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ORIGINAL ARTICLE

Trends in socioeconomic inequalities in the incidence of cutaneous melanoma in Canada from 1992 to 2010

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Abstract

Background The incidence rates of cutaneous melanoma have been increasing in Canada over the past decades. This study aimed to quantify and assess trends in education- and income-related inequalities in the incidence of cutaneous melanoma in Canada (excluding territories) from 1992 to 2010.

Methods Data for the analyses were obtained from the Canadian Cancer Registry (CCR), the Canadian Census of Population (CCP), and the National Household Survey (NHS). The concentration index (C) approach was used to quantify income- and education-related inequalities in the incidence rates of cutaneous melanoma. Trend analyses were performed to evaluate changes in inequalities over the study period.

Results Incidence rates of cutaneous melanoma increased across Canada from 1992 to 2010. The age-adjusted value of C showed a greater concentration of cutaneous melanoma amongst Canadians with higher incomes. Although the age-adjusted value of C did not suggest a significant education-related inequality in the incidence rates, the trend analyses indicate that, with time, incidence rates are becoming more concentrated amongst both males and females with lower levels of education.

Conclusions Incidence rates of melanoma are rising across Canada and are higher amongst individuals with higher income. Our analyses suggest that incidence rates of melanoma are becoming more concentrated amongst Canadians with lower levels of education. Consequently, campaigns and public policies related to the prevention of melanoma in Canada should focus on Canadians with higher income and lower levels of education.

Keywords Inequalities · Socioeconomic status · Cutaneous melanoma · Skin cancer · Incidence

Introduction

It is estimated that one in two Canadians will develop cancer in their lifetime, with skin cancers being the most common (Canadian Cancer Society's Advisory Committee on Cancer Statistics 2017). Although not the most common skin malignancy, cutaneous melanoma, commonly referred to as melanoma, is the most aggressive and lethal form, and arises from pigment-producing cells, melanocytes, in the basal layer of the skin (Chin 2003; Volkovova et al. 2012; Rastrelli et al. 2014). Melanocytes synthesize and deliver the pigment melanin to neighboring keratinocytes. Within the keratinocytes, melanin protects the cell's DNA by absorbing and deflecting radiation (Chin 2003).

There are four main types of cutaneous melanoma: superficial spreading, nodular, lentigo maligna, and acral lentiginous. Superficial spreading melanoma is the most common, accounting for approximately 70% of all melanoma (Rastrelli et al. 2014). It typically occurs in adults and can develop anywhere on the body, but principally appears on the head and trunk in men, and on the lower extremities in women (Gruber and Armstrong 2006; Ghazawi et al. 2019). These tumors usually begin with a horizontal proliferation of melanocytes, followed by a vertical growth phase. If left untreated, melanoma can invade the basement membrane, reach the blood or the lymphatic systems, and spread to other organs, most commonly the liver, brain, and lung (Rodolfo et al. 2004). Tumors detected at early stages have a five-year survival rate of 85% in men and 92% in women; nonetheless, since melanomas are resistant to most forms of chemotherapy, advanced disease carries an inferior prognosis (Miller and

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Mihm 2006). While the incidence and mortality rates are decreasing for many types of cancer, melanoma rates have been increasing in Canada (Ortiz et al. 2005; Ghazawi et al. 2019). Additionally, melanoma incidence and mortality rates are greater in older compared to younger Canadians, which is of concern as the population ages (Canadian Cancer Society's Advisory Committee on Cancer Statistics 2014).

The etiology of cutaneous melanoma is complex and appears to result from the interaction of genetic, host, and environmental influences. The known genetic features associated with increased melanoma susceptibility include germline mutations of the CDKN2A and CDK4 genes and polymorphisms in the MC1R gene associated with the red-hair phenotype (Palmer et al. 2002; Goldstein and Tucker 2013; Azoury and Lange 2014). Somatic mutations in the BRAF gene are the most common in sporadic cases of the disease (Davies et al. 2002; Burotto et al. 2014). The presence of a large number of melanocytic nevi, or moles, is also a significant risk factor, and the presence of dysplastic, or atypical, nevi act as an additional risk (Swedlow et al. 1986; Holly et al. 1987). Other host factors implicated in the development of this cancer include light hair color, light eye color, increased freckling, inability to tan, and immunosuppression (Smith et al. 1993; Tucker and Goldstein 2003; Brewer et al. 2011). Although genetic phenotypes, genotypes, and increasing age contribute to the risk of this disease, exposure to ultraviolet (UV) radiation is the most significant factor for the development of melanoma (Miller and Mihm 2006; Volkovova et al. 2012). UVB radiation is responsible for the formation of the principal DNA lesions, whereas UVA radiation causes oxidative damage (Ichihashi et al. 2003; Situm et al. 2007). This DNA damage typically leads to programmed cell death; however, in melanocytes, which are resistant to apoptosis, a high dose of UV radiation will cause genetic damage, but does not ultimately lead to cell death (Gilchrest et al. 1999). For this reason, unlike basal cell and squamous cell carcinomas, skin cancers associated with total cumulative exposure to sunlight, melanomas are associated with intermittent sun exposure and a history of sunburns (Elwood and Jopson 1997).

