Towards the construction of place-specific measures of deprivation: a case study from the Vancouver metropolitan area

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There have been numerous attempts to measure population health outcomes using socio-economic indicators. Few investigations have utilized a survey-based approach. This article develops a new means for identifying key socio-economic indicators of relative health outcomes within greater Vancouver, British Columbia (BC). The index, referred to as the Vancouver Area Neighbourhood Deprivation Index (VANDIX), was constructed from a survey of provincial Medical Health Officers (MHOs). The MHOs were asked to rank socio-economic indicators selected from the 2001 National Census by their relative influence on health outcomes throughout the province. Response consistency was evaluated with a weighted Kappa test statistic. The VANDIX score was assigned to Census Dissemination Areas and Census Tract administrative geographies. The scores were then compared to a subset of the 2003 Canadian Community Health Survey (CCHS) Cycle 2.1 database on self-assessed health. Outcome scores between the

Vers la construction de mesures de privation spécifiques au lieu: une étude de cas sur la région métropolitaine de Vancouver

On a tenté, à plusieurs reprises, de mesurer les résultats de santé de la population à l'aide d'indicateurs socioéconomiques. Seul un nombre restreint d'études s'appuient sur une enquête par sondage. Cet article présente une nouvelle manière d'identifier les principaux indicateurs socioéconomiques concernant les résultats de santé dans la région de Vancouver, Colombie-Britannique. Un indice de privation à l'échelle des quartiers de la région de Vancouver (VANDIX) est élaboré à partir d'un sondage mené auprès de médecins hygiénistes en chef de la province. Ces derniers ont été invités à classer des indicateurs socioéconomiques tirés du Recensement canadien de 2001 selon la répercussion possible sur les résultats de santé dans l'ensemble de la province. La concordance des réponses a été vérifiée par un test statistique Kappa pondéré. Le

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VANDIX and CCHS self-assessed health records were compared with two previously constructed Canadian deprivation indices to examine possible discrepancies in the survey. Research results illustrate the benefit of linking local knowledge from surveys with census-based methodologies.

score VANDIX est appliqué aux unités géographiques comprises dans les aires de diffusion et les secteurs de recensement. Par la suite, les scores sont comparés à un échantillon de la base de données de l'Enquête sur la santé dans les collectivités canadiennes (ESCC) 2003, cycle 2.1, qui porte sur l'autoévaluation de l'état de santé. Les résultats obtenus du VANDIX et de l'autoévaluation de l'état de santé de l'ESCC ont été mis en parallèle avec deux indices de privation déjà élaborés au Canada en vue d'examiner certaines contradictions au niveau du sondage. Les résultats de recherche soulignent l'intérêt de mettre en relation des connaissances locales issues des sondages avec des méthodes de recensement.

Introduction

The relationship between health outcomes and social circumstance is well established around the globe (Marmot 1986; Townsend *et al*. 1986; Townsend *et al*. 1987; Evans *et al*. 1994; Acheson 1998; Hertzman 1999; Singh and Siahpush 2002; Singh 2003). At a more local level, linking health outcomes with neighbourhood characteristics poses important, perplexing challenges to public policy regarding the interrelationship between 'health and place'. This need has fuelled demand for spatialized empirical health information for small area populations. In Canada, this interest is widely demonstrated (CPHI 2002; CIHR 2004).

Examining health outcomes at the local level increases the capacity for targeting prevention and risk-reduction strategies. The modifiable areal unit problem (MAUP) is an endemic concern to developing any spatialized measure but is most pronounced at large scales (small areas). Availability and reliability of small area data are other ongoing issues, which have necessitated a strong reliance on national census's to study the relationship between health and socio-economic status (SES) (Bartley and Blane 1994). The logic of using census data as small-area socio-economic indicators, otherwise referred to as area-based deprivation indicators (ABDIs), is due to the structure and availability of the census, which is frequently the most robust spatialized source of information to assess neighbourhood socio-economic characteristics.

Although some studies use SES indicators specific to a study area (DETR 2000; NAfW 2000; Dunn 2002), private or large-scale surveys which collect more robust socio-economic data can be exceedingly difficult to standardize and more susceptible to changes over time than nationally standardized census questionnaires. Data error, access and the spatial extent of surveys can also pose substantial problems for examining finer grain population wide socio-economic data. To circumvent this limitation, we constructed an ABDI based on census variables for urban areas throughout British Columbia (BC) with the assistance of several provincial Medical Health Officers (MHOs). The resulting index is called the Vancouver Area Neighbourhood Deprivation Index (VANDIX). We used a survey of MHOs asking them to rank the census variables they felt best-characterized health and socio-economic outcomes within the province. In the absence of more accessible or robust data on place, building ABDIs around inputs from local stakeholders may produce an informative picture of the spatial patterning of health and SES at a large scale. By design, the ABDIs are census driven constructs that, at best, can only loosely predict how the places in which we live influence our health, yet these analyses are highly beneficial and the point of view of provincial MHOs may facilitate better public health policy and health promotion in BC.

This article provides a brief literature review of ABDIs and discusses the rationale for emphasizing survey-based ABDI construction. The VANDIX

is compared with self-reported health data obtained from the Canadian Community Health Survey (CCHS) Cycle 2.1 database and two other previously constructed Canadian ABDIs. The indices are contrasted against the population of greater Vancouver, which at the time preceding the 2001 Census represented nearly 55 percent of the total population of BC. We examined the consistency of MHO response scores using a Kappa statistic. Finally, we conclude with a discussion of the benefits of constructing ABDIs using survey-based methods and point to future application of the VANDIX in BC.

Building Socio-economic Deprivation Indices: From P to Z

Using ABDIs to contrast against relative health outcomes is a widely popularized technique (Salmond *et al.* 1998; Benach and Yasui 1999; Takano and Nakamura 2001). The indices are ultimately designed to condense multiple census indicators into 'social' and 'material' components—two separate but interconnected dimensions of class or socio-economic position, both of which were considered as key determinants of health in *The Black Report* (Black *et al.* 1982)—one of the earliest and most influential reports on social gradients in health. The material component represents an individual's ability to purchase goods and services. Census variables, such as income, employment characteristics or educational attainment are some of the most accessible indicators of material deprivation. Material deprivation has also been measured indirectly using percentages of car or home ownership in countries where specific questions on income or education are not available. Social deprivation refers to political norms or values, customs or activities and workplace or family dynamics and is typically the more difficult of the two deprivation components to directly quantify from census questionnaires. Instead, variables such as heading a lone parent family, or being separated, divorced, or widowed indirectly reflect the likelihood of higher levels of social deprivation. An individual's or sub-population's aggregate SES relative to the surrounding area is then assessed by weaving together both constructs or separately examining each against health outcomes. The index measures provide a metric for contrasting how health outcomes vary according to contextual (i.e., neighbourhood) or compositional (i.e., individual) factors. By identifying these determinants researchers can predict where and perhaps why gradients in health outcomes will appear. Because of the well-established relationship between SES and health, deprivation indices are often used as surrogate measures of health and well being in the absence of high-resolution health data.

