Econometric methods for secondary data in health research

by

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Abstract

This dissertation integrates econometric methods into the multidisciplinary field of health research. Applied econometric methods commonly used in academic economic research are powerful tools that can optimize the use of secondary data. This dissertation applies these tools in four independent chapters that are specifically targeted to government policy decision makers. The first chapter applies the instrumental variable regression models to study the relationship between Canadian Obesity and income and finds evidence of inequity in the context of public health. The second chapter studies the relationship between vitamin D and various mental health indicators while expanding ordered logistic regression models with margin effects. The results from this chapter can be used as a promotional tool as an interim solution for vitamin D deficiencies in Canada. The third chapter studies the acute myocardial infarction key performance indicator that has been mandated by the Alberta Ministry of Health and Wellness government department through an economic lens. The final chapter validates the CMG+ costing estimate of acute myocardial infarction for the province of Alberta. Each chapter incorporates a unique use-case for government decision makers as well as incorporates applied econometrics to optimize secondary data for health research targeted to these decision makers.

Preface

Chapters one and two of this research was supported by funds to Canadian Research Data Centre Network (CRDCN) from the Social Sciences and Humanities Research Council (SSHRC), the Canadian Institute for Health Research (CIHR), the Canadian Foundation for Innovation (CFI), and Statistics Canada. Although the research and analysis are based on data from Statistics Canada, the opinions expressed do not represent the views of Statistics Canada.

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All literature review, research design, and data analysis are my original work. All listed co-authors provided guidance and support during all stages of the research.

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List of Abbreviations

25(OH)D	25-Hydroxyvitamin D
AMI	Acute Myocardial Infarction
IHDA	Alberta Health and Wellness Interactive Health Data Application
AHS	Alberta Health Services
BMI	Body Mass Index
CCHS	Canadian Community Health Survey
CFI	Canadian Foundation for Innovation
CHMS	Canadian Health Measures Survey
CIHI	Canadian Institute for Health Information
CIHR	Canadian Institute for Health Research
CRDCN	Canadian Research Data Centre Network
CANSIM	Canadian Socio-economic Information Management System
CMG+	Case Mixed Groups
CABG	Coronary Artery Bypass Grafting
CPWC	Cost Per Weighted Case
DRG	Diagnosis Related Group
DAD	Discharge Abstract Database
ELOS	Expected Length of Stay
HUI3	Health Utility Index 3
IV	Instrumental Variable
ICD-10	International Classification of Diseases tenth Revision
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
IU/D	International unit per day
KPI	Key Performance Indicator
KT	Knowledge Transfer
LOS	Length of Stay
MIS	Management Information System
NPHS	National Population Health Survey
PCCF	Postal CodeOM Conversion File
PHAC	Public Health Agency of Canada
RCT	Randomized Controlled Trial
RIW	Resource Intensity Weights
SAD	Seasonal Affect Disorder
SEM	Socio-Ecological Model
SSHRC	Social Sciences and Humanities Research Council
VDR	Vitamin D receptors
WHO	World Health Organization

Introduction

Interdisciplinary research has become the dominant model in health research [**1**]. Research in medicine incorporates interdisciplinary tools and methods from many areas of studies such as epidemiology, biostatistics, behavioral sciences, social sciences, and many others. Economics in health research has had major developments in cost-effectiveness, cost-benefit, and cost-utility analysis but health research has not efficiently used other tools from economics. These tools such as 2-stage IV regression and margin effects have been commonly used in the field of economics but rarely used in health research. Integration of these tools into health research would allow health researchers to maximize the use of secondary health data.

A key consideration when utilizing more complex models in health research is the transfer of research findings into practice; this is often a slow and haphazard process. For many reasons, research findings are not being taken up in practice settings. This situation results in inefficient use of health resources. This growing awareness that research findings are not making its way into practice in a timely fashion, along with the growing emphasis on evidence-based decision making has stimulated the increased interest in finding ways to minimize the knowledge-to-action gap. [**2**] Knowledge translation is a concept to describe the gap between research knowledge and its application. The typical Knowledge Translation (KT) processes begins with the knowledge creation and then subsequently the knowledge is integrated, refined and converted into a use-able package for the target audience. This dissertation will attempt to minimize the knowledge-to-action gap by minimizing the complexity of economic modeling where ever possible as well as integrating possible policy implications and use-cases within each research chapter.

This dissertation is composed of four independent chapters that integrates econometric modeling to maximize secondary data in health policy research. Examples of econometric modelling applied throughout many parts of this dissertation are Instrumental Variable (IV) regression models that can control unobservable confounders or confounders not found in secondary health databases as well as to estimate causal models when randomized control trials are unrealistic [**3**]. IV regression methods have been used in many fields in Canada such as studying banking and economic growth [**4**], currency substitution and the demand for money [**5**], energy consumption [**6**], environment and emissions [**7**], foreign exchange [**8**] and many others. They have also been used in health research to study: antidepressants [**9**], treatment effects [**10**], drug safety [**11**], and vaccine effectiveness [**12**]. However, they are still uncommon for government policy studies. This type of regression model requires a set of variables that are highly correlated with the variable of interest and not correlated with the outcome. Any correlation with the outcome will cause a correlation with the regression residual causing a bias in the IV estimation [**13**], In many health studies, utilizing secondary data, such as population health surveys, it is often difficult and sometimes impossible to find an IV that meets all these criteria's [**14**]. This dissertation also proposes a new set of IVs that can be linked through postal codes or health regions which are common in many government and health data bases such as patient diagnostic abstracts or health administrative databases.

The first chapter studies the socio-economic effect of obesity, specifically the relationship between personal income and obesity. If a negative relationship exists between income and obesity (as shown in many studies across the world) then this relationship could be used as a health promotion tool, where the results could be used in a marketing campaign for dis-incentivizing obesity or the results can be used as evidence of inequity in public health.

The objective of the second chapter is to investigate the association of serum 25(OH)D concentrations with indicators of mental health such as depression, anxiety, and stress. The possibility of a low-risk and low-cost solution for depression and anxiety in itself is an action-able knowledge transfer. If a possible relationship is found, then policy makers can promote vitamin D for a gain in public mental health. Alternatively, positive results can also be used as a health promotion marketing tool for the public to increase vitamin D supplementation as it has been shown that Canadians on average are deficient in vitamin D [**74**].

The main function of vitamin D is calcium homeostasis [**15**] [**16**]; however, emerging evidence has correlated adequate serum 25-hydroxyvitamin D (25(OH)D) concentrations with other health conditions including better mental health [**17**]. Ordered logistic regression is a common tool used in epidemiology [**18**] but this chapter will take this common tool one step further by using marginal effects which will plot the predictive probabilities against serum 25(OH)D concentrations levels. This plot provides a visual representation of complex results for the average Canadian adult and their probability of being in a better mental health state with each increase in serum 25(OH)D concentrations. The simplicity of this plot will optimize the knowledge transfer to decision makers for effective changes in health policy.

The third chapter ties in with the Alberta Ministry of Health and Wellness mandated to provide Albertans with the best possible care and outcomes possible. One of the key performance indicators (KPI) of measuring these outcomes is assessing the quality of Acute Myocardial Infarction (AMI) services provided to Albertans. This chapter explores the relationship between hospital costs and quality of care for AMI in the Edmonton area hospitals. The importance of this relationship is realized when decision makers are faced with challenging budgetary constraints [**19**] [**20**]. This study uses parametric and semi-parametric economic regression modelling with increasing specifications.

The final chapter is an extension of the third chapter which expands the robustness checks by validating the costing proxy for economic evaluations for acute myocardial infarction. This is the first study to evaluate the Case Mixed CMG+ as a costing proxy for acute myocardial infarction patients. The CMG+ introduced by CIHI replaces the former Case Mixed Group system that was designed to classify discharge patients to one of approximately 600 resource groups with 25 major clinical categories based on the most responsible diagnosis. This allowed hospital costs to be estimated based on similar cost and hospital length of stay. [**21**] [**22**] [**23**] This chapter will compare the CMG+ costing proxy for AMI patients with its actual micro-costing data by using Intra-class correlation coefficients based on Kappa Statistics cut points. These intra-class correlation coefficients will test the agreeability between the two costing data sets. The validation of these costing estimates will aid government and health research between departments, jurisdictions or research bodies when sharing of micro-level data is not possible due to data sensitivity and privacy concerns.

This dissertation focuses on expanding health research for evidence-based health promotion and policy changes by using econometric methods to maximize secondary health data.

Chapter 1: The Obesity Wage Penalty

1.1.0 Introduction and background

The direct cost of obesity has been studied substantially but the indirect cost of obesity is relatively unknown in Canada. The Canadian prevalence of adult obesity has drastically increased from 6% to 18% between 1989 and 2011 [**24**]. Obesity has also been shown to be associated with increased healthcare utilization, decreased productivity, increased chronic diseases, and shorter life expectancy [**25**]. Luther (2010) claimed that wage penalties exist for obese individuals in Canada [**26**]. However, this argument has very limited empirical evidence, especially since Canadian social norms are drawn from different cultures, genders, and races. This study explores the association and attempts to estimate causations between the effects of obesity on personal income for Canadians in the general labor market, while simultaneously controlling for confounders from the perspective of the SEM framework such as socioeconomic status, demographics, health, lifestyles, industry, and occupations. The results from this study will aid health promotion at the health policy level.

Currently, only two Canadian obesity-penalty studies exist. The first [5] investigates the impact of obesity on employment and income for Canadians aged 25-53 in the labor market using a longitudinal data set. They found that obesity was associated with a reduction in annual income of 2% and 4.5% for men and women respectively. Their study found no causal evidence using lagged BMI (the BMI of the respondent in previous years) as the IV. The same longitudinal data set will be applied in this study but with different methodologies.

These methodological differences include a larger age sample, less restrictive sample inclusion criteria, different extrapolation methods for missing variables, and an additional causal model. These differences will provide supporting evidence and ensure robustness of the results presented by Larose et al., (2016) and add to the limited Canadian literature. [**27**]

The second Canadian study utilizes a cross-sectional dataset to study the effect of household income and obesity. Their causal model suggested that a 1% increase in household income caused a 0.76% and 0.27% decrease in the probability of being obese for men and women, respectively. Our study considers different factors that provide more individual specific data such as personal income instead of household income and the longitudinal nature of our data set allows us to control for individual heterogeneity across time. A comparison of the current study along with the other two studies would provide insight on the Canadian obesity wage-penalty and ensure robustness of all current Canadian literatures [**25**], as well as support Canadian policy makers.

The effect of obesity on wage and employment has been investigated in many other countries such as Australia [**28**], Brazil [**29**], China [**30**], Denmark [**31**], Ethiopia [**32**], general Europe [**33**] [**34**] [**35**] [**36**] [**37**], Finland [**38**], Germany [**39**] [**40**], Russia [**41**], Spain [**42**], Taiwan [**43**], United Kingdom [**44**] [**45**] [**46**] [**47**], and the United States [**48**] [**13**] [**49**] [**50**] [**51**] [**52**] [**53**] [**54**] [**55**] [**56**].

It is important to establish if the obesity wage-penalty is an association or causation. Among working class females, obesity was found to have an inverse relationship with income in studies using data from Austria, Belgium, Italy [**37**], Denmark [**33**] [**37**], England [**44**], Finland [**33**] [**38**] [**37**], general Europe [**34**] [**36**], Germany, United States [**39**], and Portugal [**33**] [**37**]. Similarly, an inverse relationship for working class males was found in England [**44**], general Europe [**34**], and Italy [**36**]; while obesity was found to be associated with higher income for the working class males in Belgium [**33**], Brazil [**29**], China [**30**], Finland [**37**], Portugal [**37**], and United States [**39**]. Researchers have tried to impute causation and control for unobservable variable bias using a two-stage regression model, but were unable to find any effects for both male and female working age groups in Australia [**28**], Brazil [**29**], China [**30**], England [**44**], and Ethiopia [**32**]. However, one study [**34**] found evidence of a negative causation between obesity and income amongst the working population for both genders in general Europe. Another study found evidence of a positive causation in post-Soviet Russia for the female working population [**41**].

Endogeneity has been a subject of great importance within the obesity wage-penalty literatures. Many studies have attempted to impute causation and control for unobservable characteristics. These unobservable characteristics are immeasurable variables that have associations with both obesity and income, which will bias the results. It has been suggested that these unobservable variables include differences in individual time preferences, such as one's willingness to sacrifice today's consumption for a higher future consumption. This causes differences in investments to human capital and health [**52**].

It has also been suggested that these unobservable variables include individual abilities and genetic factors that influence both weight and income [**13**].

There are currently three general methodologies for endogeneity. The first is from older studies where lagged (BMI) was used to control for reverse causation [**57**] [**58**]. However, this fails if any serial inter-temporal correlation exists in the wage residuals; for example, any lagged factors from the past that are associated with obesity today could also be correlated with non-lagged factors from today [**13**] [**52**].

The remaining two methodologies for endogeneity in the obesity wage-penalty involve two-stage IV regression models. The first type of instrument is based on a genetic and non-genetic decomposition of body weight. Genetic and non-genetic factors, such as individual environment and individual choices will contribute to one's body weight and income. These analogous factors are usually unobservable and will bias the true relationship. It has been suggested that a variable highly correlated with genetics but not with income, would be a strong IV [**13**], The respondents sibling's BMI controlled for age and gender was used as an IV in Cawley (2004), which lead many subsequent studies to adopt similar family related variables as instruments [**39**] [**34**] [**35**] [**36**] [**51**] [**30**] [**31**] [**28**] [**46**] [**55**]. However, this family or genetic decomposition method would fail if family members share unobserved earning endowment factors [**52**].

The final general methodology is an area-based instrument proposed by Morris (2006). He argues that area-based instruments such at the average BMI and prevalence rates of obesity in the respondent's inhabitant area will capture the environmental influences that affect attitudes and behaviors related to the determinants of obesity. Morris (2006, 2007) used the average BMI and prevalence rate of obesity as an IV for each respondent's health region, while simultaneously controlling for many regional characteristics that could affect the respondent's income. The advantage of such area-based instruments are that any instrument correlations with the wage residual must be through the respondent's socio-economic status and health, which can be controlled with self-reported health and health region-based measurements such as average income and average health status. To our knowledge, there exists no current criticism of the area-based IV. There is currently only one other study besides Morris (2006, 2007) that has tried area-based instrumentation [**41**] due to the difficult nature of deriving such instrumentation.

This paper used a four-year lagged BMI to provide comparisons with older studies and follows similar instrumentation methods from Morris (2006). This instrumentation used the prevalence of obesity in each respondent's health authority region while simultaneously controlling for each region's socio-economic status and health.

1.2.0 Data and methodology

1.2.1 Data

This paper used 5 waves of restricted longitudinal data from the National Population Health Survey (NPHS) from 2002 to 2011 and the Postal Code Conversion File (PCCF) version June 2013 [**59**]. All inclusion criterions were determined at each wave. Each NPHS wave were bootstrapped with its respective probability weight to draw a representative sample of the Canadian population. The NPHS collected demographic and micro level data every 2 years. NPHS provided pre-derived BMI values for each respondent but excluded pregnant women. Our main analysis used the unbalanced longitudinal panel and also excluded pregnant women; however, pregnant women were included in the robustness check. All missing BMIs were derived using self-reported weight and height information based on the WHO definition. A selective list of variables used in the regression analysis can be seen in Table 1.

The lowest age-of-majority[1] across the provinces of Canada is 18 while the typical age of retirement is 65. Following these criteria, we restricted the sample population to include only respondents aged 18 to 65 in each wave. This restriction resulted in the inclusion of only the adult sample population in the analysis. This sample was further restricted to include only respondents who participated in the labor market (both employed and unemployed), and whose main source of income was from salaries or wages, and did not self-identify as students. These restrictions ensured that only the general Canadian labor market is captured for the study.

Descriptive Statistics for the Canadian labor market by BMI classifications can be seen in Table 2. It is shown that approximately 46% and 22% of the general male working class are overweight and obese, respectively. While approximately 29% and 19% of the general female working class are overweight and obese, respectively. The data cleaning, which employed the restrictions, ensured the capture of only the general Canadian labor market sample

[1] Defined as the legally fixed age of adulthood by the provincial government

population represents approximately 95% and 89% of all males and females in the NPHS database, respectively. The average hours worked per week are 46 and 38 for the general sample male and female, respectively. The average working hours are consistent between all BMI classifications for both genders. Approximately 80% and 85% of all males and females in the NPHS for each BMI classification specified that their main source of income was from salaries or wages.

Personal income was determined by the survey question "What is your best estimate of your total personal income, before taxes and deductions, from all sources in the past 12 months". However, this question suffered from a high non-response bias due to the sensitivity of this question. A three-stage iteration process for data imputation was used to estimate missing personal income (2351 missing observations before estimation). All estimated personal income data from the earlier stages were eliminated from the imputation procedures and did not affect the later stages of estimation. All estimations included a binary control variable in the regression analysis. The first-stage of imputation used the midpoint of the personal income category in the NPHS when available (1130 observations remained missing). The second-stage imputation used the respondent's provincial personal income average, which was separated by gender, wave, and education (less than 165 observations remained missing). The third-stage imputation used the average personal income by the respondent's occupation group, separated by wave and gender (less than 25 observations remained missing). Due to the sensitive nature of the personal income, respondents had answered all other survey questions but opted to skip the income question. All imputation was done to maximize the use of available data. The robustness check using a balanced panel will not include these imputations and will re-confirm any evidence found while using the imputations. Lastly, all personal income was inflation adjusted using the Consumer Price index to year 2002. A constant by gender and race was added to personal income prior to a logarithmic transformation to reduce skewness to zero.

Socioeconomic status was controlled for using marital status, education, and home ownership. Demographics were controlled with a quadratic age function, number of children in the household, immigration status, and the degree of urbanization. Life style choices were controlled with the respondent's smoking status and the average daily alcoholic beverage consumption. Health conditions were controlled by: the number of chronic conditions, if the respondent had any long-term disabilities, and the HUI3. The HUI3 was developed in Canada and it can be used as a proxy for overall health. The instrument includes eight attributes, which are vision, hearing, speech, mobility, dexterity, cognition, pain and discomfort, and emotions. Each attribute was measured on a scale between one and six along with a description for each level. The HUI3 index has a scale between -0.360 and 1, where 1 indicates perfect health; death at 0, and a negative score indicates health states worse than death [**60**].

Obesity-wage penalty studies have been criticized for failing to control for occupations such as sales and services, which resulted in customer discrimination instead of an obesity-wage penalty [**61**]. However, this study controlled for variations in income between industries using two methods. The first method segmented the respondents into 20-industry groups according to the North American Industry Classification System. The second method aggregated the respondents into 10 occupation groups including sales and services as defined by the NPHS.

Economic factors that influenced personal income such as monetary and fiscal policies, gross domestic product, business cycles, and inflation were accounted for by year fixed effects. Unobserved individual heterogeneity was controlled with individual fixed effects. The respondents were divided into "white" or "non-white" ethnic groups based on the 12 self-identified backgrounds due to small sample sizes of most of these groups.

CANSIM is Canada's publicly available socioeconomic database with a wide array of statistics. Health Data on CANSIM is based on the CCHS by Health authority regions (2013 health boundaries). The health variables included individual's perceived health, prevalence of current daily smoking, prevalence of heavy drinking, and average fruit and vegetable consumption. Additionally, the prevalence of obese individuals were extracted from CANSIM for calendar years 2003 to 2011. The average income based on the Canadian Census by health regions (2013 health boundaries) were also extracted for years 2006 and 2011. Similar to Morris (2006), the prevalence of obesity by health regions were used as an instrument for obese respondents. The first requirement of the instrument is that it is correlated with our obesity indicator conditional on the other explanatory variables that affect obesity. Again following similar arguments made by Morris (2006), Area BMI-measures provide a summary measure of environmental influences such as those in the community level of the SEM framework that affects obesity thus having the ability to induce changes in the respondent's obesity indicator, which satisfies the first criteria of a strong IV. These area-based instrumental variables are also included in the appendix 1 that can be linked to many other health databases such as discharge abstracts or other health administration databases. The second condition of a valid instrument is that it must have no effect on the dependent variable. The prevalence of obesity in the respondent's health regions are likely correlated with personal income, which will fail the exclusion criteria of an IV regression model. However, these correlations are through various socio-economic reasons such as the affordability of high quality food and public amenities. Based on this argument, the correlation can be controlled by regional socioeconomic status and regional health variables such as the ones listed above. These regional controls are used in both stages of the IV regression to ensure that the exclusion restriction on income is met. Respondents' postal code information was linked with the PCCF to derive the respondents' respective health region based on year 2013 health boundaries.

