ABSTRACT

The main objectives of this study were to determine the geographic distribution of low birthweight rates in London, Ontario and to identify small areas within the city that have low birthweight rates not adequately explained by the areas' socioeconomic characteristics. The following socioeconomic variables were used in a weighted, ecological, multiple regression analysis: % unwed mothers, % teen mothers, % low income, % low education, % unemployment and % immigrants. The overall variation in low birthweight rates was statistically significant and largely, but not entirely, explained by the socioeconomic characteristics of the areas. Two out of 31 census tract clusters were identified as having low birthweight rates which were higher than would be expected based on their socioeconomic profile. This methodologic approach may interest health planners as it draws attention to local factors other than socioeconomic ones which may be important when developing local strategies for low birthweight prevention.

ABRÉGÉ

Les objectifs de notre étude étaient d'évaluer la répartition géographique des taux des nouveau-nés de faible poids à London, Ontario, et d'identifier de petits secteurs géographiques de la ville qui présentent des taux de nouveau-nés de faible poids que les caractéristiques socio-économiques ne suffisent pas à expliquer. Les variables socio-économiques suivantes ont été utilisées dans une analyse par régression multiple écologique et pondérée : % des mères célibataires, % des mères adolescentes, % lié au faible revenu; % lié au faible niveau de scolarité, % lié au chômage et % d'immigrants. Cette tendance générale était statistiquement significative et s'expliquait dans une large mesure, mais pas totalement, par les caractéristiques socio-économiques des secteurs géographiques. Sur les 31 groupages de secteurs de recensement, deux ont été identifiés comme ayant des taux de nouveau-nés de faible poids plus élevés que ce que l'on pourrait s'attendre de par leurs caractéristiques socio-économiques. Cette information pourrait servir à nos planificateurs en santé publique pour mettre au point des facteurs locaux, autre que les facteurs socio-économiques, qui pourraient être importants dans le développement des stratégies locales de prévention des nouveau-nés de faible poids.

Small Area Variation in Low Birthweight: Looking Beyond Socioeconomic Predictors

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Low birthweight is considered the single most important predictor of infant mortality, especially of deaths within the first month of life.¹⁻³ It is also a significant determinant of infant and childhood morbidity, particularly of neurodevelopmental impairments such as mental retardation and learning disabilities.^{4,5} Pregnant mothers' stature, health status and health-related behaviours, which are associated with socioeconomic factors, largely determine the birthweight of the newborn.² Further, socioeconomic factors have been shown to play a major role in explaining inter-area variations in low birthweight rates.⁶⁻⁸ In short, the low birthweight rate is a good indicator of the maternal and infant health of a population and can be largely explained by an area's socioeconomic characteristics.

The objectives of our study were threefold: to determine the geographic distribution of low birthweight rates in London, Ontario; to determine how well ecological-level socioeconomic factors predict low birthweight rates of areas in London; and subsequently, to identify small areas within the city that have low birthweight rates not adequately explained by the areas' socioeconomic characteristics. The methodologic approach presented here may be of inter-

est to health planners as it draws attention to local factors other than socioeconomic ones which may be important when developing local strategies for low birthweight prevention. For example, areas can be identified where factors other than socioeconomic ones have adversely affected the low birthweight rates (i.e., low birthweight rates were higher than would be expected based on their socioeconomic profile). Conversely, areas can be identified where non-socioeconomic factors have had a positive effect on low birthweight rates (i.e., low birthweight rates were lower than expected based on their socioeconomic profile).

METHODS

Design and data management

Our study was based on an ecological design in which the units of analysis were 31 census tract clusters (CTCs) within the City of London, Ontario (Figure 1). CTCs were formed based on the following three criteria: 1) census tracts within a cluster were contiguous; 2) census tracts within a cluster were homogeneous with respect to socioeconomic status (i.e., the smallest possible coefficient of variation for the percentage of people who are from low-income families); 3) the number of low birthweight infants per CTC were sufficient to produce stable rates (i.e., > 15).

