Identifying Social Determinants of Melanoma Incidence and Diagnosis

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Table of contents

Abstract 2

Résumé 4

Preface 7

Contributions 8

Acknowledgements 9

List of tables 10

List of figures 11

List of appendices 12

List of abbreviations 13

Chapter 1: Introduction 14

Chapter 2: Goal and objectives 16

Chapter 3: Comprehensive review of the relevant literature 17

Chapter 4: Results 26

Preface to manuscript 26

Manuscript 27

Postscript to manuscript 59

Chapter 5: Discussion of the results 60

Chapter 6: Conclusion 65

Appendix 1: Ethics approval 66

Reference list 67

Abstract

Background

Melanoma is the seventh most common cancer in Canada, with incidence on the rise for both men and women. This has been largely attributed to increased exposure to ultraviolet radiation (UVR), as well as improved early detection of melanoma. Melanoma prevention and early detection are lifesaving interventions. In fact, despite increasing incidence, melanoma mortality rates are on the decline. The identification of Canadians at risk of developing melanoma is essential for policy makers and clinicians. A Statistics Canada Health Report on UVR exposure and melanoma risk within the 1991 Canadian Census Health and Environment Cohort found that overall melanoma risk was associated with higher sociodemographic characteristics of income, education, and occupation. A recent systematic review of Canadian studies on the relationship between socioeconomic status (SES) and melanoma was limited by the small number of studies, heterogeneous study design and use of different measures of socioeconomic status.

Objective

This single manuscript thesis investigates the relationships between sociodemographic factors and the age at diagnosis and stage at diagnosis of melanoma using Canada-wide data from the national cancer registry linked to individual responses from the Canadian Community Health Survey (CCHS).

Methods

This study is conducted using an existing linked dataset from Statistics Canada: Canadian Population Health Survey data (CCHS Annual and Focus Content) integrated with mortality, hospitalization, historical postal codes, cancer registry, tax files and Census data. Data files from the Canadian Cancer Registry (CCR) from 2010-2016 are linked to responses from the 2015, 2016 and 2017 CCHS cycles. By linking these datasets, I examine relationships between the age of

patients at diagnosis and sex, education, household income, and area of residence using bivariate and multivariate regression. I further study the relationships between the presence of an in situ or malignant melanoma at diagnosis and these variables using logistic and multivariate logistic regression.

Results and discussion

I obtained a study sample of 360 individuals with cutaneous melanoma diagnosed over 18 years-old outside of Quebec between January 1st 2010 and December 31st 2016 who answered one of the CCHS cycles conducted in 2015, 2016 and 2017. My findings highlight that individuals with melanoma are primarily white, elderly and of a higher socioeconomic status. Specific sociodemographic characteristics are associated with earlier diagnosis of melanoma. Women (- 3.29 years, 95% CI: -6.31, -0.28), post-secondary educated (-10.39 years, 95% CI: -14.72, -6) and higher household income (-12.37 years, 95% CI: -18.73, -6.01) Canadians are diagnosed with melanoma at a younger age. Inconsistent staging data by province limits the study of the association between sociodemographic factors and stage at diagnosis, but preliminary findings include increased odds of malignant melanoma at diagnosis in post-secondary educated individuals (1.19, 95% CI: 0.65, 2.21) while results suggest that a higher household income is protective against malignant melanoma (0.49, 95% CI: 0.17, 1.43 when controlling for education).

Conclusion

This thesis contributes to the understanding of the influence of sociodemographic factors in melanoma incidence in Canada. It highlights disparities in melanoma incidence based on sociodemographic characteristics within a universal healthcare system. Furthering this understanding will inform melanoma prevention and detection strategies for the Canadian context.

Résumé

Contexte

Le mélanome est le septième cancer le plus fréquent au Canada, avec une incidence en hausse tant chez les hommes que les femmes. Cette hausse est attribuée à l'augmentation de l'exposition aux rayons ultraviolets (UV), ainsi qu'à la détection précoce du mélanome. La prévention et la détection précoce du mélanome sont des interventions qui sauvent des vies. Malgré l'augmentation de l'incidence, les taux de mortalité par mélanome sont en baisse. L'identification des Canadiens à risque de développer un mélanome est essentielle pour les décideurs politiques et les cliniciens. Un rapport de Statistique Canada concernant l'exposition aux rayons UV et le risque de mélanome a révélé que le risque de mélanome était associé à des caractéristiques sociodémographiques plus élevées de revenu, d'éducation et d'emploi. Une revue systématique récente des études canadiennes sur l'association entre le statut socio-économique et le mélanome était limitée par le petit nombre d'études, leur conception hétérogène et l'utilisation de différentes mesures de statut socio-économique.

Objectif

Cette thèse à manuscrit étudie les relations entre les facteurs sociodémographiques et l'âge et le stade au moment du diagnostic de mélanome en utilisant des données pancanadiennes du registre national du cancer liées aux réponses individuelles de l'Enquête sur la santé dans les collectivités canadiennes (ESCC).

Méthodes

Cette étude est réalisée à l'aide de données couplées de Statistique Canada : l'ESCC intégrée aux données sur la mortalité, l'hospitalisation, les codes postaux historiques, le registre du cancer, les fichiers fiscaux et les données de recensement. Des cas de mélanome du Registre canadien du cancer (RCC) de 2010 à 2016 sont liés aux réponses des cycles 2015, 2016 et 2017 de l'ESCC. Le

couplage permet d'examiner les associations entre l'âge des patients au moment du diagnostic et le sexe, l'éducation, le revenu du ménage et la région de résidence à l'aide de régressions bivariées et multivariées. J'étudie également les associations entre la présence d'un mélanome in situ ou malin au moment du diagnostic et ces variables à l'aide de régressions logistiques et logistiques multivariées.

Résultats et discussion

L'échantillon est composé de 360 personnes atteintes d'un mélanome cutané diagnostiqué à partir de 18 ans à l'extérieur du Québec entre le 1er janvier 2010 et le 31 décembre 2016, qui ont également répondu à l'un des cycles de l'ESCC de 2015, 2016 et 2017. Mes résultats soulignent que les personnes atteintes de mélanome sont principalement de race blanche, âgées et de statut socioéconomique plus élevé. Des caractéristiques sociodémographiques spécifiques sont associées à un diagnostic plus précoce du mélanome. Les femmes (- 3,29 ans, IC 95 % : -6,31, -0,28), les personnes ayant fait des études postsecondaires (-10,39 ans, IC 95 % : -14,72, -6) et les Canadiens à revenu de ménage élevé (-12,37 ans, IC 95 % : -18,73, -6,01) reçoivent un diagnostic de mélanome à un plus jeune âge. Les données de stade de cancer disponibles limitent l'étude de l'association entre les facteurs sociodémographiques et le stade au moment du diagnostic, mais les résultats préliminaires indiquent une probabilité accrue de mélanome malin chez les personnes ayant fait des études postsecondaires (1,19, IC 95 % : 0,65, 2,21), tandis que les résultats suggèrent qu'un revenu de ménage plus élevé protège contre le mélanome malin (0,49, IC 95 % : 0,17, 1,43 après prise en compte de l'éducation).

Conclusion

Cette thèse contribue aux connaissances sur l'influence de facteurs sociodémographiques sur l'incidence du mélanome au Canada. Elle met en évidence les disparités dans l'incidence du mélanome en fonction des caractéristiques sociodémographiques dans un système de soins de santé

universel. L'approfondissement de cette compréhension contribuera à l'élaboration de stratégies de prévention et de détection du mélanome dans le contexte canadien.

Preface

This is a manuscript-based thesis containing one unpublished manuscript. It is divided into six chapters. The first chapter introduces the rationale of the present thesis. Chapter 2 provides the objectives and specific aims of the thesis. Chapter 3 presents a literature review of social determinants of melanoma incidence and diagnosis in Canada, and briefly presents what is known outside of Canada. Chapter 4 presents the results of my study as a manuscript. Chapter 5 provides additional discussion of my results and their implications. Chapter 6 consists of a summary and conclusions to the thesis. It is followed by appendices and references.

This thesis was prepared through the Master's in Epidemiology Intensive for Clinicians program in pursuit of my Public Health and Preventive Medicine Residency training. Specific attention was given to creating ties between the topics of cancer epidemiology and public health practice.

Contributions

Julia Heron, M.D.,C.M.

I was responsible for the production of the thesis and manuscript, with the support of Erin Strumpf and Joe Cox. I designed the study, obtained access to Statistics Canada datasets at the Research Data Centre (RDC), conducted data analysis and statistical analyses, and wrote initial drafts of all chapters of the present thesis. This work was performed during my Public Health and Preventive Medicine residency training.

Erin Strumpf, PhD

Dr. Erin Strumpf was the thesis supervisor and member of the thesis committee. She participated in the design of the study, the application for the Statistics Canada research contract and planning of statistical analyses. She contributed to the interpretation of results and reviewing all chapters of the present thesis.

Joseph Cox, MD

Dr. Joseph Cox was a member of the thesis committee. He provided support and assistance in interpreting results to highlight public health considerations in this thesis. He reviewed all chapters of the present thesis.

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List of tables

Table 1: Sociodemographic characteristics of the melanoma-CCHS cohort, CCHS respondents sample and melanoma CCR sample, excluding Quebec.....51
Table 2: Bivariate regressions of age at diagnosis by sociodemographic characteristics 52
Table 3: Multivariate regressions of age at diagnosis by sociodemographic characteristics 53
Table 4: Logistic regressions for the odds ratio of malignant melanoma by sociodemographic characteristics 54
Table 5: Multivariate logistic regressions for the odds ratio of malignant melanoma by sociodemographic characteristics……..……..……...…55
Table 6: Correlation coefficients of studied sociodemographic characteristics…56

List of figures

Figure 1: Melanoma CCR sample obtained from all linked CCR files.....48
Figure 2: CCHS sample of respondents to the 2015, 2016 and 2017 cycles.....49
Figure 3: Distribution of CCHS responses in relation to melanoma diagnosis.....50

List of appendices

Appendix 1: Ethics approval

List of abbreviations

CCR: Canadian Cancer Registry
CCHS: Canadian Community Health Survey
CI: confidence interval
IARC: International Agency for Research on Cancer
M.D.,C.M.: Doctor of Medicine and Master of Surgery
MeSH: Medical Subject Headings
OR: odds ratio
RDC : Research data centre
SES: socioeconomic status
UVR: ultraviolet radiation

Chapter 1: Introduction

Cutaneous melanoma is a potentially life-threatening cancer that affects all age groups. The incidence of cutaneous melanoma is increasing in Canada. This is largely attributed to UVR exposure, a leading modifiable risk factor for melanoma,(1) as well as increased early detection of melanoma (2). Melanoma prevention messages primarily target individual sun safety behaviours as there is no organized screening program for melanoma in Canada. Early detection is considered an important strategy to reduce the burden of this cancer by improving survival.(1-3) In fact, melanoma mortality rates have been decreasing in Canada despite increasing incidence.(1)

Increasing trends in melanoma incidence and decreasing mortality have been described internationally, including in the United States where it has been suggested that melanoma overdiagnosis is contributing to the observed increased incidence and decreased mortality.(4-6) Overdiagnosis is a phenomenon in which lesions that would not have led to severe disease are more readily detected and treated without leading to a mortality benefit.(7, 8) In the United States, overdiagnosis occurs in more in higher SES groups who have better access to healthcare and melanoma diagnosis.(7) Overdiagnosis has been described for a variety of disease states in Canada, but has not been studied for melanoma.(8-10)

Cancer diagnosis and care disparities have been well documented for some of Canada's most common cancers despite our universal healthcare system.(11-14) However, little is known about disparities in melanoma diagnosis and clinical care in Canada. Previous literature has identified that people with higher income, education and from certain occupational groups have a higher incidence of melanoma.(15, 16) Explanations have included more sun vacations and UVR exposure in these groups.(16) Literature from outside of Canada has found associations between lower SES and more advanced stage at diagnosis.(17-21)

This raises questions about who is most at risk of melanoma, and who is accessing a melanoma diagnosis and clinical care in the Canadian healthcare system.

This thesis contributes to improving our understanding of the sociodemographic characteristics of patients diagnosed with melanoma in Canada and the roles these characteristics play in melanoma diagnosis. This is of particular interest to identify inequities that may persist in our universal healthcare system. Public health messaging on sun protection and melanoma prevention can then be tailored to reach the desired at-risk public without worsening health inequities.

Chapter 2: Goal and objectives

This thesis studies the relationships between sociodemographic characteristics of adult patients diagnosed with melanoma in Canada. Specifically, to better understand these relationships with respect to age and stage at diagnosis.

Using a national sample of adult cutaneous melanoma cases diagnosed between 2010 and 2016, and linking them to CCHS responses, specifics aims are the following:

1. Describe the sociodemographic characteristics of melanoma patients in Canada and compare them to the distribution from a representative Canadian sample (the CCHS).

2. Estimate the relationships between age at diagnosis and sociodemographic characteristics of melanoma patients, controlling for selected characteristics.

