An ICES/PHO Report

Appendix
SEVEN MORE YEARS:
The impact of smoking, alcohol, diet, physical activity and stress on health and life expectancy in Ontario

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SEVEN MORE YEARS: THE IMPACT OF SMOKING, ALCOHOL, DIET, PHYSICAL ACTIVITY AND STRESS ON HEALTH AND LIFE EXPECTANCY IN ONTARIO

An ICES/PHO Report

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LIST OF EXHIBITS

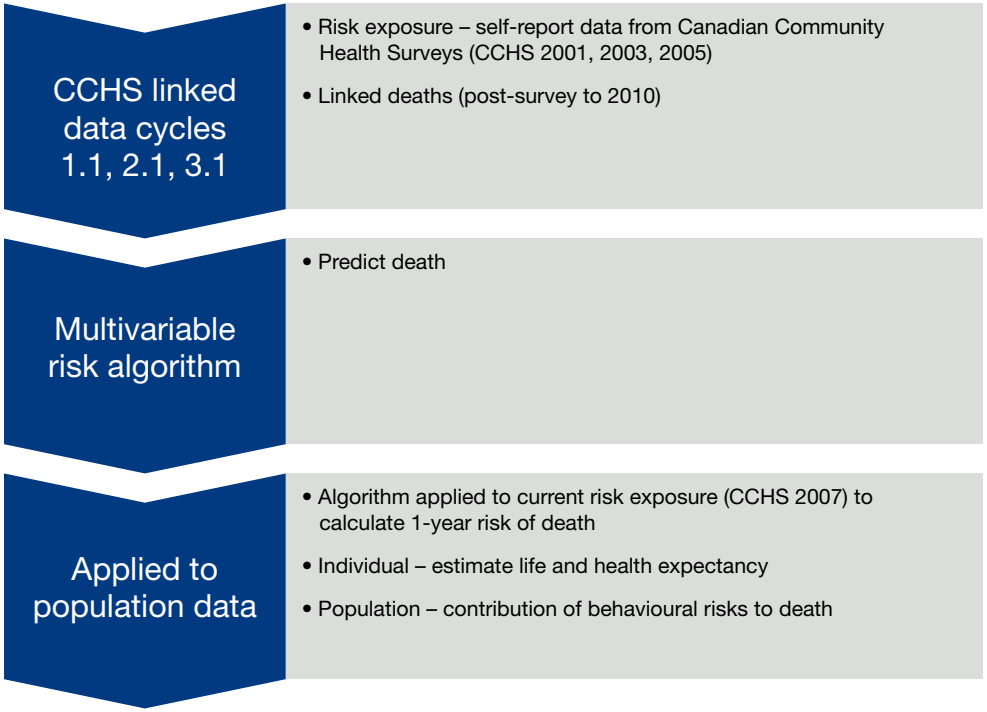
Introduction

This study developed, validated and applied a novel population-based risk algorithm for hazard of death (Exhibit A-1). The purpose of the algorithm was two-fold—first, to predict death using self-report information routinely collected in population-based surveys (in particular, the Canadian Community Health Surveys from Statistics Canada); and second, to estimate the hazard of death associated with five behavioural risks: current smoking, unhealthy alcohol consumption, physical inactivity, poor diet and high stress.

We used the algorithm to predict differences in life expectancy and health-adjusted life expectancy for groups of people in the general population with exposure to different health behaviours, and to estimate the contribution of behavioural risks to these differences in life and health expectancy.

The algorithm was developed from historic cohort data, but was applied for population prediction using a current Canadian Community Health Survey (CCHS), and could be applied using similar surveys in the future. It was designed to be discriminating and well-calibrated for a general Canadian population aged 20 and older, including subgroups of age, sex, socioeconomic position, body mass index (BMI) and local health planning regions (Local Health Integration Network [LHIN]).

Exhibit A-1
Overview of study methods



Methods

STUDY DATA

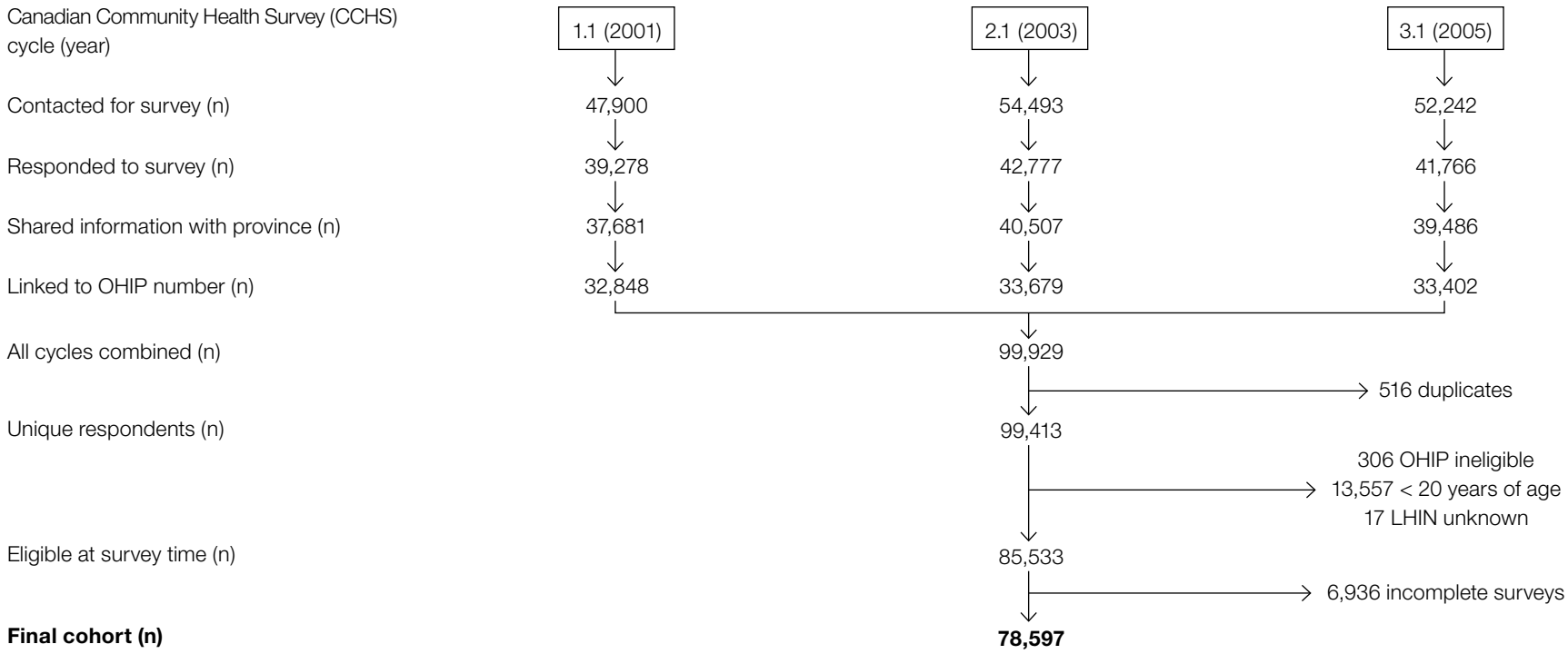
Data for this study were from the Canadian Community Health Survey (CCHS) Cycles 1.1 (conducted in 2001), 2.1 (2003) and 3.1 (2005). The CCHS is a cross-sectional survey conducted by Statistics Canada that collects data every two years on health determinants, health status and health care utilization. It employs a complex multi-stage sampling strategy to randomly select households in each health region. Individuals living in each household are then randomly selected to participate in the survey. A weight is assigned to each respondent signifying the number of people the respondent represents in the target population. The target population includes individuals aged 12 years and older across Canada's 10 provinces and three territories (excluded are individuals living on Indian Reserves, institutional residents, full-time members of the Canadian Forces and residents of certain remote areas).

COHORT DEVELOPMENT

The three cycles of the CCHS were combined to generate 123,821 valid interviews of Ontarians (Exhibit A-2). Of these respondents, 117,674 agreed to share their interview information with the provincial government, and 99,929 were successfully linked to their Ontario Health Insurance Plan (OHIP) number using a probabilistic algorithm. For individuals with multiple interviews, all subsequent interviews following their initial interview were excluded. Also excluded were individuals not eligible for OHIP at the time of the survey, those under 20 years of age, and those whose LHIN could not be identified. This produced a cohort of 85,533 eligible individuals who were then linked with records of deaths that occurred between the date of their survey administration (in 2001, 2003 or 2005) and the end of follow-up (December 31, 2010).

Individuals who became ineligible for OHIP during the follow-up period were censored at the time they first became ineligible. In the event a death record occurred within 30 days of an individual becoming OHIP ineligible, the death record was taken as the date of last follow-up and the death record was included. Survey responses to variables of interest were missing for 6,936 individuals who were therefore excluded. The final cohort had 78,597 individuals with 568,997 person-years of follow-up which included 6,399 deaths.

