DISTRIBUTION OF TOBACCO USE IN POPULATIONS

DISTRIBUTION OF TOBACCO USE IN POPULATIONS: A COMPARATIVE MULTILEVEL AND LONGITUDINAL ANALYSIS OF CANADA AND INDIA

By

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ABSTRACT

Smoking/tobacco use is the leading preventable cause of death worldwide. Despite understanding the health consequences of smoking, less is known as to how and why the effects of smoking emerge differently between countries and within populations both over time and across socioeconomic groups and geographic locales. In this thesis, we examined socioeconomic status (SES) and geography as two potential causes of variability in current rates of tobacco use and cessation in Canada and India, countries at diverse levels of economic development and epidemiological transition. The major findings were: (i) low SES, defined by education, income, and occupation, was associated with increased risk of tobacco consumption in both Canada and India, although there was variability in the strength of this association by form of tobacco use in India; (ii) in a 60-year longitudinal study, rates of smoking have fallen over time in Canada but socioeconomic gaps have widened; (iii) smoking quit rates were higher in Canada than India; although in both countries there was a positive association between SES and quitting; (iv) geographic variation in tobacco use and quit rates remained after accounting for individual socioeconomic and demographic characteristics, suggesting the importance of place in shaping patterns of tobacco use in Canada and India. Taken together, these findings indicate that tobacco use in populations is strongly patterned along socioeconomic and geographic dimensions. Future prevention and cessation programs will need explicit consideration of socioeconomic and geographic aspects of the tobacco use distribution to effectively improve the situation across all areas and groups.

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ABBREVIATIONS

APHRI – Andhra Pradesh Rural Health Initiative
BC – British Columbia
BMI – Body mass index
CB – Chronic bronchitis
CCHS – Canadian Community Health Survey
CHD – Coronary heart disease
CI – Confidence interval
COPD – Chronic obstructive pulmonary disease
CTUMS – Canadian Tobacco Use Monitoring Survey
CVD – Cardiovascular disease
DA – Census dissemination areas (Canada)
EPOCH – Environmental Profile of a Community's Health
GATS – Global Adult Tobacco Survey (India)
GNI – Gross national income per capita
HIC – High income countries
HR – Health regions
LFS – Labour Force Survey
LMIC – Low and middle income countries
M – Male
MCMC – Markov chain Monte Carlo
MI – Myocardial infarction
MOR – Median odds ratio
NFLD – Newfoundland
NRT – Nicotine replacement therapy
NWT – Northwest Territories
OR – Odds ratio
PCA – Principal component analysis
PCCF – Postal Code Conversion File
PEI – Prince Edward Island
PQL – Penalized quasi-likelihood
R – Rural
RR – Relative Risk
SD – Standard deviation
SE – Standard error
SES – Socioeconomic status
TB – Tuberculosis
U – Urban
VPC – Variance partitioning coefficient
WHO – World Health Organization

DECLARATION OF ACADEMIC ACHIEVEMENT

Daniel J. Corsi's contribution to this thesis was in the following capacity: 1) conception of the project, 2) study design, 3) assembly and analysis of the data, 4) interpretation of results, 5) drafting of manuscripts, 6) critical revision of manuscripts, and 7) final write-up of the thesis

PREFACE

This thesis includes six studies on the social and geographical distribution of tobacco use in general populations. The findings are of importance for the understanding of the social epidemiology of tobacco related health burden, designing tobacco control strategies, and for targeting geographic-based resource allocation in diverse settings. The focus is on two countries, Canada and India; chosen as examples of countries which are at different phases of the tobacco epidemic, have different levels of economic development, have different exposures to tobacco use, and have different tobacco control policies in place.

The thesis is divided into four parts, which are outlined below. The primary objective is to examine the socioeconomic patterning of tobacco cross-sectionally and over time in Canada and India. Its secondary objective is to assess geographic variability in smoking in Canada and India using multilevel analytical techniques. All of the investigations have been undertaken and manuscripts prepared during the period from June 2010 to July 2012 as part of my PhD studies.

OUTLINE

Part I Background

Chapter 1 consists of an introduction and rationale for the thesis, describes the over-arching hypothesis and specific research questions, and provides a literature review and synthesis of what is known about the distribution of tobacco use according to socioeconomic characteristics and geography. A profile of the data sources is given

along with a description of their strengths and limitations. In addition, an overview of the analytical methodology employed in the thesis will be described.

Part II Socioeconomic patterning and large area influences on tobacco use in Canada and India

Chapter 2 presents a cross-sectional investigation into current socioeconomic and geographic distribution of smoking behaviour in Canada. The primary focus will be on socioeconomic and geographic indicators of current smoking and quitting. The geographic variability in current smoking and quitting will be explored using fixed effects and random effects models. In addition, we assess the variability in current smoking across Canadian provinces according to socioeconomic status (SES) using educational attainment as the primary marker of SES. Finally, we will examine the consistency of the association between SES and smoking across provinces.

Chapter 3 will comprise a comparative analysis of the socioeconomic and geographic patterning of tobacco use in India. This chapter will highlight differences in the patterns of tobacco use in high versus low and middle income countries (see **Appendix A** for country economic classification). Differences in tobacco use by sex, method of consumption (bidis, cigiarettes, chewing), amount of consumption and socioeconomic indicators will be investigated. Geographical variation in smoking will be assessed at the level of local areas (communities) and states.

Chapter 4 presents a longitudinal investigation into smoking trends in Canada by sex, education, and geography. The aim of this study is to examine and quantify the variability in the rate of change in current smoking prevalence among men and women

according to socioeconomic status and geography (province). Relative and absolute differences in current smoking prevalence between according to socioeconomic status (defined by educational attainment) and province of residence will be summarized over time from 1950 to 2010. In addition, we present in this chapter a systematic review of all studies in high income countries that reported on trends in smoking according to SES, to which we compared our findings from Canada.

Part III Contextual versus compositional influences on smoking and levels of consumption in Canada

Chapter 5 quantifies the variation in smoking between communities, regions, and provinces in Canada. The focus is in describing the extent to which there is geographic variation in smoking in Canada which is independent of the individual characteristics of residents.

Chapter 6 presents an analysis of the geographic variation in smoking using three measures of smoking behaviour: smoking prevalence, number of cigarettes smoked per day, and history of smoking intensity (number of packs per day times number of years smoking). Questions of substantive interest that are address are whether the effect of individual SES indicators are similar in direction and magnitude between smoking prevalence and amount of consumption and whether geographical areas (health regions and provinces) with a high prevalence of current smoking are also high in the number of cigarettes smoked per day or smoking intensity.

Part IV Conclusions and salient findings

Chapter 7 presents a summary of conclusions and salient findings from the thesis. A comparison of major findings between the Canadian and Indian studies is presented and the implications discussed. Major topical and methodological advances will be discussed by chapter. Future directions and follow-up investigations will be proposed.

PART I: Background

Chapter 1 Introduction, rationale, and data sources

Introduction

Despite tremendous achievements in our understanding of the health consequences of smoking[1-6], several important gaps remain as to how and why smoking patterns emerge differently between countries and within populations both over time and across socioeconomic groups and geographic locales. Globally, although tobacco has been smoked on a large scale since at least the sixteenth century, there has been marked differences in the rate and form of consumption between populations and over time.[7]

The custom of burning tobacco leaves and inhaling the smoke was first adopted in Central America by the Mayans about 2500 years ago.[7] The burning of tobacco was initially done for religious and medicinal reasons; later tobacco was smoked and inhaled for pleasure across much of North and South America and the Caribbean. Tobacco was introduced into Europe by the Spaniards after their arrival in South America. Pipe smoking was initially the most common form of smoking in Europe until the seventeenth century, when it was gradually replaced by snuff, then cigars, and more recently by cigarettes, which were brought to Spain and Portugal from South America in the early 19th century.[7] In the period between the First and Second World Wars, manufactured cigarettes emerged as the dominant form of tobacco consumption in high-income countries (classified by the World Bank as countries where gross national income (GNI) per capita was >$12,276 in 2011, see Appendix A).[8-9]

The Tobacco Epidemic

Widespread use of tobacco across many populations has been termed the global tobacco epidemic.[10] Various models which characterize changes in the distribution of tobacco use in populations over time have been proposed in an effort to inform the development of public health and tobacco control policies in response to the epidemic.[11-12] The most widely used model, proposed by Lopez and colleagues[12], describes the progression of the tobacco epidemic in four stages. In the initial stage, the prevalence of smoking is low (<15%) but rising in men and <5% in women. In the second stage, the prevalence of smoking continues to rise over several decades in both men and women before reaching a peak prevalence of between 50% and 80% in men and a maximum prevalence of 35-45% in women. The third stage is characterized by a continuing decline in the prevalence of smoking among men. Patterns among women in this stage are marked by an initial decline followed by a period of stability where rates of smoking remain slightly below the peak. In the final stage, smoking rates are similar between men and women and continue to slowly decline in both sexes.

The progression of the tobacco epidemic through the various stages is believed to largely coincide with a country's economic development and epidemiologic transition.[12-13] Evidence from historical trends in smoking in high-income countries, described in more detail in the following section, seem to support this model.[14] There remains uncertainty as to what extent this model of the tobacco epidemic will accurately depict the experiences of low and middle income countries (countries with GNI per capita <$12,475 in 2011), many of which have yet to undergo the epidemiologic transition.[15-16] Early evidence, however, indicates that the patters are likely to be similar in these

countries as well, indicating that tobacco will continue to be a growing epidemic into the coming decades.[17-18]

Historical patterns of tobacco consumption in high income countries

Since the first half of the twentieth century, the prevalence of smoking in several high-income countries, including the US, Canada, and the UK, has followed a fairly consistent pattern: first rising quickly among men during the first 2 or 3 decades and then declining over time through a combination of tobacco control measures and rising social unacceptability.[12, 19] For example, by the 1940s cigarette smoking had become widespread in high-income countries and up to three-quarters of men were regular smokers.[14] After reaching a peak in the late 1940s, rates of cigarette smoking have declined among men in the United States, Canada and many other high-income countries[9, 20]. Rates of mortality from lung cancer and other smoking-attributable causes have followed a similar trend which is shifted in time; peak rates of smoking-attributable mortality emerged 20-30 years after the peak in consumption.[21-23]

Trends in high-income countries have revealed that the progression of the smoking epidemic emerged later in women and did not reach the same high prevalence of male populations.[24-25] Among US women born prior to 1900, only 7% smoked; however the prevalence rose quickly in the post-war period and reached 44% in the mid-to late 1950s.[25] The 1931-1940 cohort of women also reached a peak prevalence of 44% (at 20-30 years of age), around the time of the first report of the Surgeon General's Committee on Smoking and Health in 1964.[26] The overall peak in smoking prevalence among US women followed in the mid-1960s, about two decades later than in men.[27] Although a

similar pattern was seen in Britain, changes in the rates of smoking in women did not occur at the same time in all populations; for example in Southern European countries increases in prevalence were not seen until much later.[24, 28] Further, there does not appear to be a common prevalence curve which is followed in all populations; large variations in the general pattern are possible both within and between countries at different levels of economic development and epidemiological transition.

The current global burden of tobacco

Smoking is the leading preventable cause of death among adult populations[29], responsible for approximately 5.4 million deaths per year among those over the age of 30.[30] Up to 30 million young people begin smoking each year, the majority of whom are in low and middle-income countries (GNI per capita <$1,005 - $12,275 in 2011).[31] Assuming that only one third of new smokers will eventually quit (cessation is uncommon outside of high-income countries, see Chapters 2 and 3), up to 10 million people could be killed by smoking per year (100 million per decade) by 2030, and 80% of deaths will occur in low- and middle-income countries.[23, 32] For the individual smoker, the risk of mortality is substantial; among those who begin smoking in early life, nearly 50% will die from smoking-related causes and half of these deaths will be among middle-aged adults (defined as 35-69 years) who (in high-income countries) will loose on average more than 20 years of life.[33-34]

Scientific evidence on the health effects of smoking began to emerge in the middle of the twentieth century, first on the relationship between smoking and lung cancer[1-4, 35-37] and later in relation to other diseases.[6-7, 33] Although the early evidence on

the harms of smoking was derived in large part from studies among men in the US and UK, more recently the major findings have been replicated in populations in other parts of the world.[38-40] It is now accepted that smoking is positively associated with up to 40 diseases or causes of death (with a majority of these associations likely to be causal[7]), including: coronary heart disease (CHD)[40-41], stroke[42-43], chronic obstructive pulmonary disease (COPD), chronic bronchitis (CB), emphysema[44] , and tuberculosis (TB).[45-46] Despite available evidence of health risks, tobacco control remains a key global health challenge in the 21st century.

Smoking prevalence over time and current patterns

Data on trends in smoking prevalence are primarily available from high-income countries, where smoking rates have fallen substantially since the 1970s.[20] In 1975, smoking prevalence was greater than 40% in men and 30% in women in the United States, United Kingdom, Australia, Canada, and Norway.[20] By 2008, smoking prevalence among men and women in these countries was 20% or lower.[10] Reductions in smoking prevalence over the past four decades have been achieved in high income countries through the introduction of tobacco control measures including health education, cessation support, restricted access to tobacco products for adolescents, increased taxation, health warnings (both graphic and written), advertising bans, and smoke-free workplaces.[19, 47]

In contrast to the declines observed in high-income countries, the prevalence of smoking has risen substantially in recent years among men in several low- and middle-income countries.[23, 48] In addition, smoking continues to be highly prevalent in many

parts of the world both in men and women (**Figure 1.1a**, **Figure 1.1b**). In India, rates of smoking have been stable at around 30% in men over the past decade but have risen in women from 2.4% in 1998 to 3.8% in 2009.[49-50] Smoking in India is largely in the form of bidis, which are smaller, hand-rolled cigarettes that contain less tobacco than manufactured cigarettes.[51] Smokeless (chewing) tobacco is also regularly used in India, and in some regions it constitutes a majority of all tobacco consumed.[52] Overall rates of chewing in India in 2009 were 30.4% in men and 18.5% in women.[50] Similar to smoking, the rates of chewing have been stable in men at about 30% while the rates in women have increased from 12.0% in 1998 to 18.5% in 2009.[53]

Rationale

While the overall declines in smoking prevalence observed in many parts of the world are good news, the average falls in smoking rates hide large variations in current smoking rates within some populations.[54-55] There are a number of potential sources of this variation. For example, variation could be related to an uneven distribution and/or uptake of tobacco control initiatives, including cessation support and health education.[56] In this research, we examine two potential causes of variability in smoking prevalence and cessation: SES and geography.[57] A more detailed understanding of these sources of variation will advance our understanding of the influences on tobacco use behaviour and strengthen the available evidence for the development of novel strategies to reduce the consumption and uptake of tobacco use. For example, while there is evidence that first-line interventions such as raising cigarette taxes are effective at reducing demand for tobacco, such policies explain less than a quarter of overall changes in prevalence.[57] In

addition, other evidence suggests that mainstream smoking prevention policies (e.g. smoke free environments and health promotion messages) may differentially reduce smoking prevalence among higher SES groups.[58] Uncovering sources of geographic variation in smoking rates will be important both for targeting geographic-based resource allocation and for greater understanding of potential contextual influences that may encourage or discourage smoking in certain areas. The findings of this thesis will provide key information for designing tobacco control policies and identifying areas where more or differing strategies are required.

Investigations in this thesis are focused on two countries: Canada and India. Both of these countries are diverse geographically and in their socioeconomic and demographic profiles. In addition, these countries are at difference phases of the tobacco epidemic cycle and have large differences in current exposures to tobacco use in their populations.[12] Further, these two countries represent the overall global variation in tobacco use and stage of the epidemic: current smoking in 2009 was 15% in men and 12% in women in Canada; 2009 rates in India were 30% in men, 4% in women and 26% for chewing.[10, 50] These differences facilitate a cross comparative examination of the smoking epidemic in countries at different levels of economic development and at different stages of the epidemiological transition.[15]

Hypothesis and research questions

The over-arching hypothesis to be tested in this thesis is that tobacco use behaviours will be dependent on SES and geographical location in Canada and India. To

address this hypothesis, a series of research questions have been formulated which will be answered in the subsequent chapters.

First, in Part 2 of this thesis, the following questions are addressed:

(1) How is tobacco use behaviour patterned by SES markers cross-sectionally and over time in Canada and India? (Chapters 2-4)

(2) Is there geographic variation in current smoking and quitting at the level of provinces and states and is this independent of individual demographic and SES factors? (Chapters 2-3)

(3) Is the observed geographic variability consistent for individuals at different levels of SES? (Chapter 2)

(4) Is the observed SES-tobacco use relationship similar in both direction and magnitude within and between the two countries studied? (Chapters 2-3)

In Part 3, the geographic contribution to variation is considered in more detail for Canada. The following questions are addressed:

(5) What is the relative importance of the different levels of geographic organization (small community or neighbourhood, region [health region], and province) in shaping current smoking patterns in Canada? (Chapter 5)

(6) To what extent is the geographic variability observed at each level a function of individual compositional characteristics of the communities, regions, and provinces? (Chapter 5)

(7) To what extent are there similarities or differences (in terms of direction and magnitude) in effects of markers of SES on the prevalence of current smoking compared to the effects of these markers on levels of tobacco consumption in smokers? (Chapter 6)

(8) What is the correlation in smoking prevalence and level of consumption between geographical areas in Canada, after taking into account individual characteristics? (Chapter 6)

What do we already know about socioeconomic and geographic variation in smoking?

A closer examination of the trends presented previously reveals that, despite overall declines, considerable variability remains in rates of smoking across socioeconomic groups and geographical areas within countries. For example, many populations now exhibit marked socioeconomic gradients in smoking, with current smoking being up to three-fold higher among the socioeconomically disadvantaged groups (see Chapters 2 and 4; **Table 1.1**).[59-61] In addition, large differences in smoking have been observed across geographical regions within high-income countries such as Canada.

In 2010, the Canadian Community Health Survey (CCHS) reported an age-standardized prevalence of daily smoking of 15.5% (men and women combined, 95% confidence interval [CI]: 15.1-16.0) for the whole of Canada; this varied between 12.5% (95% CI: 11.2-13.8) in British Columbia and 48.8% (95% CI: 42.0-55.6) in Nunavut (**Figure 1.2a** and **Figure 1.2b**).[62] A recent study from Canada reported a smoking prevalence as high as 83.7% among a cohort of Inuit residents from Nunavik (Northern Quebec).[63] Further, variation has been observed within provinces using health region divisions, which are geographic areas defined by the provinces for the administration of public health services.[64] For example, within the province of Ontario, the smoking

prevalence in 2010 varied from 10.1% in York region to 24.2% in the District of Algoma (Sault Ste. Marie, Ontario).

In India, the GATS study reported considerable diversity in smoking rates between states. Smoking rates varied from 9.9% in Goa to 66.3% in Meghalaya in men and from <0.1% in Kerala to 20.5% in Mizoram in women (**Figure 1.3a** and **Figure 1.3b**)

As described in Table 1.1, a strong and inversely graded relationship between SES markers and smoking prevalence has been established in many upper-middle and high-income countries.[59-61, 65-71] In Canada, for example, and odds ratio of 3.79 (95% CI: 2.81-5.11) has been reported for current smoking among the least compared to the highest educated.[61] The strength and direction of this association was consistent across studies in the literature which have reported SES-smoking associations in 11 high and upper-middle income countries (summarized in Table 1.1). In total 41/42 (98%) of the reported SES associations (using various markers of SES including education, occupation, income or other measures of disadvantage) demonstrated an inverse association (with smoking more common among low SES groups); 39/42 (93%) of the reported associations were statistically significant.

The SES-patterning of smoking in lower income countries like India has been mixed[72], although based on more recent and larger nationally representative samples[55, 73], it is now apparent that the burden of smoking is greater among the lower SES groups in India in a similar manner as in high income countries. For example, in a review of the literature on the SES patterning of smoking in India, we identified 22 studies which reported a total of 74 associations between a marker of SES and smoking and/or another

form of tobacco use (e.g. chewing) (**Table 1.2**).[53, 55, 73-92] In total, 62% of these associations were found to be negative and statistically significant. In contrast, 10.8% of the associations were positive (higher smoking/tobacco use among the higher SES groups) although no positive associations were statistically significant ($p<0.05$).

The variability in tobacco use in India along SES lines seems to resemble that of high income countries; although the relationship is complicated by the numerous forms in use, each popular within different socioeconomic and demographic groups.[93] In general, an inverse relationship (higher consumption among lower SES groups) has been observed for chewing and bidi smoking[55, 72, 94] (Table 1.2); although there is some evidence to suggest that the reverse may occur for cigarette smoking with higher cigarette consumption among higher SES groups observed in some urban areas.[83, 91]

Geography

In Canada, research on the geographical variation in current and former tobacco use has typically focused on 'average' differences between provinces, territories, and health regions.[54] In the present research, we extend this approach to consider the underlying variability in smoking behaviour both within and between levels of geography using a multilevel modeling approach[95] Specifically, we employ a detailed examination of place-to-place variation in smoking between provinces, health regions, and communities in Canada. We are not aware of any previous studies using a multilevel analytical framework to investigate spatial variation in smoking prevalence in Canada, although a multilevel approach ahs been applied to investigate the geographic variability in smoking and chewing in India.[55, 94] These studies identified important sources of

variation in smoking behaviour between households, districts, and states, with the bulk of the variation between states.[55] In Chapter 3 we employ a multilevel analytical approach to explore the geographic variability at the village level in rural Andhra Pradesh and at the state level using a nationally-representative survey.

Methodological overview

A detailed description of the methodology is provided with each chapter. This section provides an overview of the sources of data employed in Canada and India and the general approach to analysis.

Data sources

Analyses in the following chapters are based on data from multiple health surveys that have collected information on smoking and tobacco use prevalence in Canada and India.

Canada

In Canada, the two primary sources of data are the Canadian Tobacco Use Monitoring Survey (CTUMS) and the Canadian Community Health Survey (CCHS). The CTUMS is a nationally-representative (with the exclusion of the territories) telephone-based survey that has been conducted on an ongoing basis since 1999 with the specific purpose of monitoring trends in smoking prevalence.[96] The CCHS is a large-scale heath survey which covers a range of topics, including detailed questions on smoking, and was designed to provide data on health indicators at the sub-provincial

(health region) level of geography in Canada.[97] The advantage of the CCHS is the large sample size and the ability to examine smaller levels of geography than is possible with the CTUMS. In addition, in Chapter 4 we utilize a range of health surveys which have captured smoking prevalence across Canada between 1950 and 2010. Further details are provided in Chapter 4 and in **Appendix C**.

India

In India and other low- and middle-income countries, there are relatively few sources of high-quality, reliable, and representative data on tobacco consumption.[98] For this thesis, we have identified two sources of data from India: the Global Adult Tobacco Survey (GATS-India)[50] and the Andhra Pradesh Rural Health Initiative (APRHI) survey.[99] GATS-India is a nationally-representative survey that was conducted in 2009-2010 and provides the most recent available prevalence estimates on multiple forms of tobacco use (including cigarettes, bidis, and chewing). The GATS-India data are used to examine national estimates of tobacco use (smoking and chewing) prevalence, socioeconomic correlates of consumption, and geographic variation at the state level.

The APHRI survey is a representative cross-sectional survey that was carried out in 2005 with the objective to determine the prevalence of CVD and cardiovascular risk factors in rural communities in the state of Andhra Pradesh.[100] About 70% of India's population resides in rural areas[101], and sufficiently detailed data on CVD and risk factors, including smoking are scarce in these areas. The aim of the APHRI programme was to provide statistics on the burden of disease and on the prevalence of CVD risk factors for the rural regions of India. Because of its high quality design, detailed

questionnaire, and good coverage of rural areas, we use these data for a detailed examination of the socioeconomic patterning and local area variation in tobacco use in rural India. In addition, estimates of current smoking and chewing from the APHRI data are largely comparable with estimates in rural India derived from the national surveys (see Chapter 3).

Analytical strategy

The general approach to analysis involves logistic regression for binary outcomes (current smoking or not) and multinomial regression for categorical outcomes (current smoking, former smoking, never smoking). For example, current smoking [coded as 0 (absent) and 1 (present)] was modelled as a function of individual-level markers of SES (including education, income, occupation) and other important demographic characteristics (age, sex, ethnicity, marital status). Estimated models provide coefficients for each of the explanatory variables which are presented as odds ratios and 95% confidence intervals. In addition, we use a simulation procedure[102] to transform the estimated coefficients into adjusted probabilities for current and/or former smoking which are presented as estimates of prevalence (in %) along with corresponding 95% confidence intervals.

The models described above were then extended in various ways to incorporate additional complexity. First, we begin by specifying a random intercepts model, where for example, the estimated regression intercepts at different levels of geography (e.g. provinces, states) were allowed to vary around the overall mean relationship across all provinces.[95] In Chapter 2, we consider the different treatment of geographical levels as

'fixed' versus 'random' parameters in regression models. In the full multilevel model, for example in Chapter 5, we allow random intercepts at the level of communities, health regions, and provinces in Canada. Other *multivariate* multilevel models were utilized throughout the thesis. There are both substantive and technical reasons for using this approach. For example, multiple forms of tobacco use within a given individual (e.g. any combination of cigarette or bidi smoking or chewing) can be modelled together. This allows for the specification of more realistic models of potentially complex smoking behaviour within populations. In addition, all of the sample can be considered in one model instead of having to specify separate models for 'users' and 'non-users' or further splitting 'users' by form of consumption. Such models are employed in Chapters 3 and 6. Further details of the estimation procedure specific to each of the analyses are provided in each of the following chapters. Statistical analyses are undertaken with Stata (version 11.2) and MLwiN (version 2.25).[103-104]

Summary

The present research complements and advances current knowledge by employing a systematic approach to uncovering variability in tobacco use behaviours both within and between countries along socioeconomic and geographic dimensions. A consistent set of analyses were developed to enable a cross-comparative assessment to be made between the SES patterning of tobacco use in Canada and India. In addition, uncovering sources of variation in tobacco use both within and between populations is a crucial first step in informing tobacco control policies and will potentially allow for the identification of

areas where more or differing interventions are required to increase smoking cessation and decrease smoking uptake.

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TABLES

Table 1.1 Characteristics and overview of existing studies in high income countries in which a relationship between socioeconomic status (SES) and smoking has been shown

Author	Country	Study period	Coverage	Age	Sample Size	Sex	SES marker	Odds ratio (95% CI)
Barbeau[59]	United States	2000	National	18-64	24,276	Combined	Poverty-income ratio (<100%)	1.79 (1.56-2.05)
							Education (<12 y)	4.04 (3.49-4.66)
							Occupation (blue collar)	1.28 (1.15-1.41)
Baumann[65]	France	2005	Regional	15+	6,216	Men	Education (low)	1.39 (1.08-1.79)
							Occupation (manual)	1.75 (1.42-2.14)
							Perceived income (low)	1.69 (1.25-2.28)
						Women	Education (low)	1.08 (0.84-1.39)
							Occupation (manual)	1.13 (0.82-1.56)
							Perceived income (low)	2.50 (1.86-3.36)
Flint[67]	United States	1983-1993	National	18+	236,311	Combined	Poverty threshold (below)	1.26 (1.11-1.43)
Fukuda[68]	Japan	2001	National	18-54	41,299	Men	Income (low)	1.43 (1.30-1.59)
						Women		2.44 (2.17-2.78)
Helasoja[69]	Estonia	1994-2002	National	20-64	6,271	Men	Education (low)	2.18 (1.69-2.81)

						Women		1.90 (1.42-2.52)
	Latvia				6,106	Men	Education (low)	3.32 (2.55-4.31)
						Women		3.09 (2.28-4.18)
	Lithuania				9,824	Men	Education (low)	2.20 (1.79-2.70)
						Women		0.86 (0.59-1.26)
	Finland				15,764	Men	Education (low)	2.80 (2.40-3.27)
						Women		3.00 (2.53-3.55)
Reid[61]	Canada	2006	National	25+	11,320	Combined	Education (less than secondary)	3.79 (2.81-5.11)
Siahpush[71]	Australia	1995	National	18+	39,113	Men	Socioeconomic disadvantage (high)	1.99 (1.78-2.22)
							Education (low)	1.91 (1.68-2.18)
							Income (low)	1.53 (1.37-1.72)
						Women	Socioeconomic disadvantage (high)	1.90 (1.69-2.13)
							Education (low)	1.69 (1.46-1.97)
							Income (low)	1.43 (1.26-1.63)
Jarvis[60]	United Kingdom	2000-2003	National	16+	-	Men	Social class (V)	2.01 (1.60-2.53)
						Women		1.96 (1.50-2.57)
						Men	Education (no qualification)	2.52 (2.20-2.89)

						Women		2.73 (2.38-3.14)
Chaix[66]	France	1999	National	16-75	12,948	Combined	Education (low)	1.50 (1.32-1.70)
Hill[58]	New Zealand	1996	National	15-79	2,483,727	Men	Income (low)	1.53 (1.51-1.54)
						Women		1.51 (1.50-1.53)
						Men	Education (none)	1.85 (1.84-1.86)
						Women		2.02 (2.01-2.03)
Laaksonen[70]	Finland	2000-2001	Regional	40-60	6243	Men	Education (basic)	1.73 (1.27-2.36)
						Women		2.92 (2.38-3.57)
						Men	Occupation (manual)	1.74 (1.26-2.40)
						Women		3.81 (2.97-4.88)
						Men	Household income (lowest)	2.04 (1.39-3.00)
						Women		1.58 (1.28-1.95)

Table 1.2 Overview and characteristics of studies from India in which socioeconomic status (SES) has been related to smoking/tobacco use

Author	Location	Setting	Year	Sample size	Outcome-SES marker (sex)	Measure of association	Estimate (low SES vs High SES)
Gupta[79]	Local	R	1994	3148	Smoking-Education (F)	Odds ratio	1.92
					Smoking-Education (M)		2.08
Narayan[83]	Local	U	1996	13558	Smoking-Education (F)	Odds ratio	1.31
					Smoking-Education (M)		1.77
					Smoking-Occupation (F)		1.68
					Smoking-Occupation (M)		2.05
Gupta[77]	Local	U	1996	99598	Smoking-Education (M)	Prevalence	7.1% (l); 14.5% (h)
					Smoking/chewing-Education (F)		72.2% (l); 10.0% (h)
					Smoking/chewing-Education (M)		77.1% (l); 25.5% (h)
Singh[89]	Local	R	1997	1935	Smoking/chewing-Composite (F)	Prevalence	5.0% (l); 8.0% (h)
					Smoking/chewing-Composite (M)		32.0% (l); 31.0% (h)
Singh[90]	Local	R	1997	1769	Smoking-Composite (F)	Prevalence	5.9% (l); 6.0% (h)
					Smoking-Composite (M)		33.5% (l); 34.0% (h)
Singh[88]	Local	R	1998	1806	Smoking-Composite (F)	Prevalence	16.6% (l); 10.3% (h)
					Smoking-Composite (M)		37.5% (l); 25.0% (h)
Chaturvedi[74]	Local	C	1998	375	Chewing-Education (C)	Prevalence	14.3% (l); 19.3% (h)
					Smoking-Education (C)		31.1% (l); 27.4% (h)
					Smoking/chewing-Education (C)		46.4% (l); 41.6% (h)

Singh[87]	Regional	U	1999	3257	Smoking-Composite (F)	Prevalence	8.7% (l); 8.2% (h)
Reddy[84]	Local	U	2002	650	Smoking-Composite (M)	Prevalence	44.4% (l); 54.9% (h)
Gupta[78]	Local	U	2003	1123	Smoking-Education (F)	Prevalence	28.2% (l); 2.8% (h)
					Smoking-Education (M)		54.4% (l); 23.8% (h)
Rani[53]	National	C	2003	315598	Chewing-Education (F)	Odds ratio	1.22
					Chewing-Education (M)		1.68
					Chewing-Social caste (F)		2.69
					Chewing-Social caste (M)		2.53
					Chewing-Wealth (F)		1.48
					Chewing-Wealth (M)		1.68
					Smoking-Education (F)		1.17
					Smoking-Education (M)		1.38
					Smoking-Social caste (F)		2.51
					Smoking-Social caste (M)		2.59
					Smoking-Wealth (F)		1.26
					Smoking-Wealth (M)		1.55
Subramanian[55]	National	C	2004	301984	Chewing-Education (C)	Odds ratio	1.72
					Chewing-Wealth (C)		1.70
					Smoking-Education (C)		1.40
					Smoking-Wealth (C)		1.51
					Smoking/chewing-Education (C)		1.45
					Smoking/chewing-Wealth (C)		1.48

Neufeld[73]	National	C	2005	471143	Chewing-Education (C)	Odds ratio	2.29
					Chewing-Poverty (C)		1.95
					Chewing-Social caste (C)		1.95
					Smoking-Education (C)		1.80
					Smoking-Poverty (C)		2.72
					Smoking-Social caste (C)		2.03
Sorensen[91]	Local	U	2005	81837	Chewing-Education (F)	Odds ratio	1.05
					Smoking-Education (M)		1.03
					Smoking-Education (M)		1.79
Medhi[82]	Local	R	2006	2264	Chewing-Education (F)	Odds ratio	1.34
					Chewing-Education (M)		1.54
					Chewing-Income (F)		2.16
					Chewing-Income (M)		2.48
					Smoking-Education (M)		1.20
					Smoking-Income (M)		3.49
Reddy[85]	Regional	U	2007	19973	Smoking-Education (F)	Odds ratio	1.13
					Smoking-Education (M)		1.16
Daniel[75]	Local	R	2008	832	Smoking/chewing-Composite (C)	Odds ratio	1.13
					Smoking/chewing-Education (C)		1.09
Gupta[76]	Local	U	2010	1289	Smoking-Education (C)	Prevalence	19.0% (l); 11.7% (h)
					Smoking-Education (F)		1.0% (l); 1.2% (h)
					Smoking-Education (M)		50.9% (l); 21.4% (h)

Kinra[81]	Regional	R	2010	1983	Chewing-Wealth (F)	Prevalence	7.6% (l); 2.0% (h)
					Chewing-Wealth (M)		23.1% (l); 23.1% (h)
					Smoking-Wealth (F)		1.2% (l); 0.3% (h)
					Smoking-Wealth (M)		36.8% (l); 14.7% (h)
Kar[80]	Local	C	2010	400	Smoking-Education (C)	Prevalence	28.0% (l); 27.0% (h)
Samuel[86]	Regional	C	2012	2218	Smoking-Education (C)	Odds ratio	1.22
					Smoking-Wealth (C)		1.49
Zaman[92]	Regional	R	2012	4535	Smoking-Education (F)	Prevalence	8.5% (l); 1.2% (h)
					Smoking-Education (M)		57.7% (l); 39.5% (h)
					Smoking-Income (F)		7.1% (l); 4.2% (h)
					Smoking-Income (M)		51.7% (l); 41.8% (h)
					Smoking-Occupation (F)		7.1% (l); 1.1% (h)
					Smoking-Occupation (M)		51.3% (l); 34.1% (h)

Notes: (U) Urban; (R) Rural; (C) Combined; (S) Slum; (M) Male; (F) Female; (C) Combined

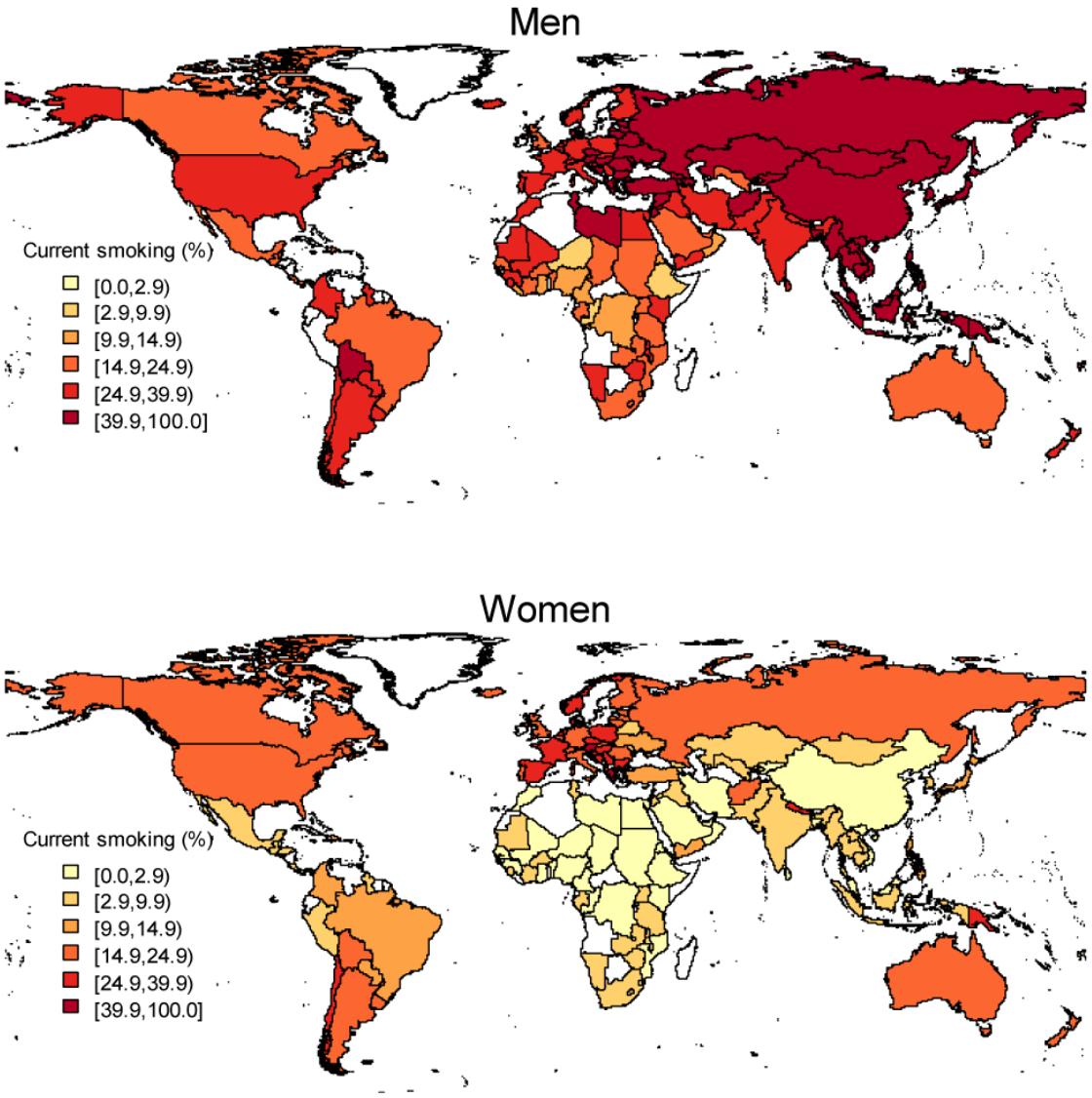

Figure 1.1 Prevalence of current smoking worldwide among men (top) and women (bottom) aged 15 years and older, World Health Organization 2011.[10]

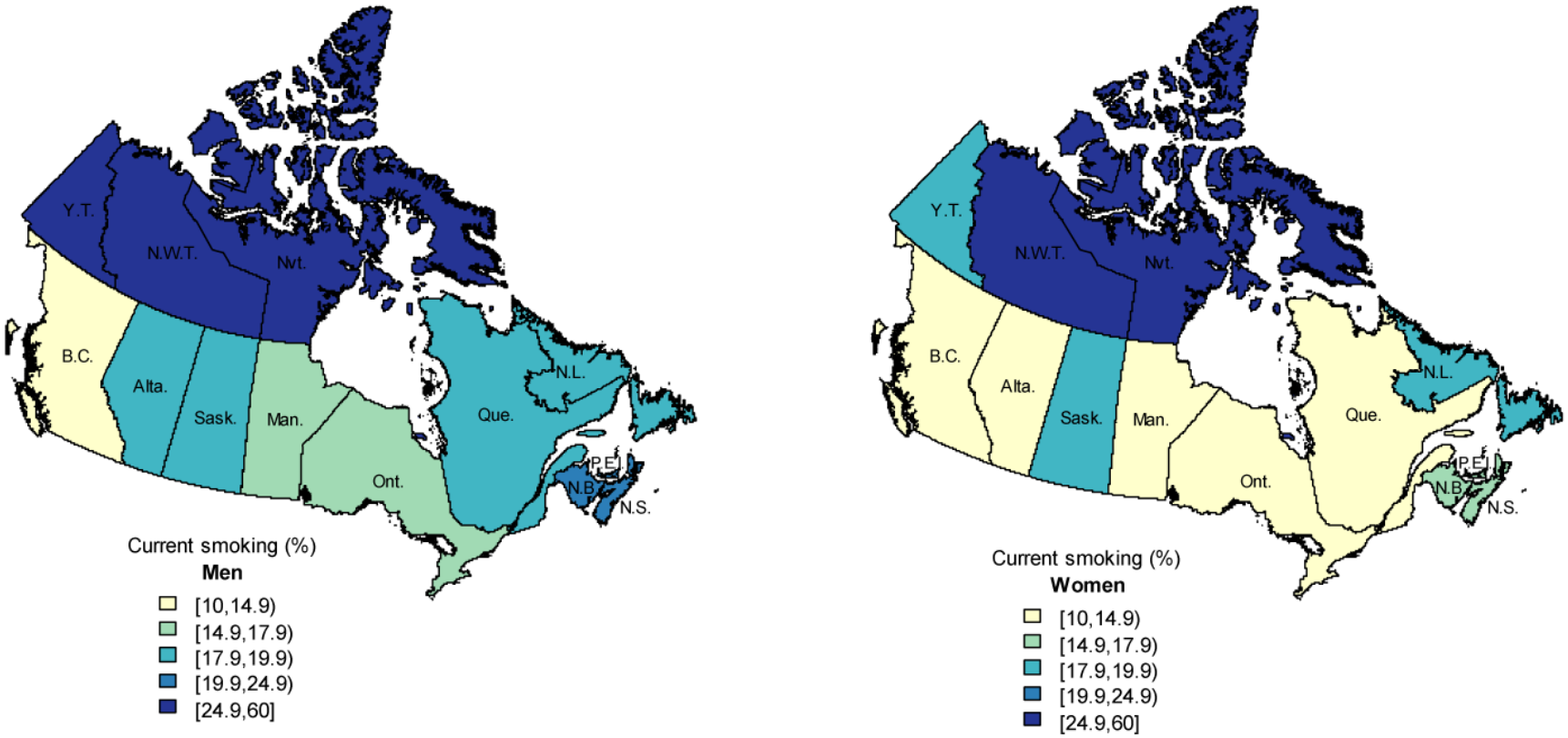

Figure 1.2 Prevalence of current smoking in Canadian provinces for men (left) and women (right) aged 12 years and over, Canadian Community Health Survey 2010.

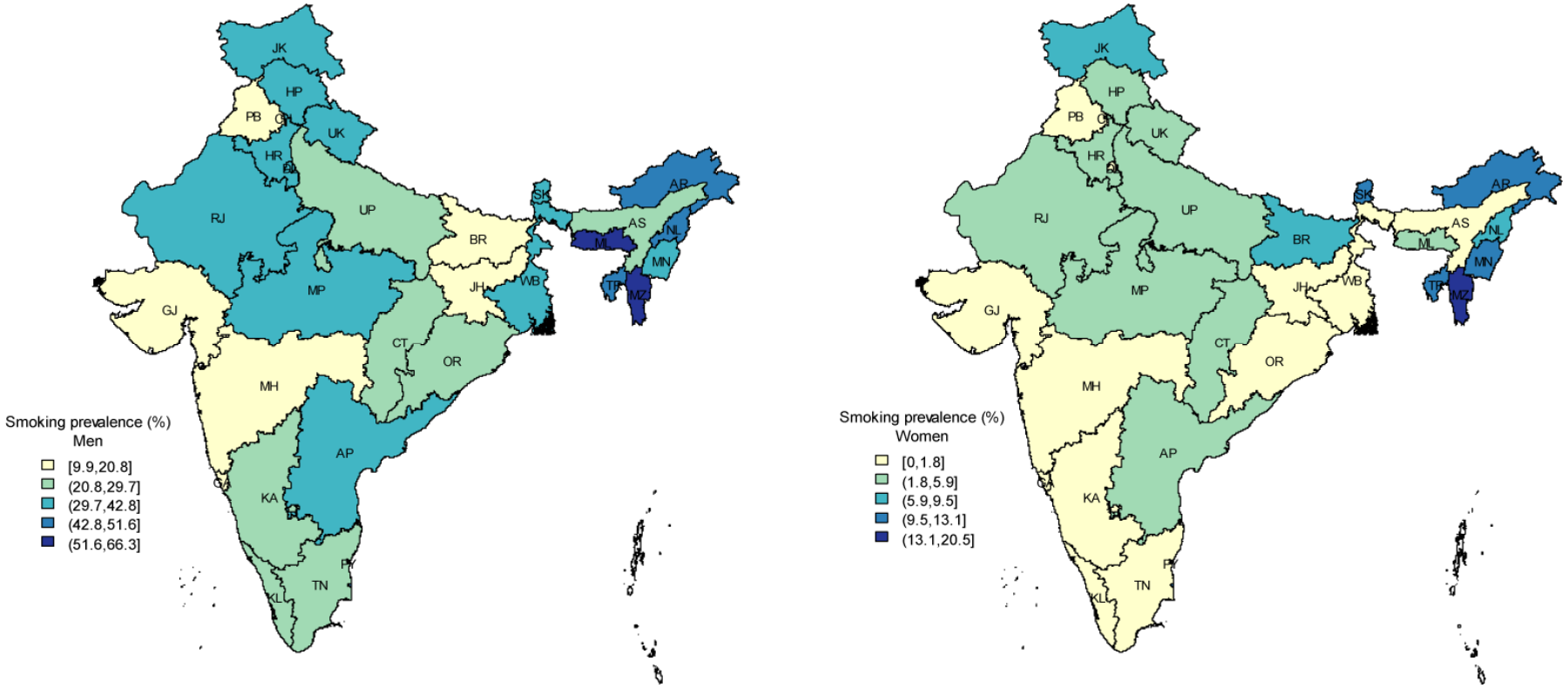

Figure 1.3 Prevalence of current smoking in Indian states for men (left) and women (right) aged 15 years and over, Global Adult Tobacco Survey (India) 2009-2010.

Part II Socioeconomic patterning and large area influences on tobacco use in Canada and India

Chapter 2 Socioeconomic and geographic patterning of smoking behaviours in Canada: a cross-sectional multilevel analysis

Abstract

Objectives To describe the socioeconomic and geographic distribution of current smoking, former smoking, and quitting in Canada.

Design Cross sectional study multi-stage sample survey.

Setting Ten Canadian provinces.

Participants 19,383 people (51% women) aged 15-85 years participating in the 2010 Canadian Tobacco Use Monitoring Survey (84% response rate).

Main outcome measure Smoking behaviour was defined as current smoking, former smoking, and never smoking. Quit rates were calculated as the proportion of former smokers divided by ever smokers (current and former smokers combined). Markers of socioeconomic status (SES) were education and occupation. Demographic covariates included age, sex, and marital status. Geography was defined by province.

Results The covariate-adjusted prevalence in this sample was 19.9% (95% confidence interval [CI]: 17.8-22.2) for current smoking and 27.1 % (95% CI: 22.9-28.2) for former smoking with 57.7% (95% CI: 54.0-62.5) of ever smokers having quit. Current smoking decreased and quitting increased with increasing SES. The adjusted prevalence of smoking was 30.6% (95% CI: 24.7-37.1) among the least educated individuals compared

with 9.9% (95% CI: 7.7-12.5) among the most educated. The quit rate was 44.1% (95% CI: 35.6-52.8) among the least educated, rising to 67.2% (95% CI: 60.2-73.6) among the most educated. There was substantial variation in current smoking and quitting smoking at the provincial level. For example, current smoking varied from 16.3% in British Columbia to 25.2% in Nova Scotia, and the quit rate varied from 50.7% in Alberta to 63.2% in Prince Edward Island (PEI). Nationally in Canada, increasing level of education was inversely associated with current smoking (odds ratio [OR] 0.60; 95% CI: 0.56-0.65) and positively associated with quitting (OR 1.36; 95% CI: 1.23-1.50). These associations were found to be consistent across all provinces.

Conclusion Our findings indicate that socioeconomic inequalities in smoking have persisted in Canada and that current smoking was less likely and quitting was more likely among the higher educated and better off groups. In addition, rates of current smoking were lower among residents of PEI, Ontario, and British Columbia.

Successful efforts to reduce smoking uptake and increase cessation in the Canadian population will need consideration of socioeconomic and geographic factors that may influence the likelihood to quit in conjunction with large-scale interventions aimed at reducing demand.