Socioeconomic status (SES) may influence the risk of cancer in many ways, including exposure, behavior, and access to care (Krieger et al. 1999; Hiatt 2004). Studies have shown lower SES to be associated with an increased risk of colorectal, lung, and cervical cancer, while higher SES is found to be associated with increased risk of breast cancer and prostate cancer (Krieger et al. 1999; Clegg et al. 2009; Sidorchuk et al. 2009). Previous studies have assessed socioeconomic gradients in melanoma incidence and concluded that, in Canada and worldwide, cutaneous melanoma is more common in those with higher SES (Gallagher et al. 1987; Hwang et al. 2013; Haider et al. 2007). However, to our knowledge, no study has used a summary measure of socioeconomic inequality, one that takes into account the distribution of melanoma incidence in all SES groups, to quantify socioeconomic inequality in the incidence of cutaneous melanoma in Canada. By linking data from the Canadian Cancer Registry (CCR), Canadian Census of Population (CCP), and National Household Survey (NHS), and by applying a widely used summary measure of socioeconomic inequality, the concentration index (C), we quantified income- and education-related inequalities in the incidence of cutaneous melanoma in Canada, excluding territories (Northwest Territories, Nunavut, and Yukon) accounting for 0.03% of the total population (Statistics Canada 2020). We examined trends in income- and education-related inequalities in the incidence of cutaneous melanoma in Canada for the period between 1992 and 2010. This is the period in which the CCR data are available for all Canadian provinces in Statistics Canada's Research Data Centres (RDCs). The main goal is to understand the difference in melanoma incidence rates amongst individuals of differing SES, in order to provide insight into target populations for intervention and management in Canada.

Materials and methods

Data sources and variables

The data used for this study were sourced from the CCR data file, the CCP (1991, 1996, 2001, 2006), and the NHS (2011). The CCR collects information about cancer cases diagnosed in Canada, including patient demographics and tumor-specific data, but does not collect SES-related information (e.g., education and income). Primary tumors are recorded in this dataset based on their International Classification of Diseases for Oncology (ICD-O) topographical and morphological codes. The third edition of the ICD-O (ICD-O-3) code number C44 (8720–8790) was used to identify individual incidences of cutaneous melanoma within the CCR data. We then obtained the individual's sex and six-digit postal code from the CCR data. We used the Postal Code Conversion File Plus (PCCF+) Version D software to identify the Census Division (CD) coordinates for each patient based on their postal code. The CDs are groups of municipalities such as cities, districts, and counties defined by Statistics Canada to conduct the CCP. The number of CDs in Canada was in the range of 276–283 from 1992 to 2010. This information was then used to calculate the number of new cases of melanoma in each CD.

The CCP collects demographic and socioeconomic information for the total Canadian population every five years. We used SES variables obtained from the 1991, 1996, 2001, and 2006 CCP and the 2011 NHS to create a dataset that contained measures of SES (average and median equivalized household income and proportion of individuals with a bachelor's degree or above), as well as population characteristics for each of Canada's CDs. Since the 2011 CCP did not collect socioeconomic information, the 2011 NHS was used to obtain socioeconomic information about the Canadian population for the more recent years included in our study. Household income was equivalized by dividing the household income by the square root of household size, as per the Organisation for Economic Co-operation and Development (OECD) publications (OECD 2011).

