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Constructing a Composite Adolescent Health and Wellness Index for British Columbia, Canada Using a Spatial Multi-Criteria Analysis Approach

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Abstract This article describes the methods used to produce a composite index of adolescent health and wellness for the province of British Columbia. The unit of analysis was health service deliveries areas (HSDAs) for which adolescent-centred indicators, that reflect both positive and negative measures of adolescent health, were readily available. Using a Delphi technique, a set of 24 indicators of adolescent health and wellness were identified. The indicators were then combined using spatial multi-criteria analysis (MCA), specifically, the *technique for order preference by similarity to an ideal solution* (TOPSIS). The composite index allowed for geographical variation of adolescent health and wellness across the Province to be explored using mapping software and statistical analysis. The index revealed an urban/rural gradient in adolescent health and wellness. Additionally, a negative relationship was found between the composite index and the percent of aboriginal population and a positive relationship was found with the percent of recent immigrants. This paper concludes by discussing the challenges, strengths and weaknesses of this composite index.

Keywords Adolescence · Health index · Spatial MCA · TOPSIS · Delphi

1 Introduction

Globally, as well as within Canada, adolescent health inequalities are receiving increased attention among researchers and policy makers (Patton et al. 2010).

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Historically, health inequalities within this group have received less consideration than those of adults and young children (Currie et al. 2008; Geddes et al. 2005). When researchers and decision makers have focused on adolescents, the adolescents are often viewed as a problem demographic cohort. This has led health research of this group to focus on risk-taking or perceived delinquent behaviors (Tonkin and Foster 2005). However, in the last decade, there has been a move to a more balanced view of adolescent health. Increasingly research strives to measure young people's well-being in addition to risk factors and negative behaviors (Ben-Arieh 2008; Lerner et al. 2005, 2009). This is primarily seen within more developed nations where moving beyond mere mortality and morbidity measures of health has become a priority (Ben-Arieh 2008; Patton et al. 2010). As Lerner et al. (2005, 10–11) states: "youth are not broken, in need of psychosocial repair, or problems to be managed. Rather, all youth are seen as resources to be developed." It is in this spirit that we sought to construct an adolescent health and wellness index for the province of British Columbia (BC).

Composite indices can be useful to measure and communicate the overall well-being of populations to researchers, policy analysts, politicians and the general public (Vandivere and McPhee 2008). Single indicators are not necessarily correlated with all facets of health and wellness; therefore, composite indices which combine a number of single indicators are more reflective of overall health and well-being (Profit et al. 2010). Composite indices also have the benefit of reducing the complexity that comes in trying to communicate multiple single measures, and therefore are an effective tool for briefing policy makers, politicians and the public (Nardo et al. 2005). These indices, when calculated for various geographic areas (i.e. countries, provinces, census tracts, etc.) give us the ability to analyze the spatial patterns of the health and wellness of the population under study.

Careful consideration must be paid when developing and calculating composite indices in order to avoid pitfalls that may occur throughout the composite process (Nardo et al. 2005; Vandivere and McPhee 2008). There are many decisions that are made along the way to the completion of the final index, such as, what indicators should be compiled to create the score, what is the relative weight of each indicator and how should the composite index be calculated. One common approach to the last question, how to combine the individual indicators into a composite index, is to use an additive method. While conceptually simple, such a method has been criticized for compensability (an area that fairs poorly on one or many indicators may do well in another, and therefore compensate for it in the composite score) (Nardo et al. 2005). Additionally, additive methods have the underlying assumption that the indicators are not correlated with each other (Malczewski 2000). Adding correlated indicators implies introduction of multiple evidence measuring the same thing that, when added up, exaggerates the importance of the trends shared by the correlated indicators. Another strategy often used to create indices is using statistical methods such as principal components or factor analysis. However, these strategies minimize opportunities of incorporating stakeholder knowledge (Bell et al. 2007). In this paper we introduce an alternative method to combining the individual variables that attempts to avoid the above issues. We combine the use of a Delphi technique, in order to get experts to select and rank a set of indicators, with the use of spatial multi-criteria analysis (MCA), to combine the indicators. Spatial MCA can be defined as a set of methods used to combine criteria with weights of importance in order to create a single measure for comparison of different geographical areas when each criteria is spatially referenced (Malczewski 1999, 2006). In the case of index construction, as undertaken in the research reported here, "criteria" are substituted by "indicators". The MCA method we employed is the *technique for order preference by similarity to an ideal solution* (TOPSIS). The benefits of using the Delphi technique and the TOPSIS method are that they: do not have the strict assumption of the additive method, they incorporate local stakeholder and expert opinions in the selection of the indicators and the relative weights of importance, and are relatively straightforward in implementation and interpretation (Malczewski 1999). Although commonly used in spatial analysis, MCA applications have been limited in social health research (Bell et al. 2007), however examples do exist (i.e. Bell et al. 2007).

The research reported here is a pilot project to create a composite index focused specifically on adolescents termed the *BC Adolescent Health and Wellness Index* (BCAHWI). It is part of a larger effort to map wellness and health in BC at a regional scale (www.geog.uvic.ca/wellness/). This work adds to a growing interest in indicators of child health and well-being by the BC provincial government. The unique contribution of the research reported here is the use of the spatial MCA TOPSIS method applied to the construction of an adolescent health and wellness index.

