



Neighbourhood socioeconomic status indices and early childhood development



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ABSTRACT

The developmental health of young children is highly influenced by the socioeconomic conditions in which they are raised. How to accurately measure these conditions is a point of debate in the current literature on child development, health, and social determinants. We have evaluated four existing indices of socioeconomic status (SES) to determine the most relevant for the analysis of early childhood development (ECD) in Canada. Following a literature review of published SES indices which used 2006 Canadian Census data, four indices were chosen based on their relevance to ECD and the number of citations in subsequent articles. These were: the Canadian Deprivation Index, the Socioeconomic Factor Index, the Canadian Marginalization Index and an index created by the Early Childhood Mapping Project in Alberta, Canada. The indices were replicated using SES data for 2038 customized geographic neighbourhoods encompassing 99.9% of the Canadian population, and the relationship of the indices to ECD was investigated by linking to aggregated data from the Early Development Instrument (EDI), a teacher-completed questionnaire used to assess kindergarten children's physical, social, emotional, and cognitive development, and communication skills. The derived SES indices were compared based on four criteria: the input variables used, the index structure, the interpretability of the index and the variance they explained (R^2) in the different EDI outcome measures. In terms of variance explained, material components of the SES indices (e.g., income, education) consistently showed the strongest association with children's language and cognitive development. The patterns of association for the non-material SES components and the other developmental domains of the EDI were more complex. We discuss the findings in regard to current developments in the field, and the need for refining empirical and theoretical approaches to examine associations between different facets of SES contextual factors and different aspects of ECD outcomes.

1. Introduction

Socioeconomic gradients in health outcomes have existed since the development of the first forms of agriculture, when the previously existing collective mentality of the hunter-gatherer communities was replaced by competitive independent workers (Frank & Mustard, 1994). Over time, the relationships between SES and health have evolved along with society. Socioeconomic gradients in health outcomes have both direct causes such as differences in access to nutrition, hygiene, work conditions, exposure to toxins, and exercise, as well as

indirect causes such as the impact of SES on stress levels and immune response (Frank & Mustard, 1994). Our understanding of health gradients at the individual level improved considerably after the Whitehall Study of British civil servants in 1967 (Marmot et al., 1991), which suggested that even after controlling for differences in behavioural factors, such as smoking and exercise, social class still had a substantial association with the health status of individuals. This was a seminal finding, because it suggested that aside from day-to-day access to resources, gradients in health outcomes may also be affected by other factors accumulating over the course of individuals' lives. In

Abbreviations: The CanDep Index, The Canadian Deprivation Index; The SEFI, Socioeconomic Factor Index; The ECDMap Index, The Early Childhood Mapping Project Index; The CanMang Index, The Canadian Marginalization Index

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particular, the Whitehall Study gave rise to an enhanced focus on stress as a critical causal mechanism that linked differences in social status to health outcomes. Furthermore, the study was seminal in spurring research in the area of social determinants of health. As a result, research over the past decades has accumulated evidence that shows that multiple social determinants, referring to the social conditions in which an individual lives, works and grows up, shape every person's day-to-day experiences.

“Socioeconomic status is commonly conceptualized as the social standing or class of an individual or group. It is often measured as a combination of education, income and occupation”, (American Psychological Association; <http://www.apa.org/topics/socioeconomic-status/>). This is one of many similar definitions of socioeconomic status (SES) found within social science literature. As the term implies, the concept of SES includes a social aspect and an economic aspect. SES is conceptualized as a composite measure combining economic (finance and wealth), human (education and training) and social (family and community relationships) resources and safeguards (i.e., “capital”) to which individuals or a community have access (Bradley & Corwyn, 2002). Townsend (1987) defined SES as the level of social and material deprivation of an individual in a society. He referred to deprivation as a state of disadvantage below socially acceptable levels compared to an individual's peers or surrounding community. While SES is often approximated by socioeconomic variables such as income or education, most authors acknowledge that single variables do not capture the complexity of the concept of SES (whether at an individual or group level) since it is inherently multi-dimensional (Krishnan, 2010; Martens, Frohlich, Carriere, Derksen, & Brownell, 2002; Matheson, Dunn, Smith, Moineddin, & Glazier, 2012; Messer et al., 2006; Pampalon & Raymond, 2000; Townsend, 1987). Rather, it is commonly proposed to use indices that combine multiple variables into overarching themes. Indices can differ in their variable composition and structure. While some indices were created based on the more traditional definition of SES involving social and material variables at various levels of analysis (Martens et al., 2002; Pampalon & Raymond, 2000; Townsend, 1987), others use expanded definitions that include cultural and demographic variables as well (Krishnan, 2010; Matheson et al., 2012). In health research, SES indices have commonly been used to examine socioeconomic gradients in population health outcomes, such as mortality, life expectancy, or disease prevalence rates (Krishnan, 2010; Martens et al., 2002). In addition to general health, SES at various levels of analysis has been shown to be associated with several indicators of child health. For instance, neighbourhood SES has been shown to relate to child injury rates (Brownell et al., 2010). Both neighbourhood- and family-level SES have been shown to correlate with childhood hospitalizations (Jutte et al., 2010). Further, family SES has been shown to correlate with mental health outcomes such as anxiety, ADHD, conduct disorders, and depression (Essex et al., 2006).

Individuals' experiences and socioeconomic circumstances can become biologically embedded over their lifetimes, especially during the developmentally sensitive period of early child development (ECD, Hertzman & Boyce, 2010), and thus influence a large range of health outcomes throughout the lifespan. The first five years of a child's life in particular are critically important for further development as they lay the foundations for development of complex skills in middle childhood and adolescence. Foremost, physiologically-based competencies, such as vision or hearing, need to be established in an optimal way in the first two years of life. Further, skills such as reasoning, understanding of symbols and relative quantities, self-regulation, develop through preschool years, with executive functioning – the decision-making skills – not fully maturing until adolescence. In the first years, the domains of development – physical, social, emotional, and cognitive (language, problem-solving, communication) are very closely intertwined and correlated, and they are all reflecting the level of the child's developmental health. These domains all contribute to later markers of success such as academic achievement (Brinkman et al., 2013; Davies,

Janus, Duku, & Gaskin, 2016; Guhn, Gadermann, Almas, Schonert-Reichl & Hertzman, 2016), and socio-emotional well-being in later grades (Guhn, Gadermann, et al. 2016; Romano, Babchishin, Pagani, & Kohen, 2010). The Early Development Instrument (EDI, Janus & Offord 2007) is the only currently available indicator of ECD that allows researchers to examine variability across all of Canada in regard to children's early physical, social, emotional, language and cognitive, and communication skills development. In this paper, the five domains measured on the EDI will be referred to as measures of developmental health: optimal early child development is equivalent to optimal developmental health. Simply put, a child cannot achieve a high level of proficiency in the domains addressed here without being physically and mentally healthy.