The most recent literature on small-area estimation of SES draws from principal component analysis (PCA) (Frohlich and Mustard 1996; Pampalon and Raymond 2000; Langlois and Kitchen 2001; Martens *et al.* 2002; Martens, Derksen, *et al.* 2004; Odoi *et al.* 2005; Rose and Gilbert 2005). PCA is a highly computational technique rooted in linear algebra. It is particularly well suited for data detection and reduction in large datasets such as the census as it iteratively reduces the number of variables needed to explain the total variance in the dataset by grouping highly collinear variables. The smaller, more manageable components thus reveal the underlying structure of the data—a structure that has also provided a theoretical base to assess how individual indicators reflective of social or material deprivation correlate. It also provides a medium for constructing an ABDI with minimal researcher bias (i.e., which variables to include or assigning variable weight) as the principal components are designed to optimize variable collinearity. It should be noted, however, that at the time of its integration into social epidemiology, the use of PCA had more to do with advancements in computing power than the advancement of population health theory as to the underlying social structure that was manifest in the variables (Macintyre *et al.* 2002). One of the principal shortcomings of the method is that in condensing a large number of indicators into a smaller number of components much of the variance exhibited in the original data structure is removed.

Standardized z-scores and log transformations of the census variables predate more advanced computational statistics (Townsend *et al.* 1987; Carstairs 1989). The z-score technique is used for standardizing data relative to its mean—the principal benefit of which is enabling the merging of disparate socio-economic indicator categories

(i.e., cost with percentage). Similarly, log transformations reduce the effect of skewness in the dataset. When using z-scores the standardized variables can also carry proportional weights relative to their importance. The principal caveat of the z-score is that there is no ceiling as to how far the distribution can spread relative to its mean, incidentally removing some of the added benefit of standardization. The z-score and log transformation are also influenced by the value of the denominator, which is of critical importance if the index is used to compare heterogeneous populations, such as urban and rural areas, simultaneously.

The last widely used index constructed from survey-based methods was the underprivileged area score (UPA8) developed by Jarman (Jarman 1983). The UPA8 was designed as a workload assessment of UK General Practitioners to help overcome the problems imbedded in a homogeneous capitation allowance. The index was then used by the British National Health Service as a payment formula to persuade GPs to practice in areas known for having a greater prevalence of individuals receiving deprivation payments and, hence, more likely to require greater medical attention of services (Jarman 1983; Davey-Smith 1991; Talbot 1991).

To construct the index Jarman used a ten percent sampling frame of British GPs, asking them to comment on the factors that increased their daily stress and workload. The final aggregate index contained eight of the most popular variables selected by the GPs, including: the elderly population living alone, families with children under five, lone-parents, those in social class V, the unemployed, those with overcrowded living conditions, those with annual mobility, and populations born in the new Commonwealth or Pakistan. All variables were obtained from the UK Census. Weights were assigned to the index variables based on the frequency of GP feedback.

Initial critique of the index stemmed from its over reliance on census data; for favouring London over the northern districts; for the scale at which it was constructed (UK Census Wards); and its weighting of the survey scores (Carr-Hill and Sheldon 1991; Davey-Smith 1991; Talbot 1991). These critiques are, however, not restricted to the Jarman UPA8 as all ABDIs fall prey to one or combination of these caveats. The underlying reason for downplaying the UPA8 was likely due to its use in assigning capitation allowances, which in some areas rose from 45 percent to 55–60 percent using the UPA8 as a payment formula (Talbot 1991). Despite these shortcomings or criticisms, the Jarman UPA8 score offered further evidence of a social gradient in health even though it was principally constructed to draw attention to the underlying conditions that influenced the daily stress and workload of British GPs. It was validated early on against the opinions of local medical committees and in studies to increase clinician-based screening on all-cause mortality (Charlton and Lakhani 1985). Presently, it is still used as a measure to estimate socio-economic gradients in health status (Kennedy *et al.* 1999; Law and Morris 1999; Pearson *et al.* 2004).

Although similar in structure to the early UK indices and the subsequent PCA-based Canadian indices, little attention has been given to survey-based index construction since the initial critique of the Jarman UPA8 score—despite the fact that literature in other socio-economic investigations has shown that a mix of survey and census-based studies are a valuable technique for uncovering local SES conditions (Fiedler *et al.* 2006). In their study investigating populations in core housing need throughout greater Vancouver, BC, Fiedler *et al.* found that surveys could be used in conjunction with the national census to obtain a finer scale understanding on residential geography—an understanding which has historically undercounted the population in core housing need due to the nature of the coarsely aggregated census aggregation units. This was an important development and does provide some indication that surveys can still play an important role in census-based SES investigations.

Whilst ABDIs do provide a good indication to an individual's or areas socio-economic position relative to the surrounding area (Townsend *et al.* 1986), certain caveats still remain when using either census-based or census-augmented datasets for measuring SES. Theorists in social epidemiology and critical cartography alike have expressed concern as to the representativeness of the census (Crampton 2004), and its tendency to diminish more meaningful information regarding the influence of 'place' on health (Macintyre *et al.* 2002). Likewise, the census is often cited as a

poor representation of the entire population, especially pertaining to First Nations living on reserves (Statistics Canada 2003).

We chose to survey the MHOs because their education and professional expertise places them in the unique position to assess conditions that influence population health (Foster *et al.* 1992). Their responsibility extends to all communities within the province to ensure that the population is well prepared for medical emergencies or natural disasters. Moreover, the MHOs may further link policy with evidence as several of the provinces health authorities have acknowledged the importance of identifying the factors that affect the social and economic environment of the population (Fraser Health Authority 2002; Interior Health Authority 2005; Vancouver Coastal Health Authority 2005; Vancouver Island Health Authority 2005).

Methods

Study area

We chose to evaluate the MHO survey responses alongside 2001 Census Dissemination Area (DA) and Census Tract (CT) population data within the Vancouver Census Metropolitan Area (CMA) (Figure 1). In the time period leading up to 2001 Census the Vancouver CMA was home to nearly two million people, representing 55 percent of the total population of the province. Incorporated in 1886 in conjunction with the expanding Canadian Pacific Railway, the port city now boasts one of the most diverse populations in Canada—with residents living in some of the poorest and wealthiest postal codes in the country.