3. Estimate the relationships between stage at diagnosis and sociodemographic characteristics, controlling for selected characteristics.

Chapter 3: Comprehensive review of the relevant literature

Scientific literature on melanoma is extensive and details melanoma etiology, pathology, clinical management, and treatment. This literature review focuses on the existing evidence on the relationships between sociodemographic characteristics and the occurrence of melanoma as well as stage at diagnosis.

Objective of the literature review

The objective of the present literature review is to provide an overview of melanoma incidence trends in Canada alongside a brief review of current clinical guidelines for melanoma prevention and treatment. Canadian literature on the relationships between sociodemographic characteristics and melanoma incidence and stage at diagnosis is reviewed comprehensively, while research on these relationships in other countries with similar exposure and melanoma rates is explored to a lesser extent. Specific characteristics of interest include age, sex/gender, income, education and rural versus urban residence.

Methods

I used PubMed and searched for articles with the key words melanoma (MeSH Major), Canada (MeSH Major) and socioeconomic or sociodemographic. This yielded 12 results. Results were reviewed individually to determine relevance to the question of sociodemographic characteristics and incidence or stage at diagnosis in Canada. Four articles were excluded for not providing information on the question of melanoma incidence or stage at diagnosis and sociodemographic characteristics in Canada.(22-25)

Evidence for other countries was obtained through searching PubMed for articles using a similar search strategy while removing the restriction to Canada. Specific countries of interest included the United States and European countries with universal healthcare and similar socioeconomic profiles to Canada. This search was not systematic.

Risk factors for melanoma

Ultraviolet radiation is widely recognized as the leading risk factor for melanoma. This exposure occurs primarily through direct exposure to sunlight but also through tanning beds and sun lamps.(1) Statistics Canada conducted a follow up of white members of the 1991 Canadian Census Health and Environment Cohort from 1992 to 2009 and published a *Health Report* in 2017 titled: *The risk of melanoma associated with ambient summer ultraviolet radiation.*(16) This report demonstrated an increased incidence of melanoma in regions with higher exposure to UVR, as well as a higher risk of developing melanoma in men than women.(16) Other risk factors include lighter skin pigmentation, multiple nevi or atypical nevi (moles), genetic factors, immunosuppression, and a personal history of melanoma.(16)

Another Statistics Canada report, which focused specifically on sun safety behaviours, identified a higher risk of sunburns in men and those with a higher SES. The authors suggested this increased risk of sunburns may contribute to higher incidence of melanoma in men and higher SES groups.(26)

Melanoma incidence in Canada

Melanoma incidence is on the rise for both men and women.(1) The annual percent change in age-adjusted incidence rates of melanoma was of 2.2% in men and 1.9% in women between 1984 and 2019. The Canadian Cancer Society estimates that in 2023 there will be 9,700 melanoma diagnoses in Canada: 5,600 men (29.2 cases per 100,000) and 4,100 women (20.4 per 100,000). It is expected that in 2023 melanoma diagnoses will represent 4.5% of new cancer diagnoses in men and 3.6% in women(1).

There is a variation in incidence rates of melanoma between provinces and territories, namely between coastal and southern parts of Canada, with observed

increased incidence in Nova Scotia, Prince Edward Island, Southern Ontario, British Columbia and coastal regions of New Brunswick .(16, 27, 28)

The increase in melanoma has been observed largely amongst older Canadians due to longer cumulative UVR exposure(29), but melanoma is diagnosed across most age groups in Canada. It is the fourth most common cancer in those aged 15-29 representing six percent of cancer diagnoses in that age group. Melanoma diagnoses make up seven-percent of cancer diagnoses in ages 30-49 and four-percent of cancer diagnoses in ages 50 to 85 and older(1).

The global burden of melanoma and non-melanoma skin cancers is expected to continue to grow as UV exposure is increased due to loss of protective ozone barriers.(30, 31) The observed increase in incidence in Canada is largely attributed to exposure to ultraviolet radiation, as well as an increase in early detection of melanoma.(1, 3) Melanoma overdiagnosis through increased detection of low-risk lesions is also suspected to contribute to the increasing incidence.(4-6) Overdiagnosis is expected to be driven by greater awareness and access to biopsies and diagnostic care, primarily in higher SES groups.(7)

Melanoma mortality in Canada

Projected age-standardized mortality rates for melanoma in 2023 are of 3.8 per 100,000 for men and 1.7 per 100,000 for women(1). Melanoma mortality rates have been decreasing in Canada since 2013 for men (annual percent change in age standardized mortality rates change of -2.6 between 1984 and 2020) and 2014 for women (annual percent change in age standardized mortality rates change of -3 between 1984 and 2020), despite increasing incidence. In fact, the five-year survival rate for melanoma is 87%, largely due to positive treatment outcomes from improved therapies, increased awareness and earlier detection of melanoma by patients or healthcare providers.(1)

Melanoma prevention and screening guidelines

There is no recommended population-level screening for melanoma in Canada. In fact, the *Canadian Task Force on Preventive Health* has no publications or reports on screening for skin cancer or melanoma.(32) For its part, the *US Preventive Services Task Force* concluded in 2016 and reiterated in 2023 that there was insufficient evidence to recommend skin cancer screening with visual skin examination.(33) It does not identify high risk groups or situations in which screening would be recommended.(34) A systematic review of international clinical practice guidelines demonstrated that guidelines did not consistently provide clinicians with guidance on how to identify or screen high risk individuals.(35) Only patients with a previous diagnosis of melanoma receive instructions to perform skin exams to detect any new melanoma at an early stage.(36)

Diagnosis and clinical care of melanoma

There are four main types of cutaneous melanoma: superficial spreading, lentigo maligna melanoma, acral lentiginous melanoma and nodular melanoma.(37) There are various clinical rules that exist to help physicians determine if a lesion is suspicious for melanoma. For example, clinicians may use the "ugly duckling" sign looking for a nevi that has an unusual appearance compared to an individual's typical morphology, the ABCDE rule (asymmetry, border irregularity, color variegation, diameter >6 mm), or the Glasgow revised seven-point checklist.(38) Dermatologists have additional expertise and examination tools to evaluate nevi. Confirmation rests on histopathologic tissue diagnosis by a pathologist following a biopsy, which is typically performed by a dermatologist. Staging of melanoma follows the Tumour, Node, and Metastasis (TNM) staging system.(38) Melanoma in situ is limited only to the epidermis and has no evidence of extension of disease. Malignant melanoma captures all four other cancer stages.(39) Treatment pathways depend on the stage at diagnosis. Local resection is sufficient for cure in localized disease, while later stage melanoma is treated primarily with radiotherapy, chemotherapy and newer immunotherapies and targeted drugs.(40, 41)

Awareness campaigns

There is no national campaign for melanoma prevention in Canada. Australia, which has the highest incidence of skin cancers in the world, is a leading example of a successful population health campaign on melanoma prevention. In response to its “National Cancer”, Australia launched a national public awareness campaign in 1981. A mascot for the campaign, Sid the seagull, reminded Australians to “Slip, Slop, Slap” (“Slip on a shirt, slop on sunscreen and slap on a hat”). This later became the central message of the Cancer Council's SunSmart program, which was updated to include “Seek” (seeking shade) and “Slide” (sunglasses).(42) In more than 30 years of programming, the campaign has influenced health policy and messaging across the country. The program has been credited with decreasing incidence rates of skin cancer in younger cohorts of Australians and increased detection of melanoma at an earlier stage.(43, 44)

Melanoma incidence and sociodemographic characteristics: Canada

As previously noted, a Statistics Canada’s Health Report found a higher risk of melanoma in men compared to women, as well as an important variation in incidence between provinces and territories. The association between melanoma and UVR was strongest among men and people of lower SES. When adjusting for age, sex, and selected socioeconomic characteristics of marital status, immigrant status, household income, educational attainment and occupation, the Health Report(16) found that overall melanoma risk was associated with higher income, education, and occupation.

A recent systematic review of seven Canadian studies covering the period between 1979-2012 also found that higher SES was associated with an increased incidence of melanoma.(15) Measures of SES varied by study, but included income, occupation, and the Ontario Marginalization Index. The authors noted that the strength of the association had lessened between an earlier study conducted between 1986 and 1993(45) and a more recent study conducted between 1992-2006.(3) There was limited evidence to suggest that populations of lower SES

living in certain regions of Canada were at increased risk of a later stage melanoma at diagnosis compared to those of a higher SES.(15) Explanations for the observed increased risk of melanoma in higher SES individuals have included more sun exposure due to travel, as well as better access to care.(3)

Income

Four studies included in the systematic review used median neighbourhood and income quintiles by postal code as a measure of socioeconomic status. All four concluded that higher SES was associated with increased incidence or prevalence of melanoma. None of the four studies included control variables for access to care or education.(15) In Ontario, median neighborhood household income was used to demonstrate an increased prevalence of melanoma in the highest SES group compared to the lowest.(46) Another study that included all provinces other than Ontario found an increased incidence of melanoma in higher income groups both for invasive and in situ melanoma. Income group was assigned by postal code.(3) An Ontarian study using income quintiles from census-based neighborhood income found that the increased incidence of melanoma in higher income populations was present in both men and women.(47) In another Ontarian study, higher income groups had a higher age-adjusted incidence rate compared to low-income patients.(45)

Occupation

Occupation was used as measure of SES in two case-control studies.(48, 49) In one study there was an increased risk of melanoma in surveyors and draftsmen and a non-significant increased risk of melanoma for professional and scientific occupations compared to unskilled workers when adjusting for individual skin pigmentation and sun exposure.(48) Another group of authors created a model to determine the impact of SES over a patient's lifespan using paternal and personal occupation history. A disadvantageous socioeconomic situation according to this model was considered protective compared to an advantageous socioeconomic situation.(49)

Urban vs rural residence

Individual studies have inconsistent findings on the incidence of melanoma by urban or rural settings.(15) While one study concluded that rural residence was a significant risk factor for developing melanoma(3), another found a lower incidence of invasive melanoma for those living in rural settings.(46) A third study did not find any association between rurality and melanoma incidence.(50) A study conducted in Ontario suggested that rurality itself was not related to outcomes, but rather the decreased access to dermatology in rural settings. Individuals who saw dermatologists in the year prior to diagnosis were less likely to be diagnosed with advanced disease, which improved their overall survival.(51) Access to a family doctor was also studied in this cohort. There was a nonlinear association between the number of visits and prognosis, with three to five visits a year being associated with better prognosis.(51) A study conducted in Nova Scotia between 1995-1999 also found that individuals with regular visits to their GP (between 2-5 in the 2 years prior to diagnosis) were less likely to have thick tumours on presentation.(52)

Melanoma Stage at Diagnosis and Sociodemographic Characteristics

Despite a lower incidence of melanoma, lower SES has been associated with more advanced stage at diagnosis and decreased survival in one Canadian study. It was conducted in Ontario using the Ontario Marginalization index as a measure of SES. It found that lower SES was associated with an increased risk ratio for advanced melanoma.(50)

Outside of Canada

The increased risk of melanoma with higher SES has been observed in many countries, including the United States(53, 54), New Zealand(55), the Netherlands(17) and Northern Europe (Denmark, Sweden, Norway, Finland, England and Wales, Scotland, and Holland).(56) The relationship between SES and stage at diagnosis has also been studied more extensively outside of Canada.

The increased risk of advanced disease in lower SES groups has been found in Sweden(18), New Zealand(19), Australia (20) , Netherlands(17), and England.(21)

Discussion

The literature reviewed suggests an association between socioeconomic status and melanoma incidence in Canada; melanoma incidence increases with increasing SES. Most Canadian studies have used income as a measure of SES. However, most of these income variables have included postal code(3) or neighbourhood median income(46, 47) and marginalization codes(50) rather than directly reported household-level income data. A recent Canadian study compared individual income of colorectal cancer patients to neighbourhood income values and found there was poor agreement between these measures and cautioned against using neighbourhood income as a proxy for individual income.(57) Only Statistics Canada's Health Report used education as a marker of SES when studying the relationship with melanoma incidence.(16)

Most of the studies included in this literature review studied only specific provinces, certain measures of SES and were limited in controlling for covariates. Many were conducted in Ontario(45-47, 50) which limits overall generalizability to the Canadian public. The relationship between urban or rural residence and melanoma incidence remains unclear, with conflicting evidence.(3, 46, 50) There is also debate as to whether rurality is a marker of SES in Canada or rather of access to specialised dermatologist care.(51)

Another area of limited Canadian evidence is the impact of SES on the stage at diagnosis, with only a single study suggesting lower SES is associated with advanced disease.(50) This study is consistent with trends observed in other countries.(17-19, 21)

Conclusion

Melanoma is a cancer with increasing incidence in Canada. Melanoma occurs in all age groups.(1) The burden of this preventable disease is expected to continue to grow. The effects of climate change on UV exposure are expected to further contribute to this increase.(30, 31) There is no national screening or prevention strategy to address the expected greater burden of cancer due to melanoma in the population.(32, 58)

There has been an observed association between higher education, income and certain occupations and the occurrence of melanoma in Canada.(15, 16) This is consistent with international literature, but Canadian evidence is largely limited to provincial and regional studies and area-level measurements of income that proxy for individual or household-level measures.(15) There is also minimal direct evidence on the relationship between SES and stage at diagnosis for Canadians.(50)

National data on personal income and education in melanoma patients will shed more light on this association. Further study of rural versus urban residency is also important to contribute to a better understanding of this relationship and resource allocation. Improving our understanding of which groups are at higher risk of melanoma and of diagnosis at advanced stages could inform public policy and prevention messaging.

