Proxies for healthcare need among populations: validation of alternatives – a study in Quebec

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Abstract

Study objective – To compare the use of a non-mortality based proxy for relative needs for healthcare among regional populations with a mortality based proxy for population relative needs and to evaluate the additional value of a proxy based on a combination of non-mortality and mortality based proxies.

Design – Analysis of cross sectional data on mortality, socioeconomic status, and self assessments of health taken from registrar general records, a population census, and a population health survey.

Setting – The province of Quebec, Canada.

Coverage – The populations of the 15 health regions in Quebec.

Main outcome measure – The levels of correlation of indicators based on mortality data, socioeconomic data, and combined data with a standardised indicator of self assessed health.

Results – Variations in scores of a proxy based on socioeconomic data among regions explain 37% of the observed variation in self assessed health, 4% more than the level of variation explained by the standardised mortality rate scores. A weighted combination of both mortality and socioeconomic based proxies explains 56% of variation in self assessed health.

Conclusions – Justification of "deprivation weights" reflecting variations in socioeconomic status among populations should be based on empirical support concerning the performance of such weights as proxies for relative levels of need among populations. The socioeconomic proxy developed in this study provides a closer correlation to the self assessed health of the populations under study than the mortality based proxy. The superior performance of the combined indicator suggests that the development of social deprivation indicators should be viewed as a complement to, as opposed to a substitute for, mortality based measures in needs based resource allocation exercises.

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Governments in many jurisdictions have accepted that the unregulated market is inappropriate as a mechanism for allocating healthcare resources. In Canada, a policy of full public funding of all hospital and physician services[1] has been used to pursue the policy goal of allocating resources according to "medical necessity".[2] But the public funding for healthcare has continued to be allocated among providers of care largely according to the levels of services provided (hospital budgets based on the previous year's activities and fee-for-service payment of physicians) as opposed to the level and mix of needs of the populations being served.[3] There is no reason why providers should "naturally" gravitate to (or serve) populations of greatest need given that payments are independent of relative levels of need.[4]

Provincial ministries of health have recognised[5–11] the importance of (and in the e of one province, Saskatchewan, implemented[12]) a population needs based approach to resource allocation.

The relative levels of risks to health, and needs for healthcare, have been identified by policy makers in many other countries as an appropriate concept for allocating resources.[13] Translating this consensus to agreement over how it may be operationalised remains a major challenge for policy makers and researchers. Measures of mortality at the population level have been proposed and used as a proxy indicator for relative levels of healthcare need in several applications of population needs based allocation formulas for healthcare[14] based on empirical findings concerning correlations observed at the population level between mortality and various aspects of morbidity.

In Canada, the use of a proxy for healthcare need based on mortality data has been criticised as "counterintuitive"[15] and general concern has been expressed about face validity as healthcare policy makers seek to move away from the notion of an illness-care system and emphasise notions of "wellness".[16] In this sense, mortality free proxies for population healthcare needs have greater "face validity" among many policy makers than indicators based on mortality data. Others[17] have questioned a strategy of "simply increasing the services available to those who are more predisposed towards low health status (as proxied by mortality indicators)" preferring policies which aim to change "the underlying inequalities in amenable socioeconomic risk factors". But this seems to be concerned with issues of allocations of resources between healthcare and other social programmes, as opposed to allocating *healthcare* resources among populations for serving the sick, or those at greatest risk of becoming sick.

More generally the use of mortality based proxies for relative needs for care has been criticised for failing to recognise the impact of social conditions on healthcare needs.[18–23] In particular, social deprivation would affect healthcare needs beyond that reflected in rel-

ative rates of mortality if the relationship between mortality and morbidity in populations were a function of social conditions in populations. For example, morbidity might be more "compressed"[24] or concentrated in periods immediately before death among populations with more favourable social conditions.