Socioeconomic and demographic information obtained from the CCP and NHS datasets was linked to CCR based on CD coordinates. Since census data are only collected every five years, cases diagnosed in 1992 and 1993 were linked with data from the 1991 census year; cases diagnosed in the 1994–1998 period, the 1996 census year; cases diagnosed in the 1999–2003 period, the 2001 census year; and cases diagnosed in the 2004–2008 period, the 2006 census year. Cases diagnosed from 2009 and 2010 were linked with 2011 NHS data. This linking allowed us to measure the incidence rates of melanoma and to estimate income- and education-related inequalities in the incidence of melanoma from 1992 to 2010.

Statistical analysis

Trends in the incidence of cutaneous melanoma

Trend analyses were performed by plotting time (19 points corresponding to the years 1992–2010) versus the incidence of melanoma. The slope value of the regression line (trend coefficient) was used to determine linear trends in melanoma incidence over time.

Socioeconomic inequalities in melanoma incidence

The concentration index (C) approach (Wagstaff et al. 1991; World Bank 2019) was used to quantify income- and education-related inequalities in the incidence of cutaneous melanoma in Canada from 1992 to 2010. The C is a summary measure of socioeconomic inequality used in health economics and public health literature. It is preferred over other measures of inequality, such as the rate difference and rate ratio, as it reflects the distribution of health outcome across all socioeconomic groups (Wagstaff et al. 1991). The C is defined based on the concentration curve (CC). The CC is a plot of the cumulative share of individuals (CDs) ordered by their SES variable (e.g., income or level of education) on the horizontal axis against the cumulative share of health outcome (incidence of melanoma) on the vertical axis (Fig. 1). If the incidence is the same for all individuals, the CC will be a linear line at 45° to the horizontal axis. This line is termed the "line of perfect equality". If the CC is above (below) the line of perfect equality, it indicates that health outcome is concentrated among higher (lower) SES individuals. The C is calculated as twice the area between the CC and the line of perfect equality. The index can ranges between −1 to +1, with zero indicating perfect equality. A negative value suggests that the health outcome (melanoma incidence) is higher among individuals with lower SES and a positive value indicates that the health outcome is higher among individuals with higher SES. The crude C can be estimated using the following "convenient regression" formula (Kakwani et al. 1997):

$$2\sigma_R^2\left(\frac{M_i}{\mu}\right) = \alpha + \delta R_i + \varepsilon_i, \qquad (1)$$

where M_i shows CDi's melanoma incidence rate, μ is the mean incidence rate of cutaneous melanoma for all CDs, α is the intercept, and R_i is the CDi's fractional rank in the distribution (i = 1 and n for the lowest SES and highest SES CDs, respectively). The R_i for each CD is calculated as $R_i = i/n$. The σ_R^2 denotes the variance of fractional rank. The ordinary least squares (OLS) estimate of δ in Eq. (1) and its standard error demonstrate the value and the standard error for the crude C, correspondingly.

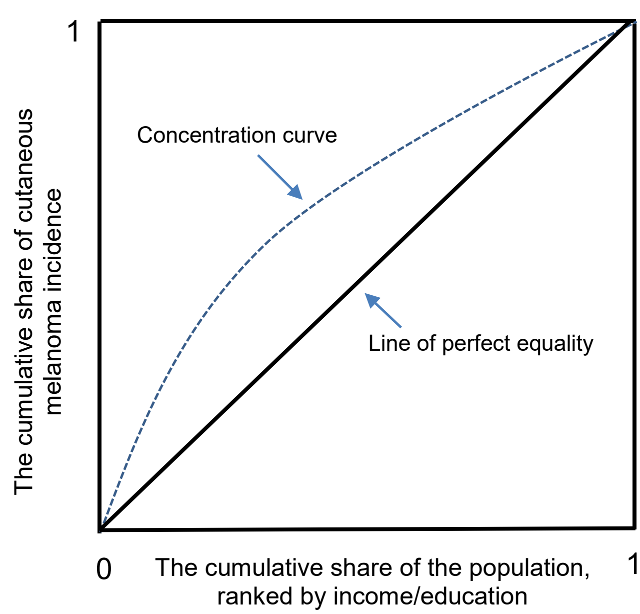

Fig. 1 Concentration curve for cutaneous melanoma incidence (an example)

Age-standardized income- and education-related inequality in the incidence rate of cutaneous melanoma can be calculated using an indirectly standardized C by including the standardizing variable age in the convenient regression as follows (O'Donnell et al. 2008):

$$2\sigma_R^2\left(\frac{y_i}{\mu}\right) = \alpha + \delta R_i + \beta_i AvAge_i + \nu_i, \qquad (2)$$

where $AvAge_i$ denotes the average age of each CDi and β_i are the coefficients for $AvAge$. The OLS estimate of δ in Eq. (2) is the age-standardized C.