Chapter 4: Results

Preface to manuscript

This manuscript describes sociodemographic characteristics of melanoma patients in Canada as obtained from the CCHS, estimates the relationships between age at melanoma diagnosis and sociodemographic characteristics and estimates the association between these same characteristics and stage at diagnosis.

This research contributes to further our understanding of sociodemographic factors that underlie melanoma incidence and stage at diagnosis in Canada. New linked datasets from Statistics Canada allow for the use of rigorous and personal sociodemographic characteristics for cancer patients across the country. Standardized CCHS variables allow for direct comparison of sociodemographic variables across provinces and territories. For instance, there is a single standard and method to determine geographic area of residence. Importantly, I am not limited to the use of indirect or proxy area and population-level measures of income. This dataset also allows me to include multiple measures of SES in a single study and study the relationships between these measures. Additionally, I can control for certain characteristics when exploring relationships of interest.

This manuscript has not yet been submitted for publication.

Manuscript

Title: Identifying Social Determinants of Melanoma Incidence and Diagnosis in Canada

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Background: Melanoma is the seventh most common cancer diagnosis in Canada, with incidence on the rise for both men and women. Studies have suggested that overall melanoma risk is associated with higher income, education, and occupation. Only a small number of studies have examined these relationships in Canada, and they include heterogeneous designs with varied measures of socioeconomic status, including proxy population measures of income. Canadian evidence is particularly limited when it comes to the effect of sociodemographic characteristics on stage at diagnosis. This study investigated the relationships between sociodemographic factors and the age of melanoma diagnosis in Canada, as well as the stage at diagnosis.

Methods: We used an existing linked dataset from Statistics Canada. Data files from the Canadian Cancer Registry (CCR) from 2010-2016 were linked with responses to the 2015, 2016 and 2017 Canadian Community Health Survey

(CCHS) cycles. By linking these datasets, we described the relationships between the age of patients at diagnosis and sex, education, household income and area of residence using bivariate and multivariate regressions. We further studied the relationships between the presence of an in situ or malignant melanoma at diagnosis and sex, education, household income and area of residence variables using logistic regression.

Results: Our findings highlight that Canadian individuals with melanoma are primarily white, elderly and of a higher socioeconomic status. We estimated a younger age at diagnosis in women (- 3.29 years, 95% CI: -6.31, -0.28), post-secondary educated (-10.39 years, 95% CI: -14.72, -6) and wealthier (-12.37 years, 95% CI: -18.73, -6.01) Canadians. Inconsistent staging data by province limited the study of relationships observed between sociodemographic factors and stage at diagnosis, but preliminary findings include increased odds of malignant melanoma at diagnosis in post-secondary educated individuals (1.19, 95% CI: 0.65, 2.21).

Conclusions: Our study highlights disparities in melanoma incidence based on sociodemographic characteristics within a universal healthcare system. Earlier detection of melanoma occurs in women, those with higher education and higher household income. Literature suggests that earlier diagnoses are associated with less advanced disease and improved survival. Further study should explore the ways that sociodemographic characteristics modify access to healthcare and preventive care for melanoma patients. This understanding will inform melanoma prevention and detection strategies for the Canadian context, as we are certain to face an increasing burden of melanoma.

Keywords: Melanoma, incidence, stage, sociodemographic, income, education, urban, rural

Background

The incidence of melanoma is on the rise for both men and women in Canada.(1) The increase in incidence has been attributed to increased exposure to ultraviolet radiation (UVR)(1), as well as greater early detection of melanoma.(2) The global burden of melanoma and non-melanoma skin cancers is expected to continue to rise as UVR exposure is increased due to a loss of protective ozone barriers.(3-5) At the same time, survival has been improving since 2013 for men and 2015 for women in Canada.(1) This has been explained by early detection, increased awareness as well as novel cancer therapies.(1) There is no screening program or recommended primary care screening for melanoma in Canada.(6-8)

Several studies on melanoma incidence outside of Canada have demonstrated more melanoma in higher socioeconomic groups.(9-12) Studies outside of Canada have also found an increased risk of advanced disease in lower socioeconomic groups.(12-16)

A small number of Canadian studies have examined the association between sociodemographic characteristics and melanoma diagnosis. Household income, education, occupation and urban vs rural dwelling were used as measures of socioeconomic status in these studies.(17, 18) One of the larger studies, conducted by Statistics Canada primarily to study UV exposure, concluded that melanoma risk was associated with higher income, education, and occupation.(18) Four smaller studies included in a systematic review on SES and melanoma in Canada likewise found an increased risk in higher income groups.(2, 17, 19-21) However, the majority of these studies were limited to specific provinces and by available measures of SES. For instance, postal code or neighbourhood income data were used as proxies for individual and household income.(2, 17, 19-21) A recent study using Canadian colorectal cancer data found that neighbourhood income was not a good indirect measure for individual income in cancer research, especially where inequalities in cancer incidence exist by income.(22) There is no consensus on the relationship between urban or rural dwelling and melanoma incidence.(2, 17, 20) Finally, only one Canadian study examined the relationships

between sociodemographic characteristics and stage at melanoma diagnosis, finding that male sex, advanced age and lower SES were associated with an increased risk ratio for advanced melanoma.(23)

This study investigates the relationships between sociodemographic factors and the age at diagnosis of melanoma in Canada, as well as the stage at diagnosis. Sociodemographic factors of study will be age, sex, household income, education and size of geographic residence area.

Methods

Data source

This study was carried out using an existing linked dataset from statistics Canada: Canadian Population Health Survey data (CCHS Annual and Focus Content) integrated with mortality, hospitalization, historical postal codes, cancer, tax data and Census.(24) A Statistics Canada research contract granted access to this dataset at McGill's Research Data Centre (RDC). The datasets of interest for analysis were the CCR and the CCHS. The datasets are provided separately to be linked in the RDC by the researcher.

The CCR has been Canada's national cancer registry since 1992. It compiles cancer incidence data on all new primary cancers in Canada.(25) Each province is responsible for collecting and submitting incident cancer cases based on the Canadian Council of Cancer Registries reporting criteria. For cutaneous melanoma, all primary malignant tumours, carcinoma in situ or non-invasive tumours as well as borderline malignancies are to be reported.(25) Cancer data for Quebec is only accessible until the year 2010, after which the province stopped reporting incident cancer cases to the CCR.(1) We excluded Quebec and chose to consider melanoma diagnoses that occurred between January 1st, 2010 and December 31st, 2016. The year 2010 is the first year in which Ontario's new reporting system was applied, which improved reporting and increased melanoma cases in the CCR.(1, 25) 2016 was the last available CCR year for which we had

access. For each diagnosis, the CCR contains basic demographic information such as age and sex, as well as clinical information on melanoma type and diagnosis date. Due to limitations in staging data completeness across all reporting provinces(1, 25), we were unable to obtain detailed staging data for our cohort. There was however consistent reporting of in situ or malignant melanoma.

The CCHS is a population health survey administered by Statistics Canada across all Canadian provinces and territories since 2001. The CCHS collects information related to health status, health care utilization and health determinants. It has been administered annually since 2007. The CCHS has undergone two redesigns in 2015 and in 2022.(26) These redesigns have made cycles after 2015 difficult to compare to previous cycles. Statistics Canada has in fact specifically cautioned against making such comparisons.(26) In that context, we chose to use the combined 2015 and 2016 CCHS cohort, which utilized the new methodology, as well as the 2017 CCHS cycle. We did not have access to more recent cycles.

Variables of interest

Variables of interest from the CCR included age at diagnosis, date of diagnosis, sex, and in situ versus malignant diagnoses. CCHS variables of interest were age at response to the survey, response date, sex, and categorical variables for education, total household income, belonging to a racial/cultural group, and population centre or rural area classification. Education was split into three categories based on the highest level of education attainment. Household income was available as a continuous variable for one cycle, but only as a categorical variable for another. We converted all household income data into the categorical variable created by Statistics Canada starting at incomes of less than 20,000$ a year and increasing by 20,000$ increments until the highest income category of greater than 80,000$ a year. Racial and cultural group belonging were limited to white, non-white, or other based on the demographics of our sample. Population centre or rural area classification was divided into 4 categories of population size, which we will refer to as area of residence.

Study population

Data files of incident melanoma diagnoses from the Canadian Cancer Registry (CCR) from 2010-2016 were linked to responses from the 2015, 2016 and 2017 CCHS cycles to obtain our melanoma-CCHS cohort.

First, we analysed the cases of incident melanoma diagnoses from the Canadian Cancer Registry (CCR) that were linked to responses to all CCHS cycles. This is illustrated in Figure 1. We restricted our CCR dataset to common cutaneous melanoma subtypes. We excluded diagnoses under the age of 18. We restricted to melanoma in situ and malignant melanoma diagnoses, eliminating any benign or borderline pathology. We excluded any diagnosis reported from the province of Quebec given that we only had diagnoses for the year 2010. Duplicate or multiple diagnoses were removed. In those situations, only the first diagnosis was kept. This is our melanoma CCR sample.

Next, we prepared our CCHS sample for 2015, 2016 and 2017. We had access to the complete CCHS cycles for individuals who consented to data linkage. We removed Quebec residents to match the CCR exclusion and restricted to those 18 years-old and older. During our data analysis, we further restricted to respondents with complete key variables to perform a complete case analysis. Our CCHS sample is summarized in Figure 2.

We linked our melanoma CCR sample to our CCHS sample to obtain our melanoma-CCHS cohort. This is a cohort of 360 individuals with cutaneous melanoma diagnosed over 18 years-old outside of Quebec between January 1st 2010 and December 31st 2016 who answered one of the CCHS cycles conducted in 2015, 2016 and 2017. Lastly, we removed observations that had missing key variables. This exclusion had minimal impact on the size of our melanoma-CCHS cohort, though it did reduce the size of our CCHS sample slightly (Figure 2).

Data analysis

We first described the demographic characteristics of our melanoma-CCHS cohort to summarize age at diagnosis, age at response to the CCHS, education, area of residence, household income and racial belonging. This descriptive data was compared to both reference populations from which the melanoma-CCHS cohort was obtained, the CCR and the CCHS. We summarized the variables of interest for the CCHS sample to serve as a summary of the more broadly sampled Canadian public. This allowed for comparison between our melanoma-CCHS cohort and the source population from which it originated. Additionally, since the CCHS is conducted to obtain a representative sample of the Canadian public, it served as representation of Canadian sociodemographic trends.

We also compared our melanoma-CCHS cohort to the larger sample of melanoma CCR files from our melanoma CCR sample with regards to average age at diagnosis and gender.

Our melanoma-CCHS cohort is made up both of individuals who received their melanoma diagnosis prior to responding to the CCHS and individuals who responded to the CCHS prior to their melanoma diagnosis. Ideally, the CCHS responses would have all been recorded prior to diagnosis. However, most of our sample responded to the CCHS after their diagnosis of melanoma. To maintain a workable sample size and considering that most variables in our study were not subject to short-term change, we determined that it was acceptable to keep the sample unified regardless of timing of response. A histogram was generated to illustrate the distribution of time elapsed between diagnosis and CCHS response.

Bivariate regression was used to study the relationships between the age of patients at diagnosis and sex, education, household income, and rural vs urban residence, respectively. We then used multivariate regression to study the relationships between multiple variables and the age at diagnosis. We chose to study the relationships between age at diagnosis and education controlling for

household income. Expecting household income and education to have a degree of collinearity, we wanted to observe changes in the relationship between education and age at diagnosis when keeping income constant. We also chose to study two additional multivariate regressions: age at diagnosis by area of residence controlling for household income and age at diagnosis by area of residence controlling for education. We selected these controlling variables to gain a better understanding of the impact of rurality or urban residence while accounting for possible demographic differences in household income and education between these population sizes. After controlling for education and household income, remaining differences between urban and rural populations would more closely reflect challenges in access and proximity to care based on geography.

We further studied the relationships between the presence of an in situ or malignant melanoma at diagnosis and individual demographic variables of sex, education and geography using logistic regression. We were unable to publish a logistic regression for stage by household income alone due to confidentiality limitations from the RDC. We performed multivariate logistic regressions using the same controlling variables as the multivariate age at diagnosis regressions.

We generated a correlation matrix for the demographic variables used in our analyses: sex, education, household income and geography.

Analyses were carried out at the RDC using Stata. Confidence intervals were calculated with a 95% confidence interval with statistical significance at the p<=.05 level. All descriptive statistics were rounded to respect vetting and confidentiality procedures. Results were reviewed by the Statistics Canada analyst prior to extraction to ensure they respected confidentiality. Ethics approval was granted through an expedited review at McGill University.

