level and area-level measures within a multilevel framework (33, 38, 39). The evidence presented in this study supporting an independent association between census tract ABSM and birth weight, over and above the effect of individual risk factors, makes our finding additionally relevant from a substantive and etiologic perspective (37, 40–50). Differences in birth weight or variations in low birth weight prevalence between census tracts (conceptualized as one possible realization of people's residential setting) often tend to be attributed to the differences among the characteristics of the infants and their parents who live in these census tracts, thereby invoking "compositional" explanations for area variations in (low) birth weight. It may be noted, however, that compositional explanations do not necessarily suggest individual explanations as, for the latter to be invoked, individual-level socioeconomic exposures would need to be truly "randomly" distributed across areas, which is rarely the case (51). Census tract differences in (low) birth weight, meanwhile, may also arise for reasons less directly associated with the individual characteristics of the infants and their parents who live in them. In the context of birth weight, a differential distribution of pregnancy and maternal health-related services, as well as socioenvironmental stressors, could be a potential contributor to producing area variations in birth weight. The independent effect of ABSMs on birth weight, even after adjustment for individual-level education, suggests that ABSMs and the individual-level socioeconomic measure are not interchangeable. Consequently, interpreting ABSMs as a shared collective or contextual dimension that *all* individuals within a context share is more appropriate and important in its own right (32, 52). This interpretation holds regardless of whether the motivation for their use is restricted to situations where no individual-level socioeconomic measures are available.

Additional considerations that have implications for interpreting our study's primary and secondary findings are now discussed. The first relates to the choice of ABSM, given that the two measures of socioeconomic deprivation (population fraction living below poverty and population fraction with less than a high school education) more closely approximated the effect estimate obtained with mother's education than did the ABSM associated with the population fraction with a college education or greater. Measures such as the population fraction with a college education or greater tend to capture the *presence of* protective mechanisms, based on access to social and institutional resources, that concentrated "affluence" may generate (53–55). As such, these measures are distinct from measures of disadvantage or deprivation (e.g., population fraction living below poverty) that capture mainly the *absence of* critical resources necessary for individual well-being. Our results, however, suggest that areas characterized in terms of deprivation seem to yield more consistent patterns with individual-level socioeconomic position, as opposed to areas characterized in terms of affluence.

The second issue concerns the geographic level at which the ABSMs are measured. Census tract ABSMs were considerably stronger predictors of birth weight than were block group ABSMs. This finding is in accord with previous studies that have considered multiple levels of geographies but in a separate rather than simultaneous manner (8, 27–29, 56). Moreover, the size of the census tract-based socioeconomic differential was similar to that of individual socioeconomic position from models that do not mutually adjust for each other. To our knowledge, this is the first time that ABSMs measured at multiple levels of geographies have been considered in a simultaneous multilevel manner, thus allowing an interpretation of the relative importance of different levels. Although novel approaches to delineating neighborhoods are likely to yield important insights regarding the etiologic importance of people's residential context (57), the census tract as a level and census-based ABSMs have been shown to be reasonable approximations for delineating neighborhoods (58). The relevance of census tracts (including comparison with block groups) gains further prominence given the routine use of census tracts by federal, state, and local governments, including public health departments, to delineate and characterize jurisdictions, determine eligibility for diverse programs, and allocate resources (59–61). The overall importance of the census tract, compared with the block group, level for birth weight is likely to be due to the importance of pregnancy and maternal health-related services and their policy relevance for identifying low income areas or medically underserved areas, both of which tend to operate in relatively larger than smaller spaces.

We acknowledge the implications of omitted variables (both observable and unobservable) for etiologic research on socioeconomic determinants of health. Including more individual- and area-level socioeconomic measures, in general, is obviously desirable to tease out the relative impacts of individual and neighborhood exposures on heath (22, 33). For the purpose of monitoring population distributions of health, however, it is inappropriate to adjust for variables that might be in the causal pathway (e.g., for birth weight, smoking); the latter is germane to etiologic research, but not for quantifying the actual magnitude of social disparities in health. Indeed, for the purposes of our study, the critical test is between two models that separately ascertain birth weight disparities by individual- and area-based socioeconomic measures. Accordingly, our results suggest that, from a standpoint of quantifying socioeconomic inequalities in health for public health monitoring, area-based inequality assessments are likely to generate effect estimates analogous to those yielded by individual-level measures or else be conservative. Indeed, area-based assessment may well be the only means to understand the extent and nature of birth weight inequities at younger ages, as the available individual-level socioeconomic data are unlikely to be meaningful (e.g., educational level for teens and young adults aged less than 25 years). At the same time, we do not claim that the reported area-based socioeconomic disparities in birth