INTRODUCTION

Smoking is the leading cause of death in high income countries such as Canada[1] and is a major risk factor for cardiovascular disease and cancer.[2-3] In Canada, approximately 20% of all deaths are attributable smoking according to 2005 estimates.[4] The majority of these deaths are due to the following causes: lung cancer, chronic obstructive pulmonary disease and ischemic heart disease.[5] About 50% of smokers die of smoking-related diseases and on average their life expectancy will be shortened by 20 years.[6-8] Importantly, however, smoking cessation can reverse the risk for mortality; quitting by age 50 can halve the lifetime risk, while quitting by age 30 can reduce the risk close to that of never smokers.[9-10]

In 2010, the Canadian Tobacco Use Monitoring Survey (CTUMS) reported an overall smoking prevalence of 17% in the Canadian population (aged 15 years and older), down from 25% and the lowest since the surveys began in 1999[11]; however the rate of decline appears to have slowed in recent years.[12] Although declines in the rates of smoking are good news, the overall trends may hide important socioeconomic and/or geographic variation. Uncovering such variation is key to informing tobacco control policies and identifying areas where more or differing strategies are required to increase smoking cessation and decrease smoking uptake.

Previous studies have indicated that the distribution of smoking is not uniform across the Canadian population. Geographically, rates of smoking vary considerably, with a higher prevalence of current smoking generally found in the Eastern and Atlantic provinces compared to Ontario and British Columbia (B.C.).[12] In addition, smoking has consistently been found to be concentrated among individuals of lower socioeconomic

status (SES) in Canada [13] and other high income countries[14-15]; while higher SES has been related to increased smoking cessation (see Chapter 1).[16-18] For example, evidence from the National Population Health Survey in Canada indicated that high levels of education and household income were associated with quitting over a two year period in men and women.[19] Despite these important findings, many questions remain including: To what extent are socioeconomic differences a source of the variation in current smoking and quit rates across provinces? And is the between-provincial variation consistent for all SES groups? Identifying geographic variation that is independent of individual characteristics and the consistency of this variation across SES groups will be an important step in tailoring future tobacco control priorities and/or priorities for resource allocations to programs aimed at tobacco use prevention and/or cessation. Further, it remains unknown whether the observed relationships between SES and smoking, and between SES and quitting are qualitatively similar in both direction and magnitude across Canadian provinces.

In this study, we examine the socioeconomic and geographic patterning of current smoking and quitting in Canada using the most recent and nationally representative survey on smoking. We consider geographic variability in current smoking and quitting using fixed and random classifications for provinces. In addition, we assess the variability in current smoking and quitting across Canadian provinces according SES (using educational attainment as the primary marker of SES) and the consistency of the associations between SES and smoking and between SES and quitting across provinces.

METHODS

Data

The data are from the Canadian Tobacco Use Monitoring Survey (CTUMS), conducted in two cycles in the ten Canadian provinces from February to June and from July to December 2010. CTUMS was conducted by Statistics Canada on behalf of Health Canada to provide nationally representative data on tobacco use and related issues in Canada.[20] CTUMS covered all persons in Canada aged 15 and older except for residents of the Yukon, Northwest Territories, Nunavut, and those living in long-term care institutions or Canadian Forces bases. As the survey was conducted by telephone, people without telephone land lines were also excluded (about 16% of the target population).[20] The sampling weights provided with CTUMS have been adjusted to account for these individuals.

Survey Design

A stratified two-stage sampling strategy was used in the CTUMS.[20] In each of the ten provinces, geographic strata were defined according to a census metropolitan area (CMA) stratum and a non-CMA stratum. CMAs are census defined areas corresponding to cities and urban areas with populations of 100,000 or more. In PEI, only 1 geographic stratum was defined. In addition, in Ontario and Quebec, a third stratum was defined for Toronto and Montreal, respectively. CTUMS used a two-stage sample design in order to increase the number of respondents in the 15 to 19 and 20 to 24 age groups. In the first phase, households were selected from telephone number sampling frames in each stratum using random digit dialing. Second, one or two individuals (or none) were selected to

participate in the survey based on the age composition of the household. The household response rate (defined as the proportion of households who were reached and provided ages of all household members) was 73.8% for both cycles of the CTUMS from February to December 2010, and the individual response rate was 84.2%.[21]

Interviews for CTUMS were conducted using a computer-assisted telephone interviewing (CATI) application. The CATI application was employed in conjunction with extensive interviewer training in order to minimize data collection errors.[21] In total CTUMS collected information from 19,822 respondents age 15-85 years in ten Canadian provinces. All respondents had complete information on current smoking status, age, gender, and province of residence. Respondents with incomplete information for any of the other independent variables (marital status, occupation, or education) were excluded (n=439, 2.2%). The final sample for analysis was 19,383.

Outcome

Categories of smoking behaviour at the time of survey were defined as follows: current cigarette smokers were individuals who had smoked 100 cigarettes in their lifetime and reported smoking daily during the past 30 days. Former smokers had smoked 100 cigarettes in their lifetime and reported having quit more than 1 year earlier. In addition, individuals who had quit within the previous year were considered former smokers if they did not report smoking any cigarettes in the 30 days prior to the survey. Never smokers included lifelong never smokers (<100 cigarettes smoked in their lifetime) and a relatively small group of individuals who were occasional smokers (2.5% of respondents reported non-daily smoking). For the primary analyses, occasional

smokers were grouped with never smokers; additional analyses indicated no substantial difference in findings with this classification compared to treating occasional smokers along with daily smokers as current smokers (see **Appendix B**). Smoking quit rate was defined as the proportion of former smokers relative to ever smokers (current and former smokers).[22] Overall in the CTUMS sample the weighted prevalence of current smoking was 14.0%; 26.4% were former smokers, 59.6% were never smokers, and the quite rate was 65.3%. Descriptive characteristics of the sample population by categories of smoking behaviour have been tabulated in **Table 2.1**.

Independent variables

We considered age, sex, and marital status as demographic characteristics. Age was grouped into the following categories: 15-19, 20-24, 25-44, 45-64, 65+ years for descriptive analyses, and centred about its weighted mean (45 years) and treated as a continuous measure in regression models. In addition, polynomial terms were included for age to allow for the assessment of non-linearity. Sex was based on self-report. Marital status was categorized as common-law/married, single, or widowed/divorced/separated (reference: married). Socioeconomic status was measured by education and occupation. Education was grouped into four categories based on the highest level completed: less than secondary school, completed secondary, completed post-secondary/college, and completed university (reference: completed university). Occupational categories were adapted from the 2006 National Occupational Classification for Statistics (NOC-S)[23], and included professional specialties, executive or managerial positions, sales/service positions, and manual occupations (including trades,

transport, industry, manufacturing, and utilities). Additional categories were specified for individuals not currently working and for respondents who did not report their occupation and professionals were taken as the reference category. Geographic location was defined as province of residence at the time of survey and verified by telephone company administrative files.

Statistical analysis

In this chapter, we used two different approaches to modeling. In the first approach, provinces were 'dummy' coded and treated as a fixed classification. In the second approach, provinces were treated as a sample and modelled as the second level in a two level multilevel model. The potential advantage of the first approach is that the target of inference is the individual provinces; in the second approach inferences are made to a 'population' of provinces. Advantages of the multilevel model include the estimation of an overall parameter to quantify between-provincial differences and the ability to make inferences beyond geographies in the sample (e.g. Canadian territories, which are not covered in the CTUMS).

In the fixed effects approach, we used a multinomial modeling approach to examine smoking status as an outcome with the following categories: current smoker, former smoker, or never smoker. Formally, y_i is the categorical smoking outcome with *t* categories for individual *i*, with the probability of being in category *s* given as $\pi_i^{(s)} = \Pr(y_i = s)$. Using never smokers as the reference category, we estimated a set of $t-1$ logistic regressions which compared the probability of reporting being a current

smoker or a former smoker to the never smokers conditional on the independent variables X (age, sex, marital status, education, occupation, and province) and written as:

$$\log\left(\frac{\pi_i^{(s)}}{\pi_i^{(t)}}\right) = \beta_0^{(s)} + \beta^{(s)}\mathrm{X}, s = 1,\ldots t-1. \quad \text{(Equation 2.1)}$$

In this model, separate intercept and slope parameters, $\beta_0^{(s)} + \beta^{(s)}\mathrm{X}$, were estimated for the current regular smoking and former smoking categories, as indicated by the *s* superscripts. These parameters are interpreted as in logistic regression models and represent, respectively, the log odds of current smoking or former smoking for individuals in the reference category ($\beta_0^{(s)}$), and the effect of a 1-unit increase in the value of X on the log odds of current regular smoking or former smoking ($\beta^{(s)}\mathrm{X}$).

The reference category was represented by a 45-year-old woman who was married, had completed university, was working in a professional specialty, and was a resident of Ontario. The coefficients and standard errors took account of the sampling weights provided with the CTUMS dataset. For presentation, logits were exponentiated and given as odds ratios (OR).[24] From this model, we calculated the adjusted prevalence of current smoking and quitting (former smoking divided by ever [current and former] smoking). The adjusted prevalence was calculated for each independent variable separately while keeping the remaining independent variables at their mean values and expressed as a percent from 0.0 to 100.0. Adjusted prevalence estimates and their 95% confidence intervals were derived using statistical simulation, taking 10,000 random draws from the joint probability distribution of parameters estimated in the multinomial model.[25-26]

Geographic variation

In the multinomial model above (Equation 2.1), provinces were treated as a fixed classification through the introduction of an indicator variable for each province (except Ontario which was the reference category). We also considered an alternative approach to modeling the geographical variation between provinces where province was considered to be a random classification and between-provincial differences were modeled as a distribution using a multilevel model.[27] We used multilevel models to further explore geographic variation in current smoking and quitting. The modeling strategy is described below, using the example of current smoking. For current smoking, a two-level model was specified with a binary response (*y*, current smoking or not) for individual *i* in province *j*. Current smoking Pr(y_{ij} = 1), was assumed to be binomially distributed $y_{ij} \sim Binomial(1, \pi_{ij})$ with probability π_{ij} related to the set of independent variables X and a random effect for each level by a logit link function:

$$Logit(\pi_{ij}) = \beta_0 + \beta \mathrm{X}_{ij} + (u_{0j}) . \qquad \text{(Equation 2.2)}$$

The right hand side of Equation 2.2 consists of the fixed part linear predictor ($\beta_0 + \beta \mathrm{X}_{ij}$) and random intercepts for provinces (u_{0j}). The intercept and the β-coefficients are interpreted as before in Equation 2.1. The set of independent variables remained consistent between models although the indicator variables for provinces were included in the random part of Equation 2.2 (u_{0j}). In the multilevel model, the random intercepts for provinces were assumed to be independently and identically distributed with variance σ_u^2.[28] The variance parameter quantifies heterogeneity in the log odds of smoking between provinces. We expressed the provincial-level variance as a percentage of the

total variance from an initial model without covariates and from a final model accounting for all covariates.

In order to examine the consistency of provincial variation in current smoking across SES groups (defined by education) and to determine whether the association between SES and smoking varied across provinces in terms of strength or direction, we expanded Equation 2.2 to allow the slope of education to vary across provinces:

$$Logit(\pi_{ijk}) = \beta_0 + \beta_{1j} education_{ij} + \beta \mathrm{X}_{ij} + (u_{0j} + u_{1j}). \quad \text{(Equation 2.3)}$$

The key feature of Equation 2.3 is that the effect of education on smoking in province *j* consists of the overall average effect across all provinces (β_1), plus a province-specific (u_{1j}) differential in this effect. We summarized this model in two ways. First, we examined heterogeneity in the degree of provincial variation in smoking across all levels of educational attainment graphically and using the level-2 variance function:

$$Var(u_{0j}x_{0ij} + u_{1j}x_{1ij}) = \sigma^2_{u0}x^2_{0ij} + 2\sigma_{u0u1}x_{0ij}x_{1ij} + \sigma^2_{u1}x^2_{1ij}, \quad \text{(Equation 2.4)}$$

where x_{0ij} is the constant term and x_{1ij} is the level of education for individual *i*. In this equation, between-provincial variation in current smoking is expressed as a function of an individual's educational attainment (see Chapter 5 for additional details on variance functions).[27] Second, we presented the results of this model (Equation 2.3) as the odds ratio for current smoking overall in Canada and for each province given a 1-category increase in educational attainment. An identical series of models were estimated using quitting as the response variable. All models were estimated using Stata (version 11.2)[26, 29] and MLwiN (version 2.25).[30]

RESULTS

Smoking behaviour

In the 2010 CTUMS, the prevalence (adjusted for age, sex, marital status, occupation, education, and province) for current smoking among Canadians 15 years of age and older was 19.9% (95% confidence interval [CI]: 17.8-22.2) and 27.1% (95% CI: 24.6-29.9) for former smoking. Odds ratios and 95% confidence intervals for current smoking and former smoking from the mutually adjusted multinomial model are presented in **Table 2.2**. The relationship between current regular smoking and age was strongly non-linear and this was emphasized by the statistical significance of the quadratic and cubic terms (P<0.001). The prevalence of regular smoking by age is presented graphically in **Figure 2.1**. This relationship had an inverse-U shape with a peak smoking prevalence found between the ages of 35 and 40 years. The prevalence increased rapidly at younger ages; it was 2.8% at age 15 and 16.0% at age 30, equivalent to a 5.9-fold increase (95% CI: 4.0-8.4).

Men were more likely to smoke than women and had an odds ratio (OR) of 1.62 (95% CI: 1.33-1.96) for current smoking. In addition, those who were widowed, divorced, or separated (OR 1.96) and singles (OR 1.88) smoked more than married individuals (P<0.001). Former smokers were more likely to be men (OR 1.59; 95% CI: 1.36-1.88) but no statistically significant association was observed with marital status. Again, age was strongly associated with former smoking; a 10 year change in age was related to an increase of 1.63 in the odds of being a former smoker (Table 2.2, Figure 2.1). By age 40, the prevalence of former smoking was estimated to be higher than the prevalence of current regular smoking.

The quit rate among ever smokers adjusted for all covariates was 57.7% (95% CI: 53.6-61.8). Quit rates are given by age in Figure 2.1. Before age 40, less than half of ever smokers were found to have quit, although greater uncertainty was present in estimates of quitter percentage at younger ages due to fewer numbers of current and former smokers. Beyond age 70, nearly 90% of ever smokers had given up. The percentage of quitters was roughly equal between men and women (57.9% and 57.6%, respectively), although the rate of quitting was 20% higher among people who were married (64.8%) compared to those who were single (45.2%), and to those who were widowed, divorced or separated (45.8%).

Socioeconomic variation in current smoking and quitting

A strong and graded association was observed between education and current smoking, with the odds of smoking being 4.65 (95% CI: 3.20-6.75) times higher among those who had not completed secondary school compared to those who had completed university (Table 2.2). Current smoking was higher among those working manual occupations (OR 2.11; 95% CI: 1.48-2.99) and in sales or service occupations (OR 1.69; 95% CI: 1.22-2.23) compared to those in professional specialties. The adjusted prevalence of current smoking across all of the study variables is presented in **Figure 2.2**. We observed substantial variation in the probability of smoking according to education; the prevalence varied from 9.9% among individuals who had completed university to 30.6% among those with less than high school education, corresponding to a difference of 20.7% (95% CI: 14.5-27.5). Large variation in the prevalence of current smoking was also observed by occupation group with a difference of 11.6% (95% CI: 6.4-16.4)

between those in professional specialties (14.1%) and those in manual occupations (25.7%) (Figure 2.2). Similarly, we observed strong gradients in the quit rates by education and occupation, with quitting being more likely among those with greater education and in higher status occupations (**Figure 2.3**). Conditional on all covariates, a 23.1% difference (95% CI: 12.7-33.2) was observed in the rate of quitting between those in highest and lowest educated groups, and a 19.9% difference (95% CI: 10.1-29.5) between those in professional and manual occupations (Figure 2.3).

Geographic variation in current smoking and quitting

A statistically significant difference in current smoking was observed between provinces in the fully adjusted multinomial model (p=0.0004). In this model, which treated province as a fixed classification, the odds of current smoking were greatest in Nova Scotia (OR 1.56; 95% CI: 1.20-2.01) and lowest in B.C. (OR 0.87; 95% CI: 0.65-1.17) compared to Ontario. Based on this model, the adjusted prevalence of current smoking varied from 16.3% in B.C. to 25.2% in Nova Scotia, equivalent to a difference of 8.9% (95% CI: 4.7-13.0). In addition, the prevalence of current smoking was lower in B.C., Ontario, and PEI compared to the national prevalence (Figure 2.2). The prevalence of quitting across provinces was also calculated from the multinomial model, again treating province as fixed. From this model, a 12.5% difference (95% CI: 5.7-19.2) was observed in quit rates between the provinces with the highest rate (Prince Edward Island, 63.2%) and lowest rate (Alberta, 50.7%). Nova Scotia, along with the western and prairie provinces (Alberta, Manitoba, and Saskatchewan) had quitter percentages lower than the Canadian average of 57.7%.

We examined geographic variation in current smoking and quitting between provinces using a multilevel modelling approach. In this approach, provinces were treated as a random sample with between provincial differences in current smoking and quitting assumed to come from a distribution estimated in the model. Compared to treating provinces as a fixed classification, the multilevel model yielded similar provincial-level estimates although the differences between provinces were found to be 35.2% (5.7% vs 8.9%) narrower for current smoking and 54.5% (5.7% vs 12.5%) narrower for quitting. The fixed effects estimates for each province, compared to the multilevel model estimates are shown for current smoking in **Figure 2.4a** and for quit rates in **Figure 2.4b**. The ordering of provinces was generally consistent in the two approaches. For current smoking, the three provinces with lower than average rates of smoking (B.C., Ontario, and P.E.I.) in the fixed effects model also emerged as statistically significantly lower than average in the multilevel model, indicating the reliability of these estimates. The multilevel model tends to 'shrink' less reliable provincial estimates towards the national average; this is apparent in the quit rate model where a smaller range in the multilevel estimates for quitting was observed compared to the fixed effects approach (Figure 2.4b).

In addition to providing estimates of the between provincial differences in current smoking and quitting, the multilevel modeling approach allows for a more detailed examination of several research questions that are of substantive interest in this chapter. These analyses revealed the amount of between-provincial variation in current smoking and quitting before and after accounting for individual characteristics (**Table 2.3**). In an initial random intercepts null model, provinces accounted for 1.3% and 1.1% of the total

variation in current smoking and quitting, respectively. The addition of demographic and socioeconomic characteristics to the model reduced the variance in current smoking by 30.2% and in quitting by 53.7%.

In order to assess geographic variability in current smoking and quit rates across levels of educational attainment, we estimated random-intercept, random slope multilevel models (Equation 2.3). In these models, the relationship between education and current smoking and between education and quitting was allowed to vary across provinces. The models are presented graphically in **Figure 2.5a** (current smoking) and **Figure 2.6a** (quitting). For current smoking, there was a negative association observed between the intercepts and slopes (r = -0.74) such that the inverse education-smoking relationship was stronger in provinces with higher average rates of smoking. This relationship, however, was not statistically significant ($\chi^2 = 3.52$, d.f.=3, p=0.32) and the two provinces that did not appear to fit this classification were B.C. (lower current smoking, steeper educational gradient) and Nova Scotia (higher current smoking, shallower educational gradient). In addition, there appeared to be increasing variability in current smoking for higher educated groups (**Figure 2.5b**); although this was not statistically significant and appeared to be largely driven by differences between B.C. and Nova Scotia.

Across all provinces the relationship between education and quitting was positive; the between province variability in this relationship is displayed in Figure 2.6a. Similar to current smoking, an inverse (r = -0.87) but not statistically significant association was observed between the intercepts and slopes ($\chi^2 = 2.54$, d.f.=3, p=0.47). Increasing variability in quit rates was observed between provinces for individuals with greater educational attainment which seems to be the result of large differences in the strength of

the education-quitting relationship between B.C., Nova Scotia, and Manitoba (**Figure 2.6b**).

To examine the consistency in the SES-current smoking and SES-quitting relationship across provinces, we estimated the odds ratio for smoking and quitting for a one-category increase in educational attainment for each province (**Figure 2.7**). The overall odds ratio for current smoking in Canada for a one-category increase in education was 0.60 (95% CI: 0.56-0.65) (Figure 2.7a). The direction of this relationship was consistent and statistically significant ($p<0.05$) in all provinces and varied between an odds ratio of 0.54 in B.C. and an odds ratio of 0.66 in Nova Scotia. The magnitude of the association was greater than the national average in the provinces of B.C., Saskatchewan, Alberta, and Quebec; where as the association was somewhat shallower in P.E.I, Ontario, and Nova Scotia. The association between education and quitting was positive across all provinces, and statistically significant in 9/10 provinces, with the exception of Nova Scotia (Figure 2.7b). The overall odds ratio for quitting with each successive increase in the level of education was 1.36 (95% CI: 1.23-1.50); the relationship was weaker than the national average in four provinces (Nova Scotia, Manitoba, Ontario, and New Brunswick) and it was noticeably higher that the national average in B.C (OR 1.61, 95% CI: 1.21-1.78).

DISCUSSION

This chapter has four principal findings. First, current smoking in Canada was strongly influenced by socioeconomic status; people who had not completed secondary level education were more than three times as likely to smoke compared to those who had

completed university. Second, geographic analyses revealed that the adjusted prevalence of current smoking was statistically significantly lower than the Canadian average in three provinces: B.C., Ontario, and PEI. This finding was consistent when provinces were treated as a fixed classification and as a random classification in a multilevel model. In addition, the relationship between education and current smoking was consistent, negative, and statistically significant across all provinces in Canada. Third, although nearly six out of ten Canadians who had ever smoked had quit, quitting was more likely to occur among those of higher socioeconomic status. Geographically, large differences in quit rates were found between provinces, although the magnitude of these differences was attenuated when province was treated as a random classification using a multilevel model. Forth, although the association between education and quitting was positive in all provinces, some heterogeneity in the magnitude was found; the education-quitting relationship was noticeably steeper in B.C. and shallower in Nova Scotia compared to the national average.

There are some limitations in this work. First, the CTUMS data are cross-sectional therefore causal inferences from our findings must be interpreted cautiously. The primary motivation for this study, however, was to investigate variability in smoking behaviour across socioeconomic and geographic dimensions and such a design is appropriate. In addition, the CTUMS data, despite the primary focus on tobacco use (which may have influence response patterns), have demonstrated good concordance with other estimates of smoking prevalence from general health surveys such as the Canadian Community Heath Survey (see Chapter 6).[31] Second, we only considered cigarette smoking in the present study. Socioeconomic and geographic differences for the use of

cigars, or smokeless (chewing) tobacco were not considered in this analysis although these forms of tobacco use may be important to consider among certain population groups in Canada. These forms of tobacco are, however, used less frequently and only in a minority of the Canadian population.[12] In addition, occasional smokers (those who reported smoking infrequently and did not smoke daily) were grouped with nonsmokers. We applied this definition of current smoking given previous findings which have demonstrated the heterogeneity of smoking behaviours among occasional smokers[32]; however additional analyses treating occasional smokers as current smokers did not substantially alter the study findings. Further research on the patterning of occasional smoking in Canada, the use other forms of tobacco, and potentially related factors such as alcohol use is needed.

The overall relationship observed between socioeconomic status markers and smoking in this study was similar to what has been reported previously in Canada.[13, 33-34] We noted a particularly strong gradient in current smoking by level of education, which was minimally changed after adjustment for potentially confounding variables. Large differences were observed between provinces in current smoking, even after accounting for demographic and socioeconomic characteristics, when treating province as a fixed classification. These differences remained in large part when treating province as a random classification in the multilevel model, although the estimated prevalence for several provinces (for example Nova Scotia and Manitoba) were 'shrunk' towards the national mean in the multilevel model. Due to the treatment of higher level units as part of a distribution, the multilevel approach is typically more conservative in estimating between group-differences.[28] The between provincial differences in quit rates were about

half as large in the multilevel modeling approach, and the most obvious pattern of attenuation compared to the fixed effects model was found for provinces estimated to have quit rates at either substantially higher or lower compared to the national average. In this way, the random effects approach is favoured because it protects against over interpretation of extreme group-level differences which are potentially less reliable.

Provinces accounted for <1% of the total variability in current smoking and quitting in the fully adjusted multilevel models. Although the magnitude of this variability was not large, adjustment for individual characteristics explained less than one third of the provincial level variation in current smoking and about half of the provincial level variation in quitting. This indirectly suggests the potential relevance of geographic context in influencing smoking behaviour in Canada.[35-36] Province was the only higher-level geographic unit that was available in the CTUMS; thus potentially important geographic variability in smoking behaviour at lower levels of aggregation (for example health regions, or communities) may have been masked in these analyses. In Chapters 5 and 6, we explore geographic variability in smoking behaviour in Canada at both proximate (community) and macro (health region/province) geographical scales.

Our study documents that current smoking in Canada follows an inverse gradient by SES which was consistent across all provinces. Similarly, a consistent and positive gradient was observed with quitting for increasing SES. Interestingly, there was some variability in the magnitude of these associations, especially for quitting. The SES gradients appear to be steepest in B.C., despite the lowest prevalence of current smoking and second highest quit rate. In comparison, SES gradients were considerably shallower in Ontario and P.E.I., where rates of smoking and quitting were comparable to those in

B.C., and in Nova Scotia where the highest rate of smoking and lowest rate of quitting was found. Our findings related to the socioeconomic differentials in quitting are of public health importance. On average, individuals who where married, highly educated, and working in higher status occupations had the highest likelihood of quitting. While a positive SES-quitting relationship has been previously reported[16-18], the implications of these findings have been given less attention in recent years. Indeed, it has been suggested that policies aimed at reducing tobacco consumption may be responsible for widening the socioeconomic differentials in smoking, at least in the short-term.[15] Individuals with greater education and/or material resources may be more responsive to accessing health services in general[37] and this may extend to primary care and other sources of cessation support including telephone quitlines[38], medication, nicotine replacement, or counselling.

Interventions carried out at a population level including taxation, dissemination of health information and pictorial warnings on tobacco products, restrictions on use, advertisements, and sale of cigarettes have been effective at reducing average consumption[39-40], although it is less clear whether these interventions are reaching all segments of the population. Indeed, there is evidence that taxation policies are being circumvented among some population groups and in some geographic areas. For example, a quarter of respondents in the Ontario Tobacco Survey reported recent purchasing of contraband cigarettes from First Nations reserves without paying applicable federal or provincial taxes.[41] In addition, the usual purchasing of contraband or low-tax cigarettes was more common among lower educated groups, heavy smokers, and those who do not intend to quit.[41]

In Canada, all provinces and territories have legislation restricting smoking in workplaces and public places including restaurants, bars, and public transportation.[42] Evidence from New Zealand, however, suggests that such workplace restrictions may have been more effective in reducing rates of smoking among those in professional occupations.[43] Successful efforts to increase smoking cessation across the entire Canadian population will need explicit consideration of lower socioeconomic, Aboriginal, and other socially disadvantaged groups. Policies such as tax increases and smoking restrictions may not be effective in increasing cessation among the poor or less educated without additional support or assistance in reducing tobacco dependence in these groups. In addition, further research is needed to understand the causes of geographic variability in smoking behaviour in Canada. Such variation may be a result of different legislation or taxation but also be influenced by different social or cultural norms across provinces.[44]

The persistence of high rates of current smoking and low quit rates in certain geographical areas and among certain socioeconomic groups in Canada indicates the failure of current smoking cessation policies to be effective in improving the situation for these areas and groups. Identifying these areas and groups is one step to examining the barriers to decreasing smoking in the population; further study is required to identify what barriers exist in these areas and what interventions may improve the situation.

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TABLES

Table 2.1 Sample sizes and weighted estimates (%) of current smoking, former smoking, never smoking, and quit rates across demographic and socioeconomic characteristics and province of residence. Canadian Tobacco Use Monitoring Survey 2010.

Variables	Smoking behaviour							
	Current smoking		Former smoking		Never smoking		Quit Rate†	Total
	No.	%	No.	%	No.	%	%	No.
Total	2798	14.0	3836	26.4	12749	59.6	65.3	19383
Age								
15-19 yrs	451	8.2	77	1.5	4466	90.3	15.4	4994
20-24 yrs	688	16.1	292	8.0	2792	76.0	33.2	3772
25-44 yrs	658	16.6	631	18.4	2116	65.0	52.5	3405
45-64 yrs	814	15.3	1757	35.8	2200	48.9	70.1	4771
65+ yrs	187	7.4	1079	45.5	1175	47.1	86.0	2441
Sex								
Female	1394	11.4	1962	23.8	7181	64.8	67.5	8846
Male	1404	16.7	1874	29.0	5568	54.3	63.5	10537
Marital status								
Common-law/Married	1051	12.2	2418	31.6	3966	56.2	72.1	7435
Single	1334	16.9	654	11.5	7689	71.5	40.5	2271
Widow/Divorced/Separated	413	17.1	764	33.1	1094	49.8	65.9	9677
Education								
Completed university	240	7.4	820	22.8	2353	69.8	75.5	5420
Completed college	610	12.4	955	26.8	3133	60.8	68.4	4868
Completed secondary	1118	19.2	1242	29.4	3492	51.4	60.6	5682
Less than secondary	830	18.2	819	26.1	3771	55.7	58.9	3413
Occupation								
Professional specialty	287	8.0	604	23.1	2231	68.9	74.4	5487
Not working	701	11.6	1462	33.5	3324	54.9	74.3	270
Executive, managerial	359	13.8	622	27.3	1742	59.0	66.5	3122
Sales or Service	717	16.2	556	17.7	3613	66.0	52.2	2723
Manual	698	25.4	534	24.8	1663	49.8	49.4	4886
Not reported	36	11.1	58	32.8	176	56.1	74.7	2895
Eastern Provinces								
Ontario	210	12.6	315	25.3	1361	62.1	66.7	1995

Prince Edward Island	229	13.2	445	30.6	1224	56.2	69.9	1898
Quebec	294	15.3	412	29.7	1237	55.0	66.0	1943
New Brunswick	291	15.5	377	29.0	1143	55.5	65.1	1760
Newfoundland	293	17.7	398	31.5	1069	50.8	64.0	1886
Nova Scotia	317	17.9	399	26.8	1279	55.3	59.9	1811
Western Provinces								
British Columbia	181	11.1	343	26.7	1207	62.1	70.6	2061
Alberta	306	16.1	343	22.1	1412	61.8	57.9	2237
Manitoba	337	17.2	400	23.5	1500	59.3	57.7	1731
Saskatchewan	340	17.7	404	25.7	1317	56.6	59.3	2061

Notes: †Quit rate among ever (current and former) smokers

Table 2.2 Mutually adjusted odds ratios and 95% confidence intervals from a multinomial regression model of current and former smoking. Canadian Tobacco Use Monitoring Survey 2010.

			Current smoking		Former smoking	
Variable	**Reference group**	**Parameter**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Age		Age (10 year change)	0.96	(0.84 - 1.09)	1.63	(1.48 - 1.80)
		Age-squared	0.80	(0.77 - 0.84)	0.89	(0.86 - 0.93)
Sex	Female	Male	1.62	(1.33 - 1.96)	1.59	(1.36 - 1.88)
Marital status	Common-law/Married	Single	1.88	(1.43 - 2.46)	0.84	(0.65 - 1.08)
		Widow/Divorced/Separated	1.96	(1.50 - 2.56)	0.90	(0.72 - 1.11)
Education	Completed university	Completed college	1.92	(1.40 - 2.64)	1.74	(1.40 - 2.16)
		Completed secondary	3.55	(2.60 - 4.84)	2.06	(1.66 - 2.55)
		Less than secondary	4.65	(3.20 - 6.75)	1.83	(1.41 - 2.38)
Occupation	Professional specialty	Not reported	1.24	(0.57 - 2.66)	1.37	(0.76 - 2.46)
		Not working	1.54	(1.13 - 2.09)	0.90	(0.69 - 1.17)
		Executive, managerial	1.58	(1.13 - 2.23)	1.15	(0.89 - 1.49)
		Sales or Service	1.69	(1.22 - 2.33)	0.85	(0.64 - 1.14)
		Manual	2.11	(1.48 - 2.99)	0.98	(0.72 - 1.35)
Province	Ontario	British Columbia	0.87	(0.65 - 1.17)	1.03	(0.82 - 1.30)
		Prince Edward Island	1.08	(0.82 - 1.42)	1.30	(1.05 - 1.61)
		New Brunswick	1.26	(0.97 - 1.63)	1.19	(0.96 - 1.48)
		Manitoba	1.26	(0.98 - 1.62)	0.95	(0.76 - 1.19)
		Alberta	1.28	(0.99 - 1.66)	0.92	(0.74 - 1.15)
		Quebec	1.35	(1.03 - 1.77)	1.32	(1.06 - 1.65)
		Saskatchewan	1.47	(1.12 - 1.92)	1.12	(0.90 - 1.39)

	Newfoundland	1.46	(1.12 -	1.89)	1.41	(1.13 - 1.76)
	Nova Scotia	1.56	(1.20 -	2.01)	1.13	(0.91 - 1.40)

Table 2.3 Variance in current smoking and quitting between provinces in Canada; expressed as percentage of the contribution to the total variance

	Null model*			Fully adjusted model**		
Response	Variance	SE	%	Variance	SE	%
Current smoking	0.043	0.030	1.3	0.030	0.022	0.9
Quitting	0.037	0.028	1.1	0.017	0.016	0.5

Notes:
*Multilevel null model with random intercepts for province adjusted
**Multilevel model with random intercepts for province and adjusted for age, sex, marital status, occupation, and education

FIGURES

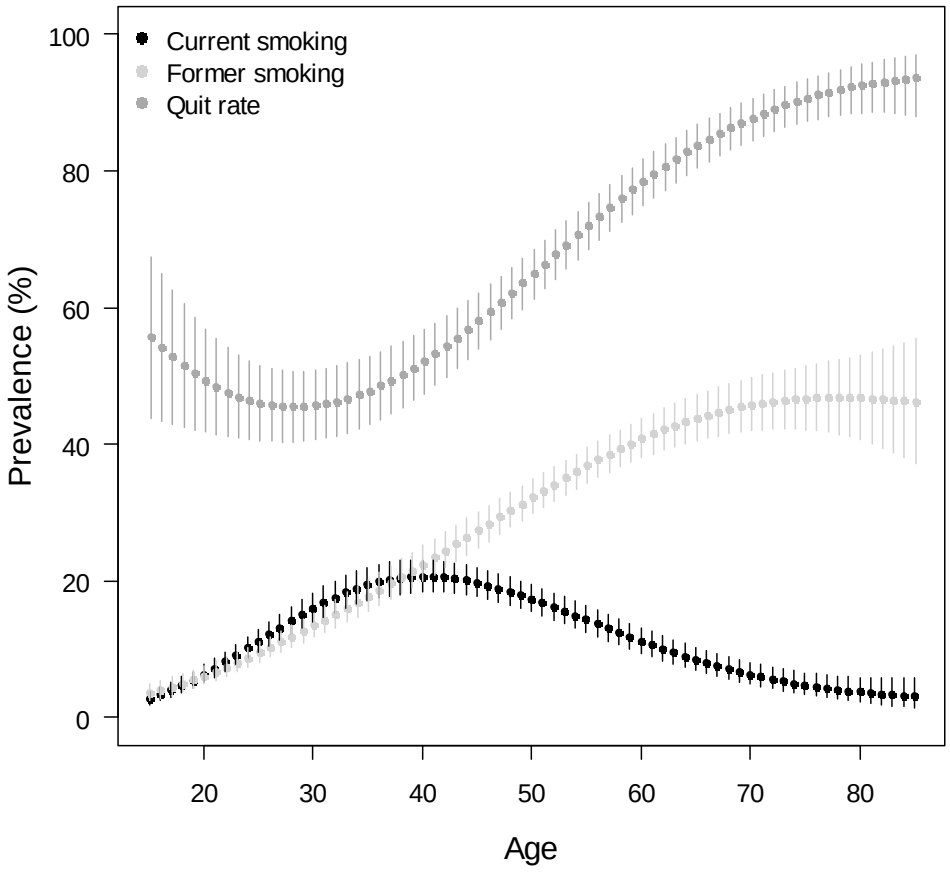

Figure 2.1 Relationship between smoking behaviour and age, 2010 Canadian Tobacco Use Monitoring Survey. Quit rate defined as the percentage of ever smokers (current and former smokers) who responded as former smokers at the time of survey. Vertical lines represent 95% confidence intervals. Adjusted for sex, marital status, occupation, education and province.

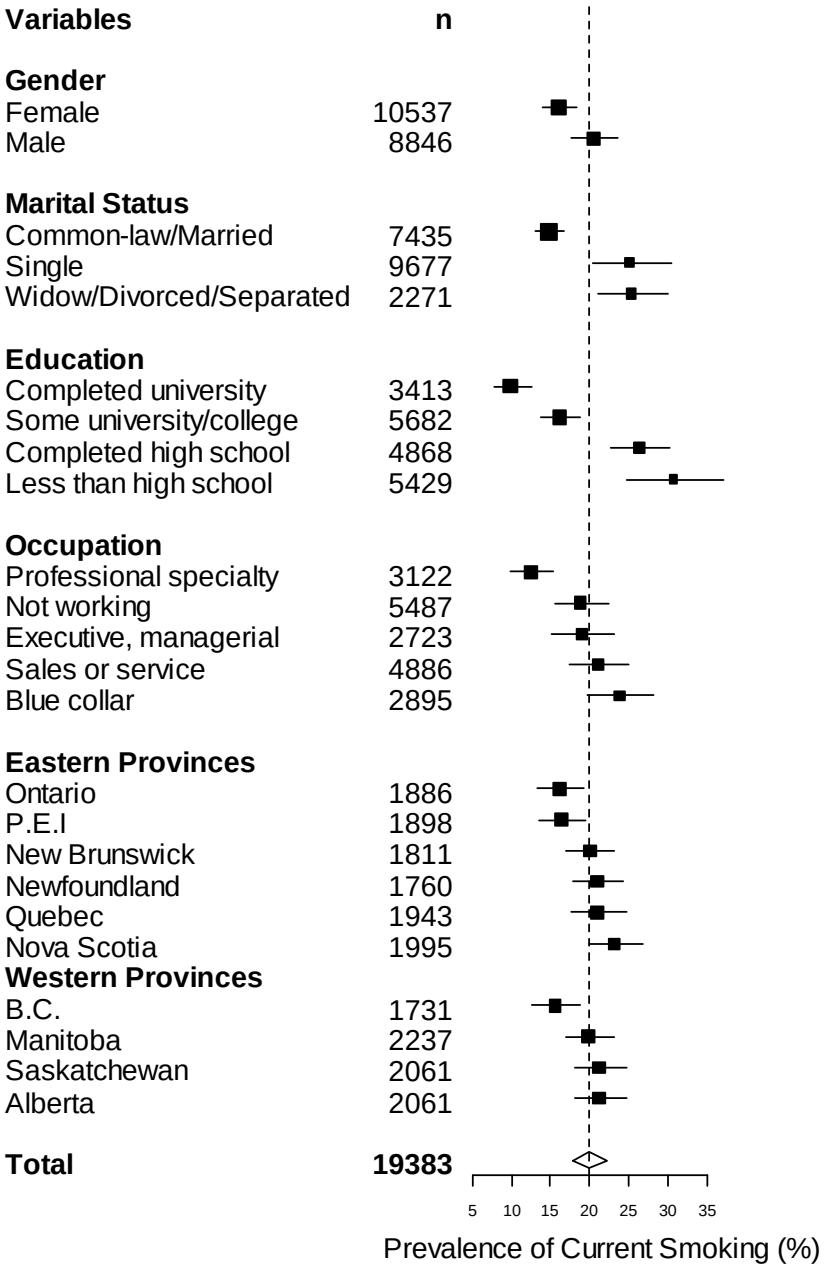

Figure 2.2 Prevalence of current regular smoking in Canada by demographic and socioeconomic characteristics and province.

Smoking prevalence and 95% confidence intervals are derived from a mutually adjusted multinomial regression model. Vertical line represents the adjusted prevalence of current smoking. The sizes of the boxes are proportional to the inverse of the variance of the estimated prevalence.

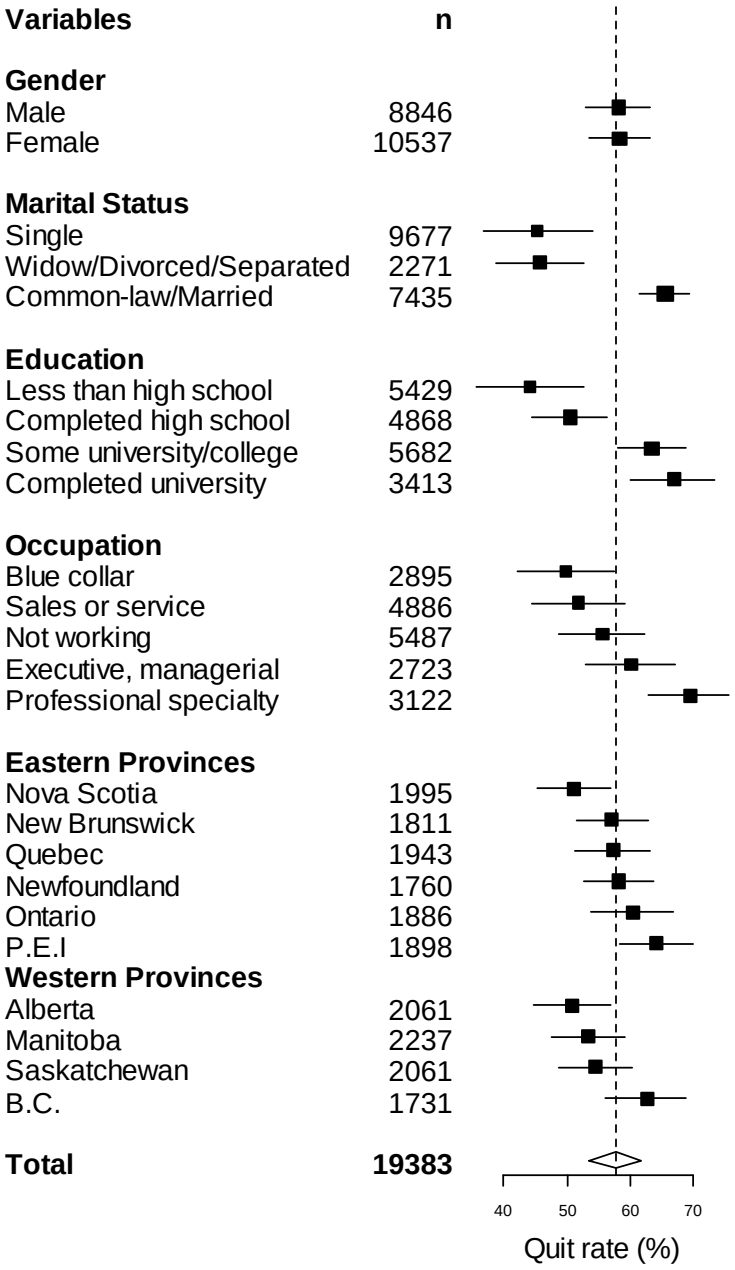

Figure 2.3 Quit rates in Canada by demographic and socioeconomic characteristics and province.

The quit rate is the percentage former smokers divided by ever smokers (former plus current) and is derived (along with the 95% CI) from the mutually adjusted multinomial regression model. Vertical line represents the overall quit rate percentage. The sizes of the boxes are proportional to the inverse of the variance of the estimated quit rate.

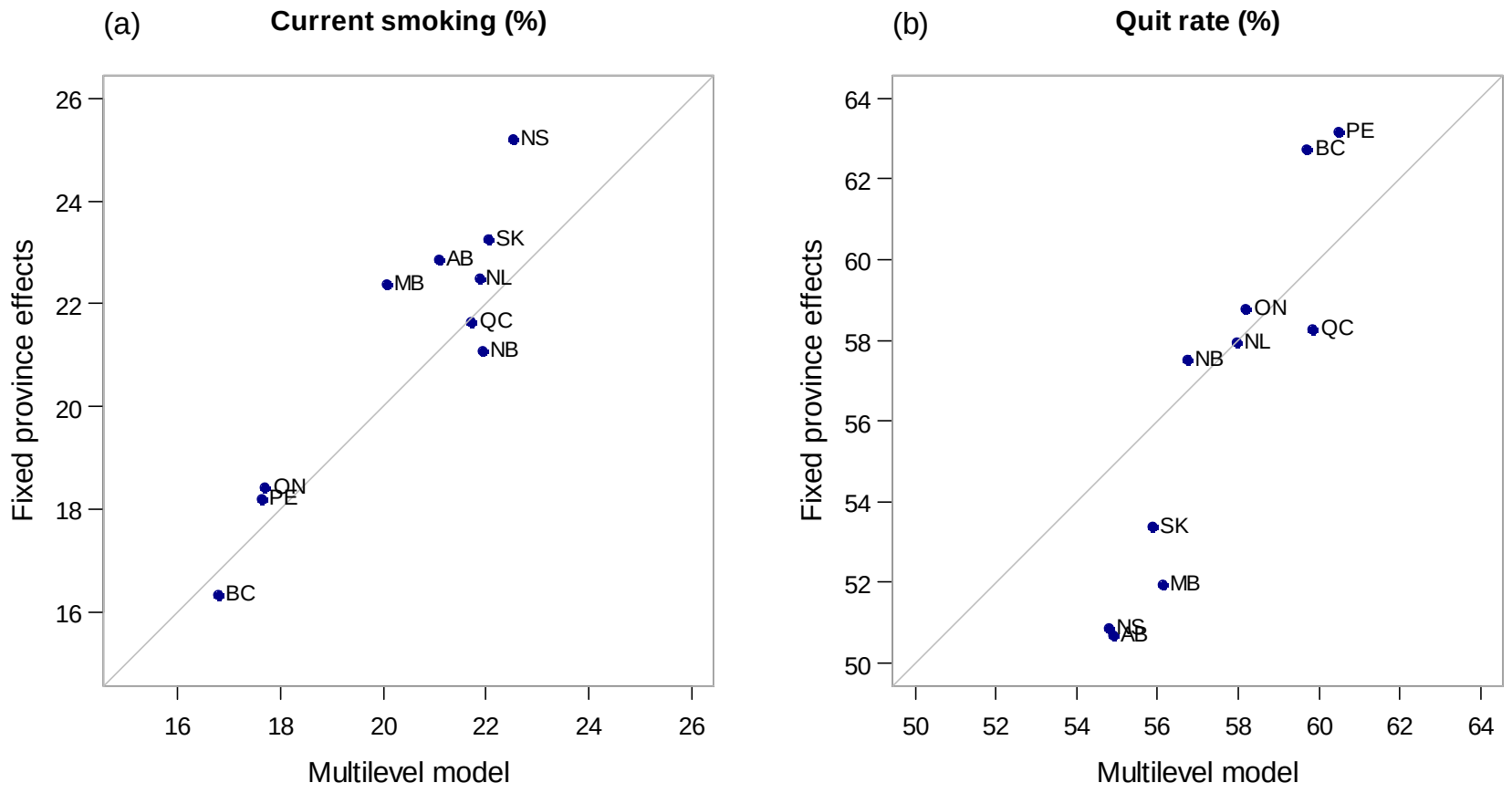

Figure 2.4 Comparison of fixed effects and multilevel model estimates for current smoking (left) and quit rates (right).

Both models were adjusted for age, sex, marital status, and occupation. In the multilevel model, provinces are treated as a random classification and between province differences are assumed to follow a distribution. Thus more extreme estimates are 'shrunk' towards the overall national estimate.

