

Aligning Method with Theory: A Comparison of Two Approaches to Modeling the Social Determinants of Health

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Abstract There is increasing interest in the study of the social determinants of maternal and child health. While there has been growth in the theory and empirical evidence about social determinants, less attention has been paid to the kind of modeling that should be used to understand the impact of social exposures on well-being. We analyzed data from the nationwide 2006 Canadian Maternity Experiences Survey to compare the pervasive disease-specific model to a model that captures the generalized health impact (GHI) of social exposures, namely low socioeconomic position. The GHI model uses a composite of adverse conditions that stem from low socioeconomic position: adverse birth outcomes, postpartum depression, severe abuse, stressful life events, and hospitalization during pregnancy. Adjusted prevalence ratios and 95% confidence intervals from disease-specific models for low income (<20,000/year) compared to high income (\geq 80,000/year) ranged from a low of 1.43 (1.09–1.85) for adverse birth outcomes to a high of 5.69 (3.59–8.84) for stressful life events. Estimates from the GHI model for experiencing three to five conditions yielded a prevalence ratio of 18.72 (9.29–35.77) and a total population

attributable fraction of 78%. While disease-specific models are important for uncovering etiological factors for specific conditions, models that capture GHIs might be an attractive alternative when the focus of interest is on measuring and understanding the myriad consequences of adverse social determinants of health.

Keywords Social determinants · Socioeconomic position · Health inequalities · Pregnancy · Birth · Biomedical model · Multinomial regression · Generalized health impact

Abbreviations

CI	Confidence intervals
GHI	Generalized health impact
LICO-AT	Low income after-tax cut-off
MES	Maternity Experiences Survey
OR	Odds ratio
PAF	Population attributable fraction
PR	Prevalence ratio
SEP	Socioeconomic position

Introduction

Socioeconomic disparities in health have been well documented since the birth of epidemiology and public health in the mid nineteenth century [1]. The “eras” of epidemiology reflect the evolution of the disease-specific model, from the pursuit of a single cause (i.e., the germ theory) of infectious diseases, to the consideration of myriad causes (i.e., the web of causation) of specific conditions with the rise of chronic diseases as the major public health threat [2, 3]. And while much of the focus of epidemiology is on etiologic contributors to single specific health conditions or

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behaviors (e.g., cardiovascular diseases, obesity, adequacy of prenatal care), social epidemiology has taken a specific interest in the myriad health consequences of social exposures (e.g., low income or poverty, ethnic density of neighborhoods, immigration, discrimination) [4–12].

Theoretical perspectives from the social sciences such as medical sociology suggest that the effects of social exposures such as socioeconomic position (SEP) are fundamental causes of poor health and do not cause a single health outcome but, rather, have a generalized impact on well-being [13, 14]. Evidence supporting this perspective includes the persistence and concentration of morbidity and mortality among the poor compared to wealthier populations across the centuries despite major shifts in the major causes of death during this time from infectious diseases to chronic conditions [15, 16]. The resurgence of interest in social conditions within epidemiology in recent decades [5, 17] may have deepened our understanding of the relationships between social position and health but did so while remaining attached to the disease-specific analytic approach pervasive within epidemiology. The disease-specific approach of identifying etiologic factors—both biological and social—is appropriate when a particular condition or problem is of interest, for example, to uncover the primary determinants of smoking during pregnancy to design effective interventions. But when the primary focus is on a social exposure (e.g., poverty, discrimination) and its impact on overall health or well-being, the disease-specific model is theoretically incompatible with this research agenda. The disease-specific modeling of fundamental social conditions may mis- or underestimate their impact on health [14, 16, 18].