1.2.2 Methodology

The respondents' BMI classifications and personal incomes were plotted with their respective probability weights separated by gender. This provides a visual interpretation of the obesity-wage relationship that is representative of the Canadian population.

Personal income was logarithmically transformed and used as the dependent variable in all regression models. The variable of interest was BMI and 4-year lagged BMI, to provide comparisons with previous studies. All BMI classifications (underweight, normal, overweight, and obese) were regressed separately to ensure the capture of the heterogeneous nature of each group[2]. White respondents and all ethnical background respondents (including white) were regressed separately due to inadequate sample size of Non-white respondents[3].

Regression analyses were performed with increasing specificity to ensure robustness of the results. The first model (equation 1) contained no controls, which provided a raw correlation between various obesity measures and personal income, where *i* was the respondent between each cycle, *t* was the wave index for years 2002- 2011, $\ln w$ was the Natural logarithm transformation of personal income, FAT_{it} was the respective body fat measure, and ε_{it} was the residual.

The second model (equation 2) controlled for demographics, such as a quadratic age function, number of children, immigration, urbanization, and education where D represents a vector of all demographic controls. The third model (equation 3) had additional socioeconomic controls such as marital status, total household income, home ownership, occupation group, and industry group

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[2] BMI groups were also regressed together with no change in results.

[3] We are unable to provide the sample size due to privacy restrictions. However interested readers can compare the small increases in observations between the "white" regression results and the "all race" regression results.

where S represented a vector of socioeconomic controls. The fourth model (equation 4) added health indicators, where H was a vector that contained HUI3, number of chronic conditions, and long-term disabilities. Model five (equation 5) included year fixed effects and individual fixed effects, which took advantage of the longitudinal nature of the data and controlled for temporal effects shown to be similar to twin-differencing as suggested Cawley (2004), where $\mathrm{FE}_{\mathrm{i,t}}$ represented both individual and year fixed effects.

$$\mathrm{lnw}_{\mathrm{i,t}} = \beta_1 \mathrm{FAT}_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,t}} \quad (1)$$

$$\mathrm{lnw}_{\mathrm{i,t}} = \beta_1 \mathrm{FAT}_{\mathrm{i,t}} + \beta_2 \mathrm{D}_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,t}} \quad (2)$$

$$\mathrm{lnw}_{\mathrm{i,t}} = \beta_1 \mathrm{FAT}_{\mathrm{i,t}} + \beta_2 \mathrm{D}_{\mathrm{i,t}} + \beta_3 \mathrm{S}_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,t}} \quad (3)$$

$$\mathrm{lnw}_{\mathrm{i,t}} = \beta_1 \mathrm{FAT}_{\mathrm{i,t}} + \beta_2 \mathrm{D}_{\mathrm{i,t}} + \beta_3 \mathrm{S}_{\mathrm{i,t}} + \beta_4 \mathrm{H}_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,t}} \quad (4)$$

$$\mathrm{lnw}_{\mathrm{i,t}} = \beta_1 \mathrm{FAT}_{\mathrm{i,t}} + \beta_2 \mathrm{D}_{\mathrm{i,t}} + \beta_3 \mathrm{S}_{\mathrm{i,t}} + \beta_4 \mathrm{H}_{\mathrm{i,t}} + \beta_5 \mathrm{FE}_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,t}} \quad (5)$$

Replacing the respondent's current obesity indicator $\mathrm{FAT}_{\mathrm{it}}$ with the respective Lagged BMI, $\mathrm{FAT}_{\mathrm{it-4}}$ in model 5 provided raw insight on the causal nature of the obesity-wage penalty. However, if some non-temporal effect existed as discussed in the introduction and background section, then this would fail to account for the unobservable variables. This means that a regular regression model would be biased since $\mathrm{E}[\varepsilon_{\mathrm{i,t}} | \mathrm{X}_{\mathrm{i,t}}] = 0$ and $\mathrm{E}[\mathrm{BMI}_{\mathrm{i,t}} | \mathrm{X}_{\mathrm{i,t}}] \neq 0$, hence the issue of endogeneity.

This paper controlled for endogeneity with a 2-stage IV regression model (equations 6 and 7). The prevalence of obesity in each respondent's health region was applied to obese respondents as an instrument. The instrumentation included socioeconomic and health regional controls that prevented correlation with the error term such that $E[v_{i,t} | Prev_{i,t}] = 0$, and where $Prev$ represented the prevalence of obesity in each health region as defined in the data and methodology section, $R_{i,t}$ was a vector of regional controls, and v was the first-stage residuals.

$$FAT_{i,t} = \Psi(Prev_{i,t}) + \beta_1 D_{i,t} + \beta_2 S_{i,t} + \beta_3 H_{i,t} + \beta_4 R_{i,t} + \beta_5 FE_{i,t} + v_{i,t} \quad (6)$$

$$\ln w_{i,t} = \beta_1 FAT_{i,t} + \beta_2 D_{i,t} + \beta_3 S_{i,t} + \beta_4 H_{i,t} + \beta_5 FE_{i,t} + \beta_6 R_{i,t} + \beta_7 FE_{i,t} + \beta_8 v_{i,t} + \varepsilon_{i,t} \quad (7)$$

The first five models identified any association between obesity and personal income. The last two models provide an estimation of the causal relationship via lagged BMI models as well as in the instrumental variable models.

1.3.0 Results

The visual correlation between BMI classifications and personal income suggests that on average males have a weight premium from underweight up till the obese BMI classification (Figure 1). However, males are faced with a slight wage penalty after being considered obese. The correlations suggested that on average females face a wage penalty (Figure 1) from the underweight to obese classification.

Regression results for males (Table 3) found no association between BMI and income for overweight and obese. Positive associations are observed for the normal BMI classifications; however, these associations are not robust across model specifications. Lagged BMI and instrumental variable regression are not shown for males due to the lack of statistical significance in these results.

Regression results for females (Table 4) show evidence of robust negative associations between BMI and personal income for obese female respondents. This evidence suggests that a one-unit increase in female BMI is associated with a 0.6% decrease in personal income at the highest model specification for both white respondents and all race-included respondents. No statistical evidence was found for the underweight and overweight BMI class in all model specifications. A weight premium was found in the normal BMI class in some model specifications, however, when life style factors are considered, all statistical significance was lost. Statistical evidence of a wage premium was found for overweight white women at the higher model specifications, however no evidence was found at the lower specifications.

The lagged BMI models showed robust statistical evidence of a wage penalty for obese females (Table 5). The results suggest that a 1-unit increase in BMI is associated with approximately a 0.7% decrease in personal income 4 years later at the highest model specifications. The lagged BMI model found no robust statistical evidence for overweight and underweight females. A wage premium is seen for females in the normal BMI weight class in the majority of the model specifications, where a 1-unit increase in BMI is associated with approximately 0.9% increase in personal income 4 years later.

Our instrumental variable regression did not find any causal effect of obese women; however, this may be due to low number of observations.

1.4.0 Robustness

All models and specifications are repeated with the full response sample population (with and without pregnant women) along with its associated balanced sample probability weights. The NPHS defines a full response as all individuals who answer all questions in all waves or have died posterior answering all questions in previous waves. This sub-sample of full response respondents has its own probability weight, which is different from the unbalanced panel's probability weight.

Statistical evidences of a wage penalty for obese females were consistent across all models and specifications in the robustness check. All male and female results in the robustness check are near identical to the main analysis, with coefficients varying by less than 0.002 for obese females and negative association remained constant. All robustness checks are available in appendix 2.

1.5.0 Conclusion

The IV model failed to impute any causal effect, which is similar to Morris (2006) where there is no evidence of causal effects from the area-based instrumental variable regression was found. In other words, there is no evidence to support any causal effect that obesity effects personal income using the proposed causal model. However, using lagged BMI we found a robust negative association for females even after applying individual fixed effects, which suggested by Cawley (2004) can control for temporal effects that is similar to twin differencing. It is possible that there is some underlying non-temporal effect, but we believe that the area-based instrumentation failed mostly due to data limitations. Regional income data, extracted from CANSIM based on the census is only collected every five years. The difference in the occurrence of survey between the census and NPHS resulted in over a 60% lost in observations. Health boundary changes during the study period and differences in underlying sample restrictions, between the NPHS and CANSIM are also contributing factors to the data limitations. These data limitations can be easily solved using the Canadian Community Health Survey (CCHS) database. The CCHS can be used to derive the health regional variables for all waves with a constant health boundary and sample population. However, our original research proposal to Statistics Canada did not include the CCHS, which prevented this study from addressing the data limitations. Future Canadian research on the obesity penalty would benefit from accessing both the NPHS and the CCHS.

1.6.0 Limitations

We acknowledge that misclassification, report, and recall bias could be present in our study. Our study is based on a self-reported survey, which can contain report and recall bias. BMI is also an inaccurate measurement of body fat and would lead to an inaccurate measurement of obesity [**62**]. BMI may also contain misclassification bias however; this bias is also consistent with other studies around the world, which allows us to make cross-country comparisons with other studies. This study will also underestimate respondents who exited the labor force due to medical reasoning relating to obesity.

The area-based IV model has a major sample size limitation due to difficulties with health region boundaries and matching the underlying sample population between data sets. The IV is based on CANSIM's regional variables, which includes all respondents over the age of 12, whereas the main analysis restricts the sample population to ages 18-65 who are currently in the general labor force. To our knowledge, there are currently no other criticisms of this type of IV model. However, this instrumentation may fail for areas with low population density. An example of this failure would be if the respondent has direct influence over the prevalence of obesity where an increase or decrease in the respondent's obesity leads to a change in the prevalence of obesity in the respondent's area.

1.7.0 Discussion

This is one of the first Canadian studies on the obesity-wage penalty. Obesity in females in Canada is associated with a lower personal income, which is similar to previous international studies [**39**] [**33**] [**44**] [**34**] [**36**] [**37**] and available Canadian studies [**27**] [**25**].

Larose et al (2016) found evidence that obesity in Canadian males was associated with a 2% reduction in income, in which their results relied on a 10% significance level. Our Canadian male analysis applied less restrictive sample inclusion criteria, which may explain the differences in results. However, the lack of statistical evidence between BMI and income for males is consistent with studies from Australia [**28**], Denmark [**31**], Europe [**35**], Finland [**38**], and the United States [**58**] [**51**].

The economic cost of obesity in the year 2008 has been suggested to be between $4.6 to $7.1 billion dollars per annum [**25**] and the prevalence of obesity is steadily increasing. Our study shows that a 1-unit increase in BMI for obese females is associated with a 0.7% decrease in personal income 4 years later. These results can be used as a financial incentive for health promotion in reducing the obesity rates in Canada for females. Because the results point to an eventual decrease in income for obese women, the evidence brought forward in this study can also be used as in effective health promotion tool through a marketing campaign, which will indirectly reduce the economic cost associated with Canadian obesity and promote cost saving in our health care system. While obesity doesn't seem to have a significant impact on income, obesity may impact other health issues such as additional medical costs, missed days at work or health issues that force an unplanned early retirement that are not captured in this study.

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Table 1.1: Selected Variable List

Name	Type
Dependent	
Personal Income	Continuous
Variable of interest	
BMI	Continuous
Lagged BMI (4 years)	Continuous
Demographics	
Age	Continuous
Children[1]	Continuous
Immigration	Binary
Urbanization	Binary
Education	Binary
Socioeconomic status	
marital status	Binary
Total Household income	Continuous
home ownership[2]	Binary
Occupation group	Binary
Industry Group	Binary
Health Indicators	
Hui3	Continuous
Number of Chronic condition	Continuous
long term disabilities	Binary
Life Style	
Smoking	Binary
Alcohol consumption	Continuous
Health Region controls	
Average Income	Continuous
Prevalence of Good Health	Continuous
Prevalence of Fair health	Continuous
Average Fruit Consumption	Continuous
Prevalence of current smokers	Continuous
Prevalence of obesity	Continuous
Prevalence of Alcohol consumption	Continuous
Fixed Effects	
Individual	Binary
Year	Binary
Controls for imputations	
Personal Income	Binary
Health region variables	Binary

[1]defined as number of children under 12 in the household.

[2]defined as if dwelling is owned by a member of the household.

Table 1.2: Selective Labor Market Information by BMI Classification

	Male	Underweight	Normal	Overweight	Obese	All
(1)	Percentage	0.59%	30.98%	46.11%	22.32%	100%
(2)	Average Income	29831*	49219	56357	55655	53624
(3)	Percent In the labour market	80.47*	96.21%	95.76%	94.16%	95.47%
(4)	Average hours worked per week	44	45	46	47	46
(5)	Percentage of the total population that earn income from salaries or wages	81.84%*	81.46%	78.83%	83.86%	80.79%
	Female	Underweight	Normal	Overweight	Obese	All
(6)	Percentage	2.42%	50.79%	28.26%	18.53%	100%
(7)	Average Income	35181	34686	33357	33424	34014
(8)	In the labour market	81.27%	89.77%	88.58%	88.11%	88.50%
(9)	Average hours worked per week	38	38	38	39	38
(10)	Percentage of the total population that earn income from salaries or wages	89.95%	83.45%	84.49%	84.55%	84.42%

Unbalanced sample restricted by age 18-65 in each wave, currently in the labour force with main income from salaries or wages, and not a student where applicable.

All values are weighted to provide a representative sample of Canada.
*Caution must be taken due to sample sizes less than 75.

Figure 1.1: Weighted Correlation Between BMI Classification and Personal Income

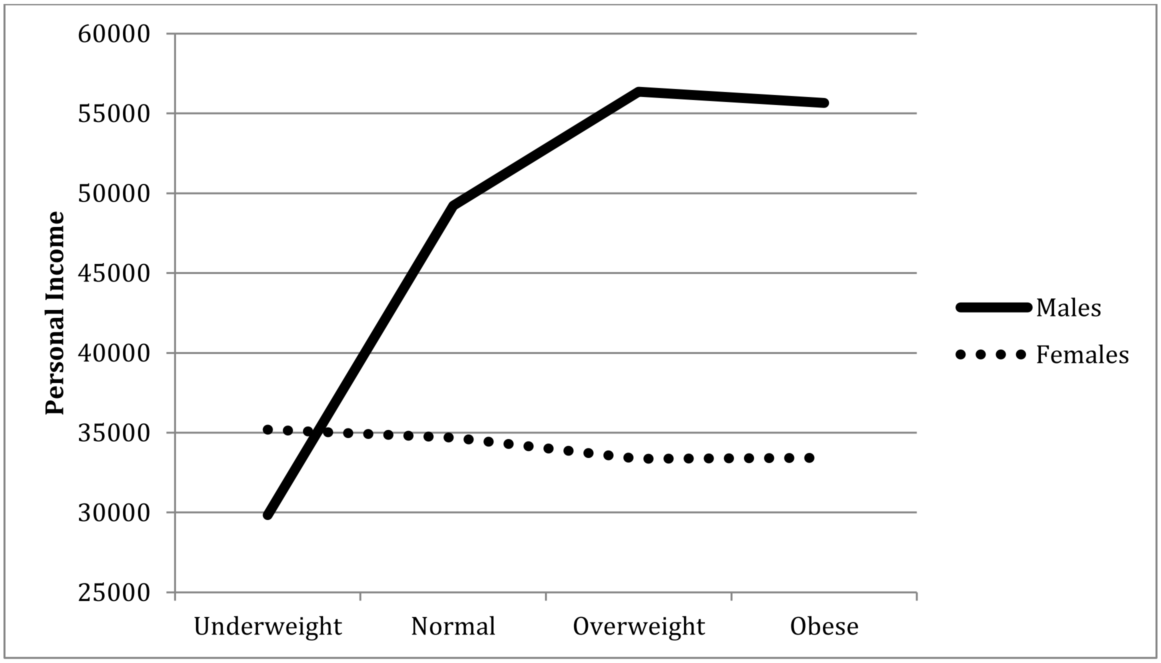

Table 1.3: Selective Unbalanced Panel Male BMI Regression Results by BMI Classification

Model specsifcations[1]	BMI Classifications[4]					
	Normal		Overweight		Obese[3]	
White only	Coef	Obs	Coef	Obs	Coef	Obs
No Controls	0.08***	2620	0.02**	4660	0.00	2346
+ Demographics	0.03**	2590	0.01*	4622	0.00	2336
+ Socioeconomic Status	0.01	2152	0.00	3923	0.00	2048
+Health Indicators	0.01	2113	0.00	3846	0.00	2003
+Life Style	0.00	1884	0.00	3418	0.00	1784
+ Fixed Effects	0.00	1884	0.00	3418	0.00	1784
All Ethnicities[2]						
No Controls	0.08***	2872	0.02**	4996	0.00	2466
+ Demographics	0.04***	2839	0.01	4954	0.00	2456
+ Socioeconomic Status	0.02**	2350	0.00	4182	0.00	2151
+Health Indicators	0.01*	2305	0.00	4099	0.00	2105
+Life Style	0.01	2025	0.00	3618	0.00	1868
+ Fixed Effects	0.01	2025	0.00	3618	0.00	1868

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.

Unbalanced weights are included In all regressions to give a representative sample of Canada.

Sample is restricted to respondents that are in the labour force, not a student, and main source of income is from salaries/wages.

[1]Models are increasing in the specified specification (see table 1).

[2]Additional race control is included

[3]Includes obese class I, II, and III.

[4]Underweight BMI class was removed due to inadequate sample size.

Table 1.4: Selective Unbalanced Panel Female BMI Regression Results by BMI Classification

Model specifications[1]	BMI classification							
	Underweight		Normal		Overweight		Obese[4]	
White only	Coef	Obs	Coef	Obs	Coef	Obs	Coef	Obs
No Controls	-0.01	181	0.02	4615	-0.01	2915	-0.01***	2008
+ Demographics	-0.03	178	0.01**	4591	0.00	2906	-0.01***	1987
+ Socioeconomic Status	0.02	135	0.01**	3657	0.01	2325	-0.02***	1630
+Health Indicators	0.01	134	0.01**	3615	0.01*	2292	-0.01***	1584
+Life Style	0.02	111	0.01	3235	0.01*	2040	-0.01**	1361
+ Fixed Effects	0.01	111	0.01	3235	0.01*	2040	-0.01***	1361
All Race[2]								
No Controls	-0.01	187	0.02***	4886	-0.01	3081	-0.01***	2154
+ Demographics	-0.02	184	0.01	4858	0.00	3071	-0.01***	2133
+ Socioeconomic Status	0.02	138	0.01**	3853	0.01	2450	-0.01***	1748
+Health Indicators	0.01	137	0.01**	3806	0.01	2409	-0.01***	1701
+Life Style	0.02	112	0.01	3371	0.01	2116	-0.01**	1444
+ Fixed Effects	0.01	112	0.01	3371	0.01	2116	-0.01***	1444

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.

Unbalanced weights are included In all regressions to give a representative sample of Canada Sample is restricted to respondents that are in the labour force, not a student, not pregnant, and main source of income is from salaries/wages.

[1]Models are increasing in the specified specification (see table 1).

[2]Additional race control is included

[4]Includes obese class I, II, and III.

Table 1.5: Selective Female IV Regression Models and 4-Year Lagged Regression Results

Model specfications[1]	BMI Classification							
	Underweight		Normal		Overweight		Obese[4]	
White only	Coef	Obs	Coef	Obs	Coef	Obs	Coef	Obs
No Controls	-0.04	86	0.02**	2323	0.00	1489	-0.01**	1,090
+ Demographics	-0.03	84	0.00	2307	0.00	1486	-0.01**	1077
+ Socioeconomic Status	-0.09**	66	0.01**	1808	0.01*	1168	-0.01***	865
+Health Indicators	-0.08	65	.010**	1780	0.01*	1146	-0.01***	839
+Life Style	-0.03	51	0.01**	1599	0.01	1031	-0.01**	738
+ Fixed Effects	-0.04	51	0.01**	1599	0.01	1031	-0.01**	738
IV Regression[3]	-	-	-	-	-	-	0.03	341
1st stage F-Stat	-		-		-		165.17	
All Race[2]								
No Controls	-0.01	89	0.02**	2442	0.00	1569	-0.01**	1163
+ Demographics	-0.01	87	0.00	2426	0.00	1565	-0.01**	1150
+ Socioeconomic Status	-0.09**	67	0.01**	1892	0.01	1224	-0.01***	922
+Health Indicators	-0.08*	66	0.01**	1864	0.01	1198	-0.01***	896
+Life Style	-0.03	51	0.01**	1661	0.01	1064	-0.01**	779
+ Fixed Effects	-0.04	51	0.01**	1661	0.01	1064	-0.01**	779
IV Regression[3]	-	-	-	-	-	-	0.02	357
1st stage F-Stat	-		-		-		45.89	

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.