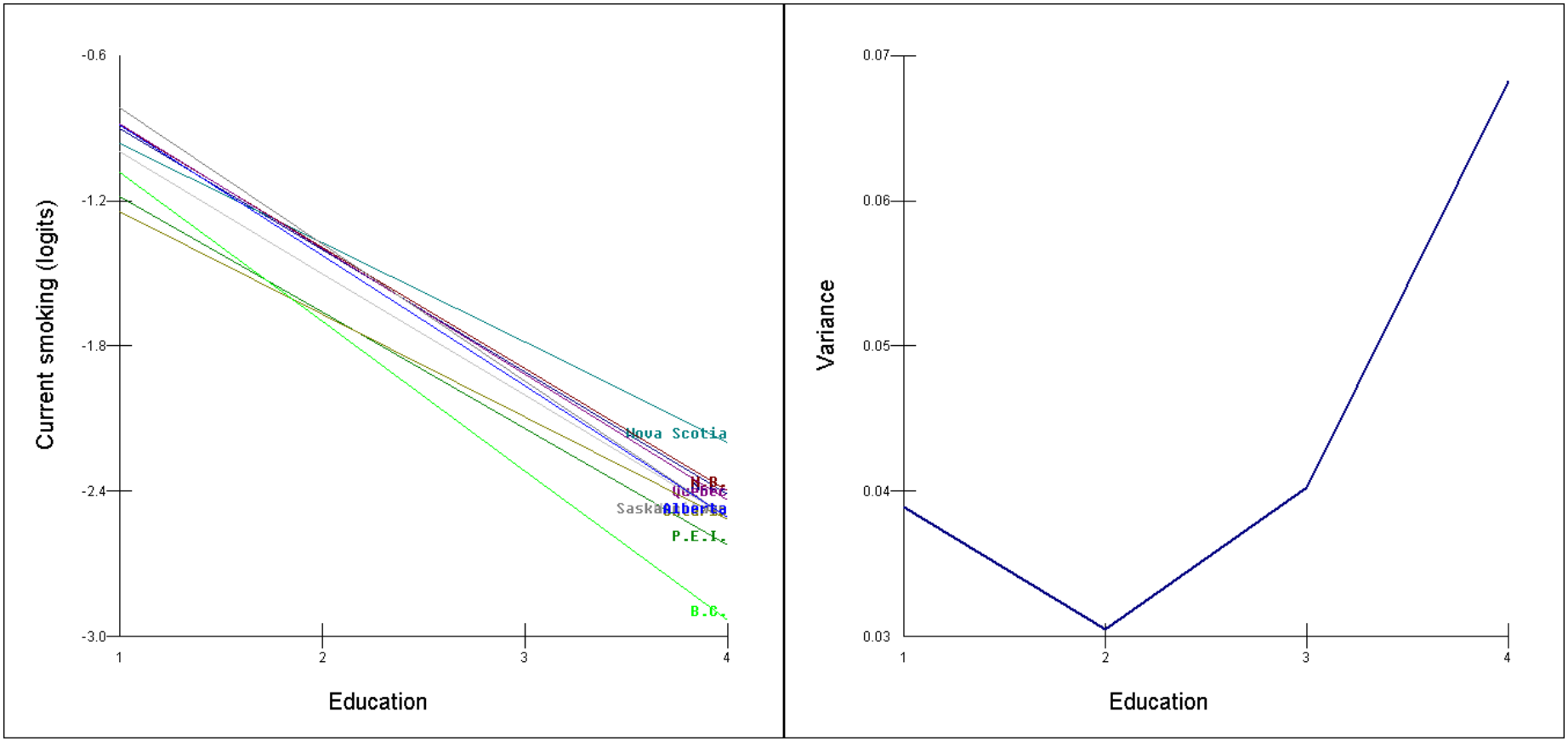

Figure 2.5 Plot of random intercept, random slope model for the relationship between education and current smoking across Canadian provinces (left) and variance function by level of education (right).

Model adjusted for age, sex, marital status, and occupation.

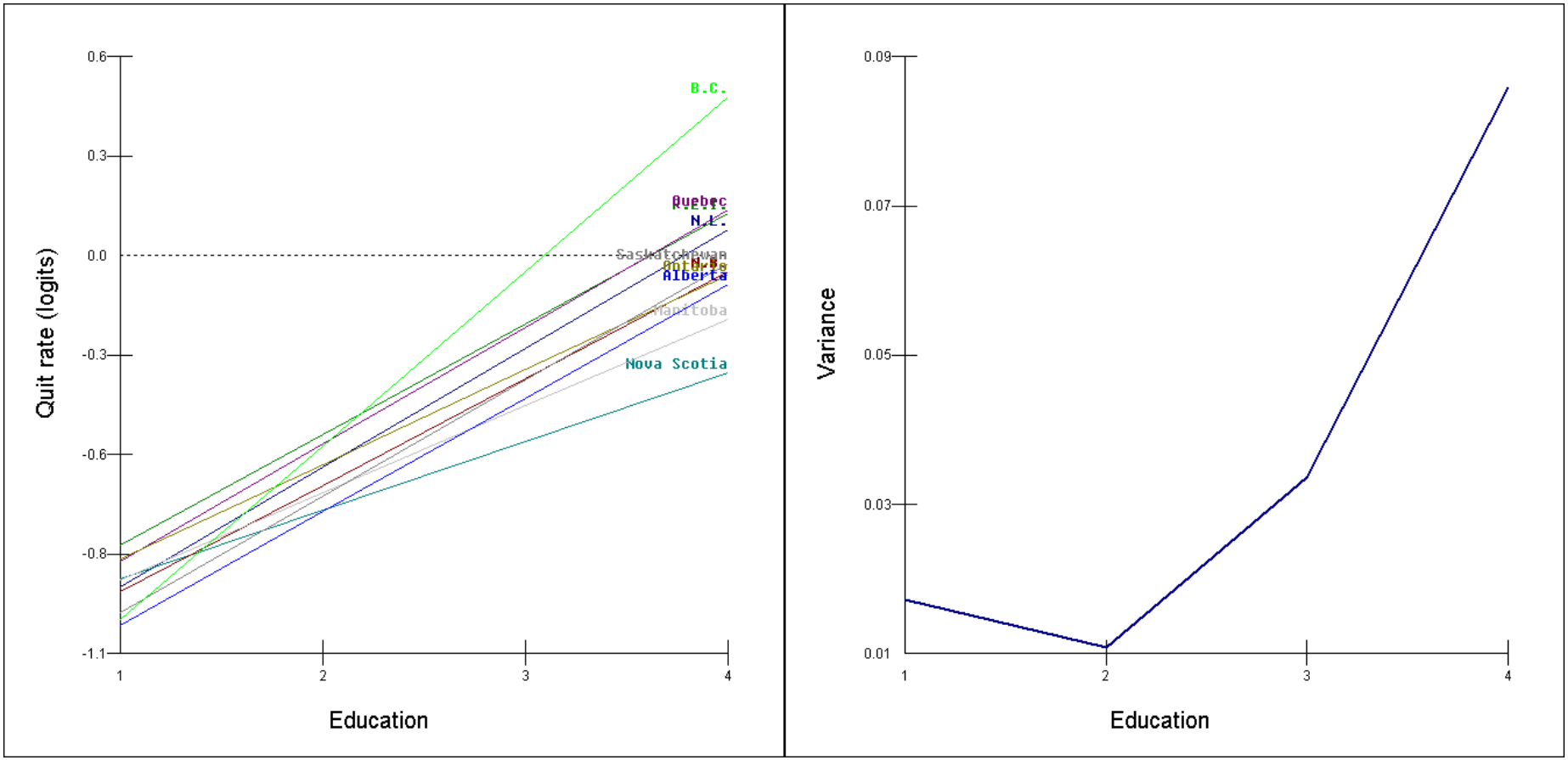

Figure 2.6 Plot of random intercept, random slope model for the relationship between education and quit rates across Canadian provinces (left) and variance function by level of education (right).

Model adjusted for age, sex, marital status, and occupation.

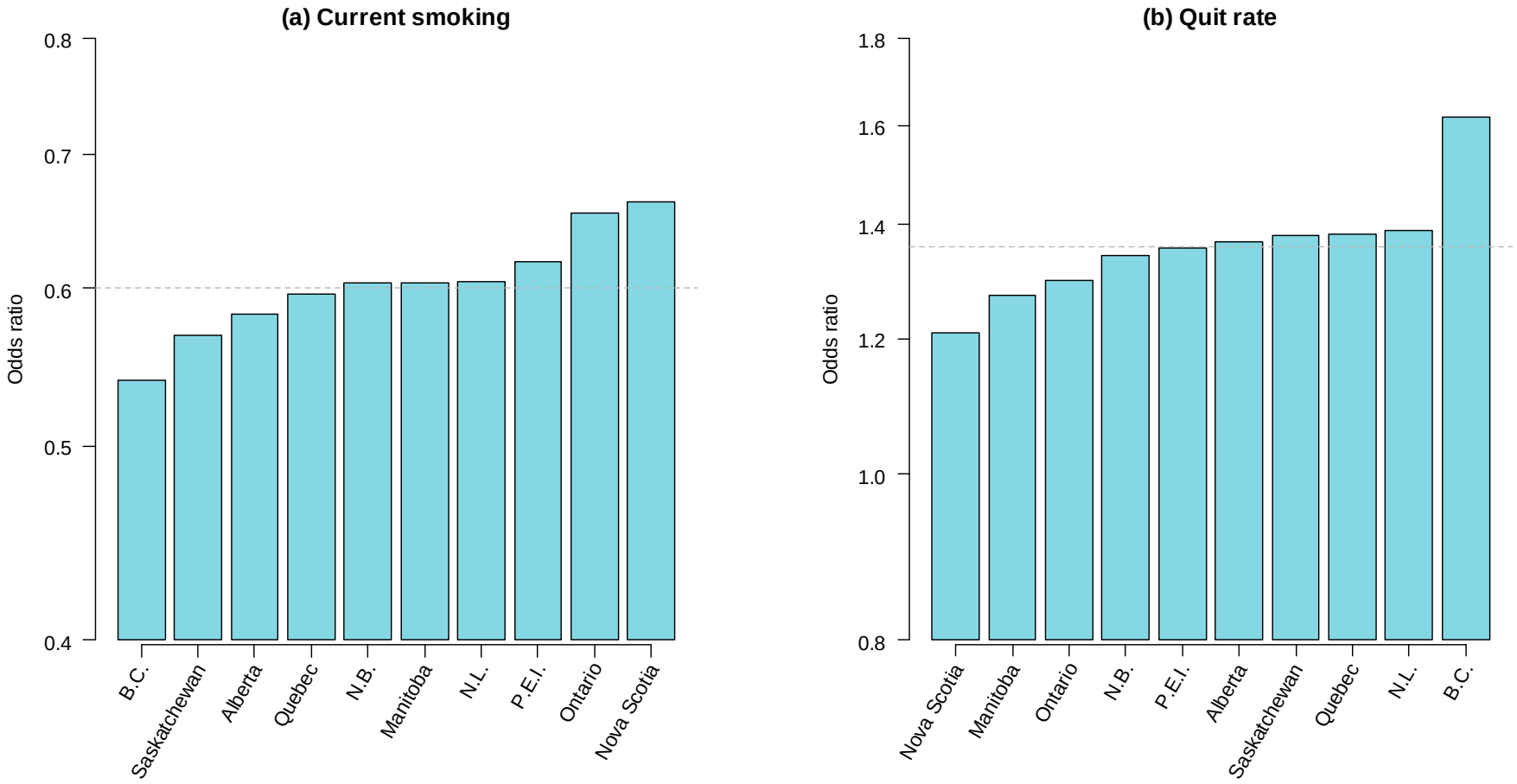

Figure 2.7 Odds ratios for current smoking (left) and quit rate (right) for a one-category increase in the level of education across Canadian provinces.

Estimates are from multilevel random intercept, random slope models adjusted for age, sex, marital status, and occupation. The horizontal line in each plot represents the overall association in Canada.

Chapter 3 Socioeconomic and geographic determinants of tobacco use and smoking quit rates among men and women in India

Abstract

Background Tobacco smoking and chewing is common in India and a majority of users are in rural areas. Little is known about patterns of smoking cessation nationally or in rural areas. In this chapter, we examine the socioeconomic and geographic determinants of tobacco use and smoking quit rates among men and women in India.

Methods Data on the prevalence of tobacco use come from two surveys. The first is a nationally-representative survey conducted in 29 states and the second survey is a large cross-sectional survey conducted in rural Andhra Pradesh. Markers of socioeconomic status (SES) were education, occupation, and income. Multinomial regression analyses were undertaken to examine the socioeconomic determinants of current smoking (cigarettes and bidis) and smoking quit rates. Multivariate models were used to explore determinants of tobacco use by type (cigarettes, bidis, and chewing). Geographic variation in current smoking, chewing and quit rates was quantified using multilevel models.

Results The age adjusted prevalence of smoking in India was 39.2% (95% CI: 34.4-44.5) in men and 5.7% (95% CI: 4.5-7.1) in women compared to 51.7% (95% CI: 48.6-54.7) in men and 5.1% (95% CI: 3.8-6.7) in women in rural Andhra Pradesh. The prevalence of tobacco chewing was 24.3% (95% CI: 23.9-24.6) nationally compared to 5.3% (95% CI: 4.1-6.8) in men and 1.0% (95% CI: 0.5-1.7) in women in rural Andhra Pradesh. The age-adjusted quit rate among ever smokers was 17.6% (95% CI: 14.5-20.8) nationally and

28.6% (95% CI: 24.1-33.3) in Andhra Pradesh. Prevalence of bidi smoking and tobacco chewing were concentrated in the socioeconomically disadvantaged groups defined by occupation, education, and income. Education showed a graded association towards increasing smoking among the least educated with an odds ratio of 2.45 (95% CI: 2.16-2.45) for current smoking among those who were illiterate compared to those who had completed secondary school or higher education. In Andhra Pradesh, this relationship was somewhat stronger with an odds ratio of 3.02 (95% CI: 2.33-3.91). In contrast, the prevalence of cigarette smoking was higher among men with higher levels of education and household income nationally and in Andhra Pradesh. We observed statistically significant geographic variation between states and local areas in current smoking, chewing and quitting. Geographic variation was higher among women compared to men and the magnitude of variation was greatest at the state level.

Conclusions Our findings suggest that in rural communities in India, the burden of tobacco consumption is concentrated among lower SES groups in a similar fashion to what has been observed in the more economically developed urban areas of India. In addition, the large geographic variation observed that was independent of individual characteristics emphasizes the need to determine the causes of the variations both at the state and local levels in order to better inform tobacco control initiatives in India.

INTRODUCTION

Tobacco use is widespread in India, particularly among men and in rural areas.[1-2] The 2009-2010 Global Adult Tobacco Survey in India (GATS India) reported that 47.9% of men over the age of 15 were using tobacco either by smoking or chewing, compared to

20.3% of women (the majority of whom chew tobacco). Furthermore, the overall prevalence of current tobacco use in all forms was more common in rural compared to urban areas (38.4% *v* 25.3%). And with a majority (69.9%)[3] of the Indian population resident in rural areas, this is equivalent to a 3.7-fold greater number of tobacco users (216 million *v* 58.8 million) in these regions.[4] The higher prevalence of tobacco use in rural areas in India is in contrast to the rural-urban patterning of other CVD risk factors such as obesity and diabetes which have generally been found to be higher among urban populations.[5-6]

The most common method of smoking tobacco in India is in the form of ***bidis*** (which are smaller, contain tobacco flakes and are hand-rolled in a temburni leaf[7]) followed by standard cigarettes and hookahs (traditional Indian water pipes).[8] In addition, smokeless tobacco is regularly used in India; consumed by chewing *paan* (betel quid), *paan masala*, or *gutkha* or through the application of powdered tobacco preparations to the teeth and gums (*mishri*).[9-10] Consumption of tobacco in any of these forms is harmful. For example, a nationally-representative study of smoking-related mortality in India reported a statistically significant increase in risk of mortality for bidi and cigarette smoking.[11] In addition, chewing has been associated with an increased risk of oral (including lip and pharynx) cancers in India.[12-13] Indeed, the incidence and mortality from these particular cancers in India is noticeably high.[14-15]

Previous studies have described the socioeconomic determinants of tobacco use nationally[16-18] or urban areas of India[19], with few studies done in rural areas. In this chapter, we present a focus on the socioeconomic patterning of tobacco use in rural areas,

where a majority of tobacco users live. In addition, we use national level surveys to explore geographic patterning of tobacco use and smoking quit rates nationally.

Current evidence on socioeconomic status (SES) determinants of smoking in rural India is limited in at least three ways. First, few studies have reported on the *type* (e.g. cigarettes, bidis) of tobacco consumed by SES in rural India.[20] This is of interest because the relationship with SES may vary by the type of consumption. In general, an inverse relationship (increasing prevalence of consumption among lower SES groups) has been reported for chewing and overall smoking[17, 21-22]; although among urban cigarette users, a positive SES relationship has been reported among the higher educated and those in professional occupations.[23-24] It is not yet clear whether this effect will persist or reverse as India moves through epidemiological transition and the health effects of smoking become clear (see Chapter 4). Second, little is known about SES determinants of the *quantity* of tobacco consumed among regular users, which is of importance in determining risk of tobacco-related disease in this population[25-26], and may be sensitive to SES factors such as income.[27] Lastly, there is no systematic evidence on the SES determinants of smoking cessation and which factors may be related to quitting among former users in rural India.

The primary objective of this chapter was to assess the socioeconomic determinants of tobacco smoking, chewing, and smoking quit rates, and to compare and contrast determinants between men and women and with a specific focus on rural India. In addition, we examine the determinants of the quantity of cigarettes or bidis smoked in rural areas of Andhra Pradesh. There are 2 secondary objectives in this chapter. First, we explore the geographic variability in smoking, chewing, and quit rates between

villages in rural Andhra Pradesh and between local areas and states in India using 2 national surveys. Second, we compare and contrast estimates of current tobacco use and quit rates in rural Andhra Pradesh with national estimates and estimates from other rural parts of India.

METHODS

Data

Analyses from rural India are based on data from a large cross-sectional survey of the prevalence of CVD risk factors in adults in the East and West Godavari districts of Andhra Pradesh.[28] The survey was conducted in 2005 by the Andhra Pradesh Rural Health Initiative (APRHI). The two districts (out of 23 in the state) covered were typical of rural communities in India; they had few large industries, workforces primarily engaged in agricultural activities, and were located about 400km from the state capital, Hyderabad.

Sampling for the survey was carried out in two stages. First, a sample of 20 villages (stratified according to region, population size, and distance from the regional coordinating site) was selected from a list of 88 villages in East and West Godavari which had been enumerated in a population census done in 2002 by the Byrraju Foundation, a local non-governmental organization. Second, age and sex stratified random samples of 400 adults (20 years of age and over) were drawn from each of the 20 villages using household and populations listings collected by the Byrraju Foundation. Of the 400 selected individuals, those who had died or permanently migrated out of the selected villages were excluded from the survey. In total, 5627 eligible individuals were

contacted and, 4535/5627 agreed to participate in the survey yielding a response rate of 80.1%.[28] The final sample size for this analysis was 4533.

National level prevalence data were taken from the nationally-representative Global Adult Tobacco Survey India (GATS India) conducted in 2009-2010.[4] GATS India was a household survey specifically designed to produce internationally comparable data on tobacco use (smoking and smokeless) and other tobacco control indicators. GATS India covered all 29 states and two Union Territories (Chandigarh and Puducherry [Pondicherry]) and targeted household residents aged 15 years and older.

The GATS survey adopted a multistage sampling strategy summarized as follows. In rural areas, two stage sampling was carried out with villages (defined by the 2001 census) as the primary sampling units (PSU). In urban areas, a three-stage sample procedure was carried out, with municipal wards as PSU and census enumeration blocks as secondary sample units. Next, field enumerators undertook a household listing operation to provide the second-stage sample frame in rural areas and third-stage sample frame in urban areas. The selection of households was done through systematic sampling, with a target of 30 households in each of the sampled units. Half of the selected households were designated 'male' (where men would be interviewed) and half 'female' (where women would be interviewed). One individual per household was chosen to participate in selected households using random sampling. The overall household response rate was 97%.[4] The analytic sample size for this survey was 69,049.

Ethical approval for the APRHI study was obtained from the CARE Hospital, Hyderabad and the University of Sydney, Australia. All participants provided informed consent at the time of survey.

Outcome measures

The main outcome measures are as follows: (i) current smoking (either cigarettes or bidis); (ii) use of smokeless tobacco (chewing); (iii) the quantity of cigarettes and/or bidis consumed daily among smokers; and (iv) smoking quit rate (former smoking divided by ever smoking). We describe the definitions of outcome measures in the APRHI survey first. Tobacco use information in APRHI was obtained from survey respondents using a structured questionnaire administered in the local language by trained field staff. Current smoking was defined as the consumption of at least 1 cigarette or bidi (also known as *chuttas* in the geographic area of the APRHI survey) daily for at least 1 year. We separately considered cigarette, bidi, and overall (cigarette or bidi) smoking. Smokers were asked to report a short smoking history which captured the number of cigarettes and/or bidis smoked per day and the number of years of smoking. From this history, we calculated 'pack-years' (a measure of cumulative tobacco exposure)[29], where one 'pack-year' was equal to 20 cigarettes/bidis smoked per day for one year.[30] Former smokers were those who had stopped smoking within the year prior to the survey. Never smoking included lifelong never smokers and those who did not smoke daily. Quit rates were defined as the percentage of ever smokers (current and former smokers) who were former smokers at the time of survey.[4] For chewing tobacco, participants were defined as users if they had consumed chewing tobacco on most days for at least 1 year. Descriptive characteristics of the APRHI survey population are given according to sex and tobacco use history in **Table 3.1**.

GATS India collected data on tobacco use directly from survey respondents. We defined categories of tobacco use to align with the APRHI data, as described above.

GATS India captured the prevalence of tobacco use both in smoked and smokeless forms. In addition, GATS also asked about former/past smoking habits. Descriptive characteristics of the GATS population are given according to sex and tobacco use history in **Table 3.2**.

Demographic and socioeconomic characteristics

Demographic characteristics considered were age and sex. Age was categorized in 10-year groups for descriptive analysis and treated as a continuous variable in regression models. Primary markers of SES were: education, household monthly income (for Andhra Pradesh data only), and occupation. Education was categorized as no education/illiterate, primary school, or secondary school/higher education according to the highest level completed (reference: secondary school/higher). Monthly income was reported by in Indian Rupees (Rs) and participants were categorized into four groups: Rs 0-749 (< US$ 0.50/day), Rs 750-1499 ($.50-1/day), Rs 1500-2999 ($1-2/day), and Rs 3000+ (>$2/day) (reference: Rs 3000+). In the Andhra Pradesh survey, current occupation was recorded according to the standard Indian classification system[31], and we defined the following categories: those who were unemployed/retired, homemakers, unskilled manual workers, skilled manual workers, and business owners/professionals (nonmanual). Professionals were treated as the reference group. In the GATS data occupation was categorized using the following groups: professionals, those who were self-employed, students, homemakers, and those who were unemployed/retired (reference: professionals). In the GATS, we included a variable to indicate place of residence (rural or urban), defined according to the 2001 Census.[4]

Statistical analysis

We carried out the following statistical analyses on the study data which corresponded to each of the chapter objectives:

1. A multinomial model to examine the socioeconomic patterning of current smoking and quit rates
2. A multivariate multilevel model of chewing, bidi smoking, and cigarette smoking
3. A two-step generalized linear model to examine daily and lifetime cigarette/bidi consumption
4. Multilevel models to examine geographic variation in current smoking and quit rates between local areas and states

A description of each of the statistical models is given below. First, in the multinomial model, overall smoking was examined as a categorical outcome with categories for current smoking (cigarettes and bidis combined), former smoking, or never smoking (Equation 3.1). Formally, y_i is the categorical smoking outcome with *t* categories for individual *i*, with the probability of being in category *s* (current or former smoking) given as $\pi_i^{(s)} = \Pr(y_i = s)$. In this model, never smoking was defined as the reference category and a set of $t-1$ logistic regressions were estimated, which separately compared the probability of current smoking or former smoking to the reference category (never smoking) conditional on the independent variables X (age, sex, occupation, education, and income) and written as:

$$\log\left(\frac{\pi_i^{(s)}}{\pi_i^{(t)}}\right) = \beta_0^{(s)} + \beta^{(s)}\mathrm{X}, s = 1,\ldots t-1. \qquad \text{(Equation 3.1)}$$

In this model, separate intercept and slope parameters, $\beta_0^{(s)} + \beta^{(s)}\mathrm{X}$, were estimated for the current smoking and former smoking categories, as indicated by the *s* superscripts. Model estimates are interpreted as in logistic regression models and, for interpretation, we present the exponent of the coefficients as odds ratios (OR).[32] Robust standard errors were implemented to account for clustering at the local area (and state) level. We used a random simulation procedure[33] to derive the predicted probability (prevalence) of current smoking and the quit rates (former smoking divided by ever smoking) from the fitted model for different values of the independent variables conditional on covariates. Quadratic and cubic terms were included for age to allow for non-linear relationships with current and former smoking.

Second, we used a multivariate multilevel model[34] to simultaneously examine tobacco use across three forms of consumption: chewing (y_1), bidi smoking (y_2), and cigarette smoking (y_3). In this model, use of each form of tobacco was modelled as a dichotomous outcome, Pr($y_{1j} = 1$), assumed to be binomially distributed $y_{1j} \sim Binomial(1, \pi_{1j})$ with probability π_{1j} related to the independent variables X (age, sex, occupation, education, and income) by a logit link function:

$$\begin{cases} Logit(\pi_{1j}) = \beta_0 + \beta \mathrm{X} chewing_{ij} \\ Logit(\pi_{2j}) = \beta_0 + \beta \mathrm{X} bidi_{ij} \\ Logit(\pi_{3j}) = \beta_0 + \beta \mathrm{X} cigarette_{ij} \end{cases} . \qquad \text{(Equation 3.2)}$$

This analytical framework allowed for the nesting of tobacco use behaviours (denoted by the subscript *i*) within individuals (denoted by subscript *j*) and provided two important substantive benefits for the present analysis. First, from this model it was possible to assess the consistency of the relationship between individual socioeconomic

and demographic characteristics and tobacco use across each of the forms of consumption. Second, the residual covariance estimated at the level of individuals provided an indication of the degree to which the use of different forms of tobacco were 'correlated' within individuals.[35]

Third, we examined patterns of daily and lifetime cigarette/bidi consumption of cigarettes and bidis using a two step generalized linear model. In this model, a logistic regression was estimated in the first stage for the probability of current smoking, $\Pr(y_i > 0)$, then a linear regression on the number of cigarettes/bidis consumed per day (or pack-years), conditional on $y_i > 0$.[36] Separate models were estimated for the number of cigarettes/bidis smoked per day and pack-years and were mutually adjusted for age, sex, occupation, education, and income. Estimates were summarized as the predicted mean numbers of cigarettes/bidis per day and pack years across demographic and socioeconomic characteristics using simulation.

Fourth, we carried out analyses to examine geographic variation in current smoking and quit rates between villages in Andhra Pradesh and between local areas (villages or census block primary sampling units) and states across India. In these analyses, we employed multilevel logistic regression.[35] Two-level models (individuals nested within villages) were used for the Andhra Pradesh data and three-level models (individual nested within local areas, within states) were used with national level data. We describe the three-level model for current smoking below. In this model, the probability of current smoking, $\Pr(y_{ijk} = 1)$, for individual *i* in local area *j* and in state *k*, was assumed to be binomially distributed $y_{ijk} \sim Binomial(1, \pi_{ijk})$ with probability

π_{ijk} related to independent variables X (age, sex, education, income, occupation, urban/rural location) and a random effect for each level by a logit link function:

$$Logit(\pi_{ijk}) = \beta_0 + \beta X_{ijk} + (v_{0k} + u_{0jk}). \quad \text{(Equation 3.3)}$$

The right hand side of Equation 3.3 consists of the fixed part linear predictor ($\beta_0 + \beta X_{ijk}$) and random intercepts for states (v_{0k}) and local areas (u_{0jk}). The intercept, β_0 represents the overall log odds of current smoking for an individual in the reference group, and the β-coefficients represent the differential in the log odds of current smoking compared to the reference group defined for each independent variable. Terms in brackets are random intercepts and these terms indicate between-state (v_{0k}) and between local area (u_{0jk}) variability in current smoking after allowing for individual characteristics in the fixed part of the model. The random terms are assumed to be independently and identically distributed and have variances estimated for states (σ_v^2) and local areas (σ_u^2).[37] The variance parameters quantify the variability in current smoking at each level, and we expressed the variances at each level as a percentage of their contribution to the total variance from an initial model adjusting for age and sex only and from a final model accounting for all covariates. All multilevel models accounted for the complex survey design and produced corrected standard errors. Sampling weights provided with each of the surveys were implemented for descriptive analyses. Statistical analyses were conducted using Stata (version 11.2)[38] and MLwiN (version 2.25).[39]

RESULTS

Tobacco use in India

Nationally in India, the age adjusted prevalence of current smoking (cigarettes or bidis) was 39.2% (95% CI: 34.4-44.5) in men and 5.7% (95% CI: 4.5-7.1) in women. Smoking was more common in rural areas: the prevalence in men was 41.4% (95% CI: 36.3-46.8) in rural areas and 33.5% (95% CI: 28.6-38.7) in urban areas. In the APRHI population, the age adjusted prevalence of smoking was 51.7% (95% CI: 48.6-54.7) in men and 5.1% (95% CI: 3.8-6.7) in women. The age and sex adjusted prevalence of chewing was 25.4% (95% CI: 25.0-25.9) nationally (19% in urban areas and 30% in rural areas), compared to only 2.2% (95% CI: 1.5-3.0) in rural Andhra Pradesh (APRHI).

Among ever smokers in India, 17.6% (95% CI: 14.5-20.8) had quit, compared to 28.6% (95% CI: 24.1-33.3) in Andhra Pradesh. In the Andhra Pradesh samples, rates of quitting were higher in women (41.1%; 95% CI: 31.6-50.7) compared to men (18.3%; 95% CI: 15.4-21.5) although rates were roughly even in the national data (17.7% in men vs 16.8% in women). The majority of current smokers in India smoke bidis. In the GATS survey, 47.6% of smokers smoked only bidis, while 29.5% smoked only cigarettes and 22.9% smoked a combination of bidis and cigarettes. Overall in the APRHI population, 37.5% (95% CI: 34.7-40.6) of men smoked bidis and 9.3% (95% CI: 8.1-10.7) smoked cigarettes. In women, 5.1% (95% CI: 3.8-6.7) smoked bidis and there were no cigarette smokers.

Focusing on the APRHI data, we present the results of the mutually adjusted multinomial model. In this model, age and sex emerged as important determinants of current and former smoking. A 10-year increase in age was associated with an odds ratio

of 1.64 (95% CI: 1.30-2.07) for current smoking. The relationship between current smoking and age is shown graphically in **Figure 3.1a** for men and women between the ages of 20 and 80 years. Among men, the relationship was not linear: the prevalence increased from less than 10% at age 20 to 46% at age 63 before beginning to decline. The prevalence of smoking among females rose steadily with age from less than 1% until age 30 to 14.4% by the age 80, although estimates had a greater amount of uncertainty in old age (95% CI: 8.6-22.1 for an 80-year old woman). Men were found to be considerably more likely to be current smokers than women (OR: 13.40, 95% CI: 9.45-18.99). Smoking quit rates increased with age in men and remained relatively stable with age in women, although quit rates were estimated with greater uncertainly in women due to fewer current and former smokers (**Figure 3.1b**).

Quitting smoking in Andhra Pradesh was nearly two times more common among women than among men, and the ratio of female to male quitting was 1.99 (95% CI: 1.37-2.74) (not shown). The corresponding ratio in the national data was 0.95 indicating similar rates of quitting between men and women. In the Andhra Pradesh data it was possible to estimate the number of the number of cigarettes/bidis smoked daily and pack-years by different groups. Overall, men consumed an average of 7 (95% CI: 6.9-7.9) cigarettes/bidis per day and had 7.7 (95% CI: 7.1-8.4) pack years of exposure, compared to 4 (95% CI: 2.6-5.0) bidis consumed per day among women and 2.0 (0.7-3.4) pack-years of exposure. The higher number of pack years among men indicates a greater level of cigarettes/bidi consumption over a longer period compared to women. Due to the way the questionnaire was designed in this study and the GATS survey, it was not possible to estimate the rates of quitting among users of chewing tobacco.

Socioeconomic patterning of current smoking, chewing, and smoking quit rates

Education showed a graded association towards increasing smoking among the least educated with an odds ratio of 2.45 (95% CI: 2.16-2.45) for current smoking among those who were illiterate compared to those who had completed secondary school or higher education. In the analysis of the Andhra Pradesh data, occupation, education, and income were independently rated to current smoking in the mutually adjusted multinomial model (**Table 3.3**). Current smoking was higher among those who were unemployed (OR: 1.55, 95% CI: 1.03-2.34) or working in unskilled manual occupations (OR: 1.58, 95% CI: 1.15-2.17), compared to professionals. Education also showed a graded association towards increasing smoking among the least educated with an odds ratio of 3.02 (95% CI: 2.33-3.91) for current smoking among those who were illiterate. In these data, a negative association was observed between current smoking and income, although the strength of this association was not as pronounced as for education.

By expressing former smoking in terms of quit rates, the socioeconomic patterning of cessation becomes apparent. Nationally, the odds ratio for quitting was 1.89 (95% CI: 1.64-2.19) for those with secondary or higher education compared to those without formal education (**Figure 3.2**). In Andhra Pradesh, quitting was 1.8-fold higher in men and 1.5-fold higher in women among those with secondary or higher education compared to those who were illiterate (**Table 3.4**). Interestingly, for both men and women, quit rates were greatest among those at the lowest level of income (<750 Rs per month), although quitting showed a graded increase with rising levels of income across the three remaining categories.

The results from the multivariate multilevel model (Equation 3.2) are summarized for chewing, bidi smoking, and cigarette smoking by education and income in Figure 3.2 and Figure 3.3. This model revealed a distinct patterning of tobacco use across SES markers and form of tobacco consumption. The prevalence of chewing declined with increasing education in men from 45.3% among those who were illiterate to 26.6% among those with a secondary or higher level of education (Figure 3.2). In Andhra Pradesh, the prevalence of chewing was lower and a statistically significant gradient with education was not found. Rates of chewing declined from 4.6% among illiterates to 3.0% among those who had completed secondary education ($p=0.27$). In Andhra Pradesh we also examined the relationship with chewing and income. Rates of chewing remained relatively constant across categories of income at about 4% in men and 1% in women.

Among men, bidi smoking demonstrated a strong inverse gradient with education: the adjusted prevalence was 30.8% (95% CI: 29.6-32.2) among the least educated and 8.8% (95% CI: 8.4-9.3) among those with secondary or higher education ($p<0.0001$) (Figure 3.2). A similar gradient between bidi smoking and education was observed among men in Andhra Pradesh (34.8% in illiterates compared to 8.0% among highest educated, Figure 3.3). Findings were generally similar in women, with rates of bidi smoking varying between 2.2% and 0.5% among the least and highest educated nationally and between 6.3% and 1.1% (95% CI: 0.7-1.5) in Andhra Pradesh. In Andhra Pradesh, a corresponding inverse relationship was observed between the prevalence of bidi smoking and increasing income among men and women although the strength of this gradient in absolute terms was not as strong as for education ($p=0.0013$). In men, a strong positive association was observed between SES and cigarette smoking that was

consistent for education and income (Andhra Pradesh only). Nationally, the prevalence of cigarette smoking was 8.6% (95% CI: 7.9-9.4) among those who were illiterate and this increased to 13.1% (95% CI: 12.5-13.6) for those with a secondary or higher level of education (Figure 3.2). The relationship was similar in Andhra Pradesh, the rate of cigarette smoking was 3.8% (95% CI: 3.1-4.6) among the least educated and rose to 9.2% (95% CI: 7.3-11.4) among the highest educated (Figure 3.3). This relationship was less consistent among women in the GATS data and could not be assessed in the APRHI sample because no women in this survey reported smoking cigarettes.

Table 3.5 presents the adjusted estimates of the typical amount of tobacco consumption (number of cigarettes/bidis smoked per day and pack years) in current smokers by SES characteristics using the APRHI data. In general, measures of tobacco consumption were higher among those from higher SES groups. In terms of occupation, professionals consumed the greatest number of cigarettes/bidis per day with an average of 8.6 (95% CI: 7.7-9.5) smoked per day in men and 5.0 (95% CI: 3.6-6.4) in women ($p=0.0004$). Graded increases were observed in the number of cigarettes/bidis smoked per day and pack years across increasing levels of education and income (Table 3.4) ($p<0.0001$). At the lowest level of income (Rs 0-749 per month), men typically smoked 6.3 (95% CI: 5.4-7.4) cigarettes/bidis per day and women smoked 2.8 (95% CI: 1.4-4.2); this increased to 9.1 (95% CI: 8.4-9.8) and 5.5 (95% CI: 4.2-6.9) per day at the highest level of income (Rs 3000+ per month) among men and women, respectively.

Geographic variation in current smoking, chewing, and smoking quit rates

Analyses of the GATS study revealed that, at the state level in India, the overall prevalence of current smoking varied from 9.9% in Goa to 66.3% in Meghalaya in men and from <0.1% in Kerala to 20.5% in Mizoram in women with the prevalence generally higher in northern and northeastern states (**Figure 3.4**). A similar pattern was observed for women, although the prevalence of current smoking among women was <1% across much of Southern India. Chewing was more common among women than smoking; rates varied considerably between states from 0.03% in Himachal Pradesh to 55.3% in Mizoram. Among men rates of chewing were also high and varied from 7.2% in Haryana to 57.7% in Bihar. The prevalence of chewing in India was strongly patterned by geography; it was lower in the south and north, and higher in the east/northeast with an increasing gradient from west to east (**Figure 3.5**). Quit rates for smoking were calculated at the state level from the GATS India data. Quit rates were more uniform across states and were generally low; combined male and female quit rates were less than 10% in two thirds (21/31) of states and union territories, compared to the national (unadjusted) average of 10.6% (**Figure 3.5**).

We examined geographic variability across local areas and states in India using multilevel models. Variance estimates from these models are displayed in **Table 3.6**. In these analyses, two sets of models were estimated for each outcome separately for men, women, and the combined sample. The first model accounted for age and sex (in the combined model) and the second model additionally accounted for education, income (in APRHI models only), and occupation. These analyses indicated that geographic variation in current smoking, chewing, and quit rates was not entirely explained by

individual socioeconomic characteristics. In addition, further adjustment for socioeconomic characteristics increased between geographic differences (especially at the state level). For example, in the first model accounting for age and sex, geographic variation at the state level accounted for 13.6% of the total variation in current smoking for men and women combined. The addition of socioeconomic characteristics to the model increased the proportion of variance at the state level to 14.8%, representing an increase of 8.7%. In contrast, variance at the level of local areas was generally reduced following the inclusion of socioeconomic characteristics to the model. In mutually adjusted models, the magnitude of between state variation was greatest for chewing overall and among men (followed by current smoking and quitting); while among women between state differences were largest for current smoking (followed by quitting and chewing). In general, all variance estimates were statistically significant at the $p<0.05$ level with two exceptions. First, estimates of between village variation in the APRHI data were generally smaller in magnitude and less statistically reliable likely due to fewer numbers of higher-level units (20 villages) and the specific geographical coverage of the survey area. Second, the variance estimates for quit rates among women were not statistically significant between local areas in the GATS data, likely due to few numbers of women reporting quitting within a specific local area.

Comparison of estimates from Andhra Pradesh to national data

The prevalence of current smoking in the APRHI population (20.6%) was slightly higher than the National Family Health Survey (18.2%) and GATS (18.6%).[2] The combined prevalence of chewing was lower in the APRHI population (5%) compared to

the overall rates for rural India (21.6%) in the National Family Health Survey, but comparable to rural areas of Andhra Pradesh (8.3%).[4] The prevalence of smoking by age and sex in APRHI was largely consistent with what has been reported among controls in a nationally-representative case-control study of smoking-related mortality.[11] In addition, the GATS reported an average consumption of 5.1 cigarettes and 11.1 bidis per day among smokers in Andhra Pradesh; comparable to our estimate of an average daily consumption of 5.5 units (7.7 cigarettes/bidis in men and 3.8 bidis in women) in APRHI, but lower than high income countries such as Canada, where the average consumption was found to be 15 cigarettes per day among current smokers (See Chapter 6).[40] Low quit rates have generally been reported in India. A study done in Mumbai (Bombay) in 1992-4 reported that 5.4% of male bidi smokers and 12.9% of male cigarette smokers had quit[19], while a study done in four urban centres (Chandigarh, Delhi, Kanpur, and Bangalore) reported that 9.4% of ever smokers had quit.[41] In our calculations from the GATS study, we found the rate of quitting to be 10.9% among ever smokers in rural areas nationally and 11.0% in rural areas of Andhra Pradesh.[4] In comparison, the adjusted rates of quitting in the APRHI survey were higher (28.6% among men and women combined). Similar to our findings of higher quit rates among women, the GATS data show quit rates of 14.7% among women and 10.3% among men in rural areas.

DISCUSSION

Our study provided several key findings on the socioeconomic and geographic patterning of tobacco use and smoking quit rates among men and women in India. First, tobacco use was concentrated in lower SES groups in rural Andhra Pradesh and the SES

gradients observed were largely similar to what has been seen in India as a whole[17-18] and in high-income countries.[42-44] Second, we identified considerable geographic variation in the prevalence of current smoking and chewing between states and local areas which was independent of demographic and socioeconomic characteristics. Geographic variation in tobacco use was especially large at the state level and for women. In addition, geographic variability in tobacco use was also observed on a smaller scale between villages in rural Andhra Pradesh. Third, there appears to be some heterogeneity in the SES-tobacco use relationship across different types of tobacco consumption. Bidi smoking and chewing were concentrated in the socioeconomically disadvantaged groups defined by occupation, education, and income. In contrast, the prevalence of cigarette smoking was consistently higher among men with greater levels of education and household income nationally and in rural Andhra Pradesh. Finally, slightly less than a third of ever smokers in APRHI population had quit compared to 11% across rural India. In addition, quitting was less consistently patterned by geography although there was statistically significant variation in quit rates between states. At the individual level, quitting was higher among women and those with greater levels of education.

Before examining these findings in greater detail, we present some limitations of the present study. First, the outcomes related to tobacco use were recorded in all surveys analyzed here on basis of self-reports. Interviews in these surveys, however, were conducted directly with respondents and thus avoided potential reporting bias associated with household/proxy respondents.[16] In addition, previous studies have demonstrated validity[45-46] and reliability[47] of self-reported smoking in epidemiological surveys. Second, data limitations due to questionnaire design did not allow us to separately

analyze cessation in the use of chewing tobacco or to differentiate among former smokers between those who smoked bidis and those who smoked cigarettes. Finally, the primary analyses of the APRHI data were based on relatively simple markers of SES and we were not able to investigate the patterns of tobacco use by social caste, religion, or by marital status in this population, although our analyses in the GATS revealed a consistency of tobacco use patterns in a national survey. Indeed, gradients in tobacco use and smoking quit rates emerged by SES (particularly for education) in the APRHI study despite the relatively simple markers used. In addition, patterns of tobacco were relatively consistent whether using income (collected in APRHI) or what has been reported for an asset-based index of household wealth (collected in the National Family Health Survey).[17]

Several aspects of our findings related to the SES patterning of tobacco use and smoking cessation in this population deserve mention. First, in this study we observed an inverse association between markers of SES and overall smoking (with higher prevalence of smoking among those without education, at the lowest levels of income, and amongst manual workers) which was largely consistent with previous data from India.[17-18] The prevalence of chewing was also higher among the lower educated and manual workers in the APRHI population, but its relationship with income was less consistent. These findings are of importance because they demonstrate that even within a relatively poor (median monthly income: Rs 1500/US $30), rural community the burden of smoking was concentrated among lower SES groups in a similar fashion to what has been observed in the more economically developed urban areas of India[24] and in high income countries.[48] Second, the SES patterning of tobacco use varied by the form of consumption. In contrast to bidi smoking, we found that the prevalence of cigarette smoking was higher

among the wealthier, educated men in this population. Similar patterns of greater cigarette use among educated professionals have been seen in urban samples in Delhi[23], Mumbai[19, 24] and in the whole of India[4], but the present study has clearly demonstrated a similar finding in a rural setting. These findings implicitly suggest that among individuals smokers of higher status or with more disposable income there is a tendency to smoke cigarettes (which are relatively more expensive), as opposed to bidis (which are inexpensive).[49] Third, although levels of tobacco consumption were lower in this population compared to high income countries, the observed levels of daily cigarette/bidi consumption still carry considerable risk. A large nationally-representative study of smoking-related mortality in India reported a statistically significant increase in risk of mortality for smoking an average of 4 bidis (RR 1.3) or cigarettes (RR 1.8) per day[11]; which is comparable to the average level of consumption among women in the APRHI population and half of the average daily consumption for men. In addition, we observed that levels of consumption increased among those with higher status occupations and among those at higher levels of income and education both in men and women. This again suggests a financial aspect to patterns of consumption; individual smokers with more resources available may tend to smoke in greater amounts which in turn may have implications for changing population patterns of tobacco consumption that could be expected with increasing economic prosperity in India. Lower average levels of consumption in India compared to high-income countries could be related to access to cigarettes/bidis in single units or smaller pack sizes. In a study of 86 communities in 5 states in India it was found that cigarettes/bidis were most commonly available in pack sizes containing less than 10 units, compared to Canada where nearly all pack sizes

contained at least 20-25 ciagarettes.[50] Finally, we observed a distinct patterning of tobacco cessation according to SES; in APRHI at the highest levels of education nearly a third of men and over half of women who were ever smokers had quit. Although we could not assess the patterns of cessation among former users of other forms of tobacco; the quit rates for smoking in this sample (especially at higher levels of education) appeared substantial when compared to other studies from India. Screening programs for diabetes and hypertension carried out in the APRHI study area by the Byrraju Foundation could have disseminated awareness of the advesere effects of smoking and thus contributed to higher levels smoking cessation compared to the national average. For example, among smokers in this population, knowledge of the benefits of smoking cessation was associated with an increased likelihood in attempting to quit (OR 3.7).[51]

At an individual level in India, socioeconomically disadvantaged groups are at greatest risk of tobacco use and these groups appear to be less likely to become quitters. Similar patterns have been reported in high-income countries and in other low- and middle-income countries.[21] Geographic variability, especially between states, was large in magnitude (15% for current smoking, 21% for chewing) compared to Canada (~1-2% at the provincial level, see Chapters 2 and 5). This finding is of interest and one possible explanation is that different states in India may be at different stages of the tobacco use epidemic.[27] Within India, states vary tremendously by level of economic development and stages of epidemiological transition and this may have implications on tobacco use patterns. In addition, social factors within states are likely to be important in contributing to the geographic variation in tobacco use behaviour across India. For example social/ cultural norms regarding the acceptability of smoking may be an important factor driving

the large state level variation seen in tobacco use among women. The unexplained geographic variation observed in the present study emphasizes the need to determine the causes of the variations both at the state and local levels.

Tobacco use remains high in India, particularly among men: nearly one third of men were smokers nationally and this increased to 1 in 2 in rural Andhra Pradesh, compared to less than 20% in Canada. Rates of chewing are also substantial especially in certain geographical areas and chewing was more common than smoking among women. The majority of the world's tobacco users live in low and middle income countries[52], with 275 million tobacco users (111 million smokers) in India.[4] The various forms of tobacco use in India, each with different socioeconomic and demographic distributions will continues to pose a challenge for tobacco control efforts.[53] Our findings demonstrate the need to determine the causes of the large variations in tobacco use patterns across India. Further understanding of the contextual determinants of smoking in India will be essential to target tobacco control strategies to reduce uptake and increase cessation in order to reduce the burden of tobacco related diseases and mortality in India.

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TABLES

Table 3.1 Sample sizes and estimates (%) of current smoking, former smoking, never smoking, and quit rates for men and women by demographic and socioeconomic characteristics. Andhra Pradesh Rural Health Initiative (APRHI) study 2005.

Variables	Men								Women							
	Regular smoker		Former smoker		Non smoker		Quit rate	Total	Regular smoker		Former smoker		Non smoker		Quit rate	Total
	n	%	n	%	n	%	%	n	n	%	n	%	n	%	%	n
Total	1034	46.9	267	12.1	904	41.0	20.5	2205	120	5.2	96	4.1	2112	90.7	44.4	2328
Age																
20-39 yrs	193	37.6	24	4.7	296	57.7	11.1	513	8	1.2	9	1.3	663	97.5	52.9	680
40-49 yrs	257	48.7	48	9.1	223	42.2	15.7	528	24	4.2	17	3.0	524	92.7	41.5	565
50-59 yrs	250	50.6	63	12.8	181	36.6	20.1	494	33	6.7	25	5.1	432	88.2	43.1	490
60+ yrs	334	49.9	132	19.7	204	30.4	28.3	670	55	9.3	45	7.6	493	83.1	45.0	593
Occupation																
Unemployed/retired	114	42.9	70	26.3	82	30.8	38.0	266	21	13.8	12	7.9	119	78.3	36.4	152
Homemaker	2	40.0	-	-	3	60.0	-	5	36	3.0	33	2.7	1147	94.3	47.8	1216
Unskilled manual	770	51.3	148	9.9	582	38.8	16.1	1500	62	7.1	51	5.8	759	87.0	45.1	872
Skilled manual	62	41.9	10	6.8	76	51.4	13.9	148	-	-	-	-	51	100.0	-	51
Professional/nonmanual	86	30.1	39	13.6	161	56.3	31.2	286	1	2.7	-	-	36	97.3	-	37
Education																
None/illiterate	609	56.8	116	10.8	348	32.4	16.0	1073	112	7.8	83	5.8	1233	86.3	42.6	1428
Primary	275	47.3	75	12.9	231	39.8	21.4	581	8	1.3	9	1.4	617	97.3	52.9	634
Secondary or higher	150	27.2	76	13.8	325	59.0	33.6	551	0	0.0	4	1.5	262	98.5	100.0	266

Monthly income																
0-749 Rs	89	53.3	24	14.4	54	32.3	21.2	167	33	10.0	34	10.3	263	79.7	50.7	330
750-1499 Rs	295	51.4	62	10.8	217	37.8	17.4	574	31	5.2	20	3.3	548	91.5	39.2	599
1500-2999 Rs	449	47.0	106	11.1	400	41.9	19.1	955	47	5.0	32	3.4	852	91.5	40.5	931
3000+ Rs	201	39.5	75	14.7	233	45.8	27.2	509	9	1.9	10	2.1	449	95.9	52.6	468
Use of chewing tobacco																
No	954	45.6	255	12.2	885	42.3	21.1	2094	111	4.8	95	4.1	2098	91.1	46.1	2304
Yes	80	72.1	12	10.8	19	17.1	13.0	111	9	37.5	1	4.2	14	58.3	10.0	24

Table 3.2 Sample sizes and estimates (%) of current smoking, former smoking, never smoking, and quit rates for men and women by demographic and socioeconomic characteristics. Global Adult Tobacco Survey, India 2009-2010.