In practice, the disease-specific model treats all potential causes (predictors) as if they had the same ontological status. However, SEP differs in several aspects from other more proximate determinants commonly studied in epidemiology, such as tobacco smoking, diet, environmental contaminants or genes. First, SEP may lead directly and indirectly to ill health through several complex pathways that change and evolve over time with the history of a given society [16]. Social organization is thus seen as a “distal”, “upstream”, or “fundamental” force that put individuals at “risk of risks” [15, 16, 19]. Second, as noted earlier, the effects of social organization on health are non-specific [14, 20]. Third, the negative effects of low social position accumulate longitudinally (i.e., the longer the exposure the greater the risk) and cluster cross-sectionally (i.e., individuals at the bottom of the social scale are more likely to experience multiple adverse outcomes) [15]. These considerations suggest that the disease-specific approach of studying only one disease manifestation of social determinants prevents us from capturing the full impact of social causes on health [14, 16, 18]. And while

there are times when researchers with an exclusive interest on multifactorial determinants of a single health condition should rely on the disease-specific model, the growing interest in social disparities with a primary focus on social determinants of well-being would benefit from the use of alternative models that facilitate evaluation of a generalized effect of social factors on outcomes [14, 18].

We draw from the sociological literature which distinguishes two types of models, etiologic or disease-specific models and consequences models or models that measure the generalized impact of a particular social exposure. Models that examine the consequences or generalized impact of social exposures have as their point of departure the social cause, not the disease [6, 14, 18, 21–23]. While the conceptual or theoretical underpinnings of the two models are quite different, the operational distinctions are quite simple and focus on the outcome variable [14, 18]. While the disease-specific model uses a single health outcome, models of the consequences of social exposures use a composite outcome. Use of composite outcomes is not new to the field of health [24–26]. In the case of the study of the consequences of social exposures, the composite outcome must be grounded in sound theory; those conditions included in the dependent variable should have solid evidence supporting its relation to the social exposure of interest. Despite its promise, models of the generalized health impact (GHI) of social exposures have been applied by social scientists in studies on mental health [14, 18, 27] but have not been widely applied by epidemiologists.

Our objective was to apply the (GHI) model to the study of maternal and newborn well-being using a national survey of Canadian childbearing women and to compare it with the traditional disease-specific approach of examining one outcome at a time. Reproductive health may be suitable for this endeavour since social disparities have been amply demonstrated for multiple pregnancy related outcomes [8, 28].

Methods

Study Population

The Maternity Experiences Survey (MES) is a population-based survey conducted by Statistics Canada during 2006–2007 on behalf of the Public Health Agency of Canada. The MES target population consisted of biological mothers who were age 15 and older at the time of their babies' singleton live birth in Canada and lived with their infants at the time of the survey [29, 30]. A stratified simple random sample was selected without replacement, using recent births drawn from the Census 2006 sampling frame. The sample was stratified on province or territory

in which the mother resided at the time of the census and on maternal age (<20 years, ≥20 years). Among 8,542 women selected from the frame, 8,244 were estimated to be eligible cases based on the target criteria. The questionnaire was successfully completed by 6,421 women (77.9% response rate). After applying the survey weights, which were adjusted for non-response, these women represented approximately 76,500 Canadian women [30]. The data were collected in a 45 min computer-assisted telephone interview by professional female interviewers in English, French and 13 non-official languages. Paper versions were used when telephone interviews were not feasible [30]. Information on postal code of the respondent was used to link the data to the 2006 Canadian census to characterize residential neighborhood. Further details of the survey design and methods have been reported elsewhere [30–34].

Outcome Measures

To compare the disease-specific and the social consequences models, we chose a priori several conditions that were strongly associated with high levels of deprivation and low SEP [7, 28, 35–40].

- a. *Adverse birth outcomes* was a composite measure defined by the presence of low birthweight (<2,500 g), preterm birth (<completed 37 weeks) or small for gestational age (birthweight below the 10th percentile of a Canadian population-based sex- and gestational age-specific reference) [41]. These measures were constructed based on maternal reports of gestational age, infant sex and birthweight. The resulting rates of singleton preterm birth and small for gestational age in the survey were consistent with national surveillance data based on birth certificates [29].
- b. *Postpartum Depression* was assessed using the Edinburgh Post-Natal Depression Scale, a ten item screening tool to identify postpartum depression at the time of its administration [42]. A score of 13 or more out of a maximum possible of 30 was used to indicate the presence of postpartum depression. Validation studies have showed that the scale can detect depression in postpartum women with 86% sensitivity and 78% specificity [43, 44].
- c. *Serious abuse* was defined as the combination of threats and physical or sexual abuse suffered right before, during or after pregnancy. The MES contained a section to assess abuse and violence. The questions were adapted from the Violence Against Women Survey [45] to capture abuse and violence during the childbearing year. Threats or potential hurting acts were defined by the occurrence of direct threats of physical harm, throwing objects at them and being pushed, grabbed or shoved in a way that could have hurt respondents. Physical or sexual abuse included at least one episode of slapping, kicking, hitting with a weapon, beating, choking, use of a gun or knife, and being forced into unwanted sexual activity. Thus, serious abuse involves at least two episodes of violence of different kinds.
- d. *Hospitalization during pregnancy* was defined as an affirmative answer to the question of whether respondents stayed at a hospital overnight before labour and the birth.
- e. *Frequent stressful life events* were considered as such when respondents identified three or more stressful events (out of 13) in the 12-month period before the baby's birth [32].