Unbalanced weights are included In all regressions to give a representative sample of Canada. Sample is restricted to respondents that are in the labour force, not a student, not pregnant, and main source of income is from salaries/wages.

[1]Models are increasing in the specified specification (see table 1).

[2]Additional race control is included.

[3]Instrumental Variable regression using the prevalence of obesity for BMI classification of Obese with average income controls via respondents health region.

[4]Includes obese class I, II, and III.

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Chapter 2: Serum 25-hydroxyvitamin-D and Indicators of Mental Health

2.1.0 Introduction

Mental health may be impacted by a range of mood disorders that affect both thinking and behavior such as depression, anxiety, schizophrenia, as well as in substance use disorder. One in every five Canadians experiences a mental health problem, and by the time Canadians reach 40 years of age one in every two Canadians have or have had a mental illness. [**63**] Reducing this disease burden will have a cascading effect on the health care system from reduced direct cost on mental health professionals and also the indirect cost of reduced substance abuse [**64**]. This study focuses on three indicators of mental health, depression, anxiety, and stress. The notion that relative inexpensive vitamin D supplements can improve mental health outcomes warrants an exploratory Canadian study. Despite vitamin D fortification, Canadians are not getting enough vitamin D to benefit from the potential protective effects especially during the winter. [**65**]

The main function of vitamin D is to regulate the absorption (homeostasis) of calcium for better bone health. [**15**] [**16**] However, emerging evidence has correlated adequate levels of serum 25-hydroxyvitamin D (25(OH)D) concentrations with better scores on indicators of mental health [**17**]. Active vitamin D binds to vitamin D receptors (VDR) to regulate physiologic functions of the body such as emotional well-being and stress. VDRs are found in more than 30 cell types throughout the body [**66**], including neuronal and glial cells [**67**] in the cortex and hippocampus which have been implicated in the pathophysiology of mood. [**68**] Experiments on rodents have demonstrated alterations to brain function and/ or behaviour due to vitamin D deficiency [**69**]. Active vitamin D also regulates tyrosine hydroxylase, which in turn regulates the production of the mood regulating neurotransmitters, norepinephrine and dopamine [**70**]. The absolute or relative lack of norepinephrine is associated with most, if not all, types of mental health outcomes. [**70**] Lower dopamine levels are associated with mental health issues, such as diminished motivation and psychomotor retardation. [**71**] Vitamin D may indirectly regulate mood by stimulating genes which produce neurotransmitters that relieve depressive emotions [**72**]. This biological link between vitamin D and mood raises the hypothesis of whether adequate vitamin D levels are associated with reduced probability of mental health illness.

Previous studies have found evidence that low serum 25(OH)D concentrations are associated with depression [**73**]. This includes studies from various countries showing a positive relationship between serum 25(OH)D concentrations and mental health indicators [**74**] [**75**] and two community based samples of older Canadians [**75**] [**76**]. It has been suggested that over one third of the Canadian population have suboptimal serum 25(OH)D concentrations [**74**]; if a causal relationship exists, this may be of considerable importance given the high rate of mental health illness in Canada [**63**]. This study investigates the relationship between serum 25(OH)D concentrations and mental health indicators using an established survey among a large sample, which is representative of Canadians.

2.2.0 Methodology and Dataset

The Canadian Health Measures Survey (CHMS) is a cross-sectional survey conducted every 2 years, developed and conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada. Currently 3 cycles are available from year 2007 to 2013. The CHMS covers the population aged 3 to 79 years living in the ten provinces. The data excludes people who are living in the three territories; living on reserves and other Aboriginal settlements; full-time members of the Canadian Forces; institutionalized population; and residents of certain remote regions. Altogether these exclusions represent approximately 4% of the Canadian population. [**77**] This study will include Canadians over the age of 18 and non-pregnant[4]. Sixteen Mobile Examination Centers across Canada with trained professional collected blood samples for the assessment of serum 25(OH)D concentrations (expressed in nmol/L) constituting the exposure of interest.

The gold standard assessment of mental health and well-being is an assessment from a mental health professional; however, this is unfeasible, impractical, and costly to obtain for a nationally representative dataset. This study uses four proxies to estimate depression, anxiety, and stress. The first proxy exists in initial two cycles of the CHMS from the Health Utility Index 3 (HUI3) questionnaire. The HUI3 was developed in Canada and was designed to

[4] Sample size 7518

quantify overall health using eight attributes measured on a scale between one and six, where one indicated a better health state. The emotional attribute from the HUI3 is extracted as the first proxy for depression and anxiety. This proxy asked the respondent “Would you describe yourself as being usually: happy and interested in life; somewhat happy; somewhat unhappy; unhappy with little interest in life; so unhappy that life is not worthwhile; where “happy and interested in life” is defined as the best mental health state in this proxy.

The remaining three proxies are available in all three cycles of the CHMS. The second proxy is self-perceived mental health, which was measured by the question “In general, would you say your mental health is: Excellent; very good; good; fair; poor”; where “Excellent” is defined as the best mental health state for this proxy.

The remaining two proxies are self-perceived stress and self-perceived general health. Stress is measured by asking the respondent “Thinking about the amount of stress in your life, would you say that most days are: not at all stressful; not very stressful; a bit stressful; quite a bit stressful; extremely stressful”; where “not at all stressful” is defined as the best mental health state in this proxy. The final proxy is a measure of general health, but it can be argued that the self-assessment of one’s general health is associated with their mental health and as such this measure will be used as a tertiary proxy of depression, anxiety, and stress. General health is measured by asking the respondent “in general, would you say your health is: Excellent; very good; good; fair; poor”; where “Excellent” is defined as the best mental health state in this proxy. All four proxies are modelled with the initial two cycles stacked and resampled with the bootstrap weights provided by Statistics Canada to increase the statistical power and to provide a representative sample of the Canada adult population. Proxies with three cycles are independently restacked and resampled with the appropriate bootstrap weights as a robustness check.

The relationship between vitamin D status and indicators mental health is entangled by many observable confounders such as demographics, socio-economic status, chronic conditions, smoking and drinking, illicit drug use and labor force status. Demographic controls in this study include age, sex, marital status, education, and ethnicity. Socio-economic status is controlled with household income and if the respondent is a student. Life style controls consist of smoking, drinking, drug use (both prescription and street drugs). Health conditions are controlled with binary indicators for chronic and acute conditions[5]. The specific variables are also described in Table 1. Ordered logistic regression analyses will be performed with increasing specificity to ensure robustness of the results. The dependent variables are the mental health proxies as described [Table 2]. Each proxy will be used independently with increasing model specifications to ensure robustness of results. Estimation equations can be found in appendix 3. Marginal effects will be used to provide a graphical representation of the results from the ordered logistic regression model for the average Canadian as defined previously.

[5] Based on self-reported diagnostics determined by medical professionals.

Unobservable confounders such as Seasonal Affect Disorder (SAD) are periodic major depression that occurs in some people during late fall to early spring, which may affect the indicators of mental health. Some patients have the opposite occurrence: depressive symptoms during spring and summer. Regardless of the season, the depression episodes occur during the same seasons every year. [**78**] The proposed datasets accounts for seasonality effects by uniformly distributing the 16 Mobile Examination Centre collection sites by region between the collection years. [**77**]

2.3.0 Results

The characteristics of the population [Table 2.1] indicate an average age for adult Canadians[6] is 45 with an average household income of $77,550. The average weight and height are 78kg and 169 cm, respectively. Approximately 50% of Canadians are married. There is an equal split between males and females. Approximately 25% of the population graduated with an university degree or higher. Seventeen percent (17%) of the population smokes daily and 68% consume alcoholic beverages on a regular basis. Over 50% of the population is considered inactive. Approximately 42% of Canadians have a normal weight. The indicators of mental health [Table 2.2] indicate that approximately 78% of Canadians are happy in life, and 34% have excellent self-perceived mental health. The indicator of self-perceived stress seems quite normally distributed with 44% of Canadians having “a bit” of self-perceived

[6] Canadians over the age of 18, excludes all pregnant females.

stress. Most Canadians have a self-perceived health of being in the good, very good, and excellent categories.

Emotional health has a positive association with serum 25(OH)D concentrations across all models (Table 2.3). For every 25 nmol/L increase of serum 25(OH)D concentrations, there is an average of a 1.16-unit increase in log odds (or a 76% increase of being in the best emotional health category of the HUI3 index)[7] across all models that controls for demographics, socioeconomic status, life style choices, and health of the respondent. Similar increases in predictive probability of being in a better mental health state are found for self-perceived mental health (75%), self-perceived stress (75%), and self-perceived general health (76%) for every 25 nmol/L increase of serum 25(OH)D concentrations in the blood stream.

The adjusted probability of being in the best mental health state for both the HUI3 emotional health category and self-perceived stress category increases with higher serum 25(OH)D concentrations (Figure 2.1). This probability is based on the average Canadian as defined previously. Similar adjusted probabilities of being in the best health state were found for self-perceived mental health and self-perceived general health for increases of serum 25(OH)D concentrations in the lower concentrations. The probability of the average Canadian being in the best mental health state has an upward tendency as serum 25(OH)D concentrations increases and more so when moving from very low levels to 100

[7] Calculated by converting log odds to probability.

nmol/l. This is also when the confidence interval is narrowest suggesting a higher confidence in the prediction. (Figure 2.1)

2.4.0 Robustness

All outcome variables of interest (self-perceived mental health, general health, and stress) available in cycle three underwent the same regression models with all three cycles stacked with the appropriate Statistics Canada bootstrap weights. All results are consistent if not better compared with the main analysis. The confidence intervals are narrower when the 3 cycles are stacked. This is most likely due to the increase in sample size that resulted in an increase of statistical power. All robustness results are available in appendix 4.

2.5.0 Limitations

There are two important limitations to this study. The first is that this study can only determine an association and not a causal effect. In other words, it is unclear whether vitamin D produces better scores on the indicators of mental health or if lower depression and anxiety leads to higher serum 25(OH)D concentrations in the blood from better nutrition and/or outdoor activities. In other words, someone with depression and anxiety may not venture outside (less exposure to sunlight) and someone without depression and anxiety that would be more active and go outside more. The inability to control for exercise may also bias the results as studies have shown a positive relationship between increase exercise and lower depressive symptoms [**79**]. The authors attempted to estimate the causal affect through instrumental variable regression methods but were unable to find a valid instrument in the dataset, with the inability to control for all unobservable confounders such as nutrient-nutrient interactions and other individual heteroscedasticities.

The second limitation is the method of ascertaining mental health. To accurately measure mental health states, a standard method completed by health professionals would be required. The DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, Firth Edition) is the current standard for physicians to assess depression but application is time and resource intensive. This would be unrealistic, impractical and costly for a nationally representative dataset. It is also very likely that due to the self-perceived nature of the questionnaires that these proxies are to be under estimated due to the sensitive nature and negative perceptions of depression and anxiety. Some of the proxies utilized in this study stems from health-related quality of life measurements and we acknowledge that these may not be as good compared to mental health related quality of life instruments. Linking of other datasets has also been considered, but due to privacy rules with the CHMS dataset, this was not an option.

2.6.0 Discussion

This study reveals robust positive associations between serum 25(OH)D concentrations and indicators of mental health (depression and anxiety) after controlling for demographics, socio-economic status, chronic conditions, smoking and drinking, illicit drug use, and labor force status. This study also found that higher serum 25(OH)D concentrations by each increment of 25 nmol/L increases the probability of the average Canadian to be in the best mental health and general health state by an average of 76%. These results can be used by policy and decision makers for either a potential low-cost and low-risk solution for public health improvements or these results can be used as a marketing tool for increase vitamin D supplementation to help reduce the Canadian Vitamin D deficiency until a completion of a RCT.

Accurate measures of mental health and well-being ideally would include an assessment from a mental health professional, which is unfeasible, impractical, and costly to obtain for a large nationally representative study sample. This study uses four established proxy measures of mental health. However, there are inherent biases such as response bias due to the nature of the question. These biases must be weighed against the possible benefits in order to assess the potential overall benefit.

Vitamin D is generally well tolerated and adverse events and toxicity are rare when taken appropriately. To raise serum 25(OH)D concentrations to optimal amounts as shown in previous studies, Canadians would need a daily intake of 1000-4000 IU/D. However, Canadians on average can only obtain 200-300 IU/D from food sources [**80**] and live at high latitudes and thus have less sun exposure and subcutaneous vitamin D synthesis. It is also important to note that vitamin D has a short half-life of about 3 weeks, which means that Canadians would need to maintain a daily intake of vitamin D supplementations over a long period of time before noticing any benefits.

Studies in countries such as China, England, Europe, Japan, Netherlands, and United States have shown a robust relationship between vitamin D status and depression [**74**] [**75**] [**81**] [**17**] [**82**]. Two studies in a sample of older Canadians participating in a preventive health program showed that higher serum 25(OH)D concentrations were associated with improved health related quality of life [**75**] [**76**]. Those observations, however, cannot be generalizable because they were in a selected group. The present study is the first to extend the finding to the entire Canadian Adult population. Given the burden of mental health issues in Canada, and the large proportion of the Canadian population with suboptimal serum 25(OH)D concentrations, [**74**] the present study adds to the support of the notion that relatively inexpensive vitamin D supplements can prevent mental health problems, improve mental health outcomes is compelling, and warrants a definitive study to determine effectiveness as well as consideration in health policy applications.

2.7.0 Acknowledgments

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2.8.0 Disclosure

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Table 2.1: Bootstrapped weighted descriptive statistics of the Canadian adult population

Control Variables	Measure
average age (years)	45
average household income (Canadian dollars)	77,548
average weight (Kg)	78
average height(cm)	169
males	50%
marital status: married	51%
education	-
secondary or less	30%
colleague/trades/certificates	45%
university or higher	25%
white racial Origin	82%
student	12%
smokes daily	17%
regular drinker	68%
used prescription drugs for recreational purposes	3%
used or tried street drugs	15%
weight status[8]	-
underweight	2%
normal weight	42%
overweight	35%
obese	20%

[8] As defined by the World Health Organization

Table 2.2: Indicators of mental health

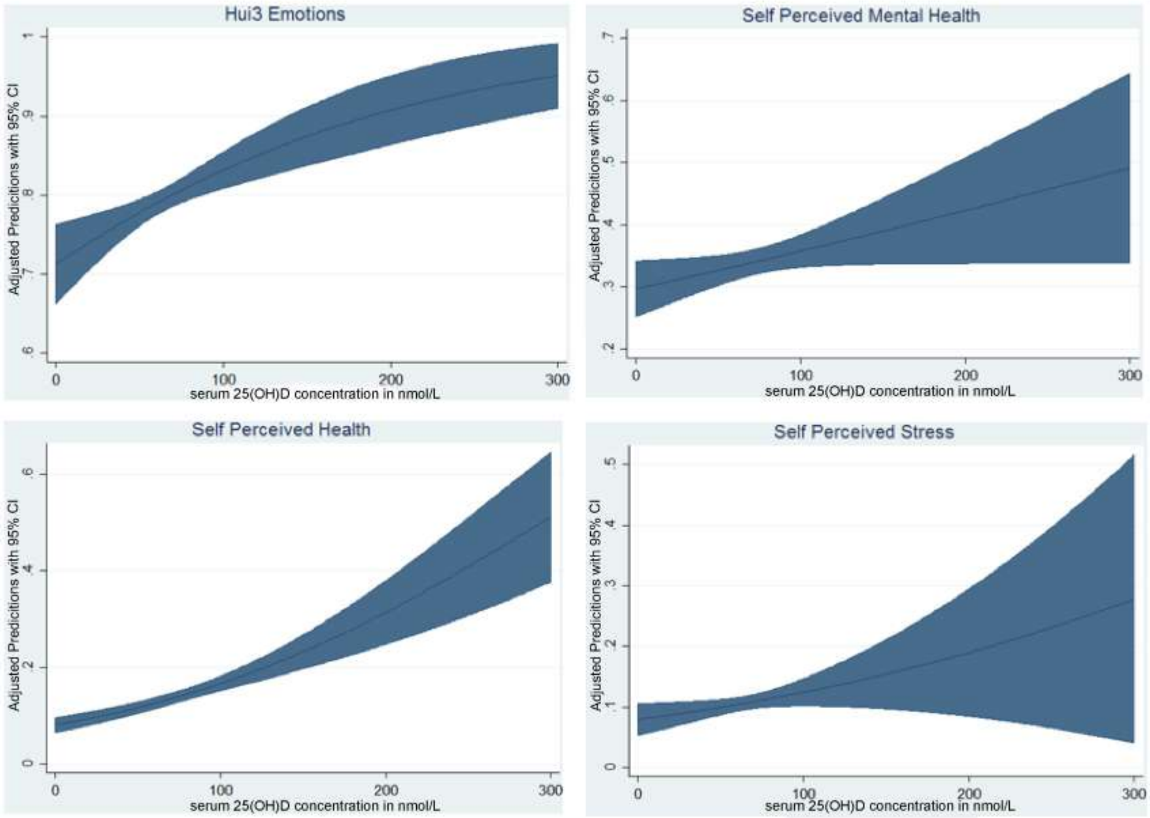
Dependent Variables	% of total population
emotional problems (HUI3)	-
life not worthwhile	0.3%
very unhappy	0.7%
somewhat unhappy	3.1%
somewhat happy	17.5%
happy in life	78.4%
self-perceived mental health	-
poor	0.9%
fair	4.3%
good	21.9%
very good	38.8%
excellent	34.1%
self-perceived stress	-
extremely	3.2%
quite a bit	16.8%
a bit	44.0%
not very	26.4%
not at all	9.7%
self-perceived health	-
poor	2.5%
fair	8.8%
good	36.4%
very good	38.4%
excellent	13.8%

Table 2.3: Odds ratios of serum 25(OH)D concentrations (per 25 nmol/L increase) with mental health indicators in regression models

Dependent Variable	Unadjusted Model	+Demographics	+Socioeconomic	+ Life Style	+ Health
Emotional health	1.24*** (0.06)	1.19*** (0.06)	1.17*** (0.06)	1.15*** (0.05)	1.16*** (0.06)
Mental Health	1.10*** (0.04)	1.10** (0.04)	1.09** (0.04)	1.07* (0.04)	1.08* (0.04)
Stress	1.09** (0.05)	1.10** (0.04)	1.10** (0.05)	1.09* (0.05)	1.10** (0.05)
General Health	1.23*** (0.04)	1.20*** (0.04)	1.19*** (0.04)	1.16*** (0.04)	1.17*** (0.04)

*,**,*** indicates 1%, 5%, 10%, significance levels, respectively.
Bootstrap standard errors in parentheses.

Figure 2.1: Adjusted probability with 95% confidence interval of being in the best mental health state by serum 25(OH)D concentrations.



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Chapter 3: Quality of Acute Myocardial Infarction Care and Costs

3.1.0 Introduction

The Alberta Ministry of Health and Wellness has been mandated to provide Albertans with the best possible care and outcomes possible in the health system and has over the years worked with various ministries to meet these goals and develop new initiatives. One of the key performance indicators (KPI) of measuring these outcomes is assessing the quality of Acute Myocardial Infarction (AMI) services provided to Albertans. However, this KPI does not take into account costs associated with the increase in quality. [**83**] The relationship between quality of care and cost is essential to all policy makers. If there is a positive relation, then budget allocations must be considered during the mandate. If there is no relationship or a negative relationship, then this may be indicative of possible efficiency gains in our health care system; in other words, it may be possible to increase quality without any additional costs. This study explores the relationship between hospital costs and quality of care for AMI in the Edmonton area hospitals, which will provide Albertans additional insight on the quality KPI on AMI. To our knowledge this is the first Canadian study on the cost-outcome tradeoff for AMI.

Cost-outcome tradeoff studies are focused on either outcome on cost [**84**] [**85**] or cost on outcome [**86**] [**87**] [**88**] [**89**] [**90**] [**91**] [**92**] [**93**]. The Canadian health care system is complex where the hospitals receive mainly global funding from the province while physicians bill the provinces after providing their services. Due to this complexity, it is unclear which methodology should be applied to the Canadian system.

