BMJ Public Health

Chasing cancer: does the social-to-medical spending ratio relate to cancer incidence and mortality in Canadian provinces? A retrospective cohort study

Cameron MacLellan ,[1] Paul Kershaw,[2] Ronald D Kneebone,[3,4] Lindsay McLaren ,[5] Tony Reiman,[6,7] Robin Urquhart,[1] Daniel J Dutton[1]

To cite: MacLellan C, Kershaw P, Kneebone RD, *et al*. Chasing cancer: does the social-to-medical spending ratio relate to cancer incidence and mortality in Canadian provinces? A retrospective cohort study. *BMJ Public Health* 2024;**2**:e000858. doi:10.1136/bmjph-2023-000858

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjph-2023-000858).

Received 18 December 2023
Accepted 16 May 2024

For numbered affiliations see end of article.

Correspondence to
Dr Cameron MacLellan; cm773019@dal.ca

ABSTRACT

Introduction Cancer is the leading cause of death in Canada, and cases are expected to rise by 83% between 2012 and 2042. Jurisdictions with higher ratios of social-to-medical spending exhibit better population health outcomes; however, the connection between the ratio and both cancer incidence and mortality is not well established. We aim to determine the association between the ratio and both age-standardised cancer incidence and mortality.

Methods Using linear regressions with provincial and yearly fixed effects, we measured associations between the ratio and incidence of the four most common cancers in Canada (ie, lung and bronchus, colorectal, breast and prostate cancer), and mortality from any cancer, from 1992 to 2017 (incidence) and 2000 to 2019 (mortality).

Results A one-cent increase in social spending for each dollar spent on medical services was significantly associated with a decrease in colorectal (−0.2%), breast (−0.1%), and prostate cancer (−0.6%). The relationship is statistically insignificant and negligible for lung cancer incidence and cancer mortality.

Conclusion The ratio was significantly associated with a decrease in three out of four cancer incidence categories, but not mortality. This implies that, consistent with the social determinants of health, preventing cancer incidence might be a function of social spending, whereas medical spending is more relevant for individuals already diagnosed with cancer. This analysis points to the importance of a health-in-all-policies perspective, as social spending might be more important for population health than spending on the medical care system. We provide evidence that morbidity measures are responsive to the ratio, building on a literature focused on mortality.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Studies outside of Canada have shown associations between social spending and improved cancer mortality. Little is known about the effectiveness of preventing cancer incidence and mortality through social expenditures in Canada.

WHAT THIS STUDY ADDS

⇒ Our results show that additional investments in social programmes are associated with fewer cases of colorectal, breast and prostate cancers over time and across provinces.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings extend the evidence supporting a health-in-all-policies approach to prioritising government budgets, suggesting that decision-making outside of health departments also play a role in improving population health outcomes.

INTRODUCTION

Cancer is the leading cause of death in Canada, and two-fifths of Canadians will be diagnosed with cancer in their lifetime.[1] Lung, colorectal, breast and prostate cancers (the four) are the most common cancers in Canada, and by 2042, yearly incidence of cancer is expected to rise by 83% due in part to an ageing population.[1 2]

Lung and colorectal cancers show socioeconomic patterning, with lower incidence, earlier detection and lower mortality among those with better resources and opportunities.[3 4] However, the relationship between screening, incidence, income and education is not straightforward for other cancers. While prostate and breast cancers are relatively more prevalent in higher income people, prostate cancers are observed more frequently among those with lower levels of education, and breast cancer survival is higher among higher income individuals.[5 6] This draws attention to how the social determinants of health, or the quality of circumstances in which we are born, grow, live, work and age, are shaped by public policies.[7]

It is estimated that up to 79.7% of cases of the four are attributed to behaviours or environmental exposures that are socioeconomically patterned.[8] Smoking rates show

an inverse relationship with socioeconomic status, and as many as 50 225 cases of avoidable cancer, or 27% of all 185 659 incident cases, will occur by 2042 if current smoking trends persist.[9 10] Increased road traffic in low-income neighbourhoods contributes to higher levels of carcinogenic air pollution associated with lung cancer.[11 12] Overall, non-medical intervention on these social factors might reduce cancer incidence.

The concept of health in all policies has become prominent in health scholarship, showing that additional policy investments outside of the medical care system are associated with better population health outcomes.[13–16] Some researchers have operationalised this phenomenon using the social-to-medical spending ratio (the ratio), representing the relative expenditures on social and medical programmes. In the USA, Bradley *et al* demonstrated that a one SD increase in the ratio (approximately a 20% increase in the median) was associated with a 2.72% reduction in lung-cancer mortality. Across Organisation for Economic Co-operation and Development (OECD) countries, a higher ratio was associated with fewer infant deaths and years of life lost.[14 17]

In Canada, medical spending and social spending are largely the purview of the provinces, and while the federal government will direct funds to the provinces, ultimately the decision on how to spend on these portfolios is up to provincial policy-makers. Medical spending constitutes spending on hospitals, physicians, drugs and support services like long-term care or home care, including public health measures like vaccination or public health nursing. Colloquially, these would be understood jointly as 'the healthcare system'. Social spending includes services like social assistance (ie, welfare), support for housing or childcare subsidisation, disability support, or support for special groups (eg, women, immigrants). With these definitions of medical and social spending, similar evidence on the ratio and population health outcomes exists in Canada, where a higher ratio was consistently associated with improved life expectancy, less potentially—avoidable mortality and fewer potential years of life lost.[15 16]