In the disease-specific models, each of the previous conditions is considered as a separate outcome. In contrast, to be consistent with the theory underpinning the GHI models we created a *compound outcome variable* by counting the number of conditions experienced by respondents [18, 24, 25, 27], and categorizing them into 0, 1, 2 and 3–5 conditions.

Exposures

- a. *Total household income*, before taxes and deductions, of all household members from all sources in the 12-month period preceding the interview. The unexposed group was considered to be composed of households with annual incomes of 80,000 dollars and higher and exposed groups were those in the income brackets of <20,000, 20,000–49,999, 50,000–79,999 dollars, and unknown income.
- b. *Neighborhood deprivation* was a contextual variable assessed by the proportion of households whose income in 2005 was below the Statistics Canada Low income after-tax cut-off (LICO-AT) [46]. The LICO-AT identifies households spending 20 percentage points more of their after-tax income than the average family in the region on food, shelter and clothing, thus leaving less income available for other expenses such as health, education, transportation and recreation. The LICO-AT cut-offs are differentiated by size of family and area of residence. Proportions of LICO-AT were computed at the dissemination area level, which is the smallest standard geographic area for which all census data are disseminated, with a population of 400–700 persons [46].
- c. *Immigrant status* was categorized into Canadian-born, recent immigrants (<10 years of stay in Canada), and long term immigrants (≥10 years of stay).

Variables for confounder control were maternal age, parity, and place of residence [46]. For the latter, place of residence was categorized into urban areas (Census Metropolitan Areas [CMA] and Census Agglomerations [CA], with an urban core of at least 10,000 inhabitants) and rural areas (non CMA/CA zones), following the Statistics Canada Standard Geographical Classification. [47]. Levels of these variables are specified in Table 1.

Analytic Methods

Survey weights were used to account for the unequal probabilities of selection of respondents and thus obtain unbiased point estimates representative of the Canadian population. Special procedures for the analysis of survey data (SURVEYFREQ and SURVEYLOGISTIC) (SAS version 9.2, SAS Institute Inc., Cary, NC) were used to

obtain weighted proportions and Odds Ratios (OR) with 95% confidence intervals (95% CI) using the Taylor Series method of variance estimation [48].

For modeling the five disease-specific conditions, the logistic model was used to compute ORs for each condition separately. To model the generalized impact of social exposures, and to take into account the multiple categories of our compound outcome, we used the multinomial model to obtain ORs for the occurrence of one, two, and three to five conditions, relative to none. The general regression equation of the multinomial model with a single predictor is given by $\text{Log}(\pi_j/\pi_J) = \alpha_j + \beta_j x$, where the response levels are $j = 1, \dots, J - 1$ and the baseline response category is J .

To avoid overestimating relative risks, odds Ratios were converted to Prevalence Ratios (PR) using a simple formula that provides a good approximation to estimates of

Table 1 Characteristics of the Maternity Experiences Survey respondents, 2006–2007, (weighted N = 71,395) by number of composite health conditions