Variables	Men								Women							
	Current smoking		Former smoking		Never smoking		Quit rate	Total	Current smoking		Former smoking		Never smoking		Quit rate	Total
	n	%	n	%	n	%	%	n	n	%	n	%	n	%	%	n
Total	10210	30.3	1731	5.1	21735	64.5	14.5	33676	1340	3.8	249	0.7	33784	95.5	15.7	35373
Residence																
Urban	3415	25.2	557	4.1	9575	70.7	14.0	13547	255	1.8	49	0.4	13572	97.8	16.1	13876
Rural	6795	33.8	1174	5.8	12160	60.4	14.7	20129	1085	5.0	200	0.9	20212	94.0	15.6	21497
Age																
15-24 yrs	875	14.2	115	1.9	5182	84.0	11.6	6172	60	0.8	9	0.1	7142	99.0	13.0	7211
25-34 yrs	2246	27.9	269	3.3	5533	68.8	10.7	8048	220	2.2	26	0.3	9923	97.6	10.6	10169
35-44 yrs	3032	35.1	363	4.2	5242	60.7	10.7	8637	316	3.9	47	0.6	7724	95.5	12.9	8087
45-54 yrs	2127	39.7	312	5.8	2925	54.5	12.8	5364	283	5.9	61	1.3	4490	92.9	17.7	4834
55-64 yrs	1100	36.9	293	9.8	1589	53.3	21.0	2982	234	8.1	51	1.8	2594	90.1	17.9	2879
65+ yrs	830	33.6	379	15.3	1264	51.1	31.3	2473	227	10.4	55	2.5	1911	87.1	19.5	2193
Occupation																
Professional	3434	29.4	567	4.9	7678	65.7	14.2	11679	184	4.3	25	0.6	4026	95.1	12.0	4235
Self-employed	5260	34.4	729	4.8	9284	60.8	12.2	15273	252	5.9	39	0.9	3995	93.2	13.4	4286
Student	257	8.4	27	0.9	2776	90.7	9.5	3060	17	0.6	2	0.1	2690	99.3	10.5	2709
Homemaker	316	45.0	58	8.3	329	46.8	15.5	703	783	3.4	155	0.7	22117	95.9	16.5	23055
Unemployed/retired	932	31.9	345	11.8	1649	56.4	27.0	2926	88	8.8	24	2.4	886	88.8	21.4	998
Not reported	11	31.4	5	14.3	19	54.3	31.3	35	16	17.8	4	4.4	70	77.8	20.0	90
Education																
None/illiterate	2602	42.7	401	6.6	3091	50.7	13.4	6094	940	7.4	183	1.4	11569	91.2	16.3	12692
Primary	3167	37.7	504	6.0	4737	56.3	13.7	8408	247	3.1	44	0.6	7582	96.3	15.1	7873
Secondary or higher	4441	23.2	826	4.3	13907	72.5	15.7	19174	153	1.0	22	0.1	14633	98.8	12.6	14808

Use chewing tobacco																
No	6698	28.6	1039	4.4	15714	67.0	13.4	23451	794	2.8	159	0.6	27895	96.7	16.7	28848
Yes	3512	34.3	692	6.8	6021	58.9	16.5	10225	546	8.4	90	1.4	5889	90.3	14.2	6525

Table 3.3 Mutually adjusted odds ratios and 95% confidence intervals from the multinomial regression model of current and former smoking. APRHI study 2005.

			Regular smoking		Former smoking	
Variable	**Reference group**	**Parameter**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Age		Age (10 year change)	1.64	(1.30 - 2.07)	1.66	(1.28 - 2.15)
Gender	Female	Male	13.40	(9.45 - 18.99)	5.17	(3.35 - 7.98)
Occupation	Professional	Unemployed/retired	1.55	(1.03 - 2.34)	1.42	(0.86 - 2.34)
		Homemaker	0.54	(0.32 - 0.90)	0.45	(0.25 - 0.81)
		Unskilled manual	1.58	(1.15 - 2.17)	1.18	(0.78 - 1.80)
		Skilled manual	1.34	(0.85 - 2.13)	0.64	(0.30 - 1.37)
Education	Secondary or higher	None/illiterate	3.02	(2.33 - 3.91)	1.46	(1.04 - 2.06)
		Primary	1.76	(1.33 - 2.31)	0.93	(0.64 - 1.35)
Monthly income	3000+ RS	0-749 RS	1.66	(1.17 - 2.36)	1.70	(1.12 - 2.59)
		750-1499 RS	1.19	(0.91 - 1.55)	0.95	(0.66 - 1.36)
		1500-2999 Rs	1.14	(0.89 - 1.45)	1.02	(0.74 - 1.41)
Use chewing tobacco	No	Yes	3.97	(2.42 - 6.51)	2.43	(1.21 - 4.87)
Use Alcohol	No	Yes	3.86	(3.07 - 4.87)	1.20	(0.81 - 1.77)
Aware of smoking harms	No	Yes	1.06	(0.88 - 1.27)	1.42	(1.10 - 1.82)

Table 3.4 Adjusted prevalence of current smoking and quit rates for men and women by demographic and socioeconomic characteristics. APRHI study 2005.

	Men						Women					
	Regular smoking			Quitting			Regular smoking			Quitting		
Characteristic	**%**	**95% CI**		**%**	**95% CI**		**%**	**95% CI**		**%**	**95% CI**	
Total	44.1	(39.7	- 48.5)	21.0	(16.6	- 25.9)	6.6	(5.0	- 8.5)	40.9	(31.1	- 51.1)
Occupation												
Unemployed/retired	48.9	(41.3	- 56.6)	23.7	(16.9	- 32.1)	8.7	(5.8	- 12.4)	44.6	(31.4	- 59.0)
Homemaker	29.6	(21.1	- 39.0)	22.5	(12.8	- 34.6)	3.4	(2.2	- 4.9)	42.5	(29.5	- 56.3)
Unskilled manual	50.7	(47.1	- 54.5)	20.1	(16.5	- 24.0)	8.9	(6.6	- 11.7)	39.7	(29.0	- 50.9)
Skilled manual	49.6	(40.5	- 59.3)	14.4	(7.2	- 24.8)	8.0	(5.0	- 11.9)	30.3	(15.7	- 48.8)
Professional/nonmanual	40.5	(33.5	- 47.5)	25.2	(17.8	- 33.8)	5.9	(3.9	- 8.6)	46.6	(32.0	- 61.6)
Education												
None/illiterate	51.6	(46.6	- 56.5)	18.5	(14.3	- 23.5)	9.0	(6.9	- 11.5)	37.2	(27.9	- 47.1)
Primary	40.5	(35.2	- 45.9)	20.0	(14.7	- 26.2)	5.6	(4.1	- 7.5)	39.4	(28.4	- 51.1)
Secondary or higher	27.7	(22.7	- 33.0)	32.0	(24.3	- 40.8)	3.3	(2.3	- 4.6)	54.8	(41.8	- 67.5)
Monthly income												
0-749	49.8	(41.8	- 57.9)	23.2	(16.0	- 31.7)	9.0	(6.4	- 12.3)	43.9	(31.9	- 56.4)
750-1499	45.1	(39.6	- 50.7)	19.0	(14.0	- 24.9)	6.8	(5.1	- 9.1)	37.9	(27.4	- 49.2)
1500-2999	43.6	(38.7	- 48.4)	20.9	(16.1	- 26.3)	6.5	(4.9	- 8.5)	40.8	(30.2	- 51.7)
3000+	40.6	(34.8	- 46.5)	22.7	(16.7	- 29.9)	5.8	(4.2	- 7.8)	43.3	(31.7	- 55.4)
Use of chewing tobacco												
No	43.2	(38.8	- 47.6)	21.2	(16.8	- 26.2)	6.4	(4.9	- 8.2)	41.2	(31.3	- 51.4)
Yes	69.6	(59.7	- 78.5)	14.4	(7.7	- 23.8)	20.4	(13.0	- 29.9)	30.3	(16.8	- 46.4)

Table 3.5 Adjusted mean numbers of cigarettes/bidis smoked per day and pack-years for men and women by demographic and socioeconomic characteristics. APRHI study 2005.

	Men				Women			
	Cigarette/Bidi per day		Pack years		Bidi per day		Pack years	
	Number	95% CI	Number	95% CI	Number	95% CI	Number	95% CI
Total	7.4	(6.9 - 7.9)	7.7	(7.1 - 8.4)	3.8	(2.6 - 5.0)	2.0	(0.7 - 3.4)
Occupation								
Unemployed/retired	7.4	(6.5 - 8.4)	7.9	(6.5 - 9.3)	3.9	(2.4 - 5.4)	2.2	(0.5 - 3.8)
Unskilled manual	6.7	(6.2 - 7.1)	7.1	(6.5 - 7.6)	3.1	(1.9 - 4.3)	1.4	(0.1 - 2.5)
Skilled manual	6.4	(5.3 - 7.6)	6.8	(5.1 - 8.7)	2.9	(1.2 - 4.6)	1.0	(0.0 - 2.9)
Professional/nonmanual	8.6	(7.7 - 9.5)	8.8	(7.4 - 10.1)	5.0	(3.6 - 6.4)	3.1	(1.7 - 4.5)
Education								
None/illiterate	7.0	(6.4 - 7.5)	7.4	(6.9 - 7.9)	3.4	(2.2 - 4.6)	1.6	(0.6 - 2.6)
Primary	7.1	(6.4 - 7.7)	7.4	(6.8 - 8.1)	3.5	(2.2 - 4.8)	1.7	(0.5 - 2.8)
Secondary or higher	9.1	(8.3 - 9.9)	9.2	(8.3 - 10.0)	5.5	(4.1 - 7.0)	3.4	(2.0 - 4.7)
Income								
0-749	6.3	(5.4 - 7.4)	6.1	(4.6 - 7.5)	2.8	(1.4 - 4.2)	0.3	(0.0 - 1.4)
750-1499	6.8	(6.1 - 7.5)	6.9	(5.9 - 7.8)	3.2	(2.0 - 4.6)	1.1	(0.2 - 2.1)
1500-2999	7.1	(6.6 - 7.7)	7.4	(6.7 - 8.2)	3.6	(2.3 - 4.9)	1.7	(0.7 - 2.6)
3000+	9.1	(8.4 - 9.8)	10.2	(9.1 - 11.2)	5.5	(4.2 - 6.9)	4.5	(3.4 - 5.5)

Table 3.6 Random effects variance estimates for current smoking, chewing, and smoking quit rates between states and local areas and states in India

	Current smoking			Chewing			Quit rates		
Random effects	Var	SE	%‡	Var	SE	%	Var	SE	%
Men									
Age adjusted									
States	0.428	(0.127)	10.5	0.533	(0.141)	12.7	0.448	(0.126)	10.8
Local areas	0.359	(0.017)	8.8	0.376	(0.015)	9.0	0.417	(0.082)	10.0
Villages (AP)†	0.097	(0.048)	2.9	0.190	(0.151)	5.5	0.180	(0.106)	5.2
Mutually adjusted									
States	0.441	(0.131)	10.9	0.479	(0.127)	11.7	0.455	(0.128)	11.0
Local areas	0.299	(0.015)	7.4	0.329	(0.014)	8.0	0.381	(0.081)	9.2
Villages (AP)	0.064	(0.040)	1.9	0.210	(0.177)	6.0	0.126	(0.091)	3.7
Women									
Age adjusted									
States	3.206	(0.908)	38.1	1.666	(0.439)	30.0	1.621	(0.748)	32.6
Local areas	1.915	(0.142)	22.8	0.602	(0.020)	10.8	0.067	(0.040)	1.3
Villages (AP)	0.054	(0.077)	1.6	1.625	(1.409)	33.1	0.033	(0.034)	1.0
Mutually adjusted									
States	3.154	(0.929)	40.6	2.115	(0.557)	35.7	1.813	(0.837)	35.2
Local areas	1.328	(0.118)	17.1	0.519	(0.019)	8.8	0.049	(0.025)	1.0
Villages (AP)	0.063	(0.073)	1.9	1.429	(1.292)	30.3	0.058	(0.062)	1.7
Total									
Age and sex adjusted									
States	0.581	(0.171)	13.6	0.930	(0.245)	20.2	0.508	(0.140)	12.2
Local areas	0.408	(0.017)	9.5	0.378	(0.012)	8.2	0.381	(0.072)	9.1
Villages (AP)	0.083	(0.041)	2.5	0.128	(0.119)	3.7	0.123	(0.063)	3.6
Mutually adjusted									
States	0.627	(0.184)	14.8	0.961	(0.253)	21.1	0.519	(0.143)	12.5
Local areas	0.332	(0.015)	7.8	0.313	(0.011)	6.9	0.354	(0.071)	8.5
Villages (AP)	0.061	(0.037)	1.8	0.097	(0.077)	2.9	0.107	(0.071)	3.1

Notes: Var; variance

†AP indicates random effects estimates for between village variation estimated in APRHI study

‡ Variances expressed as percentage of the contribution to the total variance

FIGURES

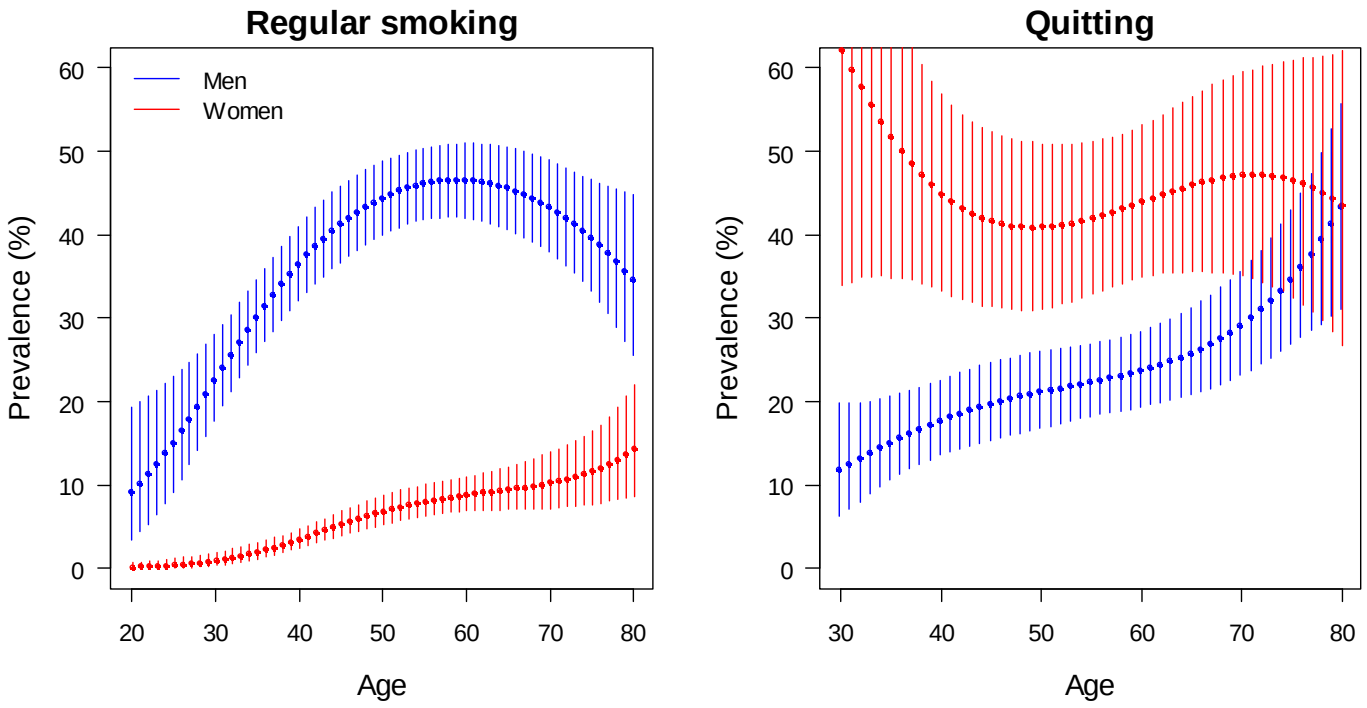

Figure 3.1 Relationship between smoking behaviour and age for men and women, Andhra Pradesh Rural Health Initiative study 2005.

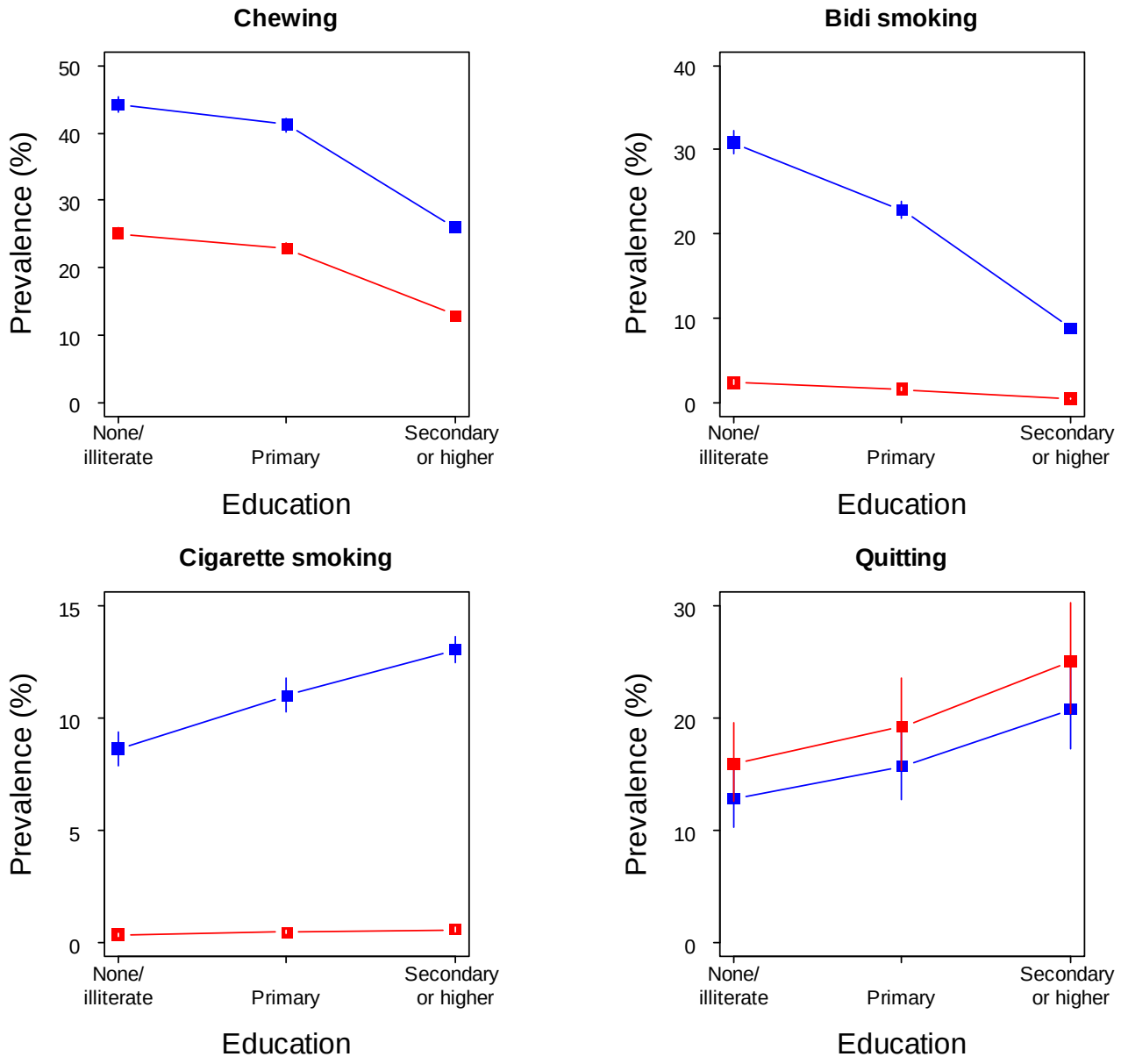

Figure 3.2 Adjusted prevalence of chewing, bidi smoking, cigarette smoking, and smoking quit rates by education for men (blue lines) and women (red lines), Global Adult Tobacco Survey, India 2009-2010.

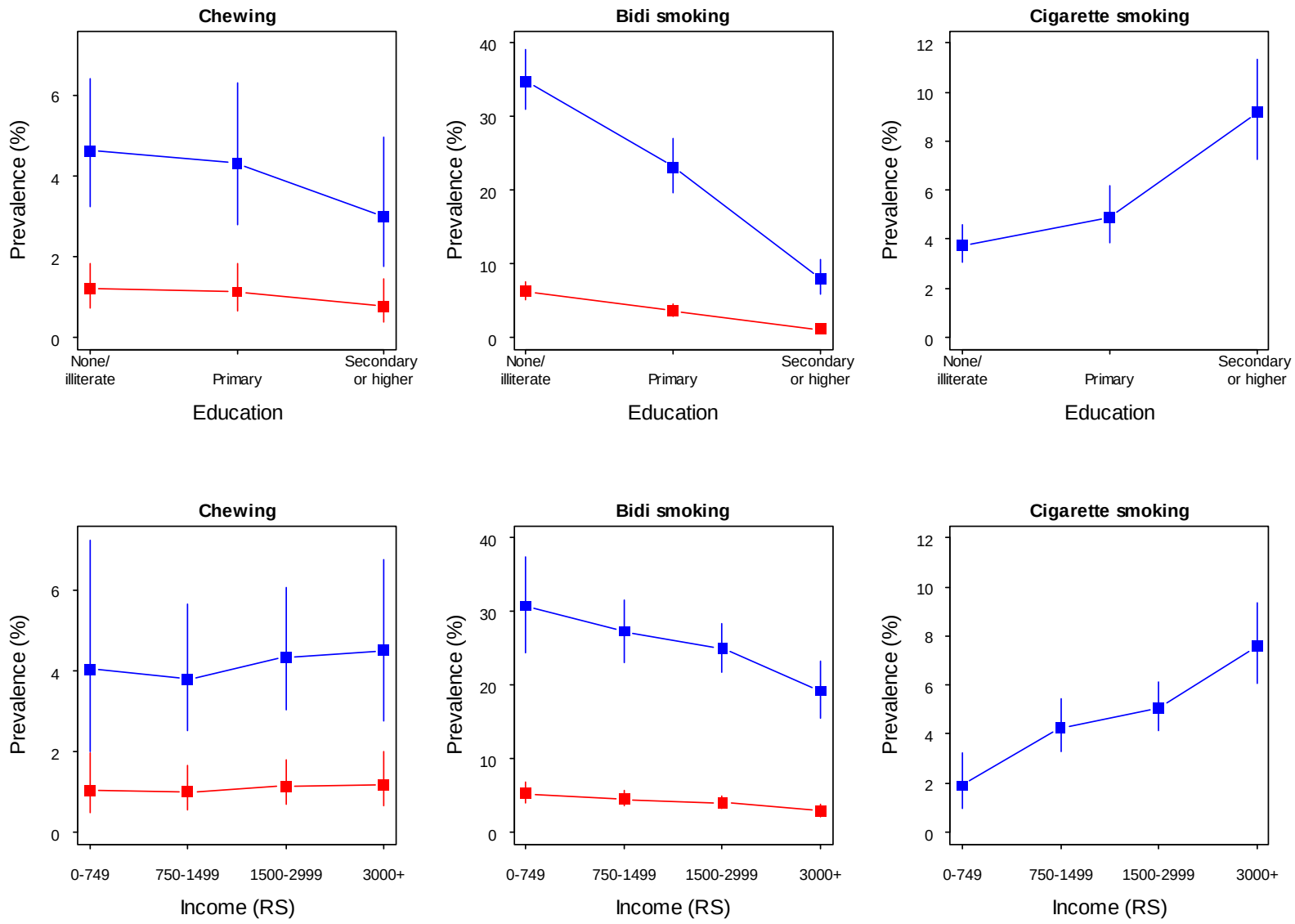

Figure 3.3 Adjusted prevalence of chewing, bidi smoking, and cigarette smoking by education and income for men (blue lines) and women (red lines), Andhra Pradesh 2005

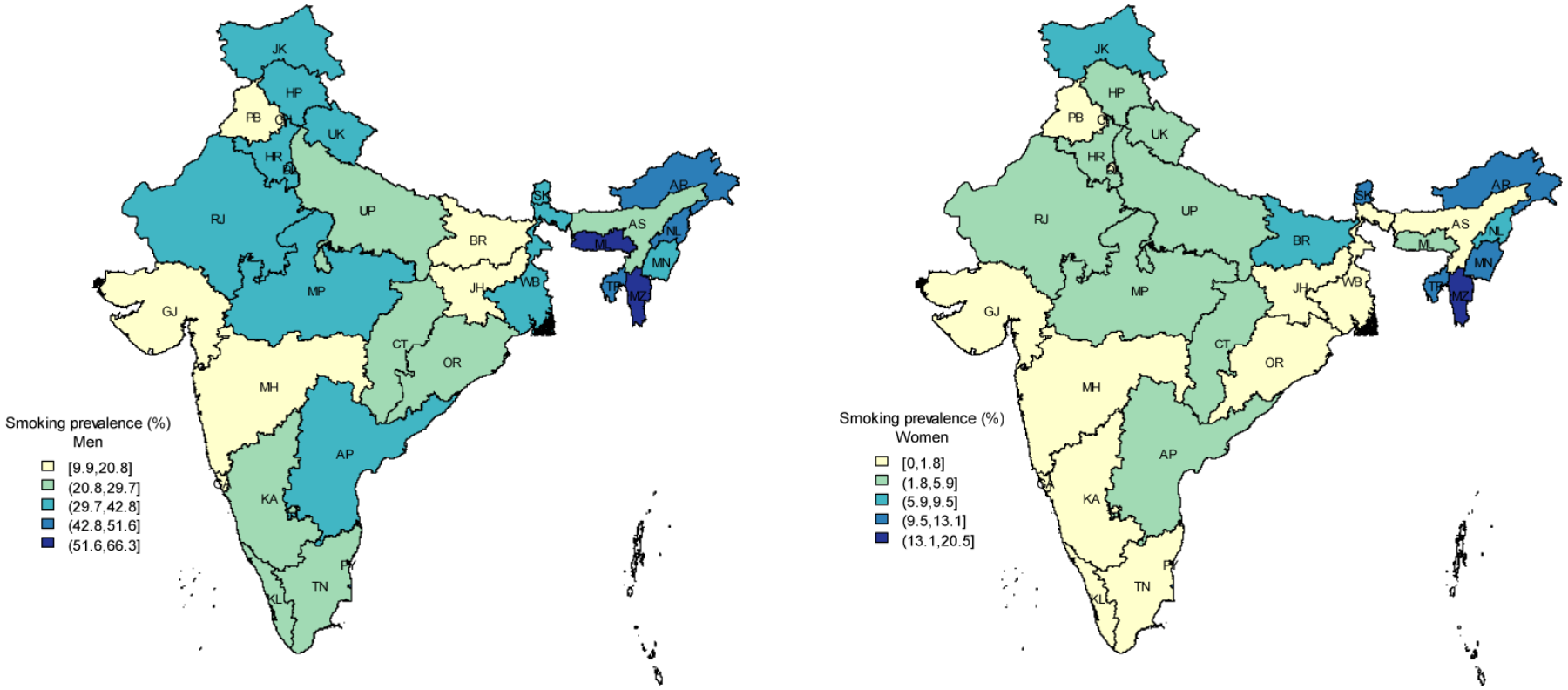

Figure 3.4 State level prevalence of current smoking in India for men (left) and women (right) aged 18 and higher, Global Adult Tobacco Survey India (2009-2010). Darker colours indicate higher prevalence.

State name abbreviations: AP Andhra Pradesh; AR Arunachal Pradesh; AS Assam; BR Bihar; CT Chhattisgarh; DL Delhi; GA Goa; GJ Gujarat; HR Haryana; HP Himachal Pradesh; JK Jammu & Kashmir; JH Jharkhand; KA Karnataka; KL Kerala; MP Madhya Pradesh; MH Maharashtra; MN Manipur; ML Meghalaya; MZ Mizoram; NL Nagaland; OR Orissa; PB Punjab; RJ Rajasthan; SK Sikkim; TN Tamil Nadu; TR Tripura; UP Uttar Pradesh; UK Uttarakhand (Uttaranchal); WB West Bengal; CH Chandigarh; PY Puducherry

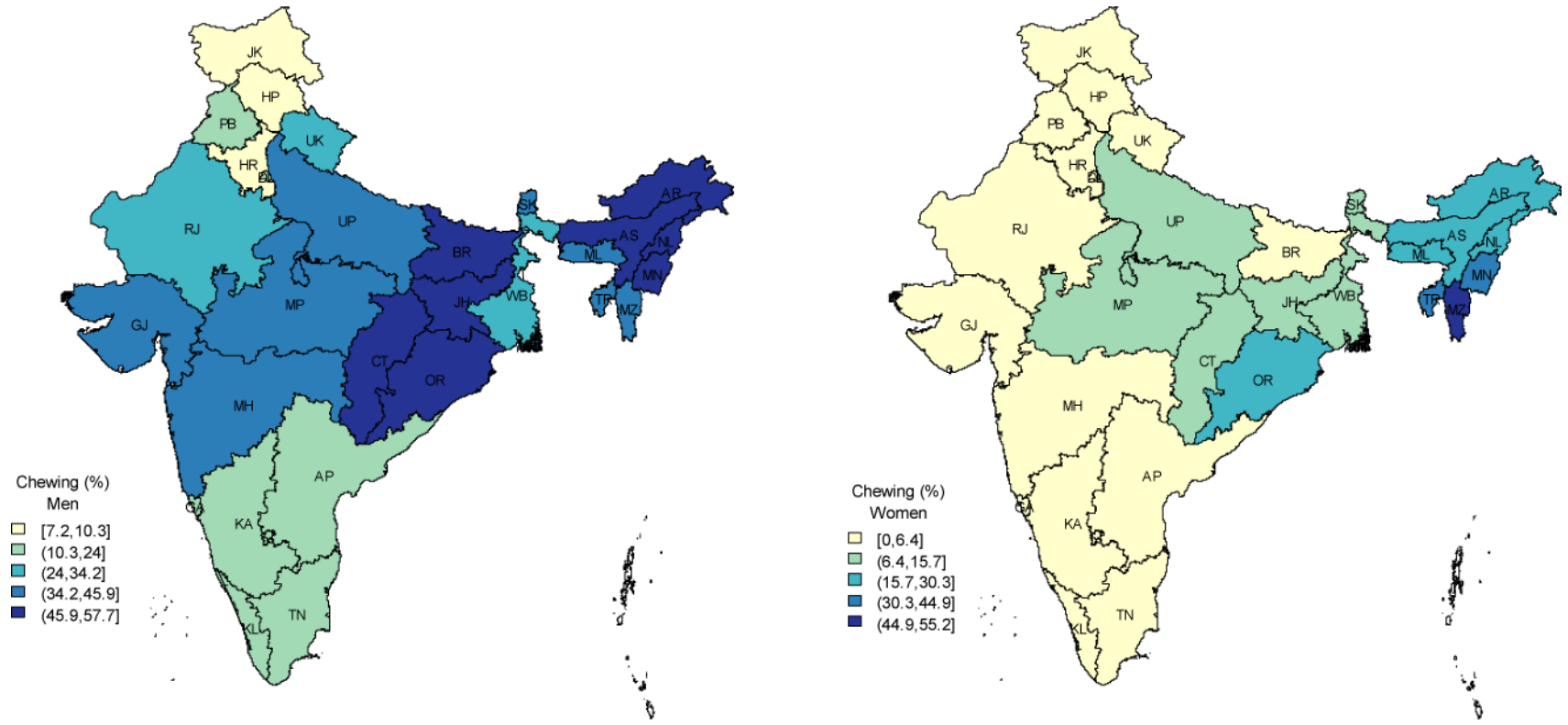

Figure 3.5 State level prevalence of tobacco chewing in India for men (left) and women (right) aged 18 and higher, Global Adult Tobacco Survey India (2009-2010). Darker colours indicate higher prevalence.

State name abbreviations: AP Andhra Pradesh; AR Arunachal Pradesh; AS Assam; BR Bihar; CT Chhattisgarh; DL Delhi; GA Goa; GJ Gujarat; HR Haryana; HP Himachal Pradesh; JK Jammu & Kashmir; JH Jharkhand; KA Karnataka; KL Kerala; MP Madhya Pradesh; MH Maharashtra; MN Manipur; ML Meghalaya; MZ Mizoram; NL Nagaland; OR Orissa; PB Punjab; RJ Rajasthan; SK Sikkim; TN Tamil Nadu; TR Tripura; UP Uttar Pradesh; UK Uttarakhand (Uttaranchal); WB West Bengal; CH Chandigarh; PY Puducherry

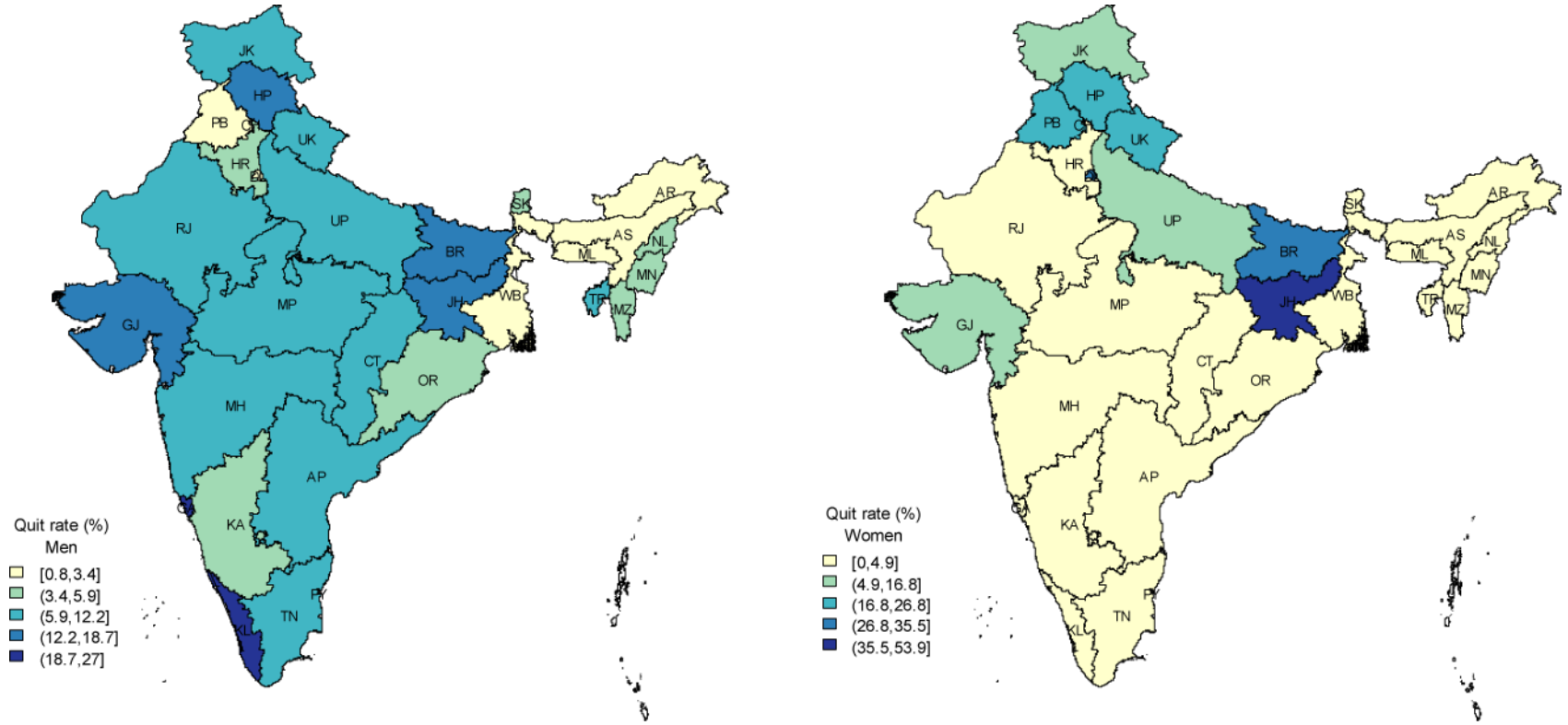

Figure 3.6 State level smoking quit rates in India for men (left) and women (right) aged 18 and higher, Global Adult Tobacco Survey India (2009-2010). Darker colours indicate higher quit rates.

State name abbreviations: AP Andhra Pradesh; AR Arunachal Pradesh; AS Assam; BR Bihar; CT Chhattisgarh; DL Delhi; GA Goa; GJ Gujarat; HR Haryana; HP Himachal Pradesh; JK Jammu & Kashmir; JH Jharkhand; KA Karnataka; KL Kerala; MP Madhya Pradesh; MH Maharashtra; MN Manipur; ML Meghalaya; MZ Mizoram; NL Nagaland; OR Orissa; PB Punjab; RJ Rajasthan; SK Sikkim; TN Tamil Nadu; TR Tripura; UP Uttar Pradesh; UK Uttarakhand (Uttaranchal); WB West Bengal; CH Chandigarh; PY Puducherry

Chapter 4 Trends in smoking in Canada from 1950 to 2010: progression of the tobacco epidemic according to socioeconomic status, and geography

Abstract

Background: Smoking has declined in Canada in recent years. However, it is not clear whether currently observed socioeconomic differences in smoking have changed over time and whether this varies by sex and geography.

Methods: We examined rates of smoking by sex, socioeconomic status (SES, defined by education), and province across 40 nationally-representative surveys conducted in Canada between 1951 and 2010. Differences in smoking were summarized using relative and absolute measures according to gender, educational attainment, and province of residence.

Results: Between 1950 and 2010 the prevalence of smoking decreased steadily in men from 59.2% (95% confidence interval [CI]: 55.6-62.8) to 14.7% (95% CI: 11.9-17.5) in men but in women increased from 26.2% (95% CI: 21.8-30.2) in 1950 to a peak of 33.9% (95% CI: 31.9-35.6) in 1968 before declining to 11.8% (95% CI: 9.0-14.6) in 2010. Among men, there was an inverse association between educational attainment and smoking which was consistent from 1950-2010. A similar gradient was not evident until the 1970s in women. Among men, differences in rates of smoking by level of education increased consistently from 7.6% in 1950 to 27.6% in 2010 despite overall declines in smoking across men at all levels of education. In women, the absolute differences in smoking rates between the highest and lowest educated groups increased from <1% in 1962 to 17.1% in 2004, before reducing slightly to 16.6% in 2010. During the study

period, rates of smoking in women were higher in Newfoundland, New Brunswick, Saskatchewan, and Nova Scotia compared to the rest of Canada. Rates of smoking in women in Ontario, British Columbia, and Alberta have reduced faster than the rest of the country. Among men, higher rates of smoking were found in the Atlantic provinces and Quebec; although these differences have declined since the 1980s in Newfoundland, Prince Edward Island, and Quebec

Conclusion: In Canada smoking rates have fallen over time but socioeconomic differences have increased. Smoking prevalence peaked later in lower SES groups and rates of decline in lower SES groups and certain provinces have been less steep. This suggests that while tobacco control policies appear to have been effective in those of higher SES, they have had limited efficacy in those of lower SES and suggests other approaches may be required to reduce smoking rates in those of lower SES.

INTRODUCTION

In high income countries, smoking rates have fallen substantially since peaking in the late 1960s.[1] In Canada and the United States, for instance, adult smoking prevalence was greater than 40% in 1965-6 and declined to 17% in Canada[2] and 19% in the United States in 2010.[3] During this period declines have been observed both in men and women, but have been more pronounced in men where the historical prevalence of smoking was higher.[4] For example, in Canada smoking prevalence in 1965 was higher in men than in women (61% vs 38%).[5] Since then, smoking prevalence has decreased to 20% in men and 14% in women; with the average decline over this period faster (0.9% decline per year) in men compared to women (0.5% per year).[6]

Studies from the last decade in high income countries have demonstrated marked gradients in smoking prevalence by socioeconomic status (SES)[7], with smoking most prevalence in those of lower SES (defined by occupation, education, and income).[8-9] It is believed that SES gradients in smoking is a feature of the later stages of the tobacco epidemic, with faster declines in prevalence among the more highly educated groups responsible for the emergence of currently observed differences.[10] While in most populations few data exist on smoking by SES prior to 1975, it is believed that the emergence SES gradients in smoking are a recent phenomenon in high income countries.

We conducted a systematic review of all available data on trends in smoking prevalence according to SES in high income countries. Based on this review, it is apparent that these gradients have generally increased over time both in absolute and relative terms. **Table 4.1** summarizes 17 studies which have presented trends in smoking prevalence by SES groups (defined by education, ethnicity, occupation, social class, or area SES) in 12 high income countries during various periods between 1955 and 2008.[1, 11-26] Studies over the longest periods from the United States and United Kingdom have documented relative increases in over 100% in the ratio of smoking prevalence between low and high SES groups*.[13, 15-16, 18] A study covering a thirty-year period in Canada (1974-2005) reported absolute and relative increases of 6.2 and 303% in the ratio of prevalence between low and high SES groups defined by education.[25] Interestingly, in this study, smoking was defined as a moderate to high level of daily consumption (>10

* The relative change in the ratio of smoking prevalence between low and high SES groups was calculated for each study as follows. First, SES ratios were defined for the first and final study years as the rates of smoking in low SES groups divided by the rates in high SES groups. Next, the relative change in the ratio was calculated as the difference in these ratios divided by the ratio in the first study year and expressed as a percentage. For example, in Barnett (first row of table 4.1) the SES ratio was 1.9 in the final year and 1.6 in the first year, yielding a relative change in the ratio of (1.925-1.58)/1.58 = 21.8%. Note ratios in the table have been rounded to 1 decimal place.

cigarettes per day) which suggests that SES gradients in may be even more acute among the heavy rather than light or occasional smokers. Further, the gradients in smoking across educational groups have remained consistent in recent years in Canada.[27]

In this chapter we extend previous analyses by considering longest time series on trends in smoking in Canada from 1950 to 2010. These findings will be used to highlight the long-term progression of the tobacco epidemic in a high income country according to SES (defined by education) and geography (Canadian provinces). The primary objective is to determine whether SES differences have narrowed or increased over time both in relative and absolute terms. In addition, we consider smoking trends across provinces both as a means of targeting inter-provincial differences in smoking rates and for an understanding of areas may converge or diverge with the progression of the tobacco epidemic.

METHODS

Data

This work is based on the combination of time series data from 40 nationally-representative surveys carried out in Canada between 1951 and 2010. Individual-level information on key variables of interest were brought together from the following sources of survey data: the Canadian Gallup Poll (1951, 1956, 1957, 1963, 1964), the Canadian Smoking Habits Surveys (1966 to 1977, 1979, 1981 and 1983), the Canadian Health Survey (1978-9), the Health Promotion Survey (1985, 1990), the Canadian Health Monitor (1988, 1993), the National Alcohol and Drug Survey (1989), the General Social Survey (1991, 1995), the Canadian Heart Health Databases (1990-1992), Canada's

Alcohol and Other Drugs survey (1994), the Survey on Smoking in Canada (1994-1995), the National Population Health Survey (1994, 1996, 1998), and the Canadian Tobacco Use Monitoring Survey (1999-2010). All surveys covered the 10 Canadian Provinces and used probability sampling methodology (further details on the sample design for each of the surveys covered in this chapter are provided in **Appendix C**).

Surveys selected for this study collected data on smoking behaviour of Canadians aged 12, 14, 15, or 18 years and over, depending on the survey. In general, surveys excluded residents of long-term care institutions, those living in the Yukon, Nunavut (after 1999), or Northwest Territories, residents of Indian reservations, and full-time members of the armed forces (~3% of the population). Data were primarily collected by telephone interviews although in some surveys (e.g. the General Social Survey) respondents over age 65 completed in-person interviews and in the Canadian Health Survey (1978-9) respondents self-completed the questionnaire.[4] Sample sizes varied between surveys and over time between ~2,100 in the Gallup polls to >70,000 in the Canadian Smoking Habits Surveys. Most surveys had a sample size of between 10,000 to 20,000 respondents. Response rates across surveys were generally high and varied between 78% in the Health Promotion Survey (1990) and 94% in the 1994 National Population Health Survey.

Outcome

The primary outcome was current smoking at the time of survey. Survey respondents were identified as smokers if they reported smoking at least 1 cigarette daily over the week immediately preceding the survey. This definition excludes occasional

smokers but is consistent with previous chapters (see Chapter 2) and has been employed in all of the national surveys considered here.[22] Although question wording sometimes varied between surveys, we ensured the consistency of the outcome by using this common classification of smoking for all surveys.

Independent variables

We considered socioeconomic status (SES), gender, and geography as independent variables. SES was defined as the highest level of education attained and categorized into four levels: less than secondary education; secondary education completed (including vocational training); post-secondary diploma or certificate; and university education (bachelors or higher) completed. Again, questionnaire wording was occasionally different between surveys but individual survey files were created ensuring the consistency of the above definitions across time. Sex was based on self-reports and geography was defined as province of residence.

Statistical analysis

Analyses were restricted to adults aged 20 years of age and older and with complete data on smoking and educational attainment. Analyses were carried out using Stata statistical software (version 11.2).[28] All point estimates were weighted using probability sampling weights provided with each survey and estimates of smoking prevalence in each survey were age standardized using the direct method taking the Canadian 1991 Census population as the standard.[29] Time trends were modeled using least squares regression models which included up to third-degree polynomials to account

for non-linearity in the trends. Interactions were included between time and education, and time and province to allow for different slopes across educational groups, and provinces. Analyses were stratified by gender except for overall analyses which compared trends in smoking prevalence between men and women. Overall analyses included an interaction between time and gender to allow different slopes between men and women. Expected values and 95% confidence intervals were simulated from each of the fitted models using 10,000 random draws from the probability distribution of all model parameters.[30]

After fitting the models, we summarized relative and absolute differences in smoking by SES and province in two ways. First, we calculated absolute differences in prevalence between 2 expected values obtained from the model over each of the 61 years between 1950 and 2010. For SES, absolute differences were calculated as the difference in prevalence between each of the three groups with lower levels of education and the group with the highest level of education (university education). And for province, absolute differences were calculated as the difference between each province and the Canadian average. Second, the relative prevalence was calculated as a prevalence ratio based on 2 expected values obtained from the models for SES and province for each year between 1950 and 2010. We used university education as the comparison group for education; women as the reference group for gender; and the overall Canadian average as the comparison group for provinces. All analyses were sex-stratified.

RESULTS

In 1950 the age-adjusted prevalence of smoking was 59.2% (95% CI: 55.6-62.8) in men and 26.2% (95% CI: 21.8-30.2) in women, with an absolute difference in prevalence between men and women of 33.0% (95% CI: 29.0-36.9) and a relative male-female ratio of 2.3 (95% CI: 2.0-2.6). **Figure 4.1** displays the trends in smoking in Canada for men and women from 1950-2010 based on prevalence estimates from surveys and the fitted regression model. Among men, a consistent decline was observed across this period and by 2010, the estimated smoking prevalence was 14.7% (95% CI: 11.9-17.5); in women the prevalence of smoking increased to a high of 33.9% (95% CI: 31.9-35.6) in 1968 before declining to 11.8% (95% CI: 9.0-14.6) in 2010. A statistically significant interaction by gender in the rate of change was observed, with men on average having a steeper rate of decline over this period ($\beta = -0.92$ for trend in men vs $\beta = -0.42$ for trend in women, P-interaction <0.001). From 1950-2010, the absolute and relative gender inequalities in smoking declined considerably before levelling off around 2000 (**Figure 4.2**). In the ten years since 2000, there appeared to be an increase in male/female inequalities in daily smoking although it was not statistically reliable; in 2010 the absolute difference was 2.9% (95% CI: -0.5-6.3), with a relative male to female ratio of 1.3 (95% CI: 0.97-1.65).