Spending on these two portfolios makes up a sizeable portion of provincial government budgets in Canada. Data from 2023 estimate Canada's medical expenditure will be 12.1% of the gross domestic product, approximately 70% of that will come from the public sector.[18] By contrast, social spending attributable to the provinces is approximately 20%–30% of the spending on medical services in recent years.[15] One important source of social spending in Canada (public pensions) come from the federal government, which matters for international comparisons but not for comparison across provinces. In international comparisons, Canada is approximately average in the OECD, falling in the middle third of countries in terms of the relative spending on social and medical services.[14] Spending decisions on these portfolios together made up 52% of provincial spending in 2021.[19]

Politically, the dominant response to cancer incidence and prevalence has increased cancer-related medical expenditures. Direct medical care system costs related to cancer increased by approximately $C15.5 billion since 2005.[20] Specifically, the cost of chemotherapy and radiation therapy rose by three to four times in almost 10 years, which is substantial when coupled with a 40% increase in prices due to inflation.[21 22] The increasing costs of treatment and the seriousness of the disease jointly imply that continuing to focus overwhelmingly on treatment is unsustainable.

There are no Canadian studies focusing on the relationship between the ratio and cancer outcomes. Because of the socially situated, preventable and expensive nature of cancer, we argue that it is critical to understand whether social spending may contribute to improving cancer incidence and mortality outcomes in Canada. In this paper, we use statistical models to estimate the relationship between the ratio and incidence of the four and mortality from all cancers.

MATERIALS AND METHODS

Data sources and variables

We accessed province-level social and medical spending data reported by public accounts through a publicly available database updated yearly at the University of Calgary.[23] This dataset aggregates and reports spending by broad portfolio, which includes social services (eg, disability support programmes, child benefits, income support and subsidised housing), providing an approximate way to operationalise some aspects of social determinants of health; and medical services (eg, long-term care (in 1999–2000, New Brunswick allocated long-term care expenditures to the Ministry of Social Development and is considered a social service. Other provinces report long-term care under medical expenditures.), drug programmes and hospital services).

Province-level cancer incidence and mortality were available from Statistics Canada Table 13-10-0747-01 and the Vital Statistics Database (via Statistics Canada, Table 13-10-0800-01). Nine provinces reported cancer incidence rates between 1992 and 2017, and cancer mortality ('all deaths from malignant neoplasms') between 2000 and 2019. The primary outcome variables were age-standardised rates of cancer incidence of the four (we include lung and bronchus cancers as one of the four types studied in this article) and mortality from any cancer per 100 000 people.

The ratio was the key predictor variable for this study, obtained by dividing social expenditures over medical expenditures for each province for each year. We multiplied the ratio by 100 so the units are interpretable as the number of cents spent on social programmes for every dollar spent on medical programmes.

We adjusted for province-level demographic and economic variables that may influence our findings. The three demographic variables included were as follows: the

proportion of residents aged 65 and over, the percentage living rurally (ie, areas with fewer than 1000 people or a population density of less than 400 people per square kilometre),[24] and the total population per province (log-transformed). We included the following five economic variables for each province: the percentage of people living below the after-tax low-income cut-off threshold, median after-tax income (log-transformed), unemployment rates, the mean-centred Gini coefficient and total provincial expenditure in billions (log-transformed) (a measure of potential scale of government operations).

Statistical analysis

We report descriptive statistics using means and SD. To examine the relationship between the ratio and both cancer incidence and mortality, we built a regression model using two-way fixed effects for time and province. To improve interpretation, the outcome variables were log-transformed. The coefficients from the models can thus be interpreted as per cent increases or decreases in the outcome when multiplied by 100.

The following two equations were used to estimate the associations between the ratio and cancer incidence of the four and mortality (equation 1), and the association of social and medical spending per capita entered in the same models as separate variables (equation 2):

$$\ln(Y) = \beta_0 + \beta_R R_{p,y} + \boldsymbol{X_{p,y}\beta_n} \quad (1)$$

$$\ln(Y) = \beta_0 + \beta_S S_{p,y} + \beta_M M_{p,y} + \boldsymbol{X_{p,y}\beta_n} \quad (2)$$

The subscripts R, S and M correspond to the ratio, social spending per capita and medical spending per capita. Province (p) and year (y) are noted in subscripts in equations 1 and 2. The term X represents our economic and demographic covariates found in table 1, and β_0 is the y-intercept. We present eight models for equations 1 and 2 modelling the four types of cancer separately, and two models that predict cancer mortality. Unadjusted results are reported in online supplemental appendix A. R studio V.4.1.2 was used for all statistical analyses.

Interaction terms between Newfoundland and the years leading up to 2006 were included in the model. In 2005, Newfoundland started collecting cancer cases identified through death certificates, which increased the detection of cancers with low survival rates (eg, lung and pancreatic cancers). After this adjustment, lung and bronchus cancer incidence increased by approximately 20% between 2005 and 2006, prompting the creation of this interaction term (figure 1).

The Durbin-Watson tests for autocorrelation in all models were statistically insignificant. The cancer incidence models were stationary in the dependent variables according to the Levin-Lin-Chu test. Cancer mortality was non-stationary but first differencing the series did not change the model's implications. The results of these tests can be found in online supplemental appendices B and C.

Patient and public involvement

We recognise that engaging patients and members of the public optimises the impact and relevancy of research; however, choosing a patient or a member of the public to represent a diverse population was not feasible. Therefore, patients and members of the public were not involved in designing this study.