	Total sample		Composite health conditions							
			0 conditions ^b		1 condition ^b		2 conditions ^b		3–5 conditions ^b	
	N ^a	(%)	N ^a	(%)	N ^a	(%)	N ^a	(%)	N ^a	(%)
Total respondents	71,395	(100)	42790	(59.9)	19822	(27.8)	6913	(9.7)	1871	(2.6)
<i>Age group</i>										
<20 years	1,995	(2.8)	559	(1.3)	706	(3.6)	460	(6.7)	271	(14.5)
20–24 years	9,149	(12.8)	3711	(8.7)	3181	(16.0)	1587	(23.0)	670	(35.8)
25–29 years	20,321	(28.5)	12871	(30.1)	5474	(27.6)	1561	(22.6)	415	(22.2)
30–34 years	23,904	(33.5)	15385	(36.0)	6329	(31.9)	1928	(27.9)	262	(14.0)
≥35 years	16,026	(22.4)	10264	(24.0)	4132	(20.8)	1377	(19.9)	253	(13.5)
No previous live birth	31,901	(44.7)	18314	(42.8)	9413	(47.5)	3235	(46.8)	940	(50.2)
<i>Household income</i>										
<\$20,000	6,039	(8.5)	1977	(4.6)	2221	(11.2)	1215	(17.6)	626	(33.5)
\$20,000–49,999	18,948	(26.5)	9883	(23.1)	6008	(30.3)	2384	(34.5)	673	(36.0)
\$50,000–79,999	19,759	(27.7)	12934	(30.2)	4792	(24.2)	1712	(24.8)	321	(17.2)
≥\$80,000	23,042	(32.3)	16311	(38.1)	5501	(27.8)	1106	(16.0)	125	(6.7)
Unknown	3,607	(5.1)	1685	(3.9)	1300	(6.6)	496	(7.2)	126	(6.7)
<i>Neighborhood deprivation</i>										
<5%	25,693	(36.0)	16621	(38.8)	6546	(33.0)	2000	(28.9)	526	(28.1)
5–14.9%	28,085	(39.3)	16548	(38.7)	8150	(41.1)	2710	(39.2)	677	(36.2)
15–24.9%	9,606	(13.5)	5683	(13.3)	2629	(13.3)	985	(14.2)	309	(16.5)
≥25%	8,011	(11.2)	3938	(9.2)	2497	(12.6)	1218	(17.6)	359	(19.2)
Rural residence	12,196	(17.1)	7044	(16.5)	3463	(17.5)	1338	(19.4)	352	(18.8)
<i>Immigrant status</i>										
Canadian-born	55,004	(77.1)	33115	(77.4)	14852	(74.9)	5387	(77.9)	1650	(88.2)
Immigrant <10 years	9,162	(12.8)	5348	(12.5)	2834	(14.3)	877	(12.7)	104	(5.6)
Immigrant ≥10 years	7,229	(10.1)	4327	(10.1)	2136	(10.8)	649	(9.4)	117	(6.3)

^a Weighted number of women

^b 0, 1, 2, and 3 or more conditions represent categories of the composite outcome

^c Measured as proportion of households in a dissemination area living at or below the Statistics Canada Low Income Cutoff (LICO)

the relative risk when direct estimation is not feasible [49]. In the formula $PR_i = (P_i/P_0) = OR_i / [(1 - P_0) + (P_0 \times OR_i)]$, P_i is the weighted proportion of cases in the exposure level i , P_0 is the weighted proportion of cases among the non-exposed and OR_i is the OR for exposure level i . This conversion further allowed comparing the disease specific and social consequence models in terms of population attributable fractions (PAF), based on the weighted proportion of cases at each exposure level and on the adjusted PRs, as expressed in the formula $PAF = (Pd_i * ((PR_i - 1) / PR_i))$, where Pd_i is the weighted proportion of cases in stratum i and PR_i is the adjusted PR in stratum i [50]. PAFs facilitated the comparison of the etiologic fraction attributed to low SEP between the disease-specific and GHI models.

Missing data were very low for most variables and therefore were not considered in the analyses, with the exception of household income, for which we created a category labelled “Unknown” to prevent a significant drop in the sample size.

The study was approved by the St. Michael’s Hospital Research Ethics Board and by the Research Data Centre Access Granting Committee of Statistics Canada.

Results

Among the 6,421 respondents in the MES, 406 women (6.3%) were excluded due to missing or invalid responses in at least one of the outcomes or covariates. The final sample for analyses was 6,015 (weighted $N = 71,400$).

About four out of 10 women had at least one adverse condition (Table 1). Among affected women, 70% had only one and seven percent three to five outcomes. The proportion of women experiencing at least one outcome decreased with advanced age, higher household income and lower neighborhood deprivation. This pattern was more evident as the number of concomitant conditions increased. Among affected women, the number of concomitant conditions increased while the proportion of immigrants decreased.