Differences and trends in daily smoking prevalence by level of educational attainment are shown for women and men in **Figure 4.3**. In women, large differences in trends across educational status groups were observed. Among women who had completed less than secondary education, the prevalence of smoking increased from 24.3% in 1950 to 40.0% in 1985 before beginning to decline to 27.8% in 2010.

Similarly, among women who had completed secondary education, the prevalence increased from 26.8% in 1950 to 34.3% in 1972 before declining to 15.8% in 2010. Although the daily smoking prevalence among women with post-secondary and university level education, was higher in the 1950s (at 38.4% and 36.6%, respectively), trends in these groups displayed a near linear decline over the 60-year period with the estimated prevalence in 2010 found to be 5.0% among university educated and 11.1% among post-secondary educated women. Among men, all educational groups exhibited a decline in daily smoking over the study period but there was heterogeneity in the rate of decline across groups (P-interaction <0.001) and the slope was shallower among those who had not completed secondary level education (**Figure 4.3b**). In 1955, the smoking prevalence was 60.9% among men with less than secondary education, compared to 47.4% among university-educated men. By 2010, the corresponding prevalence was 34.9% among those with less than secondary education and 7.3% among those who had completed university.

Trends according to socioeconomic status

Trends in the absolute differences in smoking prevalence between each of the educational groups are summarized for women and men in **Figure 4.4**. Among women, the absolute inequalities in daily smoking prevalence between the higher and lower educated groups increased rapidly into the 1980s as the prevalence of smoking continued to rise among the least educated. In recent years, however, there appears to have been a reduction in the absolute difference in smoking prevalence between the most and least educated women. In 2010, this difference was 22.8%, which was down from 25.0% in

2001. Among men, the absolute differences in smoking by level of education have increased fairly consistently since 1950 despite declines in prevalence for all groups. The difference in prevalence between the most and least educated men was 7.6% in 1950 and this climbed to 25.0% in 1976, where it remained relatively stable until the late 1990s before beginning to rise again to 27.6% in 2010.

Patterns of relative differences in daily smoking by level of education are summarized in **Figure 4.5** and are largely consistent with the findings for absolute difference. Among men and women, large and consistent increases in relative inequalities in daily smoking across different levels of education were observed over the period from 1950-2010. Among women, the ratio of daily smoking among those with a university and post-secondary education compared to those with less than secondary was <1 prior to 1960, however it has increased steadily since this time; in 2010 the ratio was 6.4 for university and 2.5 for post-secondary compared to less than secondary. In addition, no reduction in relative inequalities was seen for any of the educational groups among women, differing from the findings of a recent reduction in absolute differences. In men, relative differences in the ratio of smoking >1 were observed between those with a university education and those with post-secondary education compared to men who had not completed secondary education throughout the 60-year period. In addition, a ratio >1 for daily smoking was observed from1955 onwards between men who had completed secondary education and men who had not. This suggests that the inverse gradient between SES and smoking was established among men in Canada prior to the 1950s.

Trends according to geography

Additional models were specified to examine patterns of change in daily smoking prevalence from 1950 to 2010 across the ten Canadian provinces. The modeled trends across provinces are displayed for women and men in **Figure 4.6**. For women, the rate of change in the levels of smoking between 1950 and 2010 differed significantly across provinces (P-interaction <0.001), and there appears to have been more inter-provincial variation in 1950 compared to 2010. In several provinces including New Brunswick, Ontario, and Manitoba, increases in smoking prevalence were observed into the 1960s before reaching a maximum and declining. Among men, the patterns of change were more consistent across provinces although the test of interaction with time was found to be statistically significant (P<0.001) indicating some heterogeneity in the trends for men.

Figure 4.7 and **Figure 4.8** summarize the absolute and relative inequalities in daily smoking prevalence between each province and the Canadian average, for women and men respectively. These analyses revealed several patterns. First, absolute and relative inequalities increased from 1950 to 2010 for women in Newfoundland, New Brunswick, Saskatchewan, and to a lesser extent in Nova Scotia compared to the rest of Canada. Second, for women in Ontario, British Columbia, and Alberta, rates of smoking have decreased faster than the rest of the country. Among, men the geographical patterning was more apparent. Men in the Atlantic provinces (Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick) and Quebec had higher rates of smoking compared to the rest of Canada since the 1960s. The differences between Newfoundland, PEI, and Quebce and the national average have declined since the 1980s. Ontario and the Western provinces (with the exception of Saskatchewan) had rates of

smoking which were lower than the national average across the entire period. Compared to the Canadian average, differences in smoking rates have increased in Saskatchewan and Manitoba in recent years although Manitoba remained below the Canadian average.

DISCUSSION

This chapter has several salient findings. First, the period between 1950 and 2010 in Canada was characterized by a marked and consistent decline in the prevalence of smoking among men. A comparable decline was observed among women since 1968. Second, although absolute and relative differences between men and women declined consistently until 2000, reductions appear to have slowed or even increased in recent years. Third, in men an inverse association between SES and smoking was consistently observed during the study period and differences between the highest and lowest educated groups have increased. By 2010, the prevalence of smoking was nearly five-fold higher among men who did not complete secondary education compared to men with university degrees. A similar inverse association between SES and smoking was observed among women since the late 1960s. Relative and absolute differences in smoking by education among women have increased since this time although there is some evidence that absolute inequalities have reduced in recent years. Lastly, the patterns of change over time in most provinces followed the national trends although there was greater variability between provinces for women prior to 1980. There were greater differences in smoking among men in the Atlantic provinces and Quebec compared to the Canadian average.

The SES gradients in smoking over time in Canada appear to be similar to those reported in other high income countries including the United States[13, 16, 18] and United Kingdom[15, 24]. A previous study in Canada during the period 1974-2005[25] reported an increase in educational gradients that were larger than those found in our study; compared to university graduates the authors reported an 8-fold higher relative prevalence of heavy smoking among men and a 9-fold higher prevalence among women with less than secondary education in 2005. This study only measured educational gradients in smoking at three discrete points in time (in 1974, 1996, and 2005) as opposed to the current approach of modeling the change in gradients as a continuous function with time. Differences between the two studies are likely due to the previous study's classification of smoking based on moderate to high intensity (>10 cigarettes per day). In addition, the present study used a broader age restriction (20+ years compared to 25-64 years) to capture a larger segment of the population. It is entirely plausible that the socioeconomic inequalities are more pronounced among higher intensity smokers in Canada. No comparable studies have reported on the long term trends in daily smoking patterns in Canadian provinces.

In this study, our objective was to determine whether the differences in daily smoking had narrowed or increased over time in Canada between men and women, across SES groups defined by education, and between provinces. There are several limitations to the present analysis. First, we restricted our sample to adults over the age of 20 years. This was done in order to maintain comparability with previous studies as well as to define the population according to their highest level of education, likely attained by age 20 or within a few years. Second, we did not examine trends in

occasional smoking or by the level of smoking intensity.[31] In the early surveys, details on the number of cigarettes smoked per day were not available. Therefore daily smoking at the time of the survey was adopted as the primary marker of population level tobacco consumption and this definition was consistently employed across all surveys. Third, education was the only marker of SES that was considered in this study. Education, however, has been shown to be one of the strongest predictors of smoking behaviour[32]; in addition education was consistently reported and available in all surveys. Finally, the inequalities in smoking by education which were reported could potentially be biased because they assume a constant proportion of the population was at each educational level over time. Given that the distribution of educational attainment has changed over time in Canada[33], this is a potential limitation, although additional analyses using alternative measures of relative and absolute differences in smoking produced similar findings.[34]

Of key public health interest is the time point at which populations pass through difference stages of the tobacco epidemic. According to the model proposed by Lopez and colleagues which generalizes the historical trends in high income countries[10], the peak in male smoking prevalence marks the end of stage 2 and beginning of stage 3. Based on our model, the likely peak of male smoking prevalence was at 60% and occurred in the immediate post-war period in 1946. This suggests that smoking may have been declining in men prior to initial studies linking smoking and lung cancer emerged in the 1950s[35] and before the release of the first report of the US Surgeon General's Committee on Smoking and Health in 1964.[13] The peak in women did not occur until 23 years later in 1968. It also appears that inverse SES gradients in smoking

emerge within 5-10 years following the peak in smoking prevalence: in Canada these gradients were clearly evident in the 1950s in men and by the 1970s in women. Prior to the peak in prevalence the smoking prevalence may indeed be higher among the higher socioeconomic status groups, although the evidence in support of this is less reliable in men due to lack of survey data prior to 1950. In addition, our analyses of smoking-related inequalities by Canadian provinces indicated that the emergence of such inequalities may vary considerably with time and space within countries.

Geographically, we found more variability between provinces in rates of smoking in the 1950s compared to 2010 and this was especially apparent among women. Such differences suggest that Canadian provinces may have been at different stages of social and epidemiological transition at this time.[36] Although the tobacco epidemic has largely followed a similar progression across provinces in Canada, certain provinces including Ontario, British Columbia, and Alberta have seen reductions in rates of smoking which have been faster than the rest of the country. These findings must be interpreted with caution, however, because they are based on average provincial trends and may mask trends in SES gradients in smoking within provinces. There is now evidence that rapid average declines in smoking prevalence may actually increase SES gradients, at least in the short term.[17] Due to sample restrictions it was not possible to examine trends in smoking by SES for each province across the entire period although our preliminary findings that this may also hold true for Canada. British Columbia, for example, has had an over 84% reduction in rates of smoking in men since 1950, but now has the steepest SES gradient for smoking in Canada (see Chapter 2).

The findings in this chapter have implications in Canada and other countries and populations at different stages of the tobacco epidemic. Overall smoking prevalence within a population over time is a function of smoking initiation among the younger cohorts and cessation in older cohorts.[1] Therefore, declines in prevalence may be achieved through an increase in the rate of cessation and/or a reduction in the rate of initiation over time. The emergence and persistence of absolute and relative inequalities in smoking may therefore be related to both higher uptake and lower cessation among lower SES groups. One possible mechanism for this persistence is the ineffectiveness of smoking prevention and cessation programs among lower SES groups in Canada.[37] There is, however, potential for progress: we observed a reduction of absolute differences in recent years in women. The development and implementation of successful cessation and prevention programs among lower SES groups may characterize the next stages of the tobacco epidemic by a continued decline in overall smoking prevalence and a *decrease* in SES gradients.

Our findings are of key importance in order to predict future trends for lower and middle income countries such as India who are in early stages of the epidemic characterized by high levels of smoking and relatively low rates of cessation (see Chapter 3).[38] In India, SES gradients in smoking are already apparent in tobacco use (especially bidi smoking)[39] suggesting that India may be transitioning to a later stage of the epidemic. Although evidence on the stages of the epidemic have largely been derived from high income countries where cigarettes are the primary form of tobacco consumption, findings such as those in the present chapter are invaluable for low and middle income countries where no comparable data exist. As India moves through the

stages of the tobacco epidemic it is likely that a large and increasing number of individuals will want to quit using. It will be essential to anticipate the potential for SES gradients to increase during this period and focus tobacco control efforts among the most vulnerable populations.

In summary, this chapter provided a detailed description of the long-term trends in smoking prevalence in Canada with a specific emphasis on differences in the patterns of change between socioeconomic groups and across provinces. Our findings indicate that efforts to improve health equity in the population need to concentrate on reducing the large and increasing educational gradients for smoking. In addition, although the rapid declines in smoking prevalence seen in many provinces is a positive step, careful monitoring is required to ensure that such declines are not differentially benefiting high SES groups. Better understanding of how the tobacco epidemic evolves within SES groups will be important for predicting future trends and in the planning of public health intervention strategies in high income countries at similar stages of the tobacco epidemic and in low and middle income countries at earlier stages of this epidemic. Although it has been suggested that SES gradients in smoking is a feature of the later stages of the tobacco epidemic, our findings indicate that the inverse association between SES and smoking in Canada was clearly apparent from at least the mid-1950s (in men) suggesting that the tobacco epidemic was already beginning to shift prior to the introduction to mainstream tobacco control initiatives. Based on these findings, future tobacco control and prevention efforts should be targeted on lower SES groups in Canada.

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TABLES

Table 4.1 Studies showing trends in smoking by socioeconomic status (SES) in high income countries

Author	Country	Years	Age	SES marker (low/high)	Sex	Prevalence in first year			Prevalence in final year			Change in prevalence					
												Low SES		High SES		Change in ratio	
						Low SES (%)	High SES (%)	SES Ratio (L:H)	Low SES (%)	High SES (%)	SES Ratio (L:H)	Abs (%)	Rel (%)	Abs (%)	Rel (%)	Abs	Rel (%)
Barnett[11]	New Zealand	1981-2006	15+	Ethnicity (Maori/European)	M	51.5	32.6	1.6	35.8	18.6	1.9	-15.7	-30.5	-14.0	-42.9	0.3	21.8
					F	56.3	42.9	1.3	27.2	16.3	1.7	-29.1	-51.7	-26.6	-62.0	0.4	27.2
ONS[24]	United Kingdom	1974-1998	16+	Social class (I/V)	M	61.0	29.0	2.1	45.0	15.0	3.0	-16.0	-26.2	-14.0	-48.3	0.9	42.6
					F	43.0	25.0	1.7	33.0	14.0	2.4	-10.0	-23.3	-11.0	-44.0	0.6	37.0
Graham[15]	United Kingdom	1960-1990	16+	Social class (I/V)	M	61.0	53.0	1.2	48.0	13.0	3.7	-13.0	-21.3	-40.0	-75.5	2.5	220.8
			16+	Social class (I/V)	F	44.0	45.0	1.0	35.0	13.0	2.7	-9.0	-20.5	-32.0	-71.1	1.7	175.3
Garfinkel[13]	United States	1968-1993	20+	Education (<h.s./ college grad.)	C	36.5	33.7	1.1	35.0	14.5	2.4	-1.5	-4.1	-19.2	-57.0	1.3	122.9
Giskes[14]	Norway, Sweden, Finland, UK, Germany, Italy, and Spain	1985-2000	25-79	Education (none/ post-secondary)	M	44.9	28.9	1.6	36.3	22.6	1.6	-8.6	-19.1	-6.3	-21.9	0.1	3.5

					F	25.9	18.8	1.4	31.5	16.6	1.9	5.6	21.4	-2.2	-11.8	0.5	37.6
Hill[17]	New Zealand	1981-1996	15-79	Income tertile (low/ high)	M	38.6	32.2	1.2	30.9	20.2	1.5	-7.7	-19.9	-12.0	-37.3	0.3	27.6
					F	33.3	28.5	1.2	28.8	19.0	1.5	-4.5	-13.5	-9.5	-33.3	0.3	29.7
				Education (none/ post-school)	M	41.8	27.2	1.5	34.9	18.9	1.8	-6.9	-16.5	-8.3	-30.5	0.3	20.2
					F	33.8	21.8	1.6	32.6	16.2	2.0	-1.2	-3.6	-5.6	-25.7	0.5	29.8
				Ethnicity (Maori/European)	M	49.5	33.3	1.5	38.3	22.9	1.7	-11.2	-22.6	-10.4	-31.2	0.2	12.5
					F	51.7	28.0	1.8	44.6	20.3	2.2	-7.1	-13.7	-7.7	-27.5	0.4	19.0
Kanjilal[18]	United States	1971-2002	25-74	Poverty-income ratio (Q1/Q4)	C	44.0	33.5	1.3	37.4	13.9	2.7	-6.6	-15.0	-19.6	-58.5	1.4	104.9
				Education (<h.s/ post secondary)	C	45.1	33.5	1.3	38.6	17.1	2.3	-6.5	-14.4	-16.4	-49.0	0.9	67.7
Lee[19]	United States	1987-1994	18+	Occupation (skilled manual/ professional)	M	40.4	18.2	2.2	40.1	13.9	2.9	-0.3	-0.8	-4.3	-23.4	0.7	29.5
					F	40.9	16.5	2.5	40.9	14.3	2.9	0.0	0.1	-2.2	-13.4	0.4	15.5
Lee[20]	Canada	1994-2005	12+	Income adequacy (Q1/Q4)	C	39.7	23.5	1.7	33.0	20.0	1.7	-6.7	-16.9	-3.5	-14.9	0.0	-2.3
Millar[22]	Canada	1985-1991	25+	Education (<h.s./ university)	M	45.0	20.0	2.3	40.0	14.0	2.9	-5.0	-11.1	-6.0	-30.0	0.6	27.0
					F	34.0	15.0	2.3	35.0	13.0	2.7	1.0	2.9	-2.0	-13.3	0.4	18.8
Najman[23]	Australia	1989-2001	18+	Area SES (Q1/Q5)	M	37.2	25.7	1.4	35.0	19.4	1.8	-2.2	-5.9	-6.3	-24.5	0.4	24.6
					F	28.6	19.4	1.5	25.1	17.0	1.5	-3.5	-12.2	-2.4	-12.4	0.0	0.2

Smith[25]	Canada	1974-2005	25-64	Education (<h.s./ university)	M	49.0	23.9	2.1	35.5	4.3	8.3	-13.5	-27.6	-19.6	-82.0	6.2	302.7
					F	28.9	18.3	1.6	24.1	2.6	9.3	-4.8	-16.6	-15.7	-85.8	7.7	486.9
Harper[16]	United States	1965-2003	25+	Education (<12 y/ 16+ y)	M	51.1	40.4	1.3	32.3	11.6	2.8	-18.8	-36.8	-28.8	-71.3	1.5	120.1
					F	23.8	35.0	0.7	21.7	9.5	2.3	-2.1	-8.8	-25.5	-72.9	1.6	235.9
Lund[21]	Norway	1955-1990	-	Income	M	60.0	75.0	0.8	40.0	28.0	1.4	-20.0	-33.3	-47.0	-62.7	0.6	78.6
Pierce[1]	United States	1974-1987	20+	Education	C	36.5	28.3	1.3	35.7	16.3	2.2	-0.8	-2.2	-12.0	-42.4	0.9	69.8
	Canada	1975-1986	20+	Education	C	37.6	31.2	1.2	31.6	19.9	1.6	-6.0	-16.0	-11.3	-36.2	0.4	31.8
	Australia	1976-1986	20+	Educaton	C	37.0	32.0	1.2	32.0	24.3	1.3	-5.0	-13.5	-7.7	-24.1	0.2	13.9
	Norway	1974-1986	20+	Education	C	45.8	29.4	1.6	43.5	22.0	2.0	-2.3	-5.0	-7.4	-25.2	0.4	26.9
Federico[12]	Italy	1980-2000	25-49	Education	M	64.7	53.6	1.2	50.2	26.9	1.9	-14.5	-22.4	-26.7	-49.8	0.7	54.6
					F	17.2	40.5	0.4	24.6	21.7	1.1	7.4	43.0	-18.8	-46.4	0.7	166.9
			50-79		M	53.6	42.9	1.2	25.6	24.4	1.0	-28.0	-52.2	-18.5	-43.1	-0.2	-16.0
					F	6.2	25.3	0.2	9.2	20.0	0.5	3.0	48.4	-5.3	-20.9	0.2	87.7
Osler	Denmark	1982-1992	30-60	Education (≤7y/ ≥12y)	M	67.0	52.0	1.3	66.0	29.0	2.3	-1.0	-1.5	-23.0	-44.2	1.0	76.6
					F	55.0	44.0	1.3	66.0	25.0	2.6	11.0	20.0	-19.0	-43.2	1.4	111.2

Notes: Abs Absolute; Rel Relative; SES socioeconomic status; M male; F female; C combined. SES ratio (L:H) refers to smoking prevalence among low SES group divided by prevalence in high SES group. Absolute change in prevalence for each SES group calculated as prevalence at time 2 minus prevalence at time 1; relative change calculated as prevalence at time 2 minus prevalence at time 1 divided by prevalence at time 1. Changes in SES ratio calculated using an identical approach.

FIGURES

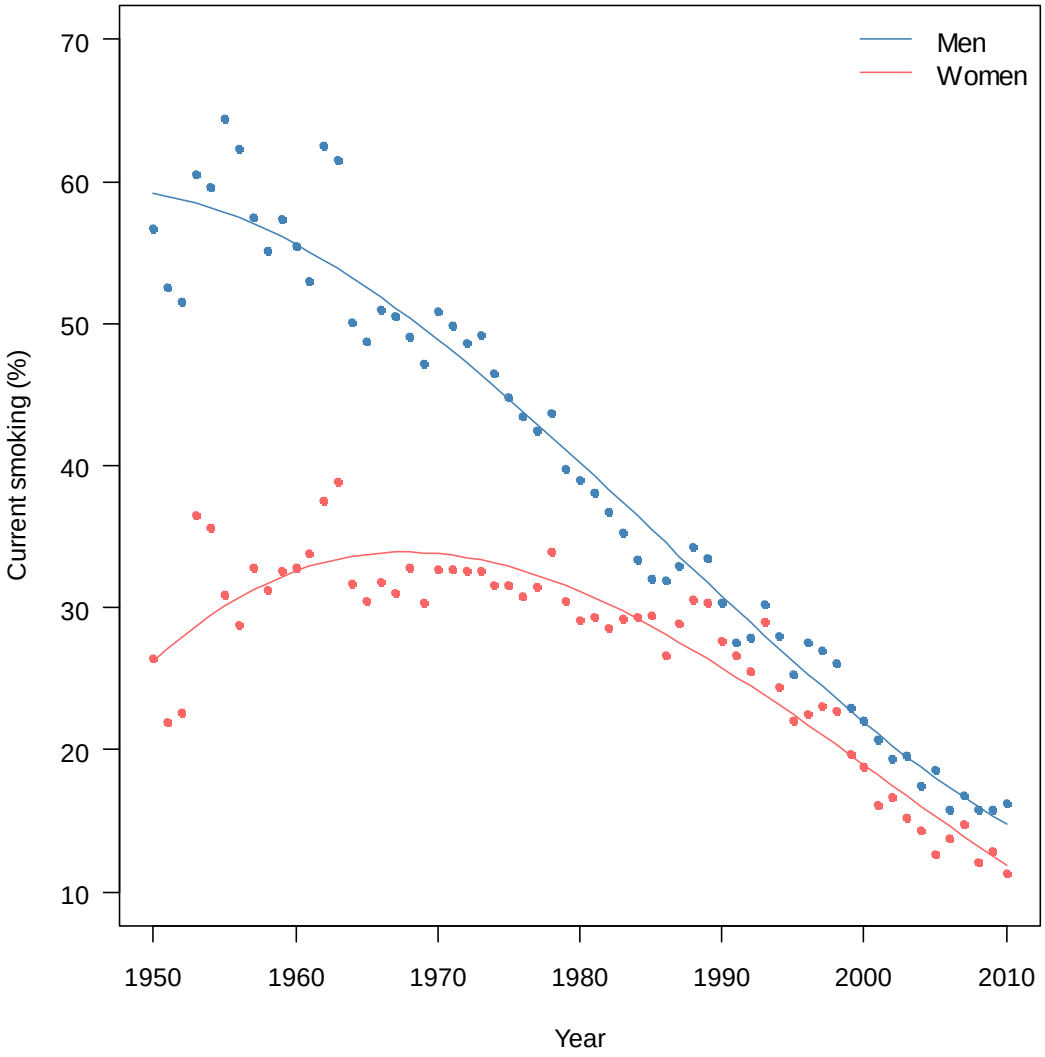

Figure 4.1 Prevalence of current smoking in Canada by sex, 1950-2010.

Data from various national surveys (see methods). Dots represent individual survey estimates, curves are fitted regression lines.

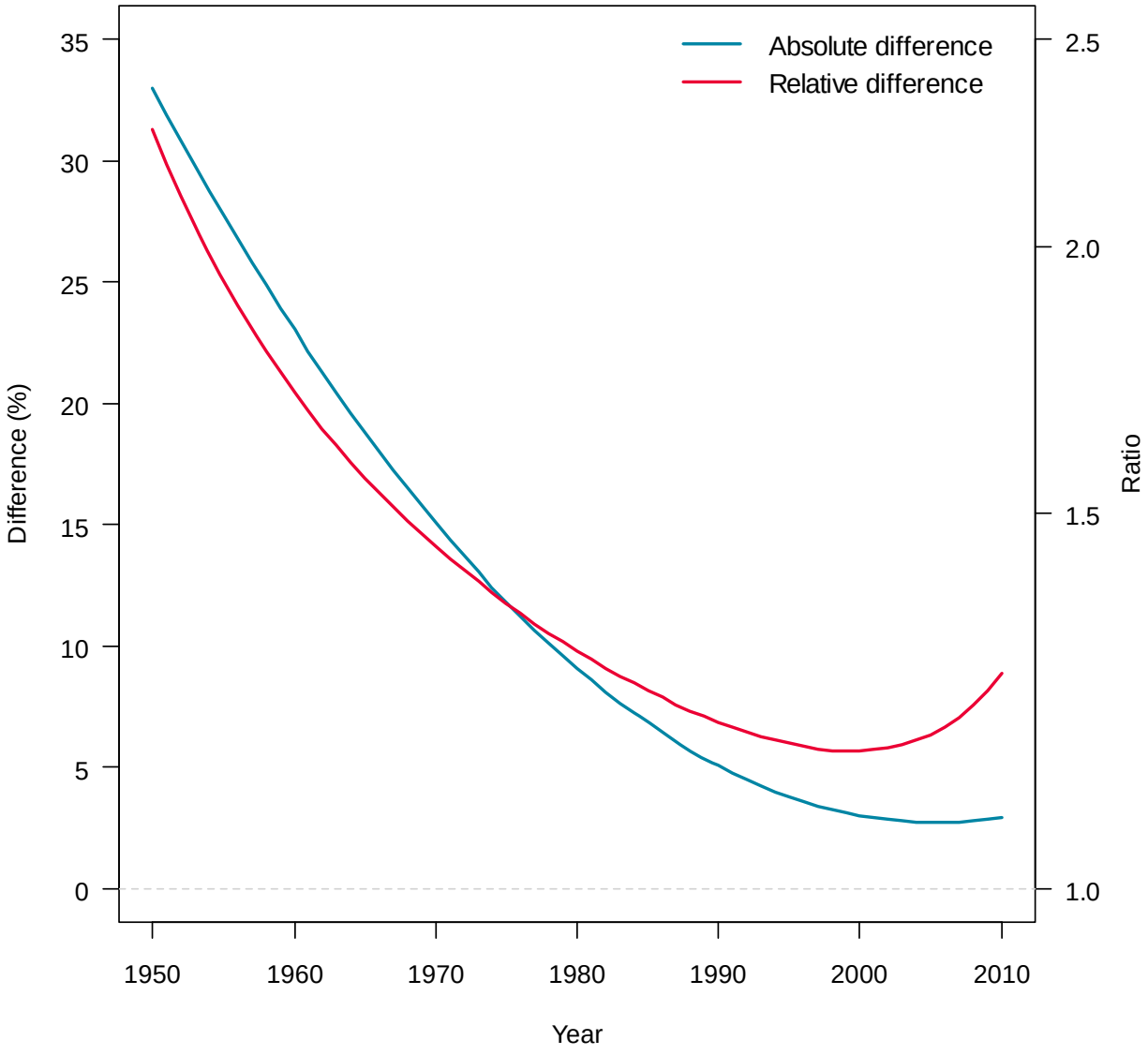

Figure 4.2 Absolute and relative difference in current smoking between men and women in Canada, 1950-2010.

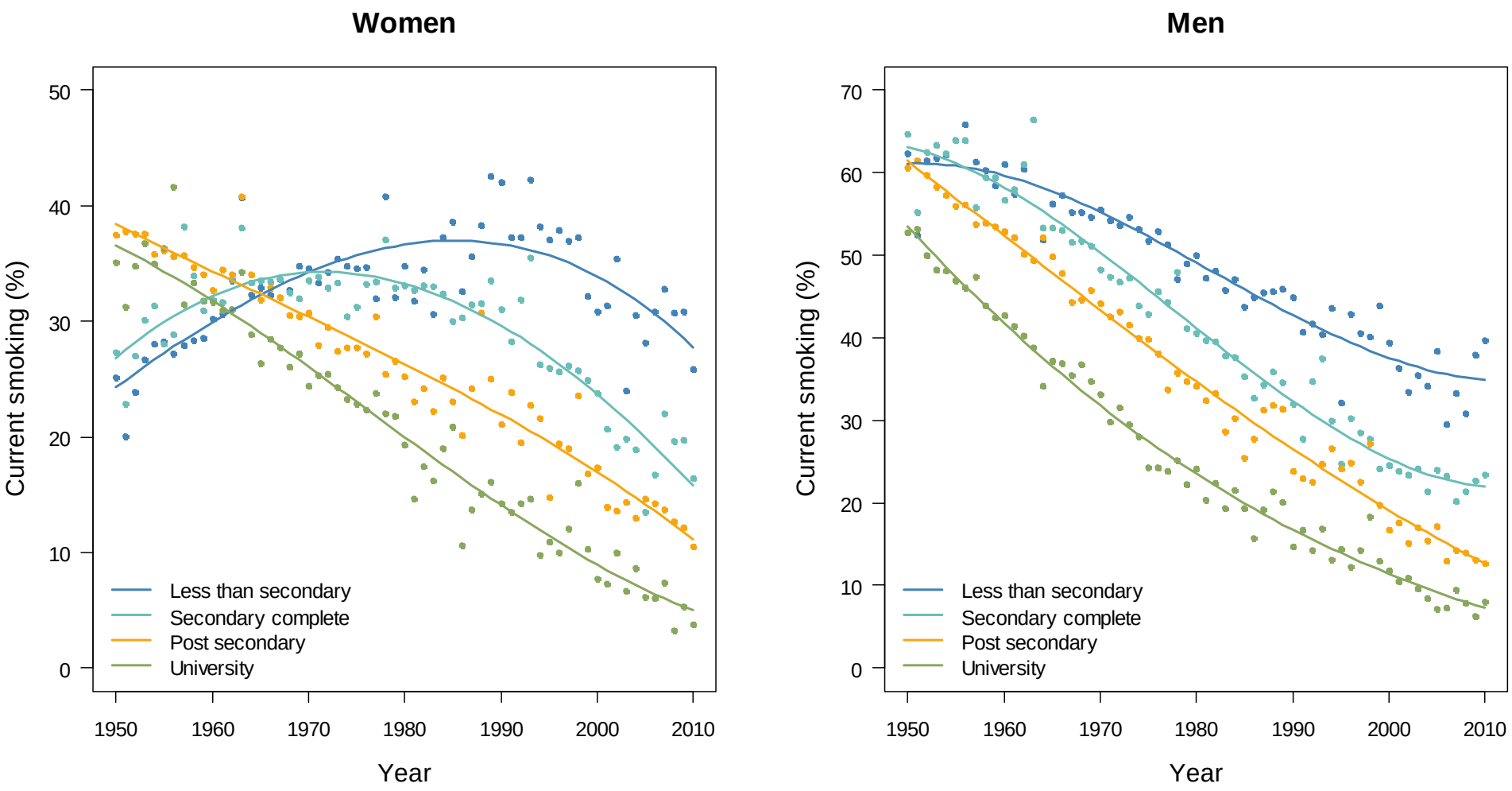

Figure 4.3 Prevalence of current smoking by level of education in Canada for women (left) and men (right), 1950-2010

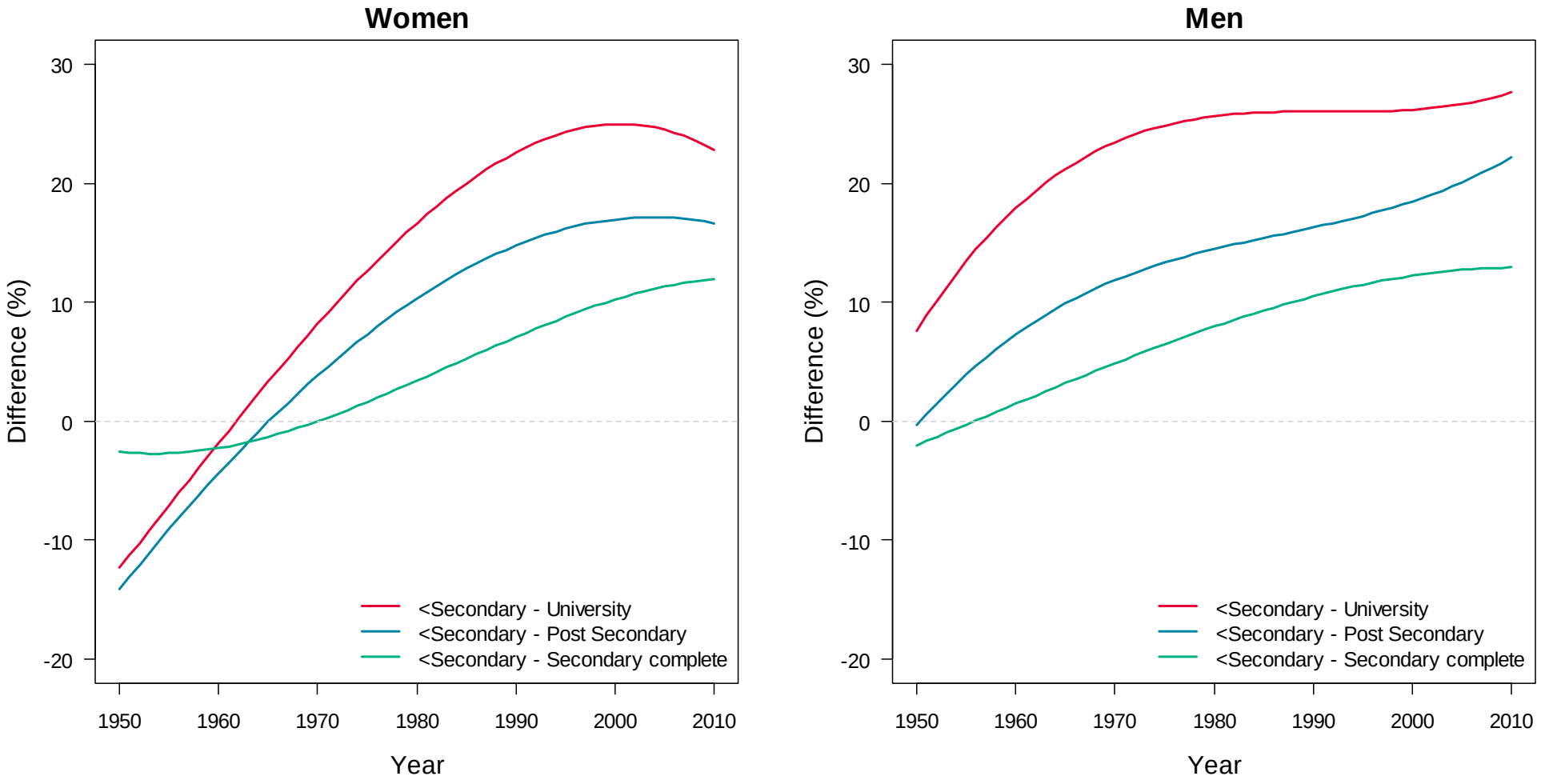

Figure 4.4 Estimated absolute differences in current smoking between educational groups in Canada for women (left) and men (right), 1950-2010

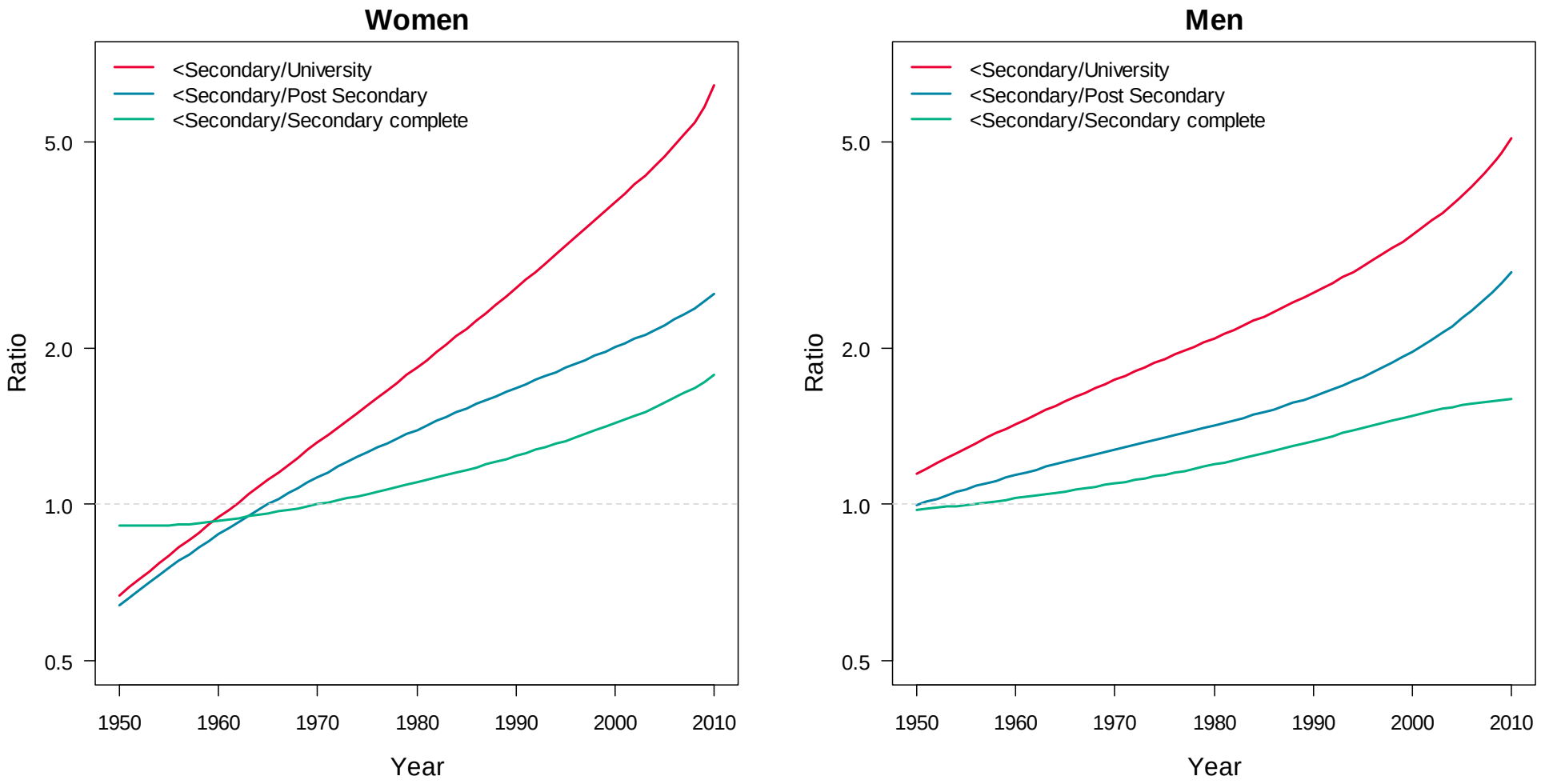

Figure 4.5 Estimated relative differences in current smoking between educational groups in Canada for women (left) and men (right), 1950-2010

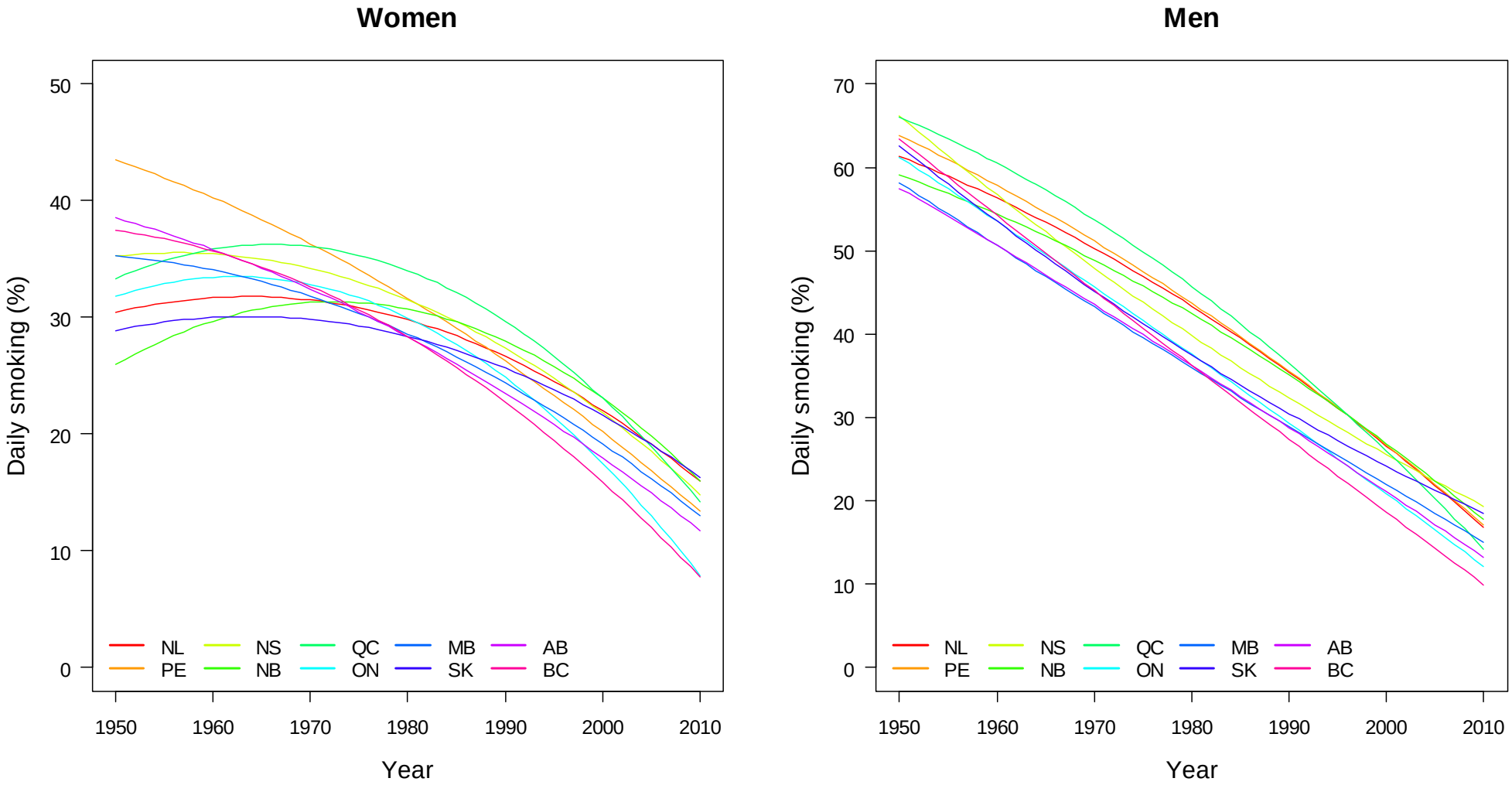

Figure 4.6 Prevalence of current smoking across Canadian provinces for women (left) and men (right), 1950-2010

Province abbreviations: NL Newfoundland; NS Nova Scotia; QC Quebec; MB Manitoba; AB Alberta; PE Prince Edward Island; NB New Brunswick; ON Ontario; SK Saskatchewan; BC British Columbia

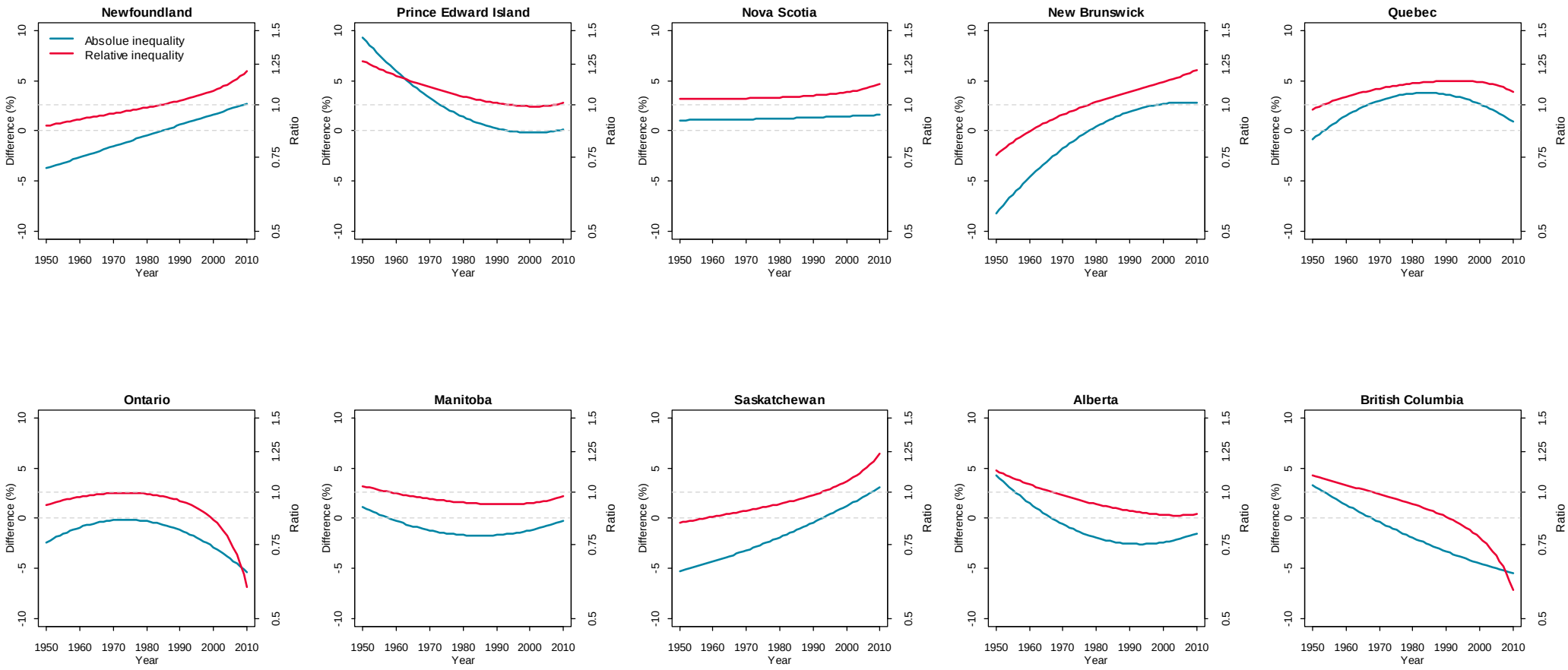

Figure 4.7 Absolute and relative difference in smoking among women in one of ten Canadian provinces compared to the national average, 1950-2010

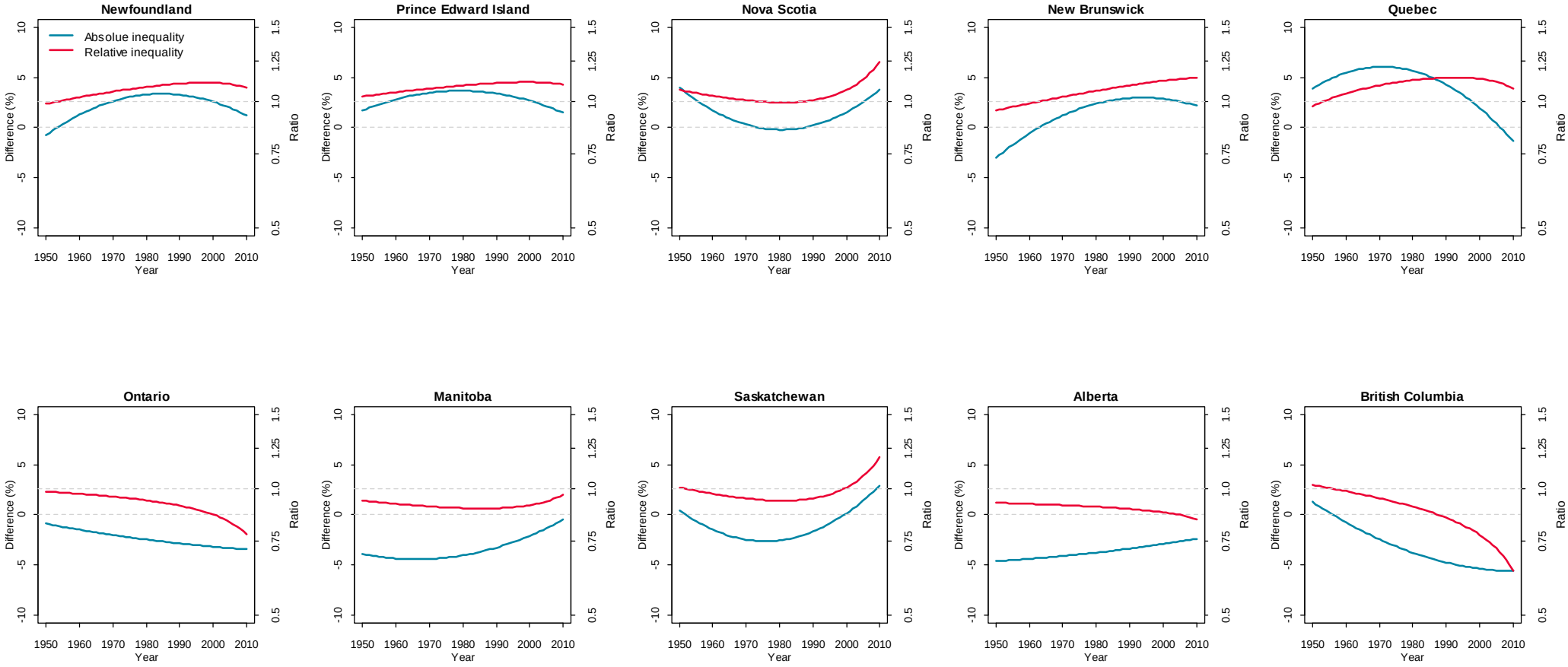

Figure 4.8 Absolute and relative difference in smoking among men in one of ten Canadian provinces compared to the national average, 1950-2010

Part III Contextual versus compositional influences on smoking and levels of consumption in Canada

Chapter 5 Socioeconomic and geographic distribution of smoking in Canada: a multilevel analysis of smoking in 49,088 communities

Abstract

Background The extent to which there is geographic variation in smoking in Canada which is independent of the characteristics of individuals has not been quantified. We estimate the extent to which there is geographic variation in smoking that is attributable to communities and provinces in Canada.