For each CTC, we calculated the low birthweight rate and rates for the following socioeconomic factors: low income, low education, unemployment, immigrants, unwed mothers and teen mothers. These factors were considered important ecologic predictors of low birthweight rates⁶⁻⁹ and were readily accessible through routinely collected government data.

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Data on low income, low education, unemployment and immigrants were from the 20 percent sample survey of the 1986 Canada Census. The low-income rate is the percentage of persons in private households living in low-income family units. Low family incomes include those below the Statistics Canada cut-off for low income while accounting for family size and urbanization of the area of residence.¹⁰ The low education rate is the percentage of non-institutionalized persons 15 years and older with less than grade 9 education. The unemployment rate is the percentage of the total labour force that was unemployed during the week prior to enumeration. Lastly, the immigrant rate is the percentage of non-institutionalized persons not born in Canada. Census data are readily available at the census tract level.

Data on low birthweight, unwed mothers and teen mothers were from the live birth and stillbirth computerized records of the Ontario office of the Registrar General of Canada, Vital Statistics Division. We used five-year averages for 1984 to 1988 to provide sufficient numbers of events to ensure stable rates. Low birthweight rate is defined as the percentage of total births (live births plus stillbirths) of infants weighing less than 2500 grams at birth. The unwed mothers rate is the percentage of total births of infants whose mothers were unwed at the time of delivery. The teen mothers rate is the percentage of total births of infants whose mothers were less than 20 years of age at the time of delivery.

To aggregate birth data to the census tract level, a special request was made to Statistics Canada to include on each record in the dataset the postal code corresponding to the mother's usual place of residence. Statistics Canada's postal code conversion file (PCCF)¹¹ was used to identify the census tract to which each record belonged. Of the 20,060 birth records, 102 (0.5%) were excluded from the analysis due to missing values and obvious data entry errors on the postal code field.

Clusters of census tracts were created when census tracts had insufficient numbers of low birthweights to produce stable rates. Twenty of the 31 CTCs comprised two or more census tracts. Two census

TABLE I
Characteristics of Census Tract Clusters (CTCs) Used for Analyses of Low Birthweight Rates in the City of London, Ontario, 1984 to 1988

CTC	Number of Census Tracts	Prevalence (%) of Low Income CV*	Range	Number of Births	Low Birthweight†		Standard Error
					Number	Percent	
1	3	22.9	5-10	726	34	4.7	0.78
2	1	0	17	381	25	6.6	1.27
3	3	18.4	16-24	1,001	51	5.1	0.69
4	3	12.1	10-12	1,103	61	5.5	0.69
5	1	0	15	474	27	5.7	1.06
6	1	0	16	514	31	6.0	1.05
7	2	18.7	11-16	630	32	5.1	0.87
8	5	19.4	5-8	1,438	66	4.6	0.55
9	3	16.9	3-5	598	31	5.2	0.91
10	2	5.4	13-15	490	23	4.7	0.95
11	3	10.4	27-36	657	45	6.9	0.99
12	3	29.0	11-21	569	29	5.1	0.92
13	1	0	23	541	37	6.8	1.08
14	1	0	39	343	27	7.9	1.45
15	3	13.5	34-47	558	41	7.4	1.10
16	1	0	29	319	28	8.8	1.58
17	1	0	18	412	26	6.3	1.20
18	3	17.7	11-16	743	45	6.1	0.88
19	1	0	20	367	26	7.1	1.34
20	1	0	34	297	33	11.1	1.82
21	2	3.7	26-28	688	50	7.3	0.99
22	1	0	21	524	32	6.1	1.05
23	3	10.8	14-21	678	27	4.0	0.75
24	3	7.8	20-24	824	48	5.8	0.82
25	1	0	14	575	43	7.5	1.10
26	2	0.7	15	594	39	6.6	1.02
27	3	12.0	27-37	933	64	6.9	0.83
28	3	11.9	9-12	578	27	4.7	0.88
29	4	40.0	3-12	910	38	4.2	0.66
30	3	39.0	4-10	716	32	4.5	0.77
31	2	4.2	20-22	773	44	5.7	0.83
city	31	-	-	19,954	1,162	5.8	0.17