Exhibit A-2
Cohort derivation and information on final cohort



Person-years of follow-up and number of deaths for final cohort (n=78,597), by CCHS cycle

CCHS Cycle	Number	Person-years of follow up (n)	Deaths (n)
1.1	25,997	237,712	2,894
2.1	26,347	190,659	2,082
3.1	26,253	140,626	1,423
Total	**78,597**	**568,997**	**6,399**

ASCERTAINMENT OF BEHAVIOURAL RISK EXPOSURE AND SOCIODEMOGRAPHIC CHARACTERISTICS

The primary risk factors of interest were smoking, alcohol consumption, fruit and vegetable consumption, leisure physical activity and stress. The possible range of derived categories for each behavioural risk factor and its covariates was limited to the availability of related variables in the surveys and the categorizations provided for those related variables. Smoking behaviour was described using a combination of smoking status, daily cigarette consumption, and the existence of past smoking behaviour. Alcohol drinking behaviour was described using daily alcohol consumption and the extent of bingeing. Leisure physical activity was described using metabolic equivalent of task (MET)/day measures derived from an aggregate list of activities (frequency and duration) that were examined in each survey. Stress was described using response to a single interview question that asked individuals to rate the amount of stress in their lives. Diet was described using separate questions regarding the total number of fruits and vegetables consumed each day, and more specific questions regarding the consumption of potatoes, carrots and fruit juice. Sociodemographic characteristics examined included age, sex, ethnicity, education, rurality,[1] neighbourhood deprivation,[2,3] BMI and regional injury hospitalization rates.[4]

STATISTICAL APPROACH

Predictive model development and validation

Age-adjusted Cox proportional hazards models were developed to examine the association between each of the primary risk factors of interest and death for each sex separately. Age-adjusted models for each risk factor were initially examined using existing survey categorizations. Additional categories were derived for regular smokers and regular drinkers to provide dose-response estimates for smoking and alcohol consumption. Diet was examined using four discrete questions related to total fruit and vegetable servings (not including fruit juice), carrots, potatoes and fruit juice. The four dietary variables were then combined into an index reflecting the protective effect observed for daily consumption of fruits and vegetables generally and carrots specifically and the harmful effect observed for daily consumption of potatoes and fruit juice (Exhibit A-3).

Using the final risk categories, age-adjusted multivariable Cox proportional hazards model including all the primary risk factors were created for each sex. In these models, age was entered as a time-varying covariate to account for the aging of individuals and included a spline to adjust for the rapid non-linear increase of hazard in older ages. Sociodemographic characteristics were included in the models in the event that they improved discrimination and/or calibration. The final models were evaluated using the c-statistic and comparing predicted death to observed deaths, including across various subgroups that were not used to develop the algorithm (e.g., income levels, BMI categories and LHIN).

Exhibit A-3

Fruit and vegetable index scoring

FACTOR	LEVEL	POINTS
Daily servings of fruits and vegetables excluding fruit juice	0 to <1	**1**
	1 to <2	**2**
	2 to <3	**3**
	3 to <4	**4**
	4 or more	**5**
Potato consumption	>1 daily serving	**-1**
Carrot consumption	No daily serving	**-1**
Fruit juice consumption	>1 daily serving	**-1**

Estimate of life expectancy and risk-deleted life expectancy

Overall life expectancy was estimated for each sex by applying the multivariable risk models to the more recent CCHS Cycle 4.1 (2007) to create period life tables. The first step generated death probability for ages 20 to 99. Because there were few individuals at some individual ages, five-year age groups were created (20–24 years, 25–29 years and so on, up to 95–99 years) and each of these cohorts was aged throughout their five-year age interval. Using the multivariable risk models, a weighted probability of death was obtained at each age from 20 to 99 years. For ages with fewer than 10 individuals, the weighted probability of death was obtained by extrapolation using a natural cubic spline curve.

Next, life tables were generated for ages 20 and older by calculating the proportion of deaths occurring at each age and the proportion of individuals alive up to each age. The proportion of deaths occurring at each age was calculated by multiplying the weighted probability of death by the proportion of individuals alive up to the given age. Deaths were then subtracted from the proportion of individuals alive up to that age to provide the proportion of individuals alive up to the next subsequent age. The calculations assumed that no one lived past 99 years of age. The result was sex-specific life tables, ranging from 20 to 99 years of age, that contained a weighted probability of death, the proportion alive and the proportion of deaths.

Life expectancy at age 20 for each sex was calculated by multiplying the proportion of deaths at each age by the age itself and then summing the results across all ages. Life expectancy from birth assumed no deaths up to age 20. Life expectancy was calculated for each level of risk factor exposure (e.g., heavy current smoker, light current smoker and former smoker) and other subgroups of interest (e.g., different deprivation levels and BMI categories).

Risk-deleted life expectancies for each risk factor were calculated by recoding individuals to the healthiest exposure of the risk factor and repeating the methodology used to calculate life expectancy on the overall cohort of each sex. In the case of alcohol, two separate healthy referent exposures were employed: one for regular drinkers and another for non-regular drinkers (occasional or current non-drinkers). Occasional drinking was employed as the healthy referent for non-regular drinkers. All risk-deleted life expectancies were calculated by recoding all risk factors to the healthiest level.

Calculation of health expectancy and risk-deleted health expectancy

Overall health-adjusted life expectancy (HALE) was estimated for each sex by using the Health Utilization Index (HUI) values that corresponded to the same life table population. For example, HUI values for women were combined with life tables for women. The HUI is a measure of health-related quality of life, where a value of 1 represents perfect health and 0 represents a health state equivalent to death. A mean weighted HUI for each sex-specific, five-year age group was calculated using the CCHS cycle 4.1 (2007). For age groups with fewer than 30 individuals, the mean weighted HUI was obtained by extrapolation using a natural cubic spline curve. The proportion of life lived for each age group was estimated from the life tables by summing the proportion of individuals who survived throughout a five-year age group and half the deaths occurring within that age group. The total for each age was multiplied by the mean weighted HUI of the corresponding age group, providing an age-adjusted health-related quality of life. The summation of these calculations across all the ages for each sex represented the HALE of a 20-year-old male or female. It was assumed that individuals lived in perfect health during their first 20 years, and therefore 20 years were added to each HALE estimate to provide an overall HALE from birth.

Estimates for subgroups were calculated by repeating this methodology using their respective life table and HUI measures. Risk-deleted HALE was estimated for each risk exposure using the same methodology as risk-deleted life expectancy and the mean weighted HUI estimates of individuals in the healthiest category for that risk factor. All risk-deleted HALEs were estimated by using all risk-deleted life tables and the mean weighted HUI estimates of individuals with healthier levels of exposure in all five risk factors (non-smoking, any alcohol consumption excluding bingeing, moderately adequate or adequate diet, active or moderate physical activity, and low stress). The healthiest level of exposure in every risk factor could not be employed for all risk-deleted HALEs because of the limited number of individuals reporting the healthiest level of exposure for all risk factors simultaneously.

Estimation of deaths and risk-deleted deaths

The number of deaths among community-dwelling Ontarians aged 20 years or older in 2007 was estimated using the created life tables and weighted population distribution of Ontarians in CCHS 4.1 (2007). The number of deaths at each age was estimated by multiplying the weighted probability of death by the weighted population. The total number of deaths for each sex was estimated by summing deaths across all ages. Risk-deleted deaths were estimated using the same methodology and the risk-deleted life tables.

Results

A multivariable Cox proportional hazards model that included all the risk factors was derived for each sex using the exposure levels established for each risk factor. Exposure categories for each behavioural risk are described in the main Report (Exhibit 3) and additional covariates are shown in Exhibit A-4. Age, education, ethnicity and neighbourhood deprivation were included in both models as covariates to provide adjusted estimates of association between the risk factors and death. The model for males was also adjusted for additional geographic covariates (urban or rural dwelling, regional rurality and injury hospitalization rate for the LHIN).

Parameter estimates for the final risk models are displayed in Exhibit A-5. Age was entered as a time-varying covariate with a B-spline consisting of a single knot to allow for the aging of individuals and the rapid non-linear increase in hazard associated with older ages. Individuals were aged one year for every 365 days of follow-up. The age knot for the multivariable risk model for each sex was systematically chosen to maximize fit by varying the knot until the lowest AIC value was obtained (age 55 for males; age 81 for females). The use of a second knot did not improve fit for the model of either sex and therefore was not included. Analysis demonstrated a healthy response bias among survey participants. The number of deaths within the first year of follow-up was much lower in relation to the number of deaths in the following years. Therefore, the base hazard for the final risk model to be used in subsequent analysis was chosen as an average of the base hazard estimates in the second, third, fourth and fifth years of follow-up. This methodology resulted in risk models for each sex that satisfied the Cox proportional hazards assumptions, and demonstrated high discrimination (c-statistic: 0.87 for both models) and excellent calibration across low to high deciles of risk (Exhibit A-6). Adequate calibration was demonstrated across BMI categories (Exhibit A-7), income levels (Exhibit A-8) and Local Health Integration Networks (Exhibit A-9). The hazard related to individual risks showed little or no attenuation with the addition of sociodemographic and neighbourhood characteristics or the exclusion of people with poor health as identified using health status measures, such as the need for assistance with daily living or low self-rated health.