Methods Data are from the Canadian Community Health Surveys conducted between 2001 and 2008 (n=461,709). Current, daily cigarette smoking among adults (≥ 18 years) was the primary outcome. Markers of socioeconomic status (SES) were education, household income, and occupation. We conducted a multilevel logistic regression analysis to model variation in smoking at the geographic scale of communities, health regions, and provinces.

Results Overall, the contribution of geography as a percentage of the total variation in smoking was 8.4%; 2.4% was attributable to provinces, 1.2% was attributable to health regions, and 4.8% was attributable to communities after adjusting for age, gender and survey period. In models additionally accounting for individual socioeconomic and demographic characteristics, the contribution of geography to the total variation in smoking was attenuated to 4.0%; 2.0% at the level of provinces, 0.4% at the level of

health regions, and 1.6% at the level of communities. Within provinces, the between-community variation in smoking varied from 2.4% in Prince Edward Island to 9.1% in British Columbia. Roughly 67% between-community and 15% of between-provincial differences in smoking were explained by individual socioeconomic and demographic factors in addition to age and gender.

Conclusions Our results demonstrate that geographic variation in smoking remained after accounting for individual socioeconomic and demographic characteristics, suggesting the importance of place, at both the level of provinces and communities in Canada. Our findings imply that area-level influences such as the social and/or environmental conditions of provinces and communities may be important sources of variation in smoking and therefore need to be considered if rates of smoking are to be modified.

INTRODUCTION

In Canada smoking is responsible for 27% of all deaths and 34% of deaths from cancer among middle age adults (35-69 y).[1] Recent surveys have indicated that although the prevalence of daily smoking has declined substantially in Canada in the past 50 years (from approximately 50% in 1965 to less than 20% in 2009), the rate of decline has slowed in the past decade.[2]

Within Canada, there is considerable variation in the prevalence of smoking across provinces from 53% in Nunavut compared to 18% in British Columbia.[3] The uneven distribution of smoking in the population may be influenced by factors acting at the individual, household, community, and provincial levels. While the individual determinants of smoking (age, gender, socioeconomic status [SES], immigrant status) have been described [4-7]; it is unclear whether place-to-place variation in smoking remains (and at what level of geography) after accounting for these individual-level characteristics in Canada. In this paper, we use a multilevel conceptual and analytical approach to investigate the potential for local geographical contexts to shape the distribution of smoking in Canada.[8]

It has been previously theorized that there are two primary explanations for geographic variation in health related behaviours: *compositional* and *contextual*.[9-10] Compositional explanations say that place-to-place variation to a function of the individual characteristics of the kinds of people living in places and hence accounting for individuals characteristics will reduce between-place variation. Contextual explanations say that there are differences in the characteristics of places that contribute to variation in health behaviours observed between places. For example, differences in smoking

patterns among professionals in Vancouver versus Montreal may be driven by dominant social and cultural attitudes in the respective environment.[10] Using a multilevel analytical framework, we can attempt to partition the variation in smoking that is attributable to individuals (composition) and places (context).[8] An assessment of the magnitude of smoking differences at the area level (provinces or communities) in Canada after taking into account important individual-level determinants of smoking would give an indication of the relative importance of the contextual influences places have in shaping the distribution of smoking.[11-12]

While there has been considerable examination of individual-level determinants of smoking [2, 4, 13], and considerable theorizing with respect to potential mechanisms that could influence smoking at a area-level, there has been little systematic analysis to support the theory of compositional and contextual factors influencing smoking variation or of the relative importance of each. In this study, we 1) quantify the variation in smoking that is attributable to geography (provinces, health regions, and communities) in Canada 2) examine what proportion of the geographic variation in smoking is attributable to individual socioeconomic and demographic characteristics and 3) examine the consistency of the geographic variation in smoking across different socioeconomic groups in Canada using measures of income and education.

METHODS

Data

Data for this study came from four cycles of the cross-sectional Canadian Community Health Survey (CCHS) conducted by Statistics Canada in 2001 (Cycle 1.1),

2003 (Cycle 2.1), 2005 (Cycle 3.1), and 2007 (Cycle 4.1).[14] The CCHS was designed to collect information on self-reported health indicators, service utilization, and determinants of health in the Canadian population and to provide reliable estimates at the sub-provincial (health region) level of geography.[14] All four waves of the CCHS incorporated the same set of variables to capture current and previous smoking, smoking frequency, and number of cigarettes smoked daily which facilities pooling of they surveys for this analysis.[15] Each CCHS cycle covered the ten provinces and three territories of Canada and individual survey master files were combined to form a pooled sample for analysis.[15] Details of the combined sample size and provincial sample sizes are provided in **Table 5.1.**

Sample procedures

The target population of the CCHS is Canadians aged ≥12 and resident in private households, excluding institutional, military, and remote populations and those living on Indian reserves. The sampling procedures used in the CCHS are similar to other cross-sectional surveys carried out by Statistics Canada (e.g. the Labour Force Survey [LFS]).[16] Specifically, the CCHS used a stratified two-stage design in each cycle.[17] A stratification procedure was used to subdivide the population of each province by large geographical areas and health regions (HR). In the first stage of sampling, smaller geographical areas (Census Dissemination areas [DA]) were selected from within each HR stratum. In the second stage of sampling, households were selected from clusters using area-based and telephone-based sample frames. One individual in selected households was chosen to complete the interview using a probabilistic sample procedure. About half of interviews

were conducted in person and the remainder over the telephone. Both types of interview used computer-assisted data capture technology.[17-18]

Study population and sample size

For this study, we included all adults aged ≥18 included in the four cycles of the CCHS (n=481,033). Among these individuals, 1,506 (0.3%) did not have information on smoking status and were excluded. An additional 16,528 (3.4%) individuals were missing data on one or more covariates and excluded. Missing or invalid residential postal codes limited the assignment of a further 1,290 observations (0.2%) to the correct dissemination area and/or health region and these individuals were not included in analyses. The final analytic sample comprised 461,709 adults from 49,088 communities, 121 health regions and 13 provinces/territories in Canada.

Outcome

The outcome was current smoking, defined as having smoked 100 cigarettes over the lifetime and currently smoking at least 1 cigarette daily. This outcome was treated dichotomously, with current non-smokers forming the reference category.

Independent Variables

We considered three measures of socioeconomic status in this study: income, education, and occupation. Income was captured as total household income reported in dollars, categorized as <$20,000, $20,000-$40,000, $40,000-$60,000, $60,000-$80,000, $80,000+, and not reported (reference: $80,000+). Respondent education categorized as: less than secondary education, completed secondary education, completed post-

secondary, and completed university (bachelor's degree/graduate school) (reference: completed university) Respondent occupation was categorized based on the 2006 National Occupational Classification for Statistics (NOC-S).[19] We considered the following occupational groups: executive, administrative, managerial; professional specialties; technicians, sales, admin/clerical; manual occupation (e.g., trades, transport, and manufacturing); Farming, forestry, fishing; occupation not reported; and not working at the time of the survey (reference: professional specialties).

In addition, the following covariates were considered in our analyses: age, sex, immigrant status, Aboriginal identity, marital status, and place of residence. Age (≥ 18y) was treated continuously (centred about the grand mean of 46 years) with a quadratic term specified to explore non-linear relationships with smoking. Sex was self-reported and female was used as reference. Immigrant status was defined as born in or outside of Canada (reference: born in Canada). Aboriginal identity was established through respondent self-reports of First Nations, Inuit, and/or Métis identity (reference: non-Aboriginal identity). Marital status was categorized as married/common-law, widowed, separated/divorced, and single (reference: common-law/married). Place of residence was a community-level covariate and indicated whether the household was located in a census-defined urban or rural area (reference: urban). All analyses included a covariate to account for survey cycle (CCHS 1-4).

Defining Areas: Provinces, Health regions and "Communities"

No standard definition of "community" exists in Canada. Previous work on community or neighbourhood influences on health in Canada have mainly used census

dissemination areas (DA) or census tracts (CT) to define an individual's local geographical context. The DA is the smallest geographical unit for which census data area available and is composed of between 400 and 700 individuals. Census tracts are larger, typically comprise about 4000 people, and are limited to urban areas.[20] In this study, the DA was taken to represent the "community". As the smallest available geographical unit in the CCHS, the DA is likely to correspond to an individual's perception of his or her community. An additional advantage of the DA over the CT is that DAs cover the entire country, where as the CT is limited to urban areas only.

Within provinces, larger geographic regions were defined based on Health Region boundaries. Health Regions in Canada are used for public health service administration and are defined by Provincial health authorities. In this study we have used the 2007 definition of Health Regions which has been provided by Statistics Canada to correspond with the geographic boundaries of the 2006 Census.[21] The substantive advantage of including health regions in this analysis is that they correspond to sub-provincial areas where policies and programs for smoking awareness, prevention, and cessation can be delivered. Provinces form the largest level of geographical aggregation in this study. In Canada there are 10 provinces and 3 territories.

Statistical analysis

Given the hierarchical structure of the data (individuals nested in communities, health regions, and provinces) and our explicit interest in modeling the variation in a dichotomous outcome (smoking) at these levels of geography in Canada, a multilevel logistic modeling approach was adopted.[8, 22-23] Formally, the model has a binary

response variable representing smoking status (y_{ijkl} , current smoker or not), calibrated for individual *i* living in community *j* in health region *k* and province/territory *l*. This model assumes that the binary response follows a binomial distribution with probability π_{ijkl} : $y_{ijlk} \sim$ Binomial (1, π_{ijkl}). The probability being a current smoker (π_{ijkl}) was related to a set of predictors *X* (income, education, occupation, age, gender, immigrant status, aboriginal identity, martial status, and place of residence) and a random intercept for community, health region, and province using the logit function as:

$$Logit(\pi_{ijkl}) = \beta_{0ijkl} + \beta X_{ijkl} + (f_{0l} + v_{0kl} + u_{0jkl}) .$$

The right-hand side of this equation consists of fixed and random parts. The fixed part ($\beta_{0ijkl} + \beta X_{ijkl}$) includes the individual demographic and socioeconomic characteristics and the random part terms, indicated by brackets, quantify variation in smoking at the level of provinces (f_{0l}), health regions (v_{0kl}), and communities (u_{0jkl}). From the model, we estimated the standard deviation of the random terms to summarize geographic differentials in the log odds of smoking at the level of provinces (σ_{f0}), health regions (σ_{v0}), and communities (σ_{u0}), assuming identical and independent distributions for each parameter and accounting for the fixed part covariates. In multilevel logistic models, no random term is estimated at the individual level.

We additionally estimated province-specific 2-level models (individuals within communities) for each province. Finally, we explored the heterogeneity in the variation in smoking at higher levels of geography (communities, health regions, and provinces) for individuals at different levels of education and household income. This was achieved by extending the models to allow the slopes for education and household income to vary at

each of the levels of geography in the overall model, and at the level of communities in province-specific models. For example, at the community-level, a variance-covariance matrix was estimated consisting of intercept variance (σ^2_{u0}), slope variance for household income (σ^2_{u1}), and covariance (σ_{u0u1}). From the variance-covariance matrices, the variability in smoking at each geographic level was summarized as a function of income (x_{1ijkl}) and presented as the standard deviation of the community-level variance: $\sqrt{Var(u_{0jkl}x_0 + u_{jkl}x_{1ijkl})}$.[8, 22]

We used 2 measures to summarize and present between-area variation in smoking. First, the variance partitioning coefficient (VPC) is a ratio of the variance attributable to higher levels (e.g. communities) from the multilevel model and expressed as a percentage from 0 to 100. The VPC for binary models assumes that the level-1 variance follows a logistic distribution with mean 0 and variance $\pi^2/3$.[24] In addition, we use the Median Odds Ratio (MOR), which has been described by Larson as an alternative presentation of higher level variances in logistic models.[25] The MOR transforms the between-area variance to the odds scale which can then be directly compared in terms of relative magnitude to the odds ratios in the fixed part of the model.

All analyses were done using the software *MLwiN* (version 2.23).[26] Models were estimated using Markov chain Monte Carlo (MCMC) simulation and the Metropolis-Hastings algorithm.[27] MCMC simulation was done for 20,000 iterations to build a simulated posterior distribution of model parameters. These methods have been shown to be accurate for estimating variance parameters in binary response models and interval estimates for variance parameters can be readily obtained from simulated distributions.[28]

RESULTS

The prevalence of current smoking in this sample was 20.0% (95% confidence interval [CI]: 19.9, 20.1), after applying the CCHS sampling weights. Smoking prevalence varied from 15.3% in British Columbia to 55.4% in Nunavut (Table 5.1). These estimates are consistent with other national statistics published on the prevalence of smoking among adults (aged ≥ 15) in Canada from 1999 to 2010.[3, 29] Descriptive analyses indicate that smoking prevalence is greater among males, those with low household income, less than high school education, and in blue collar occupations (**Table 5.2**).

In an initial multilevel model specifying age, gender, and survey cycle in the fixed part with random intercepts for provinces, health regions, and communities, the between-provincial variation in smoking was 0.29 in standard deviation (SD) units, which was equivalent to a VPC of 2.4% and a median odds ratio (MOR) of 1.48 (95% CI: 1.19, 1.95) (**Figure 5.1**). Adjustment for all individual socioeconomic and demographic characteristics reduced the VPC to 1.95% (MOR 1.41, 95% CI: 1.20-1.76) and this remained consistent after inclusion of a community-level characteristic (whether the community was urban or rural) in the fixed part of the model (VPC 2.0%; MOR 1.43, 95% CI: 1.21-1.78). Geographic variation in smoking at the level of health regions and communities accounted 1.2% (MOR 1.32, 95% CI: 1.27-1.38) and 4.8% (MOR 1.75, 95% CI: 1.72-1.78) of the total variation, respectively, in the initial model adjusted for age, gender, and survey cycle. The proportion of the total variation at these levels in Canada was reduced to 0.43% (MOR 1.18, 95% CI: 1.15-1.22 for health regions) and 1.6% (MOR 1.37, 95% CI: 1.08-1.43 for communities) with the inclusion of individual

and community level characteristics. Roughly two thirds of between-community and 15% of between-provincial differences in smoking were explained by individual socioeconomic and demographic factors.

Statistically significant community-level variation in smoking was observed across all provinces in 2-level models specified separately for each province (**Figure 5.2**). In models adjusted for age and gender, the amount of variation in smoking attributed to communities varied from 2.4% in Prince Edward Island to 9.1% in British Columbia. After adjusting for individual level factors, the corresponding amount of variation in smoking ranged from 0.7% in Nunavut to 4.6% in Northwest Territories. On average, adjustment for socioeconomic and demographic characteristics in addition to age and gender explained ~60% of the between community variation in smoking; this amount varied from 43% in Northwest Territories to >80% in Yukon.

The provinces with the greatest amount of between-community variation in smoking in fully adjusted models were generally from western Canada, including British Columbia, Northwest Territories, and Alberta. Ontario was found to have 2.1% of the variation in smoking attributable to communities in the fully adjusted model and it was ranked 3rd in terms of the magnitude. The Atlantic, eastern, and northern provinces and territories (Prince Edward Island, Newfoundland & Labrador, Quebec, Nova Scotia, New Brunswick, Yukon, and Nunavut) had a smaller amount of between-community variation in smoking (<2%) after accounting for individual level factors.

To examine the consistency of geographic variation in smoking for low versus high SES individuals, we modeled variability in smoking at the level of provinces, health regions, and communities as a function of education and income. Overall, education was

found to have an inverse association with smoking; each category increase in education was associated with an odds ratio of 0.65 (95% CI: 0.62, 0.67) for current smoking. Between-provincial variability was higher for those with low versus high education (0.24 *v* 0.22 SD), although a test of the variance-covariance matrix was not statistically significant (p=0.07) (**Figure 5.3a**). At more local levels of geography (health regions and communities) the association was positive, with greater between-area variation observed among those with higher levels of education (p<0.0001). Increases in between-area variation in smoking were observed with increasing income at the level of provinces; with health regions and communities showing a U-shaped pattern (**Figure 5.3b**). These associations were statistically significant (p<0.0001) for health regions and communities but not provinces (p=0.16), likely due to a smaller number of units at this level (n=13).

Similar analyses were conducted to model the heterogeneity in smoking between communities as a function of education and income within provinces. **Figure 5.4** plots these relationships for each of the 13 provinces and territories in Canada. Among 7/13 provinces, the between-community variation in smoking was found to increase with increasing education (p<0.05), indicating that community-level contextual differences in smoking were greater among the higher educated in these provinces. In two provinces, Quebec and Northwest Territories, between-community variation in smoking was smaller among groups with higher education. In Newfoundland, the magnitude of between-community variation in smoking was similar for those at the lowest and highest levels of education, with less variation observed for those with average education (e.g. high school). Repeating this analysis for income, we observed greater between-community differences in smoking for people of low incomes in 5 provinces (Newfoundland, New

Brunswick, Ontario, British Columbia, and Northwest Territories) and greater differences among those with high incomes in another 5 provinces (Nova Scotia, Quebec, Manitoba, Saskatchewan, and Alberta). In the remaining provinces, both high and low incomes showed more between-community variability than those of middle incomes, although these differences were only statistically significant in Yukon ($p<0.05$).

DISCUSSION

Using four large, nationally representative surveys of adults in Canada, this study investigated the role of geographic variability in smoking. We used a multilevel analytical framework to investigate spatial variation in smoking prevalence in Canada and the extent that this variation may be explained by individual socioeconomic characteristics. Our study shows several important findings. First, individual socioeconomic and demographic characteristics account for approximately two-thirds of the between-community variation in smoking but less than a quarter of between-provincial variation suggesting the importance of place, especially at the larger geographic scale in Canada. Second, the extent of community variation in smoking differs markedly across provinces providing an indication of the relative importance of local residential context in shaping health behaviours in Canada. Third, our national level findings broadly suggest that greater between-area differences in smoking exist for individuals of high socioeconomic status. Within provinces, between-community differences were generally larger among the higher educated, although the effects were less consistent for income. These findings indicate that between area differences in smoking may be greater among the higher SES groups in Canada.

Before discussing the findings further, we describe the potential weaknesses of this study. First, although this study used a large dataset from four cycles of the CCHS, it was restricted to the adult age groups (≥ 18 y). Whether a similar amount of contextual variation in smoking would be observed for younger age groups has not been fully described, although preliminary analyses youth smoking (ages 12-17) indicate greater between community differences in smoking compared to older ages in several provinces. Second, geographic information in this study was based on respondent reported postal codes. Although there is potential for misclassification, efforts were made to code individuals to their community and health region of residence using the Postal Code Conversion File (PCCF) program developed by Statistics Canada.[30] This program assigns respondents to their community (dissemination area) using the respondent's full postal code and uses probabilistic assignment in case a dissemination area overlaps more than 1 postal code.[31-32] In addition, meaningful "neighbourhood" or "community" contexts can be difficult to conceptualize in multilevel studies. Previous research in the U.S. and Canada has shown that health outcomes vary across administrative boundaries (U.S. Census tracts, Canadian Census dissemination areas) after accounting for individual composition of these areas.[33-36] The use of the census dissemination area is appropriate to approximate community context; it is the smallest defined geographical unit that is stable over time in Canada and likely to correspond to resident perceptions of their local environment.[37] An important caveat of all multilevel studies of contextual effects is that individual socioeconomic and demographic characteristics may play a role in selecting people into places[38], although it is also plausible that individual characteristics such as education, income, and occupation may be reflective of features of places and the local

environment.[10] Finally, this study compiled four cross-sectional surveys that were not conducted at the same time; however adjustments were made in all analyses to account for the CCHS survey cycle.

There are a host of area-level processes, including anti-smoking legislation, cigarette prices and/or taxes, accessibility of cigarettes for adolescents, and social acceptability of smoking which could be mechanisms through which places influence smoking patterns.[39-40] Although some of these mechanisms have been examined, for example social-cultural context among older smokers [41], comprehensive evidence remains lacking. The tobacco control literature has largely focused on identifying individual-level determinants of smoking, from which socioeconomic status variables (education, income, and occupation) have emerged as dominant. [4, 6, 13] Our study has quantified the potential for places to influence smoking, conditional on individual level factors including socioeconomic status, which is key compositional variable contributing place-to-place variation in smoking. Whether specific aspects of communities and larger geographic areas (smoking restrictions, availability, price and taxation of tobacco, social context) can be manipulated in shaping smoking behaviour in Canada remains an important question, although our findings suggest the potential importance of factors over and above individual characteristics and give an indication of the potential role for places in efforts to reduce and/or prevent smoking. In the present study we did not intend to provide any causal role for places but rather to present empirical evidence on the sources of variability in smoking in Canada.

The magnitude of contextual variation observed in this study (~2% at the provincial level, 2-5% at the community level) in adjusted models was comparable to other multilevel studies in Canada describing variation in body mass index[42] and self-reported health using the CCHS.[36] One explanation is that the detailed data on individual socioeconomic and demographic characteristics in this survey allows for wide range of covariate adjustment and thus reduces the potential for omitted variable bias at the individual level.[11] Thus, our findings give a plausible amount of variation in smoking at higher contextual levels adjustment for individual socioeconomic and demographic factors. An important advance in this study over previous research is that we examined how contextual variation in smoking may be shaped by individual socioeconomic status. The finding that contextual variation in smoking is heterogeneous across population groups supports previous theoretical arguments that the effects of places may not be constant within a population.[10]

In summary, contextual variation in smoking remained at all levels in our analyses, and should be explored further, especially at the level of provinces where the majority of observed variation was not explained in our models. The considerable range of community variation in smoking observed within provinces suggests that within Canada, smoking may be more heavily influenced by place in certain provinces compared to others. Our findings imply that area-level influences such as the social and/or environmental conditions of provinces and communities may be important sources of variation in smoking and therefore need to be considered if rates of smoking are to be modified.

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Table 5.1 Prevalence of current smoking smokers across selected covariates for adults (aged ≥ 18) participating in 4 cycles of the Canadian Community Health Survey from 2001-8 (weighted).

Province or Territory	**Individuals**	**Current smoking**			**Urban**	**Age**		**Female**	**<high school education**	**<$20,000 income**
	N	*%*	*95% CI*		*%*	*mean*	*SD*	*%*	*%*	*%*
Canada	461709	20.0	19.9	20.1	79.49	45.5	17.2	51.1	19.2	9.9
Newfoundland & Labrador	14134	22.1	21.4	22.8	61.43	46.0	16.8	51.3	26.7	15.6
Prince Edward Island	9048	22.2	21.4	23.1	52.61	46.3	17.5	51.4	24.9	11.9
Nova Scotia	18234	21.7	21.1	22.3	58.71	46.7	17.5	52.1	22.4	12.7
New Brunswick	18236	22.0	21.4	22.6	52.34	46.6	17.2	51.5	24.5	13.2
Quebec	91207	21.8	21.6	22.1	80.41	46.0	17.1	51.2	23.1	12.1
Ontario	146058	18.4	18.2	18.6	85.75	45.3	17.1	51.3	16.3	7.8
Manitoba	27027	19.7	19.2	20.2	79.53	45.9	17.8	50.9	22.3	9.9
Saskatchewan	27164	21.7	21.2	22.2	72.75	46.5	18.4	51.0	22.1	10.7
Alberta	44553	20.5	20.1	20.9	86.65	43.5	16.7	49.9	15.5	7.0
British Columbia	56828	15.3	15.0	15.6	86.32	46.0	17.3	51.1	13.9	9.5
Yukon Territory	3186	27.5	26.0	29.1	64.17	43.3	15.1	50.1	16.7	9.5
Northwest Territories	3611	32.5	31.0	34.0	64.66	40.0	14.5	48.4	26.5	9.4
Nunavut	2423	55.4	53.4	57.4	58.45	37.0	13.7	48.1	46.3	19.3

Table 5.2 Weighted frequency and percentage distribution of the CCHS sample by independent variables and smoking status.

	Smoking Status				
	Non-smoking		Current smoking		Total
	No.	*%*	*No.*	*%*	*No.*
Total	369427	80.0	92282	20.0	461709
Household income ($)					
<$20,000	32547	71.1	13214	28.9	45760
$20,000-<$40,000	65139	76.5	19982	23.5	85120
$40,000-<$60,000	64380	78.6	17509	21.4	81889
$60,000-$80,000	54533	80.5	13181	19.5	67714
$80,000+	108197	85.2	18868	14.8	127065
Not stated	44631	82.4	9529	17.6	54160
Education					
Less than high school	64251	72.3	24621	27.7	88872
High school/trade school	140652	76.5	43130	23.5	183782
Some university/college	82583	82.7	17292	17.3	99875
Bachelors/Graduate school	81941	91.9	7240	8.1	89181
Occupation group					
Executive, administrative, managerial	45148	80.5	10954	19.5	56102
Professional specialty	40537	87.5	5799	12.5	46336
Technicians, sales, admin/clerical	54325	77.7	15635	22.3	69960
Blue collar	31840	69.3	14110	30.7	45951
Farming, forestry, fishing	10311	75.9	3266	24.1	13578
Not reported	41325	80.8	9805	19.2	51130
Not working	145941	81.7	32712	18.3	178652
Immigrant Status					
Born in Canada	287979	78.0	81289	22.0	369269
Born outside of Canada	81448	88.1	10993	11.9	92440
Aboriginal identity					
Not Aboriginal	361366	80.7	86398	19.3	447764
Aboriginal	8061	57.8	5884	42.2	13945
Marital status					
Married/common-law	245162	82.3	52635	17.7	297797
Widowed	21726	86.5	3378	13.5	25105
Separated/divorced	23271	68.2	10859	31.8	34130
Single	79268	75.7	25410	24.3	104678

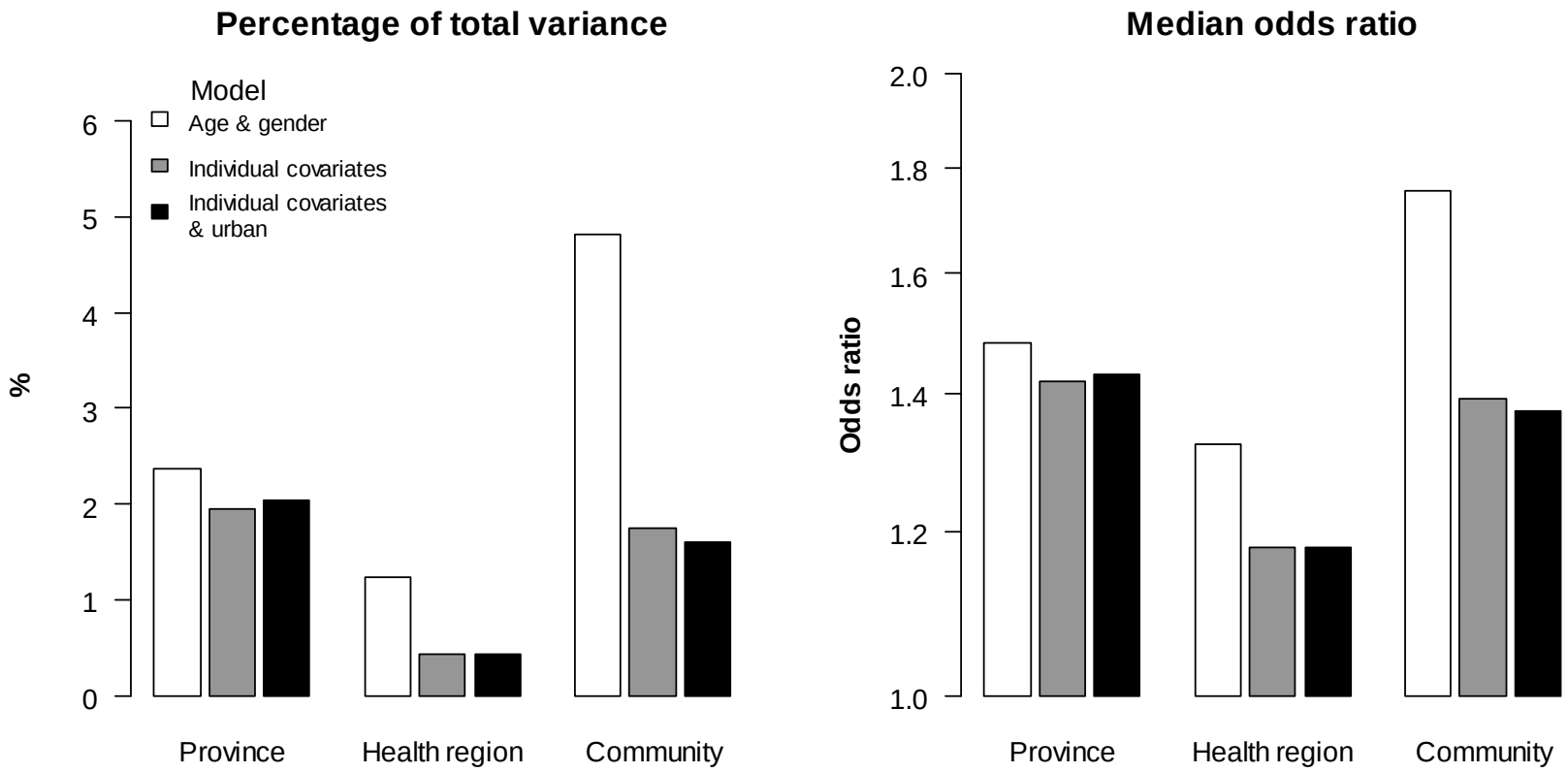


Figure 5.1 Variation in current smoking (as a percentage of total variation) among adults (≥ 18 years) attributed to provinces, health regions, and communities in Canada.

Estimates include a model accounting for age & gender (*white bars*), a model accounting for age, gender and all individual socioeconomic and demographic characteristics (*grey bars*), and a model accounting for all individual socioeconomic and demographic characteristics and community urban-rural status as a community contextual variable (*black bars*). All models also account for survey cycle as a fixed effect.

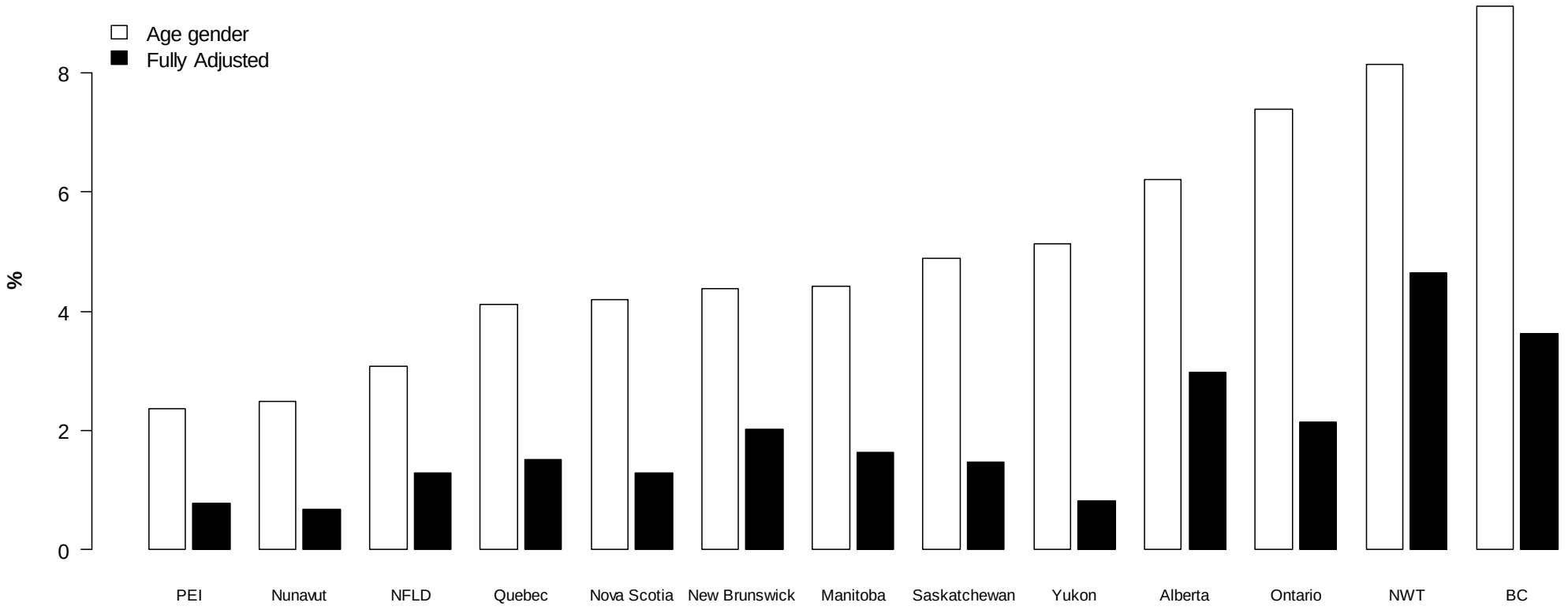


Figure 5.2 Community variation in current smoking (as a percentage of total variation) across Canadian provinces among adults (≥ 18 years).

Estimates are derived from province-specific models accounting for individual age and gender (*white bars*) and fully adjusted models accounting for individual level socioeconomic and demographic characteristics (*black bars*). PEI Prince Edward Island; NFLD Newfoundland; NWT Northwest Territories

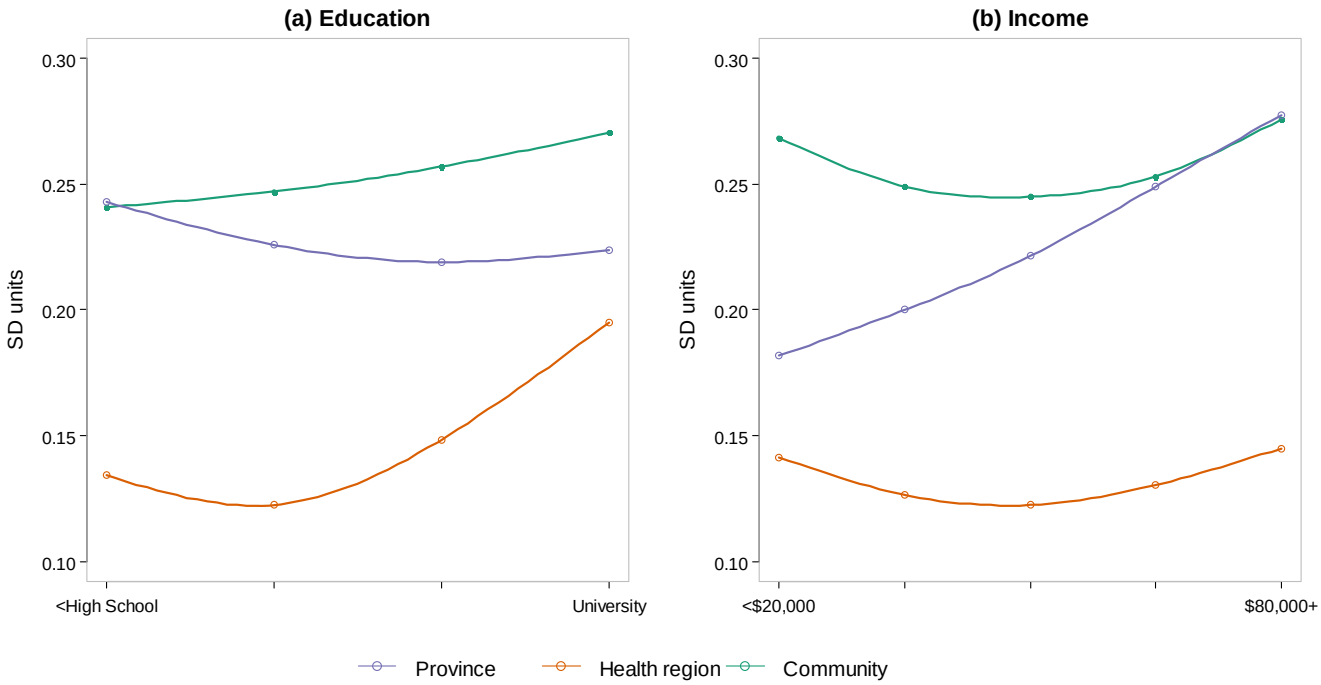
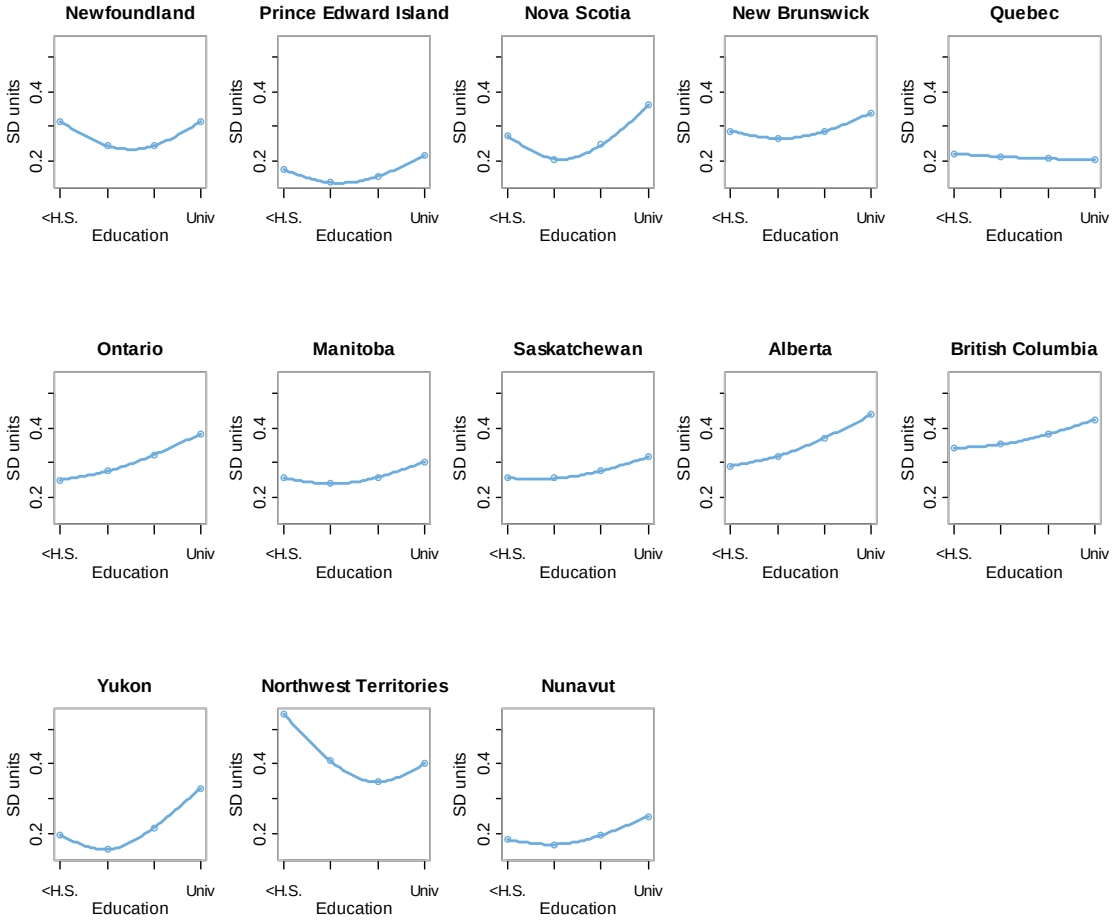


Figure 5.3 Variation in smoking between provinces, health regions, and communities Canada (in Standard deviation, SD, units) as a function of education (*a*) and income (*b*).



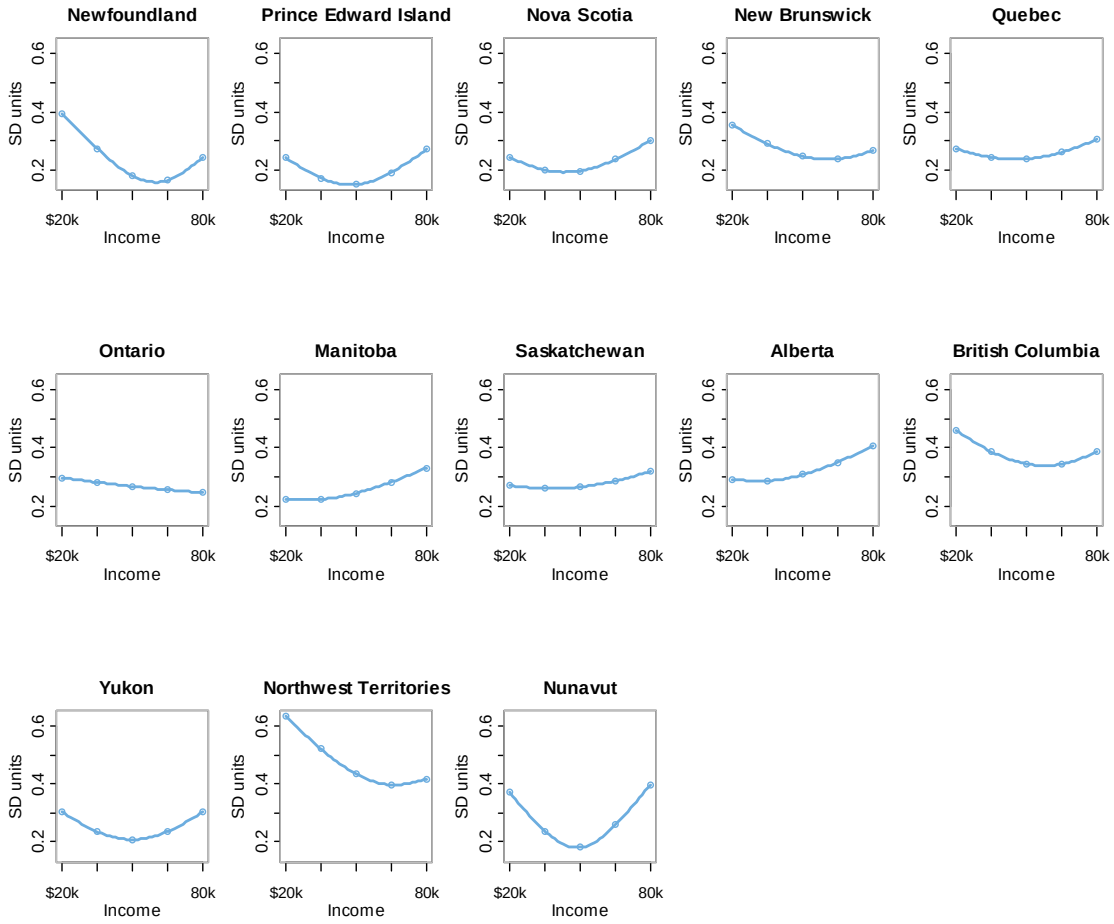


Figure 5.4 Community variation in current smoking as a function of education (previous page); and income (this page) in Canada; derived from province-specific fully-adjusted multilevel models.

Chapter 6 Co-variation in current smoking, cigarettes per day, and pack years: a multivariate multilevel analysis of smoking behaviour in Canada

Abstract

Background Few studies have considered how markers of socioeconomic status (SES) may be related to current smoking and amount of consumption in the same analysis. The objectives of this chapter were to evaluate the effects of SES on the prevalence of current smoking, consumption levels (number of cigarettes smoked per day), and cumulative smoking exposure (pack-year history). In addition, we examined the extent to which the prevalence of smoking and levels of tobacco consumption co-vary across communities, health regions, and provinces in Canada.

Methods We conducted a cross-sectional analysis of two nationally representative Canadian health surveys conducted between 2001 and 2010. Current smoking, cigarettes per day, and pack-years were considered as distinct yet interrelated outcomes within individuals using a multilevel analytical framework. Markers of socioeconomic status were education, income, and occupation. Residual covariance estimated at the geographic levels of communities, health regions, and provinces was estimated to determine if areas high in current smoking were also high on levels of consumption.

Results A strong inverse gradient was found between education and current smoking, cigarettes per day and number of pack-years of exposure. Although income was inversely related to current smoking, there was no consistent relationship between income and cigarettes per day and pack years. Among those who were not working, and those working in manual occupations current smoking, cigarettes per day, and pack-years of

consumption were higher. Large variation was found in levels of consumption between individual smokers. The co-variation between current smoking, cigarettes per day, and pack-years was positive and statistically significant at the level of communities and health regions, suggesting that at these geographical scales, places with more smokers also have higher levels of consumption (and vice versa) after taking account of individual demographic and socioeconomic factors.

Conclusions Our findings revealed that novel approaches may be needed to encourage cessation among certain population groups where patterns of smoking are much different than 'typical' smokers. Policy efforts, tobacco control initiatives, and cessation support could be targeted to population groups and places with high levels of smoking prevalence and tobacco use intensity. The analytical framework described here is applicable to other areas of health-related behaviour research; its use may provide additional insights into the distribution and patterns of these behaviours across individuals and places in Canada.

INTRODUCTION

Daily smoking of even a few cigarettes has been associated with an increased risk of myocardial infarction (MI)[1], all-cause mortality, and mortality from ischaemic heart disease and lung cancer.[2] In addition, a linear dose-effect relationship has been described between smoking and the risk of MI[3], chronic obstructive pulmonary disease (COPD), chronic bronchitis (CB), emphysema[4], and lung cancer.[5] For example, in a large international case-control study, the number of cigarettes smoked daily was found to be directly associated with risk of MI; each additional cigarette smoked increased the odds of MI by 1.056 (95% confidence interval [CI]: 1.05-1.06).[6] A similar dose-effect

relationship has been observed between cumulative cigarette smoking and lung function, with a loss of forced expiratory volume in one second (FEV_1) of 4.4 ml (95% CI: 3.2-5.6) in women and 7.4 ml (95% CI: 6.4-8.4) in men for each additional pack-year, where pack-years are the number of packs of cigarettes smoked per day times years of smoking.[7] Therefore, although smoking in even small quantities is harmful, if the dose-effect relationship between smoking and disease is assumed to be linear or log-linear, a proportional reduction in the amount or intensity of smoking among individuals (either through cessation, increased periods of abstinence during quit attempts, or non-daily smoking) could translate into large reductions in risk (e.g. of MI) within poupations.[8-9]

At the population level, strategies to reduce cumulative exposure to smoking through prevention and increasing quit rates at younger ages (thus reducing lifetime duration of smoking) have the potential for significant reduction in smoking-attributable morbidity and mortality.[10] In addition, identifying areas with particularly high rates of smoking and/or consumption will be important for targeting tobacco control initiatives along with potential development of screening programs for early diction of lung cancer.[11] At an individual level, and due to the addictive nature of tobacco, a step-down or dosing regimen of nicotine replacement has been shown to be an effective strategy for quitting success and maintaining periods of abstinence among heavy smokers (more than 30 cigarettes per day) trying to quit.[12] A logical first step which can inform policies at both the population and individual levels is the identification of population groups and geographies at greatest risk for smoking and those most likely to consume high levels of tobacco over sustained periods of time. As described in earlier chapters, low socioeconomic status defined by education, income, occupation, or housing tenure, has

been implicated as an important determinant of current smoking.[13-15] However, few studies have considered how SES markers may be related to current smoking and amount of consumption in the same analysis[16-17]; and, at the same time, no study has modeled cumulative lifetime tobacco exposure as an endpoint. In this chapter, we provide two methodological and substantive advances over previous research. First, we simultaneously evaluate the effects of demographic and socioeconomic characteristics on the prevalence of current smoking, consumption levels (number of cigarettes smoked per day), and cumulative smoking exposure (pack-year history) using a multilevel conceptual and analytical framework.[17-18] In this approach, we consider smoking, level of tobacco consumption, and cumulative exposure, as distinct yet interrelated outcomes within individuals.[18] Second, we examine the extent to which the prevalence of smoking and levels of tobacco consumption covary across provinces, health regions, and communities in Canada, providing more detailed information on the burden of tobacco at these levels of geography and examining the potential role place may have in shaping the codetermination of smoking rates and levels of tobacco consumption in the population.