Results

We present summary statistics for all variables in table 1 and table 2. On average, colorectal cancer had the lowest incidence rate (70.07 cases per 100 000 people) of the cancers considered, while prostate cancer had the highest (158.89 cases per 100 000). Average social spending per capita was consistently and considerably

Table 1 Summary statistics of the predictors and covariates for nine provinces

	Cancer incidence data (1992–2017)	Cancer mortality data (2000–2019)
Economic and demographic variables	**Mean±SD (range)**	**Mean±SD (range)**
Social spending per capita, $C000	1.08±0.22 (0.49–1.67)	1.09±0.22 (0.74–1.75)
Medical spending per capita, $C000	3.76±0.80 (2.28–6.07)	4.17±0.67 (2.74–6.07)
Social-to-medical ratio	0.30±0.09 (0.14–0.59)	0.27±0.07 (0.13–0.51)
Percentage of people aged 65 and older, %	13.81±2.21 (9.12–20.13)	14.83±2.45 (10.06–21.44)
Percentage of people living rurally, %	29.15±12.54 (12.92–50.59)	28.47±12.68 (12.76–51.13)
Total population, millions	3.56±3.84 (0.51–14.07)	3.73±4.05 (0.51–14.54)
After-tax low-income cut-off, %	15.23±3.76 (7.6–23.1)	13.14±3.14 (6.7–21.1)
Unemployment rate	8.59±3.47 (3.5–20.1)	7.69±2.96 (3.5–16.7)
Median after-tax income, $C	50,891.36±7799.14 (39 657.28–75 796.22)	54,195.92±7646.78 (42 715–75 796.22)
After-tax Gini-coefficient	0.30±0.01 (0.27–0.34)	0.30±0.01 (0.27–0.34)
Real total government expenditure, $C billions	30.87±31.89 (4.91–142.36)	33.97±35.41 (4.91–148.4)

Note: dollar amounts used in the incidence and mortality regressions are in 2017 and 2019 constant dollars, respectively.

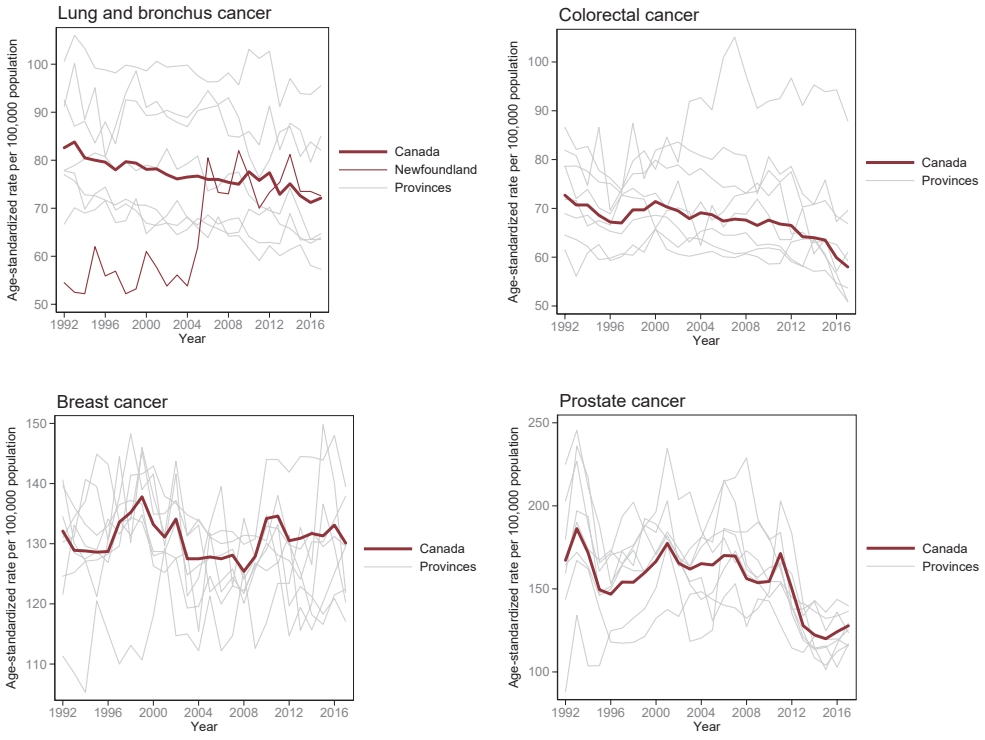

Figure 1 Provincial age-standardised cancer incidence of 'the four' (lung and bronchus; colorectal; breast; and prostate) compared with the Canadian average, 1992–2017.

Table 2 Summary statistics of the cancer outcome variables for nine provinces

	Incidence by cancer type				
	Lung and bronchus	Colorectal	Breast	Prostate	Mortality
	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)	Mean±SD (range)
Alberta	66.99±2.88 (62.6–72)	60.86±3.02 (50.8–65.7)	131.04±7.08 (120.2–146)	171.58±23.57 (133.6–234.8)	201.69±17.62 (172.7–230.4)
British Columbia	66.38±5.51 (57.2–77.8)	60.67±3.07 (50.8–65.8)	126.92±6.94 (116.5–139.6)	158.16±29.91 (104 – 227)	196.73±13.11 (174.2–214.7)
Manitoba	75.68±5.28 (63.4–82.4)	69.42±4.49 (59.3–75.6)	132.03±7.19 (116.6–145.5)	154.39±34.53 (111.5–245.5)	224.65±16.05 (192.5–252.8)
New Brunswick	87.36±4.71 (76.4–94.5)	68.17±4.82 (57–78.7)	126.18±5.86 (114.7–134.4)	174.62±37.07 (102.7–236)	227.4±17.07 (203.7–256.8)
Newfoundland and Labrador	64.96±10.53 (52.2–82)	87.83±8.8 (69.6–105.1)	119.45±10.15 (105.3–149.8)	141.68±28.08 (88.1–190.2)	247.89±16.4 (221.8–270.5)
Nova Scotia	88.71±5.01 (79.6–100.2)	77.82±4.76 (67.3–87.4)	131.85±8.05 (115.6–148.3)	163.95±28.84 (101.4–215.3)	246.21±17.18 (217.1–247.9)
Ontario	68.52±3.77 (62.7–77)	63.72±4.46 (53.7–68.9)	129.67±2.87 (124–134.8)	156.67±22.30 (113.6–185.4)	209.52±19.18 (177.9–238.8)
Quebec	98.68±3.28 (91.2–106)	75.98±4.43 (66.7–86.6)	136.08±7.1 (124.6–148)	141.97±19.32 (117.4–203.1)	236.17±19.50 (201.1–265.3)
Saskatchewan	69.12±2.94 (63.4–74.6)	66.19±4.96 (58.3–77.2)	127.48±4.93 (118–137.9)	116.99±29.45 (119–226.3)	212.58±14.14 (188.1–237)
Overall	76.27±12.72 (52.2–106)	70.07±9.8 (50.8–105.1)	128.97±8.15 (105.3–149.8)	158.89±30.25 (88.1–245.5)	222.54±24.11 (172.7–274.9)