Results

Timing of CCHS responses

The majority of responses to the CCHS in the melanoma-CCHS cohort occurred after diagnosis. Specifically, 310 individuals answered the CCHS after their diagnosis (up until a maximum of 7.6 years later) while 50 individuals answered the CCHS prior to their melanoma diagnosis (within 1.8 years prior to their diagnosis). Figure 3 is a histogram showing the timing of responses to the CCHS from time zero of melanoma diagnosis.

Demographic characteristics and comparison

The melanoma-CCHS cohort of 360 individuals covers residents in all Canadian provinces at time of diagnosis, excluding Quebec. Only one Canadian territory is represented in the sample (the Northwest Territories). Summary sociodemographic characteristics of the sample are presented in Table 1. The melanoma sample has gender parity with the same number of men and women. Nearly the entirety of the cohort, 350 of 360 individuals (97%), self-identify as white. The average age of individuals at diagnosis is 65. Ages at diagnosis range from 20 to 96 years old, with 90% of the respondents aged between 37 and 85, and 75% of respondents aged between 47 and 82. The average age when answering the CCHS is 67 with ages ranging from 20 to 100 years old. This is consistent with the finding that most of the cohort answered the CCHS after diagnosis. The melanoma-CCHS cohort is generally well educated, with 65% of the sample having a post-secondary education, 21% having a high school diploma, and 14% not having completed high school. Slightly more than half of the cohort has an annual household income of 60,000$ or more, while only 6% of the sample is in the lowest income group of less than 20,000$. Close to 40% of the cohort lives in a large urban population centre (100,000 or more), 37% live in small or medium population centres (1000 to 29,999 and 30,000 to 99,999, respectively). The last 24% live in rural areas with less than 1,000 people.

Table 1 also presents the sociodemographic characteristics of the CCHS sample which is made up of 101,030 individuals. This sample encompasses all Canadian provinces and territories other than Quebec. In comparison to the melanoma-

CCHS cohort, the CCHS sample is younger, with the average age at response being 52 years old. The age range is also broad extending from 18 to 112 years old compared to 20 to 100 years old in the melanoma sample. More women responded to these cycles of the CCHS with 55% female response to 45% male response compared to our melanoma-CCHS cohort which has gender parity. The CCHS sample remains predominantly white but less so than our melanoma-CCHS cohort with 83% of respondents self-identifying as white compared to 97% of melanoma cases. The CCHS sample has a smaller proportion of individuals with a post-secondary education at 61% compared to 65% for the melanoma-CCHS cohort. Household income is distributed over the five income groups in a similar way for the CCHS and the melanoma-CCHS cohort. The CCHS sample has a larger proportion of rural area respondents, while the melanoma-CCHS cohort has a larger proportion of urban and medium population centre dwelling individuals.

The last column of Table 1 presents the limited demographic summary of the CCR sample. The average age at diagnosis is 67 years-old in the CCR, compared to the slightly younger 65 years observed in our melanoma-CCHS cohort. We also note a similar near-gender parity between the CCR sample and melanoma-CCHS cohort.

To summarize, when comparing the melanoma-CCHS cohort to the CCHS sample, the melanoma-CCHS cohort is older and has a higher proportion of white and male individuals compared to the CCHS. The melanoma-CCHS cohort has a higher proportion of individuals with the highest level of education, while household income distribution is similar between both groups. The melanoma-CCHS cohort has a smaller proportion of individuals living in rural settings. Compared to the CCR sample, our melanoma-CCHS cohort is slightly younger than the average age of diagnosis.

Association between sociodemographic characteristics and age at melanoma diagnosis

Performing bivariate regressions, we studied the relationships between age at diagnosis and sex, education, household income and area of residence. The results are summarized in Table 2. Women receive a diagnosis of melanoma 3 years earlier then men The direction of the association we observed is consistently protective for women (95% CI: -6.31, -0.28 years).

With higher educational attainment, age at diagnosis is decreased by as much as 10 years when comparing college-educated individuals to those without a high school degree (95% CI: -14, -6). Similarly, but to a lesser extent, the decrease in age at diagnosis is observed in those who have a high school degree as their highest level of education. They are diagnosed 5 years earlier than those without a high school degree (95% CI: -10, -0.47). While the magnitude of the association is strongest between the highest and lowest education group, both the high school and college-educated groups have an observed substantial reduction in age at diagnosis compared to the reference population with less than a high school education. The 95% confidence intervals for both the college educated and high school educated coefficients have a consistent directionality of earlier diagnosis than the lowest education group.

There are slight differences observed in age at diagnosis based on area of residence. Compared to the reference population living in rural settings, small and medium population centres receive their diagnosis 1.32 (95% CI: -3.22, 5.87) and 2.24 (95% CI: -2.66, 7.14) years later. Meanwhile, individuals living in large urban centres receive their diagnosis in a comparable period to those living in the reference (rural) area with a difference of 0.15 years (95% CI: -3.81, 4.12). All of our results for area of residence have 95% confidence intervals that include the null. This could be due to a small sample size limiting our ability to detect an association, or simply reflect that there is no meaningful association to be observed. When studying age at diagnosis within household income groups, all household income groups are diagnosed earlier than the lowest income reference population. The third household income group (40,000 to 59,999$) is diagnosed

6.5 years earlier than the reference group (95% CI: -13.27, 0.32). The highest household income group has the largest magnitude of observed association and receives their diagnosis of melanoma 12 years younger than those in the lowest income group (95% CI: -18, -6). It is also the only coefficient for income in which the 95% CI does not include the null.

The results of multivariate regressions are presented in Table 3. When we consider the relationship between age at diagnosis and education controlling for household income, we see a weakening of the observed association between education and age at diagnosis. Rather than a diagnosis 10 years earlier (95% CI: -14, -6), individuals with post-secondary education receive their diagnosis 6.9 years earlier (95% CI: -11.5, -2.3) when keeping household income constant. Individuals with a high school degree receive their diagnosis 3.3 years earlier (-8.46, 1.92) instead of 5.5 years earlier (95% CI: -10.61, -0.48). The strength and direction of the relationship between high school education and age at diagnosis is lost when controlling for household income. The association between post-secondary education and age at diagnosis remains strong and the 95% confidence interval does not include the null. We note that the association between household income and age at diagnosis is also weakened when keeping education constant with the highest household income group receiving a diagnosis 8.8 years earlier (95% CI: -15.5, -2) rather than 12 years earlier (95% CI: -18, -6).

The size of the association between area of residence on age at diagnosis is increased when controlling for education. Small, medium and large areas of residence have a further increased age at diagnosis when keeping education constant compared to the reference rural population. The largest change is for urban centres, which see the age at diagnosis go from 0.15 years older (95% CI: -3.81, 4.12) to 2.26 years older (95% CI: -1.66, 6.18). When considering the relationship between age at diagnosis and area of residence controlling for household income, the direction and magnitude of the association are largely unchanged. Coefficients are decreased slightly for small population centres and

minimally increased for medium and urban population centres. As with our bivariate regressions, the 95% confidence intervals for our coefficients for area of residence include the null whether controlling by education or by household income. Of note, controlling for area of residence led to minimal changes of the estimated relationships between household income or education and age at diagnosis.

Association between sociodemographic characteristics and stage (in situ, malignant) at melanoma diagnosis

Of the melanoma diagnoses in the melanoma-CCHS cohort, 43% were in situ while 57% were malignant. The results of bivariate logistic regressions for stage at diagnosis by sex, education and area of residence are available in Table 4. Logistic regression of in situ vs malignant diagnosis by sex results in an observed small decreased odds of malignant melanoma in women of 0.94 (95% CI 0.62, 1.44). Logistic regression of in situ vs malignant diagnosis by education highlights an increased odds of malignant melanoma with higher education. This increase is very small for the high school graduate group compared to the reference group (1.03, 95% CI 0.50, 2.11). The odds ratio increases in magnitude to 1.19 for the highest education group (95% CI 0.65, 2.21). Small and urban areas of residence have a slightly increased odds of malignant melanoma compared to the rural reference population (OR for small population centre: 1.08, 95% CI 0.58, 2.03; OR for urban centre: 1.08, 95% CI 0.63, 1.87) while medium population centres have an ever so slightly decreased odds (0.97 95% CI 0.49, 1.90). The 95% confidence interval for all of these odds ratios include the null, limiting our ability to draw conclusions on the observed relationships.

It was not possible to run a logistic regression for stage at diagnosis by household income alone given limitations within the RDC's confidentiality vetting procedure. However, two of our planned multivariate logistic regressions included household income. The results of multivariate logistic regressions are in Table 5. When studying the relationship between stage at diagnosis and education controlling for

household income, we note an increase in the odds ratio for higher education groups. The odds of a malignant melanoma diagnosis are increased for high school graduates who have an OR of 1.16 (95% CI 0.54, 2.49) when keeping household income constant compared to 1.03 (95% CI 0.50, 2.11) when unadjusted. In those with post-secondary education, the odds of a malignant melanoma diagnosis are 1.33 (95% CI 0.67, 2.62) when keeping household income constant compared to 1.19 (95% CI 0.65, 2.21) when unadjusted. The 95% CI includes the null for both education groups. In this regression, all four household income groups had a protective odds ratio against malignant melanoma at diagnosis compared to the reference category of income less than 20,000$ when keeping education constant, but once again the 95% CI included the null. There was minimal to no change in the odds of malignant melanoma by area of residence when controlling for education or household income (Table 5).

Correlation between demographic variables

The correlation matrix of the demographic variables used in our statistical analyses highlights a positive moderate correlation between education and household income (0.3528). Education and geography were also mildly to moderately positively correlated (0.2072). Correlation coefficients are presented in Table 6.

Discussion

Our melanoma-CCHS cohort of 360 Canadian melanoma patients diagnosed between 2010 and 2016 who responded to the 2015, 2016 and 2017 CCHS is composed largely of older and white Canadians. The finding of white race is consistent with what is known of melanoma as a cancer with increased risk in fair-skinned populations.(18) The average age of diagnosis is also consistent with the average age for the CCR melanoma sample.

Our findings suggest that women, higher household income and educated Canadians receive their diagnosis of melanoma at a younger age compared to those who are male, of the lowest household income and least educated groups.

There was an element of collinearity between household income and education, with both income and education affected by adjusting for the other. There is only a small observed association between area of residence and the age at diagnosis with slightly older age at diagnosis for small and medium population centres compared to rural area and urban areas.

Odds of malignant melanoma are increased in those from higher education groups, specifically post-secondary education compared to the reference group. These odds increase further when controlling for household income, which is protective in all household income groups compared to the reference. Odds of malignant melanoma are also slightly increased in small and urban centres compared to rural settings.

Sex

Our evidence suggests that women received diagnoses of melanoma earlier than men, and our odds ratio for stage suggests a very slightly decreased odds of malignant melanoma in women compared to men. We cannot conclude confidently on stage at diagnosis and sex given the proximity of our odds ratio to the null. It has been found that Canadian women seek care more often than men, which could explain earlier diagnosis age.(27) Additionally, Statistics Canada found that women practice more sun protective behaviours in situations of UVR exposure.(28) This could reflect a generally better awareness of sun safety and skin cancer prevention messaging in women(28), which could also contribute to the differences we observe by gender.

Household income and education

As noted, we expected some degree of collinearity between household income and education in the prediction of age at diagnosis. This was confirmed in our correlation matrix (Table 6) which demonstrated a positive moderate correlation between education and household income. Higher education and household income groups both have an earlier age at diagnosis in our analyses, including

strong observed relationships between household income and education on age at diagnosis. We are not surprised to see household income and education demonstrate a degree of collinearity and a weakening of associations when controlling education for household income as they remain closely tied sociodemographic characteristics. Higher education and household income groups having earlier age of detection of melanoma could be explained by better access to healthcare services as well as a greater healthcare literacy. This could be consistent with overdiagnosis(29-33), or simply an earlier diagnosis of a melanoma that would have progressed to an advanced disease. It is also possible that these groups develop melanoma at an earlier age due to their observed increased sun exposure patterns.(28)

In our multivariate analysis of in situ or malignant melanoma at diagnosis, we see an increased odds of malignant melanoma in higher education groups when adjusting for household income with what we consider to be a contradictory protective odds ratio for all household income groups compared to the reference lowest income group. Additionally, all four household income groups have similar OR's compared to the reference. We would have expected education and household income to behave in a similar direction for predicting stage at diagnosis. We are limited in interpreting these results by small odds ratios with 95% CI's that include the null.

Area of residence

There are small increases in age at diagnosis in small and medium population centres compared to rural and urban areas with small observed odds with confidence intervals that include the null for all coefficients on area of residence. When controlling for education, there is an increase in age at diagnosis in small, medium and urban centres compared to the reference. This suggests that the relationship between area of residence and age at diagnosis cannot be entirely explained by differences in sociodemographic characteristics of urban vs rural populations. Our staging analyses are limited to small OR's, and controlling for

education and household income does not meaningfully change the observed results.