Geographers and social epidemiologists alike have long recognized that there are distinct geographies in health and SES outcomes throughout greater Vancouver (Bakan 1978; Hayes 1992; Burr *et al.* 1995; Dunn and Hayes 2000; Dunn 2002). Particularly well-known is the recognition of the poor living conditions of residents living in Strathcona's Downtown Eastside (DTES). Bordering the Burrard Inlet and the historic gas town district, the DTES is one of Canada's most economically disadvantaged neighbourhoods—with an average household income of $20,100, which is less than 30 percent of the average household income for the rest of Vancouver. Socio-economic barriers are not only confined to residents within the DTES. Neighbourhoods throughout greater Vancouver, including 'The Boot' planning district in lower New Westminster, Edmonds in Burnaby, and the north Surrey neighbourhoods of Whalley and Bridgeview, are collectively known to endure higher socio-economic hardships by provincial standards (Kershaw *et al.* 2005).

Health and Census data

Health data are taken from the CCHS Cycle 2.1, a cross-sectional health survey representative of the Canadian population. The CCHS is designed to allow for a comparison of health at the sub-provincial Health Region level across Canada. Data for Cycle 2.1 was collected between January and November of 2003. The target population of the CCHS is Canadians over 12 years of age who live in private dwellings. Individuals living on Reserves, Crown Lands, institutional residents and full-time members of the armed forces are excluded from the survey. Data were collected primarily by telephone using three sampling frames; 48 percent from an area frame, 50 percent from a list frame of telephone numbers and two percent from random digit dialing. In this study we use a subset of the Cycle 2.1 database (n = 6,157), which represents adult respondents between 18 and 74 years of age living in the Vancouver CMA.

Self-rated health was assessed from the CCHS question 'In general, would you say your health is: Excellent, Very Good, Good, Fair, Poor.' While self-assessed health is not a direct measure of good vs. poor health status, research suggests that it is a good proxy for health inequalities and has shown a significant relationship with levels of mortality, morbidity and health care utilization (Kaplan and Camacho 1983; Miilunpalo *et al.* 1997). For analytical purposes, individual responses were dichotomized into a *good health* component comprising responses of 'Excellent, Very Good or Good' and a *poor health* component comprising responses of 'fair or poor'.

In the 2001 Census year the Vancouver CMA contained over 400 CTs and nearly ten times as many DAs. CTs are small and relatively stable geographic areas with a population of 2,500 to 8,000 and roughly correspond in size to an urban neighbourhood. CTs are only constructed

Figure 1
Self-rated health and socio-economic data were assessed using Census Tract (CT) and Dissemination Area (DA) boundaries for the Vancouver CMA.

for large urban centers across Canada with an urban core population of at least 50,000 residents. Each CT within the Vancouver CMA represents, on average, approximately 4,000 residents. In the 2001, DAs replaced the Enumeration Area as the smallest unit of dissemination of the Canadian Census. DAs are roughly the size of a neighbourhood block and typically represent

400–700 residents. Both spatial units have been used previously in small-area analysis of census SES data as they represent a relatively homogenous geography and the characteristic of urban neighbourhoods (Krieger *et al.* 1997; Ross *et al.* 2004).

The same spatial extent was used to construct the comparison ABDI's. We chose to compare the VANDIX to the Socioeconomic Factor Index (SEFI) and the Deprivation Index for Health and Welfare Planning in Quebec (DIHWPQ) as they were separately constructed for assessing health and socio-economic deprivation in Manitoba and Québec, respectively. A complete description of both indices can be found elsewhere (Frohlich and Mustard 1996; Pampalon and Raymond 2000).

VANDIX survey and index construction

All 18 of BC's MHOs were invited to participate in the construction of the index. Respondents were contacted via e-mail and provided with an HTML link to complete the survey using a secure web server housed within the Faculty of Health Science at Simon Fraser University.[1] E-mail addresses were obtained from the Chief Provincial Health Officer. The survey was conducted between the months of June and August 2005. Using a series of closed-ended questions we asked participants to select from a list of 21 variables taken from the Census those socioeconomic variables that he or she felt best influenced relative health conditions in urban areas in BC.[2] Questions were phrased using a Likert Scale (strongly agree–strongly disagree) and additional space was provided for comments and suggestions as to other indicators that might have been included in the survey. We also asked the respondents to inform us if they were the administering health official to a predominantly urban or rural population.

The 21 variables were assigned to seven constructs and initially selected based on their ability to represent the conditions that tend to reflect social and material deprivation. All 21 Census indicators included in the survey have been used previously to construct ABDIs elsewhere. The idea was to include the variables we thought pertinent to urban areas in BC as well as other variables commonly used to construct deprivation indices elsewhere and let the local experts decide on the ones that were most relevant.

Each construct included two to six variables that can broadly be defined as representing the conditions indicative of *material wealth, housing tenure, family demographics, mobility, educational attainment, employment* or *cultural identity*. The material wealth construct consisted of two variables: average income and average dwelling value. Average income was selected given its links to a variety of health outcomes and mortality in previous studies (Wilkins *et al.* 2000). Similarly, dwelling value is an additional measure of material wealth that, like income, is a multidimensional indicator of SES and health (Dunn 2002). The housing tenure construct contained four variables that indirectly measure purchasing power, including the percentage of single-detached housing units, the proportion of renters and owners, and those residing in an apartment. These variables are important indicators of status and have previously been known to covary with health outcomes in the Vancouver area (Dunn 2002). Six variables were included in the family demographics construct, each of which is linked to long-term health outcomes (Moilanen and Rantakallio 1988; Hertzman and Wiens 1996). These six variables are an indirect means to measure the conditions that tend to reflect social deprivation. Variables included the elderly 65 and over and living alone, living alone, being the head of a single-parent family, being single, divorced, or widowed, persons under the age of five and family sizes greater than five persons. The mobility construct represented the population that changed residency within five and one years before the 2001 Census. Higher lifetime mobility rates have frequently been shown to be associated with lower SES status and poorer neighbourhood health outcomes (Ainsworth 2002; English *et al.* 2003). However, mobility is also an indicator of economic privilege (relocating for a better paying job) and may also positively co-vary with health outcomes. Unlike material wealth, educational attainment can be reflective of social

1 The IHRE web-survey can be accessed through the web at: http://www.gis.sfu.ca/survey/survey_intro.html

2 Similar phrasing was used for each question: 'Please qualify this statement. "Average income" is an influential variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas'.

position in that a person can have a low income but still be regarded in higher esteem given their level of education, or title. Education has been included as a measure of socio-economic position in previous socio-economic investigations in BC and elsewhere in Canada. The construct contained two variables representing those without a high school education and those with a university degree. Employment is one of the most well-known indicators of deprivation as it reflects the population's ability to find work and is one of the most frequently recurring variables included in deprivation index construction both in Canada and abroad. Three variables were included in the *Employment* construct, including the employment ratio, the unemployment rate and the proportion of females in the labour force, which has traditionally been included in ABDI's as a measure of social exclusion. Lastly, the cultural identity construct contained more culturally sensitive variables, including the proportion of non-Canadian citizens and the percentage of the population whose first spoken language was neither English nor French. Both variables can reflect those who are less advantaged given their citizenship, or may be subjected to additional barriers that may inhibit them from obtaining equal employment and status opportunities. A similar construct was used by Jarman (Jarman 1983).