Cancer categories are reported in age-standardised cases or deaths per 100 000 people.

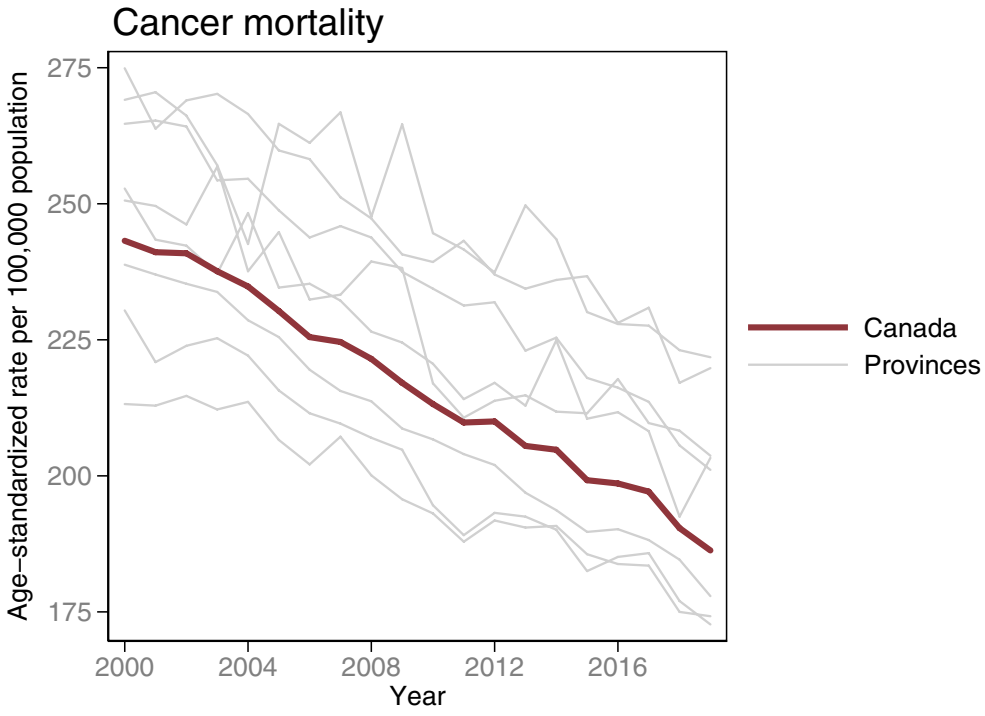

Figure 2 Age-standardised cancer mortality rates per 100 000 people between 2000 and 2019.

lower than medical spending per capita, where social spending amounted to approximately 30% of medical spending between 1992 and 2017, and 27% of medical spending between 2000 and 2019.

To illustrate cancer trends, figure 1 displays age-standardised incidence rates of the four for each province and the national average between 1992 and 2017. Three observations are notable. First, all four panels in figure 1 show downward trends in national cancer incidence, especially for prostate cancer which decreases by 39.7 cases per 100 000. Second, there is considerable variation across provinces, especially for prostate cancer which ranges from 86.9 to 245.5 cases per 100 000. Third, the lines appear to be converging across provinces by 2017, while colorectal cancer incidence diverges by 2017. Crude incidence rates of the four are provided in online supplemental appendix D.

Figure 2 shows age-standardised all-cancer mortality rates per 100 000. The national average is represented by the bold line, where we observe a decrease from 243.2 to 186.5 deaths per 100 000 between 2000 and 2019. Provincial differences from the national rate of cancer deaths are approximately constant, with no converging or diverging trends.

Tables 3 and 4 show regression results for our main analyses. Statistically significant and negative associations were found between the ratio and incidence of three of the four cancer categories. A one-unit increase in the ratio (approximately one cent spent on social services for every dollar spent on medical services) was associated with lower levels of colorectal cancer (−0.2%, 95% CI −0.3% to −0.1%), breast cancer (−0.1%, 95% CI −0.2% to −0.01%) and prostate cancer incidence (−0.6%, 95% CI −0.8% to −0.3%). A one-unit increase in social spending per capita reduced colorectal cancer incidence by 4.4% (95% CI −8.1% to −0.7%), breast cancer by 4.3% (95% CI −7.9% to −0.6%), and prostate cancer by 9.8% (95% CI −18.6% to −0.9%), while an increase in medical spending per capita was associated with higher incidence of colorectal (6.4%, 95% CI 3.0% to 9.9%), and prostate cancers (16.8%, 95% CI 8.5% to 25.2%). There was no statistically significant association between the ratio, nor its constituent parts, and lung and bronchus cancer incidence. Associations between all cancer mortality and the spending variables were negligible and statistically insignificant. Replacing all cancer mortality with mortality from 'the four' did not meaningfully change this result.