The relationship between the cost and outcome can be confounded by many unobservable variables. Recent observational outcome-cost tradeoff studies have tried to control for unobservable variable and reverse causality bias through Instrumental Variable (IV) regression modelling [**88**] [**91**] [**93**] [**89**]. The IV models require a variable (the instrument) that can induce change in the dependent variable (quality of AMI care) and must have no relationship with the explanatory variable (hospital costs) to ensure a non-bias estimate of causal effects. Instruments from previous studies include: total inpatient spending per decedent [**88**], average hospital costs in federal state and price per square meter in hospitals in the country [8], Hospital level average cost of unstable angina [**93**], and Hospital occupancy rate [**89**]. This study will use the respondent's median income by census tract, which are small geographic areas. It has been argued that area-based instruments will capture different environmental influences that affect attitudes and behaviors [**94**]**.** These environmental influences such as consumption of health foods or behaviors will induce change in the recovery time of the patient thus having an effect over the quality proxy being utilized.

This study focuses on the quality and cost of AMI care for Edmonton, Alberta, Canada. There are several advantages in using this well-defined population for this specific study. The first reason is that AMI requires immediate medical attention, which removes issues regarding patient selection between hospitals. The second is that hospitals that provide better care can substantially improve the quality relating to AMI [**91**]. The third is that the quality of care can be measured by mortality in well-defined patient groups [**93**]. Lastly, the existence of any possible relationship between quality and cost may differ between different heterogeneous sample groups such as the difference between cities, provinces, and countries, which may explain the inconsistent findings in existing literatures.

Some studies in the United States have found a positive association where higher cost leads to a better outcome [**95**] [**89**] [**90**] , while other studies from United States found no association [**86**] [**87**] [**96**] [**97**] [**88**] [**98**]. Besides our neighboring country, these inconsistent results also exist across the globe where a positive relationship was found in Sweden [**92**], Hungry, Finland [**93**] , and Germany [**91**]. No clear evidence of any association was also found for Finland, France, Germany, and Spain [**92**]. The results of this study will aid government policy and budgetary considerations.

3.2.0 Data

In this study, all micro-costing data comes from the Management Information System (MIS) from Alberta Health Services (AHS). These costs include all functional costs such as hospital direct cost, hospital drug cost, patient supply cost, patient drug cost, and hospital indirect cost. Hospital discharge data were available for 4802 AMI (ICD-10 code I21) patients in the Edmonton area hospitals between fiscal periods of April 1, 2006 to March 30, 2009[9]. Patients were excluded if they were discharged as a transfer to an acute care facility, left

[9] This was the only data available at the time of the study due to delays and difficulties of receiving hospital discharge data.

against medical advice, or had a Length of Stay (LOS) greater than 90 days (3988 patients remaining). We also excluded patients who were hospitalized for AMI within one-year prior to the index day to restrict our analysis to only new AMI hospitalizations (3554 patients remaining). We applied these terms of exclusion to remove atypical patients and to allow a comparison with previous AMI related studies. All functional costs are aggregated for each patient. The data set also contains Resource Intensity Weights (RIW's) and the Case Mixed Group Plus (CMG+), which allows a linkage to the Canadian Institute for Health Information (CIHI) costing proxy. This is used as a robustness check and is further explained in the robustness check section.

The quality indicator, consistent with the Alberta provincial government is a binary variable measured by a 30-day survival, where it takes a value of 1 if the patient is alive after 30 days and 0 if the patient died during the 30 days. This is also similar to previous studies [10] and has been argued and shown that within a well-defined patient group such as AMI, the quality or outcome of hospital care is measureable by hospital mortality in many countries such as Canada, Denmark, United Kingdom, United States, Sweden, and Finland [**93**].

Risk adjustment is controlled with binary variables for 15 comorbidities[10]. Demographic controls include both age and sex. Hospital fixed effects will account for hospital heterogeneity such as teaching or university status. Year

[10] Hypertension, Diabetes Mellitus, Cancer, COPD (Chronic Obstructive Pulmonary Disease) and Asthma, Dementia, Depression, Parkinson's disease, Mental Disorders, Renal Insufficiency, Alcoholism, Coronary Artery disease, Atrial Fibrillation, Cardiac Insufficiency (heart failure), Atherosclerosis, and Stroke.

fixed effects will account for any annual fluctuations in policy or economic conditions.

Patients' postal codes are linked with the 2006 Statistics Canada census tract to extract the respondent's neighborhood median income by census tract for the instrumental variable.

3.3.0 Methods

3.3.1 Parametric Analysis

Hospital costs were regressed with increasing model specifications starting with a simple linear regression of just hospital costs and quality (equation 1). The second model has additional demographic controls (equation 2). The third model includes risk adjustments (equation 3). The next two models include hospital fixed effects (equation 4) and year fixed effects (equation 5). Where i is the i^{th} patient treated at time t, $\boldsymbol{COST}$, is the micro-costing data from MIS, Q is the respective quality measurement as defined above, $\boldsymbol{X}$ is a vector of demographic controls, $\boldsymbol{R}$ is a vector of risk adjustments, $\boldsymbol{Hos}$ is hospital fixed effects, $\boldsymbol{Year}$ is year fixed effects, and $\boldsymbol{\varepsilon}$ is the residuals. All costs are logarithmically transformed to create a normal distribution and make easier interpretation of the results for policy makers and layman research users. The two-stage instrumental regression is shown in equation 6 and 7, where $\boldsymbol{IV}$ is the respondent's census tract neighborhood median income and $\boldsymbol{v}$ is the residuals from the first-stage regression

$$\boldsymbol{lnCOST_{i,t} = \beta_1 Q_{i,t} + \varepsilon_{i,t}} \qquad (1)$$

$$\boldsymbol{lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + + \varepsilon_{i,t}} \qquad (2)$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \beta_4 Hos_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \beta_4 Hos_{i,t} + \beta_5 Year_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$Q_{i,t} = \beta_1 X_{i,t} + \beta_2 R_{i,t} + \beta_3 Hos_{i,t} + \beta_4 Year_{i,t} + \beta_5 IV_{i,t} + v_{i,t} \quad (6)$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \beta_4 Hos_{i,t} + \beta_5 Year_{i,t} + \beta_6 v_{i,t} + \varepsilon_{i,t} \quad (7)$$

3.3.2 Semi-Parametric Analysis

If evidence of an association exists, then it is important for policy makers to know the true functional form of the relationship between quality and hospital costs. Semi-parametric regressions allowed us to relax the assumption of linearity from multi-linear regression analysis. Our model will resume the use of the linearity assumption on all parameters except the quality measurement as shown in equation 6, where F is an unknown function and the $Q_{i,t}$ coefficient remains linear. This function will be depicted in a graphical form to allow the interpretation of its true functional form.

$$lnC_{i,t} = F(Q_{i,t}) + \beta_1 X_{i,t} + \beta_2 R_{i,t} + \beta_3 Hos_{i,t} + \beta_4 Year_{i,t} + +\varepsilon_{i,t} \quad (6)$$

3.4.0 Results

Table 1 contains descriptive statistics broken down by sex for selected variables. The average age was 69 and 77 for males and females, respectively. There were approximately twice as many males than females. Male patients have increased drastically from fiscal year 2007 to fiscal year 2009. There were 1377 male and 470 female patients who received Percutaneous Coronary Intervention, which is a non-invasive and less expensive procedure compared to a Coronary Artery Bypass Grafting (CABG). 11 male patients received CABG compared to only 1 female. 43 male patients signed-out against medical advice compared to 11 female patients.

All the results from the regression models with increasing regression specifications are shown in table 3.2. The results suggest that the quality of AMI care as specified above is positively associated with hospital costs after controlling for demographics, comorbidities, and fixed effects. These results suggest that higher AMI quality of care is associated with approximately 39% higher hospital costs. The instrumental variable regression finds estimated causal evidence that the quality of AMI care causes an increase in hospital costs. The semi-parametric regression results (figure 1) show a fairly linear and positive relationship between the numbers of days survived and hospital costs.

3.5.0 Robustness

Following the CIHI methodology for CMG+ cost estimation each patient's RIW was multiplied with the provincial CPWC from years 2006/2007 to 2008/2009. However, due to changes in CIHI procedures these CPWC are no longer publicly available. This study will include these CPWC for future references[11]. To ensure further robustness of our results, this study replaces all micro-costs used in the previous analysis with the CMG+ cost estimates. The association under all specification were consistent with the previous findings

[11] Provincial CPWC values for fiscal years 06/07, 07/08, and 08/09 are $5541.24, $6152.33, and $5769.08, respectively.

when using the CMG+ cost estimates. All robustness check results are available in appendix 5.

3.6.0 Conclusion and Discussion

This study sheds some light on the cost associated with maintaining the provincial mandate of increasing the quality of AMI care without considering the cost increases caused by this KPI. Our model finds evidence that increasing the quality of AMI KPI is associated with a 39% higher hospital cost compared with lower quality of AMI care. It should also be noted that the results are only indicative of a positive association and increasing the KPI may not lead to a direct 39% increase in hospital costs. The direct relationship cannot be calculated due to limitations in the dataset. These results suggest that policy makers may need to consider additional resources or increasing efficiency of existing resource utilization for the current mandate to increase the AMI KPI.

The instrumental variable regression results found evidence that the quality of AMI care causes an increase in hospital costs. However, due to a major limitation of the quality indicator, these results are not surprising as the quality indicator was based on patient survival; as patients survive longer, they will have a longer hospital LOS thus it is expected that the cost should increase. However, this is consistent with the Alberta government KPI derivation and government policy makers should take this into consideration.

The semi-parametric regression results of the positive linear relationship between the numbers of days survived and hospital costs is expected as hospital LOS increase, the hospital cost should also increase. This should also caution policy and decision makers to understand the limitations of the KPI utilization in the province of Alberta to measure the quality of AMI care. However, this result provides additional support for the positive association found under the parametric approach assuming the correctness of this KPI.

These results have undergone various robustness checks including increasing model specifications and replacing the micro-costing data with CMG+ cost estimates. These variations ensured the robustness of a positive association between the quality of AMI care and hospital costs. Similar positive association between AMI quality and hospital costs can be found in studies from California [**90**], Germany [**91**], Sweden [**92**], and United States Veterans hospitals [**89**]. Interestingly, this study's semi-parametric approach confirms a fairly linear relationship between quality and cost, which suggest that economics of scale and diminishing marginal returns may not be applicable. This means that the return on the quality of AMI is constant for each dollar invested.

Two major strengths of this study lie in the data set used. The first is that the data set is population based and not a sample. This data set contains all patients between fiscal years 2006 to 2009 who were admitted for AMI in Edmonton Alberta. The second, is that all costs came from the Alberta Health Services MIS which contains actual patient costs that remove the need for further estimation of costs.

3.7.0 Limitations

A major limitation in all AMI outcome-cost studies is the definition of quality being used. An ideal study would need to incorporate some true measure of AMI quality instead of the quality proxy.

To our knowledge, there are no measures of the true quality of AMI and to derive such measurement would require the help of experts and physicians in AMI care. Other limitation includes that AMI treatment like PCI and CABG may be done after the initial hospitalization and in another hospital and increasingly also as outpatient operation. This may impact the cost and procedure outcomes of the current study.

This study is restricted to the Edmonton area hospitals, which may reduce the variations between cost and quality indicators. A higher-level provincial study or a cross-provincial study would be needed to provide more insight on the nature between hospital cost and AMI quality.

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3.9.0 Disclosure

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Infarction in Edmonton, Alberta, Canada. Research in Health Science, 2 (4): 314-322.

Table 3.1: Descriptive Statistics

		Fiscal Year[1]		
	Male (n=2421)	2006/2007	2007/2008	2008/2009
(1)	Age (mean)	72 (14)	70 (14)	68 (13)
(2)	Length of Stay (mean)	7.8 (6.7)	7.3 (6.6)	6.7 (5.6)
(3)	Cost (mean)	11,463 (10496)	10,684 (9554)	11,650 (11109)
(4)	CABG (#)	11	0	0
(5)	PCI (#)	277	515	585
	Female (n=1133)			
(6)	Age (mean)	81 (14)	76 (14)	76 (14)
(7)	Length of Stay (mean)	10.2 (10.8)	8.9 (8.9)	8.2 (7.80
(8)	Cost (mean)	12,287 (13175)	11,026 (8450)	12,377 (9804)
(9)	CABG (#)	1	0	0
(10)	PCI (#)	91	191	188

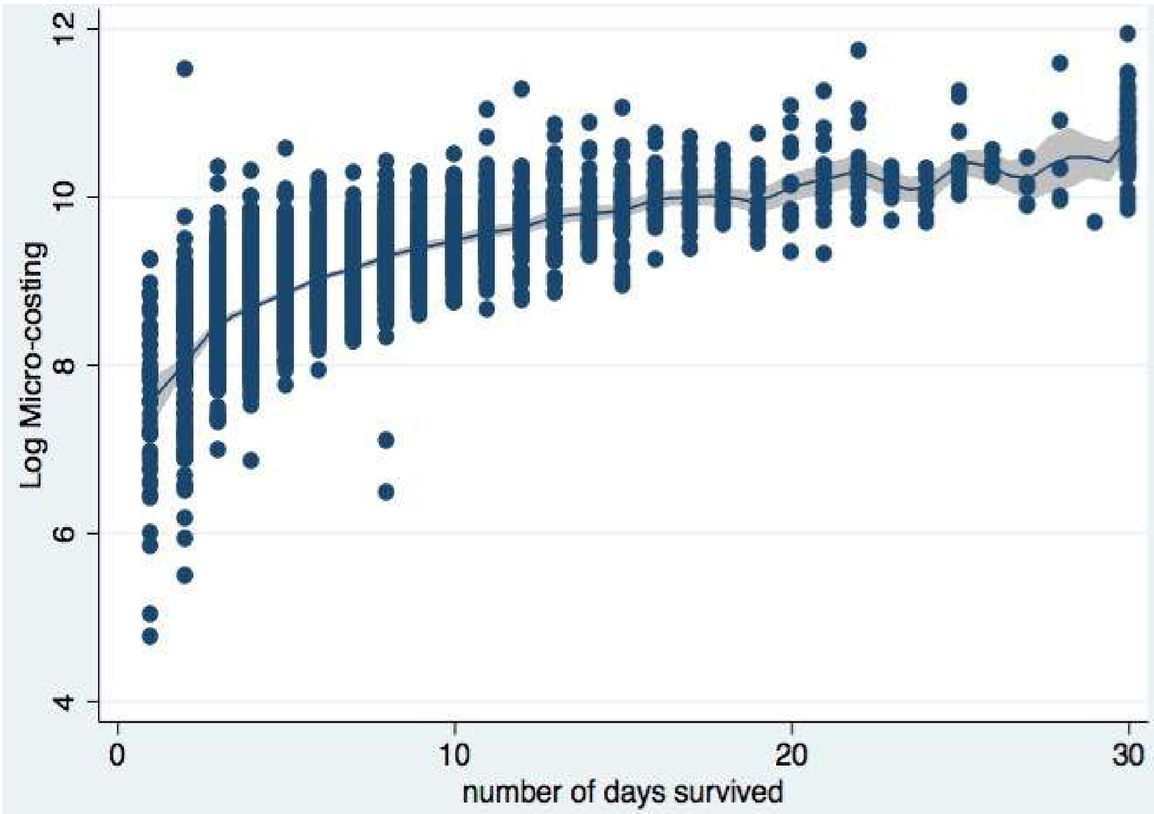
[1]Fiscal period starts in April Ends in March.
Standard Deviation in Brackets when applicable.

Table 3.2: Selective AMI Quality Regression Coefficients

Equation	Model Specifications	Quality Coefficents[1]
(1)	No Risk adjustment	.393***
(2)	+Demographics	.390***
(3)	+ Risk adjustments	.391***
(4)	+ Hospital Fixed Effects	.399***
(5)	+ Year Fixed Effects	.388***
(7)	Instrumental Variable regression	2.041*
(6)	1st Stage F-Stat	25.97

*,**,*** indicates 1%, 5%, 10%, significance levels respectively.
[1]Based on patient mortality

Figure 3.1: Functional Form of AMI Quality Key Performance Indicator vs Hospital Cost using a Semi-parametric Regression with 95% Confidence Intervals.



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Chapter 4: CMG Costing proxy for Acute Myocardial Infarction

4.1.0 Introduction

Many government health evaluations require accurate health costing data but due to many interdepartmental issues including privacy concerns, these costing data, usually from the Management Information System (MIS), would be unavailable. Canadian health care executives rely on valid cost estimates for determining resource allocations [**99**]. Currently, very little research has been done on the impact of using a costing proxy for micro-costing data [**100**], which has led to criticisms of the Canadian Case Mixed system in whether cost weights accurately represent mean hospital episode costs [**21**]. This study validates the Canadian Institute for Health Information's (CIHI) costing proxy for patients with acute myocardial infarction (AMI) in Edmonton, Alberta between the years 2006 and 2009.

Case Mixed Groups Plx (CMG), the first Canadian version of the Diagnosis-related group (DRG) system was first introduced in 1983. This system assigned discharge patients to one of approximately 600 resource groups with 25 major clinical categories based on the most responsible diagnosis. This methodology grouped patients with similar cost and hospital length of stay (LOS) by isolating complicated conditions that were statistically associated with higher cost. Average patient costs were derived from costing data submitted to CIHI annually [**21**] [**22**] [**23**]. CMG's were originally designed to collapse the ICD-9-CM and Canadian Classification of Procedure codes to a smaller, more manageable number of patient groups for gross-costing estimates [**100**] [**101**].

Case Mix Groups+ (CMG+) introduced by CIHI in 2007, replaced the former CMG system. CMG+ accounts for five factors: age category (cost variations associated with the different needs and durations for older and younger patients), comorbidity level (pre-existing conditions patients may have prior to the diagnosis, and hospital induced conditions such as infections), flagged interventions associated with higher costs, intervention event (consists of inpatient visits to an operating room or procedure suite during the hospital stay), and out-of-hospital interventions (selected interventions that are performed outside the admitting facility leading to a lower observed cost). Based on CIHI's formula to estimate inpatient cost, two components are required to derive a CMG+ cost estimate. The first is the Resource Intensity Weights (RIW), which are calculated and updated annually based on the Discharge Abstract Database (DAD) and from case cost data from hospitals in British Columbia, Alberta, and Ontario [**23**]. These RIW's are controlled for the five factors discussed above, and represent the relative resource used by each average patient within a CMG+ group. RIW values are adjusted for observed differences in LOS reported and Expected LOS by CIHI. The second component is the Cost Per Weighted Case (CPWC), which are calculated annually from the CIHI's Canadian Management Information System Database. The CPWC is calculated by dividing the net inpatient cost for a facility by the total weighted cases in that facility, which provides a measure of the average cost the facility incurs per inpatient. These two components are then multiplied together to derive a Cost Per Case estimate [**23**]. The Cost Per Case estimate can also be divided by its associated Expected

Length Of Stay (ELOS) to obtain a Cost Per Diem rate for typical patients [**102**]. Average cost, ELOS, and other factors used in the process of deriving the RIW's for each CMG+ category are publically available through the Alberta Health and Wellness Interactive Health Data Application (IHDA). We have used these intermediate variables to derive an additional cost estimate that researchers may be able to use in the absence of RIW's and MIS-costing data. The aim of this study is to provide a side-by-side comparison of the different costing estimates and compare it with the MIS costs for typical patient with new AMI hospitalization.

4.2.0 Data and Methods

Hospital discharge data was for 4802 AMI (ICD-10 code I21) patients in the Edmonton area hospitals between fiscal periods of April 1, 2006 to March 30, 2009. Patients were excluded if the patient transferred to an acute care facility, died, signed-out, or had a LOS greater than 90 days. These restrictions ensure that only typical patients (3708 patients) remained in our data set. While we considered that non-typical patients may account for a disproportionate share of the costs, this view was discussed in the CIHI costing proxy. Following EuroHOPE [**103**], we included only new AMI patients (3291 patients remaining) to ensure better comparability between patients. All functional costs in Canadian dollars (hospital direct costs, hospital drug cost, patient supply cost, patient drug cost, and indirect cost) were aggregated and matched with their associated CMG+ cost estimates.

We determined 3 possible estimates for MIS-costing data. The first estimate follows CIHI (2008) method for calculating a Cost Per Case estimate

(Equation 1), where i represents each inpatient and t represents the fiscal year. CPWC values are publically available through the CIHI website for recent years; however, due to a change in CPWC calculations, the older values from fiscal years 2006/2007 to 2008/2009 are no longer available online. We have included the CPWC values from the older years for future reference. The second Cost estimate follows Perry and Homan's (2009) RIW estimation of Cost Per Diem using ELOS from IHDA, which is extracted for each CMG+ group prior to using it as a denominator for the Cost Per Case (Equation 2). It is important to note that ELOS statistics exclude atypical patient cases and long-stay cases. Given the available information in the IHDA database, we extracted the average cost used in the process of the RIW calculations to derive a "last resort" Per-Diem cost estimation (Equation 3), where the average cost per each CMG+ is divided by the ELOS for its associated CMG+ group and then multiplied by the MIS-costing LOS. It is important to note that this derivation does not follow CIHI standards and does not take into account many cost-varying factors compared to the RIW cost estimates.