The aggregate response scores for each of the 21 indicators were used to determine the proportional weights of the indicator variables. Strongly agree selections were given a score of five, agree selections a score of four and so on. Only the aggregation of the strongly agree and agree selections were used to create the final index as we were interested in assessing the variables that the majority of MHOs felt best influenced relative health outcomes. We administered a cut-off score to only include aggregate selections that scored greater than a 'neutral' response + 1, which signified all respondents choosing a non-neutral response greater than 'neither agree or disagree'. The selected indicator variables were ordered according to respondent preference using the inverse of the original Likert scale, with the variable that received the highest aggregate sum a ranking = 1, the next most frequently selected variable = 2 and so on. The proportional weights are calculated by

$$w_i = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

where w_i is the standardized proportional weight for the selected variable, n is the total number of variables in the index, and r_j is the ordinal position of the variable. The eventual weight of the variable is obtained by dividing its ordinal position by the summation of the ranking values $(n - r_j + 1)$.

Response validation

One of the leading arguments against the use of surveys to construct a deprivation index is the biased weights created in the process of consulting with the key participants. Techniques, such as the Kappa statistic, can help increase the confidence in stakeholder responses. The Kappa test is a method for quantifying levels of discernment when considering how two or more individuals judge a particular phenomenon (Cohen 1968). An extension of the Kappa test statistic, the weighted Kappa, was used here as it can better account for moderate differences between adjacent expert responses (strongly agree and agree) in comparison to more contrasting responses (strongly agree and strongly disagree). The calculation for k is

$$k_w = \frac{\sum wP_o - wP_e}{1 - wP_e}$$

where ${}_wp_o$ is the sum of the weighted observed agreement and ${}_wp_e$ represents the sum of the weighted expected agreement. Both the weighted an un-weighted Kappa statistics were calculated using the PROC FREQ function in SAS.© Generally, weighted Kappa scores are stronger than un-weighted Kappa scores whenever responses are more similar (i.e., strongly agree to agree) than dissimilar (strongly agree to disagree). If K_w generates a lower agreement score than an unweighted K it would suggest that their is a wide range in disagreement amongst the MHOs as to the strength of each of the indicators in characterizing relative health outcomes—perhaps suggesting that the MHOs responses may be inappropriate for building the ABDI. The

interpretation of the Kappa statistic is partitioned into quintiles on a range lying between 0–1. Within this range 0–0.2 signifies low or no agreement, 0.2–0.4 fair amount of agreement, 0.4–0.6 moderately strong agreement, 0.6–0.8 strong level agreement and 0.8–1 perfect agreement between multiple individuals.

Results

Of the original 6,157 individual self-reported health responses 2,237 individual cases were later discarded due either to missing cases, or because they included individuals who were not between 18–74 years of age. Ninety-eight percent of the CTs had at least one resident who completed the survey (n = 3,920), with an average of ten residents per CT. These numbers were reduced at the DA level, with 53 percent of the DAs having at least one resident who completed the survey, with an average of two residents per DA (n = 3,879). Prevalence estimates for the proportion of the population reporting 'fair or poor' self-rated health and confidence intervals of the responses were obtained using 500 bootstrap weights provided by Statistics Canada using SAS software (SAS Institute, Cary, NC). The bootstrap weights were used to account for the complex design of the CCHS sampling frames. Sample weights were assigned to the self-rated health responses so that results were representative of the population living within the study area. Results from the analysis between self-rated health and SES quintile are reported at the scale of the study area rather than on a case-by-case basis. This was done to protect individual confidentiality and due to the low geographic sampling of the participants who completed the CCHS survey. The coefficients of variation produced using the bootstrapping weights were used to gauge the quality of estimates between the self-rated health responses and SES quintiles. Statistics Canada guidelines state that estimates less than 16.5 percent should be considered acceptable, estimates between 16.6 percent and 33.3 percent should be flagged as marginal and estimates greater than 33.3 percent should be flagged, but not released.

The return rate of the MHO web survey was 55 percent (n = 10) with an additional one hard decline. Likewise, 70 percent of the MHOs who elected to complete the survey represented a predominantly urban population. Table 1 lists the MHO responses to each of the 21 Census variables included in the survey. Out of the initial 21 variables posted on the web-survey, eight indicators were overwhelmingly agreed upon by the MHOs (with the 8th variable [percentage of renters] later excluded due to its 1:1 relationship with the percentage of home owners). Table 2 lists the seven variables and their proportional weights for the final index.

Prevalence scores of reporting 'fair or poor' self-rated health and living in a neighbourhood classified as low through high socio-economic deprivation are listed in Figures 2 and 3. Both the VANDIX and the comparison indices produced a step-wise socio-economic and prevalence of reporting fair or poor self-rated health in both DA and CT spatial extents. At the DA unit, the range between the least and most deprived quintiles and reporting 'fair or poor' self-rated health rose from 4 percent to 17.3 percent using the VANDIX, with the greatest separation between the first two (four percent) and last two (7.5 percent) quintiles. At the CT unit scores were slightly more attenuated and rates rose to five percent in the least deprived quintile and fell to 15.6 percent in the most deprived quintile. A similar gradient between SES 1 and SES 5 was found when using both the SEFI and DIHWPQ indices at both spatial extents.

Of the 2,973 DAs assessed by all three ABDIs only 135 (4.5 percent) were dissimilarly classified within two or more SES quintile rankings. At the CT extent, however, discrepancies in SES quintile rankings between the indices was considerably higher (n = 53, 13 percent). As the prevalence scores were nearly identical for each index at both spatial extents, the results point to the possible influences of the scale effect of MAUP, but more specifically to the general importance of each variable for influencing SES. Certain indicators may be more representative of specific populations groups than others.

Figures 4 and 5 illustrate the VANDIX SES classifications throughout the core census areas within the Vancouver CMA at both DA and CT extents. Areas of known material deprivation—particularly Strathcona and its constituent communities along the Hastings corridor—were equally identified by all three indices as some of the most economically disadvantaged

Table 1
MHO selections of the social and economic variables that they felt characterized relative health outcomes within urban areas in British Columbia. SA: Strongly Agree, A: Agree, NAD: Neither Agree nor Disagree, D: Disagree, SD: Strongly Disagree