Trends in socioeconomic inequalities in melanoma incidence

A trend analysis was performed by plotting time (19 points corresponding to the years 1992–2010) against the age-standardized C of each inequality measure. The slope value of the regression line (trend coefficient) was used to determine the linear trend of the age-standardized C index over time, at a p-value < 0.05.

Results

Trends in melanoma incidence

Table 1 shows the crude incidence of cutaneous melanoma in Canada by sex and province from 1992 to 2010. During this period, the linear regression analysis of the crude incidence rate revealed an increasing trend with a slope of 0.35 cases/100,000 person-years. This increase, although significant for both males and females, was slightly higher for males ($p < 0.01$). The linear regression analysis of the crude incidence rates from 1992 to 2010 revealed an increasing trend ($p < 0.05$) in

Table 1 Incidence of cutaneous melanoma in Canada (excluding territories) per 100,000 individuals by sex and province: 1992–2010

Year	Canada			Provinces								
	Both sexes	Male	Female	NL&PE†	NS	NB	QC	ON	MB	SK	AB	BC
1992	12	13	10	9	17	13	8	11	15	15	11	19
1993	12	14	11	11	16	14	8	12	18	13	13	21
1994	12	13	11	11	16	18	9	11	14	14	15	16
1995	13	14	11	12	18	14	8	13	13	14	15	16
1996	13	13	12	12	17	15	8	13	15	14	15	16
1997	13	14	12	12	16	16	8	14	17	15	15	17
1998	13	14	12	12	21	17	8	14	15	14	15	15
1999	14	15	13	14	26	24	9	14	13	16	17	15
2000	14	16	13	16	23	19	10	15	17	16	16	17
2001	15	16	14	13	22	18	9	16	13	16	16	20
2002	14	16	13	16	23	19	8	15	13	15	15	20
2003	15	17	14	17	26	20	9	16	13	17	16	20
2004	14	15	13	16	26	19	8	14	14	15	17	19
2005	15	16	14	19	23	22	9	17	15	18	15	18
2006	16	17	14	21	27	24	9	16	15	14	17	20
2007	17	18	15	23	29	23	10	18	14	14	16	22
2008	18	20	16	23	30	25	13	18	18	17	16	23
2009	19	20	17	24	32	24	14	19	17	19	17	23
2010	18	20	16	20	32	22	14	18	17	16	17	23
Trend coefficients	0.35	0.39	0.32	0.77	0.92	0.56	0.28	0.41	0.07	0.17	0.20	0.31
p-Value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.36	< 0.01	< 0.01	< 0.01

Newfoundland and Labrador and Prince Edward Island (NL&PE); Nova Scotia (NS); New Brunswick (NB); Quebec (QC); Ontario (ON); Manitoba (MB), Saskatchewan (SK); Alberta (AB); British Columbia (BC)

†In order to meet the disclosure policy of Statistics Canada's Research Data Centre (RDC), the incidence rates of cutaneous melanoma in NL and PE were combined.

Table 2 Income-related inequalities in the incidence rate of cutaneous melanoma in Canada (excluding territories): 1992 to 2010