There has been considerable attention in the recent population health literature given to the relationships between SES and ECD, since ECD is a strong determinant of health outcomes later in life (Case, Fertig, & Paxson, 2005; Heckman, 2011; Johnson & Schoeni, 2011). For example, Currie (2009) showed that children's SES has a causal effect on labour market outcomes later in life, perpetuated through gaps in childhood health. Further, in the late 1990s, a number of prominent researchers proposed that socioeconomic gradients for children might not exactly follow those for adults (Keating & Hertzman, 1999). In a comprehensive review of neuroscience research, aiming to determine the effects of traditionally defined (material and social) SES at the individual level on the developing brain, Hackman & Farah (2009) found that children's SES backgrounds tended to have a significant impact on various parts of the brain while developing in early childhood and in particular on the parts that control language and executive function. There is also some contradictory evidence in the literature regarding the SES measurement level most relevant to developmental health outcomes. For instance, in Chicago, Gibson, Sullivan, Jones, & Piquero (2009) found that neighbourhood SES was significantly correlated with children's self control, but this became non-significant when family-level SES was taken into account. In contrast, in a study of children in the Netherlands, Kalff et al. (2001) found that a significant effect of neighbourhood SES on child behaviour problems existed irrespective of individual-level SES.

What is lacking in the literature is a nuanced understanding of which operationalizations of SES are most relevant to ECD outcomes. In the current literature, associations are mostly examined using SES indices created for general populations, rather than for children specifically. The purpose of this paper is to evaluate different measures of neighbourhood SES based on their variable composition, structure, interpretability and level of association with ECD outcomes. In particular, we investigate which attributes of previously published and widely used Canadian SES indices are most important in the analysis of ECD, as measured by the EDI. It is our goal that ECD researchers use the findings of this study to inform their choice of neighbourhood SES indices. Particularly, our work will provide them with the necessary criteria to select an SES measure that will fit the requirements of their respective analyses.

2. Methods

2.1. Selection of Canadian census-based SES indices

The first step in our study was to identify Canadian census-based neighbourhood SES indices that had previously been used in research studies to examine socioeconomic gradients in health. Important pragmatic criteria for our search were that SES indices had to be derived using Canadian census data and that the source needed to provide methodological detail that would allow us to replicate the SES indices for our own empirical analyses. The complementary conceptual criterion was for the selected indices to have been based on theoretical underpinnings of the association between SES components included in the index and child health outcomes. Specifically, this final criterion

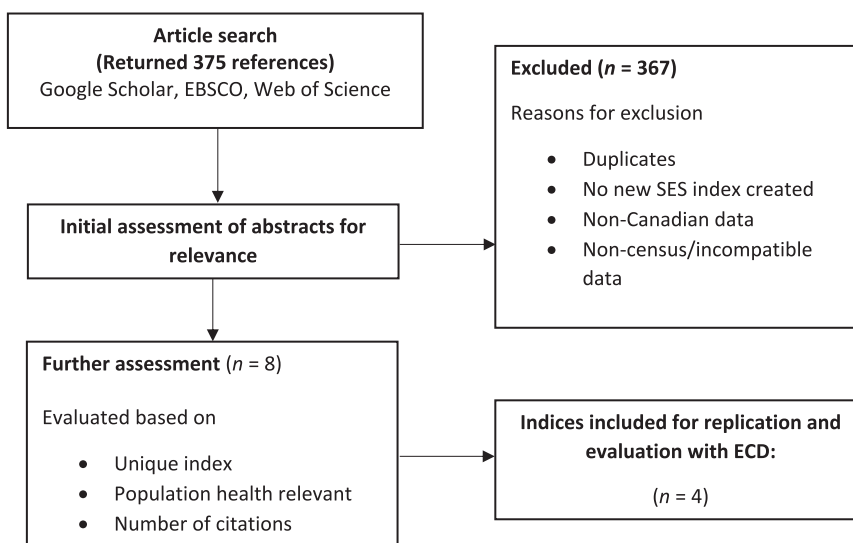


Fig. 1. Process used to select SES indices for replication.

was satisfied if an index was designed as a proxy for the social determinants of general health in a neighbourhood, and hence might have been a good proxy of the social determinants of developmental health in a neighbourhood as well. We conducted our initial search in EBSCO, Web of Science and Google Scholar using the keywords: “Index” AND “Census” AND “Health” AND (“Area based” OR “Neighbourhood”) AND “Canadian” AND (“Socioeconomic” OR “Deprivation”). The initial search, limited to results that were either French or English and published after the year 2000, yielded 6780 results. We found most of these articles used previously created indices to analyze relationships, rather than methodologies for creating indices. We therefore repeated the search, but narrowed the selection down to articles which included the terms “methods” and “principal components”. This resulted in 375 articles, which were narrowed down to eight publications (Chateau, Metge, Prior & Soodeen, 2012; Kitchen, 2001; Krishnan, 2010; Krishnan, Betts, & Wang, 2012; Matheson et al. 2012; Pampalon & Raymond, 2000; Vanasse et al., 2015; Vincent & Sutherland, 2013), by excluding 367 articles based on the criteria outlined in Fig. 1. Among the publications that created a unique index intended for use with population health outcomes, we selected the four indices with the highest citation counts (at the time of the search), according to Google Scholar: The Canadian Deprivation Index (136 citations), the Socioeconomic Factor Index (53 citations), the Canadian Marginalization Index (34 citations), and the Early Childhood Mapping Project Index (16 citations). In the next section, we provide a summary of each of the four selected SES indices.

2.1.1. Canadian Deprivation Index (Pampalon, Hamel, Gamache, & Raymond, 2009; Pampalon & Raymond, 2000)

The Canadian Deprivation Index (referred to in this paper as “CanDep”) was developed by Robert Pampalon and Guy Raymond in 2000 through l’Institut National de Santé Publique du Québec. The authors created the index using Dissemination Area (DA) level data from the Census as an approximation of socioeconomic deprivation, so that it could be linked to administrative hospital databases using postal codes to study relationships between health and neighbourhood SES in Québec. They adopted the definition of “deprivation” from Townsend (Pampalon & Raymond, 2000), who outlined the concept as both an economic and social state. The index was constructed using principal component analysis (PCA) to combine six variables (representing education, income, employment, divorce rates, lone households and lone parent families) into two components: material and social (see Supplementary Document Table A1). The index was reproduced at the Pan-Canadian level by Pampalon et al. (2009).