TABLE 2. Fixed-part results showing the relation among birth weight (in grams), parental education, and three area-based socioeconomic measures, Massachusetts, 1989–1991*

Predictor variables	Model A						Model B					
	Area-based socioeconomic measure				Parental education		Adult population fraction aged ≥25 years				Population fraction living below the federal poverty line	
	Census tract		Block group				Less than a high school education		College education or greater			
	β	95% confidence interval	β	95% confidence interval	β	95% confidence interval	β	95% confidence interval	β	95% confidence interval	β	95% confidence interval
Census tract adult population fraction aged ≥25 years with less than a high school education (%)												
0.0–14.9	Referent	Referent					Referent	Referent				
15.0–24.9	−17.8	−24.6, −11.1					−5.3	−13.2, 2.5				
25.0–39.9	−50.2	−58.2, −42.2					−20.2	−30.8, −9.5				
40.0–100	−72.0	−82.5, −61.6					−27.3	−42.8, −11.9				
Block group adult population fraction aged ≥25 years with less than a high school education (%)												
0.0–14.9			Referent	Referent			Referent	Referent				
15.0–24.9			−12.5	−19.0, −6.0			1.5	−6.0, 9.0				
25.0–39.9			−42.6	−50.0, −35.3			−11.5	−21.2, −1.7				
40.0–100			−62.7	−72.2, −53.4			−13.9	−27.8, −0.1				
Census tract adult population fraction aged ≥25 years with college education or greater (%)												
40.0–100	Referent	Referent							Referent	Referent		
25.0–39.9	5.9	−2.9, 14.7							14.7	3.3, 26.0		
15.0–24.9	−13.7	−22.3, −5.1							6.8	−6.1, 19.7		
0.0–14.9	−44.4	−53.5, −35.3							−5.4	−19.8, 9.0		
Block group adult population fraction aged ≥25 years with college education or greater (%)												
40.0–100			Referent	Referent					Referent	Referent		
25.0–39.9			−1.0	−9.3, 7.2					1.6	−9.3, 12.5		
15.0–24.9			−15.8	−24.1, −7.5					−2.1	−14.4, 10.2		
0.0–14.9			−43.9	−52.3, −35.4					−12.5	−26.1, 1.0		

Census tract population fraction below poverty line (%)												
0.0–4.9	Referent	Referent									Referent	Referent
5.0–9.9	−20.9	−27.6, −14.3									−9.8	−16.9, −2.6
10.0–19.9	−47.5	−55.7, −39.3									−24.5	−34.4, −14.6
20.0–100	−69.6	−79.1, −60.1									−37.6	−50.6, −24.6
Block group population fraction below poverty line (%)												
0.0–4.9			Referent	Referent							Referent	Referent
5.0–9.9			−14.9	−21.4, −8.4							−4.6	−11.5, 2.3
10.0–19.9			−35.2	−42.6, −27.7							−8.5	−17.4, 0.4
20.0–100			−54.8	−63.4, −46.1							−10.0	−21.8, 1.9
Mother's education												
Less than high school					−78.5	−88.2, −68.7	−73.3	−83.1, −63.4	−75.1	−85.0, −65.3	−73.8	−83.6, −64.0
High school					−40.8	−48.4, −33.2	−37.9	−45.5, −30.3	−39.1	−46.7, −31.5	−38.8	−46.4, −31.2
Some college					−2.2	−9.4, 4.9	−0.7	−7.9, 6.5	−1.6	−8.8, 5.6	−1.6	−8.7, 5.6
College education or greater					Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Missing					−8.3	−46.2, 29.5	−6.3	−44.1, 31.6	−7.1	−44.9, 30.8	−6.9	−44.8, 30.9
Father's education												
Less than high school					−60.6	−70.7, −50.4	−54.8	−65.1, −44.5	−57.0	−67.2, −46.7	−55.4	−65.6, −45.1
High school					−36.1	−43.4, −28.7	−32.8	−40.2, −25.4	−33.9	−41.4, −26.5	−33.6	−40.9, −26.2
Some college					−11.5	−19.2, −3.9	−9.6	−17.3, −1.9	−10.5	−18.2, −2.8	−10.3	−17.9, −2.6
College education or greater					Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Missing					−93	−118.5, −67.5	−88.3	−113.8, −62.8	−90.4	−115.9, −64.9	−88.5	−113.9, −63.0

* Results adjusted for infant's sex, mother's age, parents' race/ethnicity, and random effects associated with counties, census tracts, and block groups.