Year	Age-standardized C (95% confidence interval)					
	Average household equivalized income			Median household equivalized income		
	Both sexes	Male	Female	Both sexes	Male	Female
1992	0.023 (−0.039 to 0.084)	0.024 (−0.050 to 0.099)	0.023 (−0.028 to 0.073)	0.022 (−0.041 to 0.085)	0.020 (−0.056 to 0.095)	0.027 (−0.029 to 0.082)
1993	0.031 (−0.04 to 0.102)	0.047 (−0.041 to 0.135)	0.015 (−0.042 to 0.071)	0.031 (−0.042 to 0.104)	0.044 (−0.045 to 0.134)	0.018 (−0.043 to 0.079)
1994	0.035 (−0.024 to 0.094)	0.053 (−0.019 to 0.124)	0.015 (−0.045 to 0.074)	0.038 (−0.012 to 0.088)	0.052 (−0.008 to 0.111)	0.019 (−0.042 to 0.08)
1995	0.063 (0.018 to 0.107)**	0.068 (0.018 to 0.117)**	0.056 (0.008 to 0.103)*	0.075 (0.039 to 0.11)***	0.076 (0.035 to 0.116)***	0.070 (0.024 to 0.116)**
1996	0.043 (−0.017 to 0.104)	0.054 (−0.014 to 0.121)	0.034 (−0.026 to 0.095)	0.067 (0.029 to 0.106)***	0.076 (0.027 to 0.125)**	0.058 (0.014 to 0.102)**
1997	0.052 (0.002 to 0.101)*	0.063 (0.017 to 0.11)**	0.041 (−0.015 to 0.097)	0.072 (0.034 to 0.111)***	0.077 (0.038 to 0.115)***	0.068 (0.023 to 0.114)**
1998	0.038 (−0.007 to 0.084)	0.061 (0.013 to 0.109)*	0.016 (−0.034 to 0.065)	0.057 (0.015 to 0.099)**	0.077 (0.036 to 0.117)***	0.037 (−0.014 to 0.087)
1999	0.019 (−0.023 to 0.061)	0.034 (−0.012 to 0.079)	0.006 (−0.041 to 0.054)	0.036 (−0.012 to 0.083)	0.053 (−0.003 to 0.109)	0.018 (−0.029 to 0.065)
2000	0.011 (−0.039 to 0.062)	0.028 (−0.019 to 0.074)	−0.004 (−0.064 to 0.056)	0.033 (−0.014 to 0.079)	0.049 (0.004 to 0.095)*	0.015 (−0.04 to 0.069)
2001	0.051 (−0.013 to 0.115)	0.062 (0.000 to 0.125)	0.041 (−0.027 to 0.109)	0.082 (0.036 to 0.127)***	0.088 (0.043 to 0.133)***	0.074 (0.021 to 0.127)**
2002	0.056 (−0.003 to 0.116)	0.061 (0.002 to 0.12)*	0.053 (−0.013 to 0.118)	0.084 (0.037 to 0.131)***	0.082 (0.036 to 0.127)***	0.084 (0.028 to 0.141)**
2003	0.040 (−0.016 to 0.095)	0.043 (−0.019 to 0.104)	0.039 (−0.018 to 0.095)	0.071 (0.024 to 0.118)**	0.078 (0.024 to 0.133)**	0.062 (0.013 to 0.111)*
2004	0.066 (−0.006 to 0.138)	0.081 (0.006 to 0.156)*	0.047 (−0.024 to 0.118)	0.092 (0.034 to 0.15)**	0.101 (0.038 to 0.164)**	0.076 (0.017 to 0.135)*
2005	0.062 (0.004 to 0.121)***	0.063 (0.01 to 0.117)*	0.060 (−0.006 to 0.126)	0.095 (0.047 to 0.142)***	0.084 (0.037 to 0.13)***	0.103 (0.052 to 0.154)***
2006	0.052 (−0.02 to 0.124)	0.063 (−0.014 to 0.141)	0.041 (−0.028 to 0.109)	0.094 (0.039 to 0.148)***	0.105 (0.045 to 0.165)***	0.077 (0.022 to 0.132)**
2007	0.063 (−0.001 to 0.127)	0.057 (−0.007 to 0.121)	0.070 (0.006 to 0.134)*	0.101 (0.051 to 0.151)***	0.095 (0.052 to 0.139)***	0.103 (0.041 to 0.165)**
2008	0.038 (−0.025 to 0.102)	0.062 (0.004 to 0.12)*	0.011 (−0.058 to 0.08)	0.079 (0.031 to 0.127)**	0.088 (0.046 to 0.13)***	0.064 (0.006 to 0.121)*
2009	0.050 (−0.008 to 0.108)	0.069 (0.017 to 0.122)*	0.028 (−0.038 to 0.093)	0.096 (0.053 to 0.139)***	0.103 (0.063 to 0.143)***	0.085 (0.034 to 0.136)**
2010	0.032 (−0.022 to 0.086)	0.050 (0.004 to 0.097)*	0.008 (−0.057 to 0.073)	0.067 (0.018 to 0.116)**	0.069 (0.028 to 0.11)**	0.058 (−0.006 to 0.122)
Trend coefficients	0.00076	0.00082	0.0006	0.0029	0.0024	0.0031
p-Value	0.23	0.16	0.49	0.002	0.008	0.002

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; the inverse of the standard errors of the age-standardized C were used as weights in the trend analysis