Contribution to existing literature

Existing evidence on melanoma and sociodemographic characteristics in Canada has focused on melanoma incidence. Household income, education and occupation have all been associated with increased incidence of melanoma.(17, 18) Our evidence further suggests that women, higher educated and wealthier Canadians receive earlier diagnoses of melanoma. We postulate that our finding of younger age at diagnosis is driven by better healthcare access and health literacy, prompting individuals to present to care and receive an earlier diagnosis.

Existing literature has demonstrated that diagnosis at an older age increases the risk of more advanced disease.(23, 34, 35) Our data suggests that men, lower household income and lower education groups receive diagnosis at a later age, which would imply a higher risk of advanced disease. This is consistent with the one existing Canadian study which found more advanced disease in lower household income groups compared to higher household income groups.(23) Our staging regressions show protective odds against malignant melanoma for household income groups above the reference population. When it comes to education however, we note an increased odds of malignant melanoma for higher education groups. There is no Canadian literature on stage at diagnosis by education, however when we consider international studies, lower education levels are associated with later stage at diagnosis.(13)

Individual Canadian studies have not consistently identified associations between the incidence of melanoma by urban or rural settings(2, 17, 20, 23) and we were limited in our ability to highlight sizeable differences in age or stage at diagnosis.

Limitations

Our study has limitations. Firstly, we are limited by a small sample size of 360 individuals in our melanoma-CCHS cohort. This limits the size and precision of our estimates.

In addition to small sample size, our melanoma-CCHS cohort is spread across all of Canada, excluding Quebec. It is known that melanoma incidence varies across provinces, particularly around southern and coastal areas.(18, 36, 37) Our small sample does not allow for comparison within sub-groups of Canadian geography. The absence of data from Quebec is regrettable as it limits our sample size as well as the representation of individuals living in one of Canada's most populous provinces.

We are relying on reported cancer data. The CCR is certainly the most standardized and reliable source of cancer data nationally, but it is not without limitations. Each province provides its cancer files. There have been concerns about consistency and level of reporting for certain CCR variables by province. For instance, Ontario only began consistently providing in situ cancer data in 2010.(1, 25) We note the possibility of differential in situ vs malignant reporting, but there is no clear evidence of this suggested by the CCR or individual provinces(25). Key variables were available for our CCR analysis: age, sex, date of diagnosis and grade (in situ vs malignant). We had hoped to perform our logistic regressions with a more advanced staging system but were unable to do so because detailed staging data was largely absent for the CCR files.

In addition to limitations in our stage at diagnosis variable based on categorization as in situ or malignant, we were limited by the categorisation of some of our demographic variables. It is possible that the categorization of household income into five groups of 20,000$ increments limited the ability to detect the full extent of income inequalities and gaps. Especially since the literature suggested that our sample was made up of higher income individuals who would be included in the highest income categories with no way to evaluate differences in total household

incomes past 80,000$. Area of residence size categorization could similarly have affected the ability to determine how and if rural and urban dwelling affect age and stage of diagnosis.

Implications

This research highlights inequities in the distribution of melanoma cases within the Canadian public. In addition to non-modifiable characteristics of age and race, melanoma is being diagnosed at a younger age for women, educated and higher household income Canadians. Questions remain as to whether this reflects earlier onset of disease(28), earlier detection of disease through better access to care or healthcare literacy(31, 33) and surveillance of skin for worrisome findings, or a combination of the above. We were not able to demonstrate that these populations had a decreased risk of advanced disease at diagnosis with our staging data, which is what we suspected. As incident melanoma cases are expected to continue to increase in Canada(1), a more complete understanding of why women, higher educated and higher household income Canadians are receiving earlier diagnosis and care is needed, to ensure that all Canadians can received optimized preventive care for melanoma.

Our research opens the door for further study to inform and guide public health policy directions. There is significant opportunity to identify the mechanisms that underlie the earlier detection of melanoma in women, educated and high household income individuals and identify how to ensure screening programs and education campaigns can reach those who are not accessing care as early.

Conclusions

In this study of 360 melanoma patients who responded to the CCHS, women, higher household income and educated individuals received their melanoma diagnosis at a younger age compared to those who were male, of a lower household income or less educated. We did not observe important associations between area of residence size and age at diagnosis. Limitations in staging data

did not allow for the identification of significant associations between sociodemographic variables and stage at diagnosis. Areas of future study to complement our findings would include further characterisation of sociodemographic characteristics on stage of diagnosis with complete staging data and enhanced details for personal and household income and rural vs urban dwelling. A characterisation of access to healthcare within these groups is also essential to explain the mechanisms behind ages and stages at diagnosis. Cancer advocacy groups and policy makers will benefit from this improved characterisation of at-risk populations and unreached individuals in our universal healthcare system.

Abbreviations

RDC: Research Data Centre
CCHS: Canadian Community Health Survey
CCR: Canadian Cancer Registry
OR: odds ratio
SES: socioeconomic status
UVR: ultraviolet radiation

Declarations

Ethics approval: expedited ethics review was obtained through McGill University.
Data access: data was accessed exclusively through the McGill University RDC.
Competing interest: none

Figure 1: Melanoma CCR sample obtained from all linked CCR files

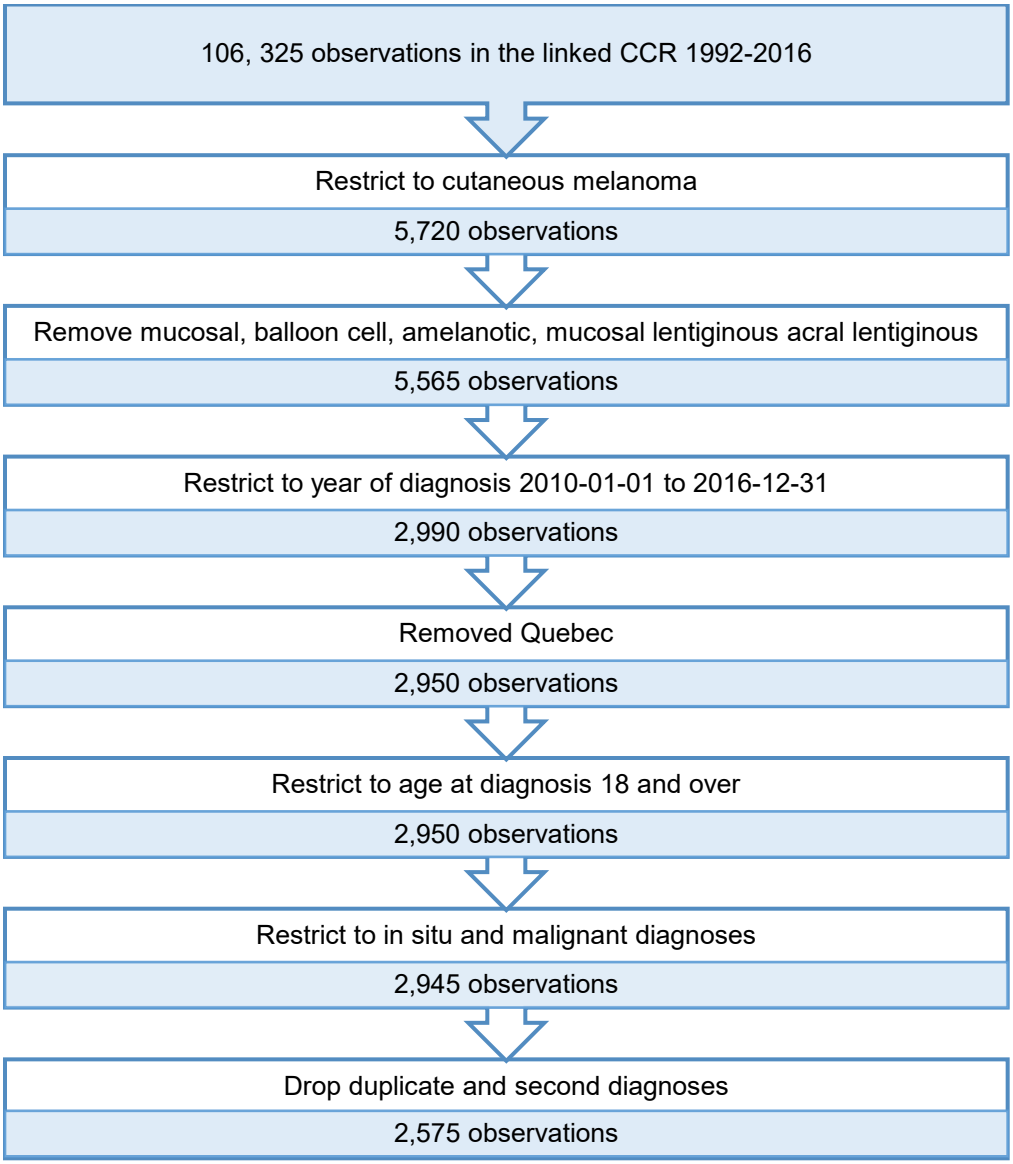


Figure 2: CCHS sample of respondents to the 2015, 2016 and 2017 cycles

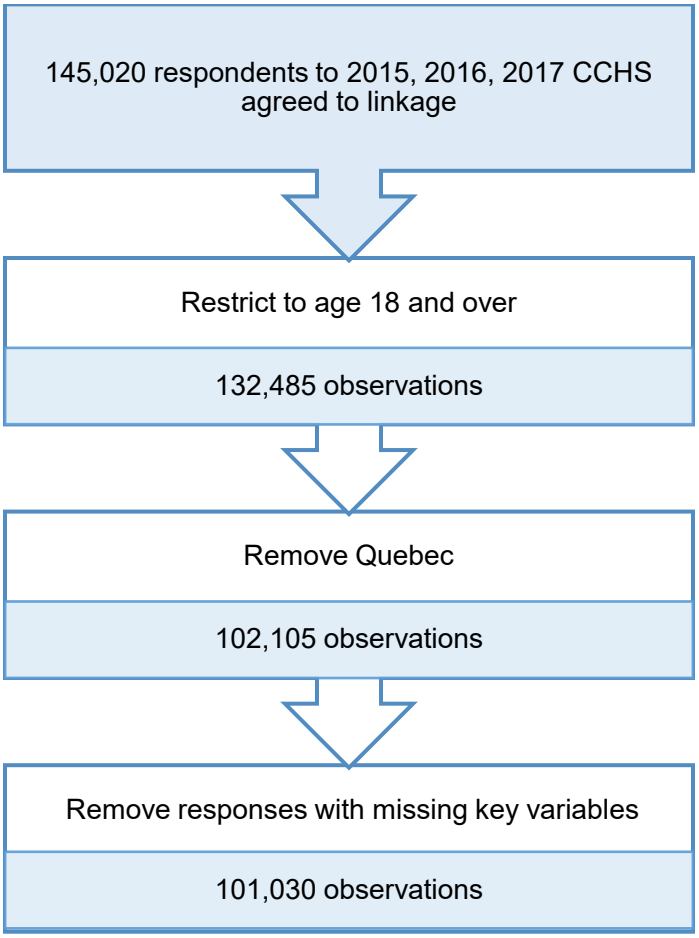
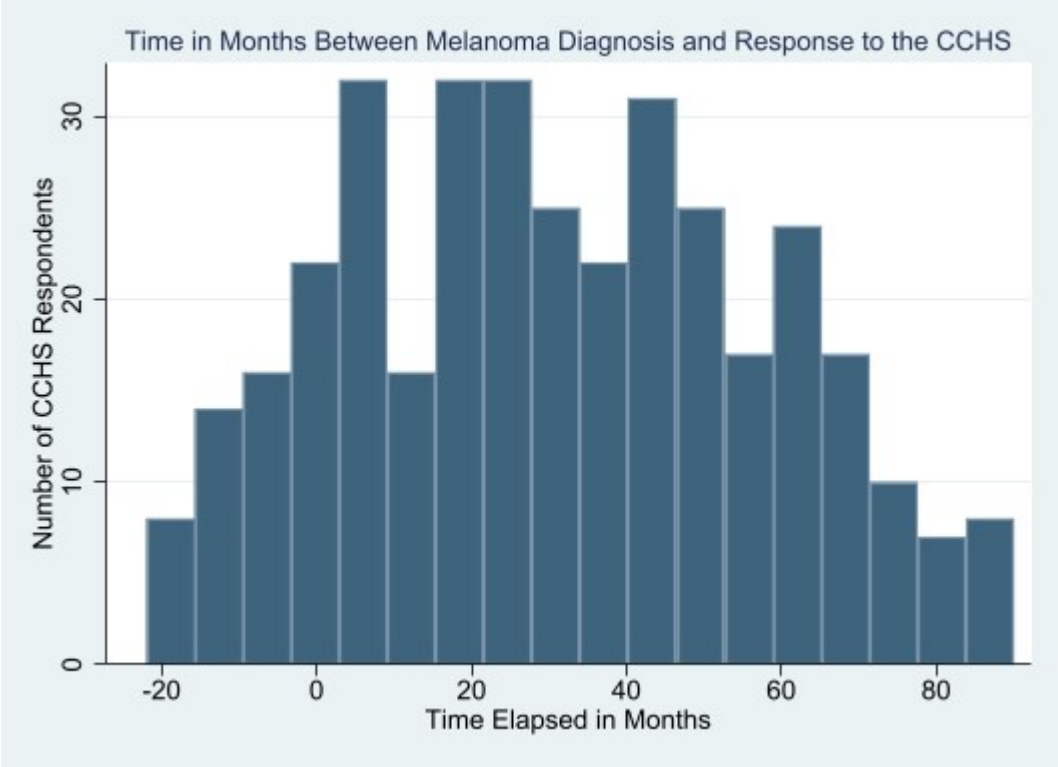


Figure 3: Distribution of CCHS responses in relation to melanoma diagnosis



This figure shows the number of months between diagnosis of melanoma (time = 0) and response to the CCHS. Positive time in months means the CCHS response was after a diagnosis of melanoma. Negative time in months is for patients who answered the CCHS prior to their melanoma diagnosis. The y axis is the number of individuals for each month interval.