2.1.2. Socioeconomic Factor Index (Chateau, Metge, Prior, and Soodeen, 2012; Martens et al., 2002)

The Socioeconomic Factor Index (SEFI) was created for the province of Manitoba using DA-level data. The Manitoba Centre for Health Policy (MCHP) created the SEFI in 2002 (Martens et al., 2002) as an indicator of socioeconomic status without using income. The reason for this was that before 2006, neighbourhood average income was suppressed in the Canadian Census using a conservatively low population count threshold, which in turn meant missing neighbourhood income data for many sparsely-populated neighbourhoods such as those in the province of Manitoba. When the threshold of data suppression was raised in the 2006 Census, MCHP updated the SEFI to a less complex version which included average income (Chateau et al., 2012). The SEFI uses four variables (education, income, single parents, and unemployment) combined into one index using PCA (see Supplementary Document Table A2).

2.1.3. Canadian Marginalization index (Matheson et al., 2012)

The Canadian Marginalization (CanMarg) index was originally constructed using Canada-wide DA-level geographic data. The Centre for Research on Inner City Health created the CanMarg index in 2006, driven by the hypothesis that other dimensions of deprivation may play an equal (if not larger) role than economic deprivation in developed countries such as Canada. The CanMarg is therefore a multi-faceted index, presenting an alternative to earlier indices which focused primarily on economic attributes of SES. Using the CanMarg’s 18 variables, Matheson et al. (2012), derived four components using PCA - residential instability, ethnic concentration, material deprivation, and dependency (see Supplementary Document Table A3).

2.1.4. Early Childhood Mapping Project index (Krishnan, 2010)

The Early Childhood Mapping Project (ECMap) index was created in Alberta using DA-level data. The index was constructed by deriving five components from 26 variables using PCA. The ECMap index was created with the intent of constructing a socioeconomic index specifically targeted to the analysis of early childhood development outcomes (Krishnan, 2010). All neighbourhood-level variables were chosen based on previous literature’s findings for theoretically important and policy-relevant socioeconomic status variables. The ECMap index is unique among the four indices included here in that the author does not state interpretations for the components of the PCA but rather suggests that the components should be named according to the variables with which they are highly associated. The author’s PCA resulted in five components which represented the following neighbourhood ‘systems’: ma-

terial system, social system, and cultural system, as well as two components which were not directly interpretable as a common construct.

2.2. ECD outcomes: Early Development Instrument data

Our measure of ECD came from the EDI (Janus & Offord, 2007), which measures children's developmental health at school entry. With data collected at a population level since the early 2000s in many Canadian jurisdictions, the EDI offers a unique opportunity to analyze the relationship between the SES indices and ECD. The EDI is a 103-item questionnaire, which kindergarten teachers complete for each child in their classroom in the second half of the kindergarten year. The EDI assesses children's developmental health in five developmental domains: Physical Health and Well-Being, Social Competence, Emotional Maturity, Language and Cognitive Development, and Communication Skills and General Knowledge. The Physical Health and Well-being domain consists of 13 items, the Social Competence domain 26 items, the Emotional Maturity domain 30 items, the Language and Cognitive Development domain 26 items, and the Communication Skills and General Knowledge domain 8 items. Internal consistencies for the five domains were shown to be satisfactory: Physical Health and Well-Being 0.84; Social Competence 0.96; Emotional Maturity 0.92; Language and Cognitive Development 0.93; and Communications Skills and General Knowledge 0.95 (Janus & Offord, 2007). Many previous studies have confirmed the psychometric properties and validity of the EDI in Canada and other jurisdictions, based on its differential item functioning, multilevel validity, factor structure, internal consistencies, and associations with other developmental outcomes (Brinkman et al., 2013; Brinkman et al., 2007; Chateau et al., 2012; Forer & Zumbo, 2011; Guhn, Gadermann, & Zumbo, 2007; Hymel, LeMare, & McKee, 2011; Janus et al., 2007; Lloyd, Irwin, & Hertzman, 2009).

Six EDI outcomes were used in our analyses: the neighbourhood-level proportion of vulnerable children for each of the five developmental domains along with overall vulnerability, defined as the proportion vulnerable on one or more domains (Janus et al., 2007). Vulnerability on each domain is determined if children's scores fall below the lowest 10th percentile boundary for the domain. The percentile distribution was based on a normative Canadian dataset of children. The rationale for using a dichotomous measure of overall vulnerability based on the 10th percentile cut-off is two-fold. First, it provides a summary EDI-based measure without the necessity of averaging or summing scores among the five domains of school readiness. Second, the overall vulnerability score captures children who have multiple domain strengths and also weaknesses.

2.3. Neighbourhoods

Neighbourhoods were custom-defined for this project to create area-level units that allowed for aggregate data analyses. Specifically, we aimed to examine the ecological correlation between neighbourhood-level vulnerability rates on the EDI and neighbourhood-level SES data. Neighbourhoods for this study were defined using a standardized set of criteria for all 12 provinces/territories in Canada that participated in the EDI data collection (the technical details of this neighbourhood definition process are listed in Guhn, Janus, et al. 2016, Box 1 and 2, Pg. 4 - 5). One central criterion when defining the neighbourhoods was to have EDI data for at least 50 children per neighbourhood; this helps ensure sufficient statistical reliability of the EDI vulnerability scores, as well as meeting confidentiality requirements. The final 2,038 neighbourhoods in the paper have total population sizes of 355 to 95,295 people (based on the 2006 Census) and cover areas of 0.42 to 792,320 square kilometres – ranging from a city block in densely populated urban areas, to large areas (thousands of square kilometres) in remote rural areas. The neighbourhoods were also socioecono-

mically diverse: the median income in the neighbourhoods ranged from 9,800 to 52,000 CAD, unemployment ranged from 1% to 46% and the percentage of lone parents ranged from 2% to 47%.

It is important to note that with our neighbourhood-level data, the SES-ECD relationships we observe could be a result of two effects: intra-family effects (a combined average of the individual family effects) and inter-family effects (the relationships between families in the neighbourhood). While our neighbourhood-level analyses cannot differentiate between these two effects, it is important to be aware that our analyses measure aggregate level relationships, which may be a combination of several factors. Therefore, we would like to emphasize that readers should be careful not to generalize the findings to be representative of either of these effects on their own.