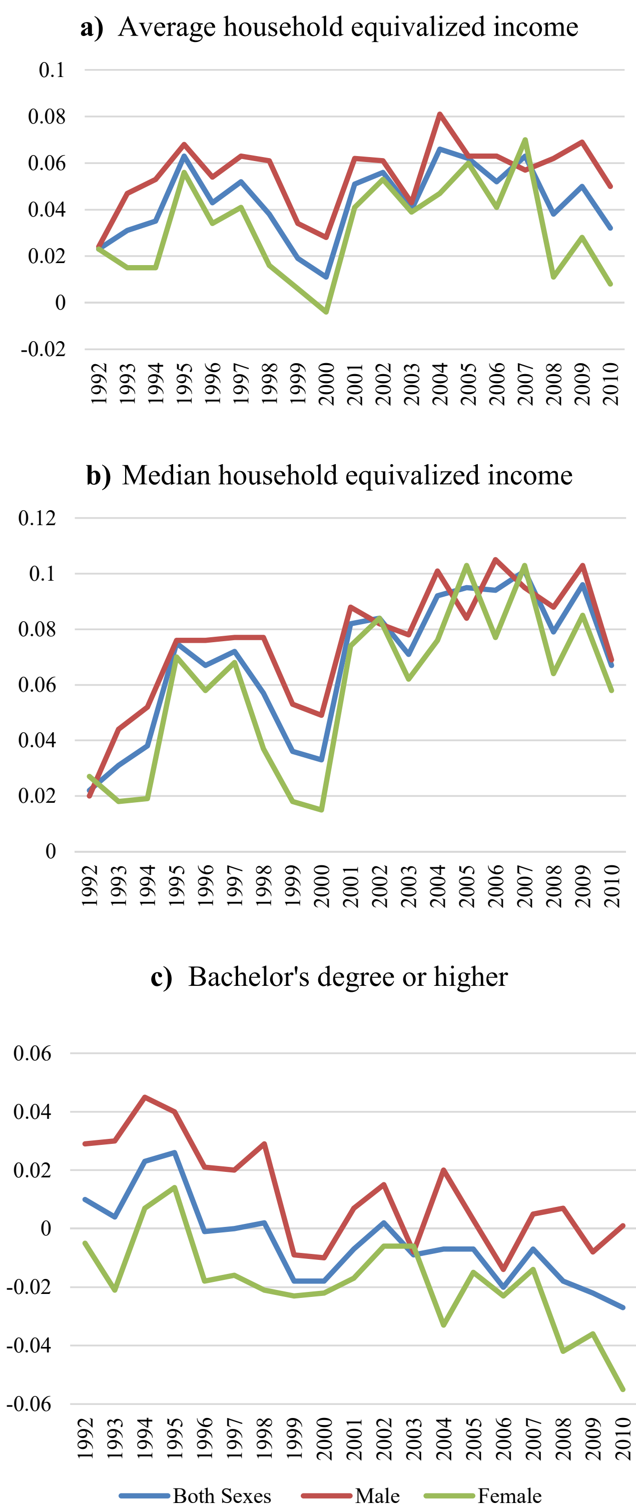

Fig. 2 Socioeconomic inequalities in the age-adjusted incidence of cutaneous melanoma in Canada (excluding territories): 1992 to 2010. **a** Average household equivalized income. **b** Median household equivalized income. **c** Bachelor's degree or higher

all provinces, except Manitoba. The highest increases were seen in the Atlantic Provinces, with Nova Scotia experiencing the most considerable increase.

Socioeconomic inequalities in melanoma incidence

Income-related inequalities

Income-related inequalities (using average and median household equivalized income) in the incidence rates of cutaneous melanoma in Canada from 1992 to 2010 are reported in Table 2 and displayed in Fig. 2a and b. As reported, the values of all the age-standardized C (using average household equivalized income in the calculation) are positive; however, the majority of the 95% confidence intervals (CIs) contain zero values. Years where the CI intervals of the age-standardized C do not include the zero value are 1995, 1997, and 2004 for both sexes, 1995, 1997, 1998, 2002, 2005, and 2008–2010 for males, and 1995 and 2007 for females, suggesting that income-related inequalities in cutaneous melanoma incidence are concentrated among individuals with higher average household equivalized income in these years (see Table 2 and Fig. 2a). Linear regression analysis of the age-standardized C calculated using average household equivalized income did not reveal any significant trends from 1992 to 2010.