Table 1: Sociodemographic characteristics of the melanoma-CCHS cohort, CCHS respondents sample and melanoma CCR sample, excluding Quebec[1, 2]

		Melanoma-CCHS cohort	CCHS sample[3]	Melanoma CCR sample[4]
Number of individuals		360	101,030	2,575
Sex	Male	180 (50%)	45,850 (45%)	1,320 (51%)
	Female	180 (50%)	55,175(55 %)	1,255 (49%)
Average age (years)	At diagnosis	64.5		67
	At CCHS response	67	52	
Race	White	350 (97%)	83,755 (83%)	
	Non-white	5 (1%)	10,625 (11%)	
	Non-stated, unknown	5 (1%)	6,650 (7%)	
Education	Less than high school	50 (14%)	14,810 (15%)	
	High school degree, no post-secondary degree	75 (21%)	25,070 (25%)	
	Post-secondary certificate, diploma, university degree	235 (65%)	61,145 (61%)	
Total estimated household income before taxes	No income or less than $20,000	20 (6%)	8,140 (8%)	
	$20,000 to $39,999	70 (19%)	18,030 (18%)	
	$40,000 to $59,999	70 (19%)	17,415 (17%)	
	$60,000 to $79,999	50 (14%)	15,260 (15%)	
	$80,000 or more	150 (42%)	42,185 (42%)	
Area of residence	Rural area (≤ 1,000)	85 (24%)	27,500 (27%)	
	Small population centre (1,000 - 29,999)	75 (21%)	21,740 (22%)	
	Medium population centre (30,000 - 99,999)	60 (16%)	14,350 (14%)	
	Large urban population centre (≥ 100,000)	140 (39%)	37,440 (37%)	

[1]Due to Statistics Canada rounding for confidentiality, values may be slightly discrepant.

[2] Shaded empty cells are for variables that do not exist in each dataset or sample.

[3]CCHS responses to 2015-2016-2017 cycles, excluding Quebec, for respondents over 18 who consent to data linkage.

[4] Melanoma CCR files from 2010-2016 included in Statistics Canada linkage project.

Table 2: Bivariate regressions of age at diagnosis by sociodemographic characteristics[1]

Sociodemographic variable	Difference in years[2] and 95 CI%
Sex	
Male	Reference
Female	-3.29 (-6.31, -0.28)
Education	
Less than High School	Reference
High School Graduate	-5.55 (-10.61, -0.48)
Post Secondary Education	-10.39 (-14.72, -6.07)
Area of residence	
Rural (< 1,000)	Reference
Small population centre (1,000 to 29,999)	1.32 (-3.22, 5.87)
Medium population centre (30,000 to 99,999)	2.24 (-2.66, 7.14)
Large urban population centre (100,000 or greater)	0.15 (-3.81, 4.12)
Total household income	
No income or less than $20,000	Reference
$20,000 to $39,999	-1.98 (-8.75, 4.79)
$40,000 to $59,999	-6.48 (-13.27, 0.32)
$60,000 to $79,999	-2.91 (-10.02, 4.20)
$80,000 or more	-12.37 (-18.73, -6.01)

[1] *Regressions were run on the complete sample, n=360.*

[2] *Our regression coefficient represents a difference diagnosis age in years.*

Table 3: Multivariate regressions of age at diagnosis by sociodemographic characteristics[1]

Sociodemographic variables	Difference in years and 95 CI% as a bivariate regression[1]	Multivariate adjusted difference in years and 95 CI%[1]
Education controlling for total household income		
Less than High School	Reference	Reference
High School Graduate	-5.55 (-10.61, -0.48)	-3.27 (-8.46, 1.92)
Post Secondary Education	-10.39 (-14.72, -6.07)	-6.90 (-11.50, -2.30)
No income or less than $20,000	Reference	Reference
$20,000 to $39,999	-1.98 (-8.75, 4.79)	-0.17 (-6.99, 6.64)
$40,000 to $59,999	-6.48 (-13.27, 0.32)	-3.72 (-10.75, 3.32)
$60,000 to $79,999	-2.91 (-10.02, 4.20)	-0.19 (-7.53, 7.14)
$80,000 or more	-12.37 (-18.73, -6.01)	-8.80 (-15.53, -2.07)
Area of residence controlling for education		
Rural (< 1,000)	Reference	Reference
Small population centre (1,000 to 29,999)	1.32 (-3.22, 5.87)	2.31 (-2.11, 6.73)
Medium population centre (30,000 to 99,999)	2.24 (-2.66, 7.14)	4.03 (-0.79, 8.84)
Large urban population centre (100,000 or greater)	0.15 (-3.81, 4.12)	2.26 (-1.66, 6.18)
Less than High School	Reference	Reference
High School Graduate	-5.55 (-10.61, -0.48)	-6.26 (-11.40, -1.12)
Post Secondary Education	-10.39 (-14.72, -6.07)	-11.10 (-15.53, -6.66)
Area of residence controlling for total household income		
Rural (< 1,000)	Reference	Reference
Small population centre (1,000 to 29,999)	1.32 (-3.22, 5.87)	0.57 (-3.78, 4.93)
Medium population centre (30,000 to 99,999)	2.24 (-2.66, 7.14)	3.00 (-1.67, 7.67)
Large urban population centre (100,000 or greater)	0.15 (-3.81, 4.12)	0.80 (-2.99, 4.59)
No income or less than $20,000	Reference	Reference
$20,000 to $39,999	-1.98 (-8.75, 4.79)	-2.02 (-8.83, 4.79)
$40,000 to $59,999	-6.48 (-13.27, 0.32)	-6.75 (-13.61, 0.10)
$60,000 to $79,999	-2.91 (-10.02, 4.20)	-3.17 (-10.36, 4.01)
$80,000 or more	-12.37 (-18.73, -6.01)	-12.60 (-19.00, -6.20)

[1] *Regressions were run on the complete sample, n=360.*

[2] *Our regression coefficient represents a difference diagnosis age in years.*

Table 4: Logistic regressions for the odds ratio of malignant melanoma by sociodemographic characteristics[1,2]

Sociodemographic variables	Odds ratio[3] and 95 CI%
Sex	
Male	Reference
Female	0.94 (0.62, 1.44)
Education	
Less than High School	Reference
High School Graduate	1.03 (0.50, 2.11)
Post Secondary Education	1.19 (0.65, 2.21)
Area of residence	
Rural (< 1,000)	Reference
Small population centre (1,000 to 29,999)	1.08 (0.58, 2.03)
Medium population centre (30,000 to 99,999)	0.97 (0.49, 1.90)
Large urban population centre (100,000 or greater)	1.08 (0.63, 1.87)

[1] *Regressions were run on the complete sample, n=360.*

[2] *Logistic regression of odds ratio of malignant melanoma by income could not be extracted from the RDC due to confidentiality limitations.*

[3] *The odds ratio is the odds of a malignant melanoma at diagnosis.*

Table 5: Multivariate logistic regressions for the odds ratio of malignant melanoma by sociodemographic characteristics [1,2]

Sociodemographic variables	Odds ratio and 95 CI% as a bivariate regression	Odds ratio and 95 CI% as multivariate regression
Education controlling for total household income		
No income or less than $20,000		Reference
$20,000 to $39,999		0.40 (0.14, 1.18)
$40,000 to $59,999		0.49 (0.16, 1.49)
$60,000 to $79,999		0.37 (0.12, 1.17)
$80,000 or more		0.49 (0.17, 1.43)
Less than High School	Reference	Reference
High School Graduate	1.03 (0.50, 2.11)	1.16 (0.54, 2.49)
Post Secondary Education	1.19 (0.65, 2.21)	1.33 (0.67, 2.62)
Area of residence controlling for education		
Less than High School	Reference	Reference
High School Graduate	1.03 (0.50, 2.11)	1.03 (0.50, 2.14)
Post Secondary Education	1.19 (0.65, 2.21)	1.19 (0.64, 2.24)
Rural (< 1,000)	Reference	Reference
Small population centre (1,000 to 29,999)	1.08 (0.58, 2.03)	1.06 (0.57, 2.01)
Medium population centre (30,000 to 99,999)	0.97 (0.49, 1.90)	0.95 (0.48, 1.88)
Large urban population centre (100,000 or greater)	1.08 (0.63, 1.87)	1.04 (0.60, 1.82)
Area of residence controlling for total household income		
Rural (< 1,000)	Reference	Reference
Small population centre (1,000 to 29,999)	1.08 (0.58, 2.03)	1.06 (0.56, 2.00)
Medium population centre (30,000 to 99,999)	0.97 (0.49, 1.90)	0.96 (0.49, 1.89)
Large urban population centre (100,000 or greater)	1.08 (0.63, 1.87)	1.03 (0.59, 1.78)
No income or less than $20,000		Reference
$20,000 to $39,999		0.44 (0.15, 1.26)
$40,000 to $59,999		0.56 (0.19, 1.63)
$60,000 to $79,999		0.42 (0.14, 1.29)
$80,000 or more		0.58 0.21, 1.58)

[1] Regressions were run on the complete sample, n=360.

[2] Shaded cells are due to confidentiality restrictions that prohibit sharing of simple logistic regression results for income.

Table 6: Correlation coefficient between sociodemographic characteristics

	Sex	Education	Household income	Area of residence
Sex	1			
Education	0.0113	1		
Household income	-0.176	0.3528	1	
Area of residence	-0.0482	0.2072	0.0748	1

Reference list

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 2023. Toronto, ON; 2023.

2. Johnson-Obaseki SE, Labajian V, Corsten MJ, McDonald JT. Incidence of cutaneous malignant melanoma by socioeconomic status in Canada: 1992-2006. J Otolaryngol Head Neck Surg. 2015;44:53.

3. World Health Organization. Radiation: Ultraviolet (UV) radiation and skin cancer 2017 [Available from: https://www.who.int/news-room/questions-and-answers/item/radiation-ultraviolet-(uv)-radiation-and-skin-cancer].

4. Parker ER. The influence of climate change on skin cancer incidence - A review of the evidence. Int J Womens Dermatol. 2021;7(1):17-27.

5. The Lancet O. Climate change and skin cancer: urgent call for action. Lancet Oncol. 2023;24(8):823.

6. Canadian Task Force on Preventive Health Care. Published guidelines: The Canadian Task Force on Preventive Health Care; 2023 [Available from: https://canadiantaskforce.ca/guidelines/published-guidelines/].

7. Joshua AM. Melanoma prevention: are we doing enough? A Canadian perspective. Curr Oncol. 2012;19(6):e462-7.

8. Mangione CM, Barry MJ, Nicholson WK, Chelmow D, Coker TR, Davis EM, et al. U. S. Preventive Services Task Force. Screening for Skin Cancer: US Preventive Services Task Force Recommendation Statement. JAMA. 2023;329(15):1290-5.

9. Singh SD, Ajani UA, Johnson CJ, Roland KB, Eide M, Jemal A, et al. Association of cutaneous melanoma incidence with area-based socioeconomic indicators-United States, 2004-2006. J Am Acad Dermatol. 2011;65(5 Suppl 1):S58-68.

10. Ortiz CA, Goodwin JS, Freeman JL. The effect of socioeconomic factors on incidence, stage at diagnosis and survival of cutaneous melanoma. Med Sci Monit. 2005;11(5):RA163-72.

11. Pearce J, Barnett R, Kingham S. Slip! Slap! Slop! Cutaneous malignant melanoma incidence and social status in New Zealand, 1995-2000. Health Place. 2006;12(3):239-52.

12. van der Aa MA, de Vries E, Hoekstra HJ, Coebergh JW, Siesling S. Sociodemographic factors and incidence of melanoma in the Netherlands, 1994-2005. Eur J Cancer. 2011;47(7):1056-60.

13. Eriksson H, Lyth J, Mansson-Brahme E, Frohm-Nilsson M, Ingvar C, Lindholm C, et al. Low level of education is associated with later stage at diagnosis and reduced survival in cutaneous malignant melanoma: a nationwide population-based study in Sweden. Eur J Cancer. 2013;49(12):2705-16.