2.4. EDI data collection timeframes

It has been theorized that a child's development is influenced most by the socioeconomic conditions concurrent with the time of birth and/or first years of life (Center on the Developing Child, 2007). Since the Canadian Census variables used to construct the indices were from the 2006 Census, EDI data collected in 2010—if available—were considered the most relevant. The children with existing EDI data from that cohort would have been 1–2 years of age at the time of Census data collection.

However, EDI data were not available in all provinces in 2010, so our protocol was to use the EDI data closest to 2010 for each province and territory. This resulted in a dataset consisting of a single time point from each of 2,038 neighbourhoods in Canada. Provincial/territorial EDI collection timeframes used are shown in Table 1. It is important to note that there is a standard protocol for collecting EDI data in all provinces/territories so the data are directly comparable. It is also noted that for some provinces, population-level EDI data were obtained over the course of more than one year, as shown in Table 1 (see edi.offordcentre.com for additional details about the EDI).

2.5. Analytical strategy

The methods used for deriving the SES indices were replicated based on the information provided by the developers of the indices. The only differences between the original indices and the replicated indices used in this paper are that the latter use our custom-defined neighbourhoods as geographic units, and use a Canada-wide scope for the analyses. The details of the replication process and differences in component loadings for the indices are provided in a separate

Table 1

EDI data collection timeframes for each Canadian province/territory. Each individual in the sample has a single EDI assessment.

Province/ Territory	Data collection timeframe	Number of neighbourhoods ^a	Number of individuals in the analysis
Alberta	2009 to 2013	267	36028
British Columbia	2009 to 2011	285	46160
Manitoba	2011	75	12191
New Brunswick	2009	52	6922
Newfoundland	2013	41	4792
Northwest Territories	2012	3	578
Nova Scotia	2013	57	8309
Ontario	2010 to 2012	796	123944
Prince Edward Island	2008	6	1035
Québec	2012	395	64977
Saskatchewan	2009 to 2011	55	10744
Yukon	2010	6	335
	Total:	2038	316015

^a Neighbourhoods are custom-defined geographical units developed for this project. Data were not available for Nunavut.

Supplementary Document.

To compare the indices with each other statistically, both overall and at the component level, regarding associations with ECD outcomes, we performed a number of linear regression analyses. The first step used measures of fit (adjusted R² values) from regressions to investigate which of the indices were associated with the most variation in overall vulnerability on the EDI. These analyses used the percentage of children in a neighbourhood vulnerable on one or more of the EDI domains as the dependent variable, and – in analyses for each of the four indices, respectively – all components of the given index as independent variables. The reason for including the components separately (rather than the overall index score) is that each index had a different method suggested for combining its components into a single index, which would have led to four indices with different scales and formats (e.g., some discrete quartile rankings and some continuous scales). To enable the fairest comparison of indices, we used, for each component, the standardized, continuous scores, and reported adjusted R² (instead of R²) to account for the different number of explanatory variables. To establish whether the explanatory power varied substantially between provinces, we reported the adjusted R² values for the four largest (in terms of number of neighbourhoods) Canadian provinces individually, Ontario, British Columbia, Québec, and Alberta, as well as the Pan-Canadian level. This was a necessary step in the analysis because there are important jurisdictional differences between Canadian provinces (particularly policy differences and geographic attributes). To supplement these findings, we also calculated the adjusted R² values for regressions of the overall index scores on overall vulnerability, to demonstrate the effect their respective aggregation methods have on the indices’ explanatory power. The last set of regressions explored the relationships between the indices and the five EDI domains, as well as the overall vulnerability at the pan-Canadian level.

While the explanatory power of the various indices is a major part of the analysis in this paper, we would like to note that we do not make a claim that this is the most important criterion for choosing or particularly for creating an appropriate index to measure developmental outcomes. We use this metric as a way to compare the indices based on the amount of variation explained in EDI scores. Along with choosing an index in which at least some of the components are found in the literature to be correlated with ECD outcomes, in practice several additional non-empirical criteria (such as variable composition, index structure, and interpretability) should be considered when one is selecting an appropriate index. We include a discussion of the relevant factors to an appropriate index in Section 4.

3. Results

3.1. Descriptive statistics of sample

Table 2 shows descriptive statistics for the EDI vulnerability rates of the 2038 neighbourhoods with data in the timeframe chosen for the analysis in this paper (closest available provincial EDI collection to 2010). All of the SES indices are structured using z-scores to create their components and therefore all of the components of the indices have a mean of 0 and a standard deviation of 1 across the neighbour-

Table 2 Descriptive Statistics of the neighbourhood-level vulnerability rates.

	N	Mean	SD	Min	Max
Physical Health and Well-Being	2,038	11.8	6.6	0.0	41.5
Social Competence	2,038	10.8	5.4	0.0	36.5
Emotional Maturity	2,038	13.1	5.4	0.0	37.7
Language and Cognitive Development	2,038	9.1	5.2	0.0	38.1
Communication Skills and General Knowledge	2,038	13.3	6.7	0.0	50.8
One or More Domains	2,038	28.2	9.2	2.7	66.4

hoods in the sample.

3.2. Overall vulnerability

Using Pan-Canadian data, and overall EDI vulnerability as the dependent variable, the ECD index had the largest adjusted R² (0.25), followed by the CanDep (0.17) and CanMarg (0.17) indices, and the SEFI (0.16). The indices were regressed on overall vulnerability for each of the four largest provinces to investigate whether or not the effects of the indices were consistent across these provinces (see Table 3). For all four indices, the provincial analyses suggested that the effects are not always consistent across the four provinces. For example, all four indices had the largest adjusted R² from the regression with Alberta data and the lowest values for Québec data.

While these regressions with individual PCA components allow the effects of the different dimensions of an SES index on the outcomes to be examined, it is also common practice to combine components into an overall index. Other than the CanDep index, all of the source papers provided a method for combining their components into a unidimensional index. For the CanDep, we took the average of the material and social components (standardized scores) as the index. When adjusted R² values from regressions of these indices on the overall level of vulnerability were examined at the Pan-Canadian level (see Table 4), all values were of similar or smaller magnitude than the adjusted R² values when the components were left separate. The two indices with a larger number of components (the CanMarg and ECD indices) showed the largest decrease in adjusted R² when they were combined into aggregate indices. The two aggregate indices which explained the most variation in overall vulnerability were the CanDep and ECD indices (both 0.17 adjusted R² values).

3.3. EDI Domains

Tables 5 and 6 show adjusted R² values and coefficients from regressions using vulnerability rates in each of the five domains as the dependent variables and the individual PCA components of each index as the independent variables. Since the indices were in standard deviation units, the size of the regression coefficients can be compared to each other and these represent the average increase in the

Table 3 Adjusted R-squared values of regressions on the overall percent vulnerability on the EDI in a neighbourhood by province.