DISCUSSION

Building on previous work about the ratio in relation to all-cause avoidable mortality,[15 16] we focused specifically on cancer, estimating the association between the ratio and both cancer incidence and mortality in Canada. Table 3 shows that the ratio was negatively associated with three of the four types of cancer, while table 4 shows that this relationship reflects social spending (the numerator) and not medical spending (the denominator). These results indicate that cancer displays a similar relationship to the ratio as other population health indicators studied.

As shown in other work, the ratio decreases over time due to substantial growth in medical spending.[16] While temporary decreases in medical spending could lead to

Table 3 Regression results of cancer incidence and mortality based on the social-to-medical spending ratio

	Cancer incidence				
Variables	**Lung and bronchus**	**Colorectal**	**Breast**	**Prostate**	**Mortality**
Ratio of social-to-medical spending	−0.001 (−0.002 to 0.0002)	−0.002* (−0.003 to −0.001)	−0.001* (−0.002 to −0.001)	−0.006* (−0.008 to −0.003)	0.061 (−0.064 to 0.186)
Age >65, %	0.01 (−0.002 to 0.022)	−0.002 (−0.013 to 0.009)	0.012* (0.001 to 0.023)	0.034* (0.008 to 0.006)	−0.001 (−0.007 to 0.005)
Rural residence, %	−0.008 (−0.02 to 0.005)	−0.006 (−0.019 to 0.006)	0.007 (−0.005 to 0.02)	−0.04* (−0.07 to −0.011)	−0.003 (−0.009 to 0.003)
Total population, millions, natural log	−0.432* (−0.603 to -0.262)	−0.407* (−0.576 to −0.238)	0.055 (−0.108 to 0.219)	−0.182 (−0.583 to 0.219)	−0.205* (−0.323 to −0.088)
After-tax low-income cut-off, %	−0.011* (−0.02 to −0.003)	−0.009* (−0.017 to −0.001)	−0.011* (−0.019 to −0.003)	−0.03* (−0.049 to −0.012)	−0.004* (−0.008 to -0.0002)
Unemployment rate	0.011* (0.0004 to 0.021)	−0.003 (−0.013 to 0.008)	−0.005 (−0.015 to 0.005)	0.004 (−0.021 to 0.029)	0.002 (−0.003 to 0.006)
Median after-tax income, natural log	0.189 (−0.1 to 0.478)	0.443* (0.15 to 0.737)	−0.109 (−0.393 to 0.176)	−0.362 (−1.058 to 0.335)	0.09 (−0.043 to 0.223)
Gini coefficient of after-tax income	0.003 (−1.091 to 1.097)	0.586 (−0.464 to 1.636)	1.095* (0.078 to 2.112)	−0.522 (−3.013 to 1.97)	−0.002 (−0.007 to 0.003)
Real total expenditure, $C billions, natural log	0.117* (0.002 to 0.232)	0.002 (−0.112 to 0.115)	0.018 (−0.092 to 0.128)	−0.032 (−0.301 to 0.238)	−0.043 (−0.108 to 0.022)
Interaction between NL and 1992–2005	−0.209* (−0.269 to −0.148)	NA	NA	NA	NA
Observations	234	234	234	234	180
R-squared (unadjusted)	0.9309	0.8923	0.5487	0.7055	0.9748
Number of provinces	9	9	9	9	9

*Indicates statistical significance at the 0.05 level. Year and province fixed effects are included but not reported. CIs are reported in parentheses, and estimates are interpretable as per cent changes when multiplied by 100.

increases in the ratio, this is rare in our data. We therefore attribute increases in the ratio to increases in social spending and interpret our findings in that context.

We observed no association between the ratio and lung cancer incidence. This is surprising considering highly inequitable patterning among lung cancer and smoking.[10] Although smoking is the likely cause of 70%–80% of lung cancers, we could not control for smoking between provinces due to a lack of reliable and consistently measured data.[10] Although admirable attempts at tracking smoking prevalence exist,[25] they are not available annually by province.

Medical care systems are a constant focus of government action on health. Our findings suggest that governments can improve population health through a small reprioritisation of how future expenditure increases are allocated. Colorectal, breast and prostate cancers were estimated to cost the Canadian medical care system approximately $C2.468B, $C2.141B and $C1.514B, respectively, in 2021,[20] and spending on cancer treatment has increased over the last decades. A key question thus emerges: are we chasing cancer cases through medical investment instead of reducing incidence upstream through social investments? Our study suggests the answer to this question is yes. Rather than preventing disease through social investments, we are leaving population health improvements unrealised.

The magnitude of the changes we model is relative to spending patterns in each jurisdiction. In Ontario, medical spending is projected to increase from $C75.2 to $C78.3B by 2024.[26] Social spending is only scheduled to increase from $C18.3B to $C18.6B, which would decrease the ratio. To raise the ratio by one cent, $C1.5B is required for social spending, a commitment over four times larger than planned.

It is possible that the negligible relationship between mortality and the ratio is due to increased medical spending improving survival for those with a cancer diagnosis; once a patient accesses the medical system for cancer care, medical spending becomes more important to survival.