Regression models for each single condition showed moderate to strong associations between low household income and each outcome, with PR ranging from 1.4 to 5.7, after adjustment (Table 2). In comparison, the multinomial model showed two types of gradients; the well-known gradient by which the lower the income the poorer the outcomes, and a new gradient by which, within each exposed income group, the PR increase with the number of conditions, reaching a prevalence ratio of 17 for women in the lowest income households having 3–5 conditions. The prevalence of 3–5 conditions was 10.36% among women living in households making <20,000 dollars (626/6,039

from Table 1) versus 0.54% among those whose household income was 80,000 or above (125/23,042 from Table 1).

In the fully adjusted model, neighborhood deprivation was not consistently associated with the outcomes.

In contrast to the findings for the socioeconomic exposures, logistic models show that being an immigrant was associated with higher risk of postpartum depression but lower risk of abuse, hospitalizations and stressful life events, particularly among recent immigrants. Multinomial models show a trend towards lower risk of concomitant adverse outcomes, particularly among recent immigrants.

Another approach to compare the magnitude of effects is to examine the Population Attributable Fraction (PAF) for the social exposures. Here we show PAFs for income. Low income PAFs ranged from 15 to 55% for single conditions based on the single outcome model (Table 3). In comparison, PAFs in the composite condition model were substantially larger at 51 and 78% for 2 and 3–5 conditions, respectively.

Discussion

To our knowledge, this is the first study to apply the GHI approach to model pregnancy related outcomes. In a representative sample of Canadian childbearing women, we found that, compared to the disease-specific model, a GHI model detects stronger effects of social position on pregnancy related outcomes. Both approaches showed the well documented gradient of decreasing risk with increasing household income. In addition, we were able to demonstrate a strong dose–response relationship using the GHI model. The stronger gradient is explained, in part, by having fewer individuals with conditions related to low SEP in the ‘condition free’ category of the GHI model which is not true for the disease specific models.

Immigrants also exhibited linear trends according to the number of adverse outcomes, but in contrasting directions. Even after controlling for household and neighborhood income, immigrants were less likely to experience multiple conditions, particularly recent immigrants. This observation is consistent with the “healthy migrant effect” and also suggestive of its loss with increasing time spent in the new country [51].

Strengths of our study are the use of a high-quality nationally representative survey and the simultaneous consideration of a wide array of adverse outcomes. Such approaches are particularly relevant for research focussing on social determinants for example in the study of social disparities [6, 23, 52]. Our findings are strengthened by the existence of a dose–response relationship between lower income and increasing number of adverse outcomes. Although we focused our attention on household income,

Table 2 Prevalence ratios of reporting a single condition or compound health problems among Canadian women in the maternity experiences survey (MES), 2006–2007