Mays *et al*[25] note that, "despite these criticisms several studies have produced results which support the use of mortality data, both as a morbidity indicator and as an indicator of social deprivation likely to be associated with additional health-resource needs". Nonetheless, various attempts have been made to develop population based measures of social deprivation as either an alternative for, or a supplement to, mortality based proxies.[26-28] These attempts often involve various socioeconomic variables based on the well established associations between prosperity and health.[29-32] But as Mays *et al* note,[25] "it is difficult to know which of the needs indicators currently used (in resource allocation formula) or favoured for inclusion by critics of the prevailing formula, or used to validate other indicators, . . . are themselves valid indicators of needs associated with ill health". So although the use of social deprivation indicators as proxies for relative needs for healthcare resources might have more face validity than mortality based ones, the real issue to be addressed is how do the two approaches perform as proxies for relative needs for care among populations?

It therefore seems appropriate to identify an underlying concept of need for care that, although preferred as a basis for allocations, cannot be used because of limitations in the frequency, timing, or availability of data for complete populations. This can then be used as a basis for validating other potential proxy indicators for which data are, or could be made, available, whether they are based on mortality, deprivation, or even utilisation data. For example, Carr Hill[33] used variations in both mortality rates and social conditions to explain variations in self reported morbidity among populations. In this way the derived indicators are selected on their ability to reflect the subject of the exercise. For this study, self assessed health status is used as the underlying and independent measure of relative need among populations based on the close correlations observed between this variable and several other measures of health status or indicators of needs for care. For example, in a recent analysis of the health and activity limitations survey in the UK, self rated health was found to correlate with a wide range of health and socioeconomic variables at both the population and individual level.[25] This confirmed earlier findings of significant correlations, usually of moderate strength, between self rated health and physician assessments,[34-38] number and/or type of self reported health problems, diagnoses or chronic disease,[37 39-42] number of medications,[37 40] acute symptoms,[41] and various composite measures of health status based on either self reports or a combination of physician reported and self reported conditions and health service utilisation data.[43] It has also been shown to be a good predictor of future mortality.[44]

Mortality and non-mortality based proxies for needs are calculated and compared with regard to the levels of correlation with an index of self assessed health at the regional level. We then go on to develop a combined indicator in order to see if introducing socioeconomic variables in addition to mortality data leads to an improvement in the proxy variable, or reflects "double counting" of the same underlying relationships. The two questions to be addressed by the analysis are (a) can a non-mortality based indicator of population relative need for care be developed which is able to explain a significantly greater level of variation in needs among populations than the standardised mortality ratio? and (b) does the inclusion of socioeconomic data in addition to mortality data in a proxy for population needs lead to significant improvements in explanatory power?

Methods

For the purpose of this study, self rated health is used as an "ideal" or "gold standard" measure of population need for care. This is a five level, categorical variable in which individual respondents were asked to rate their own health as excellent, very good, good, fair, or poor compared to other persons of their own age and sex. A population composite measure of health, the standardised health ratio (SHR), is calculated by taking the ratio of observed levels of self assessed health in the region's population to the levels of health expected if the distribution of self assessed health by age group and sex were the same as observed in the province as a whole. We then develop a standardised socioeconomic indicator (SEI), given by a score based on a logistic model linking morbidity to demographic and socioeconomic variables. Finally, we calculate standardised mortality ratios (SMRs) for each region based on relative rates of premature mortality (ie, deaths at ages 0–74) in each region. The particular details of the calculation of each indicator can be found in the Appendix.

Taking the SHR as the standard, we calculate and compare the Pearson correlation coefficients between (a) SHR and SEI scores for each region, and (b) the SHR and SMR scores for each region. A linear regression model is then used in which SHR scores are regressed onto both SMRs and SEIs to see if the socioeconomic data add to the explanation of variation in SHR among regions beyond what is already explained by SMRs.

Data are used for the populations of the 15 healthcare planning regions in the province of Quebec. Data on health and socioeconomic variables are taken from the 1987 santé Quebec survey,[45] a randomised survey of the non-institutionalised population of the province with a sample size of 19 000. These data are supplemented by vital statistics data for each region for years 1984–88 and socioeconomic data taken from the 1986 population census, both provided to us directly by the Quebec Ministry of Health.