Exhibit A-4
Covariate descriptions

COVARIATE	LEVEL/DESCRIPTION
Education	Less than high school
	High school graduate
	Post-secondary graduate
Ethnicity	Caucasian
	Non-Caucasian
Deprivation	Low: Neighbourhoods in the bottom two quintiles for both social and material deprivation
	Moderate: Neighbourhoods not meeting the criteria for low or high
	High: Neighbourhoods in the top two quintiles for both social and material deprivation
Age1	Time-varying variable which was equal to the individual's age at each year of follow-up
Age2	Time-varying variable which was equal to the individual's age above the chosen B-spline knot at each year of follow-up
Dwelling*	Urban community dwelling
	Rural community dwelling
Injury rate*	Local Health Integration Network (LHIN) injury hospitalization rate relative to the provincial mean
Rurality*	LHIN's rurality relative to the provincial mean

*Covariates included only in male multivariable Cox proportional hazards model

Exhibit A-5
Risk models

PARAMETER	EXPOSURE LEVEL	PARAMETER ESTIMATE	
		Male Risk Model	Female Risk Model
Base hazard		0.000011857	0.000006059
Smoking	Heavy smoker	1.02569	1.07453
	Light smoker	0.77767	0.80339
	Former smoker	0.31784	0.50267
	Non-smoker	Reference	Reference
Alcohol	Binge drinker	0.26557	0.30607
	Heavy drinker	0.17999	0.14776
	Light drinker	0.22783	0.13337
	Occasional drinker	0.32546	0.35524
	Current non-drinker	0.44099	0.57596
	Moderate drinker	Reference	Reference
Physical activity (leisure time)	Inactive	0.320640	0.41720
	Moderately active	0.097954	0.058885
	Active	Reference	Reference
Diet (fruits and vegetables)	Very poor diet	0.41452	0.45126
	Poor diet	0.27734	0.24782
	Fair diet	0.16097	0.16392
	Adequate diet	Reference	Reference

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EXHIBIT A-5 CONTINUED...

PARAMETER	EXPOSURE LEVEL	PARAMETER ESTIMATE	
		Male Risk Model	Female Risk Model
Stress	High stress	0.22122	0.15774
	Low stress	Reference	Reference
Education	< High school	0.21056	0.13438
	High school	0.053548	0.061672
	Post-secondary	Reference	Reference
Ethnicity	Non-Caucasian	-0.43839	-0.36315
	Caucasian	Reference	Reference
Deprivation level	High	0.18722	0.28017
	Moderate	0.85159	0.099727
	Low	Reference	Reference
Age1	-	0.085491	0.091402
Age2	-	0.021290	0.024090
Dwelling	Rural	-0.139970	N/A
	Urban	Reference	N/A
Injury rate	-	0.094390	N/A
Rurality	-	0.080641	N/A