TABLE 3.   Odds ratios and 95% confidence intervals associated with parental education and two area-based socioeconomic measures for being low birth weight (<2,500 g), Massachusetts, 1989–1991*

Predictor variables	Model A						Model B			
	Area-based socioeconomic measure				Parental education		Adult population fraction aged ≥25 years with less than a high school education		Population fraction living below the federal poverty line	
	Census tract		Block group							
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
Census tract adult population fraction aged ≥25 years with less than a high school education (%)										
0.0–14.9	Referent	Referent					Referent	Referent		
15.0–24.9	1.14	1.08, 1.21					1.04	0.98, 1.12		
25.0–39.9	1.28	1.21, 1.36					1.08	0.99, 1.18		
40.0–100	1.43	1.34, 1.54					1.14	1.01, 1.27		
Block group adult population fraction aged ≥25 years with less than a high school education (%)										
0.0–14.9			Referent	Referent			Referent	Referent		
15.0–24.9			1.11	1.05, 1.18			1.02	0.95, 1.09		
25.0–39.9			1.26	1.19, 1.33			1.07	0.99, 1.16		
40.0–100			1.39	1.30, 1.49			1.11	0.99, 1.23		
Census tract population fraction below poverty line (%)										
0.0–4.9	Referent	Referent							Referent	Referent
5.0–9.9	1.14	1.08, 1.20							1.07	1.01, 1.14
10.0–19.9	1.25	1.17, 1.33							1.10	1.01, 1.19
20.0–100	1.41	1.31, 1.51							1.17	1.06, 1.29
Block group population fraction below poverty line (%)										
0.0–4.9			Referent	Referent					Referent	Referent
5.0–9.9			1.08	1.02, 1.14					1.01	0.95, 1.07
10.0–19.9			1.19	1.12, 1.26					1.04	0.97, 1.12
20.0–100			1.34	1.26, 1.43					1.10	1.00, 1.21
Mother's education										
Less than high school					1.37	1.26, 1.49	1.32	1.21, 1.43	1.33	1.22, 1.44
High school					1.21	1.13, 1.30	1.19	1.11, 1.27	1.20	1.12, 1.28
Some college					1.02	0.96, 1.10	1.01	0.94, 1.09	1.02	0.95, 1.09
College education or greater					Referent	Referent	Referent	Referent	Referent	Referent
Missing					1.08	0.82, 1.42	1.06	0.81, 1.40	1.07	0.81, 1.42
Father's education										
Less than high school					1.41	1.29, 1.54	1.35	1.23, 1.47	1.36	1.24, 1.49
High school					1.29	1.20, 1.38	1.26	1.17, 1.35	1.26	1.18, 1.36
Some college					1.16	1.08, 1.25	1.14	1.06, 1.23	1.15	1.07, 1.24
College education or greater					Referent	Referent	Referent	Referent	Referent	Referent
Missing					1.48	1.22, 1.81	1.44	1.18, 1.75	1.44	1.18, 1.75

* Results adjusted for infant's sex, mother's age, and parents' race/ethnicity in the fixed part and random effects associated with counties, census tracts, and block groups.

weight are entirely due to those specific socioeconomic dimensions. Finally, because our analyses were based on data observed in 1990, the extent to which our results apply to more contemporaneous circumstances is an important empirical question. If the trends in birth weight and area-based socioeconomic measures have changed in the same direction and by approximately similar magnitude, the time period of the study itself is likely to be less important.

From both policy and etiologic perspectives, it is necessary to have an estimate of the magnitude and patterning of the health problem, including whether the problem is getting better or worse over time, which then requires inquiries for systematic explanations. The primary objective of this study was to demonstrate the relevance of ABSMs in obtaining an estimate of the differential burden of (ill) health in populations, as reflected through inequalities in birth weight. Area- and individual-based socioeconomic measures, meanwhile, do not have the same meaning and, therefore, are not interchangeable. However, contrary to an earlier assessment questioning the validity of ABSMs (9, 10), our study demonstrates, at least in the case of disparities in (low) birth weight, that aptly chosen ABSMs provide estimates of health inequalities that are comparable with those based on individual-based socioeconomic measures. The risk, if any, in the absence of individual-based socioeconomic information is a conservative estimate of socioeconomic inequalities in health.

ACKNOWLEDGMENTS

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