Table 1 Relative odds (95% confidence intervals) for self assessment of "unhealthy" based on logistic regression. Quebec, 1987*

		Relative odds	(95% CI)
Sex	Female	1.00	—
	Male	0.87	(0.78,0.96)
Age group (y)	≥65	1.00	—
	45–64	0.95	(0.82,1.09)
	25–44	0.35	(0.30,0.41)
	15–24	0.24	(0.19,0.30)
Household income	<20	1.00	—
($000s)	20–29	0.79	(0.69,0.91)
	30–39	0.57	(0.48,0.66)
	40–49	0.52	(0.43,0.63)
	≥50	0.47	(0.39,0.56)
Education	Did not complete secondary school	1.00	—
	Secondary school graduation	0.48	(0.42,0.55)
	Post-secondary without degree	0.35	(0.27,0.45)
	University degree or equivalent	0.34	(0.29,0.41)

* Other variables entered into the equation but not found to be significant were employment status (currently employed; not currently employed), smoking status (smokes cigarettes, pipe, cigars, and/snuff on a regular basis, occasionally or never) and drinking status (consumes alcoholic beverage more than three times a week, less than 3 times a week or never).

Results

Using data for the provincial population as a whole, an equation was estimated using logistic regression to explain the relative odds of reporting one's health as either poor or fair in terms of a set of socioeconomic variables measured at the individual level. Variables were selected for inclusion in the estimations based on the level of their simple correlation with the self assessed health variable. The final equation was based on the set of socioeconomic variables making significant contributions to explaining the variation in self assessed health.

The estimated relative odds for each "explanatory" variable found to be significantly correlated with self assessed health are recorded in table 1. The estimated relative odds produce the expected patterns with older groups, members of poorer households and less educated groups all being more likely to rate themselves as "unhealthy" than groups with other levels of each variable.

This estimated equation for poor or fair health was then used to calculate the standardised economic indicator (SEI) for each region by applying regional levels of each variable to the estimated equation. The SEI scores for each region are recorded in table 2 along with the SMR and SHR scores calculated directly from the regional distributions of mortality and illness as described in the previous section, the

rankings of regions for each indicator and the Pearson correlation coefficients. The SHR and SMR values are statistically significant (p<0.05) for each region (with the exception of the SHR score for Laurentides and SMR for Quebec). This indicates that the difference between the region's score and the provincial score was more than could be explained by chance. However, many of the confidence intervals for regional scores overlap indicating differences between regions may be due to chance. Because the SEI was calculated using a linear combination of relative odds, confidence intervals for SEI scores cannot be calculated.

Taking the SHR as the "standard" we can consider whether a region's score suggests that it has either a lower or higher prevalence of "unhealthy" individuals than the province as a whole (ie, a score of less than or greater than one respectively). This dichotomous classification can then be compared with the equivalent classification using the SEI and the SMR. On this basis the SEI, which provides scores inconsistent with the SHR for just one region, performs better than the SMR, for which four regions have inconsistent scores.

In terms of the statistical correlations, both SEI and SMR scores are significantly correlated with the SHR. However, the SEI provides a higher (though not statistically significantly higher) level of correlation. The levels of correlation observed here imply that variations in the SMR explain one third of the between region variation in SHR scores. The SEI scores explain 37%.

It is worth noting that the data used for both the SMR and SEI were collected for the entire population, while the santé Quebec survey from which the health assessment data were taken was based on the non-institutionalised population only. It might be that data collected for corresponding population definitions would produce closer correlations. Another possible explanation for the modest levels of correlation is the loss of variation arising from the combination of health status categories into "healthy" and "unhealthy". In effect we are trying to explain variation in a measure for which between-region variation is modest. Larger sample sizes – not currently available –

Table 2 Calculated needs indicators and correlation coefficients between indicators for regional populations. Quebec, 1987