	Estimates derived from logistic regression for five conditions separately					Estimates derived from multinomial regression for concomitant conditions (reference category is zero conditions)					
	Adverse pregnancy outcome	Postpartum depression	Severe abuse	Hospitalized during pregnancy	Stressful life events	1	2	3-5	1	2	3-5
	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)	PR ^a (95% CI)
<i>Household income</i>											
<\$20,000	1.41 (1.08, 1.82)	2.30 (1.60, 3.24)	6.14 (3.89, 9.45)	1.45 (1.09, 1.92)	5.27 (4.35, 6.25)	1.95 (1.67, 2.23)	4.90 (3.58, 6.52)	18.72 (9.29, 35.77)	1.95 (1.67, 2.23)	4.90 (3.58, 6.52)	18.72 (9.29, 35.77)
\$20,000–49,999	1.32 (1.09, 1.60)	1.64 (1.22, 2.20)	2.11 (1.34, 3.30)	1.27 (1.03, 1.57)	3.05 (2.50, 3.66)	1.42 (1.25, 1.58)	2.65 (2.01, 3.46)	5.84 (2.82, 11.89)	1.42 (1.25, 1.58)	2.65 (2.01, 3.46)	5.84 (2.82, 11.89)
\$50,000–79,999	1.11 (0.91, 1.36)	1.09 (0.80, 1.51)	1.50 (0.93, 2.38)	1.19 (0.96, 1.46)	1.75 (1.41, 2.17)	1.05 (0.92, 1.19)	1.77 (1.33, 2.34)	2.70 (1.24, 5.82)	1.05 (0.92, 1.19)	1.77 (1.33, 2.34)	2.70 (1.24, 5.82)
\$80,000 and more	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unknown	1.75 (1.30, 2.30)	1.48 (0.92, 2.34)	2.88 (1.61, 5.04)	1.16 (0.81, 1.65)	2.57 (1.88, 3.45)	1.56 (1.26, 1.88)	2.85 (1.88, 4.20)	5.32 (2.21, 12.54)	1.56 (1.26, 1.88)	2.85 (1.88, 4.20)	5.32 (2.21, 12.54)
<i>Neighborhood deprivation[‡]</i>											
<5%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5–14.9%	1.12 (0.95, 1.32)	1.06 (0.82, 1.35)	1.06 (0.77, 1.44)	1.10 (0.94, 1.30)	1.17 (1.00, 1.35)	1.13 (1.01, 1.25)	1.24 (1.00, 1.53)	1.12 (0.73, 1.70)	1.13 (1.01, 1.25)	1.24 (1.00, 1.53)	1.12 (0.73, 1.70)
15–24.9%	0.99 (0.78, 1.25)	1.13 (0.82, 1.55)	0.96 (0.63, 1.47)	1.01 (0.79, 1.30)	1.18 (0.95, 1.45)	1.00 (0.85, 1.17)	1.16 (0.86, 1.55)	1.15 (0.66, 1.96)	1.00 (0.85, 1.17)	1.16 (0.86, 1.55)	1.15 (0.66, 1.96)
≥25%	1.31 (1.03, 1.65)	1.37 (0.99, 1.87)	1.52 (0.99, 2.32)	1.09 (0.82, 1.42)	1.31 (1.04, 1.63)	1.15 (0.95, 1.35)	1.74 (1.28, 2.31)	1.69 (0.99, 2.86)	1.15 (0.95, 1.35)	1.74 (1.28, 2.31)	1.69 (0.99, 2.86)
Urban	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rural	0.93 (0.77, 1.12)	1.11 (0.85, 1.44)	0.71 (0.51, 0.99)	1.35 (1.13, 1.59)	0.92 (0.78, 1.09)	1.03 (0.91, 1.16)	1.12 (0.74, 1.40)	0.90 (0.59, 1.38)	1.03 (0.91, 1.16)	1.12 (0.74, 1.40)	0.90 (0.59, 1.38)
<i>Immigrant status</i>											
Canadian-born	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
non-aboriginal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Immigrant <10 years	1.25 (1.02, 1.52)	1.83 (1.40, 2.39)	0.18 (0.07, 0.39)	0.76 (0.56, 1.01)	0.45 (0.33, 0.59)	1.01 (0.86, 1.17)	0.76 (0.56, 1.03)	0.31 (0.12, 0.71)	1.01 (0.86, 1.17)	0.76 (0.56, 1.03)	0.31 (0.12, 0.71)
Immigrant ≥10 years	1.12 (0.88, 1.42)	1.52 (1.10, 2.08)	0.59 (0.34, 1.03)	1.09 (0.84, 1.41)	0.61 (0.46, 0.80)	1.08 (0.92, 1.27)	0.93 (0.65, 1.29)	0.60 (0.28, 1.27)	1.08 (0.92, 1.27)	0.93 (0.65, 1.29)	0.60 (0.28, 1.27)

^a PRs adjusted for maternal age, parity and for all other variables in the table

[‡] Measured as proportion of households in a dissemination area living at or below the Statistics Canada Low Income Cutoff (LICO)

Table 3 Population attributable fractions (PAF) for single conditions or number of concomitant conditions among women in the Canadian Maternity Experiences Survey, 2006–2007

Household income	PAF for single conditions					PAF for concomitant conditions		
	Adverse birth outcomes	Postpartum depression	Severe abuse	Hospitalized during pregnancy	≥3 stressful life events	1	2	3-5
<\$20,000	0.032	0.095	0.269	0.036	0.175	0.055	0.140	0.317
\$20,000–49,999	0.074	0.133	0.150	0.064	0.249	0.090	0.215	0.298
\$50,000–79,999	0.025	0.017	0.061	0.044	0.092	0.012	0.108	0.108
Unknown	0.034	0.022	0.056	0.008	0.038	0.024	0.047	0.055
Total sample	0.164	0.267	0.535	0.152	0.554	0.179	0.509	0.778

which cannot capture the full complexity of social location [19, 52], we also considered additional indicators, such as immigration, which was also associated with the compound outcome in a dose–response fashion.