	Medical health officer									
Census variable	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Material wealth										
Average income	*A*	*A*	*A*	*SA*	*SA*	*A*	*A*	*A*	*NAD*	*SD*
Average dwelling value	*A*	*A*	*D*	*A*	*D*	*D*	*D*	*NAD*	*NAD*	*D*
Housing										
Single-detached housing	*NAD*	*A*	*NAD*	*NAD*	*D*	*NAD*	*D*	*NAD*	*NAD*	*SA*
Home ownership	*A*	*A*	*A*	*A*	*A*	*A*	*NAD*	*NAD*	*SA*	*SA*
Proportion of renters	*A*	*A*	*A*	*A*	*A*	*NAD*	*A*	*NAD*	*SA*	*SA*
Reside in an apartment	*NAD*	*NAD*	*D*	*NAD*	*D*	*NAD*	*D*	*NAD*	*NAD*	*SA*
Demographics										
Elderly 65+living alone	*A*	*D*	*NAD*	*A*	*D*	*SA*	*NAD*	*SA*	*SA*	*SA*
Living alone	*NAD*	*D*	*A*	*A*	*NAD*	*A*	*A*	*A*	*A*	*SA*
Single parent family	*A*	*SA*	*A*	*SA*	*A*	*SA*	*SA*	*NAD*	*A*	*NAD*
Separated/divorced/widowed	*A*	*NAD*	*NAD*	*A*	*D*	*A*	*A*	*NAD*	*NAD*	*NAD*
Children under age 5	*D*	*NAD*	*NAD*	*NAD*	*D*	*A*	*A*	*NAD*	*SA*	*SA*
Family size + 5 persons	*D*	*NAD*	*NAD*	*A*	*NAD*	*NAD*	*NAD*	*NAD*	*SA*	*NAD*
Mobility										
Moved in the last 5 years	*NAD*	*NAD*	*D*	*A*	*NAD*	*NAD*	*A*	*A*	*NAD*	*NAD*
Moved in the last year	*NAD*	*NAD*	*NAD*	*A*	*NAD*	*A*	*A*	*A*	*A*	*NAD*
Education										
No high school completion	*A*	*SA*	*SA*	*SA*	*A*	*A*	*SA*	*A*	*SA*	*SA*
With a university degree	*SA*	*SA*	*NAD*	*SA*	*A*	*NAD*	*SA*	*A*	*A*	*SA*
Employment										
Employment ratio	*SA*	*SA*	*D*	*SA*	*NAD*	*NAD*	*A*	*A*	*A*	*SA*
Unemployment rate	*SA*	*SA*	*A*	*SA*	*NAD*	*SA*	*SA*	*A*	*A*	*SA*
Females in labour force	*NAD*	*A*	*NAD*	*A*	*NAD*	*NAD*	*A*	*NAD*	*A*	*SA*
Other										
Non-Canadian citizen	*D*	*NAD*	*NAD*	*NAD*	*D*	*A*	*A*	*NAD*	*A*	*SA*
First language non-official	*D*	*NAD*	*NAD*	*NAD*	*D*	*A*	*A*	*NAD*	*NAD*	*A*

neighbourhoods within the entire CMA. Likewise, VANDIX SES classifications for the Edmonds neighbourhood in Burnaby in addition to Whalley in Surrey coincide with a number of recent studies which found these neighbourhoods to be more socio-economically disadvantaged relative to intra-urban and provincial outcomes (Burr *et al.* 1995; Kershaw *et al.* 2005).

There were, however, a few key SES classification concerns between the indices. Particular of which was the downtown core community of Yale Town, which wraps northward towards Stanley Park in between Burrard Inlet and False Creek. Dissimilar classifications were also noted throughout much of the Kitsilano and West Point Grey communities, which stretch from the Endowment Lands east of the University of BC along False Creek. Although the downtown core has historically scored amongst the most socio-economically deprived neighbourhoods in terms of comparison (Burr *et al.* 1995), much of the surrounding area within the Yale Town communities have been amongst the least deprived neighbourhoods since the last census reporting. Similarly, relative to the surrounding area the West Point Grey and Kitsilano neighbourhoods are also some of the most socio-economically advantaged areas in the lower mainland. Although each index highlighted the high renter/student populations living within Shaughnessey and West Point Grey at the DA spatial extent much of the surrounding areas were inversely classified using the SEFI and DIHWPQ indices when measured at the coarser extent (Figure 6), particularly the DIHWPQ index. In these areas, it may be that the general aggregation of the age dependency ratio in the

Table 2
Indicators selected to measure neighbourhood deprivation and the assigned weights. Weights were assigned proportionally according to the number of strongly agree and agree responses

Selected census indicators	Strongly agree responses	Agree responses	Sum	Rank	Weight (%)
Material wealth					
Average income	*2*	*6*	*34*	*5.5*	*0.089*
Housing					
Home ownership	*2*	*6*	*34*	*5.5*	*0.089*
Demographics					
Single parent family	*4*	*4*	*36*	*4*	*0.143*
Education					
No high school completion	*6*	*4*	*46*	*1*	*0.250*
With a university degree	*5*	*3*	*37*	*3*	*0.179*
Employment					
Employment ratio	*4*	*3*	*32*	*7*	*0.036*
Unemployment rate	*6*	*3*	*42*	*2*	*0.214*

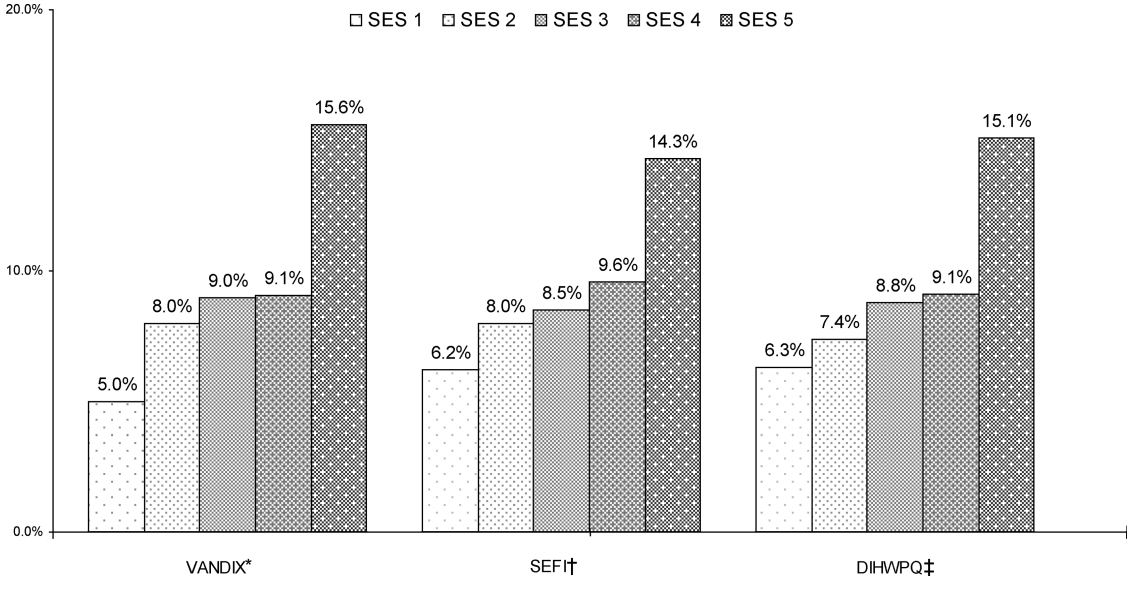

Figure 2
Census tract (CT) prevalence scores for reporting fair or poor self rated health by socio-economic quintile ranking.[a] Prevalence scores from the SEFI index were originally published in the following paper (Oliver and Hayes 2007).
[a]*Quintile 1 (value = 5.0 percent), †Quintile 1 (value = 6.2 percent), and ‡Quintile 1 (value = 6.3 percent) all have a coefficient score between 16.6 percent and 33.3 percent which is considered marginal according to Statistics Canada data quality guidelines.