$[\text{CMG Cost Per Case}]_{i,t} = [\text{RIW}]_{i,t} \text{ X } [\text{CPWC}]_{t}$ (1)

$[\text{CMG PerDiem}]_{it} = [\text{CMG Cost Per Case}]_{i,t} / [\text{ELOS}]_{i,t}$ (2)

$[\text{IHDA PerDiem}]_{i,t} = \{[\text{IHDA Average CMG+ Cost}]_{i,t} / [\text{ELOS}]_{i,t}\} \text{ X } [\text{MIS LOS}]_{i,t}$

The difference between the cost estimates and actual costs will be calculated for each inpatient prior to calculating the descriptive statistics, which will provide us with the mean differences for each costing methodology.

A linear regression analysis was used to determine which costing methodology best correlates with the MIS-costing data. Similar to the majority of economic studies, costs were logarithmically transformed. The coefficient closest to 1 in the linear regression indicates the best correlation between the costing method and MIS-costing data.

Intra-class correlation coefficients were used to determine which costing methodology best "agrees" with the MIS-costing data based on Kappa statistics cut points; less than 0.4 signaling a weak agreement, 0.4-0.6 suggest a moderate agreement, 0.6-0.8 a good agreement, and 0.8 or higher showing an excellent agreement [**100**] [**103**].

4.3.0 Results

The overall mean MIS cost was 11,387 (SD 9,930) and the average age was 71 (SD 14) years. The data set contained approximately 32% females and 68% males. By gender the average costs were 11,812 (SD 9367) CAD and 11,190 (SD 10,176) for females and males, respectively. The average ages by gender were 78 and 70 years for females and males, respectively.

The mean difference between both costs (Table 1) indicated that the RIW Cost Per Case produced estimates closest to the MIS costing mean with the lowest standard deviation. The RIW Cost Per Case cost estimate overestimated the mean by approximately $359 (SD 7,086) while RIW Cost Per Diem produced a cost estimate that underestimated the real mean by approximately $9,109 (SD 8841). When in absent of RIW values, the Cost estimates derived using information available on IHDA produced a mean that overestimated the MIS-costing mean by approximately 3,816 (SD 8441) Canadian dollars.

Regression results (Table 2 column 1) shows that the costing method using RIW's to produce Cost Per Case as specified by CIHI produced almost perfect correlation with actual MIS-costing data (correlation of 0.9). The RIW Cost Per Diem had the lowest correlation from the MIS-costing data (correlation of 0.71). When in absent of RIW's, the cost estimate derived with IHDA data produces a correlation of 0.88, which is secondary to the RIW method but relatively similar.

In regards to agreeability from the cost estimates (Table 2 column 2), Both RIW methodologies are in "good agreement" and the IHDA cost estimate is in "Excellent agreement with the MIS-costing data based on the Kappa Statistic cut points (0.66, 0.65, 0.82 for RIW Cost Per Case, RIW Cost Per Diem, and IHDA Cost estimate, respectively).

4.4.0 Discussion and Conclusion

To our knowledge this is the first study to compare the new Canadian Case Mix Groups+ (CMG+) and its associated MIS-costing data. The study provides supporting evidence for using the new CMG+ system to estimate typical inpatient Cost Per Case. The RIW Cost Per Case estimate provides good agreement and highly correlates with the MIS-costing data. The mean difference between using the RIW Cost Per Case estimates and MIS-costing data is also minimal. It is recommended for researchers to use the RIW Cost Per Case formulation when in absent of MIS-costing data. The CMG+ system is not used for reimbursement in Canada except of the small proportion of payment in Ontario. Based on our estimates, the MIS and CMG+ methodologies produce that close estimates that for the typical AMI patients it would produce a reasonably good basis for activity based funding system. When the RIW values cannot be applied, we found that using the average cost publically available through IHDA Produces reasonably accurate and close results to the RIW estimates. It is important to note that deriving cost estimates using average cost in IHDA does not follow the CIHI methodology and should not be used when RIW's are available. These findings are the first step in validating alternative costing estimates for health care administrators, executives, and health researchers in the absence of MIS-costing data for AMI in Canada.

Our results are similar to a previous study [**104**] where the old Canadian CMG was found to be similar to MIS-costing estimates. However, when they used the CMG in a cost-utility analysis in economic evaluation they found that the ratio was 16% lower compared to MIS-costing data. Our results are also similar to a study from the United States where no difference was found between the DRG cost estimates and MIS-costing data [**105**]. However, an Irish study found large differences between the DRG system and MIS-costing data for percutaneous cardiac procedures for AMI [**106**]. Based on the results and similarities from the previous studies, it is recommended that further research on the differences in outcome between using the new Canadian CMG+ and actual cost for health services research including economic evaluation studies.

A limitation to our study is that our sample is restricted to the Edmonton area hospitals, which may reduce the variations between CMG+ and actual cost leadings to a possible upward bias on the association. In addition, recent changes in the calculation of the CPWC methodology may have an effect on the representation of MIS-costing data, but due to the lack of data we are unable to investigate further. A higher-level provincial study using data after 2009 would be ideal to provide additional evidence for this type of costing studies. The study was limited to typical cases that include only patients who have undergone a normal and expected course of treatment as defined by CIHI. Since the atypical cases and alternate level of care days that constitute hospital days after a patient's planned discharge day produce substantially higher costs (long LOS) and lower costs (deaths shortly after arrival), further studies are needed to analyze the best costing methods for these type of atypical patient groups. The limitations addressed in this study should be considered for government health research when utilizing these cost-estimates.

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Table 4.1: Mean Differences between Cost Estimates and MIS Cost

Cost Estimates	Mean Difference	Observations[1]
RIW Cost Per Case	359 (7086)	3291
RIW Cost Per Diem	-9,109 (8841)	2891
IHDA Derived Cost[2]	3,816 (8441)	2891

All costs are expressed in Canadian dollars
All costs in 2010/2011 values
Difference = [Cost Estimate]- [MIS Costs]
Standard deviation in parentheses
[1]All lost observations in CMG estimates occurred in 06/07 fiscal years due to conversion from CMG Plx to CMG+ and were unable to be matched.
[2]This cost estimate is derived from intermediate variables in the calculations of RIW estimates and does not follow CIHI methodology. It should be noted that this cost estimation should only be used when in absent of RIW's.

Table 4.2: Linear Regression and Intra-Class Correlation Coefficient

	(1) Linear Regression		(2) Intra-class Correlation
Cost Estimates	Coef.	t	
RIW Cost Per Case	0.90***	54.87	0.66
RIW Cost Per Diem	0.71***	40.63	0.65
IHDA Derived Cost	0.88***	75.26	0.82

All cost are inflation adjusted to fiscal year 2010/2011 by IHDA
***,**,* represents 1%, 5%, 10% significance respectively

4.7.0 Reference

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Final Conclusion

The intended purpose of this dissertation was to provide examples of how secondary data can be maximized utilizing econometrics in health research, targeting government decision makers. The results of the first two chapters were presented to senior level staff at Health Canada- Public Health Agency of Canada (PHAC)[12] as well as Indigenous Service Canada[13]. The econometrics utilized through-out the chapters were well received and the results initiated an internal departmental discussion.

The first chapter investigated the relationship between Obesity and Personal income. The chapter contributed and introduced health region demographics as a potential instrument for IV regressions that can be used to impute causality while studying the weight-wage penalty in Canada. The models presented in this study suggest that a 1-unit increase in lagged BMI is associated with a 0.7% decrease in personal income for obese Canadian females. Similar to other studies, the results for males are inconsistent. In order to minimize the knowledge-to-action gap, the use-case of utilizing the results for a promotional marketing tool to dis-incentivize obesity was presented. However, during the discussion with senior staff, the evidence brought forward by this chapter would not be a viable option due to the results being significant for only one sex and if the results were used as a marketing tool, there may be possible backlash of gender discrimination. However, all senior staff at the discussion agreed that

[12] Presentations and discussions occurred between April 29, 2019 and May 2, 2019.
[13] Presentations and discussions occurred between May 6, 2019 and May 9, 2019.

providing use-cases for scientific results had optimized the knowledge transfer process. This chapter also sought to expand IV regression methods in health research as well as provide additional area-based methodology through health regions for government health datasets. These instruments are included in the appendix for future research. These health regions can be linked with any health database that has postal code information.

The second chapter investigates the association of serum 25(OH)D concentrations with indicators of mental health such as depression, anxiety, and stress. These indicators of mental health were examined using ordered logistic regression models with increasing specificity that account for demographics, socio-economic status, and health. Marginal effects were used to determine the probability of the average adult Canadian being in the best mental health state by groupings of serum 25(OH)D concentrations. A robust association between serum 25(OH)D concentrations and the indicators of mental health were observed. In the fully adjusted ordered logistic model, an average Canadian appeared more likely to experience better mental health when serum 25(OH)D concentrations were higher. Due to the low risk of harm from toxicity and the relative modest costs of vitamin D supplements, these results have sparked interest at the discussion table with policy analyst at PHAC. However, the establishment of effectiveness and causality came into question but was outside the scope of the exploratory research. Although, case-use for the results were not used, it accomplished the role of transferring knowledge to the target audience. The possibility of having no causal effect between vitamin D and mental health indicators is enough for the policy and decision makers to take a conservative approach to maintain public trust. A recent RCT found no causal effects between vitamin D and the incident rate of cancer or cardiovascular events despite evidence from previous ecological studies. However, the RCT also found no adverse effects[14] for high dose vitamin D (2000 IU per day).

The third chapter explores one of the KPI's from Alberta Ministry of Health and Wellness's mandate of health outcomes. The importance of the relationship between hospital costs and quality of care for Acute Myocardial Infarction is realized when policy makers face decisions about cost minimization and quality maximization during government budgetary decisions. This study uses regression modelling with increasing specifications as well as various robustness checks to ensure the accuracy of the results. The Model specifications were demographics, AMI risk adjustments, Hospital fixed effects, and year fixed effects. Semi-parametric regression removes the assumption of linearity to determine the true relationship between hospital cost and AMI quality. Higher AMI quality is associated with a 39% increase in hospital costs after adjustments and controls. The semi-parametric regression shows a fairly linear relationship between cost and AMI quality.

The final chapter extends the third chapter in that it validates the costing proxy for economic evaluations for acute myocardial infarction. Inter-department data sharing in government is often limited and acquiring micro-costing data is often difficult if not impossible. When absent these cost-data, cost estimates such

[14] Hypercalcemia, kidney stones, or gastrointestinal symptoms.

as the Canadian Case Mix Groups+ (CMG+) are required. This is the first study to evaluate the CMG+ as a costing proxy for acute myocardial infarction patients by comparing actual micro-costing data with the CMG+. Intra-class correlation coefficients based on Kappa Statistics cut points show good agreeability between the costing proxy and actual cost (ICC of 0.66). This chapter validates a hospital costing proxy for future government health cost evaluations when absent real costing data.

This dissertation is tied together with the goal of maximizing the use of secondary data by applying econometric modelling techniques used in economic research. Policy and decision makers tend to struggle with uptake of scientific knowledge especially when advance modelling is utilized but has been shown in this dissertation that these complex models can be presented in a layman way that does not hinder the KT process.

Strength and Limitations

The strength of this dissertation is that all four chapters utilize real examples of alternative analytical approaches that can be used on survey and secondary data for Canadian health research targeting policy and decision makers. The first two chapters has a national representation of Canada whereas collecting primary data for a national study is impractical if not near impossible. The last two chapters provide real examples of alternative hypothesis testing on provincial health administrative data.

All limitations from using secondary data are inherited in all four chapters. The major disadvantage of secondary data is that the data was not collected to address the particular question. These issues can be seen in all four chapters where proxies had to be used. Chapter one's BMI proxy for obesity is known to be an inaccurate measurement of obesity [**62**]. Chapter two relied on four indicators of mental health that were self-reported instead of having a professional diagnostic of mental health. Chapter three's survival rate is a poor proxy for AMI treatment quality but is the current industry proxy standard. However, the benefits of these studies far out weight the limitations.

The second major limitation with secondary data is the population representativeness. This was not an issue with the first two chapters utilizing the CCHS and NHPS databases since they were collected to represent Canada as a whole. However, the last two chapter uses a health administrative database that is only representative of AMI patients who received treatment in Edmonton, Alberta. However, this data is very representative of this population as the data contains the entire study population.

A limitation of the proposed area-based IV regression in chapter one can be seen in chapter two. The proposed area-based IV requires respondent postal codes to link (via PCCF) respondent health regions. The area-based IV regression could not be applied to chapter two due to strict Statistics Canada confidentiality rules, it was impossible to obtain the required respondent postal codes. To establish true causality a randomized control trial is needed however this can be very resource intensive. The IV regression technique can only be used to estimate causality.

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Appendix 1: Health Region Based Instrumental Variables

The following sections are the estimated Health Region demographic information used for the area based Instrumental Variable Regression discussed in chapter one. All values presented here are probability weighted to provide a representative sample of each Canadian health region. All values are computed from the unbalanced NHPS dataset. Bracketed numbers are for reference to the PCCF health region identifier. Certain health regions are combined to increase sample size.

Newfoundland & Labrador

Year	Average Household Income	Prevalence of Obesity (%)	Average HUI3 Index	Prevalence of smoking (%)	Average number of drinks per day	Average BMI
		Eastern Regional Integrated Health Authority (1011)				
1995	39108	19.41%	0.88	29.85%	0.51	24.28
1997	40207	22.36%	0.91	29.81%	0.48	24.47
1999	42537	27.58%	0.91	29.63%	0.44	24.68
2001	46037	31.76%	0.90	26.57%	0.50	25.11
2003	46991	40.54%	0.90	25.47%	0.61	25.55
2005	60139	45.83%	0.89	23.35%	0.60	25.93
2007	67635	44.30%	0.89	20.30%	0.63	26.08
2009	73695	56.06%	0.89	22.15%	0.54	26.59
2011	80292	55.42%	0.87	25.50%	0.67	26.93
		Central Regional Integrated Health Authority (1012)				
1995	34225	21.15%	0.87	30.88%	0.47	25.12
1997	33908	17.56%	0.90	26.30%	0.44	25.01
1999	33908	21.97%	0.90	30.38%	0.37	25.51
2001	41130	28.32%	0.88	28.03%	0.40	26.82
2003	42972	42.07%	0.89	22.00%	0.44	26.73
2005	51392	46.03%	0.89	21.25%	0.45	27.24
2007	53296	46.30%	0.88	19.93%	0.55	27.92
2009	56533	52.83%	0.86	18.61%	0.46	27.84
2011	72771	59.62%	0.85	22.68%	0.58	28.49
		Western Regional Integrated Health Authority (1013)				

1995	31673	23.59%	0.90	30.31%	0.46	25.08
1997	33294	26.33%	0.93	32.90%	0.47	25.54
1999	34408	25.92%	0.92	28.16%	0.41	26.09
2001	39237	26.54%	0.92	26.37%	0.27	25.58
2003	39033	39.34%	0.92	29.52%	0.29	26.32
2005	50384	36.25%	0.90	16.35%	0.57	26.42
2007	58220	52.90%	0.89	18.99%	0.48	26.89
2009	52417	51.04%	0.87	15.45%	0.46	26.90
2011	62428	61.12%	0.88	19.13%	0.39	26.90
Labrador-Grenfell Regional Integrated Health Authority (1014)						
1995	46788	12.18%	0.86	40.63%	0.75	23.91
1997	39733	20.77%	0.94	34.68%	0.31	25.21
1999	46850	31.99%	0.94	32.53%	0.60	26.76
2001	60176	47.08%	0.94	28.90%	0.47	26.39
2003	64773	45.43%	0.92	15.31%	0.42	27.53
2005	73464	57.73%	0.92	24.12%	0.40	27.62
2007	84491	44.49%	0.91	26.82%	0.75	27.76
2009	85335	55.38%	0.83	20.35%	0.50	28.13
2011	101964	61.23%	0.90	14.68%	0.52	30.16

Prince Edward Island

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
1995	37992	23.47%	0.89	30.97%	0.49	24.63
1997	39502	21.42%	0.90	33.89%	0.47	24.47
1999	41698	25.59%	0.90	31.24%	0.39	24.56
2001	45059	29.32%	0.91	31.16%	0.50	25.40
2003	48374	36.92%	0.89	27.36%	0.43	25.49
2005	55975	44.87%	0.88	22.33%	0.54	25.99
2007	64011	43.32%	0.88	20.50%	0.47	26.02
2009	68642	51.99%	0.88	19.86%	0.51	26.42
2011	73695	56.97%	0.88	21.03%	0.54	26.82

Nova Scotia

year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
		South Shore District Health Authority (1211)				
1995	41044	20.72%	0.82	40.60%	0.37	25.27
1997	37436	24.62%	0.85	37.64%	0.52	25.12
1999	39078	37.02%	0.89	32.49%	0.59	25.88
2001	43517	42.21%	0.84	32.68%	0.38	26.30
2003	47409	50.75%	0.86	25.09%	0.65	27.24
2005	66088	56.98%	0.85	27.32%	0.86	27.38
2007	63249	62.25%	0.84	24.60%	0.47	28.69
2009	69724	60.99%	0.84	23.80%	0.51	27.63
2011	71469	66.23%	0.85	26.11%	0.53	27.86
		South West Nova District Health Authority (1212)				
1995	33902	23.60%	0.85	33.67%	0.30	24.46
1997	32490	29.45%	0.86	32.24%	0.36	25.02
1999	35352	30.18%	0.87	33.79%	0.56	25.12
2001	40151	38.47%	0.89	35.95%	0.36	26.08
2003	41433	49.01%	0.89	39.41%	0.50	26.50
2005	44733	51.21%	0.86	27.78%	0.32	27.20
2007	55701	52.24%	0.88	28.14%	0.42	26.84
2009	58858	60.73%	0.86	35.21%	0.28	27.72
2011	51709	64.60%	0.83	30.16%	0.47	27.97
		Annapolis Valley District Health Authority (1223)				
1995	38025	29.03%	0.86	22.99%	0.44	25.12
1997	37374	35.67%	0.90	30.66%	0.30	25.76
1999	38564	27.34%	0.91	27.09%	0.35	26.45
2001	46393	39.56%	0.90	33.14%	0.22	27.18
2003	49181	53.49%	0.89	32.85%	0.27	26.91
2005	60516	54.32%	0.90	27.28%	0.27	27.40
2007	60481	57.00%	0.91	25.37%	0.09	28.61
2009	63075	60.65%	0.86	20.64%	0.34	29.09
2011	65846	64.71%	0.89	33.70%	0.29	28.43
		Colchester East Hants Health Authority (1234)				
1995	33561	24.72%	0.72	40.24%	0.49	24.72
1997	30999	25.64%	0.84	34.24%	0.53	24.78
1999	36858	28.58%	0.84	29.45%	0.62	25.00
2001	40207	38.41%	0.79	28.94%	0.60	25.73

2003	45166	42.68%	0.85	28.12%	0.78	26.87
2005	43041	53.56%	0.74	28.29%	0.49	27.40
2007	55763	59.16%	0.83	27.50%	0.47	28.97
2009	56659	56.43%	0.85	34.21%	0.57	27.66
2011	67382	66.79%	0.80	35.12%	0.79	27.78
		Cumberland Health Authority (1235)				
1995	26394	20.60%	0.92	35.12%	0.52	24.96
1997	29767	28.22%	0.93	37.06%	0.15	23.94
1999	37358	32.75%	0.92	45.78%	0.26	24.51
2001	42075	41.76%	0.93	36.30%	0.08	26.07
2003	45568	48.51%	0.90	28.78%	0.52	26.20
2005	47278	40.79%	0.88	30.82%	0.33	26.11
2007	54056	46.99%	0.91	32.97%	0.46	27.13
2009	59226	60.39%	0.89	28.19%	0.55	27.55
2011	55156	55.67%	0.86	34.73%	0.76	27.08
		Pictou County Health Authority (1246)				
1995	34031	27.04%	0.89	19.54%	0.49	25.70
1997	30149	23.28%	0.87	15.98%	1.07	26.67
1999	35762	34.05%	0.86	10.76%	0.93	26.74
2001	41160	63.02%	0.79	7.13%	1.38	27.08
2003	45636	53.77%	0.88	20.97%	1.87	26.30
2005	46582	69.27%	0.78	8.20%	0.64	26.98
2007	65194	59.30%	0.88	34.74%	0.66	28.11
2009	73185	70.77%	0.94	28.69%	0.45	27.37
2011	71712	73.06%	0.88	40.81%	0.47	28.72
		Guysborough Antigonish Strait Health Authority (1247)				
1995	37304	39.62%	0.86	45.18%	0.31	24.25
1997	40256	14.37%	0.88	46.39%	0.69	23.02
1999	44217	25.65%	0.88	40.97%	0.70	23.76
2001	39326	15.96%	0.89	26.54%	0.39	23.91
2003	42649	24.63%	0.91	31.84%	0.36	24.35
2005	56673	33.13%	0.85	34.89%	1.06	24.72
2007	60947	26.59%	0.85	34.04%	0.45	25.35
2009	72559	43.12%	0.79	37.45%	0.36	26.94
2011	81091	51.58%	0.84	44.55%	0.61	27.27
		Cape Breton District Health Authority (1258)				
1995	35719	21.79%	0.85	29.64%	0.45	24.26
1997	32988	25.18%	0.89	23.36%	0.32	24.49
1999	36376	23.99%	0.89	25.49%	0.28	24.57
2001	41127	33.74%	0.89	21.50%	0.32	24.90