Index # Components:	CanDep 2	SEFI 1	CanMarg 4	ECD 5
Ontario	0.31	0.31	0.30	0.33
Alberta	0.40	0.41	0.46	0.48
British Columbia	0.28	0.30	0.35	0.38
Québec	0.17	0.14	0.15	0.17
Pan-Canadian	0.17	0.16	0.17	0.25

Note: Regressions included all components from the PCA of a respective index as regressors, separate from each other.

Table 4 Adjusted R² values of four separate regressions using the aggregated indices as independent variables and the percentage of children vulnerable on one or more domain on the EDI as the dependent variable (Pan-Canadian level, N=2038).

Aggregated Indices	Adjusted R ²
CanDep Index ^a	0.17
Socioeconomic Factor Index	0.16
CanMarg Index	0.13
ECD Index	0.17

^a While this method was not developed by the authors, this variable represents the mean score on the social and material deprivation components of the CanDep index.

Table 5

Adjusted R² values for regressions using the five EDI domains and overall vulnerability (on one or more domains) as dependent variables and the components (n) of the four indices as independent variables (each domain/index combination was a separate regression).

Adjusted R ² Values						
Index (# Components)	Physical Health and Well-Being	Social Competence	Emotional Maturity	Language and Cognitive Development	Communication Skills and General Knowledge	One or More Domains
CanDep (2)	0.12	0.10	0.15	0.19	0.07	0.17
SEFI (1)	0.09	0.09	0.10	0.19	0.08	0.16
CanMarg (4)	0.08	0.09	0.13	0.18	0.20	0.17
ECMap (5)	0.24	0.13	0.17	0.25	0.27	0.25

percentage of vulnerability given an increase of one standard deviation in the given component. The coefficients for the two additional components in the ECMap index were included in the estimations in Tables 5 and 6, but are not shown in Table 6 since they were not directly interpretable in our replicated version.

3.4. Overall Vulnerability

Even though the specific variables, the number of components, and the nature of those components in indices are different, some components that reflect the differentiation of larger constructs pertaining to socioeconomic aspects of neighbourhoods appear in several indices, and those can be compared at this broad construct level. For overall vulnerability, the material components of the CanMarg and CanDep indices had the largest effect sizes for their respective components, while the social component of the ECMap index had the largest effect size among its components (Table 6). Shown in Table 5, when all PCA components of the indices were considered together the ECMap index, compared with the other three indices, had the largest adjusted R² value when regressed on overall vulnerability (0.25).

3.5. Physical Health and Well-Being

The ECMap index had the highest adjusted R² value in all five of the individual EDI domains (Table 5). The CanDep index had the second highest adjusted R² value (0.12) when regressed on the percentage of children in a neighbourhood who were vulnerable on the *Physical Health and Well-Being* domain, followed by the SEFI (0.09) and CanMarg (0.08) indices. The social deprivation components of the CanDep and ECMap indices had larger effect sizes on the *Physical Health and Well-Being* domain compared with the other components

Table 6

Effect sizes (regression coefficients) of 24 separate regressions using the five EDI domains and overall vulnerability (on one or more domains) as dependent variables and the PCA components of the four indices as independent variables (each domain/index combination was a separate regression).

Regression Coefficients in Standard Deviations							
Index	Domain:	Physical Health and Well-Being	Social Competence	Emotional Maturity	Language and Cognitive Development	Communication Skills and General Knowledge	One or More Domains
CanDep	Material	1.42	1.23	1.18	1.92	1.45	2.83
	Social	1.86	1.14	1.76	1.26	1.00	2.57
SEFI	General	1.96	1.59	1.66	2.26	1.86	3.62
CanMarg	Residential Instability	0.75	0.11 ^a	1.17	0.18 ^a	-0.64	0.43 ^a
	Ethnic Concentration	-0.02 ^a	0.85	-0.34	0.46	2.78	1.76
ECMap ^b	Material Dependency	1.56	1.17	1.26	2.05	1.36	2.90
		-0.15 ^a	0.26 ^a	-0.15 ^a	-0.15 ^a	0.36 ^a	0.02 ^a
	Cultural	.71	.81	1.21	1.82	.78	2.12
	Social	-.10 ^a	.65	-.22 ^a	.67	2.51	1.70
		1.91	1.02	1.77	1.30	.79	2.53

The largest effect size in each regression, when more than one component is present is shown in bold

^a Regression coefficients are not significant at p < 0.01.

^b The two additional components of the ECMap index were also included in these regressions but were not reported in this table since they were not interpretable.

have the second highest value (both 0.19). CanMarg has the lowest adjusted R^2 value for this domain (0.18). All three indices have individual components and the results showed that their material components had a larger effect than their other components on this domain.

3.9. Communication Skills and General Knowledge

Both the CanDep index and the SEFI had relatively low adjusted R^2 values (0.07 and 0.08, respectively) when regressed on the percentage of children in a neighbourhood who are vulnerable in the *Communication Skills and General Knowledge* domain compared with their values for other domains. The opposite was true for the CanMarg and EMap indices, which had their highest adjusted R^2 values in this domain (0.27 and 0.20, respectively). The components related to language/immigration in both the EMap and CanMarg indices had the largest effect sizes when regressed on this domain, while the material component of the CanDep index had its largest effect size for this domain.

4. Discussion

We set out to explore to what extent the four most commonly cited Canadian census-derived SES indices are associated with children's developmental health in kindergarten, measured by the EDI, in over 2000 neighbourhoods encompassing 99.9% of the Canadian population. The discussion therefore focuses on the strengths and weaknesses of the four indices in the analysis of variations in the EDI across Canada. The design of each index has two adjustable 'input' parameters: variable choice and index structure. The four criteria for evaluation include these two, along with two outcome measures for the indices: explanatory power and interpretability. We use the term interpretability to convey the level of ease with which an index (and its components) can be understood and used in analyses to draw meaningful conclusions.