However, we did not observe a negative relationship between medical spending and mortality and treatment costs might not be uniform across jurisdictions. For example, a decrease in deaths due to colorectal cancer was associated with increased spending on hospital care in Ontario,[27] and similar findings were found internationally.[28] On the other hand, one study found no association between increased medical spending and cancer mortality outcomes in the USA, possibly due to excessive expenditures on drug therapies with unknown effectiveness

Table 4 Regression results of cancer incidence and mortality based on disaggregated social and medical spending

Variables	Cancer incidence				Mortality
	Lung and bronchus	Colorectal	Breast	Prostate	
Social spending per capita, $C000	−0.025 (−0.063 to 0.012)	−0.044* (−0.081 to −0.007)	−0.043* (−0.079 to −0.006)	−0.098* (−0.186 to −0.009)	0.016 (−0.012 to 0.044)
Medical spending per capita, $C000	0.014 (−0.022 to 0.05)	0.064* (0.03 to 0.099)	0.027 (−0.008 to 0.061)	0.168* (0.085 to 0.252)	0.011 (−0.016 to 0.038)
Age >65, %	0.01 (−0.002 to 0.022)	−0.004 (−0.015 to 0.006)	0.011* (0.001 to 0.022)	0.028* (0.002 to 0.054)	−0.002 (−0.008 to 0.005)
Rural residence, %	−0.007 (−0.02 to 0.006)	−0.002 (−0.015 to 0.01)	0.009 (−0.003 to 0.021)	−0.031 (−0.06 to −0.001)	−0.002 (−0.009 to 0.004)
Total population, millions, natural log	−0.411* (−0.612 to −0.21)	−0.249* (−0.446 to −0.052)	0.107 (−0.089 to 0.304)	0.256 (−0.218 to 0.73)	−0.197* (−0.316 to −0.078)
After-tax low-income cut-off, %	−0.011* (−0.019 to -0.002)	−0.005 (−0.013 to 0.003)	−0.009* (−0.017 to −0.001)	−0.019 (−0.038 to 0.0004)	−0.004 (−0.007 to 0.0004)
Unemployment rate	0.011* (0.001 to 0.021)	−0.002 (−0.013 to 0.008)	−0.005 (−0.015 to 0.005)	0.003 (−0.022 to 0.028)	0.002 (−0.003 to 0.006)
Median after-tax income, natural log	0.187 (−0.102 to 0.477)	0.442* (0.158 to 0.726)	−0.113 (−0.396 to 0.17)	−0.364 (−1.048 to 0.319)	0.096 (−0.037 to 0.229)
Gini coefficient of after-tax income	−0.059 (−1.163 to 1.045)	0.179 (−0.861 to 1.218)	0.931 (−0.105 to 1.967)	−1.455 (−3.957 to 1.047)	−0.003 (−0.008 to 0.002)
Real total expenditure, $C billions, natural log	0.106 (−0.039 to 0.251)	−0.109 (−0.251 to 0.033)	−0.012 (−0.153 to 0.13)	−0.343* (−0.685 to −0.001)	−0.07 (−0.153 to 0.012)
Interaction between Newfoundland and 1992–2005	−0.202* (−0.264 to −0.14)	NA	NA	NA	NA
Observations	234	234	234	234	180
R-squared (unadjusted)	0.9314	0.8997	0.5551	0.7179	0.975

*Indicates statistical significance at the 0.05 level. Year and province fixed effects are included but not reported. CIs are reported in parentheses, and estimates are interpretable as per cent changes when multiplied by 100.

against mortality.[29] So, while increased medical spending could improve cancer survival, in practice the cancer treatment resulting from medical spending depends on system-level factors (including inflation) that direct the use of the funds.

More generally, our study expands on the concept of health in all policies,[13] which emphasises the impact of policy decisions made at the government cabinet table on resource allocation between ministries and consequently population health.[13 30] Ministers of Health will advocate for additional medical spending and use population health outcomes as justification, but our results extend evidence that improved population health requires attention to expenditures in social domains. Within governments, monitoring interministerial budget trends can support increased accountability for health impacts across departments. Simple tools like the ratio may help policy-makers prioritise health outcomes by considering the net impact of government programmes and alternative funding strategies.[31] If improving population health is a priority, social investments should be considered for growth more urgently than medical spending.

Although subcategories of provincial social expenditure data exist, the data do not run as long as our sample.[19] Nevertheless, there are commonalities across provinces. Social spending includes the generosity of welfare for those who are not working and exhausted employment insurance, subsidising or sponsoring childcare, housing supports and disability supports. Our results are interpretable as increases in the spending categories outlined above. Enrichment of current programmes is a natural starting point for policy discussions around increasing the ratio.

One part of the medical portfolio, public health spending, does have aspects that are preventative, like policy addressing infectious disease outbreaks, early childhood health assessments and parental education, or vaccine and sexually transmitted infection programmes. However, these programmes are still medical in scope in that they do not target the social determinants of health, and further have been shown to be crowded out by curative spending when governments allocate money within their health budgets.[32]

The value of preventing disease as a path to population health improvement is not a new policy idea in Canada. In 2002, the Romanow Report made recommendations to improve the sustainability of medical care in Canada. Among other items, it called for additional action on prevention and changes to medical care delivery to make spending more effective.[33] Over 20 years later, the sustainability of Canadian medical care systems is concerning,[34] with claims that medical care has been in a crisis all along

the way.[35 36] That has not changed: the image of resource-strapped medical care systems buckling under pressure is still invoked in discussions of Canadian population health.

Since that report, however, medical spending has risen significantly—approximately 33% per capita on average since 2002[15]—with the federal government playing an important role. Critical to that report is the importance of tying that money to specific performance indicators. The report indicated that 'more of the same' spending would not create a sustainable system, a prediction that seems borne out from the continued focus on crises despite real spending per capita increasing over time. Our analysis indicates that spending on social services could represent the kind of prevention that has been identified to make Canadians healthier, and the ratio represents a succinct way to track action on that prevention over time, while being associated with the kinds of health outcomes Canadian policy-makers and citizens care about.