2003	39487	39.15%	0.88	26.34%	0.29	25.70
2005	51075	41.77%	0.86	27.16%	0.36	26.15
2007	54189	41.82%	0.87	25.05%	0.35	26.72
2009	53826	48.82%	0.86	18.34%	0.37	26.40
2011	51720	60.01%	0.83	20.31%	0.40	26.75
		Capital District Health Authority (1269)				
1995	43894	22.58%	0.85	33.51%	0.46	24.29
1997	43397	25.33%	0.89	30.19%	0.45	24.32
1999	47881	27.47%	0.89	27.01%	0.49	24.85
2001	52370	32.35%	0.90	29.76%	0.48	25.50
2003	55497	38.81%	0.88	18.75%	0.45	25.50
2005	67405	44.26%	0.87	22.73%	0.51	26.12
2007	82022	43.33%	0.88	19.19%	0.46	26.09
2009	86620	53.06%	0.88	19.17%	0.48	26.59
2011	86679	54.85%	0.86	15.38%	0.53	26.94

New Brunswick

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
		Zone 1-Moncton area (1301)				
1995	40129	17.27%	0.83	25.11%	0.43	25.28
1997	37820	24.06%	0.89	26.56%	0.50	25.28
1999	42879	28.15%	0.88	25.68%	0.44	25.19
2001	43729	34.13%	0.89	22.11%	0.38	25.79
2003	50759	41.17%	0.86	21.28%	0.38	26.26
2005	60175	51.66%	0.85	17.20%	0.38	26.30
2007	67791	47.26%	0.87	20.10%	0.35	26.70
2009	69441	50.70%	0.83	21.51%	0.34	26.43
2011	77026	57.63%	0.84	13.96%	24.51	27.16
		Zone 2-Saint John area (1302)				
1995	39037	17.99%	0.87	30.84%	0.87	24.31
1997	38112	18.36%	0.90	28.71%	0.49	24.09
1999	42183	21.98%	0.90	32.12%	0.66	24.65
2001	44966	32.49%	0.90	30.76%	0.58	24.92
2003	47019	39.07%	0.89	31.58%	0.59	25.46
2005	55134	43.64%	0.88	25.34%	0.69	25.53
2007	62844	43.82%	0.85	22.48%	0.68	26.08
2009	75799	54.47%	0.86	24.85%	0.83	26.05

2011	71213	55.05%	0.86	22.09%	0.85	26.23
		Zone 3-Fredericton area (1303)				
1995	39596	25.25%	0.88	33.74%	0.41	24.72
1997	42621	21.88%	0.91	29.90%	0.31	24.52
1999	43543	21.21%	0.93	25.38%	0.28	24.68
2001	48912	33.23%	0.92	27.93%	0.33	25.06
2003	52342	44.16%	0.87	21.65%	0.47	26.28
2005	68852	45.27%	0.89	20.59%	0.46	26.87
2007	63860	47.38%	0.86	19.54%	0.52	27.08
2009	79709	49.23%	0.89	16.39%	0.50	26.71
2011	80709	56.75%	0.86	16.48%	0.92	27.93
		Zone 4-Edmundston area (1304)				
1995	37267	29.18%	0.88	42.66%	0.34	25.84
1997	39512	20.62%	0.94	33.62%	0.31	25.49
1999	39339	29.81%	0.88	28.68%	0.41	25.69
2001	43952	41.45%	0.92	19.22%	0.27	25.71
2003	49137	45.96%	0.89	13.41%	0.24	26.08
2005	49883	47.63%	0.88	12.46%	0.83	26.53
2007	56099	55.07%	0.92	12.76%	0.74	26.75
2009	65869	76.21%	0.89	18.60%	0.44	27.92
2011	69376	61.68%	0.89	9.84%	0.71	27.91
		Zone 5-Campbellton area (1305)				
1995	37444	10.69%	0.79	39.80%	0.29	25.07
1997	37552	13.51%	0.84	23.91%	0.37	24.90
1999	30678	32.32%	0.81	26.72%	0.21	25.98
2001	45643	42.01%	0.89	21.62%	0.48	26.09
2003	49184	54.06%	0.87	18.68%	0.46	27.25
2005	59442	62.26%	0.84	4.03%	0.20	28.05
2007	66272	52.14%	0.86	10.83%	0.34	27.44
2009	69140	73.13%	0.82	9.48%	0.45	27.43
2011	78051	78.54%	0.89	27.02%	0.66	29.83
		Zone 6-Bathurst area (1306)				
1995	35193	24.39%	0.87	30.08%	0.21	25.25
1997	34205	29.62%	0.90	29.56%	0.21	25.04
1999	38669	42.19%	0.89	32.14%	0.29	25.59
2001	40362	45.50%	0.85	24.19%	0.42	25.66
2003	43426	58.97%	0.86	17.84%	0.09	27.16
2005	52331	58.81%	0.88	14.96%	0.28	26.82
2007	58264	51.97%	0.89	20.77%	0.20	25.52
2009	56879	64.84%	0.85	13.51%	0.39	26.99

2011	51905	70.50%	0.86	22.59%	0.31	27.46
		Zone 7-Miramichi area (1307)[2]				
1995	36317	17.30%	0.87	26.61%	0.48	23.09
1997	37028	23.41%	0.88	27.51%	0.43	25.09
1999	36317	32.59%	0.85	24.91%	0.64	25.75
2001	39227	35.59%	0.86	30.20%	0.68	25.20
2003	38691	46.94%	0.83	26.68%	0.71	25.61
2005	50466	54.69%	0.81	26.17%	0.60	26.87
2007	53202	48.95%	0.81	25.89%	0.53	26.70
2009	61441	67.34%	0.83	27.41%	0.54	28.46
2011	59557	59.70%	0.84	18.53%	0.50	26.79

Quebec

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
		RÈgion du Bas-Saint-Laurent (2401)				
1995	33065	9.80%	0.89	40.73%	0.35	24.02
1997	32066	15.17%	0.86	34.28%	0.77	24.22
1999	36163	23.65%	0.88	35.00%	0.55	24.54
2001	38189	27.31%	0.91	29.70%	0.50	25.38
2003	42069	33.59%	0.90	34.62%	0.52	24.94
2005	54321	43.59%	0.89	26.25%	0.44	25.79
2007	51364	37.07%	0.90	36.62%	0.72	25.73
2009	59478	45.65%	0.87	34.72%	0.66	26.69
2011	63823	48.05%	0.88	20.34%	0.82	26.51
		RÈgion du SaguenayóLac-Saint-Jean (2402)				
1995	34967	18.96%	0.88	33.86%	0.46	23.45
1997	36922	20.39%	0.92	34.36%	0.35	23.88
1999	39559	20.98%	0.92	25.17%	0.29	23.82
2001	46939	24.13%	0.90	19.70%	0.26	24.22
2003	47186	34.21%	0.89	23.24%	0.34	25.19
2005	50983	40.26%	0.91	25.84%	0.33	24.84
2007	55255	44.48%	0.88	27.00%	0.47	25.50
2009	66989	41.25%	0.88	19.58%	0.37	25.17
2011	67342	43.47%	0.83	20.83%	0.61	26.29
		RÈgion de la Capitale-Nationale (2403)				
1995	42704	16.82%	0.88	29.34%	0.43	23.87
1997	42836	14.46%	0.91	28.71%	0.56	23.57

1999	45016	23.41%	0.88	26.28%	0.53	23.89
2001	49326	24.73%	0.93	25.99%	0.43	23.78
2003	49919	36.92%	0.91	21.26%	0.49	24.65
2005	63857	37.24%	0.89	22.78%	0.56	24.46
2007	72742	38.28%	0.89	23.98%	0.66	25.29
2009	77385	40.01%	0.87	20.73%	0.54	25.42
2011	83050	41.76%	0.88	16.14%	0.61	25.76

RÈgion de la Mauricie et du Centre-du-QuÈbec (2404)

1995	37979	13.41%	0.89	39.07%	0.52	23.07
1997	36889	16.97%	0.91	34.09%	0.39	23.08
1999	39820	18.59%	0.90	30.08%	0.59	23.69
2001	44811	22.44%	0.92	26.45%	0.35	24.19
2003	47574	28.33%	0.91	23.88%	0.62	24.36
2005	55037	36.12%	0.89	20.62%	0.37	24.86
2007	57255	35.12%	0.87	21.58%	0.62	24.97
2009	66685	43.28%	0.88	17.80%	0.56	24.98
2011	70326	45.87%	0.88	18.71%	0.82	25.17

RÈgion de l'Estrie (2405)

1995	37737	18.96%	0.92	27.64%	0.65	23.86
1997	37003	28.84%	0.92	24.21%	0.93	23.19
1999	39539	28.85%	0.92	24.94%	0.54	23.76
2001	40766	27.22%	0.91	30.67%	0.74	23.84
2003	49076	43.16%	0.92	21.91%	0.57	24.17
2005	56551	53.35%	0.92	19.16%	0.68	24.94
2007	62238	45.86%	0.91	24.18%	0.56	25.43
2009	67956	49.17%	0.90	27.06%	0.54	25.26
2011	70128	55.79%	0.89	25.70%	0.79	25.05

RÈgion de MontrÈal (2406)

1995	38806	15.39%	0.90	31.46%	0.38	23.34
1997	39480	22.41%	0.92	28.46%	0.37	23.49
1999	46727	31.52%	0.91	26.12%	0.53	23.84
2001	48094	35.69%	0.92	28.72%	0.59	24.12
2003	54152	44.11%	0.90	24.47%	0.52	24.53
2005	62930	49.31%	0.89	22.95%	0.48	25.02
2007	68171	49.22%	0.87	21.08%	0.79	25.20
2009	79382	56.99%	0.85	23.24%	0.54	25.77
2011	79688	60.93%	0.87	19.64%	0.61	25.78

RÈgion de l'Outaouais (2407)

1995	52034	20.75%	0.87	35.05%	0.61	24.54
1997	52785	22.01%	0.90	36.50%	0.68	24.10

1999	56637	24.50%	0.93	29.67%	0.67	24.48
2001	58460	35.20%	0.92	32.17%	0.88	25.06
2003	59268	48.99%	0.90	24.46%	0.78	26.33
2005	92353	41.41%	0.93	26.95%	0.69	25.56
2007	96745	47.18%	0.90	23.47%	0.95	25.88
2009	109350	44.37%	0.92	30.87%	1.02	26.06
2011	112930	48.71%	0.88	26.13%	0.79	26.12
RÈgion de l'Abitibi-Tèmiscamingue (2408)						
1995	38155	14.70%	0.87	87.71%	0.66	23.44
1997	36329	29.61%	0.92	37.37%	0.50	24.52
1999	41274	37.43%	0.85	28.95%	0.23	24.41
2001	39120	42.51%	0.85	32.34%	0.46	24.08
2003	40279	44.54%	0.86	27.62%	0.16	25.37
2005	49502	55.71%	0.84	21.03%	0.44	25.14
2007	53854	53.09%	0.86	19.68%	0.58	26.24
2009	53516	58.11%	0.86	19.29%	0.72	26.33
2011	65536	61.99%	0.88	17.07%	0.53	26.41
RÈgion de la CÙte-Nord (2409) & RÈgion du Nord-du-QuÈbec (2410)						
1995	50393	18.58%	0.92	48.67%	0.46	23.97
1997	42056	20.83%	0.90	51.41%	0.77	25.50
1999	45987	23.11%	0.83	36.12%	0.57	25.70
2001	56063	36.38%	0.90	42.16%	0.15	26.08
2003	56830	39.14%	0.92	40.27%	0.49	25.30
2005	68398	54.87%	0.91	22.44%	0.27	26.53
2007	64985	54.82%	0.90	22.55%	0.35	28.32
2009	72579	48.67%	0.89	25.05%	0.45	27.73
2011	72004	57.35%	0.92	22.39%	0.34	28.17
RÈgion de la GaspÈsieóŒles-de-la-Madeleine (2411)						
1995	36406	11.04%	0.87	34.81%	0.66	23.57
1997	30267	15.12%	0.86	28.40%	0.91	24.32
1999	32671	25.03%	0.86	28.11%	0.63	24.09
2001	35251	28.03%	0.87	29.32%	0.26	24.32
2003	37467	30.39%	0.84	37.37%	0.63	24.42
2005	46903	42.14%	0.81	31.12%	0.44	25.05
2007	68701	49.63%	0.81	27.78%	0.79	25.05
2009	62437	48.47%	0.87	26.41%	0.89	26.20
2011	98340	53.92%	0.87	12.55%	1.13	25.52
RÈgion de la ChaudiËre-Appalaches (2412)						
1995	39534	13.43%	0.43	36.01%	0.39	22.72
1997	37837	16.61%	0.93	33.68%	0.45	23.06

1999	43761	17.64%	0.92	29.38%	0.52	23.18
2001	48638	20.54%	0.92	23.86%	0.43	23.70
2003	49193	32.54%	0.93	20.47%	0.45	24.09
2005	67126	38.78%	0.93	16.90%	0.33	24.18
2007	71340	37.20%	0.91	20.46%	0.65	24.34
2009	74952	41.58%	0.91	20.53%	0.64	24.48
2011	77496	42.99%	0.90	22.26%	0.82	24.95

RÈgion de Laval (2413)

1995	45508	23.24%	0.92	25.48%	0.54	24.70
1997	44014	20.00%	0.93	24.33%	0.27	23.45
1999	53303	25.79%	0.94	24.02%	0.48	24.84
2001	54905	31.17%	0.94	25.07%	0.34	25.70
2003	52766	39.39%	0.89	14.34%	0.48	25.34
2005	74993	53.80%	0.89	18.87%	0.61	27.13
2007	78621	46.80%	0.89	21.13%	0.67	26.58
2009	78781	57.13%	0.91	13.82%	0.63	27.19
2011	76726	53.68%	0.86	21.49%	1.01	27.96

RÈgion de LanaudiËre (2414)

1995	40839	15.37%	0.89	32.15%	0.50	23.25
1997	43815	25.11%	0.92	28.01%	0.45	23.81
1999	43450	32.63%	0.92	29.13%	0.73	23.25
2001	49264	34.76%	0.90	23.85%	0.41	24.06
2003	50697	37.05%	0.90	23.45%	0.60	24.27
2005	60939	47.85%	0.88	18.68%	0.56	24.89
2007	77862	43.58%	0.90	17.75%	0.50	25.07
2009	74390	56.77%	0.87	16.36%	0.63	26.09
2011	84034	50.83%	0.87	18.88%	0.46	25.64

RÈgion des Laurentides (2415)

1995	43314	15.87%	0.87	29.42%	0.39	23.23
1997	41799	23.44%	0.89	35.12%	0.54	23.55
1999	48634	28.49%	0.89	30.77%	0.44	24.34
2001	48962	26.17%	0.91	29.67%	0.54	24.03
2003	56735	33.00%	0.89	20.00%	0.66	24.82
2005	69771	44.14%	0.92	18.60%	0.36	25.45
2007	72766	42.97%	0.90	20.13%	0.52	25.62
2009	80072	42.46%	0.89	19.44%	0.69	24.51
2011	79317	44.21%	0.91	25.77%	0.67	25.27

RÈgion de la MontÈrÈgie (2416) & RÈgion des Terres-Cries-de-la-Baie-James (2418)

1995	46208	18.06%	0.89	39.86%	0.43	23.31
1997	45778	21.04%	0.94	39.25%	0.45	23.81

1999	48571	23.21%	0.91	35.79%	0.48	23.96
2001	52052	31.81%	0.91	30.97%	0.47	24.85
2003	52907	38.65%	0.90	29.64%	0.48	24.84
2005	71795	41.90%	0.89	27.21%	0.51	25.13
2007	75597	40.60%	0.89	24.88%	0.56	25.63
2009	83008	44.84%	0.90	28.11%	0.62	25.99
2011	82642	49.14%	0.89	25.65%	0.68	26.32

Alberta

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
			South Zone (4831)			
1995	46845	17.17%	0.87	22.97%	0.33	24.20
1997	46258	20.59%	0.91	22.64%	0.38	24.42
1999	44882	31.63%	0.91	23.02%	0.34	24.96
2001	49044	32.73%	0.90	22.62%	0.36	25.46
2003	52504	28.80%	0.86	28.02%	0.53	25.49
2005	70371	39.09%	0.87	23.99%	0.53	25.74
2007	72640	39.80%	0.89	25.51%	0.50	25.97
2009	76631	49.78%	0.87	26.49%	0.67	26.50
2011	88323	46.99%	0.87	25.61%	0.69	26.79
			Calgary Zone (4832)			
1995	47509	14.94%	0.89	25.52%	0.48	22.96
1997	47978	19.50%	0.93	24.97%	0.50	23.19
1999	55566	24.20%	0.91	28.08%	0.48	23.74
2001	61114	30.25%	0.90	27.92%	0.49	24.36
2003	61081	31.66%	0.87	22.84%	0.53	24.73
2005	81611	38.58%	0.87	21.84%	0.61	25.18
2007	95086	40.94%	0.88	19.48%	0.58	25.70
2009	96647	50.10%	0.87	18.48%	0.70	26.14
2011	96388	50.48%	0.86	18.45%	0.65	26.10
			Central Zone (4833)			
1995	38601	23.85%	0.88	37.75%	0.65	24.63
1997	40588	26.87%	0.89	36.68%	0.60	24.88
1999	47699	31.19%	0.89	33.39%	0.74	25.42
2001	52254	46.26%	0.89	35.69%	0.41	25.88
2003	49911	47.99%	0.85	32.16%	0.46	26.32
2005	68395	49.15%	0.88	26.46%	0.44	26.87

2007	80902	51.93%	0.88	30.26%	0.68	27.20
2009	87606	56.92%	0.90	28.19%	0.55	27.63
2011	96642	56.69%	0.90	26.24%	0.67	27.68
			Edmonton Zone (4834)			
1995	43437	19.39%	0.89	28.52%	0.41	23.87
1997	43752	22.87%	0.89	26.95%	0.45	24.34
1999	50642	28.58%	0.89	24.91%	0.46	24.48
2001	54516	31.48%	0.88	25.80%	0.39	24.76
2003	57969	37.52%	0.88	20.64%	0.32	25.04
2005	73743	41.51%	0.88	20.97%	0.48	25.37
2007	84614	50.10%	0.86	18.16%	0.58	25.84
2009	94675	58.87%	0.86	13.69%	0.46	26.68
2011	96349	57.87%	0.87	18.56%	0.58	26.70
			North Zone (4835)			
1995	47247	14.33%	0.91	37.64%	0.53	23.47
1997	45408	26.84%	0.92	27.43%	0.45	24.92
1999	57407	27.42%	0.92	29.07%	0.49	24.16
2001	58653	43.63%	0.92	22.47%	0.49	26.42
2003	58418	45.76%	0.91	20.68%	0.42	26.08
2005	82922	42.18%	0.90	22.51%	0.48	26.09
2007	95504	48.32%	0.90	23.52%	0.45	27.13
2009	105791	57.63%	0.87	26.66%	0.54	27.55
2011	112360	63.04%	0.89	21.16%	0.34	28.40