2 Methods

Spatial MCA requires selection of an appropriate geographical scale of analysis and a meaningful set of indicators for which spatially referenced data (i.e. by country, census tract, postal code or street address) are available, and for which geographic variation across the area of interest are exhibited (Malczewski 1999). After careful consideration of data availability we opted to use as a scale of analysis BC's 16 ($N=16$[1]) health service delivery areas (HSDAs) (Fig. 1). This required consideration of a trade-off between meaningful data and the ability to conduct more detailed geographical analysis at a finer scale, such as examining for spatial clustering using measures of spatial autocorrelation and/or spatial scan statistics. Finer geographical scale population data, for example at the census division level, are available. They do however lack data with the individual adolescent as the unit of observation. Data reflecting the perspectives of adolescents is critical to a meaningful index that seeks to include measurements from the adolescent's perspective (Bradshaw and Richardson 2009). It also is part of the evolution of the child indicators movement (Ben-Arieh 2008) and, we believe, is consistent with the spirit of the UN Convention on the Rights of the Child (www.unicef.org/crc/). Because of this we sought data that were collected at the individual level, for which the data source was designed to be representative of the HSDAs, which were then aggregated to the HSDA level (Vandivere and McPhee 2008).

[1] Two of the HSDAs (Fraser East and Northeast) were missing data or had sample sizes too small to disclose given several data providers' guidelines. We therefore were able to calculate an index score for only 14 of the 16 HSDAs.

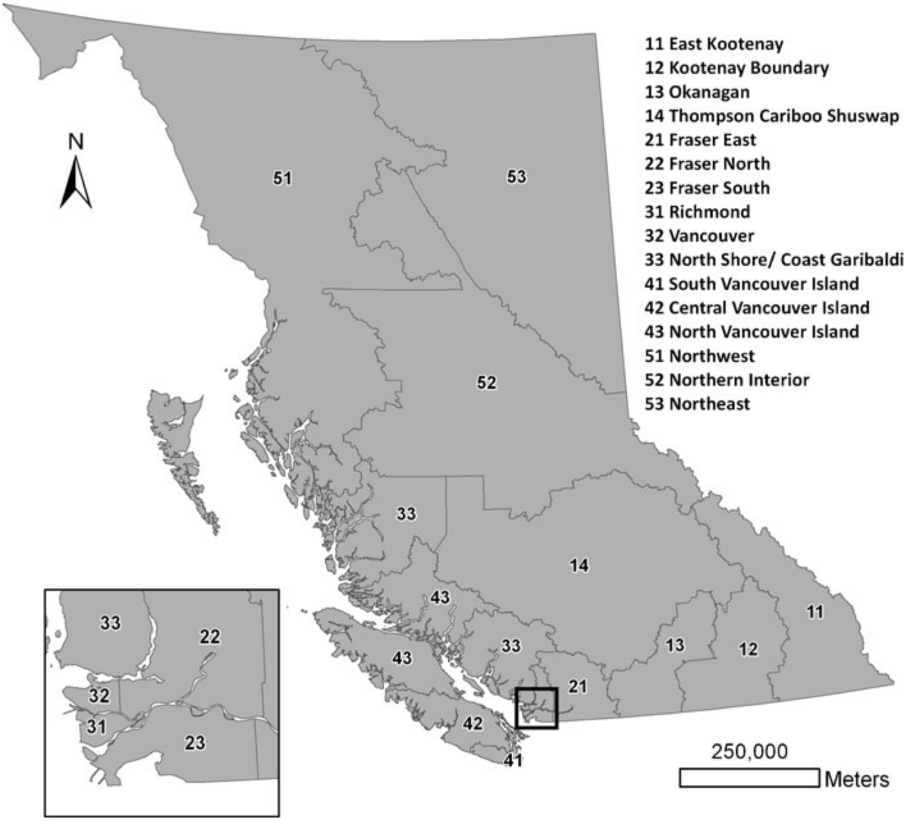

Fig. 1 British Columbia health service delivery area (HSDA) boundaries

Additionally, this level of measurement is useful for policy and decision making as the HSDAs nest into the larger health authorities ($N=5$) which are charged with governing, planning, and coordinating health care services within the Province. Future studies may repeat the methodology at a finer geographical scale, collecting primary data to complement secondary data where and as needed.

Below we introduce the different steps undertaken in the construction of the index before reporting research findings in Section 3.

2.1 Delphi Study Design

In order to select the indicators to be included in the composite index we conducted a three-round Delphi study that commenced July of 2009 and completed December of 2009. We used the Delphi technique to determine two things. First, it was used to identify what indicators a panel of expertise felt was influential in measuring adolescent health and wellness in BC. Second, the Delphi technique helped determine each indicator's relative weight of importance. Weights derived from a set of experts, although more time consuming, have been found to be a viable technique that is useful in uncovering local conditions (Bell et al. 2007; Profit et al. 2010).

The Delphi technique, developed by the RAND Corporation (Fink et al. 1991) uses a series of questionnaire rounds to illicit and distribute information to and from a panel of members, who are anonymous to each other, with expertise on the topic under study (Hanafin and Brooks 2005). It has been deemed a strong method for answering questions based on expertise from a panel of selected participants (Okoli and Pawlowski 2004; Malczewski 1999). It is considered a useful tool when evidence is limited, when subjective evidence can be of benefit, when little factual data exist, or when there is uncertainty surrounding the topic being investigated (Malczewski 1999; Vernon 2009; Syed et al. 2009). Since measuring health and wellness is recognized to be an "inexact and changing science" (Millar and Hull 1997) the Delphi technique was deemed suitable to address the questions at hand.