METHODS

Data sources

Data for this chapter come from the Canadian Tobacco Use Monitoring Survey (CTUMS) and the Canadian Community Health Survey (CCHS). Both surveys were developed and conducted by Statistics Canada[19-20], and have been previously described (see Chapter 2 and 5). In brief, CTUMS is designed to provide Health Canada with continuous data on the prevalence of smoking in Canada and the provinces; it has been

conducted annually since 1999 and over-samples 15 to 24 year olds, who are at elevated risk for taking up smoking.[21] The CCHS is a large nationally-representative survey which collects health-related data at sub-provincial levels of geography in Canada. We analyzed data from the 2010 CTUMS, conducted between February and December 2010[22], and from four cross-sectional cycles of the CCHS conducted in 2001, 2003, 2005, and 2007-8.[23] The four CCHS cycles incorporated identical questions on smoking history and were combined to form a pooled sample for analysis.[24] Further details are provided in Chapter 5.

Survey design

CTUMS was conducted by telephone and targeted a sample of the Canadian population aged 15 and older, excluding residents of Yukon, Nunavut, and Northwest Territories (0.3% of the population)[25], and full-time residents of institutions. CCHS targeted the household population aged 12 or older can covered all provinces and territories but excluded Canadian Forces Bases, Indian reserves, and some remote areas. Both surveys employed a stratified, multistage design. In CTUMS, the sample design was based on a stratified random sample of telephone numbers.[20] First, each province was divided into two geographic strata according to census defined metropolitan areas (with a population of 100,000 or more) and non-metropolitan areas. In Prince Edward Island, only one geographic stratum was defined, and in Ontario and Quebec a third stratum was defined for Toronto and Montreal, respectively.[20] Second, households were selected from telephone number sampling frames in each stratum using random digit dialling. Finally, based on the composition of the household, and to increase the numbers

of respondents between the ages of 15 and 24 years, one or two individuals (or none) were selected to participate in the survey. The overall household response rate for the 2010 CTUMS was 73.8%, with an individual response rate of 84.2%.[22]

The CCHS used area-based and telephone-based sampling frames.[26] The area frame was designed for the Labour Force Survey and was the primary sampling frame for the CCHS. A sample of dwellings from within this frame was drawn using a multistage stratified cluster design (see Chapter 5). To increase coverage in some geographical areas, the area-based sampling frame was supplemented through telephone-based sampling frames and random-digit dialling in these areas. Roughly 80% of the CCHS sample comes from households selected in the area sample. In-person interviews were held with respondents in the area frame; respondents in the telephone frames were interviewed by telephone. CCHS response rates varied from 84.7% in 2001 to 77.6% in 2007.[27-28]

Description of geographic areas

In Canada there are 10 provinces and 3 territories at the highest level of geography. Province was the only geographic identifier included with the CTUMS data and these analyses are restricted to individuals nested within provinces. In the CCHS, geographic identifiers were available for health regions and communities in addition to province/territory. Health regions are geographic regions within provinces and are defined by Statistics Canada and provincial health authorities. We have used the 2007 definition of health regions, which correspond with the geographic boundaries of the 2006 Census.[29] Communities were defined based on census dissemination areas (DA).

DA are the smallest geographical units for which census data area available; they are composed of between 400 and 700 individuals and cover the entire country. No standard definition of community exists for Canada but, as the smallest available geographical unit in the CCHS, the DA is likely to correspond to an individual's perception of his or her community (see Chapter 5).

Sample for analysis

In total CTUMS collected information from 19,822 respondents aged 15-85 years. All respondents had complete information on current smoking status, age, sex, and province of residence. Respondents with incomplete information for marital status, occupation, or education were excluded (n=439, 2.2%); and the final sample for analysis was 19,383. The CCHS sample included all adults aged ≥18 (n=481,033). Among these individuals, 1,506 (0.3%) did not have information on smoking status and were excluded. An additional 16,528 (3.4%) individuals were missing data on one or more covariates and excluded. Missing or invalid residential postal codes limited the assignment of a further 1,290 observations (0.2%) to the correct dissemination area and/or health region and these individuals were not included in analyses. The final analytic sample comprised 461,709 adults from 49,088 communities, 121 health regions and 13 provinces/territories in Canada.

Outcome measures

Current cigarette smoking at the time of survey was defined as individuals who had smoked 100 cigarettes in their lifetime (about 5 packs), and reported smoking at least

1 cigarette daily over the 30 days preceding the survey. If individuals did not report having smoked 100 cigarettes, but had been smoking daily for at least 1 year, or had reported smoking at least 100 cigarettes over the previous 30 days, they were considered current smokers. Non-smokers included lifelong never smokers, former smokers at the time of survey, and individuals who smoked less than 1 cigarette per day. Smokers were asked to report detailed smoking histories which captured the age at which they first began smoking and number of cigarettes smoked on each of the seven days leading up to the survey. The usual level of tobacco consumption was calculated as the average number of cigarettes smoked daily using the respondent's smoking history of the previous week. Cumulative exposure to tobacco was defined in 'pack-years', where one 'pack-year' is equivalent to 20 cigarettes smoked per day for one year.[30]

SES markers

We considered, education, and occupation, and income (in the CCHS only) as the key markers of SES. Education was categorized as less than secondary school, completed secondary school, completed post-secondary/college, or completed university, with the reference group being those who had completed university. Occupation was categorized following the 2006 National Occupational Classification for Statistics[31], and included categories for professional specialties (reference), executive or managerial positions, sales/service positions, and manual occupations (including trades, transport, industry, manufacturing, and utilities). We included categories for individuals not currently working and for respondents who did not report their occupation, and for those working in farming, forestry, or fishing (CCHS only). Income was captured in the CCHS

as total household income reported in dollars, and we defined the following categories: <$20,000, $20,000-$40,000, $40,000-$60,000, $60,000-$80,000, $80,000+, and not reported (reference: $80,000+).

Independent variables

The following demographic variables were included as covariates the analysis: age, sex, marital status, immigrant status, and Aboriginal identity. Age was treated as a continuous variable centred about its mean (45 years in the CTUMS, and 46 years in the CCHS) in regression models. In addition, polynomial terms were included to allow for non-linearity in the relationship between age, current smoking, cigarettes per day, and pack years. Sex was specified as a categorical variable, with females as the reference category. Marital status was categorized as common-law/married (reference), single, or widowed/divorced/separated. Due to the larger sample size, widowed was treated as a separate category in analyses involving the CCHS. In addition, immigrant status and Aboriginal identity were available as covariates in the CCHS. We defined immigrant as being born in or outside of Canada (reference: born in Canada). Aboriginal identity was established through respondent self-reports of First Nations, Inuit, and/or Métis identity (reference: non-Aboriginal identity). The frequency and percentage distribution of the study sample by independent variables, and mean cigarettes per day and pack years by categories of independent variables are given in **Table 6.1** for the CTUMS sample and in **Table 6.2** for the CCHS sample.

Statistical analyses

A multilevel analytical framework allows for the consideration of multiple interrelated health behaviour outcomes which can be clustered within individuals.[18, 32-33] In the present study, we used a multivariate multilevel structure to simultaneously consider the qualitative (current smoker or not) and quantitative (how many daily cigarettes/pack years) aspects of smoking behaviour within individuals, who are in turn nested within their province of residence. For example, a diagram of the 3-level multilevel structure used in the CTUMS analyses (responses nested within individuals nested within provinces) is given in **Figure 6.1**. Importantly, this structure allows for data imbalance within individuals: those who do not smoke have only a categorical response variable (coded '0' indicating non-smoker); whereas smokers have both a categorical response indicating regular smoking (coded '1') along with a continuous response for number of cigarettes consumed daily or pack-years. Within the modelling framework, we specified a mixture of 2 models: 1) a logistic model relating to the occurrence of smoking, and 2) with a linear model relating to daily consumption/pack years.

Specifically, we used the following model in all analyses, described below using the CTUMS data with responses for smoking and number of cigarettes per day as an illustrative example. Formally, the model has two responses representing current smoking (y_{1jk}) and number of cigarettes smoked per day (y_{2jk}) calibrated for individual *j* in province *k*. The set of responses *i* are nested within individuals at level 1. Current smoking was binary and modelled according to a binomial distribution with probability π_{1jk} : $y_{1jk} \sim$ Binomial (1, π_{1jk}), while number of cigarettes per day was continuous and

modelled according to a normal distribution. The probability of being a current smoker (π_{1jk}) and the number of cigarettes per day (y_{2jk}) was related (using a logit link function for current smoking) to a set of predictors *X* (education, occupation, age, sex, and martial status) and a random intercept for province and individual (in the cigarettes per day equation only):

$$\begin{cases} Logit(\pi_{1jk}) = \beta_{0ijk} + \beta X_{ijk} + (v_{0k}) \\ y_{2jk} = \beta_{1ijk} + \beta X_{ijk} + (v_{1k} + u_{1jk}) \end{cases} . \qquad \text{(Equation 6.1)}$$

The right-hand sides of both components of Equation 6.1 consist of fixed and random parts. The fixed part ($\beta_{0ijk} + \beta X_{ijk}$) includes the individual demographic and socioeconomic characteristics and the random part terms, indicated by brackets, quantify variation in smoking at the level of provinces (v_{0k}, v_{1k}) for current smoking and number of cigarettes per day, respectively. In this model, a variance-covariance matrix was estimated at the level of provinces and contains terms which quantify the variance in random intercepts for current smoking (σ^2_{v0}), number of cigarettes per day (σ^2_{v1}), and their covariance (σ_{v01}). The covariance term represents the 'correlation' between the random intercepts for current smoking and number of cigarettes per day at the provincial level, providing an indication of the extent to which high smoking prevalence coexists with high consumption in provinces after accounting for individual characteristics in the fixed part of the model.[17] Covariance terms were expressed as correlation coefficients and varied between -1 and 1.

In each of the surveys, separate models were estimated for current smoking and daily cigarette consumption, and for current smoking and pack-years. In addition, models estimated in the CCHS data included random intercepts at the level of

communities and health regions and covariates for income, immigrant status, aboriginal identity, and place of residence in the fixed part of the model. All models were estimated with penalized quasi-likelihood (PQL) procedures using the software *MLwiN* (version 2.24).[34] Sampling weights for the CTUMS and CCHS were used in descriptive analyses.

RESULTS

Table 6.3 presents the adjusted odds ratios (with 95% confidence intervals) and adjusted prevalence estimates for current smoking and the beta coefficients with adjusted mean values for number of cigarettes consumed daily and number of pack-years across all covariates in the CTUMS data. The results for current smoking were nearly identical between the two models (i.e., number per day and pack years) and therefore have only been presented once. Based on these models, the overall prevalence of smoking for a 45 year-old in Canada was 20.2% (95% confidence interval [CI]: 18.4-22.1); among regular smokers the typical number of cigarettes smoked per day was 15.5 (95% CI: 14.6-16.3) and cumulative exposure was 25.9 (95% CI: 24.8-27.1) pack-years. Men had an odds ratio of 1.08 (95% CI: 0.99-1.19) for regular smoking compared to women; this was equivalent to an adjusted prevalence of 20.9% for current smoking among men compared to 19.6% among women. In addition, men consumed more cigarettes than women both in numbers per day (15.5 *vs* 14.1) and pack years (28.0 *vs* 23.9). Compared to married couples, those who were widowed, divorced, or separated had a higher prevalence of current smoking (30.0% *vs* 17.2%), consumed more cigarettes per day (16.5 *vs* 15.2), and had a greater number of pack years (27.6 *vs* 25.4) compared to married couples.

In the CCHS, being born outside of Canada was associated lower rates of current smoking (OR 0.64), and fewer numbers per day and pack years (**Table 6.4**). Interestingly, being of Aboriginal identity was positively associated with current smoking (OR 1.56; 95% CI: 1.50-1.62), but inversely associated with cigarettes per day (β = -1.3; 95% CI: -1.6, -1.1) and pack years (β = -1.5; 95% CI: -1.9, -1.0). Current smoking was somewhat less common among residents of rural communities (OR 0.92), but individuals from these communities reported greater numbers of cigarettes per day (β = 0.3) and pack-years (β = 0.6) of consumption. Patterns of smoking were substantially different in the territories compared to the rest of Canada (Table 6.2). For example, the rate of current smoking was high in Nunavut compared to the Canadian average (55.4% *vs* 20.0%); although cigarettes per day and pack-years were lower (12.4 *vs* 16.0 for cigarettes per day and 11.8 *vs* 20.7 for pack-years).

The relationship between age and regular smoking, cigarettes per day, pack-years is plotted in **Figure 6.2**. The highest prevalence of current smoking was found among adults in their mid-30s, reaching a maximum of 25.7% (95% CI: 23.5-28.0) at age 38. Among current smokers, those younger than 30 typically smoked 9 to 13 cigarettes daily, whereas smokers between 40 and 60 reported smoking on average about 15 cigarettes daily. There was considerable uncertainty in estimating the average number of cigarettes consumed daily among older age groups, since few respondents reporting daily smoking. Cumulative smoking exposure increased continuously before levelling off at 38.0 pack-years (95% CI: 35.7-40.3) at age 73. Stated differently, current smokers who had continued to smoke into their 70s had consumed an average of 277,400 cigarettes (95% CI: 260,610-294,190).

Socioeconomic patterning of current smoking and levels of consumption

A strong, graded, and consistent association was observed between educational attainment and current smoking, the amount per day and number of pack-years (**Figure 6.3**). In the CTUMS, and compared to individuals who had completed university, those with less than secondary level education had an odds ratio of 4.7 (95% CI: 3.9-5.6) for current smoking, consumed 2.9 (95% CI: 1.6-4.2) more cigarettes per day, and had 5.5 (95% CI: 3.3-7.7) additional pack-years of tobacco exposure (Table 6.3). The findings for education were largely consistent in the CCHS sample: the OR for current smoking among lower educated groups was 4.31 (95% CI: 4.2-4.6), the coefficient for cigarettes per day was 2.8 (95% CI: 2.6-3.0), and the coefficient for pack-years was 5.2 (95% CI: 4.7-5.6). A similar but less pronounced SES gradient was found between current smoking and income in the CCHS sample (Table 6.4). In contrast, despite a modest increase in pack years for the lowest income group (<$20,000), the number of cigarettes smoked per day and pack-years were not associated with income.

There was considerable variability in the probability of smoking by occupation, with adjusted prevalence of current smoking among those in professional occupations found to be 14.8% (95% CI: 13.0-16.9) compared to 27.4 % (95% CI: 24.7-30.3) for manual workers in the CTUMS. Compared to professionals (mean cigarettes per day 15), the number of cigarettes consumed per day was higher among those not working (16.1; 95% CI: 15.0-17.1, p=0.33) and manual workers (16.5; 95% CI: 15.4-17.6, p<0.0001), although it was relatively consistent between executives and those in the sales or service industry. Similarly, the number of pack years was consistent between executives, professionals, and sales or service (at 25) but was higher among manual workers (26.5)

and those who were not working (27.0). The patterns of current smoking, cigarettes per day and pack years across occupational groups were similar in the CCHS; those in manual occupations were more likely to be current smokers (OR 1.5), followed by those who were not working (OR 1.28) and those in sales or service (OR 1.24) ($p<0.001$). Again, the numbers of cigarettes per day and pack years were highest among manual workers and those in farming, forestry, or fishing although those in latter group were only marginally more likely to be current smokers (OR 1.1).

Geographic co-variation in current smoking, cigarettes per day, and pack years

Table 6.5 summarizes the difference between provinces in patterns of current smoking, cigarettes smoked per day, and pack-years in the CTUMS sample. These estimates have been derived from Equation 6.1 and have been adjusted for age, sex, marital status, education, and occupation. British Columbia had the lowest rates of current smoking at 16.9% (95% CI: 14.8-19.1), compared to 22.4% (95% CI: 20.0-24.9) in Nova Scotia. With the exception of Prince Edward Island, current smoking was generally higher in the Atlantic Provinces (Nova Scotia, New Brunswick, Newfoundland) and Quebec, followed by Saskatchewan and Alberta. Manitoba was found to have the lowest rate of daily consumption with an average of 14.1 (95% CI: 13.1-15.1) cigarettes per day, while British Columbia had the lowest cumulative exposure with an average of 24.6 (95% CI: 23.0-26.2) pack years. The average number of cigarettes per day and pack-years were greater in the Atlantic Provinces (with the exception of Newfoundland) and Quebec compared to the overall Canadian population.

Using the multivariate multilevel model, we estimated the covariance between current smoking and cigarettes per day and between current smoking and pack years between individuals, communities, health regions, and provinces. Estimates from the random part of two multivariate multilevel models which describe the magnitude of variation and co-variation in the outcomes at each geographic level in the CCHS sample are provided in **Table 6.6**. Before describing the geographic co-variation in the smoking outcomes, we note that the values obtained for between individual variance in cigarettes per day and pack years were very large (69.86 and 226.43), indicating that most of the variation in these aspects of smoking behaviour is between individuals. Similar estimates of between individual variance were obtained for cigarettes per day (68.46) and pack years (186.20) in the CTUMS data (not shown).

An important advantage of modelling approach is the ability to estimate the residual covariance between the random intercepts variance for current smoking and cigarettes per day and between current smoking and pack-years at each of the higher levels of geography (communities, health regions, and provinces). For example, a strong positive covariance term, at a given geographic scale, would indicate that areas with high rates of current smoking were similarly high in smoking intensity. Our analyses of the covariance between smoking and measures of smoking intensity revealed several interesting patterns at the level of provinces, health regions, and communities. First, we observed a negative covariance (correlation coefficient -0.63) between current smoking and number of cigarettes per day and between current smoking and pack years (correlation coefficient -0.52) at the provincial/territorial level in the CCHS (**Figure 6.4**). These estimates were not statistically significant (p=0.07 for cigarettes per day and

p=0.13 for pack-years) and seemed to be driven in large part by two territories: Nunavut and the Northwest Territories where were current smoking was found to be substantially higher but cigarettes per day and pack years were lower than the Canadian average (see Table 6.2). In the CTUMS data, which did not include these territories, the provincial level covariance between current smoking was found to be positive (but not statistically significant) for number of cigarettes per day and pack-years, with the latter relationship being somewhat stronger (correlation coefficients 0.27 and 0.45) (**Figure 6.5**). In general, and with the exception of Nunavut and Northwest Territories, it appeared that there was a weak but positive relationship between current smoking and amount of consumption, although some caution is required because estimates at this level were less statistically reliable due to fewer geographical units (10 provinces and 3 territories). However, at the level of health regions (with a total of 121 units), a clear and positive association was found between current smoking and cigarettes per day and between current smoking and pack-years (**Figure 6.6**). The correlation coefficients were 0.67 and 0.71 ($p<0.0001$) indicating that at this geographical scale, places with high (or low) rates of current smoking also have high (or low) rates of average cigarette consumption and pack-years among smokers. In addition, statistically significant positive correlations were fond at the level of communities between current smoking and cigarettes per day (0.58) and between current smoking and pack-years (0.54), suggesting the potential importance of local neighbourhood context in shaping aspects of smoking behaviour (Table 6.6).

DISCUSSION

In this chapter, we presented novel evidence on the interrelated aspects of current smoking, cigarettes smoked per day, and pack-years in Canada. Our objectives were to examine how the effects of individual characteristics (demographic and socioeconomic) on both current smoking and level of consumption along with investigating covariance between rates of smoking and levels of consumption at different levels of geography in Canada. Our principal findings are summarized as follows. First, in terms of demographic characteristics, although rates of current smoking among the older ages were low, the amount of daily consumption was relatively consistent throughout middle age (30 to 70 years) indicating a greater cumulative exposure among those who continue to smoke. Men and those who were divorced or separated were more likely to be smokers and have a higher level of consumption over the lifetime compared to women and married people. Immigrants to Canada were less likely to be current smokers and those who did smoke had lower levels of consumption, while individuals of Aboriginal identity were more likely to be current smokers but typically consumed lower amounts of tobacco. Second, in terms of SES, we observed strong inverse gradient by education that was consistent across smoking outcomes, with less education related to higher levels of current smoking, consumption of more cigarettes per day and a greater number of pack-years of exposure. Although income was inversely related to current smoking, there was a weak, if any, relationship between income and cigarettes per day and pack years. In addition, those who were not working and those working in manual occupations were more likely to be current smokers and to have higher levels of consumption in terms of cigarettes per day and pack-years. Finally, although there was large variation in levels of

consumption between individual smokers, the co-variation between current smoking, cigarettes per day, and pack-years was positive and statistically significant at the level of communities and health regions, suggesting that at these geographical scales, places with more smokers also have higher levels of consumption (and vice versa) after taking account of individual demographic and socioeconomic factors. Patterns at the provincial/territorial level were less consistent. This likely arose both from a statistical limitation (fewer geographic units at this level) and from the largely different patterns of smoking in the territories (with higher than average rates of current smoking but lower than average levels of consumption among smokers).

Like other studies based on cross-sectional observational data, the associations observed between demographic and socioeconomic characteristics and smoking/level of consumption are founded on the basis of prevalence, thus limiting the inference on the incidence of smoking or smoking behaviour by individual characteristics.[35] In addition, we have only considered cigarettes and not other forms of tobacco use such as cigars, pipes, or hand-rolled cigarettes. Use of tobacco in these forms is less readily comparable to manufactured cigarettes in terms of the amount of tobacco delivered to the smoker, although Wood and colleagues have developed a simple formula to measure pack years for users of loose tobacco.[36] In this study we did not consider occasional, non-daily smokers as a separate group but as part of the non-smoker group. It is not clear if the quantitative measures of tobacco consumption (cigarettes per day and pack years) would be directly applicable to occasional smokers. In addition, our sensitivity analyses suggested that findings related to the demographic and socioeconomic patterning of current smoking were robust to the exclusion of occasional smokers from the current

smoker group (see **Appendix B**). A further limitation is that our analysis of co-variation in smoking and the amount of consumption at the provincial/territorial level was less reliable due to the smaller number of units (n=10 or 13) at this level. Estimates of geographical variation for certain outcomes will generally be more consistent where there are more units. For instance, in our preliminary analyses in India, we found a positive and statistically significant covariance (correlation coefficient 0.87) between current smoking and number of cigarettes at the state level, with 29 states available for analysis at this level. Finally, the mixed multivariate multilevel model is a simplification of the complex nature of smoking-related behaviour.[17] Despite this limitation, the approach is useful for extracting additional information from population tobacco use surveys compared to traditional analyses which do not simultaneously consider the qualitative and quantitative aspects of tobacco use.

The multilevel framework offers several advantages in health-related behaviour research. First, the approach allows for an examination of interrelated health behaviours with both quantitative and qualitative aspects, including smoking, alcohol or other substance use, and physical activity.[17-18] Second, models can be expanded to examine whether the factors related to engaging in certain behaviours are also related to the intensity of those behaviours across multiple outcomes within individuals. In addition, the direction and magnitude of association of independent variables (e.g. socioeconomic status) can be compared across different aspects of health behaviours. Finally, models can accommodate different levels of geography (e.g., provinces and communities) which may be of substantive importance. At a given geographic level, the residual covariance

can be estimated to provide a measure of correlation between places in, for example as in this study, the prevalence of smoking and the level of consumption.

Our findings have substantive implications for clinical practice, population health research, and policy development. In terms of clinical practice, our models provide information (with an associated level of uncertainty) which is of direct relevance to clinicians including the likelihood that a patient may be a smoker, and for regular smokers, the typical amount of daily and cumulative tobacco exposure given simple demographic and socioeconomic characteristics. For example, it could be calculated that a women who was 35 years old, married, worked in sales/service and had a college education would have a probability of smoking of 11.3% (95% CI: 9.6-13.5) and smokers of a similar demographic would have an average exposure of 6.9 (95% CI: 4.4-9.5) pack years; versus a probability of smoking of 35.1% (95% CI: 30.8-39.5) and an average pack year history of 30.8 (95% CI: 28.7-33.0) among a man aged 50, who was divorced, had completed secondary education and was working in a manual occupation. In addition, pack years and other concepts such as 'lung age' (the age of a healthy person who would have a comparable lung function) may be helpful in eliciting behaviour change among smokers.[38] The adjusted prevalence of smoking, mean cigarettes per day, and pack-years have been provided across the demographic and socioeconomic characteristics in this study to facilitate other similar comparisons.

The methods proposed here for the consideration of interrelated health behaviour outcomes could be readily implemented in other areas of population health research in Canada such as research on alcohol and substance use, diet, and physical activity patterns where nationally-representative data have been collected.[39-41] Finally, policy efforts,

tobacco control initiatives, and cessation support could be targeted to population groups and places with high levels of smoking prevalence and tobacco use intensity. For example, the persistence of high rates of current smoking among working class groups is a concern both in Canada and other high-income countries.[42] One possible policy approach which has shown success in improving rates of cessation among these groups in the United States is the integration of cessation programs with other job-related health and safety training.[43] Our findings revealed that novel approaches may be needed to encourage cessation among certain population groups where patterns of smoking are much different than 'typical' smokers. For example, among aboriginal groups, levels of current smoking were high although typical amount of consumption was much lower than other groups. Finding successful strategies to encourage cessation among groups with similar patterns of smoking will be important not only in Canada but in other settings where the tobacco epidemic is at a similar stage. For instance, in rural India rates of current smoking, cigarettes per day, and pack years among men were similar to patterns seen in Canadian Aboriginal communities (see Chapter 3). In addition, places with, for example, low overall smoking prevalence but high intensity of consumption among those that do smoke could benefit from further context-specific research to identify potential explanations as to why certain groups may be less responsive to tobacco control initiatives.[44]

In conclusion, we have presented a multilevel approach which has the potential to provide useful information for identifying variations in patterns of smoking in Canada, and in addition, for simultaneously identifying variations in the patterns of current and cumulative tobacco consumption and the extent to which demographic and

socioeconomic characteristics are associated with both aspects of smoking behaviour. The analytical framework described here is directly applicable to other areas of health-related behaviour research; its use may provide additional insights into the distribution and patterns of these behaviours across individuals and places in Canada.

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TABLES

Table 6.1 Weighted prevalence estimates (%) of current smoking and mean number of cigarettes and pack years among smokers by demographic and socioeconomic characteristics and province, Canadian Tobacco Use Monitoring Survey 2010

		Current Smoking	Cigarettes per day		Pack years	
Characteristic	No.	%	Mean	SD	Mean	SD
Total	19383	14.0	14.6	8.6	21.0	19.6
Age						
15-19 yrs	4994	8.2	10.9	7.0	2.4	2.3
20-24 yrs	3772	16.1	11.9	6.7	4.5	3.5
25-44 yrs	3405	16.6	14.4	8.0	14.5	10.3
45-64 yrs	4771	15.3	16.0	9.5	30.4	20.9
65+ yrs	2441	7.4	14.2	8.5	40.7	26.3
Sex						
Women	10537	11.4	12.6	7.9	19.0	18.0
Men	8846	16.7	15.9	8.8	22.4	20.5
Marital status						
Common-law/Married	7435	12.2	14.4	8.9	22.7	19.6
Single	9677	16.9	14.2	8.1	13.6	14.6
Widowed/Divorced/ Separated	2271	17.1	16.0	8.3	31.9	22.8
Education						
Completed university	3413	7.4	13.0	7.6	21.5	20.1
Completed college	5682	12.6	14.7	8.7	18.8	17.4
Completed secondary	4868	20.3	14.0	7.9	19.6	16.3
Less than secondary	5420	18.2	16.4	9.7	26.3	25.6
Occupation						
Professional specialty	3122	8.0	13.2	7.9	15.6	13.3
Not working	5487	11.6	15.6	8.9	30.3	23.3
Executive, managerial	2723	13.8	14.1	9.1	20.4	18.9
Sales or Service	4886	16.2	12.3	6.9	14.5	13.3
Manual	2895	25.4	16.2	8.9	20.8	19.8
Not reported	270	11.1	14.1	7.9	16.5	17.8
Eastern Provinces						
Ontario	1886	12.6	14.4	8.5	20.8	19.6

Prince Edward Island	1898	13.2	16.2	8.3	24.8	19.2
New Brunswick	1811	15.5	17.3	11.3	24.5	23.7
Newfoundland	1760	17.7	13.9	10.0	19.2	19.0
Quebec	1943	15.3	14.7	8.7	21.6	21.5
Nova Scotia	1995	17.9	16.2	10.0	24.0	22.0
Western Provinces						
British Columbia	1731	11.1	14.7	8.0	23.0	16.9
Alberta	2061	16.1	14.2	8.0	18.2	16.4
Manitoba	2237	17.2	12.9	7.4	18.3	16.3
Saskatchewan	2061	17.7	14.5	8.5	21.1	19.7

Table 6.2 Weighted prevalence estimates (%) of current smoking and mean number of cigarettes and pack years among smokers by demographic and socioeconomic characteristics and province/territory, Canadian Community Health Survey 2001-2008

	Current Smoking (n=96,815)	**Number of cigarettes per day**		**Pack years**	
	%	*Mean*	*SD*	*Mean*	*SD*
Total (n=461,709)	20.0	16.0	8.9	20.7	18.7
Sex					
Male	22.1	17.4	9.4	22.3	20.4
Female	18.0	14.4	7.9	18.7	16.3
Immigrant status					
Born in Canada	22.0	16.4	8.9	21.0	18.9
Born outside of Canada	11.9	13.1	8.2	18.2	17.3
Aboriginal identity					
Not Aboriginal	19.3	16.1	8.8	21.0	18.8
Aboriginal	42.2	14.1	8.8	15.6	17.0
Household income ($)					
<$20,000	28.9	16.5	9.7	23.8	21.8
$20,000-<$40,000	23.5	16.3	9.0	22.2	20.3
$40,000-<$60,000	21.4	16.2	8.6	20.4	17.5
$60,000-$80,000	19.5	15.8	8.5	19.3	16.3
$80,000+	14.8	15.6	8.4	18.8	16.2
Not stated	17.6	15.2	9.2	19.3	19.6
Education					
Less than secondary	27.7	17.4	9.8	25.4	22.1
Completed secondary	23.5	16.0	8.5	19.5	17.4
Completed college	17.3	14.9	8.2	18.1	15.8
Completed University	8.1	13.5	8.2	17.6	16.9
Occupation group					
Executive, administrative, managerial	19.5	15.0	7.9	18.5	14.9
Professional specialty	12.5	13.6	7.7	16.2	14.0
Sales or service	22.3	14.8	7.9	15.8	14.9
Manual	30.7	18.0	9.2	20.6	17.6
Farming, forestry, fishing	24.1	18.1	9.6	20.8	17.7
Not reported	19.2	15.8	8.5	18.8	16.5
Not working	18.3	16.3	9.4	25.2	22.1

Marital status					
Married/common-law	17.7	16.3	8.8	22.6	18.3
Widowed	13.5	15.4	9.1	35.2	23.5
Separated/divorced	31.8	17.7	9.5	27.5	19.8
Single	24.3	14.6	8.4	11.8	14.4
Community type					
Rural	22.1	17.0	9.0	22.8	19.2
Urban	19.4	15.7	8.8	20.0	18.5
Eastern Provinces					
Ontario	18.4	15.6	8.6	19.8	17.9
Nova Scotia	21.7	16.8	8.8	22.5	19.5
Quebec	21.8	17.1	9.4	23.1	20.4
New Brunswick	22.0	17.1	9.0	22.2	18.6
Newfoundland & Labrador	22.1	15.9	9.4	20.7	19.9
Prince Edward Island	22.2	17.0	8.9	22.0	19.2
Western Provinces					
British Columbia	15.3	15.1	8.5	20.3	18.2
Manitoba	19.7	15.2	8.4	19.5	17.6
Alberta	20.5	15.6	8.4	19.1	17.4
Saskatchewan	21.7	15.8	8.6	20.6	18.5
Territories					
Yukon	27.5	16.1	9.3	21.6	20.2
Northwest Territories	32.5	14.3	8.9	16.3	17.1
Nunavut	55.4	12.4	8.5	11.8	13.3

Table 6.3 Estimates and 95% confidence intervals (CI) from the fixed part of a mixed multivariate multilevel model of smoking behaviour, Canadian Tobacco Use Monitoring Survey 2010

	Current smoking			Cigarettes per day			Pack years		
Characteristic	**Odds ratio**	**95%CI**	**Adjusted prevalence**	**β**	**95%CI**	**Adjusted Mean**	**β**	**95%CI**	**Adjusted mean**
Age (10 year change)	0.66	(0.6 - 0.7)	-	0.64	(0.2 - 1.1)	-	8.56	(7.8 - 9.4)	-
Sex									
Women	Ref.		19.6	Ref.		14.1	Ref.		23.9
Men	1.08	(1.0 - 1.2)	20.9	2.75	(2.0 - 3.5)	15.5	4.09	(2.9 - 5.3)	28.0
Marital status									
Common-law/Married	Ref.		17.2	Ref.		15.2	Ref.		25.4
Single	1.54	(1.4 - 1.7)	24.4	0.66	-(0.2 - 1.5)	15.8	1.07	-(0.4 - 2.5)	26.5
Widowed/Divorced /Separated	2.07	(1.8 - 2.4)	30.0	1.35	(0.3 - 2.4)	16.5	2.26	(0.6 - 3.9)	27.6
Education									
Completed university	Ref.		10.2	Ref.		14.2	Ref.		23.7
Completed college	2.05	(1.7 - 2.4)	18.8	1.11	-(0.1 - 2.4)	15.3	2.04	(0.0 - 4.1)	25.7
Completed secondary	3.72	(3.2 - 4.4)	29.7	1.69	(0.4 - 2.9)	15.9	2.87	(0.8 - 4.9)	26.5
Less than secondary	4.71	(4.7 - 5.6)	34.5	2.93	(1.6 - 4.3)	17.1	5.54	(3.3 - 7.7)	29.2
Occupation									
Professional specialty	Ref.		14.8	Ref.		15.0	Ref.		25.1
Executive, managerial	1.22	(1.0 - 1.8)	17.6	-0.53	-(1.8 - 0.8)	14.5	0.01	-(2.2 - 2.2)	25.2
Sales or Service	1.56	(1.3 - 1.8)	21.3	-0.001	-(1.2 - 1.2)	15.0	0.02	-(2.0 - 2.0)	25.1
Not working	1.66	(1.4 - 2.0)	22.5	1.09	-(0.2 - 2.4)	16.1	1.80	-(0.3 - 3.9)	27.0
Manual	2.17	(1.8 - 2.6)	27.4	1.54	(0.3 - 2.8)	16.5	1.39	-(0.7 - 3.5)	26.5
Not reported	1.18	(0.8 - 1.7)	17.2	1.42	-(1.5 - 4.3)	16.4	4.06	-(0.7 - 8.8)	29.3

Table 6.4 Estimates and 95% confidence intervals (CI) from the fixed part of a mixed multivariate multilevel model of smoking behaviour, Canadian Community Health Survey 2001-2008

			Current Smoking		Cigarettes per day		Pack Years	
Variable	**Reference group**	**Parameter**	**Odds ratio**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
Sex	Female	Male	1.21	(1.2 - 1.2)	3.04	(2.9 - 3.2)	5.11	(4.9 - 5.3)
Immigrant status	Born in Canada	Born outside of Canada	0.64	(0.6 - 0.7)	-2.54	-(2.7 - -2.3)	-4.68	-(5.0 - -4.3)
Aboriginal identity	Not Aboriginal	Aboriginal	1.56	(1.5 - 1.6)	-1.31	-(1.6 - -1.1)	-1.45	-(1.9 - -1.0)
Household income ($)	$80,000+	<$20,000	2.03	(2.0 - 2.1)	0.02	-(0.2 - 0.2)	0.49	(0.1 - 0.9)
		$20,000-<$40,000	1.62	(1.6 - 1.7)	-0.04	-(0.2 - 0.2)	0.19	-(0.1 - 0.5)
		$40,000-<$60,000	1.34	(1.3 - 1.4)	0.08	-(0.1 - 0.3)	0.16	-(0.2 - 0.5)
		$60,000-$80,000	1.21	(1.2 - 1.2)	-0.11	-(0.3 - 0.1)	-0.13	-(0.5 - 0.2)
		Not stated	1.26	(1.2 - 1.3)	-0.22	-(0.5 - 0.0)	0.03	-(0.4 - 0.4)
Education	Completed University	Less than secondary	4.31	(4.2 - 4.4)	2.80	(2.5 - 3.0)	5.16	(4.7 - 5.6)
		Completed secondary	2.94	(2.9 - 3.0)	1.89	(1.7 - 2.1)	3.31	(2.9 - 3.7)
		Completed college	2.12	(2.1 - 2.2)	1.11	(0.9 - 1.4)	1.87	(1.4 - 2.3)
Occupation group	Professional specialty	Executive, administrative, managerial	1.19	(1.1 - 1.2)	0.30	(0.0 - 0.6)	0.37	-(0.1 - 0.9)
		Sales or service	1.24	(1.2 - 1.3)	0.53	(0.3 - 0.8)	0.80	(0.3 - 1.3)
		Manual	1.50	(1.4 - 1.6)	1.89	(1.6 - 2.2)	1.67	(1.2 - 2.2)
		Farming, forestry,	1.10	(1.0 - 1.2)	1.84	(1.5 - 2.2)	1.70	(1.0 - 2.4)

		fishing									
		Not reported	1.23	(1.2 -	1.3)	1.07	(0.8 -	1.4)	1.28	(0.7 -	1.9)
		Not working	1.28	(1.2 -	1.3)	1.40	(1.1 -	1.7)	2.13	(1.7 -	2.6)
Marital status	Married/common-law	Widowed	1.45	(1.4 -	1.5)	0.36	(0.1 -	0.6)	-1.48	-(2.0 -	-1.0)
		Separated/divorced	1.85	(1.8 -	1.9)	1.25	(1.1 -	1.4)	1.95	(1.7 -	2.2)
		Single	1.27	(1.2 -	1.3)	0.53	(0.4 -	0.7)	0.71	(0.4 -	1.0)
Community type	Urban	Rural	0.92	(0.9 -	0.9)	0.30	(0.2 -	0.4)	0.60	(0.4 -	0.8)

Table 6.5 Prevalence of current smoking and mean number of cigarettes per day and pack years (with 95% confidence intervals [CI]) for Canada and provinces, Canadian Tobacco Use Monitoring Survey 2010

	Prevalence of current smoking			Cigarettes per day			Pack years		
Province	**%**	**95% CI**	**Rank**	**Mean**	**95% CI**	**Rank**	**Mean**	**95% CI**	**Rank**
Canada	20.2	(18.4 - 22.1)	-	15.5	(14.6 - 16.3)	-	25.9	(24.8 - 27.1)	
British Columbia	16.9	(14.8 - 19.1)	1	14.6	(13.5 - 15.8)	3	24.6	(23.0 - 26.2)	1
Prince Edward Island	17.7	(15.6 - 19.9)	2	16.6	(15.5 - 17.7)	8	26.4	(24.9 - 27.9)	7
Ontario	17.8	(15.7 - 20.0)	3	15.4	(14.2 - 16.5)	6	25.7	(24.1 - 27.2)	5
Manitoba	19.8	(17.7 - 22.1)	4	14.1	(13.1 - 15.1)	1	24.9	(23.5 - 26.3)	3
Alberta	21.0	(18.8 - 23.4)	5	15.2	(14.1 - 16.2)	5	25.6	(24.2 - 27.1)	4
Newfoundland	21.7	(19.3 - 24.2)	6	14.6	(13.6 - 15.6)	2	24.6	(23.2 - 26.1)	2
Saskatchewan	21.7	(19.4 - 24.1)	7	15.1	(14.1 - 16.1)	4	25.9	(24.5 - 27.3)	6
New Brunswick	21.9	(19.5 - 24.4)	8	16.7	(15.7 - 17.8)	10	27.5	(26.0 - 28.9)	10
Quebec	22.0	(19.7 - 24.6)	9	15.8	(14.7 - 16.8)	7	26.5	(25.1 - 28.0)	8
Nova Scotia	22.4	(20.0 - 24.9)	10	16.7	(15.7 - 17.7)	9	27.3	(25.9 - 28.7)	9

Table 6.6 Variation and co-variation in current smoking, numbers per day and pack years between provinces, health regions, communities, and individuals in Canada, Canadian Community Health survey 2001-2008

	Cigarettes per day		Pack years	
	Estimate	**SE**	**Estimate**	**SE**
Province				
Current Smoking	0.066	0.027	0.065	0.027
Consumption	0.568	0.257	0.857	0.421
Covariance	-0.121	0.067†	-0.124	0.082‡
Correlation	-0.625		-0.524	
Health Region				
Current Smoking	0.013	0.002	0.013	0.002
Consumption	0.318	0.057	0.071	0.014
Covariance	0.042	0.009	0.045	
Correlation	0.670		0.706	
Community				
Current Smoking	0.034	0.003	0.034	0.003
Consumption	0.833	0.156	2.361	0.506
Covariance	0.097	0.016	0.152	0.03
Correlation	0.582		0.538	
Individual				
Consumption	69.864	0.35	226.427	1.142

All variance estimates were statistically significant at $p<0.05$, except where indicated †$p=0.07$; ‡$p=0.13$

FIGURES

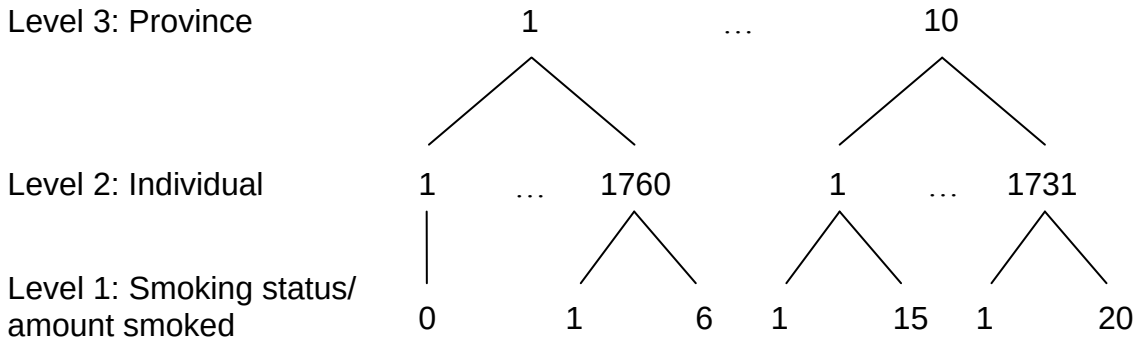

Figure 6.1 Schematic of the multivariate multilevel data structure for smoking behaviour in the Canadian Tobacco Use Monitoring Survey (2010).

Current smoking (coded 0 for non-smokers, 1 for current smoker) and amount smoked (number per day/pack years for current smokers only) are the responses at level 1 nested within individuals at level 2 nested within provinces at level 3.

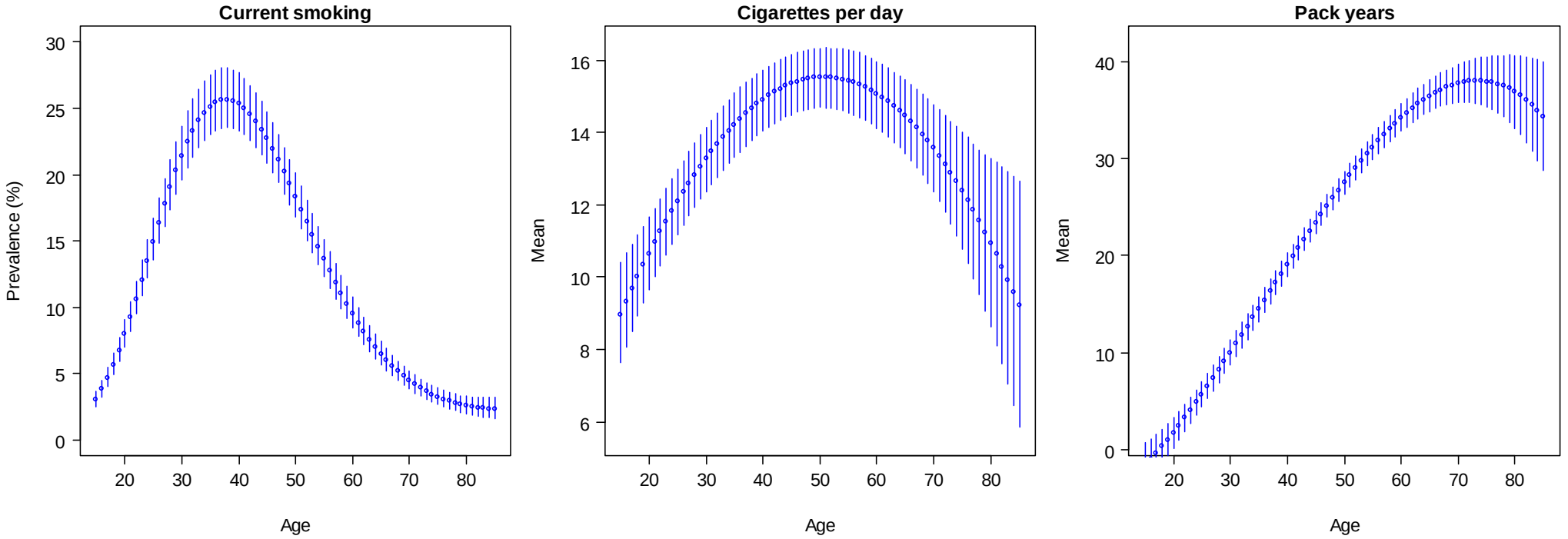

Figure 6.2 Relationship between age and the prevalence of current smoking (left); and among smokers the relationship between age and mean number of cigarettes per day (centre) and mean number of pack years of cumulative exposure (right), ages 15-85 years, Canadian Tobacco Use Monitoring Survey 2010.

Vertical bars represent 95% confidence intervals.

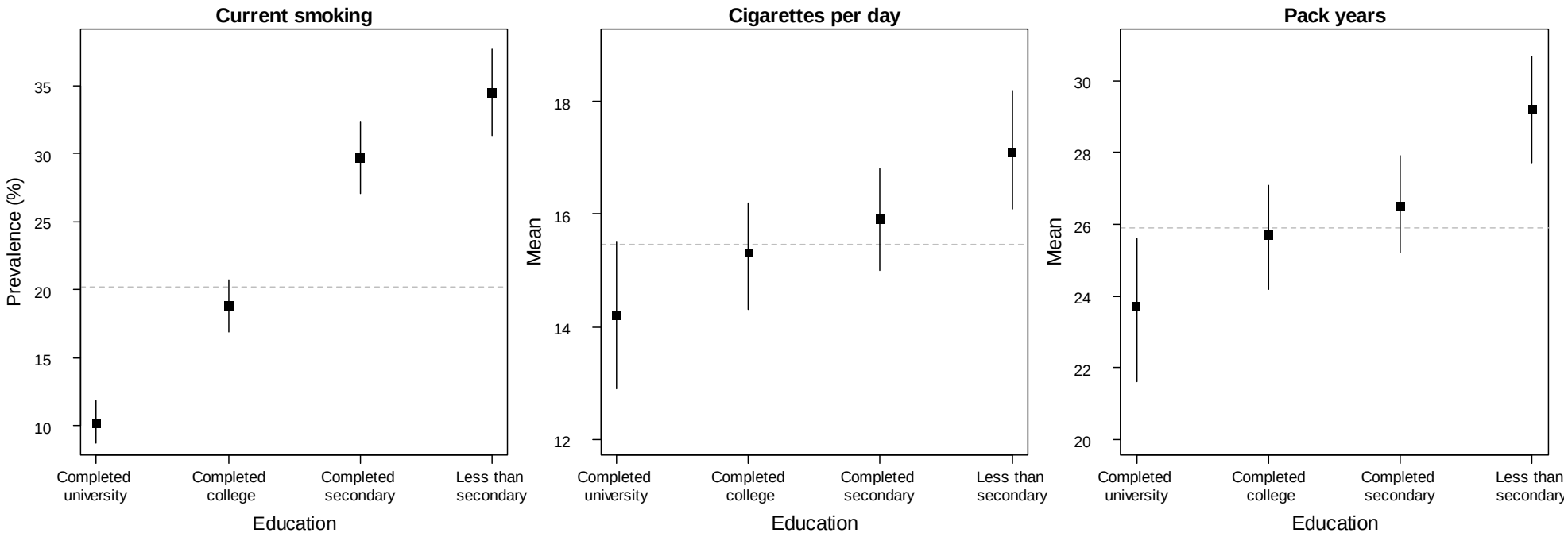

Figure 6.3 Relationship between education and the prevalence of current smoking (left); and among smokers the relationship between age and mean number of cigarettes per day (centre) and mean number of pack years of cumulative exposure (right), Canadian Tobacco Use Monitoring Survey 2010. Dashed horizontal lines represent the overall prevalence or total mean.