The EMap index showed the strongest associations with the EDI neighbourhood vulnerability rates. It had the highest adjusted R^2 values across the four provinces examined as well as for Canada as a whole; this was true for all five domains of the EDI and for overall vulnerability. However, this should not be surprising because the EMap index uses the most variables and has the largest number of components allowing for more flexibility in regression results. However, when the indices were aggregated into single measures, the adjusted R^2 value of the EMap index was similar to that of the CanDep index and the SEFI. The main limitation of the EMap index might be the lack of interpretability. The large number of variables in the EMap index made it difficult to interpret what construct was being measured by each component. Further, we were not able to interpret two of the components due to the diverse nature of the variables which loaded strongly on them. Amongst the more easily interpretable components, there were some unexpected results based on large component loadings. For example, the variable representing the percentage of the population in the respective neighbourhood using public transit regularly showed the highest degree of correlation with the cultural component (see [Supplementary Document](#)). Overall, the EMap index demonstrates that an index with a large number of variables can achieve high explanatory power over EDI outcomes, but also that there can be a trade-off between explanatory power and interpretability with regard to the number of variables and the grouping of these variables into an index.

The CanMarg index had the second highest adjusted R^2 in two out of the four provinces examined. At the same time, its adjusted R^2 values tended to be similar to, or below, those of the SEFI and CanDep indices in all EDI domains other than the *Communication Skills and General Knowledge* domain. In this domain, the EMap and CanMarg both have relatively high associations. Relative to their other compo-

nents, the effect sizes of the components representing immigration/language in a neighbourhood was the largest for both of these indices. This suggests that the relationship between these components and the *Communication Skills and General Knowledge* domain is driving a large proportion of its explanatory power on overall vulnerability. This makes intuitive sense because the *Communication Skills and General Knowledge* domain primarily represents children's proficiency in communicating in the schools' language of instruction, which would be a challenge for the newly immigrated families in a neighbourhood coming from language backgrounds other than English or French. The fact that the CanMarg index has 18 variables representing a diverse range of constructs poses a limitation/challenge in terms of interpretability. Also, when combined into an aggregated index, the CanMarg index has the lowest adjusted R^2 value among all of the other indices.

The SEFI's biggest advantage, in our view, was its interpretability. With only four variables and one component, it was arguably the most easily interpretable index we examined. Its adjusted R^2 values were of a comparable magnitude to CanDep and CanMarg across most provinces and domains. However, while the advantage of the SEFI was the simplicity of its single component structure, it was also its disadvantage. The single component did not allow for the SEFI to be used in the discussion of differential effects sizes between different aspects of SES, and excluded language/immigration factors altogether. This said, the results indicate that a relatively simple index, such as the SEFI, may be as useful as the more complex indices in terms of explanatory power for ECD outcomes if highly relevant variables are used.

The CanDep index's advantage is that it performed moderately well on all of our criteria, making it a well-rounded index. In terms of explanatory power, the CanDep index performed similarly to the SEFI and the CanMarg index. When aggregated, the CanDep index had one of the highest adjusted R^2 values. In terms of interpretability, the CanDep index had only six variables and two components, meaning that it competed with the SEFI for the simplest index structure. Also, the CanDep index has both a material and social component, enabling it to be used in regressions distinguishing between the effects of these two aspects of SES. One limitation of the CanDep index is that it does not include a language/immigration component, or another component that relates to 'cultural diversity' or other cultural aspects of neighborhoods. In sum, similar to the SEFI, the CanDep index is another simple index which explains a relatively large amount of variation, however it goes further than the SEFI by making use of a two-component structure.

4.1. Implications

The analyses in this paper demonstrated several key findings regarding the structure and variable composition of an ideal neighbourhood SES index to analyze ECD data. The first, and perhaps most obvious, is that an index that is used to analyze ECD outcomes at the neighbourhood level should use variables which represent known mechanisms by which neighbourhood and family SES impact ECD. This at the minimum will ensure that the variables included are relevant to the analysis of ECD. The second finding is that the indices varied in regard to their structure, the number of variables, and ambiguity and interpretability of components. Depending on the purposes of the respective indices, differences in these aspects affect to what extent a given index may be useful and understandable to the general public who may be interested in the relationships between components of neighbourhood SES and ECD. The third attribute of an ideal index is having multiple, differentiable components. While we were limited to the examination of the types of components included in the four indices we chose, it appears that an index that includes a material (economic indicators), social (family stability/demographics) and cultural (language/immigration) component may be useful to the extent that these different components seem to be associated independently with different domains of ECD.

There may be other ways of thinking about or designing an index for ECD purposes that were not touched on in these four papers. One possible extension is in the datasets used to draw SES variables. While to date there is no accessible individual level database of socioeconomic variables for a population-level Canadian context, datasets such as the Canadian Census and Income Tax data can be broken down by subgroups such as family types (e.g. families with children under six, lone parent families). These datasets would help focus analyses on particular populations of interest. Another possible route of exploration would be mapping the index construction to a theoretical ECD framework such as social determinants of health, rather than allowing a PCA to design the variable loadings and index structure, independent of ECD measures. It is also important to consider whether aggregated indices are preferable to single variables. On one hand, using separate, individual variables makes regressions simpler and more interpretable. On the other hand, indices allow the variables to be mapped onto multiple social determinant ‘concepts’ (i.e. material or social deprivation) that lend themselves more to theory-driven neighbourhood effects research and to the analysis of interaction effects between these concepts. Indices also allow easier knowledge translation (e.g. maps) by giving a single number that can be used to compare neighbourhoods or the same neighbourhood over time.

4.2. Limitations

This paper has some data-related limitations. We chose the Canadian Census because it is the most in-depth database of socioeconomic variables at the pan-Canadian level that exists to date. The mandatory Long-Form Canadian Census was implemented every five years and we chose 2006 because this was the most recent year before it was replaced with the voluntary National Household Survey in 2011 (note that the mandatory long-form Census was reinstated for the year 2016). The first limitation of the findings in this paper are that the Census data were collected at one specific time point (2006). This means that the relationships which were found in this study may not be the same as we would observe at a different point in time. Further, we use only indices which were originally constructed from Canadian Census data. There may be other useful SES indices constructed in other countries or using other types of data, but these were not considered for the current paper. Another limitation of the study was the variation in the timeframes of EDI collection from province to province. Although a consistent timeframe would be preferable in this study, the timeframe chosen minimized the variation in time periods compared to other potential criteria (such as choosing the closest collection after 2006). No provincial EDI data collected more than three years earlier or later than 2010 were included. However, not all provinces started collecting their EDI data at the same time, so the variation of collection time must simply be acknowledged as a limitation. Finally, due to the use of principal component analysis, the change of geographical scope and unit from the original papers of the indices also produced some minor changes in the component loadings. As shown in the [Supplementary Document](#), however, the replicated indices look quite similar in terms of component loadings to their initially developed versions. Last, it is important to note that these analyses explore associations between neighbourhood SES and ECD, but do not attempt to draw causal links.