Exhibit A-6

Observed and predicted deaths, by sex and risk decile in Ontario, 2007

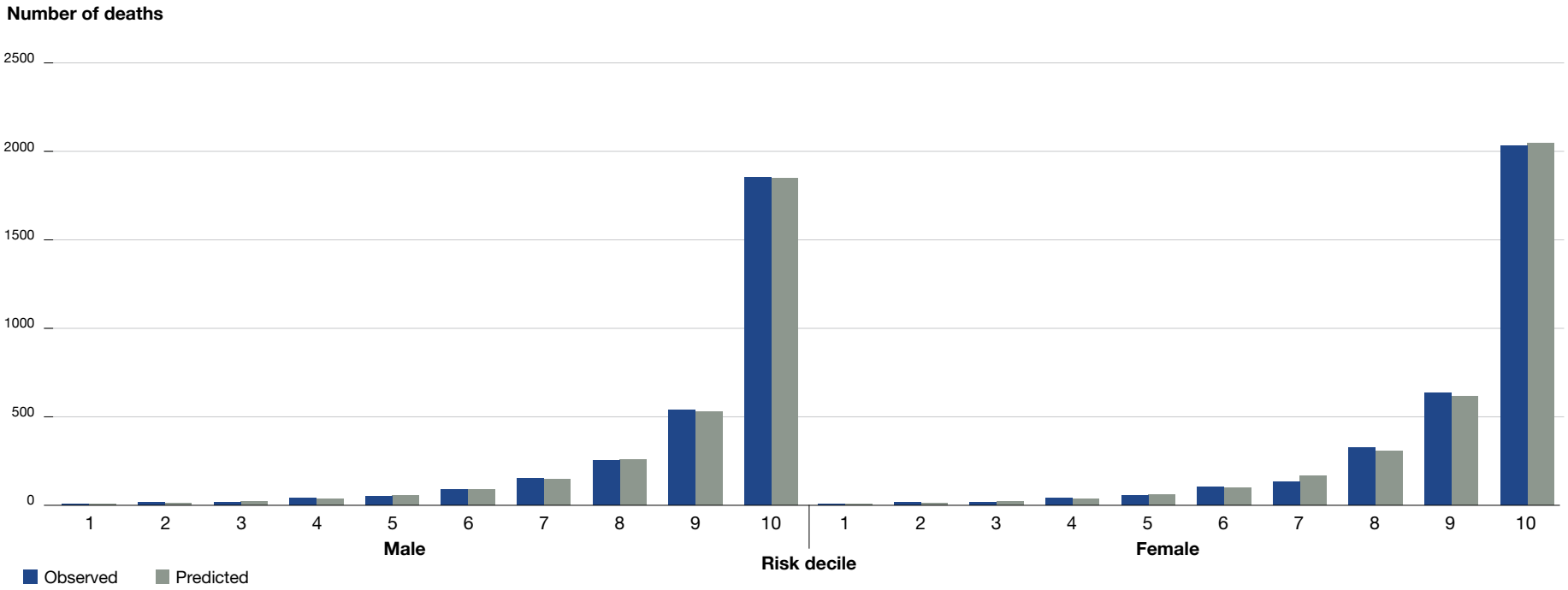


Exhibit A-7

Observed and predicted death rates, by sex and BMI score in Ontario, 2007

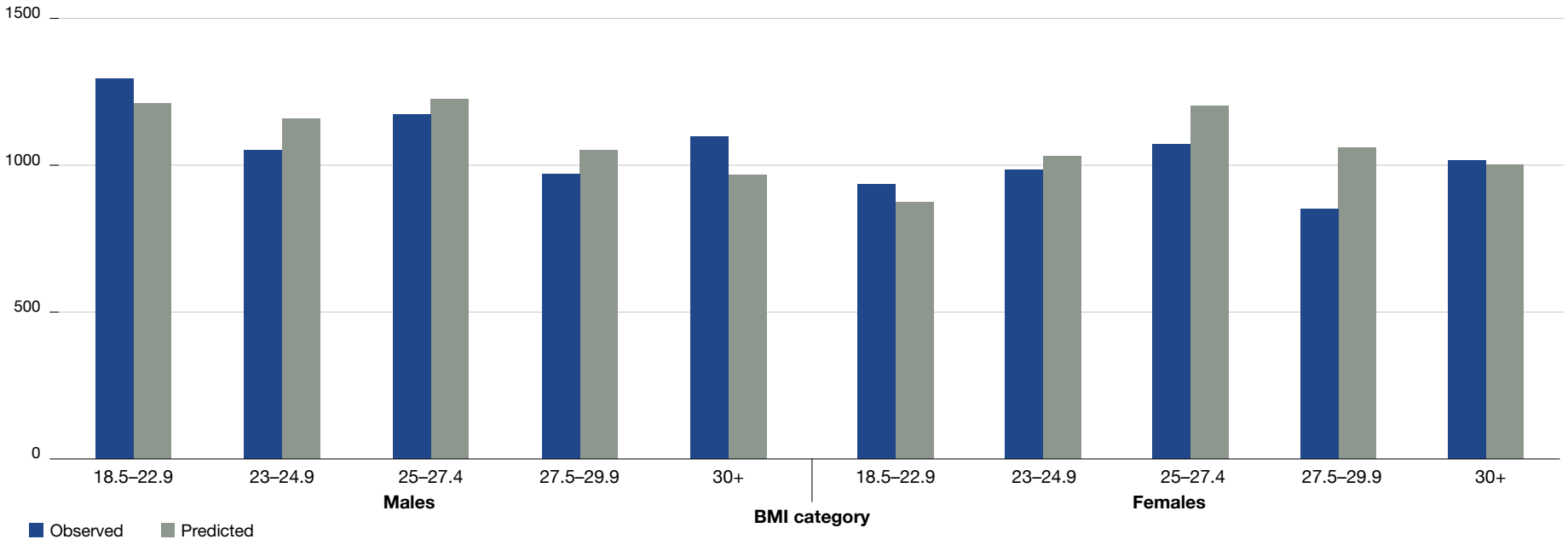


Exhibit A-8

Observed and predicted death rates, by sex and income level in Ontario, 2007

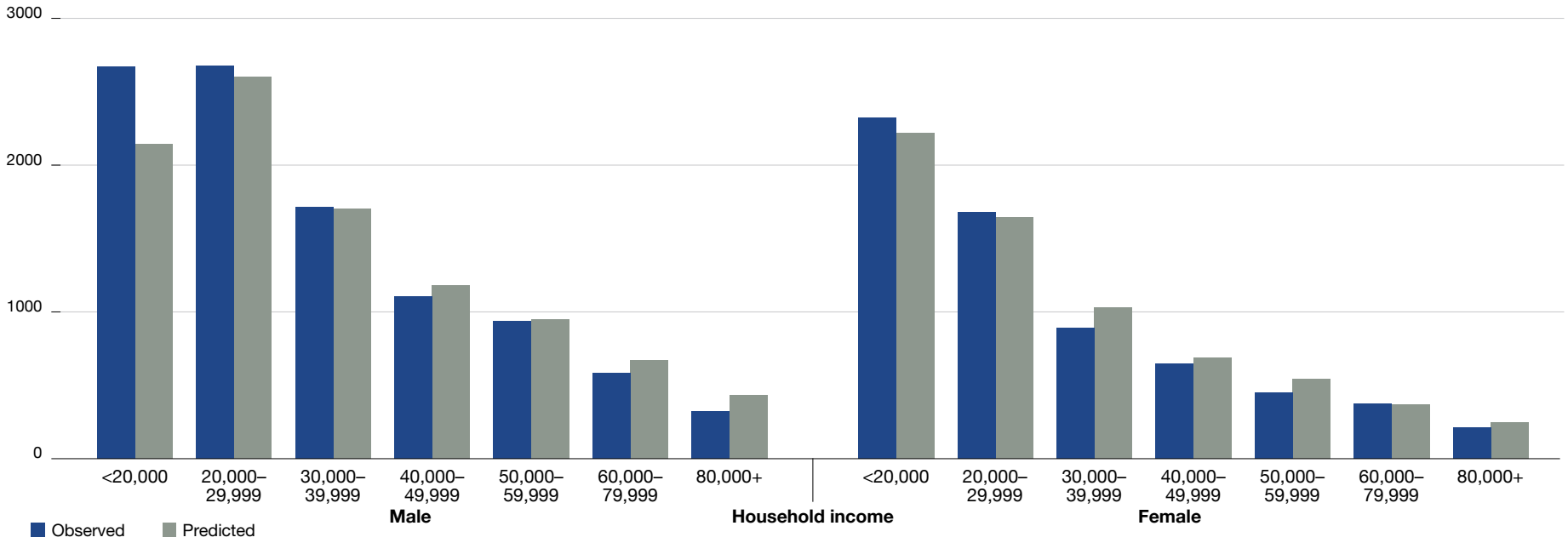
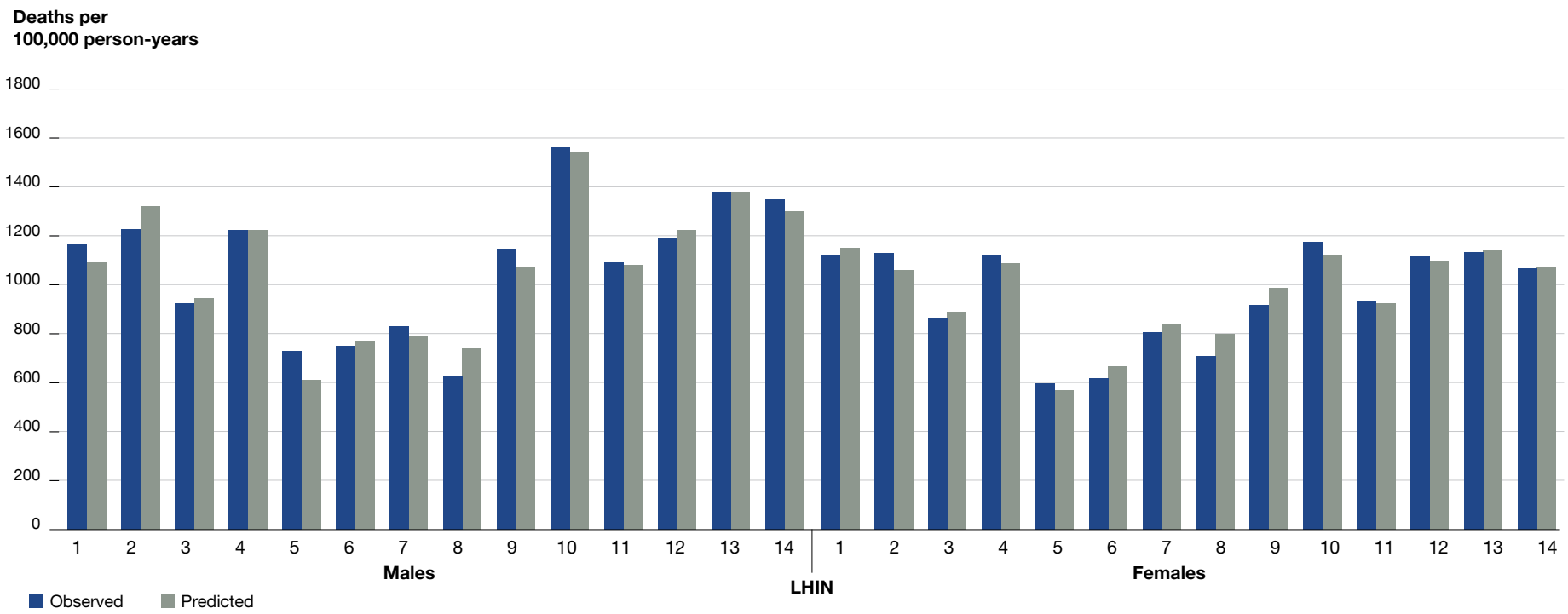


Exhibit A-9

Observed and predicted death rates, by sex and Local Health Integration Network (LHIN) in Ontario, 2007



LHIN

1—Erie St. Clair 2—South West 3—Waterloo Wellington 4—Hamilton Niagara Haldimand Brant 5—Central West 6—Mississauga Halton
7—Toronto Central 8—Central 9—Central East 10—South East 11—Champlain 12—North Simcoe Muskoka 13—North East 14—North West

Exhibits A-10 to A-18 present findings from the main report but in greater detail. Exhibit A-10 shows projected life expectancies by sex. Exhibit A-11 shows health status, including additional measures of health-related quality of life for sub-categories of risk exposure. Exhibits A-12 and A-13 show the prevalence of individual risks by socioeconomic position and BMI, as well as life and health expectancy for these subgroups. Exhibit A-14 summarizes the study's main findings, including prevalence and hazard ratios for each exposure level of the five behavioural risks. Exhibit A-15 shows the impact of eliminating the behavioural risks by sex. Exhibits A-16 and A-17 show, by sex, the contribution of each behavioural risk to the gaps in life expectancy and health-adjusted life expectancy across deprivation levels. Exhibit A-18 shows greater detail regarding the calculation of the "most important" behavioural risk from an individual perspective.