There is a growing recognition of the need for studies on public expenditure and population health outcomes.[37] Cancer, like other conditions associated with the ratio,[14 38] is the result of a complicated process of biological and social factors. Our analysis shows very small changes in the incidence of cancer correlated with small changes in the ratio, in line with past research on the ratio that has suggested the benefits of a higher ratio take time to be evident in a population's health.[38] The marginal changes in incidence we observe with contemporaneous changes to the ratio could indicate the start of a longer run relationship.

The analytical techniques and datasets used in our study strengthened the results in two ways. First, many observations were available across provinces and over time, which increased the accuracy of our results. Second, the two-way fixed effects models reduced the effect of omitted variable bias and isolated the effect of the ratio on both cancer incidence and mortality.

There are several limitations within our study to accompany our inability to account for smoking trends noted above. First, not all Canadian subnational units were used in our analysis; the Canadian territories are remote, large and expensive in terms of cost of living (including government expenditures), and the smallest province of Prince Edward Island did not have adequate spending data for many decades. Second, although we controlled for the lack of reported lung cancer cases in Newfoundland prior to 2006, we believe this contributed to the insignificant association between the ratio and lung cancer. Third, one may argue that reductions in incidence rates are related to cancer screening access. While we could not control for screening rates, no obvious or sustained increases were observed from screening programmes initiated in the provinces across time.[39] Fourth, we could not control for genetic factors, which may explain the high incidence of colorectal cancers in Newfoundland.[40] Fifth, we were unable to separate public health from medical spending due to the aggregate nature of this dataset. Sixth, while total government expenditures imperfectly account for the scale of government operations, our social and medical spending data do not capture potential economies of scale.

Finally, provinces may spend more on medical services in response to the number of cancer cases within the same year, allowing for the possibility of reverse causality. To address this limitation, we report our models using yearly lags in online supplemental appendix C; however, no significant associations were found beyond the contemporaneous year. Whether medical spending reacts quickly to cancer incidence as it does to emergencies like the COVID-19 pandemic is unknown, since indiscriminate growth in medical spending is potentially unrelated to concrete health problems.[18] Future research should focus on the appropriate timeframe for social spending and cancer incidence associations.

Author affiliations
[1]Community Health & Epidemiology, Dalhousie University, Halifax, Nova Scotia, Canada
[2]School of Population and Public Health, The University of British Columbia, Vancouver, British Columbia, Canada
[3]Economics, University of Calgary, Calgary, Alberta, Canada
[4]The School of Public Policy, University of Calgary, Calgary, Alberta, Canada
[5]Department of Community Health Sciences Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
[6]Division of Medical Oncology, Dalhousie University Faculty of Medicine, Halifax, Nova Scotia, Canada
[7]Faculty of Science Applied Science and Engineering, University of New Brunswick, Saint John, New Brunswick, Canada

Contributors CM analysed data collected by RDK. CM and DJD wrote the original draft. All authors contributed equally to the conception of the study, interpretation of the results, revisions of the manuscript, approval of the final manuscript and agree to be accountable for the accuracy and integrity of the manuscript. The guarantor is DJD.

Funding This manuscript benefitted from funding from the New Brunswick Innovation Foundation (NBIF) and Research NB, which supported the salary of research staff working on this project. The work was also supported by the Canadian Institutes for Health Research (CIHR) grant 181113.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iDs
Cameron MacLellan http://orcid.org/0000-0001-6641-305X
Lindsay McLaren http://orcid.org/0000-0002-8435-4804