5. Conclusion

In Canada, and amongst the four indices examined in this paper, our analysis suggests that there is a trade-off between explanatory power and the interpretability of a neighbourhood SES index when it is used for the analysis of ECD. We also found that material, social and cultural (language/immigration) constructs were all necessary to include in an SES index because these three types of constructs all affect the domains of the EDI in different, but significant ways. The

patterns of differences in the strengths of association between material and social index components and specific EDI domains may point towards promising areas for improvement to decrease inequalities in early childhood outcomes. Further research into SES indices will help to identify specific pathways and mechanisms through which the SES of a neighbourhood impacts aspects of child development, particularly the variety of factors that play a role and how they interact throughout the life course.

While this paper focused primarily on discerning the aspects of a neighbourhood SES index which make it relevant to the analysis of ECD outcomes, there are many more analytical questions which could be asked using such an index. While answering specific research questions was beyond the scope of this paper, one insight which can be inferred from our analysis is that the geographical area and specific ECD outcome of interest should be thought out carefully since the scope of analysis (both in terms of geography and outcomes) may impact the findings. For instance, if a research question in one jurisdiction was whether children tended to score worse on the *Physical Health and Well-Being* domain in neighbourhoods with high material deprivation, the highest level of precision would be achieved by narrowing the geographical scope (and therefore reference group) to include only that specific jurisdiction and narrowing the outcome of interest specifically to this domain. This also implies that findings regarding a gradient in Canada may not apply directly to other countries. Analyses in other countries would have to use the neighbourhood SES indices most relevant to their experience and analyze their relationship to ECD outcomes specific to that country, which has already been done, for example, in Australia and Scotland (Brinkman et al., 2012; Woolfson, Geddes, McNicol, Booth, & Frank, 2013). Even though the distribution of scores may be specific to Canada, the methodology used in this paper for finding the most relevant indices could inform similar studies in other countries. The findings that certain index components showed relatively larger associations with certain domains of ECD could also be tested in other countries to put results in context. Based on the analyses in this paper, we believe that indices relevant to children's developmental outcomes anywhere need to include, at a minimum, material, social and cultural components.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.ssmph.2016.11.006](https://doi.org/10.1016/j.ssmph.2016.11.006).

References

- Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology*, 53(1), 371–399. <http://dx.doi.org/10.1146/annurev.psych.53.100901.135233>.
- Brinkman, S., Gialamas, A., Rahman, A., Mittinty, M. N., Gregory, T. A., Silburn, S., & Lynch, J. W. (2012). Jurisdictional, socioeconomic and gender inequalities in child health and development: Analysis of a national census of 5-year-olds in Australia. *BMJ Open*, 2(5). <http://dx.doi.org/10.1136/bmjopen-2012-001075>.
- Brinkman, S., Gregory, T., Harris, J., Hart, B., Blackmore, S., & Janus, M. (2013). Associations between the early development instrument at age 5, and reading and numeracy skills at ages 8, 10 and 12: A prospective linked data study. *Child Indicators Research*, 6(4), 695–708. <http://dx.doi.org/10.1007/s12187-013-9189-3>.
- Brinkman, S., Silburn, S., Lawrence, D., Goldfeld, S., Sayers, M., & Oberklaid, F. (2007). Investigating the validity of the Australian Early Development Index. *Early*