There is no agreement on the ideal number of members in a Delphi panel (Vernon 2009) but experience from past studies recommends 10–18 participants (Okoli and Pawlowski 2004). Additionally, the Delphi technique does not require that a statistical sample from recognized stakeholder groups make up the panel. What is critical is that the panel members have a deep understanding of the issue under investigation (Okoli and Pawlowski 2004). Professional knowledge, which may also include privileged information, often places one in an expert position (Vernon 2009). Therefore, for the purpose of this pilot study, we defined a suitable expert as an individual who: 1) is experienced and qualified in the field of youth and/or health and wellness and 2) who had been employed within two or more public sector or research organization, over their career, that either develop or research policy and programs and/or deliver services related to adolescent health and wellness in BC. We then used a convenience sample based on best knowledge of "who is who" in BC capitalizing on experience of the authors to identify key individuals in the major provincial government ministries and research organizations that deal with adolescent health and wellness issues. Agencies included amongst others the Ministries of Aboriginal Relations and Reconciliation, Children and Family Development, Citizens' Services, Education, and Healthy Living and Sport. This led to identification of a panel of 21 experts. This is a number above that recommended to participate in a Delphi survey (10–18), and sufficient to allow for non-responses and/or attrition. We recognize that a limitation in this study is that we only solicited expert opinion from one group, omitting front line staff such as health care workers and teachers as well as adolescents themselves. We recommend that future studies broaden consultation to include these groups.

We commenced the first round of the Delphi study by asking the panel of experts to each identify the top dozen indicators they judged to be of relevance and importance in measuring adolescent health and wellness, and to provide a short explanation of why they felt these indicators were important. Survey Monkey online survey software (www.surveymonkey.com) was used to facilitate these data collection. Input from round one was then analyzed to remove duplicates, unify terminology, and sort indicators into logical domains based on knowledge from literature and using thematic analysis (Boyle and Torrance 1984; Aronson 1994; Fereday and Muir-Cochrane 2006). In order to maintain the feasibility of index construction, preliminary analysis was undertaken at this point to remove indictors that did not have available secondary data sources at the HSDA level. We recognize that exclusion of variables because of lack of readily available data is a potential weakness of any study. In light of this, we made a best effort to find surrogates if and where appropriate. However, in order for index construction based on secondary data sources to be viable this is a step that we reasoned must be taken.

In the second round of the Delphi survey we asked the same experts to verify the compiled list of indicators and domains produced from the first round in order to reflect on what they had contributed, and to offer additional comments. We then modified and refined the list of indicators and domains to reflect any comments.

For the third, and final, round we asked respondents to use a Likert scale in order to determine each remaining indicator's relative importance. Previous Delphi studies have shown that the Likert rating scale is relatively efficient and manageable in achieving comparisons (Turoff 1975). We used a 5 point Likert scale ranging from "very influential" to "not very influential", including an option of "unsure". We then summed and calculated the mean Likert score for each indicator. This allowed us to eliminate indicators from consideration in the composite index that were deemed to be of relatively less influence by the majority (Boyle and Torrance 1984). All indicators with a mean score of 4 or higher were maintained for consideration in the index. Calculation of the Likert mean also allowed us to compute a measure of relative overall weight of importance for each indicator. Table 1 shows the indicators included in the BCAHWI.

Krippendorff's alpha (α) was employed after the third round to examine agreement regarding the indicators importance by the panel (Hayes and Krippendorff 2007). Krippendorff's α is a reliability coefficient used to measure the amount of agreement among raters when dealing with more than 2 raters and ordinal data that may include missing values (Hayes and Krippendorff 2007; Krippendorff 2007). When $\alpha=1$ it indicates perfect agreement among raters; $\alpha=0$ indicates no reliability, equivalent to raters recording responses by the throwing of a dice or other method of chance. Krippendorff's α was analyzed using a specifically designed macro in SPSS v.17 (www.spss.com)(Krippendorff 2007).

Our study was reviewed and approved by the Human Research Ethics Board at the University of Victoria (certificate # 09–194).

2.2 Data Sources

Data utilized in the index came from both administrative and survey data. The sources of survey data came from the Canadian Community Health Survey (CCHS) 2007/2008 and the BC Adolescent Health Survey (AHS) 2008. The CCHS is a nationwide cross sectional survey conducted by Statistics Canada of those 12 years in age or older (only those up to 19 years in age were considered in the index), living in private dwellings and not living on aboriginal reserves or military bases. The CCHS is designed to measure various health outcomes and is representative of the population at the HSDA level (Statistics Canada 2009). The BC AHS is a survey undertaken by the McCreary Center Society in BC public schools of students in grades 7–12 (generally ages 12 to 19 years) using a cluster-stratified sampling design in randomly selected classrooms. It is also representative of the population at the HSDA level. The cluster stratification was accounted for by using SPSS complex samples software in estimating the rates and proportions (Saewyc and Green 2009). That the BC AHS 2008, includes only students in public school and the CCHS 2007/2008 does not include those who live on aboriginal reserves, military bases and those not living in a private dwelling, implies that adolescents who: live on aboriginal reserves, are homeless, are not attending