* Percent coefficient of variation = (standard deviation/mean) x 100

† Low birthweights are based on total births (live births and stillbirths)

TABLE II
Crude Associations Between Low Birthweight Rate and Predictor Variables in the City of London, Ontario, 1984 to 1988

% Low Birthweight Versus:	Squared Coefficient of Correlation	Standardized Regression Coefficient*	p value
% unwed mothers	0.620	7.00	0.0001
% teen mothers	0.582	6.35	0.0001
% low income	0.540	5.85	0.0001
% unemployed	0.514	5.54	0.0001
% low education	0.423	4.60	0.0001
% immigrants	0.0004	0.11	0.9134

* Regression coefficient divided by its standard error.

tracts were excluded from the study: one had no births and no data on the census variables, the other had no data on low income. Characteristics of the CTCs are presented in Table I.

After the births and census datasets were merged by census tract and coded for CTC, rates were calculated for each variable by CTC. Data management and statistical analyses were done using PC SAS version 6.03.¹²

ANALYSIS

The geographic distribution of low birthweight by CTC was mapped using Atlas Pro.¹³ The extent to which the overall variation in rates was due to chance alone was tested using the chi-squared test of homogeneity.¹⁴ The crude association between low birthweight rate and each of the explanatory factors was examined using simple linear regression statistics. To test for collinearity, a

TABLE III
Studentized Residuals and Observed and Expected Numbers of Low Birthweight Infants Based on a Weighted Regression Model for Census Tract Clusters in the City of London, Ontario, 1984 to 1988

Census Tract Cluster	Studentized Residual	O*	E†
25	2.42	43	31
20	2.02	33	23
22	1.84	32	25
16	1.04	28	23
6	1.04	31	27
26	1.01	39	34
2	0.86	25	22
4	0.83	61	57
9	0.66	31	29
5	0.58	27	25
18	0.37	45	43
19	0.33	26	25
11	0.31	45	43
14	0.23	27	26
17	0.20	26	25
31	0.08	44	44
13	-0.10	37	38
3	-0.25	51	52
30	-0.36	32	33
7	-0.38	32	34
12	-0.60	29	31
27	-0.63	64	68
8	-0.66	66	69
21	-0.71	50	54
28	-0.81	27	30
10	-0.99	23	26
1	-1.06	34	38
24	-1.09	48	54
29	-1.16	38	43
15	-1.36	41	48
23	-1.64	27	33

* Observed number of low birthweight infants

† Expected number of low birthweight infants

correlation matrix of all explanatory variables found to be statistically significant in the bivariate analysis was examined (collinearity was defined as $r > 0.85$).

A weighted multiple regression analysis was used to determine the predictive power of the socioeconomic factors. The best-fitting model was selected using the forward step-wise regression procedure with a selection criterion of 0.05. Weights were used to account for the variation in sampling error¹⁵ and were based on the number of births in each CTC, which ranged from 297 to 1,438 (Table I). Those areas with large numbers of births, and hence relatively small sampling errors, were weighted more heavily than were areas with small numbers of births and large sampling errors.

Residuals (observed rate minus predicted rate) from the regression models were analyzed to identify CTCs with low birth-

Figure 1. Low birthweight rates by census tract cluster in the City of London, Ontario, 1984-1988.

Figure 2. Census tract clusters in the City of London, Ontario using 1986 Census boundaries.

weight rates which were not adequately explained by their socioeconomic status, that is, CTCs which had rates that were significantly higher or lower than would be expected based on the areas' socioeconomic characteristics. Standardized residuals were deemed statistically significant ($p < 0.05$) if their absolute value was greater than or equal to 2.0.¹⁶ The geographic distribution of the residuals was mapped using Atlas Pro.