REFERENCES

1 Canadian Cancer Statistics Advisory Committee in collaboration with the Canadian Cancer Society, Statistics Canada and the Public Health Agency of Canada. *Canadian cancer statistics*. Toronto, Ontario, 2021. Available: https://cdn.cancer.ca/- /media/files/research/cancer-statistics/2021-statistics/2021-pdf-en-final.pdf
2 Poirier AE, Ruan Y, Walter SD, *et al*. The future burden of cancer in Canada: long-term cancer incidence projections 2013–2042. *Cancer Epidemiol* 2019;59:199–207.
3 Dickman PW, Auvinen A, Voutilainen ET, *et al*. Measuring social class differences in cancer patient survival: is it necessary to control for social class differences in general population mortality? A Finnish population-based study. *J Epidemiol Community Health* 1998;52:727–34.
4 Hajizadeh M, Charles M, Johnston GM, *et al*. Socioeconomic inequalities in colorectal cancer incidence in Canada: trends over two decades. *Cancer Causes Control* 2022;33:193–204.
5 Hajizadeh M, Whelan A, Johnston GM, *et al*. Socioeconomic gradients in prostate cancer incidence among Canadian males: a trend analysis from 1992 to 2010. *Cancer Control* 2021;28:107327482110552.
6 Kumachev A, Trudeau ME, Chan KKW. Associations among socioeconomic status, patterns of care and outcomes in breast cancer patients in a universal health care system: Ontario's experience. *Cancer* 2016;122:893–8.
7 Closing the gap in a generation: health equity through action on the social determinants of health: commission on social determinants of health final report. Geneva, Switzerland World Health Organization, Commission on Social Determinants of Health; 2008.
8 Poirier AE, Ruan Y, Volesky KD, *et al*. The current and future burden of cancer attributable to modifiable risk factors in Canada: summary of results. *Prev Med* 2019;122:140–7.
9 Statistics Canada. Smoking gap by income has widened over time [Infographic]. 2015. Available: https://www.cihi.ca/en/smoking-gap-by-income-has-widened-over-time
10 Poirier AE, Ruan Y, Grevers X, *et al*. Estimates of the current and future burden of cancer attributable to active and passive tobacco smoking in Canada. *Prev Med* 2019;122:9–19.
11 Pinault L, Crouse D, Jerrett M, *et al*. Socioeconomic differences in nitrogen dioxide ambient air pollution exposure among children in the three largest Canadian cities. *Heal rep* 2016;27:3–9.
12 Hamra GB, Laden F, Cohen AJ, *et al*. Lung cancer and exposure to nitrogen dioxide and traffic: a systematic review and meta-analysis. *Environ Health Perspect* 2015;123:1107–12.
13 Kershaw P. A "health in all policies" review of Canadian public finance. *Can J Public Health* 2020;111:8–20.
14 Bradley EH, Elkins BR, Herrin J, *et al*. Health and social services expenditures: associations with health outcomes. *BMJ Qual Saf* 2011;20:826–31.
15 Dutton DJ, Forest P-G, Kneebone RD, *et al*. Effect of provincial spending on social services and health care on health outcomes in Canada: an observational longitudinal study. *CMAJ* 2018;190:E66–71.
16 Liu T, Dutton DJ. With great inequality comes great responsibility: the role of government spending on population health in the presence of changing income distributions. *Can J Public Health* 2021;112:199–209.
17 Bradley EH, Canavan M, Rogan E, *et al*. Variation in health outcomes: the role of spending on social services, public health, and health care, 2000-09. *Health Aff (Millwood)* 2016;35:760–8.
18 Canadian Institute for Health Information. National health expenditure trends. 2023. Available: https://www.cihi.ca/en/national-health-expenditure- trends#:~:text=Total%20health%20spending%20in%20Canada,mere%201.5%25%20gro wth%20in%202022
19 Statistics Canada. The daily—government spending by function, 2021. 2022. Available: https://www150.statcan.gc.ca/n1/daily-quotidien/221125/dq221125a-eng.htm
20 Garaszczuk R, Yong JHE, Sun Z, *et al*. The economic burden of cancer in Canada from a societal perspective. *Curr Oncol* 2022;29:2735–48.
21 de Oliveira C, Weir S, Rangrej J, *et al*. The economic burden of cancer care in Canada: a population-based cost study. *CMAJ Open* 2018;6:E1–10.
22 Statistics Canada. Table: 18-10-0004-08 consumer price index, monthly, percentage change, not seasonally adjusted, Canada, provinces, Whitehorse and Yellowknife — health and personal care [data table]. 2023.
23 Kneebone R, Wilkins M. Canadian provincial government budget data, 1980/81 to 2013/14. *Can Public Pol* 2016;42:1–19.
24 Statistics Canada. Population centres and rural area classification. 2016. Available: https://www.statcan.gc.ca/en/subjects/standard/pcrac/2016/introduction
25 Smoking in the provinces. University of Waterloo. n.d. Available: https://uwaterloo.ca/tobacco-use-canada/adult-tobacco-use/smoking-provinces
26 Office of the Auditor General of Ontario. Review of the pre-election 2022 multi-year fiscal plan. n.d. Available: https://www.auditor.on.ca/en/content/specialreports/specialreports/Pre-Election- 2022_EN.pdf
27 Stukel TA, Fisher ES, Alter DA, *et al*. Association of hospital spending intensity with mortality and readmission rates in Ontario hospitals. *JAMA* 2012;307:1037.
28 Maruthappu M, Watson RA, Watkins J, *et al*. Unemployment, public-sector healthcare expenditure and colorectal cancer mortality in the European Union: 1990–2009. *Int J Public Health* 2016;61:119–30.
29 Chow RD, Bradley EH, Gross CP. Comparison of cancer-related spending and mortality rates in the US vs 21 high-income countries. *JAMA Health Forum* 2022;3:e221229.
30 Smith N, Mitton C, Kershaw P. The reallocation challenge: containing Canadian medical care spending to invest in the social determinants of health. *Can J Public Health* 2016;107:e130–2.
31 McLaren L, Famuyide T, Kershaw P, *et al*. Wellbeing budgeting: better health via smarter fiscal policy in Alberta. University of Calgary O'Brien Institute for Public Health, Centre for Health Policy; 2022.
32 Jacques O, Arpin E, Ammi M, *et al*. The political and fiscal determinants of public health and curative care expenditures: evidence from the Canadian provinces, 1980–2018 can. *Can J Public Health* 2023;114:584–92.
33 Romanow RJ. Building on values: the future of health care in Canada. 2002:xxxiv.
34 Government of New Brunswick, Department of Health. Striving for dependable public health care a discussion paper on the future of health care in New Brunswick. 2017. Available: https://www2.gnb.ca/content/dam/gnb/Departments/h- s/pdf/en/Publications/HealthCare/DependablePublicHealthCare-DiscussionPaper.pdf
35 Ghose T. The real crisis in medicare Canada needs (and can afford) complete national health care. Canadian Centre for Policy Alternatives; 2012.
36 Deber RB. Health care reform: lessons from Canada. *Am J Public Health* 2003;93:20–4.
37 Dunn JR, Park G-R, Brydon R, *et al*. Income inequality and population health: a Political- economic research agenda. *J Epidemiol Community Health* 2022;76:756–8.
38 Rubin J, Taylor J, Krapels J, *et al*. *Are better health outcomes related to social expenditure? A cross-national empirical analysis of social expenditure and population health measures*. Santa Monica, CA: RAND Corporation, 2016. Available: https://www.rand.org/pubs/research_reports/RR1252.html
39 Schreuders EH, Ruco A, Rabeneck L, *et al*. Colorectal cancer screening: a global overview of existing programmes. *Gut* 2015;64:1637–49.
40 Woods MO, Younghusband HB, Parfrey PS, *et al*. The genetic basis of colorectal cancer in a population-based incident cohort with a high rate of familial disease. *Gut* 2010;59:1369–77.