Table 1 Indicators, data definitions and weights included in the BCAHWI

Domain	Indicator	Definition	Rank sum weight	Rank reciprocal weight
General health	Physical Activity[1]	% who scored active or moderately active on the Leisure Time Physical Activity Index	0.067	0.057
	Healthy Weight[2]	% who have a healthy weight based on self reported height and weight	0.042	0.023
	Healthy Diet[1]	% who eat fruits and vegetables five or more times or servings a day	0.067	0.057
	Freedom From Chronic Conditions[2]	% who do not have a health condition or disability that keeps them from doing some things other kids their age do	0.067	0.057
	Self Rated Health[1]	% who report good to excellent health	0.008	0.013
Relationships	Family Connectedness[2]	Average score on the Family Connectedness Scale	0.078	0.190
	Positive Peer Influence[2]	% whose friends would be upset if they got arrested, beat someone up, carried a weapon for protection, got pregnant or got someone pregnant, dropped out of school, got drunk or used marijuana	0.053	0.032
	Residing Outside Of Parental Home[2]	% of students grade 7–12 who reported they do not live with a parent or step parent most of the time but rather live with another adult (related or unrelated) or no adults	0.022	0.015
	Child Welfare Contacts[2]	% who reported that they had been in group homes, foster homes or youth agreements at some point	0.008	0.013
	Positive Adults Mentors[2]	% who felt there was an adult in their family who they could talk to, or an adult not in their family they could talk to if they had a serious problem	0.053	0.032
Community	Community/Cultural Connectedness[1]	% who have a strong sense of belonging to local community	0.027	0.017
	Housing and Neighbourhood[2]	% who answered "yes" to the question "do you have your own bedroom?"	0.008	0.013
Education	Educational Achievement[3]	% who did NOT graduate	0.022	0.015
	School Connectedness[2]	Average score on the School Connectedness Scale	0.067	0.057
	Literacy[4]	Average % of students who did NOT pass or write grade 10 English exam	0.042	0.023
Substance use	Tobacco Use[1]	% presently a non-smoker	0.008	0.013

Table 1 (continued)

Domain	Indicator	Definition	Rank sum weight	Rank reciprocal weight
	Illicit Drug Use[2]	% who have never tried marijuana, prescription pills without a doctor's consent, cocaine (coke, crack), hallucinogens (LSD, acid, PCP, dust, mescaline, salvia), ecstasy, mushrooms (shrooms, magic mushrooms), inhalants (glue, gas, nitrous, whippits, aerosols), amphetamines (speed), crystal meth, heroin, injected an illegal drug (shot up with a needle), or steroids without a doctor's prescription	0.033	0.019
	Tobacco/Alcohol Use of Teen Mothers[5]	% of mothers that did NOT have smoking OR alcohol identified as a risk factor during the current pregnancy	0.047	0.026
Behaviour and safety	Adolescent Pregnancies[6]	Pregnancy rate/1,000 females	0.030	0.018
	Adolescent Crime[7]	Average juvenile crime rate [the number of offences (charges for juveniles) per 1,000]	0.017	0.014
	Freedom from Abuse[2]	% who have never been physically OR sexually abused	0.078	0.190
Mental health	Adolescent Suicide[2]	% who have not considered suicide in the last 12 months	0.037	0.020
	Good Mental Health[1]	% who report good to excellent self-perceived mental health	0.067	0.057
	Feeling Good at Something[2]	% who can think of some things they are really good at?	0.053	0.032
Sum			1.00	1.00

[1] Canadian Community Health Survey 2007/2008, ages 12–19

[2] McCreary Adolescent Health Survey 2008, grades 7–12

[3] BC Statistics 2007/2008, calculated as the population 18 years old minus the number of high school graduates as a % of 18 year olds. It is used as an indicator of the high school dropout rate

[4] BC Statistics 2005/2006–2007/2008, grade 10 provincial exam non-completion rate for English, is the percent of students enrolled in Grade 10 who did not take or did not pass the provincial examination. Data are three-year averages

[5] BC Perinatal Database April1, 2007–March 31, 2008, <=19 at age of delivery

[6] BC Statistics 2005–2007, ages 15–17. Data are three-year averages

[7] BC Statistics 2004–2006, ages 15–17 when a charge is laid that the age of the suspect is determined. Data are three-year averages

school, and are in private schools are not represented in some of the survey indicators. We recognize this as a weakness but did not see a feasible way to obtain the additional data required to overcome this problem.

Administrative data were also considered for inclusion in the index. The BC Stats website was reviewed (www.bcstats.gov.bc.ca) as a central source of various administrative and census data. We also evaluated the BC Perinatal Database Registry website (www.perinatalservices.bc.ca).

2.3 Weighting

The indicators selected in the Delphi study were combined using three different weighting techniques. Two weighting techniques (rank sum and rank reciprocal) were derived using the average value of importance from the Delphi study. Additionally, primarily for comparison purposes, all criteria were assumed to carry the same importance, giving each equal weight.

Rank Sum:

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

Rank Reciprocal:

$$w_j = \frac{1/r_j}{\sum (1/r_k)}$$

where w_j is the normalized weight for the *j*th indicator, n is the number of indicators (k=1, 2,…,n), and r_j is the *j*th indicator's ranked position (Malczewski 1999). Table 1 shows the weights yielded from the three weighting techniques.

2.4 TOPSIS

Malczewski (1999, 2006) offers a thorough introduction and discussion of spatial MCA. We do not repeat a detailed review and discussion here but provide a brief summary of the TOPSIS method and note that we selected to use the TOPSIS MCA method in light of efforts to avoid problems associated with the previously noted issues of compensability and correlation (Malczewski 1999). This was deemed important as the holistic nature of human health led us to expect that some of the indicators selected for use in the index would by highly correlated.

The TOPSIS method was first developed by Hwang and Yoon (1981) and assumes that the "best" alternative or area is the one that is the nearest to an ideal (the best value of each indicator) and farthest from the negative ideal (the worst value of each indicator) (Opricovic and Tzeng 2004; Zanakis et al. 1998; Jakimavcius and Burinskiene 2007; Hwang and Yoon 1981). It produces a set of cardinal values that range from 0 to 1, 1 indicates the area has the best value of all indicators and 0 indicates an area has the worst value of all indicators (Malczewski 1999). The method handles both positive and negative indicators since it allows for the ideal positive to be either minimized or maximized. For instance, it is desirable to maximize the average school connectedness, but to minimize teenage pregnancy rates.