Exhibit A-10

Projected life expectancies for Ontarians with high levels of exposure to behavioural risk factors and with a reference of healthy exposure, by sex, 2007

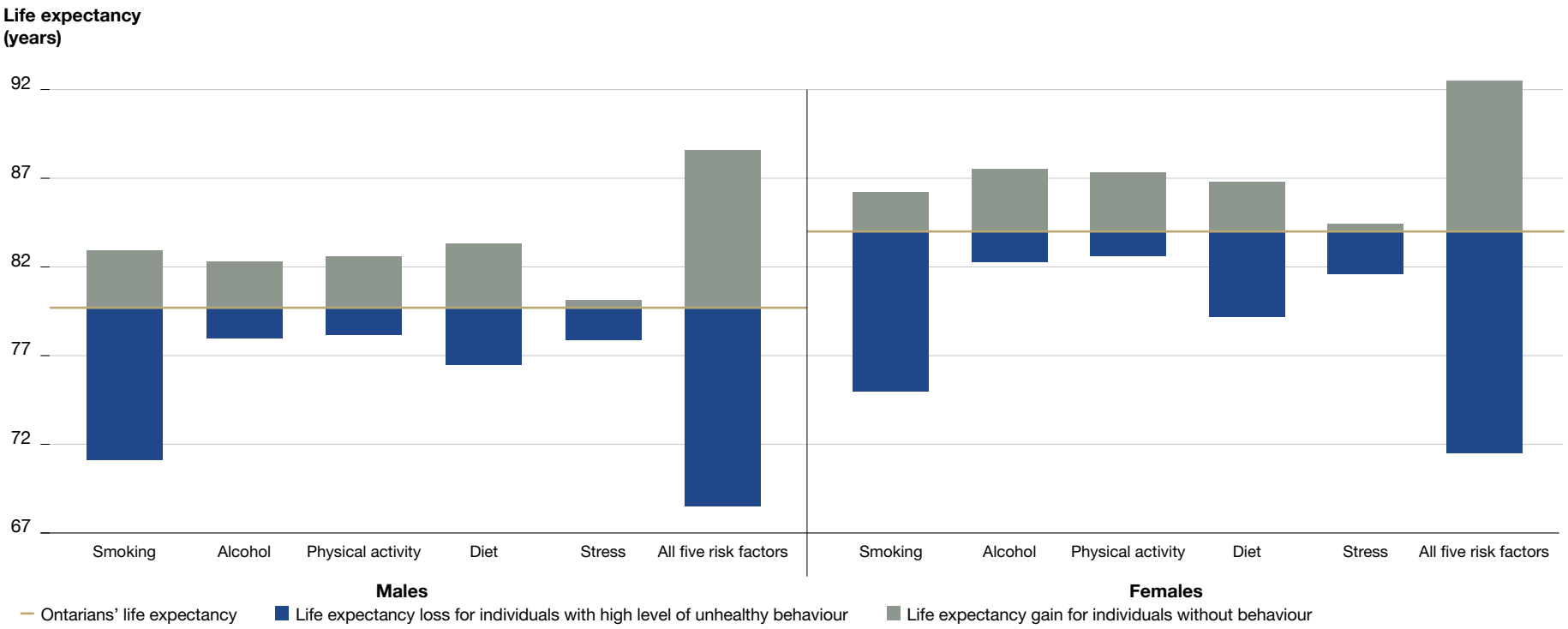


Exhibit A-11

Measures of health status, by sex and risk factor in Ontario, 2007

PARAMETER	EXPOSURE LEVEL	LIFE EXPECTANCY (YEARS)	HEALTH-ADJUSTED LIFE EXPECTANCY (YEARS)	SELF-RATED HEALTH ≥ "GOOD" (%)	ACTIVITIES RESTRICTED BY HEALTH (%)	REQUIRE HELP WITH BASIC TASKS (%)	LIKELIHOOD ALIVE AT AGE 75 YEARS (%)
Male	**Overall**	**79.7**	**71.9**	**89.5**	**21.7**	**5.7**	**73.4**
Smoking	Heavy current	71.1	63.4	78.5	32.2	8.5	47.7
	Light current	75.2	66.5	85.0	23.2	6.2	61.6
	Former	79.6	72.1	88.5	24.9	6.4	73.6
	Never	82.9	75.6	92.9	17.4	4.3	81.5
Alcohol	Binger*	78.0	70.7	88.9	23.0	4.4	67.8
	10-24 drinks/week	80.2	72.5	88.9	18.0	2.1	73.5
	5-9 drinks/week	82.3	76.2	94.4	18.4	3.8	79.1
	0-4 drinks/week	80.7	73.5	90.8	20.2	5.0	75.7
	Occasional (<1/month)	78.9	70.3	86.3	26.1	7.2	71.2
	Current non-drinker	78.2	68.6	84.4	23.4	10.4	69.5
Physical activity	Inactive	78.2	69.4	86.1	24.1	7.6	76.3
	Moderate	81.5	74.7	91.4	20.0	4.1	79.2
	Active	82.6	76.6	94.4	18.6	2.9	80.3
Diet (fruits and vegetables)	Poor	76.5	68.1	83.9	26.8	9.8	64.0
	Inadequate	79.0	71.3	89.5	21.7	5.3	71.8
	Moderately adequate	81.2	74.3	91.7	19.1	4.3	76.1
	Adequate	83.3	77.6	90.9	22.7	4.8	80.3
Stress	High	77.9	65.7	81.5	30.1	9.6	67.5
	Low	80.1	73.4	91.4	19.5	4.8	74.4

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EXHIBIT A-11 CONTINUED...

PARAMETER	EXPOSURE LEVEL	LIFE EXPECTANCY (YEARS)	HEALTH-ADJUSTED LIFE EXPECTANCY (YEARS)	SELF-RATED HEALTH ≥ "GOOD" (%)	ACTIVITIES RESTRICTED BY HEALTH (%)	REQUIRE HELP WITH BASIC TASKS (%)	LIKELIHOOD ALIVE AT AGE 75 YEARS (%)
Female	**Overall**	**84.0**	**73.6**	**87.7**	**27. 1**	**12.0**	**81.2**
Smoking	Heavy current	75.0	62.3	73.5	43.4	20.9	57.0
	Light current	77.9	67.6	85.0	33.0	12.8	68.1
	Former	82.1	73.1	87.8	31.9	12.6	78.8
	Never	86.2	75.3	89.0	23.0	10.9	86.2
Alcohol	Binger*	82.3	73.6	90.5	25.0	6.8	77.7
	6-17 drinks/week	85.5	79.2	96.2	22.5	7.5	84.2
	3-5 drinks/week	87.5	81.1	93.8	24.6	7.2	86.5
	0-2 drinks/week	85.8	76.5	90.8	24.9	8.5	84.6
	Occasional (<1/month)	83.9	73.2	84.6	32.4	14.1	80.3
	Current non-drinker	82.3	69.7	81.2	27.7	17.6	77.1
Physical activity	Inactive	82.6	71.2	84.4	29.6	14.7	77.6
	Moderate	86.7	78.3	91.2	23.5	8.3	85.6
	Active	87.3	79.4	94.0	22.8	7.7	86.5
Diet (fruits and vegetables)	Poor	79.2	66.5	78.0	36.1	19.5	67.5
	Inadequate	82.8	72.1	86.1	28.5	12.6	78.2
	Moderately adequate	84.9	75.8	89.8	25.5	10.8	83.4
	Adequate	86.8	76.3	90.7	24.9	10.7	85.5
Stress	High	81.6	66.7	77.5	39.2	19.9	75.5
	Low	84.4	75.2	90.3	23.7	9.9	81.1

***Bingeing was defined as ≥5 drinks/day (men) or ≥4 drinks/day (women) on any day in the previous week or weekly bingeing behaviour in the previous month.**

Exhibit A-12

Measures of risk factor prevalence, health-related quality of life, life expectancy and health-adjusted life expectancy, by sex and socioeconomic position, Ontario, 2007

	DEPRIVATION INDEX					
	Male			Female		
	High	Middle	Low	High	Middle	Low
Risk factor prevalence (%)						
Current smoking	36.2	25.7	19.4	25.6	17.7	14.0
Unhealthy alcohol consumption	21.3	19.7	19.4	9.9	8.7	8.9
Physical inactivity	57.4	49.8	43.1	61.0	57.2	51.2
Poor diet	66.9	60.0	58.4	52.8	42.2	35.5
High stress	20.9	20.7	23.8	25.2	24.1	24.1
Health-related quality of life indicators (%)						
Self-rated health ≥ "good"	84.5	89.7	92.4	81.7	88.3	90.3
Activities restricted by health	28.1	20.8	21.2	31.6	26.8	24.8
Require help with basic tasks	8.3	5.4	4.8	14.8	11.7	10.4
Life expectancy (years)	77.1	79.8	81.1	81.3	84.1	86.2
Health-adjusted life expectancy (years)	68.5	71.9	74.7	69.0	73.5	77.7

Exhibit A-13

Measures of risk factor prevalence, health-related quality of life, life expectancy and health-adjusted life expectancy, by sex and body mass index (BMI) in Ontario, 2007

	BMI (KG/M²)					
	Male			Female		
	≥30.0	25.0–29.9	18.5–24.9	≥30.0	25.0–29.9	18.5–24.9
Risk factor prevalence (%)						
Current smoking	21.1	23.1	29.7	18.1	17.3	18.6
Unhealthy alcohol consumption	20.0	19.8	20.8	7.1	8.2	8.9
Physical inactivity	53.0	47.5	46.9	62.8	58.7	51.1
Poor diet	62.9	59.5	60.5	44.2	40.2	41.8
High stress	23.5	22.2	19.1	24.1	24.1	23.7
Health-related quality of life indicators (%)						
Self-rated health ≥ "good"	83.2	91.1	91.0	77.6	86.5	91.4
Activities restricted by health	30.0	20.0	19.7	39.6	29.1	21.5
Require help with basic tasks	8.1	5.0	5.1	18.4	12.1	8.9
Life expectancy (years)	79.1	79.6	80.0	82.8	83.9	84.4
Health-adjusted life expectancy (years)	70.8	72.5	72.2	69.3	74.3	74.8