Several weaknesses exist. First, as data are self-reported, recall bias is always a possibility. However, our variables focused on the 2-year period preceding the interview and bias resulting from inaccurate recall is likely to be small. Second, the main exposure was total household income since disposable income after application of redistributive policies was not available in the survey, which would be more accurate as a measure of the material resources actually available to the households. The use of pre-tax income is likely to bias the estimates toward the null, yet we found strong and consistent associations. It is unlikely that reverse causation could explain our findings as prospective studies suggest that the cross-sectional associations between income and health chiefly reflect the influence of income on health rather than the opposite [13, 53]. Unfortunately, we did not have life course data to fully explore the problem of reverse causation. In the case of immigrant status, it is a fixed attribute that cannot be affected by the outcomes. Third, our list of outcomes and exposures is not exhaustive and we were constrained by what we could include by the survey. With regard to outcomes, we chose a priori a limited number of known consequences of low individual and neighborhood SEP for comparison purposes but the use of a different set of outcomes may result in different effect estimates. We anticipate that, if low SEP is associated with each single outcome, the use of the GHI model would reveal similar patterns. Moreover, the GHI approach is well suited for documenting the impact of social determinants on well being but may be less appropriate for revealing the mechanisms or pathways by which social factors result in adverse health given the outcome is a composite of many variables, some of which may have unique pathways resulting from deprivation. We did not control for correlates of income, such as maternal education and marital

status, because of potential overcontrol or collinearity issues. Adjustment for smoking and substance use was discarded since these are conceptualized as mediators of the relationship of interest [8]. Finally, while we used logistic and multinomial regression, alternative approaches, such as structural equation modeling might have been employed to explore the same research questions. We anticipate that if such approaches were used, a similar set of findings would result.

Despite these limitations, our application of the GHI model provides further evidence supporting the hypothesis that the negative consequences of social position cluster among the socially disadvantaged. While socioeconomic gradients constitute one of the most robust findings in social and perinatal epidemiology [28], our study reveals a less known gradient towards the simultaneous occurrence of multiple adverse outcomes associated with increasing disadvantage. Income inequalities accounted for 51 and 78% of the excess risk of having 2 and 3–5 conditions, respectively, supporting their role as a fundamental cause [16]. While we provided evidence supporting the existence of a clustering of multiple adverse outcomes with increasing deprivation, we did not have appropriate longitudinal data to test the related hypothesis that, at a given level of lower social position, the occurrence of concomitant adverse outcomes would be higher among those who have been exposed longer or repeatedly to low SEP [13, 15]. Such approaches might be useful for examining specific questions around social exposures such as discrimination [54] or issues of deprivation such as the weathering hypothesis [55, 56]. Further research in this area will benefit from adopting a life-course perspective [57] and analysing longitudinal datasets.

Our findings have important implications for research and practice. From an analytic perspective, the disease-specific model underestimates the negative impact of low SEP on health. In particular, it overlooks the fact that socially disadvantaged individuals are also affected by related conditions other than the one under investigation.

Thus, the broad non-specific effects of SEP on health domains may be better captured by the GHI model. From a policy perspective, the understanding that low SEP is not only independently associated with various adverse outcomes but also with their simultaneous occurrence suggests that greater health gains may be achieved if investments focus on reducing the social inequities behind the health disparities rather than on tackling proximate risk factors that may hopefully prevent one but not all negative consequences of low social position [58, 59]. It is important to clarify that the GHI model does not intend to replace disease-specific research, which is the model of choice when the interest is to unveil the mechanisms and pathways for specific and well-defined health outcomes. However, when the goal is to weigh the non-specific sequels of SEP on a general domain of health, such as mental health or reproductive health, the GHI model has clear advantages.

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