14. Haynes R, Pearce J, Barnett R. Cancer survival in New Zealand: ethnic, social and geographical inequalities. Soc Sci Med. 2008;67(6):928-37.

15. Lyratzopoulos G, Abel GA, Brown CH, Rous BA, Vernon SA, Roland M, Greenberg DC. Socio-demographic inequalities in stage of cancer diagnosis: evidence from patients with female breast, lung, colon, rectal, prostate, renal, bladder, melanoma, ovarian and endometrial cancer. Ann Oncol. 2013;24(3):843-50.

16. Youl PH, Baade PD, Parekh S, English D, Elwood M, Aitken JF. Association between melanoma thickness, clinical skin examination and socioeconomic status: results of a large population-based study. Int J Cancer. 2011;128(9):2158-65.

17. Li HO, Bailey AJ, Grose E, McDonald JT, Quimby A, Johnson-Obaseki S, Nessim C. Socioeconomic Status and Melanoma in Canada: A Systematic Review. J Cutan Med Surg. 2021;25(1):87-94.

18. Pinault L, Bushnik T, Fioletov V, Peters CE, King WD, Tjepkema M. The risk of melanoma associated with ambient summer ultraviolet radiation. Health Rep. 2017;28(5):3-11.

19. Gorey KM, Holowaty EJ, Laukkanen E, Fehringer G, Richter NL. Association between socioeconomic status and cancer incidence in Toronto, Ontario: possible confounding of cancer mortality by incidence and survival. Cancer Prev Control. 1998;2(5):236-41.

20. Haider A, Mamdani M, Shear NH. Socioeconomic status and the prevalence of melanoma in Ontario, Canada. J Cutan Med Surg. 2007;11(1):1-3.

21. Langley A, Levesque L, Baetz T, Asai Y. Brief Report: Increase in Melanoma Incidence in Ontario. J Cutan Med Surg. 2018;22(5):476-8.

22. Davis LE, Mahar AL, Strumpf EC. Agreement between individual and neighborhood income measures in patients with colorectal cancer in Canada. J Natl Cancer Inst. 2023;115(5):514-22.

23. Mavor ME, Richardson H, Miao Q, Asai Y, Hanna TP. Disparities in diagnosis of advanced melanoma: a population-based cohort study. CMAJ Open. 2018;6(4):E502-E12.

24. Statistics Canada. Canadian Population Health Survey data (CCHS Annual and Focus Content) integrated with mortality, hospitalization, historical postal codes, cancer, tax data and Census Canada. 2022. updated 2022-09-22. [Available from: https://www.statcan.gc.ca/en/microdata/data-centres/data/cchs.]

25. Canada S. Canadian Cancer Registry (CCR) Canada. updated 2023-05-15. Available from: [https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3207#a2].

26. Statistics Canada. Canadian Community Health Survey - Annual Component (CCHS). updated 2023-01-03. [Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226]

27. Thompson AE, Anisimowicz Y, Miedema B, Hogg W, Wodchis WP, Aubrey-Bassler K. The influence of gender and other patient characteristics on health care-seeking behaviour: a QUALICOPC study. BMC Fam Pract. 2016;17:38.

28. Pinault L, Fioletov V. Sun exposure, sun protection and sunburn among Canadian adults. Health Rep. 2017;28(5):12-9.

29. Welch HG, Fisher ES. Income and Cancer Overdiagnosis - When Too Much Care Is Harmful. N Engl J Med. 2017;376(23):2208-9.

30. Welch HG, Mazer BL, Adamson AS. The Rapid Rise in Cutaneous Melanoma Diagnoses. N Engl J Med. 2021;384(1):72-9.

31. Weyers W. The 'epidemic' of melanoma between under- and overdiagnosis. J Cutan Pathol. 2012;39(1):9-16.

32. Theriault G, Grad R, Dickinson JA, Singh H, Antao V, Bell NR, Szafran O. Beware of overdiagnosis harms from screening, lower diagnostic thresholds, and incidentalomas. Can Fam Physician. 2023;69(2):97-100.

33. Adamson AS, Welch H, Welch HG. Association of UV Radiation Exposure, Diagnostic Scrutiny, and Melanoma Incidence in US Counties. JAMA Intern Med. 2022;182(11):1181-9.

34. Austin PF, Cruse CW, Lyman G, Schroer K, Glass F, Reintgen DS. Age as a prognostic factor in the malignant melanoma population. Ann Surg Oncol. 1994;1(6):487-94.

35. Lasithiotakis K, Leiter U, Meier F, Eigentler T, Metzler G, Moehrle M, et al. Age and gender are significant independent predictors of survival in primary cutaneous melanoma. Cancer. 2008;112(8):1795-804.

36. Conte S, Ghazawi FM, Le M, Nedjar H, Alakel A, Lagace F, et al. Population-Based Study Detailing Cutaneous Melanoma Incidence and Mortality Trends in Canada. Front Med (Lausanne). 2022;9:830254.

37. Ghazawi FM, Cyr J, Darwich R, Le M, Rahme E, Moreau L, et al. Cutaneous malignant melanoma incidence and mortality trends in Canada: A comprehensive population-based study. J Am Acad Dermatol. 2019;80(2):448-59.

Postscript to manuscript

In this manuscript, I demonstrated an association between higher household income, education and female sex and earlier age at melanoma diagnosis. Additionally, this association appears greatest when comparing highest and lowest household income and education groups.

This manuscript highlights the need for continued study to understand inequities in cancer care within Canadian healthcare institutions. More research is needed to understand the relationships we have observed and the mechanisms that explain earlier diagnosis of melanoma. That knowledge will be instrumental to create health programs and administer services in an equitable way.

Chapter 5: Discussion of the results

There are multiple additional considerations in the analysis and next steps from the manuscript.

Confounding

There were possible confounders to the associations under study that could not be accounted for using the existing CCHS and CCR datasets. A confounder of great interest is the practice of sun safety behaviours. If possible, I would have considered the associations under study while accounting for sun safety behaviours across all sociodemographic characteristics. Other possible confounders to consider would be occupational or recreational sun exposure, skin pigmentation and access to primary care or specialized dermatological care.

Selection bias

Using a linked dataset allowed me to obtain sociodemographic characteristics for individuals with a melanoma diagnosis from across the country. There is no way to obtain this level of information for all incident melanoma cases as this data is not integrated directly into the CCR. The use of CCR files that were linked to the CCHS provided me with the sociodemographic information I required, but it did open my cohort to selection bias because I only had access to melanoma cases included through a CCHS cycle. This also significantly reduced my sample size compared to the overall burden and case count of melanoma in Canada.

There are known exclusions to the CCHS: persons living on reserves and other Aboriginal settlements, persons living in Nunavik and Terres-Cries-de-la-Baie-James, full-time armed forces members and institutionalized persons(59). This means that my sample did not include these populations who, while comprising less than 3% of the Canadian public, deserve inclusion in such national-level analyses.

Selection into the CCHS sample may also be differential based on sampling methodology. Statistics Canada does not provide specific information on whether the sampling structure of the CCHS leads to under-represented groups for my variables of interest. For instance, if vulnerable and low-income individuals were less likely to be included in the CCHS sampling structure, it is possible that this group was differentially underrepresented in my melanoma-CCHS cohort. Selection into the CCHS sample may also be differential based on response, which is voluntary.(59) From a cancer epidemiology perspective, differential response based on diagnosis is a source of bias. In those already diagnosed at the time of the CCHS, if individuals with advanced melanoma refused to respond to the CCHS in larger numbers than those with earlier stage disease, these more advanced cases would be absent from my sample.

Consent to data linkage may also limit cases from becoming part of my sample. Respondents to the CCHS are asked to consent to participate in linked datasets. I was unable to find information to suggest that patients with melanoma or specific sociodemographic characteristics are more or less likely to consent to data linkage.

Information bias

Information bias could have affected my sample through the CCR files. Each province reports incident cancer diagnoses to the CCR from their provincial and territorial cancer registries on a yearly basis. As noted in the 2023 Canadian Cancer Statistics Report, reporting procedures and information are still uneven across provinces, though there has been continued improvement of case-finding and mortality data. Under reporting of in situ cancers(1) is a concern for my study since I used in situ and malignant categories as a stand in for staging in my logistic regression. I was unable to use detailed staging data because of missing data and minimal staging reporting by certain provinces. Under-reporting of in situ cases means that my sample may be smaller and may be disproportionally malignant. This is especially relevant in the context of possible overdiagnosis.(7) The effect

of overdiagnosis will be underappreciated if in situ melanomas are missing from my sample.

Of course, the absence of data from Quebec is a significant source of information bias when leading a national study on cancer data. This is due to Quebec ending its participation in the CCR as of 2010 when it stopped contributing cancer data.(1) When it comes to other provinces though, issues noted with reporting for Ontario and Newfoundland and Labrador have improved by the years of interest for my sample.(1)

In the lab, I had access to both the CCR and the IARC files for cancer data. The CCR file was chosen because it includes more cancer diagnoses. This is due to stricter reporting rules for multiple cancer diagnoses in the IARC.(1) Considering that individuals may have multiple melanoma diagnoses in their lifetime, I wanted to be sure to capture diagnoses in 2010-2016, and not be limited to only a first diagnosis which may have occurred outside if my study period.

Information bias: categorical variables

In addition to limitations in reporting of cancer data, specifically cancer staging data, I was limited by the classification of some of my categorical variables. The categories used for some sociodemographic characteristics may have limited the ability to observe certain relationships. Total household income in the CCHS came from either linked tax files, self-reported household income if tax files were unavailable or linkage was refused or lastly from imputation based on a nearest neighbour imputation.(59, 60) Total household income was divided into five groups, with the lowest income group of less than 20,000$ and the highest income group of 80,000$ as an annual household income. These categories are not household income quintiles for the Canadian public. As such, the distribution of household income in my sample and in the CCHS is uneven, with most Canadians in the higher income categories. Importantly, this categorization makes it impossible to fully capture variations in wealth and household income with the

granularity that a continuous income variable would have afforded me. In future research, utilizing T1 tax files linked to the CCHS and CCR files to obtain a continuous variable for all cycles would provide this additional level of detail.
I used area of residence size as a proxy for access to healthcare services and chose to control for education and household income to better appreciate rurality without sociodemographic differences in population centres. This remains an imperfect proxy for healthcare service access, especially in the context of a nationwide study. Access and proximity to services is influenced by far more than population size alone, including by province size and geographic proximity to another large region.(61) Future studies could use healthcare access data from the CCHS to study the relationship between access to primary care and specialist care and melanoma diagnosis.

Melanoma incidence also varies across the country with higher incidence in coastal and southern areas. I did not have a sufficient sample size to restrict my sample to specific regions, but this could be considered in future research. For instance, the impact of area of residence size could be explored more specifically in coastal eastern parts of Canada, such as Nova Scotia and Prince Edward Island, which have some of the highest incidence rates of melanoma in Canada.(1, 27)

Importantly, limited staging data restricted our staging analysis to a binary in situ vs malignant category. This is a significant loss of information of the four stages of malignant melanoma, which carry differences in clinical care, severity and survival.(40, 41)

Timing of responses

The melanoma-CCHS cohort included individuals who responded to the CCHS before they had a diagnosis of melanoma, and individuals who responded to the CCHS after they had a melanoma diagnosis. My preference was for individuals to have answered to the CCHS prior to receiving a diagnosis of melanoma, to obtain their sociodemographic characteristics without capturing potential impacts of the

disease. For example, loss of household income following cancer diagnosis and treatments. However, since the vast majority of my sample responded to the CCHS after their diagnosis, I included both timing options in the sample.

Timing of response is unlikely to affect most of the sociodemographic variables I studied. For the adults in my sample, the passage of a few years after being diagnosed with melanoma would not affect their response to sex, race or education in the CCHS. Total household income is the variable most likely to be affected. For instance, individuals having retired or stopped working due to their diagnosis would no longer have a household income at the time of response that captures their income at the time of diagnosis. Considering that about half of my sample is made up of in situ cancers, there would likely be no impact on earning based on a treatment with a simple resection. Similarly, for low stage malignant melanoma's, treatment options are minimally invasive and would not cause lasting impact on a household's income. This leaves only a small number of advanced melanoma cases in which individuals may see household income affected. Area of residence size may have changed for some respondents between CCR and CCHS diagnosis. This is unlikely to be tied directly to a melanoma diagnosis. It is not impossible that an individual with advanced cancer would move to be closer to a large hospital centre but remains a very tiny proportion of individuals.

Despite limitations, this research is a first use of linked datasets to study sociodemographic characteristics of melanoma in Canada. More work needs to be done to understand the mechanisms behind earlier diagnosis in certain populations. Next steps could include use of linked tax files and use of access to care information. As provinces continue to enrich the CCR, staging data may also eventually be available at a more detailed level.