RESULTS

The low birthweight rates generally increased from west to east, with the highest rates occurring in the far east end and core of the city (Figure 1). These rates ranged from 4.0 to 11.1%, with the rate for the entire city of London at 5.8% (Table I). The use of confidence intervals would be recommended for comparing low

birthweight rates between individual CTCs. The overall variation in rates was highly unlikely to have been due to chance alone (chi-squared test of homogeneity: 59.36, $df = 30$, $p = 0.001$) (Table I).

The association of each individual explanatory variable with low birthweight is provided in Table II. The immigrant variable was excluded from regression analysis because it had virtually no univariate association with low birthweight. Although the teen mothers and unemployment variables were each highly predictive of low birthweight (Table II), they were excluded from the regression analysis because of collinearity (i.e., $r > 0.85$). Further, although low income and low education were each important predictors of low birthweight (Table II), once unwed motherhood was taken into account they had virtually no unique information to contribute to the prediction of low birthweight. Thus, unwed motherhood was the only variable selected into the model by the stepwise procedure. On its own, unwed motherhood served to represent a constellation of socioeconomic factors associated with low birthweight since it was highly correlated with the teen mothers, unemployment, low education and low income variables. This variable was highly

statistically significant ($p = 0.0001$) and explained 65.9% of the variation in low birthweight rates. We log transformed the outcome variable because it normalized the distribution and resulted in a more highly explanatory model.

The two CTCs on the eastern edge of the city (CTCs 20 and 25, see Figure 2) were found to have significantly large residuals, and a third (CTC 22, see Figure 2) came very close to achieving statistical significance (Table III). Both residuals were positive which indicates that the low birthweight rates of these CTCs were higher than what would be expected based on their socioeconomic status. The geographic distribution of the residuals is presented in Figure 3.

DISCUSSION

The overall variation in low birthweight rates across the city of London, Ontario was statistically significant and largely, but not entirely, explained by the socioeconomic characteristics of the areas. The 66% level of explanation of variation in low birthweight rates in our study is lower than in other studies which reported about 80% in the U.K.^{6,7} and over 94% in the U.S.⁸ The smaller R^2 might be explained

by the larger degree of random error in our study due to the substantially smaller populations analyzed compared to the other studies.

The strong and statistically significant crude associations between low birthweight rate and rates of unwed mothers, low income, unemployment, and low education, with the unwed mothers variable having the strongest association, are consistent with the findings of other studies.⁶⁻⁸ Low income, which explained over one half (54%) of the inter-area variation in our study, could be used on its own as a reasonably good ecologic indicator of low birthweight. This may be relevant to health planners who do not generally have access to low birthweight data on a small area basis but can readily access census tract level data on low income from the Canada census database.

The lack of association between the immigrant rate and low birthweight rate in our study may have been due to the heterogeneity of the immigrant population. The use of more specific data on the race/ethnicity of residents of an area, rather than general information on place of birth, might have proved to have been a better predictor of low birthweight rates.

The residuals in two or possibly three of the CTCs were large enough to be statistically significant, that is, they were unlikely to have been due to random error alone. These large residuals, therefore, must be due to explanatory factors not included in the regression model. Multiple births would be one such factor¹⁷ if the rate of multiple births were unusually high in these areas and not in any of the others. Discussions with public health nurses visiting high risk pregnancies in London, however, suggest that this is not the case. Factors such as cigarette smoking, poor nutrition, maternal morbidity, and short maternal stature, although well established direct causes of low birthweight, are also strongly associated with socioeconomic status;¹⁷ and therefore, when socioeconomic factors are taken into account, to a certain extent these factors are as well. Alternatively, factors such as physical environment, access to prenatal care, and the availability of transportation might be considered as possible explanatory factors.

It would therefore appear that the large residuals found in our study were due to factor(s) other than those which are socioeconomic or strongly associated with socioeconomic factors, assuming that all of the important socioeconomic factors were accounted for in the regression analysis. While the present analysis cannot determine which specific factors contributed to the unexpectedly high rates of low birthweight, it should provide useful information for health planning and for generating specific causal hypotheses for future investigations.

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