SEFI index and the separated-divorced-widowed variable in the DIHWPQ are influencing the deprivation scores, which would suggest that both indices are more adapt to measuring the conditions that tend to reflect social deprivation in Vancouver rather than being used for markers of material deprivation.

The average un-weighted Kappa score of the MHO responses to the 21 census indicators was 0.06, suggesting a very low level of agreement beyond the agreement expected by chance between BC's MHOs and the variables that they felt represented the strongest relationship between SES and relative health outcomes. Although this value

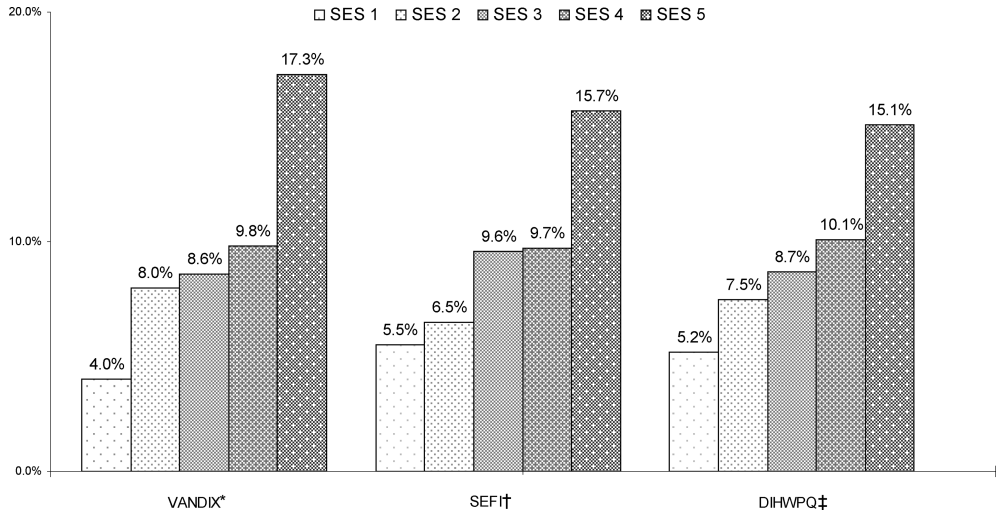

Figure 3
Dissemination Areas (DA) prevalence scores for reporting fair or poor self rated health by socio-economic quintile ranking.[a] Prevalence scores from the SEFI index were originally published in the following article (Oliver and Hayes 2007).
[a]*Quintile 1 (value = 4.0 percent), †Quintile 1 (value = 5.5 percent), and ‡Quintile 1 (value = 5.2 percent) all have a coefficient score between 16.6 percent and 33.3 percent which is considered marginal according to Statistics Canada data quality guidelines.

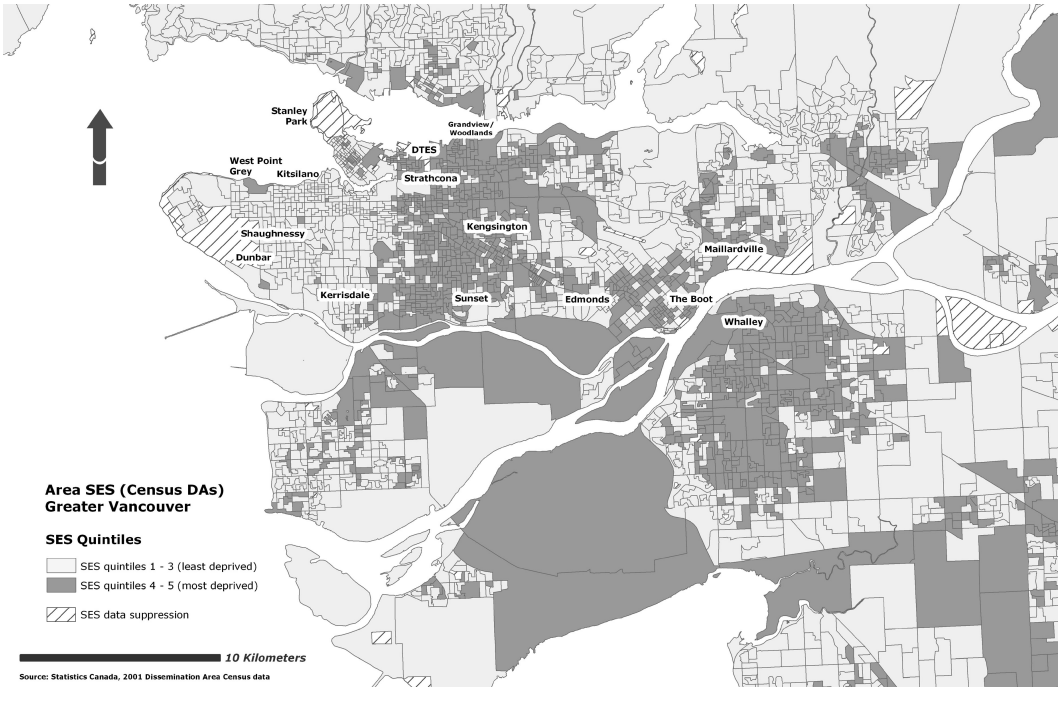

Figure 4
Greater Vancouver Census Tract (DA) SES quintile Rankings—VANDIX index.