Region	SHR	(95% CI)	Rank*	SMR	(95% CI)	Rank*	SEI	Rank*
Bas St-Laurent	1.19	(1.1855,1.1857)	3 =	0.97	(0.9695,0.9705)	13	1.04	2
Saguenary/Lac-St-Jean	1.13	(1.1307,1.1309)	6 =	1.09	(1.0897,1.0903)	3 =	1.02	4 =
Quebec	0.83	(0.8311,0.8311)	15	1.00	(0.9998,1.0002)	9	0.99	11 =
Mauricie/Bois-Francs	1.06	(1.0626,1.0627)	8	1.02	(1.0198,1.0202)	7	1.02	4 =
Estrie	1.18	(1.1762,1.1764)	5	0.98	(0.9796,0.9804)	10 =	1.03	3
Montreal-Centre	0.93	(0.9338,0.9339)	13	0.98	(0.9800,0.9801)	10 =	1.00	8 =
Outaouais	1.20	(1.2010,1.2012)	2	1.10	(1.0997,1.1003)	2	1.00	8 =
Abitibi/Temiscaminque	1.27	(1.2720,1.2725)	1	1.12	(1.1195,1.1205)	1	0.99	11 =
Cote-Nord	0.97	(0.9729,0.9734)	12	1.09	(1.0890,1.0910)	3 =	0.98	13 =
Gaspesie	1.19	(1.1912,1.1917)	3 =	1.03	(1.0292,1.0308)	6	1.05	1
Chaudier/Appalaches	1.02	(1.0234,1.0235)	9	0.95	(0.9497,0.9503)	14	1.01	6 =
Laval	0.84	(0.8427,0.8428)	14	0.87	(0.8694,0.8706)	15	0.96	15
Lanaudiere	1.13	(1.1298,1.1300)	6 =	1.06	(1.0597,1.0603)	5	1.00	8 =
Laurentides	1.00	(0.9951,0.9952)	10	1.01	(1.0097,1.0103)	8	1.01	6 =
Monteregie	0.98	(0.9821,0.9821)	11	0.98	(0.9799,0.9801)	10 =	0.98	13 =
Correlation with SHR				0.577 (0.10 0.84)			0.607 (0.14 0.85)	

SHR = observed number unhealthy/expected number unhealthy;
SMR = observed deaths/expected deaths;
SEI = population weighted by "unhealthy" population characteristics/actual population;
* = higher ranking indicates poorer health.

would allow us to explore this possible refinement of the analysis either through finer categorisations of health levels or/and the use of smaller, more homogeneous populations.

Finally, an equation was estimated to explain variation between regions in SHR scores in terms of both SMRs and SEI scores. The best combination of the two indicators, in terms of the power of the combination to explain regional variations in SHR, involves a partial weighting of both indicators as follows:

$$I = 1.03 \text{ SMR} + 3.02 \text{ SEI}$$

where I is the combined proxy for SHI and the weights are given by the estimated coefficients in the equation for self assessed health. This weighted indicator increases the explanatory power of the SHI equation to 56% based on the adjusted R^2 indicating that the two explanatory variables represent substantially different underlying factors in the regional variation in SHR.

Discussion

Approaches to healthcare resource allocations that are intended to incorporate differences in population needs for healthcare require valid indicators of these differences in need. From a conceptual perspective, self assessed health is perhaps the best indicator of population morbidity, particularly at the primary care level since it tends to reflect individuals' perceptions of their health in the context of their expectations for their health. From an empirical perspective, self assessed health has been found to correlate closely with a whole range of other health and healthcare need indicators. However, attempts to incorporate self assessed health data into resource allocation formulas are limited by the lack of frequently collected data for large representative populations. Instead the population based, self assessed health data that are available can be used as a basis for comparing alternative proxies for relative needs for healthcare among populations. We calculated correlation coefficients between an index of self assessed health and separate proxies for need based on mortality and socioeconomic data. The non-mortality based SEI provides a marginally better proxy for self assessed health status than the SMR based on correlation coefficients of 0.607 and 0.577 respectively. Although the levels of correlation observed in this study are modest, they are similar to the levels found in other studies. For example, based on an analysis of UK data, Mays *et al* reported a correlation co-efficient of 0.69 between self assessed health and SMRs and 0.52 between self assessed health and the best of three alternative social deprivation indices.[25]