The first step is to standardize all indicators so that they can be compared meaningfully (Malczewski 1999). Once a standardized matrix of all indicators is produced, it is weighted by multiplying the weights (where the sum of the weights is equal to 1) by each standardized indicator value. An ideal positive and negative value is then assigned for each indicator, this being the most and least desirable value present in the standardized indicator matrix. The deviation from the ideal positive and negative are then derived, enabling the relative closeness of each area to an ideal solution to be quantified. The TOPSIS method was conducted using Triptych v. 3.10.395 software (www.stat-design.com).

The seven steps for a spatial TOPSIS are outlined below (adapted from Jakimavcius and Burinskiene 2007):

1. Standardize the indicator matrix:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}}$$

where r_{ij} = the standardized value of the *i-th* measure for each area of the *j-th* indicator, x_{ij} = the performance measure of the *i-th* measure for each area of the *j-th* indicator, and m = all indicators.

2. Multiply the standardized indicator matrix by the vector of weight values as follows:

$$\text{Weighted Standardized Matrix} = \begin{bmatrix} v_{1_1} & v_{1_2} & \cdots & v_{1_{24}} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ v_{14_1} & v_{14_2} & \cdots & v_{14_{24}} \end{bmatrix} = \begin{bmatrix} w_1 r_{1_1} & w_2 r_{1_2} & \cdots & w_{24} r_{1_{24}} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ w_1 r_{14_1} & w_2 r_{14_2} & \cdots & w_{24} r_{14_{24}} \end{bmatrix}$$

where v_{ij} = *i-th* measure for each area (1…14) of the *j-th* indicator (1…24) multiplied by the *i-th* weight (w) measure (1…24).

3. Formulate the ideal positive value (the best area value for each indicator) (v_j^+)
4. Formulate the ideal negative value (the worst area value for each indicator) (v_j^-)
5. Calculate the deviation from the ideal positive value

$$S_j^+ = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_j^+\right)^2}$$

6. Calculate the deviation from the ideal negative value

$$S_j^- = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_j^-\right)^2}$$

7. Calculate the proportional value deviation from the ideal

$$C_j = \frac{S_j^-}{S_j^+ + S_j^-}$$

The results yield a score for each HSDA identified as the BCAHWI score.

2.5 Sensitivity Analysis

Indicator weights are often the greatest source of uncertainty in spatial MCA (Y. Chen et al. 2009). This uncertainty may arise because participants may not be clearly able to state their preference (Ozturk and Tsoukias 2005). To address this, sensitivity analysis was conducted on the index scores derived by the weighting techniques that used expert opinion, by systematically changing the weights of the ten most heavily weighted indicators by 0.001, to see if this would considerably change the results. Sensitivity analysis is important to verifying the stability of the results of the analysis (Delgado and Sendra 2004). If rankings are unaffected as the weights are varied the results are deemed stable.

2.6 Cluster Analysis

A hierarchical cluster analysis was conducted in order to classify the HSDAs by their statistical similarity on the BCAHWI. Ward's method was used to measure the squared distance between the HSDA's BCAHWI scores and the mean centre of the cluster. Ward's method joins cases into clusters in a way that minimizes the variance within a cluster. The results of the cluster analysis were then mapped in order to examine any regional effects (O'Sullivan and Unwin 2003).

2.7 External Factors

In order to gain a better understanding of the regional variation of the pilot BCAHWI, we examined possible external factors that may show association with it. These were: a) economic status, b) urban/rural, c) percent of aboriginal population, and d) percent recent immigrants. Correlations were tested using Spearman's rho.

Economic status was measured by the median family income and incidence of economic families with low income as defined by Statistics Canada's Low Income Cut-Offs (LICO), which is updated by the Consumer Price Index and varies by family size and by community (Statistics Canada 2010). Both measures are from the 2006 census.

Urban/rural demographics were measured by the 2009 estimated percent of total population contained in each HSDA, the 2006 census estimated population density rate per 1,000 km squared and the proportion of students sampled in the 2008 BC AHS who attended a school classified as rural or small town (RST). For these purposes rural or small town is defined as populations living outside of the commuting zones of urban cores with a population of 10,000 or more (du Plessis et al. 2001).

To test for correlation with percent of aboriginal population and percentage of recent immigrants we used self-identification of aboriginal heritage reported in the 2006 Canada Census along with recent immigration (percentage of population who came to Canada between 2001 and 2005).

3 Results

Of the 21 experts approached to participate in the study 14 accepted and completed all rounds of the survey. The mean number of years each participant worked in their capacity in the field of adolescence and/or health was 15.6 (Min = 6; Max = 32; SD = 8.5). Fifty percent of the panel self-identified as a researcher, 29% as a decision maker and 21% as a service provider or other. Further details concerning round one and round two of the Delphi study are reported in detail in Martin 2010.

Round three of the Delphi study produced a list of 24 indicators with a mean score of 4 or higher on the Likert scale that had available data and showed sufficient geographic variation. Geographic variation was deemed insufficient if the indicator showed no variation across the Province after standardization. Testing showed this to occur when the coefficient of variation was less than 0.015.

The 24 indicators were grouped into eight domains: general health, relationships, community, education, substance use, behavior and safety, material wellness, and mental health (see Table 1). A correlation matrix was performed to confirm that many of the indicators are correlated and therefore the TOPSIS method rather than an additive method was the most appropriate choice to combine these data into a composite index. As shown in Table 2 all of the indictors were significantly correlated with at least one other indicator.