- Education and Development*, 18(3), 427–451. <http://dx.doi.org/10.1080/10409280701610812>.
- Brownell, M. D., Derksen, S. A., Jutte, D. P., Roos, N. P., Ekuma, O., & Yallop, L. (2010). Socio-economic inequities in children's injury rates: Has the gradient changed over time? *Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique*, 101, S28–S31.
- Case, A., Fertig, A., & Paxson, C. (2005). The lasting impact of childhood health and circumstance. *Journal of Health Economics*, 24(2), 365–389. <http://dx.doi.org/10.1016/j.jhealeco.2004.09.008>.
- Center on the Developing Child (2007). The Science of Early Childhood Development (InBrief). Retrieved from (<http://developingchild.harvard.edu/resources/inbrief-science-of-ecd/>)
- Chateau, D., Metge, C., Prior, H., & Soodeen, R.-A. (2012). Learning From the Census: The Socio-economic Factor Index (SEFI) and health outcomes in Manitoba. *Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique*, 103, S23–S27.
- Currie, J. (2009). Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. *Journal of Economic Literature*, 47(1), 87–122. <http://dx.doi.org/10.1257/jel.47.1.87>.
- Davies, S., Janus, M., Duku, E., & Gaskin, A. (2016). Using the Early Development Instrument to examine cognitive and non-cognitive school readiness and elementary student achievement. *Early Childhood Research Quarterly*, 35, 63–75. <http://dx.doi.org/10.1016/j.ecresq.2015.10.002>.
- Essex, M. J., Kraemer, H. C., Armstrong, J. M., Thomas, B. W., Hill, G. H., H, K. M., & J, K. D. (2006). Exploring risk factors for the emergence of children's mental health problems. *Archives of General Psychiatry*, 63(11), 1246–1256. <http://dx.doi.org/10.1001/archpsyc.63.11.1246>.
- Forer, B., & Zumbo, B. D. (2011). Validation of multilevel constructs: Validation methods and empirical findings for the EDI. *Social Indicators Research*, 103(2), 231–265. <http://dx.doi.org/10.1007/s11205-011-9844-3>.
- Frank, J. W., & Mustard, J. F. (1994). The determinants of health from a historical perspective. *Daedalus*, 123(4), 1–19.
- Gibson, C. L., Sullivan, C. J., Jones, S., & Piquero, A. R. (2009). "Does it take a village?": Assessing neighborhood influences on children's self-control. *Journal of Research in Crime and Delinquency*. <http://dx.doi.org/10.1177/0022427809348903>.
- Guhn, M., Gadermann, A. M., Almas, A., Schonert-Reichl, K. A., & Hertzman, C. (2016). Associations of teacher-rated social, emotional, and cognitive development in kindergarten to self-reported wellbeing, peer relations, and academic test scores in middle childhood. *Early Childhood Research Quarterly*, 35, 76–84. <http://dx.doi.org/10.1016/j.ecresq.2015.12.027>.
- Guhn, M., Gadermann, A., & Zumbo, B. D. (2007). Does the EDI measure school readiness in the same way across different groups of children? *Early Education and Development*, 18(3), 453–472. <http://dx.doi.org/10.1080/10409280701610838>.
- Guhn, M., Janus, M., Enns, J., Brownell, M., Forer, B., Duku, E., & Raos, R. (2016). Examining the social determinants of children's developmental health: Protocol for building a pan-Canadian population-based monitoring system for early childhood development. *BMJ Open*, 6(4). <http://dx.doi.org/10.1136/bmjopen-2016-012020>.
- Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, 13(2), 65–73. <http://dx.doi.org/10.1016/j.tics.2008.11.003>.
- Heckman, J. J. (2011). The economics of inequality: The value of early childhood education. *American Educator*, 35(1), 31.
- Hertzman, C., & Boyce, T. (2010). How experience gets under the skin to create gradients in developmental health. *Annual Review of Public Health*, 31(1), 329–347. <http://dx.doi.org/10.1146/annurev.publhealth.012809.103538>.
- Hymel, S., LeMare, L., & McKee, W. (2011). The Early Development Instrument: An examination of convergent and discriminant validity. *Social Indicators Research*, 103(2), 267–282. <http://dx.doi.org/10.1007/s11205-011-9845-2>.
- Janus, M., Brinkman, S., Duku, E., Hertzman, C., Santos, R., Sayers, M., & Walsh, C. (2007). *The Early Development Instrument: A population-based measure for communities. A handbook on development, properties, and use* Hamilton, ON: Offord Centre for Child Studies.
- Janus, M., & Offord, D. R. (2007). Development and psychometric properties of the Early Development Instrument (EDI): A measure of children's school readiness. *Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement*, 39(1), 1–22. <http://dx.doi.org/10.1037/cjbs2007001>.
- Johnson, R. C., & Schoeni, R. F. (2011). The influence of early-life events on human capital, health status, and labor market outcomes over the life course. *The B.E. Journal of Economic Analysis & Policy*, 11.
- Jutte, D. P., Brownell, M., Roos, N. P., Schippers, C., Boyce, W. T., & Syme, S. L. (2010). Rethinking what is important: Biologic versus social predictors of childhood health and educational outcomes. *Epidemiology*, 21(3), 314–323. <http://dx.doi.org/10.1097/EDE.0b013e3181d61e61>.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Hendriksen, J. G. M., Feron, F. J. M., Steyaert, J., & van Os, J. (2001). Neighbourhood level and individual level SES effects on child problem behaviour: A multilevel analysis. *Journal of Epidemiology and Community Health*, 55(4), 246–250. <http://dx.doi.org/10.1136/jech.55.4.246>.
- Keating, D. P., & Hertzman, C. (1999). *Developmental health and the wealth of nations: Social, biological, and educational dynamics*. Guilford Press.
- Kitchen, P. (2001). An approach for measuring urban deprivation change: The example of East Montréal and the Montréal urban community, 1986 – 96. *Environment and Planning A*, 33(11), 1901–1921. <http://dx.doi.org/10.1068/a3450>.
- Krishnan, V., Betts, S., & Wang, X. (2012). Living Conditions Index (LCI): A context-based measure to understand Children's developmental outcomes. Retrieved from: (<https://www.ualberta.ca/~media/ualberta/faculties-and-programs/centres-institutes/community-university-partnership/research/ecmap-reports/livingconditionsindex.pdf>)
- Krishnan, V. (2010). Constructing an area-based socioeconomic index: A principal components analysis approach. Edmonton, Alberta: Early Child Development Mapping Project. Retrieved from (http://www.cup.ualberta.ca/wp-content/uploads/2013/04/SEICUPWebsite_10April13.pdf)
- Lloyd, J. E. V., Irwin, L. G., & Hertzman, C. (2009). Kindergarten school readiness and fourth-grade literacy and numeracy outcomes of children with special needs: A population-based study. *Educational Psychology*, 29(5), 583–602. <http://dx.doi.org/10.1080/01443410903165391>.
- Marmot, M. G., Stansfeld, S., Patel, C., North, F., Head, J., White, I., & Smith, G. D. (1991). Health inequalities among British civil servants: The Whitehall II study. *The Lancet*, 337(8754), 1387–1393. [http://dx.doi.org/10.1016/0140-6736\(91\)93068-K](http://dx.doi.org/10.1016/0140-6736(91)93068-K).
- Martens, P. J., Fröhlich, N., Carriere, K. C., Derksen, S., & Brownell, M. (2002). Embedding child health within a framework of regional health: Population health status and sociodemographic indicators. *Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique*, 93, S15–S20.
- Matheson, F. I., Dunn, J. R., Smith, K. L. W., Moineddin, R., & Glazier, R. H. (2012). Development of the Canadian Marginalization Index: A new tool for the study of inequality. *Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique*, 103, S12–S16.
- Messer, L. C., Laraja, B. A., Kaufman, J. S., Eyster, J., Holzman, C., Culhane, J., & O'Campo, P. (2006). The development of a standardized neighborhood deprivation index. *Journal of Urban Health*, 83(6), 1041–1062. <http://dx.doi.org/10.1007/s11524-006-9094-x>.
- Pampalon, R., Hamel, D., Gamache, P., & Raymond, G. (2009). A deprivation index for health planning in Canada. *Chronic Dis Can*, 29(4), 178–191.
- Pampalon, R., & Raymond, G. (2000). A deprivation index for health and welfare planning in Quebec. *Chronic Diseases in Canada*, 21(3), 104–113.
- Romano, E., Babchishin, L., Pagani, L. S., & Kohen, D. (2010). School readiness and later achievement: Replication and extension using a nationwide Canadian survey. *Developmental Psychology*, 46(5), 995–1007. <http://dx.doi.org/10.1037/a0018880>.
- Townsend, P. (1987). Deprivation. *Journal of Social Policy*, 16(02), 125–146. <http://dx.doi.org/10.1017/S0047279400020341>.
- Vanasse, A., Courteau, J., Orzanco, M. G., Bergeron, P., Cohen, A. A., & Niyonsenga, T. (2015). Neighbourhood immigration, health care utilization and outcomes in patients with diabetes living in the Montreal metropolitan area (Canada): A population health perspective. *BMC Health Services Research*, 15(1), 1–17. <http://dx.doi.org/10.1186/s12913-015-0824-1>.
- Vincent, K., & Sutherland, J.M. (2013). A review of methods for deriving an index for socioeconomic status in British Columbia. Vancouver, BC: *UBC Centre for Health Services and Policy Research*. Retrieved from: (<http://healthcarefunding.ca/files/2013/04/Review-of-Methods-for-SES-Index-for-BC.pdf>)
- Woolfson, L. M., Geddes, R., McNicol, S., Booth, J. N., & Frank, J. (2013). A cross-sectional pilot study of the Scottish early development instrument: A tool for addressing inequality. *BMC Public Health*, 13(1), 1–10. <http://dx.doi.org/10.1186/1471-2458-13-1187>.