Ontario

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
			Erie St. Clair (3501)			
1995	43372	24.49%	0.87	28.84%	0.56	24.24
1997	43817	25.04%	0.92	23.14%	0.44	24.40
1999	50648	30.64%	0.89	20.14%	0.62	24.63
2001	57002	34.29%	0.91	18.76%	0.60	24.41
2003	57052	44.77%	0.88	16.38%	0.53	25.20
2005	80657	47.02%	0.89	13.79%	0.49	25.75
2007	78185	50.01%	0.88	19.32%	0.61	26.05
2009	90819	62.37%	0.87	11.10%	0.42	26.57
2011	87264	66.30%	0.89	7.29%	0.42	26.85
			South West (3502)			

1995	43303	19.73%	0.86	24.14%	0.55	24.36
1997	46774	25.10%	0.90	26.26%	0.62	24.45
1999	49381	29.88%	0.90	26.58%	0.66	24.68
2001	53688	32.47%	0.91	23.60%	0.55	25.28
2003	56215	37.81%	0.86	22.06%	0.63	25.66
2005	71112	48.04%	0.87	26.69%	0.77	26.95
2007	75162	53.32%	0.85	20.13%	0.67	26.60
2009	86410	65.30%	0.81	13.28%	0.79	27.26
2011	81932	65.09%	0.85	16.68%	0.69	27.66
			Waterloo Wellington (3503)			
1995	48961	14.58%	0.86	29.86%	0.39	23.69
1997	48069	21.68%	0.91	26.52%	0.44	24.33
1999	55529	28.91%	0.90	27.12%	0.63	24.88
2001	57068	37.20%	0.90	27.30%	0.39	25.50
2003	63032	39.74%	0.89	24.93%	0.53	25.30
2005	82209	50.61%	0.89	18.20%	0.45	26.21
2007	88516	47.19%	0.88	22.88%	0.58	26.04
2009	93764	56.41%	0.87	18.83%	0.56	26.80
2011	93113	59.38%	0.89	11.28%	0.62	27.21
			Hamilton Niagara Haldimand Brant (3504)			
1995	47690	20.11%	0.87	27.76%	0.58	24.24
1997	46442	22.36%	0.90	29.36%	0.46	24.46
1999	52911	28.35%	0.87	27.37%	0.53	24.60
2001	56356	35.95%	0.89	24.72%	0.49	24.89
2003	60517	40.27%	0.87	20.55%	0.63	25.38
2005	76612	44.61%	0.87	16.47%	0.47	25.76
2007	85470	47.83%	0.87	19.12%	0.64	25.95
2009	86923	53.32%	0.83	15.14%	0.63	26.56
2011	81749	55.94%	0.84	22.41%	0.69	26.09
			Central West (3505)			
1995	48420	22.31%	0.86	28.18%	0.64	24.15
1997	49325	25.44%	0.90	24.06%	0.54	23.92
1999	58408	29.90%	0.90	22.14%	0.55	24.24
2001	63254	33.38%	0.92	25.19%	0.51	24.95
2003	64118	37.92%	0.89	20.67%	0.90	24.98
2005	86058	43.32%	0.91	13.58%	0.50	25.24
2007	91193	54.49%	0.88	19.71%	0.73	26.21
2009	97054	55.51%	0.88	15.69%	0.76	25.75
2011	98915	60.08%	0.84	19.13%	0.66	26.24
			Mississauga Halton (3506)			

1995	56574	15.84%	0.91	27.76%	0.57	23.01
1997	56011	23.67%	0.92	25.18%	0.46	23.73
1999	65696	28.89%	0.92	22.75%	0.57	24.39
2001	64911	34.18%	0.93	21.02%	0.51	24.76
2003	68801	39.29%	0.90	21.25%	0.55	24.73
2005	100216	44.22%	0.89	15.12%	0.40	25.24
2007	104808	51.13%	0.89	22.38%	0.63	25.50
2009	110361	57.21%	0.87	23.32%	0.75	25.93
2011	108085	60.28%	0.88	19.96%	0.75	26.60
			Toronto Central (3507)			
1995	45850	20.52%	0.87	22.87%	0.66	23.58
1997	49727	25.90%	0.88	28.01%	0.52	23.56
1999	55132	33.56%	0.88	27.36%	0.50	23.84
2001	59559	39.59%	0.89	29.39%	0.57	23.85
2003	60424	43.28%	0.88	28.01%	0.90	24.70
2005	85252	47.19%	0.88	25.28%	0.51	24.54
2007	98055	55.72%	0.88	21.94%	0.70	25.11
2009	99847	61.33%	0.87	19.84%	0.74	24.81
2011	98546	60.41%	0.87	19.83%	0.85	25.55
			Central (3508)			
1995	50856	22.26%	0.60	18.30%	0.34	23.80
1997	52803	25.18%	0.92	18.03%	0.48	23.98
1999	56265	26.82%	0.90	17.12%	0.40	23.84
2001	57696	34.73%	0.90	12.85%	0.28	24.51
2003	61302	40.98%	0.87	13.79%	0.42	24.74
2005	87224	47.93%	0.87	9.98%	0.41	25.12
2007	93986	53.95%	0.88	15.43%	0.44	25.89
2009	96440	55.89%	0.85	6.62%	0.45	25.67
2011	87245	59.86%	0.86	6.66%	0.55	25.40
			Central East (3509)			
1995	49073	24.70%	0.88	27.99%	0.46	24.29
1997	48588	20.68%	0.89	24.67%	0.55	24.13
1999	57364	25.27%	0.89	20.20%	0.50	24.12
2001	62413	34.69%	0.88	23.01%	0.51	24.95
2003	64020	37.60%	0.87	22.16%	0.69	24.98
2005	86595	48.08%	0.88	20.70%	0.71	25.22
2007	89462	53.04%	0.86	19.59%	0.88	25.99
2009	98456	54.46%	0.88	24.32%	0.88	26.02
2011	90858	58.46%	0.84	20.19%	0.88	26.32
			South East (3510)			

1995	47287	17.21%	0.87	29.84%	0.41	24.49
1997	43484	19.25%	0.91	25.70%	0.37	24.68
1999	49580	30.00%	0.88	25.26%	0.48	25.18
2001	51377	34.65%	0.92	23.83%	0.46	25.16
2003	58501	40.10%	0.89	23.53%	0.54	25.52
2005	71725	46.72%	0.89	21.29%	0.25	26.36
2007	79354	44.95%	0.89	19.49%	0.78	26.51
2009	86000	57.15%	0.87	14.17%	1.28	26.79
2011	87545	58.95%	0.89	13.83%	0.55	26.66
			Champlain (3511)			
1995	49027	18.30%	0.87	30.25%	0.49	23.78
1997	47946	19.30%	0.91	29.88%	0.49	24.23
1999	51331	28.07%	0.89	25.47%	0.51	24.56
2001	56058	35.61%	0.90	25.36%	0.40	24.82
2003	60985	37.17%	0.88	20.94%	0.39	25.36
2005	82152	45.57%	0.87	22.32%	0.52	25.91
2007	93010	50.75%	0.87	19.68%	0.73	26.20
2009	94659	56.18%	0.88	16.29%	0.65	26.43
2011	99342	57.13%	0.84	17.05%	0.67	26.86
			North Simcoe Muskoka (3512)			
1995	45653	19.43%	0.90	38.28%	0.66	23.63
1997	47128	18.59%	0.93	36.27%	0.63	23.81
1999	54024	28.03%	0.90	36.22%	0.93	24.56
2001	58821	29.09%	0.93	36.33%	0.97	24.58
2003	62165	34.73%	0.89	32.44%	0.72	24.80
2005	75209	35.46%	0.90	25.70%	0.87	25.18
2007	77301	43.82%	0.87	17.47%	1.19	25.41
2009	88241	53.77%	0.82	23.79%	0.97	26.58
2011	91541	56.60%	0.86	25.99%	0.89	26.30
			North East (3513)			
1995	42159	19.03%	0.58	32.11%	0.58	24.10
1997	42508	25.12%	0.85	33.98%	0.56	24.54
1999	46867	30.37%	0.88	31.94%	0.51	24.97
2001	52419	34.03%	0.91	28.79%	0.50	24.98
2003	54198	38.52%	0.85	22.68%	0.77	25.32
2005	64976	45.32%	0.84	32.24%	0.70	25.73
2007	71186	46.38%	0.87	19.54%	0.56	25.44
2009	82457	57.53%	0.80	24.44%	0.43	26.06
2011	74947	57.95%	0.82	28.45%	0.72	25.85

North West (3514)

1995	48699	25.46%	0.80	30.61%	0.69	24.99
1997	50840	30.67%	0.85	28.50%	0.62	24.66
1999	57901	28.80%	0.83	31.97%	0.85	24.72
2001	56309	42.78%	0.85	37.09%	0.76	25.17
2003	59156	45.75%	85.35%	34.61%	0.66	25.21
2005	71339	46.77%	0.86	22.28%	0.72	25.63
2007	85505	47.57%	0.87	23.80%	0.88	25.42
2009	97485	51.68%	0.89	18.50%	0.82	25.75
2011	97563	53.13%	0.88	21.94%	1.09	26.49

Manitoba

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
			Winnipeg Regional Health Authority (4601)			
1995	43548	19.22%	0.87	28.32%	0.60	23.69
1997	45502	21.99%	0.89	30.39%	0.61	24.41
1999	51186	29.82%	0.86	26.11%	0.66	24.81
2001	53585	39.25%	0.88	24.08%	0.57	24.80
2003	56984	44.32%	0.87	18.97%	0.48	25.18
2005	73480	49.01%	0.84	16.18%	0.48	25.64
2007	81496	56.59%	0.86	15.58%	0.56	26.07
2009	86408	64.83%	0.87	16.38%	0.56	26.50
2011	93355	64.74%	0.83	18.99%	0.62	26.47
			Prairie Mountain Health (4602)			
1995	34005	18.72%	0.89	27.56%	0.52	24.46
1997	36838	26.01%	0.90	24.51%	0.45	24.48
1999	41828	28.41%	0.89	23.03%	0.37	25.15
2001	44965	30.59%	0.88	21.10%	0.34	25.52
2003	47235	41.38%	0.89	20.73%	0.40	25.71
2005	60390	48.24%	0.86	21.93%	0.41	26.42
2007	62443	48.85%	0.85	22.09%	0.36	26.81
2009	77274	58.08%	0.84	19.82%	0.35	27.00
2011	69561	63.99%	0.82	18.41%	0.47	27.33
			Interlake-Eastern Regional Health Authority (4603)			
1995	43241	18.90%	0.87	28.79%	0.52	24.02
1997	45753	29.93%	0.88	29.98%	0.65	24.65
1999	48098	27.68%	0.91	24.04%	0.68	24.27
2001	53496	40.07%	0.92	22.71%	0.88	26.11

2003	50684	39.92%	0.90	22.69%	0.34	25.79
2005	70770	45.31%	0.88	25.32%	0.54	25.85
2007	77003	45.39%	0.90	22.37%	0.73	26.14
2009	82211	56.98%	0.87	14.77%	0.58	27.63
2011	74059	55.55%	0.91	18.85%	0.57	27.19
			Northern Regional Health Authority (4604)			
1995	46510	26.37%	0.87	58.73%	0.86	25.70
1997	46140	38.73%	0.92	51.03%	0.63	25.55
1999	53176	32.12%	0.92	43.37%	0.49	25.29
2001	52071	47.58%	0.92	22.11%	0.40	27.11
2003	56739	42.74%	0.89	42.62%	0.48	26.47
2005	77324	59.58%	0.90	14.49%	0.50	28.30
2007	80827	60.11%	0.90	11.38%	0.62	28.25
2009	96961	62.56%	0.88	27.73%	0.68	27.56
2011	95594	60.47%	0.86	37.44%	0.69	26.92
			Southern Health (4605)			
1995	37271	23.74%	0.88	25.82%	0.36	0.55
1997	37936	16.09%	0.91	20.26%	0.41	23.55
1999	39746	24.71%	0.89	22.78%	0.60	24.20
2001	44426	36.07%	0.91	22.30%	0.51	25.49
2003	49632	44.59%	0.90	15.33%	0.35	25.42
2005	59312	43.91%	0.90	23.75%	0.48	26.01
2007	72674	43.87%	0.90	25.12%	0.47	26.52
2009	72693	44.57%	0.89	14.51%	0.39	25.98
2011	76672	53.63%	0.87	13.49%	0.55	26.32

Saskatchewan

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
			Sun Country Regional Health Authority (4701)			
1995	35991	27.63%	0.86	35.94%	0.75	24.30
1997	43303	26.29%	0.92	30.60%	0.29	23.79
1999	45960	21.02%	0.89	35.03%	0.58	24.17
2001	49445	32.93%	0.91	25.38%	0.50	24.17
2003	55624	38.26%	0.88	22.50%	0.56	25.86
2005	53681	42.61%	0.86	22.59%	0.60	26.20
2007	63912	43.89%	0.87	21.09%	1.44	27.08
2009	86615	55.23%	0.88	17.29%	0.81	27.03

2011	91770	58.14%	0.84	15.40%	0.73	27.56
		Five Hills Regional Health Authority (4702)				
1995	38200	26.32%	0.87	26.36%	0.32	24.35
1997	39670	20.84%	0.94	29.19%	0.42	24.21
1999	46216	23.97%	0.87	26.65%	0.44	25.41
2001	43519	37.67%	0.86	20.35%	0.43	25.92
2003	54912	52.44%	0.88	18.13%	0.45	27.22
2005	73149	42.89%	0.85	12.33%	0.48	26.49
2007	79950	52.22%	0.93	14.39%	0.42	26.64
2009	94098	59.95%	0.85	29.91%	0.60	27.16
2011	96327	61.77%	0.86	18.34%	0.72	26.24
		Cypress Regional Health Authority (4703)				
1995	45315	22.58%	0.84	27.81%	0.57	23.28
1997	47326	13.61%	0.88	31.33%	0.48	23.95
1999	43582	22.46%	0.85	21.80%	0.90	24.91
2001	46138	23.72%	0.87	28.98%	0.16	25.41
2003	43520	38.26%	0.86	27.27%	0.76	24.49
2005	53461	56.37%	0.81	31.75%	1.66	26.98
2007	66145	48.88%	0.90	33.87%	0.22	26.38
2009	52308	51.67%	0.84	36.25%	1.04	25.18
2011	68826	52.40%	0.86	36.60%	0.92	25.73
		Regina Qu'Appelle Regional Health Authority (4704)				
1995	43642	20.51%	0.87	25.73%	0.57	24.09
1997	42398	19.51%	0.90	27.28%	0.48	24.65
1999	47425	27.40%	0.89	23.84%	0.38	24.89
2001	50409	29.29%	0.89	27.90%	0.46	25.42
2003	52018	39.00%	0.88	20.96%	0.44	25.92
2005	72457	43.48%	0.86	17.96%	0.40	26.51
2007	77030	47.75%	0.88	15.19%	0.47	26.99
2009	81330	56.13%	0.87	17.13%	0.42	26.96
2011	86809	60.65%	0.84	19.60%	0.42	26.96
		Sunrise Regional Health Authority (4705)				
1995	27913	16.26%	0.86	33.12%	0.56	24.77
1997	28334	26.17%	0.86	23.03%	0.45	25.44
1999	35963	32.65%	0.81	22.78%	0.31	25.97
2001	39536	40.46%	0.87	17.78%	0.24	26.69
2003	42583	41.83%	0.87	21.14%	0.28	26.08
2005	60145	42.05%	0.84	19.53%	0.52	27.55
2007	69441	46.09%	0.85	15.41%	0.51	27.35
2009	81576	49.92%	0.82	19.70%	0.42	28.27

2011	80029	65.14%	0.86	15.07%	0.60	28.48
		Saskatoon Regional Health Authority (4706)				
1995	40511	22.94%	0.87	29.40%	0.53	24.40
1997	37875	26.32%	0.89	26.90%	0.53	24.79
1999	47194	30.29%	0.89	31.60%	0.62	24.53
2001	45174	32.53%	0.89	27.84%	0.43	24.99
2003	50350	42.93%	0.88	17.37%	0.42	26.07
2005	63678	43.27%	0.86	23.74%	0.46	25.49
2007	69817	46.04%	0.85	25.20%	0.81	26.05
2009	78713	59.28%	0.88	17.48%	0.53	26.03
2011	86605	58.02%	0.86	20.92%	0.44	26.21
		Heartland Regional Health Authority 4707)				
1995	36201	24.03%	0.87	31.02%	0.31	25.63
1997	39392	26.80%	0.88	40.88%	0.49	25.35
1999	44514	30.85%	0.93	28.28%	0.23	26.08
2001	40217	39.58%	0.90	37.12%	0.29	26.71
2003	46855	46.39%	0.89	18.53%	0.32	26.25
2005	53649	37.98%	0.86	21.55%	0.35	26.93
2007	58440	57.35%	0.81	44.28%	0.56	28.26
2009	62212	62.40%	0.90	16.56%	0.42	27.95
2011	88067	58.70%	0.86	15.78%	0.51	27.60
		Kelsey Trail Regional Health Authority (4708)				
1995	35068	9.41%	0.88	26.57%	0.60	25.11
1997	42235	23.11%	0.90	22.69%	0.50	24.45
1999	31835	24.22%	0.91	26.38%	0.59	26.46
2001	41426	36.17%	0.89	22.55%	0.14	25.21
2003	46960	35.78%	0.86	15.41%	0.49	26.56
2005	68407	48.40%	0.89	17.49%	0.60	28.66
2007	68203	47.66%	0.84	20.38%	0.37	27.13
2009	68069	62.01%	0.78	15.79%	0.25	31.95
2011	80708	67.63%	0.84	15.70%	0.53	30.29
		Prince Albert Parkland Regional Health Authority (4709)				
1995	38077	34.04%	0.80	42.61%	0.62	25.07
1997	35852	32.80%	0.89	25.99%	0.60	26.41
1999	37761	29.14%	0.89	30.27%	0.79	25.31
2001	46126	39.82%	0.88	32.29%	0.39	26.69
2003	48072	44.12%	0.84	30.38%	0.63	27.10
2005	63171	51.22%	0.83	32.37%	0.91	27.61
2007	76165	58.34%	0.88	12.11%	0.19	28.40
2009	74951	61.91%	0.85	20.66%	0.23	28.48

2011	74141	62.84%	0.83	18.30%	0.24	28.93

Prairie North Regional Health Authority (4710) & Mamawetan Churchill River Regional Health Authority (4711) & Athabasca Health Authority (4713)2

1995	38006	12.60%	0.89	32.06%	0.49	24.17
1997	34807	29.58%	0.89	43.88%	0.21	24.43
1999	42175	27.47%	0.91	35.51%	0.37	23.98
2001	39800	35.35%	0.89	34.31%	0.20	25.47
2003	40041	56.13%	0.83	35.63%	0.19	25.39
2005	58024	63.87%	0.88	24.43%	0.34	25.73
2007	58133	59.14%	0.85	32.05%	0.37	26.90
2009	77807	63.71%	0.85	33.74%	0.37	26.46
2011	78301	73.50%	0.76	40.70%	0.47	27.21

British Columbia

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
East Kootenay Health Service Delivery Area (5911) & Kootenay-Boundary Health Service Delivery Area (5912)						
1995	43819	34.38%	0.84	33.22%	0.81	25.23
1997	44621	18.71%	0.85	39.00%	0.45	24.18
1999	49799	27.29%	0.85	34.85%	0.52	24.50
2001	55047	30.65%	0.88	24.33%	0.42	23.82
2003	54444	40.54%	0.89	17.86%	0.43	24.71
2005	70509	39.66%	0.88	15.43%	0.59	24.35
2007	79212	46.52%	0.84	20.88%	0.55	25.02
2009	81180	53.29%	0.85	6.25%	0.34	24.73
2011	85393	54.97%	0.83	14.13%	0.43	25.41
Okanagan Health Service Delivery Area (5913)						
1995	43802	13.02%	0.88	27.52%	0.90	23.92
1997	44600	16.56%	0.92	21.00%	0.69	23.85
1999	46524	24.80%	0.90	20.51%	0.66	24.79
2001	53249	31.66%	0.91	15.44%	0.52	25.17
2003	55707	36.10%	0.87	22.56%	0.64	24.36
2005	64843	46.66%	0.87	17.91%	0.57	25.64
2007	83516	47.90%	0.86	20.54%	0.62	25.82
2009	73303	54.31%	0.83	15.94%	0.72	26.38
2011	89915	60.54%	0.83	9.77%	0.74	26.16
Thompson/Cariboo Health Service Delivery Area (5914)						
1995	43452	16.54%	0.88	35.53%	0.63	23.97