Because the information on which we based our SEI index came from census data, normally collected at best at five year intervals, the gain in explanatory power is offset by the infrequency of up to date information. Estimation procedures could be used to estimate intercensal values of these variables. However such estimates are subject to potential biases in the adjustment procedures which could only be verified after the event. Moreover, increasing the frequency of data collection is costly, and may not be justified on the basis of its use in resource allocation formulas alone.

The marginal (and not significant) improvements in correlation with self assessed health achieved by use of the non mortality based proxy translates into a 3.5% increase in the power to explain variations in SHR values among regions. Concerns about the face validity of mortality based measures are therefore not substantiated by the research. Similarly, Mays *et al*[25] found the SMR to be a, "reasonable proxy for both objective and subjective definitions of ill health . . . (and is also) well correlated (at the regional level) with deprivation indices . . . (although it was) poorly correlated with longstanding illness at the regional level".

The hypothesis that the variations in health explained by SMR and SEI scores represent separate sources of variation was supported by our analysis of a combined indicator. Additional explanatory power was provided by including the non-mortality based measure even after allowing for variation explained by mortality rates. But over one third of the variation explained by the SEI alone was already explained by the SMR. As a consequence, the temptation to replace mortality measures with deprivation indicators in any allocation formula should be resisted. Instead attention might focus on attempts to apportion and include separate influences from the two types of measure based on careful analysis of the appropriate combination (ie, weighting) of the measures in the explanation of variations in the health of regional populations. Our construction of the SEI indicator was based on the same notions of the broader determinants of health or inequalities in health underlying the construction of the various deprivation indicators appearing in the literature. However, the use of general socioeconomic indicators as opposed to a restricted focus on deprivation per se reflects the increasing recognition and emerging evidence that relationships between health and economic wellbeing are observed throughout the range of affluence and not restricted to the poorest groups.[31] Nevertheless, the data available to us for the development of the SEI were predominantly measures of material, as opposed to social, deprivation. Although the demarcation between material and social deprivation is not clear,[31] in general social deprivation concerns an individual's place in society as opposed to the resources or possessions at his or her disposal. The number of ethnic minority households, the number of elderly persons living alone, and the number of lone-parent female heads of households might all be considered potential indicators of social deprivation and each has been used in the development of social deprivation indicators.[26 27 32 46-48] Regional data on these variables were not available for inclusion in this analysis. Although data on ethnicity were included in the survey,[45] the data referred to mother tongue and were highly skewed towards French and, less so, English, representing the anglophone-francophone domination of the population under con-

sideration. It may be that at a less aggregate level of population, "pockets" of other ethnic groups might be found such that the association between ethnic minorities and self assessed health could be estimated. But at the regional level the percentage of the population with mother tongue that is neither French nor English is tiny (mean 0.04), and with the exception of one outlier (Montreal, 0.216) there is little variation between regions (range 0.006–0.216, coefficient of variation 8.53).