Krippendorff's α was .2163 (CI = .1851 and .2476), indicating a fairly low level of agreement amongst the panel participants. Bootstrapping (number of bootstrapped samples = 5,000) was applied to the dataset in order to provide a sampling distribution to derive confidence intervals. Krippendorff's α does not provide whether observed agreement is sufficiently above chance as this null hypothesis is not appropriate in questions of participant agreement; rather the question is whether the observed agreement is tolerable in subsequent analysis (Hayes and Krippendorff 2007). Although there was a low level of agreement, it proved greater than expected by chance. When treating the data other than ordinal Krippendorff's α declined. This demonstrates that although consensus was not met, the participants' ordinal perceptions of the indicator's rankings were confirmed (Krippendorff 2007)

Sensitivity analysis revealed rank sum as the more robust weighting technique as it showed the least amount of change when small systematic changes were applied to the weights, for more details on this see Martin 2010. It is also the more conservative weight based on expert opinion as it correlates more closely with the equal weights result (Pearson's r=.961, sig <0.01) than does rank reciprocal (Pearson's r=.947, sig <0.01). The rank sum derived index was also highly correlated with the rank reciprocal derived BCAHWI scores (Pearson's r=.984, sig <0.01). For the above reasons, and for readability sake, only the results of the ranks sum weighting are discussed below.

Figure 2 shows that the HSDA of Fraser South ranked the highest for adolescent health and wellness, followed by Fraser North. Results are presented in quintiles. This method of data categorization was selected because of its ease of interpretation as well as to be complementary and to facilitate comparison with other ongoing research mapping wellness in BC (www.geog.uvic.ca/wellness/). Vancouver also ranks highly in the second quintile, although Richmond, its neighbor to the south, falls into the third quintile. The Northwest and the Northern Interior rank the lowest. It is of interest to observe that 2009 population estimates show the HSDAs with the lowest BCAHWI scores (Northwest and Northern Interior) to have the highest percentages of adolescents in BC (Martin 2010).

Table 2 Pearson's r correlation matrix of indicators that populated the BCAHWI, N=14

	Family connectedness (I1)	Freedom from abuse (I2)	Physical activity (I3)	Healthy diet (I4)	Freedom from chronic conditions (I5)	School connectedness (I6)	Good mental health (I7)	Positive peer influence (I8)	Positive adult mentors (I9)	Feeling good at something (I10)	Tob/Alc use of teen mothers (I11)	Healthy weight (I12)	Literacy (I13)
I1	1												
I2	.685[a]	1											
I3	0.218	−0.185	1										
I4	0.064	0.114	0.164	1									
I5	0.321	.730[a]	−0.199	0.169	1								
I6	.739[a]	.838[a]	−0.046	0.112	.723[a]	1							
I7	0.106	−0.185	0.374	0.338	−0.224	−0.008	1						
I8	0.05	.603[b]	−0.324	0.158	.889[a]	.560[b]	−0.174	1					
I9	0.392	−0.218	.556[b]	−0.172	-.655[b]	−0.158	0.298	−.835[a]	1				
I10	0.301	−0.366	0.382	−0.045	−.726[a]	−0.222	0.453	−.828[a]	.889[a]	1			
I11	0.325	−0.168	0.387	−0.015	−0.218	0.131	.618[b]	−0.195	0.406	.605[b]	1		
I12	0.47	.600[b]	0.192	0.527	.725[a]	.618[b]	0.075	.577[b]	−0.307	−0.429	−0.093	1	
I13	−.614[b]	−.675[a]	−0.195	−0.345	−.751[a]	−.690[a]	0.252	−.569[b]	0.244	0.365	−0.006	−.837[a]	1
I14	.639[b]	.858[a]	−0.05	0.003	.794[a]	.840[a]	−0.093	.625[b]	−0.275	−0.384	−0.024	.615[b]	−.666[a]
I15	0.146	.669[a]	−0.378	0.13	.900[a]	.595[b]	−0.198	.986[a]	−.793[a]	−.799[a]	−0.212	.611[b]	−.605[b]
I16	−.587[b]	−.549[b]	−0.148	−0.069	−.699[a]	−.576[b]	0.232	−.536[b]	0.214	0.365	−0.019	−.737[a]	.879[a]
I17	.603[b]	0.171	.563[b]	0.268	−0.033	0.386	0.384	−0.249	.611[b]	.595[b]	0.442	0.219	−0.264
I18	−0.531	−0.309	−0.295	−0.433	−0.396	−.594[b]	−0.453	−0.291	−0.019	−0.098	−0.474	−.712[a]	.579[b]
I19	−.693[a]	−.803[a]	−0.08	−0.029	−.716[a]	−.656[b]	0.317	−.541[b]	0.161	0.309	0.093	−.618[b]	.833[a]
I20	−.596[b]	−.722[a]	0.087	0.034	−.655[b]	−.677[a]	0.184	−.587[b]	0.221	0.393	−0.035	−.702[a]	.755[a]
I21	0.102	0.062	0.204	0.36	0.124	−0.013	−0.013	0.131	0.027	0.032	0.26	0.371	−0.459
I22	0.166	0.312	0.096	.582[b]	.664[a]	0.319	0.202	0.48	−0.421	−0.353	−0.032	.653[b]	−.538[b]
I23	0.121	−0.447	0.237	−0.112	−.849[a]	−0.387	0.105	−.935[a]	.836[a]	.871[a]	0.284	−.538[b]	0.43
I24	−.614[b]	−0.511	−0.064	−0.086	−.704[a]	−.678[a]	0.057	−0.528	0.2	0.194	−0.23	−.690[a]	.786[a]

Table 2 (continued)