The values of all age-standardized median household equivalized income C indexes are positive. The majority of the 95% CIs do not span zero; this is especially true for the later years of the study, 2001 to 2009. Years where the CIs do not span zero include 1995–1998 and 2001–2010 for both sexes, 1995–1998, 2000, and 2001–2010 for males, and 1995–1997 and 2001–2009 for females, suggesting that, for most years included, income-related inequalities in cutaneous melanoma incidence are concentrated among individuals with higher income level. Linear trend analysis of the age-standardized C calculated using median household equivalized income revealed an increasing trend from 1992 to 2010 for both males and females (see Table 2 and Fig. 2b). This suggests that income-related inequalities in cutaneous melanoma incidence are becoming more concentrated among individuals with higher incomes ($p < 0.05$) over time.

Education-related inequalities

Education-related inequalities in the incidence rate of cutaneous melanoma in Canada from 1992 to 2010 are reported in Table 3. Most values of the age-standardized C are negative, suggesting that cutaneous melanoma cases are concentrated among individuals with lower levels of education; however, these findings were not found to be significant for men, and 2010 is the only year where there was statistical significance for women. Linear trend analysis of the age-standardized C, reported in Table 3 and displayed in Fig. 2c, revealed a decreasing trend in the value of C from 1992 to 2010 for both males and females, suggesting that, with time, incidence rates

Table 3 Education-related inequalities (bachelor's degree or higher) in the incidence of cutaneous melanoma in Canada (excluding territories): 1992 to 2010

Year	Age-standardized C (95% confidence interval)		
	Both sexes	Male	Female
1992	0.01 (−0.046 to 0.067)	0.029 (−0.039 to 0.096)	−0.005 (−0.063 to 0.053)
1993	0.004 (−0.06 to 0.067)	0.030 (−0.047 to 0.107)	−0.021 (−0.08 to 0.038)
1994	0.023 (−0.036 to 0.083)	0.045 (−0.027 to 0.117)	0.007 (−0.052 to 0.066)
1995	0.026 (−0.023 to 0.075)	0.04 (−0.014 to 0.094)	0.014 (−0.041 to 0.069)
1996	−0.001 (−0.071 to 0.068)	0.021 (−0.06 to 0.101)	−0.018 (−0.085 to 0.049)
1997	0.000 (−0.059 to 0.059)	0.020 (−0.036 to 0.076)	−0.016 (−0.082 to 0.049)
1998	0.002 (−0.054 to 0.058)	0.029 (−0.033 to 0.091)	−0.021 (−0.077 to 0.034)
1999	−0.018 (−0.064 to 0.028)	−0.009 (−0.063 to 0.045)	−0.023 (−0.067 to 0.02)
2000	−0.018 (−0.066 to 0.03)	−0.01 (−0.054 to 0.034)	−0.022 (−0.079 to 0.034)
2001	−0.007 (−0.071 to 0.057)	0.007 (−0.054 to 0.068)	−0.017 (−0.086 to 0.053)
2002	0.002 (−0.062 to 0.065)	0.015 (−0.049 to 0.078)	−0.006 (−0.073 to 0.06)
2003	−0.009 (−0.073 to 0.055)	−0.008 (−0.077 to 0.06)	−0.006 (−0.071 to 0.06)
2004	−0.007 (−0.059 to 0.046)	0.020 (−0.038 to 0.078)	−0.033 (−0.082 to 0.016)
2005	−0.007 (−0.055 to 0.042)	0.003 (−0.043 to 0.05)	−0.015 (−0.069 to 0.039)
2006	−0.02 (−0.076 to 0.035)	−0.014 (−0.08 to 0.052)	−0.023 (−0.07 to 0.024)
2007	−0.007 (−0.06 to 0.047)	0.005 (−0.05 to 0.059)	−0.014 (−0.071 to 0.043)
2008	−0.018 (−0.069 to 0.033)	0.007 (−0.041 to 0.055)	−0.042 (−0.097 to 0.014)
2009	−0.022 (−0.07 to 0.026)	−0.008 (−0.058 to 0.043)	−0.036 (−0.084 to 0.013)
2010	−0.027 (−0.068 to 0.015)	0.001 (−0.039 to 0.041)	−0.055 (−0.101 to −0.009)*
Trend coefficients	−0.0020	−0.0021	−0.0020
p-Value	0.000	0.000	0.003

*$p < 0.05$; the inverse of the standard errors of the age-standardized C were used as weights in the trend analysis

are becoming more concentrated among individuals with lower levels of education ($p < 0.01$).