It may be that similar low levels of variation in proxy scores or the underlying variables on which they are based are responsible for the modest levels of explanatory power. In other words, within-region variation might be more important in identifying and understanding relationships among need and the proxies used here than between-region variation. For example, the SEI derived in this analysis showed only a 9% variation between the least and most "deprived" regions (compared to 25% and 44% variation in SMR and SHR values respectively). However, the analytical methods for exploring these potentially more meaningful variations may be inadequate to uncover underlying relationships. In particular, the use of individual, family, and community based variables alongside one another fails to reflect the hierarchical structure of the underlying model[49] and may lead to bias in the estimated relationships. More appropriate methods that reflect this hierarchical structure have been developed and used[49] in an attempt to derive better estimates of underlying relationships. Research aimed at further informing policy on relative needs for care among populations might therefore consider the use of increased sample sizes in order to permit the use of these multi-level estimation methods in explaining variations among and within regional populations. Perhaps the most important message emerging from this study is the importance of the appropriate basis for assessing alternative indicators of need for care. Although there may be strong support for building deprivation weights of various kinds into allocation formulas, justification for such weights is often based more on subjective preferences than objective criteria. If resources are to be allocated in accordance with populations' relative needs for those resources, attempts to improve on the use of mortality-based indicators should be based on empirical support for the indicator's performance. In particular, criteria for introducing non-mortality based indicators should include the explanatory power of the indicators in equations for needs measured independently of the variables used in the construction of proxy indicators, as well as the cost effectiveness of any such improvements. But until that time, the available evidence suggests that large investments in data collection and analysis would be required to achieve only marginal improvements in the validity of the population indicators. In view of the pressures of increasing demands and expectations on constrained healthcare budgets this implies that for the purposes of allocating resources in accordance with populations' relative needs, mortality, as an indicator, is inevitable!

Appendix
DERIVATION OF THE STANDARDISED HEALTH RATIO AND STANDARDISED ECONOMIC INDICATOR

Standardised health ratio (SHR)
The SHR expresses the levels of health of the population in relation to the health levels that would be expected if the age and sex specific levels of health of the provincial population were experienced by the region's population. In this way, the method of standardisation is analogous to that in the calculations of standardised mortality ratio. The three stages of the calculation are as follows:

(a) Calculate population rates of self reports of health as fair or poor (ie, the unhealthy group) for each age and sex category of the population of the province based on the population sample.

(b) Apply the calculated provincial rates of prevalence of "unhealthy" in relation to age and sex to the age and sex distribution of each region's population.

(c) Calculate the SHR, which is the ratio of the observed number of "unhealthy" individuals in a region based on the sample responses in that region to the expected number of "unhealthy" individuals as calculated in the previous step.

An SHR score of greater than 1 indicates that the population of the region has lower levels of self assessed health than expected given the age and sex distribution of the population. A population with a score of less than 1 has higher levels than expected.

Standardised economic indicator (SEI)
The SEI expresses the socioeconomic status of a region's population in terms of the values of characteristics observed to be significantly correlated with self assessed health. The three stages of the calculation are set out below.

Estimate an equation at the individual level for the probability of reporting health as fair or poor among the provincial population using a logistic regression[50] with explanatory variables, sex, age group, marital status, employment status, smoking behaviour, alcohol consumption, household income, and education. Variables significantly associated with the health variable ($p<0.05$) were included in the SEI equation.

Ideally an ordered probit model[51] would be used to take account of the full variation in the self rated health measure. However, in doing this, several of the health/age group/sex cells had no observations implying that the estimation of relative risks of the finer categorisation would be based on these combinations never occurring. Given the relatively small size of the sample, it is more likely that there are individuals with these combinations of characteristics but not in sufficient numbers to be identified in a survey of 19 000 individuals.

Following Yuen *et al*,[52] use the estimated coefficients to calculate odds ratios of being "unhealthy" for each level of those explanatory variables found to be statistically significant ($p<0.05$) in the SEI equation. Variables not

statistically significant are assigned relative odds of 1.

Calculate a SEI score for each region by applying the relative odds to the number of individuals in the region with each level of the explanatory variable and summing these weighted regional populations to reflect the additive form of the SEI equation. This weighted population is thus divided by the actual population of each region and standardised around a provincial population mean of 100.

ie, $SEI_i = [(P_{i,a} \times RO_a) + (P_{i,b} \times RO_b)...]/P_i$

where P_i is the total population of the region $P_{i,a}$ is the population in the region with characteristic a RO_a is the relative odds of being "unhealthy" for those in the provincial population with characteristic a.

In principle we could calculate an "extended" SEI which adjusts for the economic variables in the same way that we adjust for age and sex in the calculation of the SHR. However, this increases the number of "cells" considerably and results in many empty cells. Instead the approach outlined above allows us to introduce variation in self rated health associated with these socioeconomic variables using econometric methods.

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