	Suicide (I14)	Illicit drug use (I15)	Adolescent pregnancies (I16)	Community/cultural connectedness (I17)	Residing outside the parental home (I18)	Educational achievement (I19)	Crime (I20)	Self rated health (I21)	Tobacco use (I22)	Housing and neighbourhood (I23)	Child welfare contacts (I24)
I1											
I2											
I3											
I4											
I5											
I6											
I7											
I8											
I9											
I10											
I11											
I12											
I13											
I14	1										
I15	.652[b]	1									
I16	−.581[b]	−.604[b]	1								
I17	0.183	−0.236	−0.133	1							
I18	−0.353	−0.319	0.486	−.567[b]	1						
I19	−.792[a]	−.605[b]	.795[a]	−0.234	0.335	1					
I20	−.652[b]	−.676[a]	.836[a]	−0.024	0.466	.693[a]	1				
I21	−0.101	0.158	−0.333	0.248	−0.44	−0.217	−0.351	1			
I22	0.425	0.461	−0.392	0.103	−0.47	−0.401	−0.154	0.224			
I23	−.572[b]	−.901[a]	0.448	0.306	0.176	0.424	0.450	−0.036	−.537[b]	1	
I24	−.683[a]	−.581[b]	.819[a]	−0.386	.692[a]	.731[a]	.703[a]	−0.342	−0.452	0.449	1

[a] Correlation is significant at the 0.01 level (2-tailed)

[b] Correlation is significant at the 0.05 level (2-tailed)

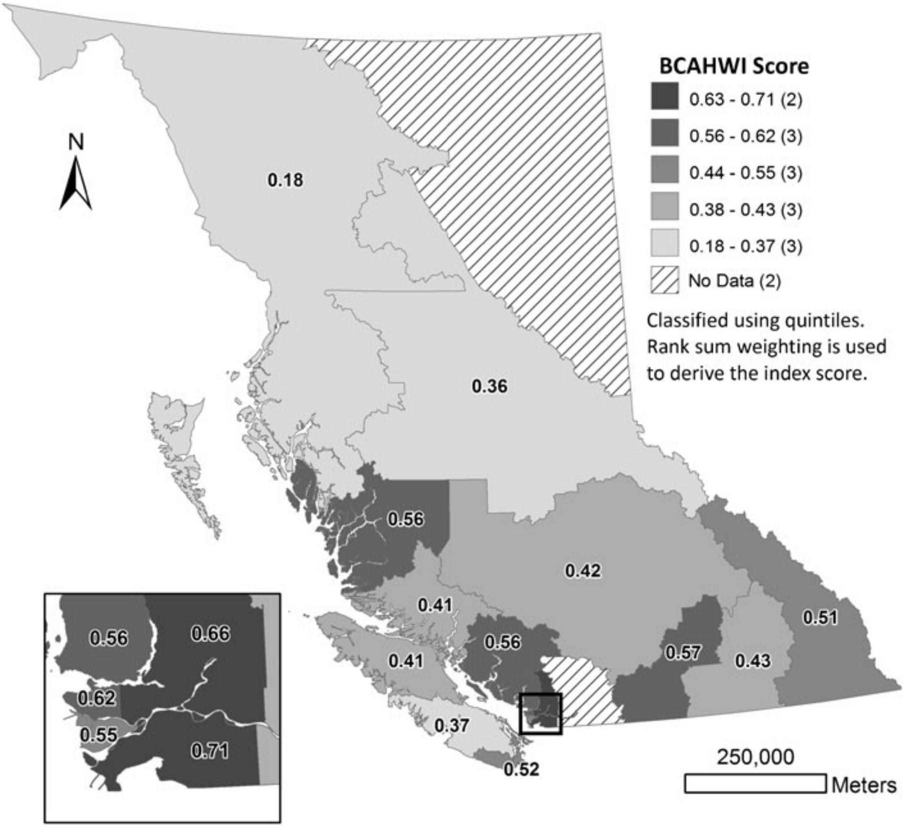

Fig. 2 BCAHWI scores of health service delivery areas

Statistical cluster analysis (see Fig. 3) illustrates that there appears to be regional effects on adolescent health and wellness throughout the Province. There is a cluster of high adolescent health and wellness in the southwest region of the Province (with the exception of Richmond) while the northwest is a cluster of low levels of adolescent health and wellness. The above results held whether specifying three, four or five clusters in the analysis.

Table 3 shows that a significant positive correlation at the 0.01 level with the BCAHWI was computed for 1) percent of total population, 2) population density and 3) percent of the population who were recent immigrants. A significant negative correlation at the 0.01 level with the BCAHWI for 1) percent of population who self-identified as aboriginal, and 2) percent of students classified as rural was found. Median family income was not significantly correlated nor was incidence of low income in economic families ($p>0.05$).

4 Discussion

We set out to pilot the construction of a composite index in order to report the geographical distribution of adolescent health and wellness in BC. In this paper we