Discussion

This study aimed to measure the incidence rates of cutaneous melanoma in Canada from 1992 to 2010 and to quantify and assess trends in income- and education-related inequalities in these rates over time. The results showed an increase in the incidence of melanoma across Canada during the study period. These results are consistent with current literature proposing increasing melanoma incidence in Canada and worldwide (de Vries and Coebergh 2004; Erdmann et al. 2013; Ghazawi et al. 2019). Epidemiologic studies of melanoma have shown that the primary environmental risk factor is UV radiation. It has been suggested that these increases in melanoma rates reflect increased sunlight exposure due to ozone depletion and human behavior, such as increased use of tanning beds, rather than being associated with improvements in diagnostic efforts (Jemal et al. 2001; Boniol et al. 2012; Volkovova et al. 2012). Consequently, primary prevention strategies focus on avoidance of sunburns and decreased exposure to UV radiation (Schottenfeld and Fraumeni 2006), while secondary prevention approaches include enhancing early recognition of melanoma-like lesions, physician screening practices, and patient skin self-examination (Koh and Geller 1995; Rigel and Carucci 2000; Abbasi et al. 2004; de Vries and Coebergh 2004).

Our analysis revealed evidence of increased melanoma incidence rates amongst men and women, with higher median household incomes and increasing C values from 1992 to 2010. These trends were not observed when average household incomes were investigated; however, the median income is a more accurate measure of income, as outliers do not affect it. Lifestyle behaviors commonly associated with higher income, such as outdoors leisure or travel to lesser latitudes where levels of UV radiation are elevated, may increase susceptibility for melanoma development in these individuals (Gallagher et al. 1987). Additionally, individuals with lower SES may have decreased access to screening and examination (Koh et al. 1991). These results are in agreement with the current literature which indicate higher SES being associated with higher incidence of melanoma in Canada (Gallagher et al. 1987; Gorey et al. 1998; Ortiz et al. 2005; Haider et al. 2015; Johnson-Obaseki et al. 2015; Langley et al. 2018), in Scotland (Doherty et al. 2010; MacKie and Hole 1996), and in the United States (Lee et al. 1992; White et al. 1994; Goodman et al. 1995; Harrison et al. 1998); however, these studies do not consider income and education separately in their definitions of SES.

Our analysis showed no statistically significant association between level of education and melanoma incidence in men, and none in women until 2010. In 2010, incidence rates were higher amongst women with lower levels of education. Furthermore, our trend analyses suggest that higher levels of education are becoming increasingly protective against the incidence rates of cutaneous melanoma. An explanation for this finding may be associated with an increasing amount of education related to sun safety. These results contradict studies that report the greatest incidence rates amongst individuals with higher levels of education (Lee et al. 1992; White et al. 1994; Goodman et al. 1995; Harrison et al. 1998). However, such studies were published before the year 2000 and did not focus on the Canadian population.

This study is subject to some limitations. First, although studies have found area-based SES measures, such as CDs, to be comparable to individual-based measures, neighborhood characteristics do not always reflect individual characteristics (Mustard et al. 1999; Krieger et al. 2002). Second, the development of cutaneous melanoma is associated with factors such as family history, skin color, and genetics; we could not control for these factors. Finally, as the census is not conducted every year, to obtain relevant socioeconomic data, we had to use the closest census years to our CCR year of interest.

In conclusion, Canadians with higher incomes have higher incidence rates of melanoma, and trends suggest that incidence is becoming more concentrated amongst Canadians with lower levels of education. Consequently, education and income should be considered separately when discussing the impact of SES on melanoma incidence. Canadian guidelines, campaigns, and public policies should focus on individuals with higher median income and those with lower levels of education.

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Compliance with ethical standards

Ethics statement The data files used for this study, the Canadian Cancer Registry (CCR), the Canadian Census of Population (CCP), and the National Household Survey (NHS), are available at the Statistics Canada's Research Data Centre Network (RDCN). Data were accessed in the Atlantic Research Data Centre (ARDC) located at Dalhousie University. Data obtained through the ARDC are exempt from research ethics board review based on the Tri-council policy statement: Ethical conduct for research involving humans (TCPS2) article 2.2 (a).

Conflict of interest The authors declare that they have no conflict of interest.

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