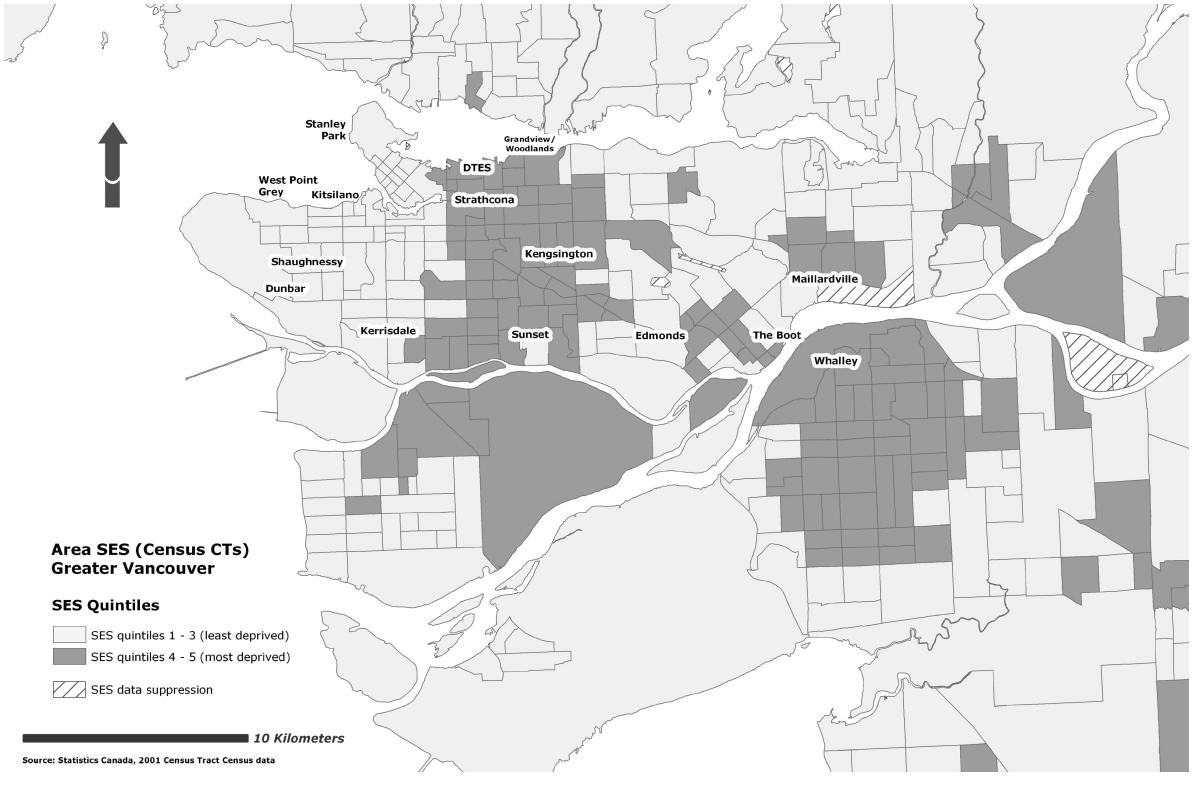

Figure 5
Greater Vancouver Census Tract (CT) SES quintile rankings—VANDIX index.

is lower than expected, the likelihood of obtaining a high Kappa statistic decreases as the number of respondents and categories increases. However, out of all 210 of the stakeholder selections there was only a single 'strongly disagree' response. We re-assessed the Kappa statistic by removing the 'strongly disagree' category from the survey (replacing MHO 10 response with a 'disagree' rating), but this had no observed effect on the value. The weighted Kappa score was stronger ($K_w = 0.16$) than the un-weighted Kappa, suggesting that although there was a low level of consistency between individual MHO responses, the magnitude of their disagreement was over a smaller (e.g., strongly agree–agree) than wider range (e.g., strongly agree–disagree). Indeed, this likely stemmed from the high proportion of 'neutral' responses ($n = 71$, 34 percent) When the three non-urban MHO responses were removed from the analysis the K_w decreased by 0.03, which suggests that there were dissimilarities between urban and rural MHO responses.

Discussion

Relatively consistent patterns were observed over most of the 210 response selections (ten respondents × 21 questions) from the MHOs. All experts either agreed or strongly agreed that having a high school education plays an important role in influencing the health of British Columbians, with all but two responses (coded as neutral) agreeing to the same extent in terms of importance of post-secondary education. Both variables are well-known indicators of not only health outcomes, but also with their link to healthy employment, income, and social cohesion (Levin 2004). Similar

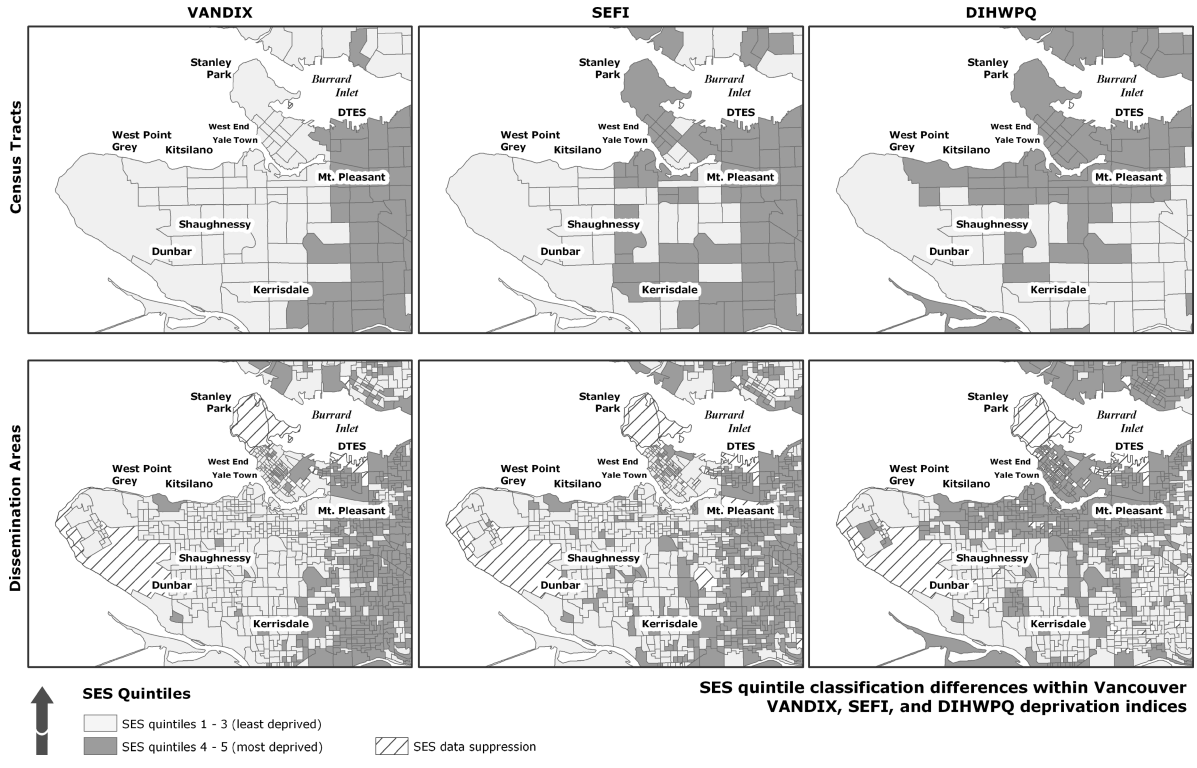

Figure 6
Comparison vignette of Vancouver and the VANDIX, SEFI and DIHWPQ quintile rankings at two spatial extents.

trends were observed in the MHO responses to income, employment, and home ownership, with only two negative responses given between all three indicators.