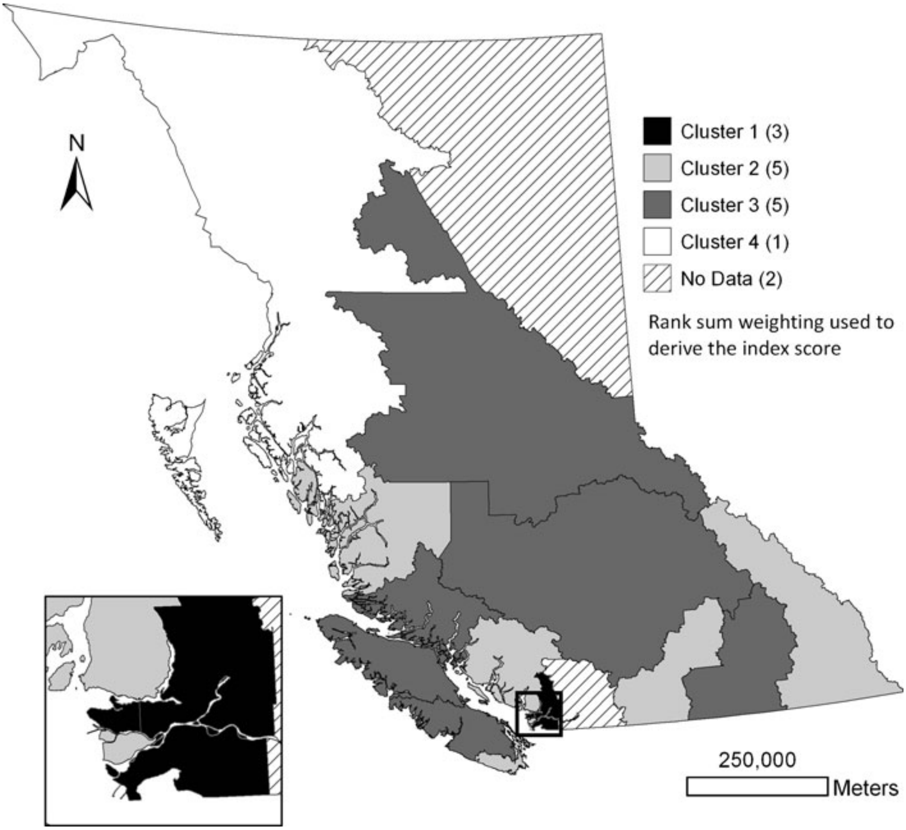

Fig. 3 Hierarchial cluster analysis results (4 clusters specified)

document how we constructed the index of adolescent health and wellness utilizing a spatial MCA technique. The TOPSIS method allowed for correlating indicators to be combined to create cardinal values for each HSDA which are easily interpretable. The methods reported in this paper can readily be duplicated for other populations, geographical areas and updated as data becomes available.

Table 3 Spearman's rho of BCAHWI with external factors

External factor	Correlation with BCAHWI
Percent aboriginal population	−.833[a]
Percent recent immigrant population	.752[a]
Percent of total population	.798[a]
Population density	.763[a]
Percent of students classified as rural/small town	−.664[a]
Median income	.349
Incidence of low income in economic families	.350

[a] Correlation is significant at the 0.01 level (2-tailed)

The indicators selected by the panel covered a range of domains. It is disappointing that a higher level of agreement between the participants was not found after three rounds of the Delphi survey. Additional rounds of the Delphi survey could have been conducted to explore communalities and disagreements. However, given time constraints and the risk of losing research participants by attrition we decided against additional rounds. As noted in previous sections, our selection of experts can be criticized for not including other experts in adolescent health and wellness, including health care practitioners and adolescents themselves. Future study should give this consideration.

The composite index allows the complexity of adolescent health and wellness to be visualized in order to gain a better understanding of the spatial patterns and geographic inequalities of adolescent health and wellness. The BCAHWI paints an informative picture of the well-being of adolescents within the Province. Adolescents living in the southwest region experience greater levels of health and wellness than the rest of the Province and there is a clear association between urban/rural measures and overall adolescent health and wellness. This is supported by literature that states rural adolescents have higher rates of high-risk behaviour (such as substance use) (Atav and Spencer 2002), often have fewer youth services and programs, and have less access to public transportation (Shepard 2005; Tonkin and Murphy 2002). Additionally, areas with relatively high percentages of new immigrants were associated with higher levels of adolescent health and wellness. This may be explained by a phenomenon termed “the healthy immigrant effect” which argues that new immigrants to Canada are generally in better health than those born in Canada. This is related to both self-selection of people choosing to come to Canada, and Canada’s fairly rigorous selection process which focuses on admitting those who are healthy (J. Chen et al. 1996; Beiser 2005).

Areas with a high percent of those self-identified as aboriginal have lower levels of adolescent health and wellness. Generally, in BC Aboriginal peoples have consistently been shown to have much poorer health and wellness outcomes than the rest of the population. The reasons for these conditions are many and complex. They are argued to include factors such as the impacts of colonialization, assimilation, residential school policies and poor economic conditions (Kendall 2009). In addition, BC has a large number of remote aboriginal settlements (Elliot and Foster 1995) thus, this is a possible confounding factor with urban/rural relationship noted above.

It is important to note that the analysis presented here is subject to concerns of ecological fallacy and the Modifiable Area Unit Problem (MAUP) (Carstairs 2000; Frohlich and Mustard 1996; Gatrell 2002). The challenge with aggregation of a population into geographical regions is that the number of geographical units and the determination of the exact location of the geographical boundaries of each area determine the outcome of analysis. Demographic differences may be contained within each HSDA (Frohlich and Mustard 1996). Generally data at higher resolutions (finer scale) are less biased (Malczewski 1999, 2000). However, when using larger scale units the areas are less likely to be influenced by the ‘small number problem’, where the addition and subtraction of a single individual can alter the estimate drastically, thus yielding unstable estimates (Gatrell 2002). The bottom line is that we remind the reader that all adolescents living in an area clearly do not share in all characteristics measured in this study, and that it is important to note that in exploratory studies, such as this, the inference remains at the aggregated level (Richardson and Monfort 2000). Although the research is conducted at the regional scale, findings are of potential interest and value at the local level as long as additional evidence is gathered to understand within region variation.

Limitations of the survey data are that only students in public schools were assessed in the BC AHS 2008, and the CCHS 2007/2008 does not survey those on aboriginal reserves or those without a residence. This implies that neither marginalized (i.e. those who have dropped out of school or who are living on the street) nor "privileged" adolescents (i.e. those who are in high cost private schools) are represented in some of the data sources. We recognize this as a weakness and it should be kept in mind when interpreting findings.

Spatial MCA provides a greater understanding to a situation rather than providing a solution (Malczewski 1999). The indicators identified by the panel of expertise may be relevant at the time of this study but, as social circumstances change, the indicators will need to be reviewed for relevance (Barnes et al. 2009; Carstairs 2000).

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