Exhibit A-14

Risk factor exposure, risk of death, and risk-deleted estimates of life expectancy (LE) and health-adjusted life expectancy (HALE), by sex in Ontario, 2007

RISK FACTOR	EXPOSURE LEVEL	POPULATION (N)	PREVALENCE (%)	HAZARD RATIO	RISK-DELETED LE (YEARS)	RISK-DELETED HALE (YEARS)	IMPACT ON LE (YEARS)	IMPACT ON HALE (YEARS)
Male								
Smoking	Heavy current	390,000	8.4	2.8 (2.4, 3.2)	82.5	75.3	2.8	3.3
	Light current	802,000	17.3	2.2 (1.9, 2.5)				
	Former	1,273,000	27.5	1.4 (1.3, 1.5)				
	Never	2,169,000	46.8	Reference				
	Non-responders	41,800						
Alcohol	Bingeing*	886,000	19.8	1.3 (1.1, 1.5)	80.9	73.6	1.2	1.7
	10-24 drinks/week	242,000	5.4	1.2 (1.0, 1.4)				
	5-9 drinks/week	579,000	13.0					
	0-4 drinks/week	1,556,000	34.9	1.3 (1.1, 1.4)				
	Occasional (<1/month)	479,000	10.7	1.4 (1.2, 1.6)				
	Current non-drinker	724,000	16.2	1.6 (1.4, 1.8)				
	Non-responders	197,000						
Physical activity	Inactive	2,250,000	49.3	1.4 (1.3, 1.5)	81.7	75.3	2.0	3.4
	Moderate	1,121,000	24.6	1.1 (1.0, 1.2)				
	Active	1,193,000	26.1	Reference				
	Non-responders	111,000						
Diet (fruits and vegetables)	Poor	669,000	15.2	1.5 (1.3, 1.8)	82.0	74.6	2.2	2.7
	Inadequate	2,010,000	45.5	1.3 (1.1, 1.6)				
	Moderately inadequate	1,226,000	27.8	1.2 (1.0, 1.4)				
	Adequate	513,000	11.6	Reference				
	Non-responders	257,000						

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EXHIBIT A-14 CONTINUED...

RISK FACTOR	EXPOSURE LEVEL	POPULATION (N)	PREVALENCE (%)	HAZARD RATIO	RISK-DELETED LE (YEARS)	RISK-DELETED HALE (YEARS)	IMPACT ON LE (YEARS)	IMPACT ON HALE (YEARS)
Stress	High	989,000	21.3	1.3 (1.1, 1.4)	80.0	73.3	0.3	1.4
	Low	3,654,000	78.7	Reference				
	Non-responders	32,000						
Overall		4,676,000			87.6	82.8	7.9	10.9
Female								
Smoking	Heavy current	183,000	3.8	2.9 (2.6, 3.4)	86.1	75.6	2.2	2.0
	Light current	701,000	14.4	2.2 (2.0, 2.5)				
	Former	974,000	20.0	1.7 (1.5, 1.8)				
	Never	3,013,000	61.9	Reference				
	Non-responders	35,000						
Alcohol	Bingeing*	426,000	9.0	1.4 (1.1, 1.8)	85.3	76.0	1.3	2.4
	6-17 drinks/week	342,000	7.2	1.2 (0.9, 1.4)				
	3-5 drinks/week	469,000	9.9	Reference				
	0-2 drinks/week	1,305,000	27.5	1.2 (1.0, 1.4)				
	Occasional (<1/month)	950,000	20.0	1.4 (1.2, 1.7)				
	Current non-drinker	1,257,000	26.5	1.8 (1.5, 2.2)				
	Non-responders	148,000						
Physical activity	Inactive	2,730,000	56.6	1.5 (1.4, 1.7)	87.0	77.3	2.7	3.7
	Moderate	1,160,000	24.0	1.1 (0.9, 1.2)				
	Active	939,000	19.5	Reference				
	Non-responders	81,000						
Diet (fruits and vegetables)	Poor	370,000	8.0	1.6 (1.4, 1.8)	85.8	76.4	1.9	2.8
	Inadequate	1,615,000	34.6	1.3 (1.1, 1.5)				
	Moderately inadequate	1,606,000	34.0	1.2 (1.0, 1.4)				

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EXHIBIT A-14 CONTINUED...

RISK FACTOR	EXPOSURE LEVEL	POPULATION (N)	PREVALENCE (%)	HAZARD RATIO	RISK-DELETED LE (YEARS)	RISK-DELETED HALE (YEARS)	IMPACT ON LE (YEARS)	IMPACT ON HALE (YEARS)
Diet (fruits and vegetables) (continued)	Adequate	1,092,000	23.4	Reference				
	Non-responders	223,000						
Stress	High	1,177,000	24.3	1.2 (1.1, 1.4)	84.2	75.4	0.2	1.8
	Low	3,707,000	75.7	Reference				
	Non-responders	22,000						
Overall		4,906,000			91.1	82.3	7.1	8.7

***Bingeing was defined as ≥5 drinks/day (men) or ≥4 drinks/day (women) on any day in the previous week or weekly bingeing behaviour in the previous month.**

Exhibit A-15

Impact of eliminating five behavioural risks on life expectancy and health-adjusted life expectancy, by sex in Ontario, 2007

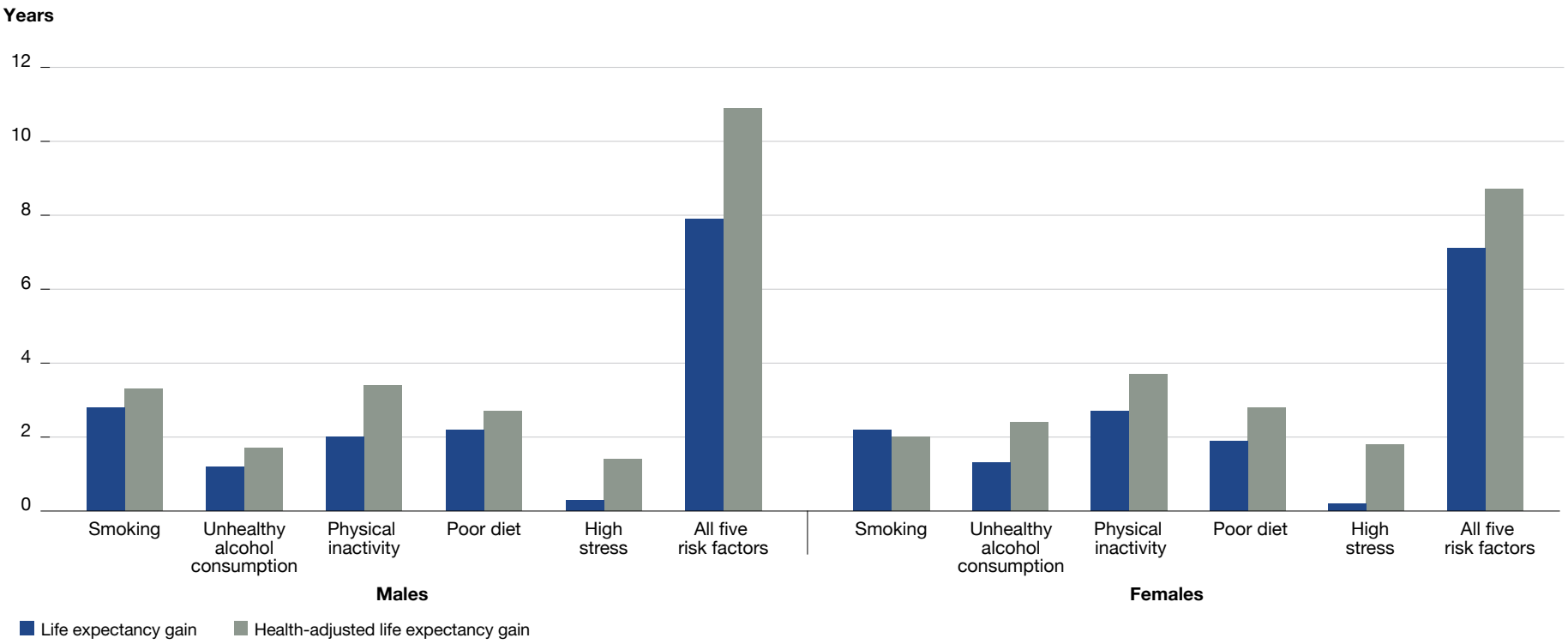

Exhibit A-16

Effect of risk factor exposure on the life expectancy (LE) gap across deprivation levels, by sex in Ontario, 2007