1997	41894	20.55%	0.92	30.27%	0.77	23.65
1999	45936	29.35%	0.91	34.07%	0.61	23.89
2001	51065	36.08%	0.93	28.26%	0.78	24.37
2003	52835	33.09%	0.88	32.46%	0.69	25.04
2005	61653	36.63%	0.90	17.72%	0.76	24.46
2007	84727	49.86%	0.86	24.64%	0.68	26.79
2009	92916	59.31%	0.84	31.89%	0.92	26.08
2011	74465	60.50%	0.89	40.60%	1.05	26.43
		Fraser East Health Service Delivery Area (5921)				
1995	45220	21.90%	0.85	33.35%	0.64	0.44
1997	41987	23.88%	0.91	24.99%	0.55	23.24
1999	40501	35.26%	0.90	31.03%	0.35	23.57
2001	50540	42.65%	0.88	32.11%	0.41	24.66
2003	53849	36.87%	0.90	27.33%	0.71	23.99
2005	57297	40.08%	0.88	21.08%	0.39	24.88
2007	70004	51.27%	0.86	24.15%	0.42	25.65
2009	77807	60.52%	0.83	12.26%	0.47	25.84
2011	90099	61.14%	0.88	17.40%	0.44	26.86
		Fraser North Health Service Delivery Area (5922)				
1995	48274	13.92%	0.85	25.68%	0.57	23.19
1997	48010	22.96%	0.88	25.45%	0.45	23.64
1999	54511	32.89%	0.90	19.71%	0.70	24.18
2001	59772	35.74%	0.92	19.54%	0.53	24.74
2003	60486	42.37%	0.90	19.26%	0.65	24.81
2005	73385	41.90%	0.89	20.25%	0.63	24.75
2007	92575	52.31%	0.90	23.15%	0.50	25.86
2009	94035	61.84%	0.92	26.58%	0.47	26.26
2011	88673	63.89%	0.88	25.60%	0.69	26.45
		Fraser South Health Service Delivery Area (5923)				
1995	47558	15.81%	0.85	22.30%	0.54	23.16
1997	49045	23.20%	0.90	21.42%	0.50	23.75
1999	54289	36.61%	0.87	25.15%	0.54	24.08
2001	57436	36.53%	0.88	20.42%	0.52	24.07
2003	59461	43.11%	0.86	16.68%	0.48	24.88
2005	85543	48.68%	0.85	17.61%	0.51	25.47
2007	90197	52.08%	0.86	14.92%	0.68	25.11
2009	90359	54.71%	0.83	21.77%	0.70	25.37
2011	80757	61.39%	0.85	11.05%	0.67	25.91
		Richmond Health Service Delivery Area (5931)				
1995	43743	10.62%	0.85	18.30%	0.25	23.15

1997	50586	21.57%	0.91	18.32%	0.31	23.61
1999	56321	30.59%	0.91	16.15%	0.39	23.70
2001	52896	41.08%	0.86	12.17%	0.49	23.94
2003	56550	48.65%	0.84	15.44%	0.58	24.26
2005	70073	57.38%	0.86	16.48%	0.25	24.78
2007	78866	57.11%	0.86	6.72%	0.29	25.01
2009	61090	61.67%	0.84	11.52%	0.17	24.90
2011	89562	54.43%	0.88	6.09%	0.46	24.75
Vancouver Health Service Delivery Area (5932)						
1995	42001	12.37%	0.90	20.91%	0.55	22.97
1997	44384	23.15%	0.91	18.49%	0.51	23.16
1999	46984	28.22%	0.90	18.47%	0.73	22.89
2001	51532	34.28%	0.91	16.01%	0.50	23.24
2003	56729	46.47%	0.92	10.20%	0.54	24.18
2005	71840	41.04%	0.88	17.75%	0.62	24.02
2007	69144	49.25%	0.89	10.58%	0.93	24.05
2009	96190	55.59%	0.89	7.48%	0.60	24.13
2011	88788	55.90%	0.87	6.91%	0.74	25.10
North Shore/Coast Garibaldi Health Service Delivery Area (5933)						
1995	56537	17.89%	0.91	13.59%	0.70	23.62
1997	54985	28.62%	0.92	10.20%	0.77	24.08
1999	61884	38.48%	0.90	11.87%	0.70	24.89
2001	57215	39.76%	0.90	12.64%	0.57	24.19
2003	63768	43.87%	0.90	11.46%	0.62	24.25
2005	79066	42.51%	0.87	12.25%	0.80	24.71
2007	80766	53.32%	0.86	4.95%	0.75	24.72
2009	94939	55.89%	0.88	12.87%	1.19	24.88
2011	84446	64.45%	0.89	12.83%	0.84	25.94
South Vancouver Island Health Service Delivery Area (5941)						
1995	46713	20.60%	0.84	18.61%	0.15	23.55
1997	43981	24.99%	0.89	17.84%	0.45	23.48
1999	51054	30.59%	0.87	13.12%	0.32	23.84
2001	56839	32.99%	0.85	15.10%	0.45	24.22
2003	53158	39.24%	0.88	13.96%	0.40	24.47
2005	73121	38.94%	0.90	14.86%	0.62	24.57
2007	77016	43.99%	0.86	13.69%	0.55	24.88
2009	92371	54.86%	0.89	18.26%	0.48	26.30
2011	93671	60.19%	0.86	15.37%	0.69	26.60
Central Vancouver Island Health Service Delivery Area (5942)						
1995	39923	15.93%	0.81	40.85%	0.46	24.05

1997	39704	19.12%	0.88	30.55%	0.51	23.27
1999	44489	24.97%	0.86	28.95%	0.62	23.66
2001	52697	27.34%	0.88	26.96%	0.47	23.47
2003	56641	33.79%	0.88	26.66%	0.56	23.98
2005	66909	46.09%	0.87	20.95%	0.52	23.89
2007	73239	46.37%	0.85	23.50%	0.50	25.13
2009	78665	58.31%	0.81	26.27%	0.53	26.19
2011	76039	60.92%	0.82	15.23%	0.57	25.67
North Vancouver Island Health Service Delivery Area (5943)						
1995	41544	16.87%	0.88	30.20%	0.50	24.39
1997	45163	22.12%	0.88	27.37%	0.63	24.62
1999	50090	18.39%	0.88	21.40%	0.50	25.11
2001	49063	25.54%	0.89	24.87%	0.71	24.66
2003	48851	28.72%	0.90	19.26%	0.52	25.32
2005	59765	34.00%	0.90	18.34%	0.71	26.19
2007	75511	44.13%	0.91	14.92%	0.82	26.54
2009	76027	49.16%	0.88	19.81%	0.72	26.58
2011	74289	46.55%	0.87	23.40%	0.68	26.68
Northwest Health Service Delivery Area (5951)						
1995	48551	20.98%	0.92	24.21%	0.31	22.01
1997	50130	23.67%	0.91	21.44%	0.26	23.42
1999	50704	25.75%	0.81	14.15%	0.25	22.55
2001	61280	23.17%	0.82	22.96%	0.31	23.36
2003	62192	34.66%	0.93	12.22%	0.25	23.92
2005	68350	37.08%	0.88	12.53%	0.92	24.68
2007	92790	38.34%	0.80	22.71%	0.18	24.08
2009	92722	44.41%	0.81	16.64%	0.54	25.95
2011	84585	59.39%	0.89	21.81%	0.25	26.69
Northern Interior Health Service Delivery Area (5952)						
1995	47005	21.21%	0.90	28.84%	0.57	24.14
1997	41633	28.05%	0.93	29.45%	0.24	24.12
1999	50921	27.22%	0.89	32.52%	0.36	24.89
2001	49511	41.15%	0.89	30.95%	0.35	25.24
2003	53690	42.16%	0.90	34.76%	0.44	25.77
2005	75768	49.50%	0.89	21.67%	0.57	25.51
2007	68460	58.66%	0.91	24.70%	0.69	25.52
2009	81043	57.30%	0.85	17.68%	0.54	27.83
2011	88228	58.94%	0.91	20.69%	0.32	27.17
Northeast Health Service Delivery Area (5953)						
1995	40365	22.49%	0.90	27.52%	0.11	23.96

1997	49109	19.63%	0.95	17.39%	0.26	24.57
1999	46871	23.35%	0.92	19.07%	0.42	23.93
2001	54910	38.32%	0.92	41.77%	0.54	25.49
2003	50976	46.88%	0.95	17.94%	0.20	26.11
2005	56423	47.59%	0.87	35.03%	0.23	25.26
2007	63510	37.46%	0.88	24.86%	0.19	24.02
2009	69088	56.15%	0.90	55.01%	0.45	25.69
2011	99626	59.07%	0.83	24.54%	0.66	27.76

Yukon, Northwest Territories, and Nunavut

Year	Average Household Income	Prevalence of Obesity	Average HUI3 Index	Prevalence of smoking	Average number of drinks per day	Average BMI
1995	52033	0.00%	0.93	0.00%	0.16	23.41
1997	57317	0.00%	0.99	24.18%	0.45	22.24
1999	63196	4.24%	0.91	22.23%	0.36	22.31
2001	61537	23.48%	0.91	49.52%	1.00	23.10
2003	55471	56.15%	0.85	0.00%	0.55	25.04
2005	86044	15.98%	0.91	0.00%	0.29	22.85
2007	100096	10.76%	0.89	10.01%	0.35	24.82
2009	92835	20.19%	0.93	17.39%	1.23	26.32
2011	80453	4.80%	0.85	31.69%	0.31	23.86

Appendix 2: Chapter 1 Robustness Check

Table Appendix.2.1: Selective balanced panel Male BMI regression results by BMI classification

Model specsifcations[1]	BMI Classifications[4]					
	Normal		Overweight		Obese[3]	
White only	Coef	Obs	Coef	Obs	Coef	Obs
No Controls	.063***	1767	0.01	3363	0.00	1655
+ Demographics	0.02	1751	0.01	3340	0.00	1647
+ Socioeconomic Status	0.00	1490	0.00	2846	0.00	1462
+Health Indicators	0.00	1465	0.00	2797	0.00	1434
+Life Style	0.00	1315	0.00	2479	0.00	1274
+ Fixed Effects	0.00	1315	0.00	2479	0.00	1274
All Ethnicities[2]						
No Controls	.067***	1909	0.01	3556	0.00	1729
+ Demographics	.026**	1893	0.01	3530	0.00	1721
+ Socioeconomic Status	0.01	1599	0.00	3001	0.00	1528
+Health Indicators	0.01	1569	0.00	2949	0.00	1499
+Life Style	0.01	1393	0.00	2609	0.00	1331
+ Fixed Effects	0.01	1393	0.00	2609	0.00	1331

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.
balanced weights are included In all regressions to give a representative sample of Canada
Sample is restricted to respondents that are in the labour force, not a student, and main source of income is from salaries/wages.
[1]Models are increasing in the specified specification (see table 1).

[2]Additional race control is included
[3]Includes obese class I, II, and III.
[4]Underweight BMI class was removed due to inadequate sample size.

Table Appendix.0.1.2: Selective balanced panel Female BMI regression results by BMI classification

Model specifications[1]	BMI classification							
	Underweight		Normal		Overweight		Obese[4]	
White only	Coef	Obs	Coef	Obs	Coef	Obs	Coef	Obs
No Controls	-0.01	129	0.01	3469	0.00	2226	-.013***	1564
+ Demographics	-0.03	126	0.01	3458	0.00	2219	-.010***	1547
+ Socioeconomic Status	0.02	98	.013**	2793	.012*	1802	-.008**	1268
+Health Indicators	0.02	98	.012**	2758	.014**	1773	-.006**	1232
+Life Style	0.02	85	0.01	2460	.018**	1568	-.006**	1076
+ Fixed Effects	0.04	85	.010*	2460	.019**	1568	-.007**	1076
All Race[2]								
No Controls	-0.01	133	0.01	3631	0.00	2333	-.013***	1643
+ Demographics	-0.03	130	0.00	3619	0.00	2326	-.009***	1626
+ Socioeconomic Status	0.03	101	.011**	2914	0.01	1886	-.007**	1335
+Health Indicators	0.02	101	.012*	2878	0.01	1853	-.006**	1299
+Life Style	0.02	86	0.01	2546	.013*	1619	-.006**	1119
+ Fixed Effects	0.03	86	0.01	2546	.014*	1619	-.007**	1119

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.

balanced weights are included In all regressions to give a representative sample of Canada

Sample is restricted to respondents that are in the labor force, not a student, not pregnant, and main source of income is from salaries/wages.

[1]Models are increasing in the specified specification (see table 1).

[2]Additional race control is included

[4]Includes obese class I, II, and III.

Table Appendix.2.0.2: selective female balance causal models with lagged BMI regressions and non-lagged IV regression results

Model specfications[1]	BMI Classification							
	Underweight		Normal		Overweight		Obese[4]	
White only (4 year lag)	Coef	Obs	Coef	Obs	Coef	Obs	Coef	Obs
No Controls	-0.01	68	.011*	1899	-0.01	1227	-.008**	928
+ Demographics	-0.01	66	0.00	1892	0.00	1225	-.008**	916
+ Socioeconomic Status	-0.10	51	.011**	1497	.009*	967	-.008**	729
+Health Indicators	-.152**	51	.013**	1472	.010*	948	-.010***	707
+Life Style	-0.06	43	.013**	1316	0.01	844	-.009**	627
+ Fixed Effects	0.03	43	.013**	1316	0.01	844	-.009**	627
IV Regression (No lag)[3]	-	-	-	-	-	-	-0.01	192
1st stage F-Stat	-		-		-		22.18	
All Race (4 year lag)[2]								
No Controls	0.00	70	.010*	1981	0.00	1284	-.010**	973
+ Demographics	-0.01	68	0.00	1974	0.00	1282	-.008**	961
+ Socioeconomic Status	-0.10	52	.010*	1555	0.01	1009	-.007**	766
+Health Indicators	-.153**	52	.012*	1530	0.01	987	-.008**	744
+Life Style	-0.06	43	.011*	1356	0.01	869	-.008**	654
+ Fixed Effects	-0.06	43	.011*	1356	0.01	869	-.008**	654
IV Regression (No lag)[3]	-	-	-	-	-	-	-0.01	199
1st stage F-Stat	-		-		-		16.48	

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.

balanced weights are included In all regressions to give a representative sample of Canada. Sample is restricted to respondents that are in the labor force, not a student, not pregnant, and main source of income is from salaries/wages.

[1]Models are increasing in the specified specification (see table 1).

[2]Additional race control is included

[3]Instrumental Variable regression using the prevalence of obesity for BMI classification of Obese with average income controls via respondents health region

[4]Includes obese class I, II, and III.

Appendix 3: Chapter 2 Estimating Equations

Proportional logistic regression analyses were performed with increasing specificity to ensure robustness of the results. The first model (equation 1) contained no controls, which provided a raw correlation between serum 25(OH)D concentrations and various mental health proxies, where *j* is the probability of the ordered category with j=1 being the best mental health state. The second model (equation 2) controlled for demographics as defined in the chapter. The third model (equation 3) has additional socioeconomic controls as defined in the chapter. The fourth model (equation 4) added life style controls as defined in the chapter. The last model (equation 5) adds in health controls as defined in the chapter.

$$ln\left(\frac{F_{i,j}}{1-F_{i,j}}\right) = \beta_1 MH_{i,j} + \varepsilon_{i,j} \qquad (1)$$
$$ln\left(\frac{F_{i,j}}{1-F_{i,j}}\right) = \beta_1 MH_{i,j} + \beta_2 D_{i,j} + \varepsilon_{i,j} \qquad (2)$$
$$ln\left(\frac{F_{i,j}}{1-F_{i,j}}\right) = \beta_1 MH_{i,j} + \beta_2 D_{i,j} + \beta_2 S_{i,j} + \varepsilon_{i,j} \qquad (3)$$
$$ln\left(\frac{F_{i,j}}{1-F_{i,j}}\right) = \beta_1 MH_{i,j} + \beta_2 D_{i,j} + \beta_2 S_{i,j} + \beta_2 L_{i,j} + \varepsilon_{i,j} \qquad (4)$$
$$ln\left(\frac{F_{i,j}}{1-F_{i,j}}\right) = \beta_1 MH_{i,j} + \beta_2 D_{i,j} + \beta_2 S_{i,j} + \beta_2 L_{i,j} + \beta_2 H_{i,j} + \varepsilon_{i,j} \qquad (5)$$

Appendix 4: Chapter 2 Robustness check

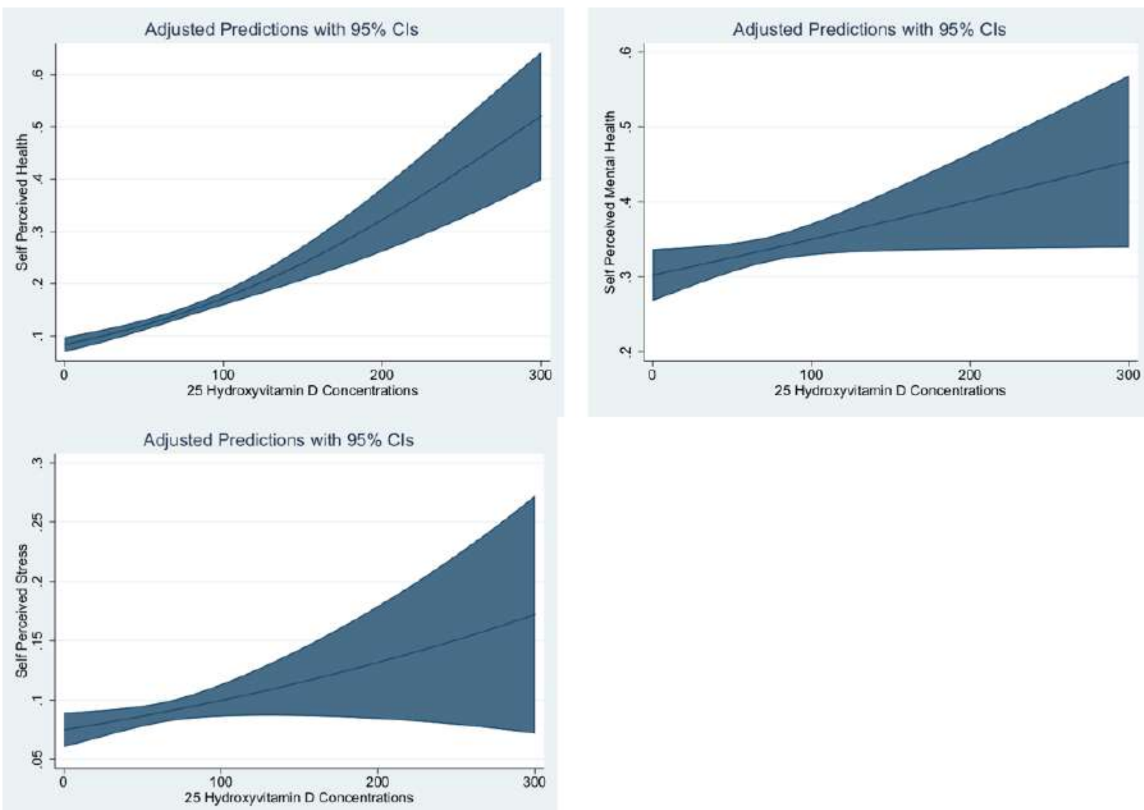
Table Appendix 4.0.1: Odds ratio of serum 25(OH)D concentrations (per 25 nmol/L increase) with mental health indicators in various regression models robustness check

Dependent Variable	Unadjusted Model	+Demographics	+Socioeconomic	+ Life Style	+ Health
Mental Health	1.12*** (0.02)	1.11** (0.03)	1.11** (0.03)	1.10* (0.03)	1.09* (0.04)
Stress	1.10** (0.03)	1.10** (0.04)	1.10** (0.04)	1.09* (0.05)	1.09** (0.04)
General Health	1.22*** (0.02)	1.20*** (0.03)	1.19*** (0.03)	1.17*** (0.02)	1.16*** (0.03)

*,**,*** indicates 10%, 5%, 1%, significance levels, respectively.

Bootstrap standard errors in parentheses.

Figure Appendix 4.1: Adjusted probability with 95% confidence interval of being in the best mental health state by serum 25(OH)D concentrations robustness check



Appendix 5: Chapter 3 Robustness check

Table Appendix 5.1: Selective AMI Quality Regression Coefficients Robustness check

Equation	Model Specifications	Quality Coefficents[1]
(1)	No Risk adjustment	.401***
(2)	+Demographics	.398***
(3)	+ Risk adjustments	.399***
(4)	+ Hospital Fixed Effects	.395***
(5)	+ Year Fixed Effects	.394***
(7)	Instrumental Variable regression	2.203*
(6)	1st Stage F-Stat	26.47

*,**,*** indicates 10%, 5%, 1%, significance levels respectively.

[1]Based on patient mortality