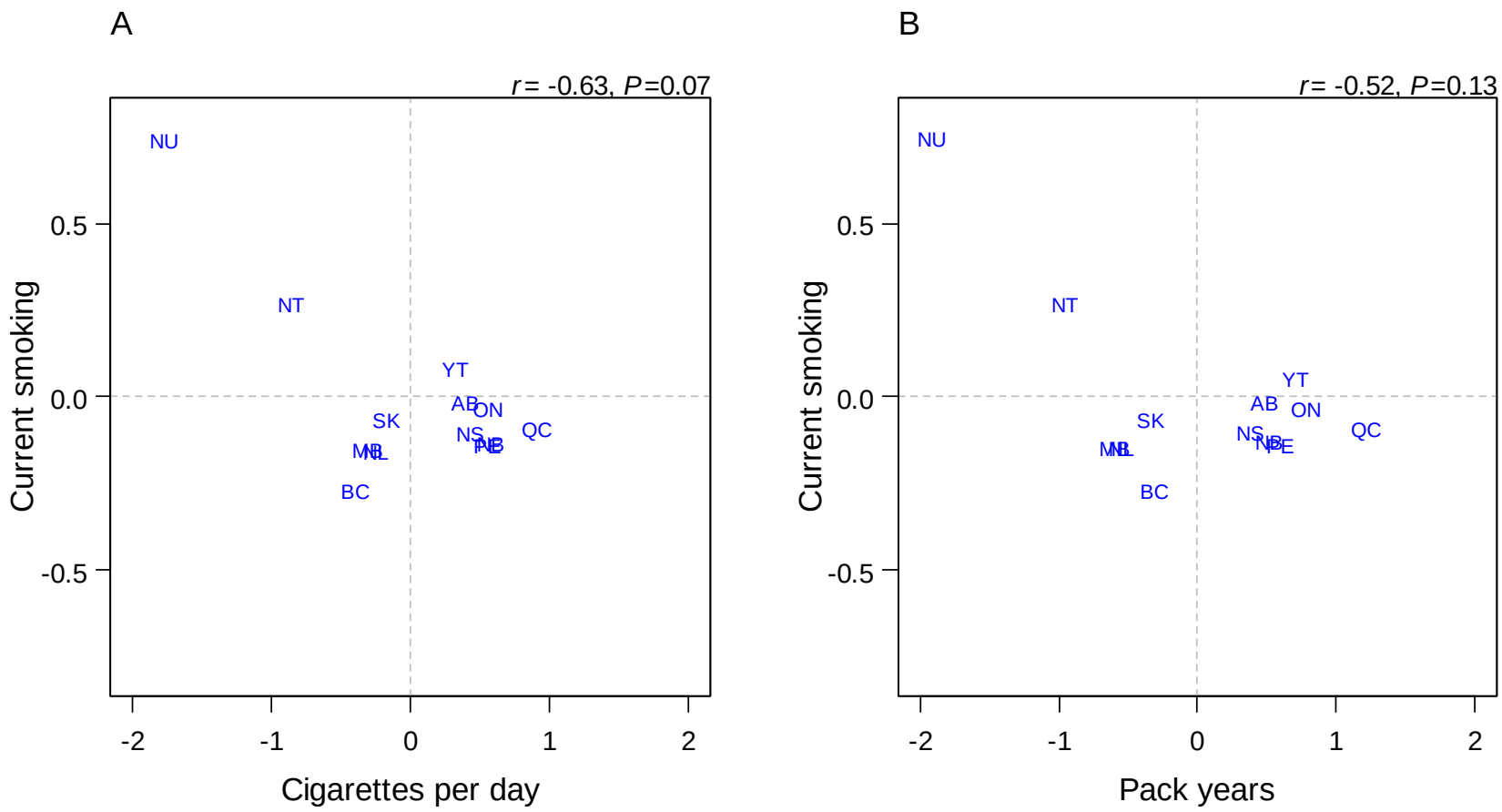

Figure 6.4 Scatter plot of the province/territory specific residuals for current regular smoking and number per day (panel A) and smoking and pack years (panel B). The y-axis residuals represent logit values for current smoking; the x-axis residuals represent number of cigarettes smoked per day and pack years; zero on each axis represents the Canadian average. Canadian Community Health Survey 2001-2008.

Province/territory abbreviations: AB Alberta; BC British Columbia; MB Manitoba; NB New Brunswick; NL Newfoundland; NT Northwest Territories; NS Nova Scotia; NU Nunavut; ON Ontario; PE Prince Edward Is; QC Quebec; SK Saskatchewan; YT Yukon

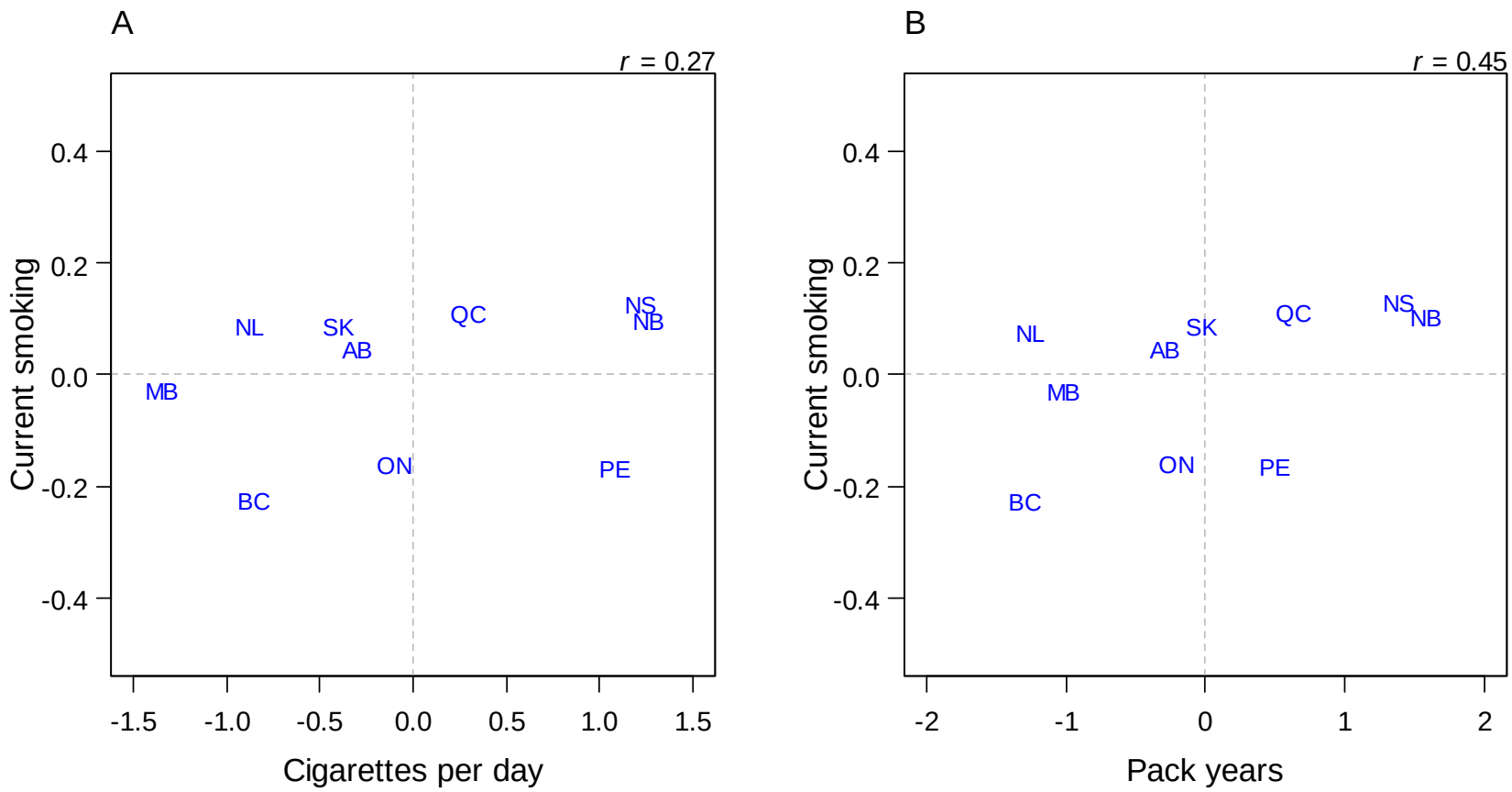

Figure 6.5 Scatter plot of the province specific residuals for current regular smoking and number per day (panel A) and smoking and pack years (panel B). The y-axis residuals represent logit values for current smoking; the x-axis residuals represent number of cigarettes smoked per day and pack years; zero on each axis represents the Canadian average. Canadian Tobacco Use Monitoring Survey 2010.

Province abbreviations: AB Alberta; BC British Columbia; MB Manitoba; NB New Brunswick; NL Newfoundland; NS Nova Scotia; ON Ontario; PE Prince Edward Island; QC Quebec; SK Saskatchewan

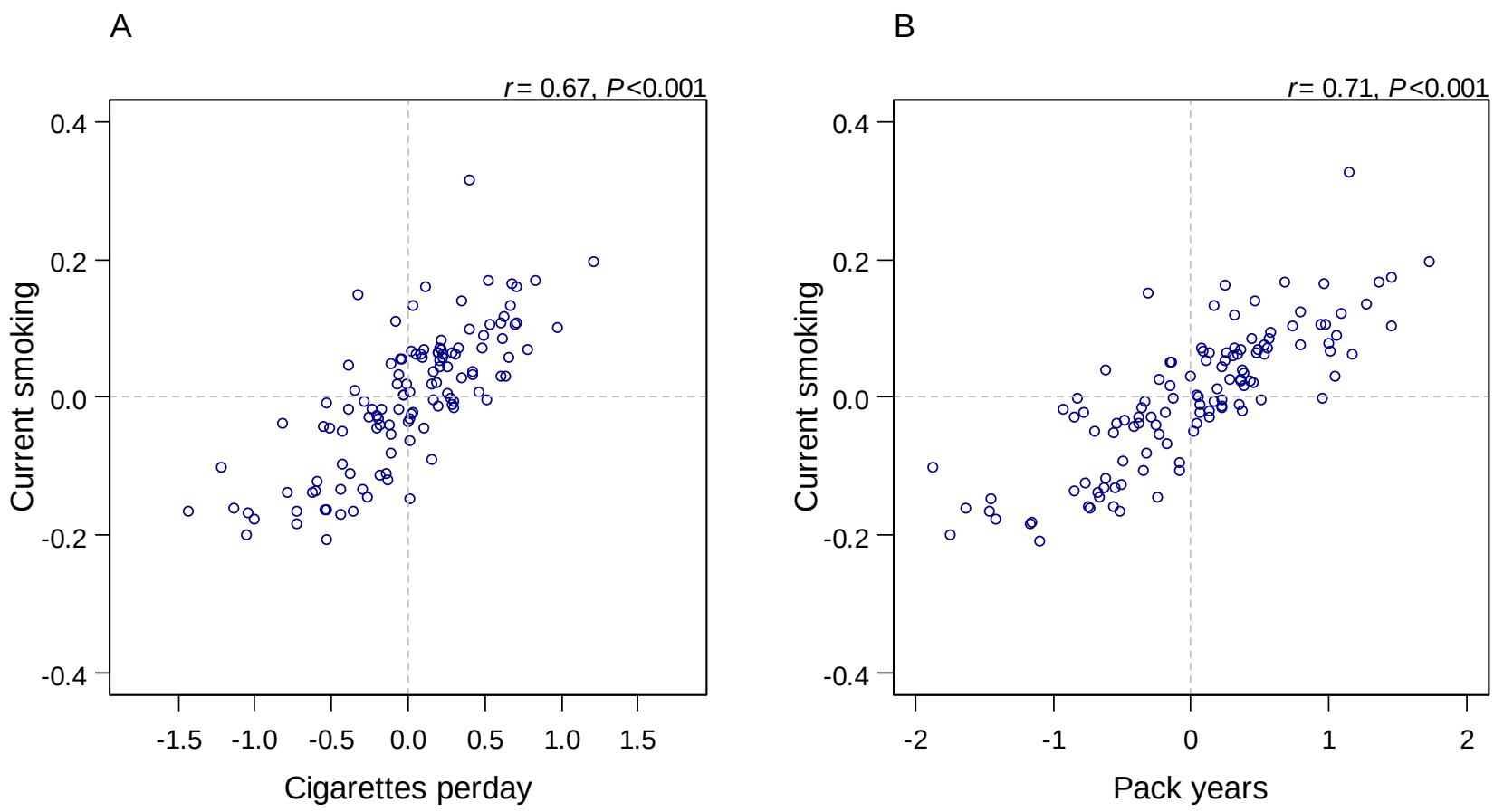

Figure 6.6 Scatter plot of the province specific residuals for smoking and number per day (panel A) and smoking and pack years (panel B).

Each dot represents 1 of 121 Health Regions in Canada. The y-axis residuals represent logit values for current smoking; the x-axis residuals represent number of cigarettes smoked per day and pack years; zero on each axis represents the Canadian average. Canadian Community Health Survey 2001-2008.

Part IV Conclusions and salient findings

Chapter 7 Summary and discussion of novel contributions

Plausibility of the over-arching hypothesis

The findings of this thesis were consistent with the over-arching hypothesis that current rates of tobacco use and cessation are strongly patterned by socioeconomic status and geography in Canada and India. In the following chapter, we discuss the major findings and their support of the over-arching hypothesis in greater detail.

Salient findings

This thesis has sought to explore the variability in tobacco use according to individual socioeconomic characteristics and geography in Canada in India. These two countries were chosen to represent different stages of economic development and epidemiological transition and are at varying stages of the tobacco epidemic with large differences in the patterns of tobacco use. A summary of the socioeconomic status (SES) associations and geographic variation in tobacco use and quit rates in Canada and India is presented in **Table 7.1.** In the following section, we further discuss six salient findings of this thesis and their implications.

- First, tobacco use was more prevalent among the poor and less educated. We found that tobacco use was negatively associated with socioeconomic status (SES), defined according to education, income, and occupation in Canada and India (Table 7.1). These findings strengthen the evidence that the prevalence of smoking is higher among the poor and less educated worldwide.[1] In Canada,

tobacco use (chiefly in the form of cigarette smoking) was strongly patterned by SES; the lowest educated groups were more than three times as likely to be current smokers as the most educated. In addition, tobacco use in India demonstrated an overall inverse association with SES, although the strength of this relationship depended on the type of consumption. The inverse SES gradient was strongest for bidi smoking, followed by tobacco chewing. Cigarette smoking, however, demonstrated a positive association with income and education nationally, and in rural areas of Andhra Pradesh, which may be related to economic growth[2], which has been rapid in India over the past two decades.[3] The prevalence of cigarette smoking, however, was much lower than the prevalence of bidi smoking throughout India.

- Second, a strong inverse gradient was found between education and current smoking, cigarettes smoked per day and number of pack-years among smokers in Canada. Although income was inversely related to current smoking, there was no consistent relationship between income and cigarettes per day and pack years in Canada. This may be an indication that low income groups are more responsive to the price of tobacco and that their consumption of cigarettes is restricted by their income.[4] Fewer data, however, are available on the number of cigarettes smoked daily by different socioeconomic groups in other countries. Our findings from India indicated that levels of consumption increased among those with higher status occupations and among those at higher levels of income and education in both men and women. This is consistent with our findings of a positive SES-cigarette smoking association in India (Table 7.1). It would seem

that higher SES smokers in India tend to consume more cigarettes, which are relatively more expensive, while lower SES smokers tend to consume tobacco in the relatively inexpensive form of bidis.[4] Comparing India to Canada, however, the average levels of tobacco consumption among Indian men were about half as high as in Canada; and among women, about a quarter as high.

- Third, rates of smoking have fallen over time in Canada but socioeconomic gaps have widened. From our empirical findings from Canada, and based on our systematic review of other high income countries, it appears that rates of smoking peaked later in lower SES groups and rates of decline in the lower SES groups have been less steep. A key implication of the findings from Canada is that the SES gradients in smoking appear to have emerged about one decade following the peak of smoking prevalence, indicating a clear transition to the later stages of the tobacco use epidemic.[5] Identifying this peak in prevalence in other populations may be a crucial point to launch interventions to address the potential widening of SES gradients that will likely follow as the epidemic evolves.
- Fourth, smoking quit rates were much higher in Canada compared to India; although in both countries there was a positive association found between SES and quitting. In addition, in India, rates of quitting were relatively higher among women compared to men.
- Fifth, geographic variation in tobacco use and quit rates remained after accounting for individual socioeconomic and demographic characteristics, suggesting the importance of place in Canada and India. The amount of variation was relatively higher in India compared to Canada, which may suggest a greater diversity of

specific area-level determinants of smoking (e.g. tobacco control legislation, availability and price of tobacco, health education, quit services, and social/cultural norms) across geographic regions in India.

- Sixth, co-variation between current smoking, cigarettes per day, and pack-years was positive and statistically significant at different levels of geography in Canada and India. This finding suggests that places with more smokers also have higher levels of consumption (and vice versa) after taking account of individual demographic and socioeconomic factors indicating that there are potentially protective (discourage smoking) or adverse (encourage smoking) influences acting at the level of communities and regions in both countries.

Implications

There are several important implications of this thesis. First, our findings from Canada have identified that low SES groups were more likely to smoke than high SES groups. This suggests that tobacco control initiatives that have been ongoing in Canada have not reached all segments of the population evenly. It has been argued that there are certain groups of 'hard-core' smokers that have no intentions to quit smoking and may be resistant to anti-smoking campaigns.[6] While this may be the case to some extent, our findings underscore the need to appropriately design interventions to target low SES groups who are likely not being reached by mainstream interventions and who may have less frequent access to health services[7] or cessation advice compared to high income groups.[8] It is not clear whether the widening SES gradients in current smoking are a result of the progression of the tobacco use epidemic or if general interventions (which

have not targeted low SES groups) are differentially benefiting the high SES groups in terms of encouraging cessation.[9] In addition, the large geographical variation both in current smoking and quit rates highlight the need to re-evaluate geographic-based resource allocation for tobacco control and prevention across the provinces. One strategy would be to equalize the large differences in rates of tobacco taxation across provinces[10] and to redirect potential increases in revenue toward educational programs about tobacco's effects and support for access to health services among low SES groups.

It was previously believed that the SES patterning of smoking was different in low and middle-income countries[4], although our findings from India combined with other evidence suggests that tobacco use patterns in India have been inversely associated with SES since before the current stage of epidemiological transition.[11-13] It may be that the current inverse association between SES and smoking in India has developed through transmission of knowledge and norms from high income countries at later stages of the epidemic.[14] However, the positive association between SES and *cigarette* smoking does not support this interpretation, especially since norms and knowledge are more likely to be transmitted first to urban, middle-class populations who in India are more likely to smoke cigarettes compared to rural, poor populations who are more likely to smoke *bidis*.[15-16] In addition, price considerations and/or cultural factors may have important influences on which forms of tobacco are consumed in India. For these reasons, it can be argued that the tobacco use epidemic in India is following a more variable pattern than what has been observed in high income countries (where cigarette smoking is the predominant form of consumption) which has implications for both for planning of

tobacco control strategies and for understanding the epidemiology of tobacco related burden of disease.

The large geographic variation that we observed in India is potentially the result of differences in tobacco control policies, price and levels of tobacco taxes, and access to health services or cessation advice across states in India. It is likely that some of this diversity is at least in part related to large variation in economic development across states in India, although more focused research is needed within certain regions of India in order identify the sources of this variation and other contextual factors (e.g. social/cultural norms) which may influence the pattern of smoking and tobacco use in different parts of India.

Topical and methodological advances

The major novel topical and methodological contributions of the thesis are described below, by chapter:

Chapter 2: Socioeconomic and geographic patterning of smoking behaviours in Canada: a cross-sectional multilevel analysis: This chapter uses the most recent nationally-representative data on smoking in Canada to comprehensively investigate the variability in current smoking and quit rates according to SES and geography. The major topical advances included: (1) evidence of strong socioeconomic gradients in smoking that were consistent across provinces (i.e., high rates of current smoking and low quit rates among low SES groups); and (2) inter-provincial differences in smoking and quit rates, with rates of current smoking lowest in Prince Edward Island, Ontario, and British Columbia. The persistence of high rates of current smoking and low quit rates in certain

geographical areas and among certain socioeconomic groups in Canada indicates the ineffectiveness of current tobacco control policies for certain groups and areas. The comprehensive investigation into the sources of variability in smoking and quit rates and the identification of groups and areas at greatest risk is a fundamental step toward identifying the potential barriers to decreasing smoking in the population.

This chapter used a novel approach to the modeling of geographic variation in current smoking and quit rates by using fixed and random classifications for provinces. In the first approach, provinces were 'dummy' coded and treated as a 'fixed' classification and inferences made for each province in comparison to the 'reference' province. In the second approach, geographical differences between provinces are assumed to come from a common distribution and thus inferences are made to a 'population' of provinces.[17] The second (multilevel) approach is useful for technical as well as substantive reasons. Technical benefits include the estimation of an overall parameter to assess geographical differences and 'conservative' estimation for group-level differences because of the pooling of information across provinces.[18] In addition to technical benefits, multilevel models provide an important framework in which to explore the role of geography for shaping patterns of smoking within population and allow for the specification of a richer set of research questions.[19] For example in Chapter 2, we used the flexibility of the multilevel approach to examine the consistency of provincial variation in current smoking and quitting across SES groups and to determine whether the association between SES and current smoking and quitting varied across provinces in terms of strength or direction using variance functions and random coefficient models.

Because of this flexibility and our interest in examining the role of context, we return to the multilevel approach in each of the remaining chapters in the thesis.

Chapter 3: Socioeconomic and geographic determinants of tobacco use and smoking quit rates among men and women in India: Recent trends in global tobacco use patterns indicate that a majority of the worlds nearly 1 billion users live in low and middle income countries[20], with 216 million in rural areas of India alone.[15] This chapter provides a comparative perspective on the socioeconomic and geographic patterning of tobacco use in India, which compared to Canada is at a lower level of economic development and at an earlier stage of the epidemiological transition and tobacco use epidemic.[5, 21] The major topical advance was to provide a further understanding of the socioeconomic and geographic patterning of tobacco use in India which has implications for planning tobacco control initiatives, geographic-based resource allocation, and to determine the epidemiology of tobacco related health burden based on patterns of consumption. In addition, all of the major analyses from the Canadian investigations were replicated in India to gain a comparative perspective across two countries that are at different phases of the tobacco epidemic, at different levels of economic development, and have different patterns of tobacco use. We focused on two aspects of tobacco use which are markedly different in India compared to Canada: patterns by sex and by type of tobacco. First, in India, men have much higher rates of tobacco use compared to women[15, 22]; in Canada and other high income countries current smoking rates, while generally higher in men, are much closer between the sexes.[23] Second, there is a considerable diversity in the method of tobacco consumption in India. Among methods

of smoking, bidis are used most commonly followed by cigarettes. The use of chewing tobacco is also highly prevalent in India. In this chapter, we focused on smoking and chewing, and where possible, differentiated between cigarettes and bidis. Major findings from this chapter indicated that the use of different forms of tobacco was common among different SES groups and in different geographical regions in India. Bidi smoking and chewing were more common among low SES groups although cigarette smoking was more prevalent among higher SES men. Understanding of the socioeconomic and geographic patterning of tobacco use by type is important; health risks are different in chewing compared to smoking. For instance, chewing has been associated with an increased risk of oral cancers in India[24-25], where as smoking has been associated with lung cancer, cardiovascular diseases, and tuberculosis.[26] Smoking even small amounts bidis per day has been shown to increase the risk of death, even though bidis are smaller and contain about a quarter of the tobacco as cigarettes.[26]

This chapter is also the first study to investigate SES patterning of the amount of smoking (both daily and in pack-years) and the geographic patterning of quit rates in India. Findings on the amount of smoking suggest that, in India, level of consumption increases with increasing education and income. This is in contrast to findings from Canada which showed that the amount smoked was greatest among the lowest educated, although the gradient did not hold for income. It appears that, for Canada, lower income smokers may be more responsive to the price of cigarettes and this may lower their level of consumption.[4] The contrary may be true in India, where higher SES individuals with more disposable income consume more cigarettes and the relatively more expensive forms. It is believed that as societies move through the tobacco epidemic, the more

educated groups will be the first to abandon smoking as the ill health effects become clear.[4-5] India does not seem to be at the point at which this transition is occurring because the number of cigarettes/bidis smoked daily was highest in the highest SES groups, despite a greater awareness of the ill effects of smoking in these groups.[27] These findings implicitly suggest a financial aspect to patterns of consumption; among individual smokers of higher status or with more disposable income there is a tendency to smoke in higher quantities.

Another important topical advance of this chapter was the consideration of quitting. Little is known about the socioeconomic and geographic patterning of quit rates in low and middle income countries. Smoking quit rates were markedly lower in India compared to Canada. In addition, we observed large heterogeneity between states in rates of quitting (especially among women) which was independent of the characteristics of individual residents. This further implies that there are large regional variations in contextual determinants of quitting such as access to cessation support or such as nicotine replacement therapies (NRT) across regions of India and that there may be variations in the stage of the tobacco epidemic between states.

This chapter had several important methodological advances. First, we developed two novel methods to analyze quit rates (the same methods were also used in the preceding chapter). In the first method, the quit rate was calculated as the proportion of former divided by ever smokers[28], based on the simulated probabilities of current and former smoking from a multinomial logistic regression model.[29-30] In the second, we modeled the proportion of former over ever smokers directly using a multilevel model.[17] The advantage of the multilevel model was the ability to assess the geographic variability

in quitting between states, local areas, and villages in India. Second, we used a multivariate multilevel model to examine the SES determinants of several forms of tobacco use within a single model. This approach allows for the consideration of an individual's use of more than one form of tobacco (e.g. smoking and chewing), and in addition, increases efficiency by modeling all of the data at once.

Chapter 4: Trends in smoking in Canada from 1950 to 2010: progression of the tobacco epidemic according to socioeconomic status, and geography: This chapter presents the longest analysis of differences in current smoking according to SES (education) and geography (province) over a 60 year period from 1950-2010. The primary findings of this chapter indicated that although smoking rates have fallen over the past 60 years in Canada, SES gradients have increased. Smoking prevalence peaked later in the lower SES groups and rates of decline in lower SES groups and certain provinces have been less steep. In addition, the rapid declines in certain provinces may be masking large underlying differences in the rate of decline according to SES groups within these provinces.

This chapter provides an important examination of the historical trends in smoking by SES in Canada. The importance of this chapter is twofold. First, the analysis of the trends in currents smoking by SES and province is useful to predict future trends across different population groups for the planning of public health interventions and policies. Our findings suggest that current smoking prevention and cessation programs have been ineffective among lower SES groups in Canada. Rates of smoking will continue to be high in these groups unless action towards the improvement of health

equity is taken at both the provincial and federal levels of government. Second, this analysis is invaluable for anticipating smoking patterns across SES groups in lower and middle income countries (LMICs) at earlier stages of the tobacco epidemic.[16] As LMICs move towards the later stages of the tobacco epidemic an increasing number of individuals in these countries will likely try and quit using tobacco products. It will be essential to plan for the potential for SES gradients to emerge and then increase during this period and by focusing tobacco control efforts among the most vulnerable populations in these settings. Our findings from this chapter also indicated that there is about a ten year period between the time at which a population reaches a peak in the overall prevalence of smoking until a clear inverse SES gradient in smoking is evident. Although this finding is based on data from Canada and may not hold in all settings, it is potentially useful as a marker of transition to a later stage of the tobacco epidemic in LMICs such as India where SES gradients in smoking are apparent.

The primary methodological advance of this chapter is the use of individual-level data from 40 nationally-representative surveys in Canada. This is the largest available dataset on smoking trends according to SES and geography in Canada. In addition, because we accessed the individual-level data files, we were able to increase comparability across surveys and over time by ensuring consistency of variable definitions and age restrictions within each survey. Data from each survey year were standardized to a common population (1991 census population) in order to adjust for differences in population age structure during the study period.[31] Further, the large number of surveys available allowed for the modeling of change in the SES gradients in smoking as a continuous function with time.

In our analyses in this chapter, we defined two metrics for the assessment of differences in rates of current smoking across SES groups: the absolute difference and the relative difference. These metrics and their associated levels of uncertainty were estimated by simulating 10,000 random draws from the probability distribution of all model parameters.[30] This approach is extremely valuable for summarizing fitted models and calculating any quantities of interest on the original scale of the outcome variable (in this case current smoking).[29] We have used a similar approach to summarize our statistical models and improve interpretation and presentation of estimated quantities throughout this thesis.

Chapter 5: Socioeconomic and geographic distribution of smoking in Canada: a multilevel analysis of smoking in 49,088 communities: This is the first study which has explored the extent to which smoking varies between small geographic areas (communities) in Canada. This chapter presents two topical advances in the study of geographic variation in tobacco use in Canada. First, we considered contextual and compositional sources of variation in current smoking across communities, health regions, and provinces. The objective was to establish the extent to which place-to-place variation in smoking was due to community effects (contextual influences) or the characteristics of individuals living in these communities (compositional effects). Second, we considered the relative importance of multiple hierarchical contexts (communities, health regions, and provinces) in influencing patterns of current smoking in Canada.

Public health efforts to reduce/prevent smoking can potentially be strengthened by understanding the potential of places to influence smoking along with specific characteristics of places that would help to achieve that objective. In this study, we began by quantifying geographic variation in smoking in Canada that is independent of individual level factors, which gave a plausible indication of the potential role for places in shaping smoking behaviour. Our results demonstrated that significant geographic variation in smoking remained at the level of provinces and communities after accounting for individual socioeconomic and demographic characteristics. Our findings suggest the importance of places in shaping the distribution of tobacco use and imply that area-level influences such as the social and/or environmental conditions of provinces and communities may account for some of the observed variation in smoking and therefore need to be considered if this variation in smoking is to be modified.

In these analyses, we found that individual socioeconomic and demographic characteristics accounted for approximately two-thirds of the between-community variation in smoking but less than a quarter of between-provincial variation. It appears that individual level characteristics are able to explain more of the place level variation at smaller geographical scales (e.g. between communities) compared to large scales (e.g. between provinces or between countries). We have reported similar findings using a different outcome (body mass index [BMI]) in a large sample of LMICs.[32] The between provincial variation found in the current smoking was larger than what was found using a similar analytic approach in Chapter 2 (2% vs <1%). The most likely explanation for this difference was the inclusion of the three territories in the current analyses which were not

available in the CTUMS data used for Chapter 2. Patterns of smoking were found to be substantially different in the territories compared to the rest of Canada (see Chapter 6).

This study had several methodological advances. First, we used a multilevel approach to quantify the differences in smoking attributable to three geographic scales (communities, health regions, and provinces) in data from four cycles of the Canadian Community Health Survey conducted between 2001 and 2008 (n=461,709). In order to construct this dataset, survey respondents were geo-coded to their community, health region, and province of residence using the Postal Code Conversion File (PCCF) program developed by Statistics Canada.[33] In addition, we accounted for changes to geographical divisions that occurred during the study period between the 2001 and 2006 censuses in order to limit potential misclassification of survey respondents to within geographical units. Second, this study used complex variance functions[34] – an extension of multilevel models using random coefficients – to model heterogeneity in the variation in smoking at higher levels of geography (communities, health regions, and provinces) for individuals at different levels of education and household income. This is an important advance as it allows for a further understanding of how variance in current smoking can change across higher levels of geography as a function of individual characteristics. Our findings in these analyses generally indicated that variability in current smoking was higher among those of higher SES at the level of communities, health regions and communities.

Chapter 6: Covariation in current smoking, cigarettes per day, and pack years: a multivariate multilevel analysis of smoking behaviour in Canada: This chapter used a multivariate multilevel methodological approach to simultaneously consider both the

prevalence of smoking and the current/cumulative consumption of cigarettes. It is only the second paper to use such a methodology[35]; and it appears to be the first paper from Canada and the first to consider cumulative smoking history (pack-years). A major finding was that the covariation between current smoking, cigarettes per day, and pack-years was positive and statistically significant at the level of communities and health regions, suggesting that at these geographical scales, places with more smokers also have higher levels of consumption (and vice versa) after taking account of individual demographic and socioeconomic factors.

The primary advantages of the approach used in this chapter are both substantive and technical. Technical benefits included the added efficiency gained from modeling all data at once instead of restricting the sample to respondents who were currently smoking. In addition, this framework provided a method to formally examine if the effect of a particular variable, for instance educational status was related in the same direct and magnitude to both smoking (which is a binary outcome) and number of cigarettes/pack-years (continuous outcome).

Substantive advantages included the ability to explore co-variation in the residual variation of random effects of current smoking and levels of consumption at different levels of geography. For example, it was possible to determine at the level of communities if areas high in current smoking were also high on the intensity of smoking among smokers. Limitations of the application of this methodology to the CTUMS dataset included the lack of sub-provincial geographic identifiers (eg. Health region) restricting the levels of analysis with these data. Although there are only 10 geographical 'units' at the provincial level in Canada, multilevel methods can still be beneficial when

the number of units at any particular level is greater than 5.[18] It is more difficult, however, to determine 'statistical significance' for the random parameters when the number of units is small due to greater estimation uncertainty.

Conclusions and future directions

The major conclusion of this thesis is that tobacco use in populations is strongly patterned along socioeconomic and geographic dimensions. The inverse socioeconomic gradients in smoking have persisted and increased in Canada and are now emerging in India. Quitting was more likely among the higher educated and better off groups in both countries and in certain geographical regions in Canada. Findings in this thesis indicate that efforts to reduce smoking uptake and increase cessation in populations can be strengthened through explicit consideration of socioeconomic and geographic distribution of tobacco use and factors that may influence the likelihood to start/quit smoking in conjunction with large-scale interventions aimed at reducing demand in populations. A second major finding is that while tobacco control policies appear to have been effective among those of higher SES in high income countries, they have had limited efficacy in those of lower SES and this suggests that other approaches may be required to reduce smoking rates in those of lower SES. Further, there is evidence to suggest that population-level interventions may actually increase the SES gradients, underscoring the need for consideration of lower socioeconomic, Aboriginal, and other socially disadvantaged groups when designing and implementing smoking prevention and cessation programs. Continued efforts are required to reduce tobacco consumption and limit uptake until it is no longer a significant threat to global public health.

There are several important of future research directions which have developed as a result of this work. First, we plan to strengthen the existing data on the socioeconomic and geographic patterning of tobacco use in India and other LMICs (e.g. Bangladesh, Pakistan, China, Russia). The rational for studying these countries is that majority of the world's smokers live in LMICs and a more detailed investigation is required across countries at a range of levels of economic development and epidemiological transition in order to characterize the distributive aspects of the tobacco epidemic outside of high income settings.[36] Some of the important questions can be answered in existing data sources (for example the Global Adult Tobacco Survey[15]), although in many cases more reliable and higher quality data will need to be collected. Projects such as the Environmental Profile of a Community's Health (EPOCH)[37] will be useful because it has taken a novel approach to collecting data on community-level factors that may be relevant for shaping tobacco use patterns such as current restrictions on smoking in public places, health education campaigns to discourage smoking, measures of the social acceptability of smoking, and knowledge of the health effects of smoking in communities.

The second proposed direction is to investigate trends in quit rates by SES in Canada since 1950 using an extension of the methodology presented in Chapter 4. In addition, we will plan to compile and incorporate data on tobacco and cigarette taxes during this period in order to look at the associations between changes in levels of taxation over time with changes in rates of cessation. These analyses will consider sex, socioeconomic status, and geography in a similar fashion as described in this thesis. We will develop a novel approach to model how quit rates change with changes in level of

tobacco taxes. The results of this analysis will potentially be use for governments in the planning and implementing of taxes and the most effective level to promote cessation.

Third, we plan to expand analyses presented in Chapter 5 through the consideration of specific contextual variables at the level of communities and provinces which may account for unexplained variation in current smoking at these levels of geography. The focus Chapter 5 was on unpacking the variation current smoking and quantifying the magnitude of residual variation at higher contextual levels after adjustment for individual socioeconomic and demographic factors. The potential for communities to influence health behaviours is being increasingly recognized.[38] Ascertaining how much variation exists at the community or neighbourhood level independent of individual composition is an important first step towards establishing the potential importance of neighbourhoods and such variation can be interpreted as a "common" ecological effect of places on current smoking.[39] A natural next step is the consideration of "specific" characteristics of communities and provinces which may explain the remaining variation including area level SES, community smoking restrictions, workplace smoking restrictions, and levels of provincial tax on cigarettes. These contextual variables can be derived both from existing surveys and through novel approaches such as EPOCH.[37, 40] Other possible directions related to Chapter 5 include the consideration of geographic variation in smoking quit rates at the level of communities and health regions in Canada (this was explored at the level of provinces in Chapter 2). In addition, there is interest in geographic variability in non-daily smoking and other types of tobacco use. Non-daily smoking and other forms of tobacco are used

by a sizable minority of Canadian smokers (see Appendix A) and there is evidence to suggest that there is substantial variability in across provinces.[23]

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Table 7.1 Summary of socioeconomic status (SES) associations and geographic variation in tobacco use and quitting in Canada and India

	Canada				India			
	Smoking	Quantity	Quitting	Covariation (smoking/quantity)	Smoking	Chewing	Quitting	Covariation (smoking/quantity)
SES markers (direction)								
Education	↓	↓	↑	-	↓	↓	↑	-
Income	↓	≈	-	-	↓	≈	-	-
Occupation	↓	↓	↑	-	↓	≈	-	-
Level of geography (% variation)								
Province/state	2.4	1.5	1.1	≈	13.6	20.2	12.2	↑
Health region	1.2	0.5	-	↑	-	-	-	-
Community	4.8	1.2	-	↑	9.5	8.2	9.1	↑

Notes: "↑" indicates statistically significant positive association ($p<.05$); "↓" statistically significant negative association; "≈" indicates no statistically significant association.

APPENDICES

Appendix A World Bank Country income groups, 2011

Table A.1 Economic classification for all countries with populations of more than 30,000, based on gross national income (GNI) per capita in 2011.[1]

Low-income economies ($1,025 or less)		
Afghanistan	Gambia, The	Mozambique
Bangladesh	Guinea	Myanmar
Benin	Guinea-Bisau	Nepal
Burkina Faso	Haiti	Niger
Burundi	Kenya	Rwanda
Cambodia	Korea, Dem Rep.	Sierra Leone
Central African Republic	Kyrgyz Republic	Somalia
Chad	Liberia	Tajikistan
Comoros	Madagascar	Tanzania
Congo, Dem. Rep	Malawi	Togo
Eritrea	Mali	Uganda
Ethiopia	Mauritania	Zimbabwe
Lower-middle-income economies ($1,026 to $4,035)		
Albania	Indonesia	Samoa
Armenia	India	São Tomé and Principe
Belize	Iraq	Senegal
Bhutan	Kiribati	Solomon Islands
Bolivia	Kosovo	South Sudan
Cameroon	Lao PDR	Sri Lanka

Cape Verde	Lesotho	Sudan
Congo, Rep.	Marshall Islands	Swaziland
Côte d'Ivoire	Micronesia, Fed. Sts.	Syrian Arab Republic
Djibouti	Moldova	Timor-Leste
Egypt, Arab Rep.	Mongolia	Tonga
El Salvador	Morocco	Ukraine
Fiji	Nicaragua	Uzbekistan
Georgia	Nigeria	Vanuatu
Ghana	Pakistan	Vietnam
Guatemala	Papua New Guinea	West Bank and Gaza
Guyana	Paraguay	Yemen, Rep.
Honduras	Philippines	Zambia
Upper-middle-income economies ($4,036 to $12,475)		
Angola	Ecuador	Palau
Algeria	Gabon	Panama
American Samoa	Grenada	Peru
Antigua and Barbuda	Iran, Islamic Rep.	Romania
Argentina	Jamaica	Russian Federation
Azerbaijan	Jordan	Serbia
Belarus	Kazakhstan	Seychelles
Bosnia and Herzegovina	Latvia	South Africa
Botswana	Lebanon	St. Lucia
Brazil	Libya	St. Vincent and the Grenadines
Bulgaria	Lithuania	Suriname
Chile	Macedonia, FYR	Thailand

China	Malaysia	Tunisia
Colombia	Maldives	Turkey
Costa Rica	Mauritius	Turkmenistan
Cuba	Mexico	Tuvalu
Dominica	Montenegro	Uruguay
Dominican Republic	Namibia	Venezuela, RB
High-income economies ($12,476 or more)		
Andorra	Germany	Oman
Aruba	Greece	Poland
Australia	Greenland	Portugal
Austria	Guam	Puerto Rico
Bahamas, The	Hong Kong SAR, China	Qatar
Bahrain	Hungary	San Marino
Barbados	Iceland	Saudi Arabia
Belgium	Ireland	Singapore
Bermuda	Isle of Man	Sint Maarten
Brunei Darussalam	Israel	Slovak Republic
Canada	Italy	Slovenia
Cayman Islands	Japan	Spain
Channel Islands	Korea, Rep.	St. Kitts and Nevis
Croatia	Kuwait	St. Martin
Curaçao	Liechtenstein	Sweden
Cyprus	Luxembourg	Switzerland
Czech Republic	Macao SAR, China	Trinidad and Tobago
Denmark	Malta	Turks and Caicos Islands

Estonia	Monaco	United Arab Emirates
Equatorial Guinea	Netherlands	United Kingdom
Faeroe Islands	New Caledonia	United States
Finland	New Zealand	Virgin Islands (U.S.)
France	Northern Mariana Islands	
French Polynesia	Norway	

Appendix B Consistency of findings based on an alternate definition of current smoking

Definition of current smoking

The primary definition for smoking in this thesis has been "current daily" smoking or the consumption of at least 1 cigarette per day.[2] This definition excludes non-daily or "occasional" smokers who are treated as part of the non-smoker group. Non-daily smokers are a heterogeneous group comprised of younger smokers in early stages of smoking initiation, older smokers trying to quit, and a distinct group of "sustained" non-daily smokers.[3-4] Although the prevalence of non-daily smoking is low in the population (the age and sex adjusted prevalence was 2.4% in the 2010 CTUMS), this groups represents 12.2% of all current smokers (daily and non-daily combined). For this reason, we investigated the sensitivity of our findings to the treatment of non-daily smokers as "current" smokers or as "never smokers".

Sensitivity analysis

We conducted a sensitivity analysis to explore the consistency of our findings across alternate definitions of current smoking. Using the CTUMS data, we estimated 2 logistic regressions of current smoking on demographic and socioeconomic characteristics and province of residence. Current smoking was defined in the first model as current daily smoking and in the second model using a combined definition of current daily or non-daily smoking. In these models, the coefficients and standard errors were adjusted to account for the survey design through the use of the sampling weights provided with the CTUMS dataset.

Findings and interpretation

The odds ratios and 95% confidence intervals (CI) from the logistic regressions for demographic and socioeconomic characteristics and province are given in **Table B.1** for each of the definitions of current smoking. Estimates using the two definitions were largely comparable. For example, the odds ratio for smoking among men using the daily smoking definition was 1.40 (95% CI: 1.16-1.96) compared to 1.41 (95% CI: 1.19-1.68) in the combined group. Estimates of socioeconomic status (SES) gradients were somewhat attenuated when using the combined definition of daily and non-daily smokers compared to daily smokers only. The odds ratio for smoking among those with less than secondary school education using the combined definition was 3.06 (95% CI: 2.20-4.26) compared to 3.85 (95% CI: 2.65-5.58) for daily smokers.

Based on these findings, it seems that the overall demographic and socioeconomic patterning of current smoking is robust to the choice of whether to include daily or non-daily smokers in the definition of "current smoking". The inclusion of non-daily smokers, however, seems to introduce some heterogeneity in terms of SES. Being that SES is a key variable of substantive interest in this thesis, we prefer to work with the more restrictive definition of current smoking based on daily smoking. The potential benefits of this approach are reduced bias in the estimation of SES gradients in smoking, although the resulting prevalence estimates for smoking may be marginally lower due to the exclusion of non-daily smokers. In addition, a focus on daily smoking is of public health importance as this group is at the greatest risk for smoking-related illness.

Table B.1 Mutually adjusted odds ratios and 95% confidence intervals (CI) from logistic regression models of current smoking defined as daily or non-daily smoking. Canadian Tobacco Use Monitoring Survey 2010.

			Daily smoking		Daily and non-daily smoking	
Variable	**Reference group**	**Parameter**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Age		Age (10 year change)	0.80	(0.71 , 0.91)	0.77	(0.69 , 0.87)
Sex	Female	Male	1.40	(1.16 , 1.69)	1.41	(1.19 , 1.68)
Education	Completed university	Below secondary	3.85	(2.65 , 5.58)	3.06	(2.20 , 4.26)
		Completed secondary	2.86	(2.10 , 3.89)	2.34	(1.78 , 3.06)
		Completed college	1.64	(1.20 , 2.24)	1.52	(1.15 , 1.99)
Occupation	Professional specialty	Executive, managerial	1.51	(1.09 , 2.11)	1.46	(1.09 , 1.96)
		Sales or Service	1.76	(1.29 , 2.41)	1.75	(1.32 , 2.31)
		Manual	2.12	(1.51 , 2.98)	2.01	(1.48 , 2.73)
		Not working	1.09	(0.53 , 2.26)	1.12	(0.58 , 2.15)
Marital status	Common-law/Married	Widow/Divorced/Separated	2.07	(1.60 , 2.66)	1.98	(1.56 , 2.52)
		Single	1.98	(1.51 , 2.58)	1.88	(1.46 , 2.40)
Province	Ontario	Newfoundland	1.29	(1.00 , 1.67)	1.29	(1.02 , 1.64)
		Prince Edward Island	0.99	(0.75 , 1.29)	1.03	(0.81 , 1.32)
		Nova Scotia	1.50	(1.16 , 1.93)	1.52	(1.20 , 1.92)
		New Brunswick	1.18	(0.92 , 1.53)	1.25	(0.99 , 1.58)
		Quebec	1.23	(0.95 , 1.60)	1.21	(0.95 , 1.54)
		Manitoba	1.28	(1.00 , 1.64)	1.38	(1.10 , 1.73)
		Saskatchewan	1.34	(1.04 , 1.73)	1.43	(1.13 , 1.80)
		Alberta	1.31	(1.02 , 1.68)	1.34	(1.06 , 1.69)
		British Columbia	0.86	(0.65 , 1.14)	1.01	(0.78 , 1.30)

Appendix C Sources of data on smoking and tobacco use in Canada

Table C.1 Survey year and sampling plans for nationally-representative surveys on smoking in Canada from 1950-2010.

Year	Survey	Sampling plan
1951	Canadian Gallup Poll	Modified probability sample; face-to-face and telephone interviews
1956	Canadian Gallup Poll	Modified probability sample; face-to-face and telephone interviews
1957	Canadian Gallup Poll	Modified probability sample; face-to-face and telephone interviews
1963	Canadian Gallup Poll	Modified probability sample; face-to-face and telephone interviews
1964	Canadian Gallup Poll	Modified probability sample; face-to-face and telephone interviews
1966	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1968	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1971	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1972	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1974	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1975	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews

1977	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1978	Canada Health Survey	Multi-stage stratified sample of households; self-completed questionnaire
1979	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1981	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1983	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1985	Health Promotion Survey	Stratified sample of households, random digit dialling sampling procedure; telephone interviews
1986	Canadian Survey of Smoking Habits	Multistage stratified, clustered, probability, area sample; telephone interviews
1988	Canada Health Monitor	Stratified two-stage random sampling technique; telephone interviews
1989	National Alcohol and Drug Survey	Stratified multi-stage sample of households, random digit dialling; telephone interviews
1990	Health promotion survey	Stratified sample of households, random digit dialling sampling procedure; telephone interviews
1991	General Social Survey	Stratified sample, random digit dialling; telephone interviews
1992	Heart Health Database	Stratified, multistage probability sample; face-to-face interviews
1993	Canada Health Monitor	Stratified two-stage random sampling technique; telephone interviews
1994	National Population Health Survey	Multistage stratified, clustered, probability, area sample; telephone interviews
1995	Survey on Smoking in Canada	Multistage stratified, clustered, probability, area sample; telephone interviews

1996	National Population Health Survey	Multistage stratified, clustered, probability, area sample; telephone interviews
1998	National Population Health Survey	Multistage stratified, clustered, probability, area sample; telephone interviews
1999	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2000	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2001	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2002	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2003	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2004	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2005	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2006	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2007	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2008	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2009	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews
2010	Canadian Tobacco Use Monitoring Survey	Two-stage stratified random sample of telephone numbers; telephone interviews

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