RISK FACTOR	LE BY DEPRIVATION LEVEL (YEARS)			LE GAP (YEARS)	REDUCTION IN LE GAP WITH RISK FACTOR DELETED	
	Low	Medium	High	Low–High	Years	%
Male						
None	81.5	79.8	77.1	4.4	-	-
Smoking	83.9	82.6	80.9	3.0	1.4	32.0
Alcohol	82.6	81.0	78.4	4.2	0.2	3.2
Physical activity	83.4	81.8	79.4	4.0	0.4	9.2
Diet	83.8	82.0	79.6	4.2	0.2	6.6
Stress	81.8	80.1	77.6	4.2	0.2	3.9
All	88.9	87.6	86.5	2.4	2.0	46.7
Female						
None	86.2	84.1	81.3	4.8	-	-
Smoking	88.0	86.2	84.3	3.6	1.2	25.1
Alcohol	87.4	85.4	82.8	4.5	0.3	5.4
Physical activity	88.6	86.8	84.5	4.0	0.8	15.7
Diet	88.0	85.9	83.4	4.3	0.5	10.9
Stress	86.4	84.3	81.6	4.7	0.1	2.3
All	92.3	91.2	90.0	2.3	2.5	52.5

Exhibit A-17

Effect of risk factor exposure on the health-adjusted life expectancy (HALE) gap across deprivation levels, by sex in Ontario, 2007

RISK FACTOR	HALE BY DEPRIVATION LEVEL (YEARS)			HALE GAP (YEARS)	REDUCTION IN HALE GAP WITH RISK FACTOR DELETED	
	Low	Medium	High	Low–High	Years	%
Male						
None	73.2	72.0	69.9	3.3	-	-
Smoking	76.2	75.3	74.0	2.2	1.1	32.9
Alcohol	74.9	73.7	71.6	3.3	0.0	2.2
Physical activity	76.7	75.3	73.4	3.3	0.0	1.2
Diet	75.9	74.6	72.8	3.1	0.2	6.1
Stress	74.6	73.4	71.4	3.2	0.1	3.2
All	83.8	82.8	81.8	2.0	1.3	41.0
Female						
None	75.1	73.7	71.7	3.4	-	-
Smoking	76.9	75.7	74.4	2.4	0.9	28.1
Alcohol	77.6	76.0	74.1	3.5	-0.1	-4.9
Physical activity	78.3	77.4	75.8	2.5	0.9	24.6
Diet	77.9	76.5	74.6	3.3	0.1	4.4
Stress	76.9	75.5	73.5	3.4	0.0	0.6
All	82.9	82.3	81.6	1.3	2.1	62.1

Exhibit A-18

Ranking by hazard ratio and prevalence of behavioural risk factors by sex in Ontario, 2007

MALE MODEL							
RANK	**RISK FACTOR**	**LEVEL**	**HR**	**CI**	**DIFFERENCE**	**PERCENTAGE**	**CUMULATIVE %**
1	Smoking	Heavy smoker	2.79	(2.44, 3.19)	1.42	8.3	8.3
2	Smoking	Light smoker	2.18	(1.91, 2.48)	0.81	17.8	26.1
3	Diet	Very poor diet	1.51	(1.26, 1.82)	0.51	9.6	35.7
4	Physical activity	Inactive	1.38	(1.25, 1.52)	0.38	29.3	65.0
5	Diet	Poor diet	1.32	(1.12, 1.56)	0.32	16.4	81.4
6	Alcohol	Binge drinker	1.31	(1.12, 1.54)	0.31	3.3	84.7
7	Alcohol	Light drinker	1.27	(1.12, 1.43)	0.27	7.5	92.2
8	Stress	High stress	1.25	(1.13, 1.38)	0.25	1.3	93.5
9	Alcohol	Heavy drinker	1.21	(1.03, 1.43)	0.21	0.9	94.4
10	Diet	Fair diet	1.18	(0.99, 1.40)	0.18	3.8	98.2
11	Physical activity	Moderately active	1.10	(0.98, 1.24)	0.10	0.9	99.1
12	None					0.9	100.0

HR = hazard ratio; CI = confidence interval

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EXHIBIT A-18 CONTINUED...

			FEMALE MODEL				
RANK	**RISK FACTOR**	**LEVEL**	**HR**	**CI**	**DIFFERENCE**	**PERCENTAGE**	**CUMULATIVE %**
1	Smoking	Heavy smoker	2.93	(2.56, 3.36)	1.28	3.8	3.8
2	Smoking	Light smoker	2.23	(2.00, 2.50)	0.58	14.6	18.4
3	Diet	Very poor diet	1.57	(1.34, 1.84)	0.57	5.3	23.7
4	Physical activity	Inactive	1.52	(1.35, 1.71)	0.52	41.1	64.8
5	Alcohol	Binge drinker	1.37	(1.05, 1.79)	0.37	2.9	67.7
6	Diet	Poor diet	1.28	(1.13, 1.46)	0.28	8.9	76.6
7	Diet	Fair diet	1.18	(1.03, 1.35)	0.18	13.7	90.3
8	Stress	High stress	1.17	(1.03, 1.35)	0.17	2.0	92.3
9	Alcohol	Heavy drinker	1.16	(0.94, 1.43)	0.16	0.9	93.2
10	Alcohol	Light drinker	1.15	(0.95. 1.39)	0.15	2.8	96.0
11	Physical activity	Moderately active	1.06	(0.92, 1.22)	0.06	2.1	98.1
12	None					1.9	100.0

HR = hazard ratio; CI = confidence interval

Discussion

The risk algorithm displayed very good discrimination and calibration in the study data, indicating that death can be accurately predicted using easily obtained self-report information focused on sociodemographic characteristics and health behaviour.

The algorithm was designed to be well-calibrated in a general population and generally achieved that objective. Of note, the algorithm is well-calibrated for a wide range of specific populations. For example, the algorithm accurately predicted death for people by BMI, income and health planning region, without specifically including these characteristics in the model. The algorithm was not validated in a population outside Ontario, so caution should be exercised in other settings. That stated, the strong characteristics of predictive accuracy suggest that use in other settings should provide meaningful estimates.

COMPARISON TO OTHER STUDIES

Comparisons can be made with three types of studies:

a) epidemiology studies that examine the relationship between behavioural risk factors and death;

b) burden-of-risk-factor studies that focus on individual behavioural risks; and

c) burden-of-risk-factor studies that focus on the collective contribution of multiple risks.

Epidemiology studies that examine the relationship between behavioural risks and death

In recent years, a growing number of meta- and pooled analysis studies, as well as very large cohort studies, have examined the hazard of death from behavioural risks. For example, the European Prospective Investigation into Cancer and Nutrition (EPIC) study has followed more than 500,000 people since the mid-1990s.[5] These studies usually enrol people from specific populations—rather than attempting to represent a general population—and then measure health behaviour exposure in detail, often attempting to follow changes in health behaviours. Although these studies cannot be used to estimate population burden, they are well-suited to examine the level of hazard or risk of death from health behaviours.

These studies have found characteristics of individual hazards similar to our findings (see Exhibit A-19) in three respects:

- The hazards or risk levels associated with specific health behaviours were the same or similar across the studies, although differences in how health behaviours were measured pose a challenge for direct comparison.
- Hazards showed the same rank order. Smoking had the highest relative risk (2.8 to 2.9 times for current heavy smokers compared to never smokers), about twice the risk of poor diet and inactive physical activity (1.4 to 1.6 times increased risk compared to people who are active). Stress had the lowest risk.
- The same dose-response gradients were found, with a higher risk in greater exposure for all behaviours except alcohol, where the lowest risk was in moderate alcohol consumption.