Not all responses, however, were similarly ranked by the MHOs, particular of which were the 'average dwelling value', 'children under 5' and 'family size + 5 persons' indicators. It is difficult to interpret the exact significance of these mixed responses, but taking into account the MHOs responses to the income, education, and employment characteristics, it is presumable to suggest that neither the household overcrowding or family demographic variables was seen as being an influential predictor of health outcomes when one is in good material standing.

Of the seven constructs, mobility produced the responses most difficult to interpret. Two of the MHOs gave neutral responses to 'moved in last 5 years', but agreed that 'moved in the last 1 year' were an important determinant of health. Three MHOs agreed that both '1 year' and '5 year' movers were an important determinant while four gave neutral responses to both indicators. One disagree response was also recorded, which when taken together, possibly suggests that there was some confusion as to whether the construct was referring to upward or downward socio-economic mobility. As mobility can be associated with either upward or downward SES, the responses leave many unanswered questions as to the importance of this indicator in influencing provincial health outcomes. This may not necessarily be the case, but further analysis, perhaps directed solely on mobility in BC, may be able to differentiate if mobility is most strongly representative of downward socio-economic trends or as an indicator of social cohesion as a result of neighbourhood stability.

Although the Kappa test statistic was low, the combination of the variables selected by the MHOs did produce a geographical distribution of relative SES similar to what is known for greater Vancouver, although some error likely remains due to the use of time-stamped data to assess current conditions. Nonetheless, our primary goal was to create a population-based deprivation index using provincial MHOs to populate the index with the census variables that they felt best-characterized relative health outcomes within BC. We considered a large number of census indicators for the web-survey and selected the variables based on empirical evidence from previous investigations both in Canada and abroad. Although the initial analysis was conducted using aggregated census data (at both DA and CT spatial extents) the VANDIX results primarily reflected a material deprivation gradient between SES and self-rated health throughout the Vancouver CMA. Although both the SEFI and DIHWPQ indices were stronger indicators of social deprivation, the similar pattern between SES and health outcomes between all three indices suggests that that the point of views of BC's MHOs can be used to construct an ABDI. Moreover, locally developed ABDIs may go further in public health policy and promotion, as they are specific to the population.

Prevalence scores between the three ABDIs examined in this research would suggest that no method is superior to another and that each indicator plays an important role in characterizing the social and material conditions that influence socio-economic deprivation amongst British Columbians. Interestingly, the differences between social and material deprivation outcomes were the smallest when the indices were measured using the more homogenous DA boundaries than the coarser CT boundaries. When using CTs, both the SEFI and DIHWPQ were more representative of the conditions that tend to reflect social deprivation than the VANDIX. As the prevalence scores between the comparison indices were nearly identical to the VANDIX this points to the likelihood that all variables selected for this analysis have some relevance in influencing health outcomes, but also to the importance of investigating local-scale determinants of health.

This study has a number of important limitations, most notably was the use of aggregated census data. Lack of age-standardization may be seen as a major limitation, however, a number of analyses have shown that neighbourhood SES does influence health independently of individual SES (Rejineveld 1998; Reading *et al.* 1999) and it is likely that this is the case here given similarity between the VANDIX and previous socio-economic deprivation studies within the Vancouver area. While future research will consider a more stratified approach with the VANDIX it should not discount these initial findings.

The Kappa statistic also suggests that the level of agreement between the MHOs who elected to complete the survey was low, which points to some contention as to which variables are most influential of poorer SES. It should be noted that the majority of responses were neutral and, not surprisingly, income, education and employment were the most agreed upon variables. Thus, it may be seen as advisable to consider the use of a single indicator, such as income, over multiple census indicators to reduce complexity. However, previous research suggests that aggregate socio-economic data, rather than individual indicators, are a stronger indication of relative standing (Boyle and Lipman 2002; Wilkins *et al.* 2002; Ross *et al.* 2004). An additional point of conflict against using a single indicator, such as income, is that implies that one earns their income in a vacuum, which discounts the importance of employment conditions, educational attainment, or housing (Blane *et al.* 1993).

The VANDIX is also somewhat restricted by the low *n* derived from the initial survey. Although there are relatively few provincial MHOs, administering a web-survey to a greater number of participants may alter the strength of the index. Again, this points to past concerns regarding replication. Different groups (e.g., social workers) may offer additional clarity as to the social determinants of health, but finer granularity may require the aggregation of local indicators that are not easily accessible—again pointing to another well-known caveat of the census. Moreover, such a granular approach may be less likely to see the forest for the trees. Additional caveats regarding the census pertain to the use of these particular administrative areas for measuring SES. Provincial MHOs oversee a substantially larger political area than local Census areas. Further studies could be conducted as to how medical health professionals

spatially conceptualize communities and if small area Census geographies are an adequate scale in which to ask health professionals to comment on the conditions that influence health outcomes.

Ultimately, both replication and the use of stakeholders will continue to lead some towards more robust computational approaches for building ABDIs. However, we have shown that the amalgamation of survey and census-based methods into a single indicator of socio-economic position revealed a very compelling picture as to the known spatial pattern of health and socio-economic inequalities throughout greater Vancouver. As it is arguable that each of the socio-economic indicators used in this investigation warrant some attention as to their importance in creating gradients in health local stakeholders may be in a better (or at least in as good as) position to comment on their importance.

The VANDIX was developed to help with public health policy and promotion in BC. For this study we chose to examine the VANDIX using self-rated health responses from the CCHS Cycle 2.1 database, but the index was designed to serve as a measure of socio-economic deprivation against a wide number of health outcomes throughout the province. Consequently, different comparisons metrics may produce different results, but given what we know about the importance of income, employment education and family dynamics in affecting health outcomes it is likely that similar gradients will be found when the VANDIX is contrasted against other variables. Currently, the VANDIX is being adopted by many of the provincial Health Authorities in an attempt to measure the broad socio-economic conditions associated with population health outcomes. The VANDIX has also been reconstructed by trauma specialists at Vancouver General Hospital to characterize the nature of socio-economic and geographic vulnerabilities for identifying populations with both high-injury risk and poor access to trauma services.

Conclusion

Gradients in health are found throughout all countries in the developed and the developing world and the patterning of SES carries with it information about how and where these gradients appear. Developing approaches that incorporate local stakeholders in the design of census-based socio-economic indicators is particularly germane to researchers engaged with public health policy and promotion. High-risk communities may benefit from a more local perspective of the broad day-to-day conditions that influence health outcomes. Provincial MHOs have a strong understanding of the factors that influence quality of life and building ABDIs from their point of view may be more beneficial than importing a previously constructed metric. However, survey-based methods may seem to act contrary to what has largely been an evidence-based science built on replication and predictability. Moreover, constructing place-specific deprivation indices leads us further away from a universal indicator of social position, but these concerns should not downplay the importance of integrating individuals who are theoretically informed and in a position to draw attention to the relationship between SES and health.

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Disclaimer

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