Detailed comparison to other studies is challenging due to differences in how health behaviours are measured. Our study used general self-reported measures whereas many studies used more detailed risk measurement. For example, most diet studies asked participants for detailed recall of their diet, whereas we used broad measures of consumption based on number of servings of fruits and vegetables. The more detailed measures in other studies allowed for more precise measures of specific dietary components, whereas the index used in this study likely reflects the health effects of overall diet, including foods that may or may not be included in the dietary index. As such, the diet-related hazard of death that we report is somewhat higher than previously reported hazards related to fruit and vegetable consumption.[6–10]

Exhibit A-19
Expanded list of study limitations and interpretive cautions

	INTERPRETATION	EFFECT ON STUDY FINDINGS	↑= RESULTS IN BURDEN ESTIMATES GREATER THAN EXPECTED; ↓= RESULTS LESS THAN EXPECTED
Who was included in the study?			
Community-dwelling Ontarians who responded to Statistics Canada's Canadian Community Health Surveys (CCHS). Not included in the study were children and youth, people living on Indian Reserves, and people living in long-term care facilities (the latter two groups are not surveyed in CCHS).	The study findings reflect community-dwelling Ontarians aged 20 and older.	Approximately 12% of deaths occur in residents of long-term care facilities (not included in the study). Therefore, the number of attributable deaths will be about 12% lower than reported in this study.	The effect of omitting populations: • Long-term care ↓↓↓ • Children and youth ↓↓ • First Nations ↓
How were behavioural health risks measured?			
Self-response to survey questions about healthy living and health-related quality of life.	Most people responded to the surveys by telephone. All responses were self-reported. People often overestimate their healthy living, particularly when responses are provided on telephone surveys.	Burden estimates for all behavioural risks will be underestimated.	All risks ↓↓
Brief questions about each aspect of healthy living.	Healthy living was estimated using a general population health survey, as opposed to a detailed, focused study that was exclusively about healthy living. For example, people were asked how many fruits and vegetables they ate each day rather than a repeated 24-hour food recall with specific probing questions about serving size.	Burden estimates for all behavioural risks will be underestimated. However, general questions may act as a proxy for more detailed questions. For example, this study ascertained only leisure-time physical activity and not sedentary time or physical activity during work and travel. However, people who are active in their leisure time may also be active at other times of the day.	Smoking ↓↓ Alcohol ↓↓ Physical activity ↓↓ Healthy eating ↓↓ Stress ↓↓
Only recent healthy living was questioned.	Healthy living changes over a person's life. The surveys asked only about recent healthy living, with the exception of smoking and alcohol (people were asked if they were former smokers or ever drank alcohol).	Single "baseline" ascertainment of unhealthy living generally underestimates harm compared to studies that examine healthy living at different time periods of a person's life.	All risks ↓ or ↓↓

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EXHIBIT A-19 CONTINUED...

	INTERPRETATION	EFFECT ON STUDY FINDINGS	↑= RESULTS IN BURDEN ESTIMATES GREATER THAN EXPECTED; ↓= RESULTS LESS THAN EXPECTED
Not all behavioural risks were examined.	The study examined five behavioural risks. Additional behavioural risks not examined include unsafe sex, drug misuse and unintentional injuries from risky behaviour (e.g., unsafe driving)	Unmeasured risk may be incorrectly attributed to measured risk if the two types of risk occur in the same individual. To address this issue, neighbourhood deprivation and individual income were used as proxies of unmeasured behavioural risks. The adjustment process can be overly rigorous, thereby over compensating and reducing the risk attributed to measured risks in this report.	All risks ↑↓
Behavioural risks were examined.	The study did not consider intermediate or distal risks such as obesity, high blood pressure or high cholesterol level.	—	
How was the risk of unhealthy living calculated?			
All-cause death rather than the sum of disease-specific deaths.	Many studies examine deaths from specific diseases that are causally associated with exposure to behavioural risks.	—	All risks ↑↓
Direct impact was examined.	Missing from estimates was burden attributed to second-hand exposure to health risks such as deaths to passengers in motor vehicle collisions where the driver was drinking.	Burden estimates for most behavioural risks will be underestimated.	Alcohol ↓ Smoking ↓
Predictive risks were not validated in external data.			All risks ↑↓

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EXHIBIT A-19 CONTINUED...

	INTERPRETATION	EFFECT ON STUDY FINDINGS	↑= RESULTS IN BURDEN ESTIMATES GREATER THAN EXPECTED; ↓= RESULTS LESS THAN EXPECTED
How was burden of unhealthy living reported?			
Life expectancy (LE) and health-adjusted life expectancy (HALE) estimates were calculated using a period or stationary approach.	The calculation methods for LE and HALE follow a commonly used approach. These measures are frequently misinterpreted as predictive of the future. Rather, they should be interpreted as a summary of current health, answering the question, "How long would an Ontarian live if he or she had lifelong exposure to the health behaviours and mortality risk as currently measured?"	Period life expectancy calculations are generally lower than life expectancy calculated by following people over their entire life.	(interpretive caution)
Risk-deleted life expectancy and HALE.	These estimates should be interpreted as the potential gain in LE and HALE if people in Ontario had never been exposed to the five behavioural risks examined in this study.		
Multiplicative predictive model.	The burden of individual risks should not be added together. Only the specific estimates of multiple risks should be used to estimate the combined burden of risks.		

Burden-of-risk-factor studies that focus on individual behavioural risks or the collective contribution of multiple risks

Two types of studies estimate burden from behavioural risks: studies that follow the approach of Levin combining hazard (determined from etiology studies) with level of health behaviours (from population health surveys and other sources),[11,12] and studies similar to ours that used self-reported population health surveys and followed people to identify who died.

In Ontario and Canada, studies based on Levin's method have been performed for smoking and alcohol consumption.[13–15] Direct comparison of findings between different study approaches is challenging because of a number of methodological differences. However, compared to previous reports, this study found similar, albeit somewhat higher, proportions of deaths attributable to smoking and alcohol. Canadian studies report about 21% of deaths attributable to smoking, compared to 24% in this study. In Ontario, Rehm et al. estimated 6% of deaths attributable to alcohol,[16] compared to 11% in this study. The higher estimates in this study likely represent differences in the spectrum of health measures examined.

Studies similar to ours generally take an even simpler approach to measuring health risks and, as a result, often find a somewhat lower overall burden of risks. For example, Ford et al. estimated 40% of deaths in the United States are attributable to four dichotomised (e.g., smokers versus non-smokers) behavioural risks,[17] as opposed to this study's approach of delineating different levels of risk (e.g., heavy smokers, light smokers, former smokers and non-smokers).

References

1. Canadian Institute for Health Information. Health Indicators 2008. Ottawa, ON: CIHI; 2008.
2. Canadian Institute for Health Information. *Reducing Gaps in Health: A Focus on Socio-Economic Status in Urban Canada*. Ottawa, ON: CIHI; 2008.
3. Pampalon R, Hamel D, Gamache P, Raymond G. A deprivation index for health planning in Canada. *Chronic Dis Can*. 2009; 29(4): 178–91.
4. Canadian Institute for Health Information. Health Indicators 2010. Ottawa, ON: CIHI; 2010.
5. Fahey MT, Ferrari P, Slimani N, et al. Identifying dietary patterns using a normal mixture model: application to the EPIC study. *J Epidemiol Community Health*. 2012; 66(1):89–94.
6. Bazzano LA, He J, Ogden LG, et al. Fruit and vegetable intake and risk of cardiovascular disease in US adults: the first National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. *Am J Clin Nutr*. 2002; 76(1):93–9.
7. Genkinger JM, Platz EA, Hoffman SC, Comstock GW, Helzlsouer KJ. Fruit, vegetable, and antioxidant intake and all-cause, cancer, and cardiovascular disease mortality in a community-dwelling population in Washington County, Maryland. *Am J Epidemiol*. 2004; 160(12):1223–33.
8. Rissanen TH, Voutilainen S, Virtanen JK, et al. Low intake of fruits, berries and vegetables is associated with excess mortality in men: the Kuopio Ischaemic Heart Disease Risk Factor (KIHD) Study. *J Nutr*. 2003; 133(1):199–204.
9. Steffen LM, Jacobs DR, Stevens J, Shahar E, Carithers T, Folsom AR. Associations of whole-grain, refined-grain, and fruit and vegetable consumption with risks of all-cause mortality and incident coronary artery disease and ischemic stroke: the Atherosclerosis Risk in Communities (ARIC) Study. *Am J Clin Nutr*. 2003; 78(3):383–90.
10. Strandhagen E, Hansson PO, Bosaeus I, Isaksson B, Eriksson H. High fruit intake may reduce mortality among middle-aged and elderly men. The Study of Men Born in 1913. *Eur J Clin Nutr*. 2000; 54(4):337–41.
11. Levin ML. The occurrence of lung cancer in man. *Acta Unio Int Contra Cancrum*. 1953; 9(3):531–41.
12. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med*. 2009; 6(4):e1000058.
13. Baliunas D, Patra J, Rehm J, Popova S, Kaiserman M, Taylor B. Smoking-attributable mortality and expected years of life lost in Canada 2002: conclusions for prevention and policy. *Chronic Dis Can*. 2007; 27(4):154–62.
14. Single E, Rehm J, Robson L, Truong MV. The relative risks and etiologic fractions of different causes of death and disease attributable to alcohol, tobacco and illicit drug use in Canada. *CMAJ*. 2000; 162(12):1669–75.
15. Tanuseputro P, Manuel DG, Schultz SE, Johansen H, Mustard CA. Improving population attributable fraction methods: examining smoking-attributable mortality for 87 geographic regions in Canada. *Am J Epidemiol*. 2005; 161(8):787–98.
16. Rehm J, Patra J, Popova S. Alcohol-attributable mortality and potential years of life lost in Canada 2001: implications for prevention and policy. *Addiction*. 2006; 101(3):373–84.
17. Ford ES, Zhao G, Tsai J, Li C. Low-risk lifestyle behaviors and all-cause mortality: findings from the National Health and Nutrition Examination Survey III Mortality Study. *Am J Public Health*. 2011; 101(10):1922–9.