Chapter 6: Conclusion

Melanoma continues to be a life-threatening cancer with increasing incidence in Canada for which there is no organized screening or national prevention strategy.(58) Understanding which populations are benefitting from early detection and early stage at diagnosis, and which require increased access and education is essential to guide equitable policy interventions. My findings suggest better access to early diagnosis in women, more educated and wealthier Canadians. Strategies to improve early detection and prevention of melanoma will have to take into account that men, lower education and lower household income groups are less reached by current messaging. Without this information, any future strategies would be likely to further benefit women, more educated and wealthier Canadians and deepen the observed inequities. Future research should further study the relationships observed between sociodemographic characteristics, specifically with improved staging data.

Appendix 1: Ethics approval

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eRAP/Info-Ed File Number: 23-08-038 **IRB Internal Study Number: A09-M52-23B**

Study Title: *Identifying Social Determinants of Melanoma Incidence and Diagnosis*

McGill Principal Investigator: Erin Strumpf

McGill Student Investigator: Julia Louise Heron

Dear Dr. Strumpf,

Thank you for submitting the above-referenced study for an ethics review, on behalf of your Master's student, Julia Louise Heron.

As this study involves no more than minimal risk, and in accordance with Articles 2.9 and 6.12 of the 2nd Edition of the Canadian Tri-Council Policy Statement of Ethical Conduct for Research Involving Humans (TCPS 2) and U.S. Title 45 CFR 46, Section 110 (b), paragraph (1), we are pleased to inform you that an expedited/delegated review was conducted and ethics approval for the study was provided on September 22, 2023. **The ethics certificate is valid until September 21, 2024**. The study proposal will be presented for corroborative approval at the next meeting of the Institutional Review Board.

The following documents were reviewed and approved:
- Initial Ethics Submission Form dated August 14, 2023
- Study Protocol, June 12, 2023

The Faculty of Medicine Institutional Review Board (IRB) is a registered University IRB working under the published guidelines of the Tri-Council Policy Statement 2, in compliance with the *Cadre de reference ministériel pour la recherche avec des participants humains* (MSSS, 2020), and the Food and Drugs Act (17 June 2001); and acts in accordance with the U.S. Code of Federal Regulations that govern research on human subjects (**FWA 00004545**). The IRB working procedures are consistent with internationally accepted principles of good clinical practice.

The Principal Investigator is required to immediately notify the Institutional Review Board Office, via amendment or progress report, of:

Reference list

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 2023. Toronto, ON; 2023.

2. Canadian Cancer Society. Finding skin cancer early. Canada. 2023 [Available from: https://cancer.ca/en/cancer-information/cancer-types/skin-melanoma/finding-cancer-early].

3. Johnson-Obaseki SE, Labajian V, Corsten MJ, McDonald JT. Incidence of cutaneous malignant melanoma by socioeconomic status in Canada: 1992-2006. J Otolaryngol Head Neck Surg. 2015;44:53.

4. Weyers W. The 'epidemic' of melanoma between under- and overdiagnosis. J Cutan Pathol. 2012;39(1):9-16.

5. Adamson AS, Welch H, Welch HG. Association of UV Radiation Exposure, Diagnostic Scrutiny, and Melanoma Incidence in US Counties. JAMA Intern Med. 2022;182(11):1181-9.

6. Welch HG, Mazer BL, Adamson AS. The Rapid Rise in Cutaneous Melanoma Diagnoses. N Engl J Med. 2021;384(1):72-9.

7. Welch HG, Fisher ES. Income and Cancer Overdiagnosis - When Too Much Care Is Harmful. N Engl J Med. 2017;376(23):2208-9.

8. Singh H, Dickinson JA, Theriault G, Grad R, Groulx S, Wilson BJ, et al. Overdiagnosis: causes and consequences in primary health care. Can Fam Physician. 2018;64(9):654-9.

9. Baines CJ, To T, Miller AB. Revised estimates of overdiagnosis from the Canadian National Breast Screening Study. Prev Med. 2016;90:66-71.

10. Theriault G, Grad R, Dickinson JA, Singh H, Antao V, Bell NR, Szafran O. Beware of overdiagnosis harms from screening, lower diagnostic thresholds, and incidentalomas. Can Fam Physician. 2023;69(2):97-100.

11. Mitra D, Shaw A, Tjepkema M, Peters P. Social determinants of lung cancer incidence in Canada: A 13-year prospective study. Health Rep. 2015;26(6):12-20.

12. Hajizadeh M, Charles M, Johnston GM, Urquhart R. Socioeconomic inequalities in colorectal cancer incidence in Canada: trends over two decades. Cancer Causes Control. 2022;33(2):193-204.

13. Purificacion SJ, French JG, d'Agincourt-Canning L. Inequities in access to cancer care in Canada: An ethical perspective. Healthc Manage Forum. 2015;28(6):265-9.

14. Jackson EB, Simmons CE, Chia SK. Current Challenges and Disparities in the Delivery of Equitable Breast Cancer Care in Canada. Curr Oncol. 2023;30(8):7263-74.

15. Li HO, Bailey AJ, Grose E, McDonald JT, Quimby A, Johnson-Obaseki S, Nessim C. Socioeconomic Status and Melanoma in Canada: A Systematic Review. J Cutan Med Surg. 2021;25(1):87-94.

16. Pinault L, Bushnik T, Fioletov V, Peters CE, King WD, Tjepkema M. The risk of melanoma associated with ambient summer ultraviolet radiation. Health Rep. 2017;28(5):3-11.

17. van der Aa MA, de Vries E, Hoekstra HJ, Coebergh JW, Siesling S. Sociodemographic factors and incidence of melanoma in the Netherlands, 1994-2005. Eur J Cancer. 2011;47(7):1056-60.

18. Eriksson H, Lyth J, Mansson-Brahme E, Frohm-Nilsson M, Ingvar C, Lindholm C, et al. Low level of education is associated with later stage at diagnosis and reduced survival in cutaneous malignant melanoma: a nationwide population-based study in Sweden. Eur J Cancer. 2013;49(12):2705-16.

19. Haynes R, Pearce J, Barnett R. Cancer survival in New Zealand: ethnic, social and geographical inequalities. Soc Sci Med. 2008;67(6):928-37.

20. Youl PH, Baade PD, Parekh S, English D, Elwood M, Aitken JF. Association between melanoma thickness, clinical skin examination and socioeconomic status: results of a large population-based study. Int J Cancer. 2011;128(9):2158-65.

21. Lyratzopoulos G, Abel GA, Brown CH, Rous BA, Vernon SA, Roland M, Greenberg DC. Socio-demographic inequalities in stage of cancer diagnosis: evidence from patients with female breast, lung, colon, rectal, prostate, renal, bladder, melanoma, ovarian and endometrial cancer. Ann Oncol. 2013;24(3):843-50.

22. Brastianos HC, Nguyen P, Sahgal A, Eisenhauer EA, Baetz T, Hanna TP. Association of Innovations in Radiotherapy and Systemic Treatments With Clinical Outcomes in Patients With Melanoma Brain Metastasis From 2007 to 2016. JAMA Netw Open. 2020;3(7):e208204.

23. Bergeron C, Moran C, Coroiu A, Korner A. Development and initial validation of the Self-Efficacy for Skin Self-Examination Scale in a Canadian sample of patients with melanoma. Eur J Oncol Nurs. 2019;40:78-84.

24. Aase A, Bentham G. Gender, geography and socio-economic status in the diffusion of malignant melanoma risk. Soc Sci Med. 1996;42(12):1621-37.

25. Elwood JM, Gallagher RP, Hill GB, Pearson JC. Cutaneous melanoma in relation to intermittent and constant sun exposure--the Western Canada Melanoma Study. Int J Cancer. 1985;35(4):427-33.

26. Pinault L, Fioletov V. Sun exposure, sun protection and sunburn among Canadian adults. Health Rep. 2017;28(5):12-9.

27. Conte S, Ghazawi FM, Le M, Nedjar H, Alakel A, Lagace F, et al. Population-Based Study Detailing Cutaneous Melanoma Incidence and Mortality Trends in Canada. Front Med (Lausanne). 2022;9:830254.

28. Ghazawi FM, Cyr J, Darwich R, Le M, Rahme E, Moreau L, et al. Cutaneous malignant melanoma incidence and mortality trends in Canada: A comprehensive population-based study. J Am Acad Dermatol. 2019;80(2):448-59.

29. Ontario Health: Cancer Care Ontario. Cancer Fact: Skin cancers increasing among adults Ontario: Cancer Care Ontario; 2021. updated 05-2021. [Available from: https://www.cancercareontario.ca/en/cancer-facts/skin-cancers-increasing-among-adults.]

30. World Health Organization. Radiation: Ultraviolet (UV) radiation and skin cancer. 2017 [Available from: https://www.who.int/news-room/questions-and-answers/item/radiation-ultraviolet-(uv)-radiation-and-skin-cancer.]

31. The Lancet O. Climate change and skin cancer: urgent call for action. Lancet Oncol. 2023;24(8):823.

32. Canadian Task Force on Preventive Health Care. Published guidelines: The Canadian Task Force on Preventive Health Care; 2023 [Available from: https://canadiantaskforce.ca/guidelines/published-guidelines/.]

33. Mangione CM, Barry MJ, Nicholson WK, Chelmow D, Coker TR, Davis EM, et al. U. S. Preventive Services Task Force. Screening for Skin Cancer: US Preventive Services Task Force Recommendation Statement. JAMA. 2023;329(15):1290-5.

34. Asgari MM, Crane LA. Skin Cancer Screening: The Importance of Identifying High-risk Subgroups and the Need for US-Based Population Research. JAMA. 2023;329(15):1259-60.

35. Watts CG, Dieng M, Morton RL, Mann GJ, Menzies SW, Cust AE. Clinical practice guidelines for identification, screening and follow-up of individuals at high risk of primary cutaneous melanoma: a systematic review. Br J Dermatol. 2015;172(1):33-47.

36. National Institute for Health and Care Excellence (NICE). Melanoma: assessment and management. United Kingdom. 2015. updated 27-07-2022. [Available from: https://www.nice.org.uk/guidance/ng14/chapter/Recommendations#follow-up-after-treatment-for-melanoma]

37. Canadian Cancer Society. Types of melanoma skin cancer 2023 [Available from: https://cancer.ca/en/cancer-information/cancer-types/skin-melanoma/what-is-melanoma/types-of-melanoma.]

38. Susan Swetter, Alan C Geller. Melanoma: Clinical features and diagnosis: UpToDate 2023. updated 04-10-2023

39. BC Cancer. Melanoma: Provincial Health Services Authority; 2021. updated 09-2021. [Available from: http://www.bccancer.bc.ca/health-info/types-of-cancer/skin/melanoma].

40. Ontario Health: Cancer Care Ontario. Skin Cancers Pathway Map. Ontario. Ontario Health. 2022. [Available from: https://www.cancercareontario.ca/en/pathway-maps/skin-cancer]

41. American Cancer Society. Treatment of Melanoma Skin Cancer, by Stage 2023. updated 27-10-2023. [Available from: https://www.cancer.org/cancer/types/melanoma-skin-cancer/treating/by-stage.html.]

42. Cancer Council. Slip, Slop, Slap, Seek, Slide¨. Australia [Available from: https://www.cancer.org.au/cancer-information/causes-and-prevention/sun-safety/campaigns-and-events/slip-slop-slap-seek-slide.]

43. Iannacone MR, Green AC. Towards skin cancer prevention and early detection: evolution of skin cancer awareness campaigns in Australia. Melanoma Manag. 2014;1(1):75-84.

44. Tabbakh T, Volkov A, Wakefield M, Dobbinson S. Implementation of the SunSmart program and population sun protection behaviour in Melbourne, Australia: Results from cross-sectional summer surveys from 1987 to 2017. PLoS Med. 2019;16(10):e1002932.

45. Gorey KM, Holowaty EJ, Laukkanen E, Fehringer G, Richter NL. Association between socioeconomic status and cancer incidence in Toronto, Ontario: possible confounding of cancer mortality by incidence and survival. Cancer Prev Control. 1998;2(5):236-41.

46. Haider A, Mamdani M, Shear NH. Socioeconomic status and the prevalence of melanoma in Ontario, Canada. J Cutan Med Surg. 2007;11(1):1-3.

47. Langley A, Levesque L, Baetz T, Asai Y. Brief Report: Increase in Melanoma Incidence in Ontario. J Cutan Med Surg. 2018;22(5):476-8.

48. Gallagher RP, Elwood JM, Threlfall WJ, Spinelli JJ, Fincham S, Hill GB. Socioeconomic status, sunlight exposure, and risk of malignant melanoma: the Western Canada Melanoma Study. J Natl Cancer Inst. 1987;79(4):647-52.

49. Nicolau B, Madathil SA, Castonguay G, Rousseau MC, Parent ME, Siemiatycki J. Shared social mechanisms underlying the risk of nine cancers: A life course study. Int J Cancer. 2019;144(1):59-67.

50. Mavor ME, Richardson H, Miao Q, Asai Y, Hanna TP. Disparities in diagnosis of advanced melanoma: a population-based cohort study. CMAJ Open. 2018;6(4):E502-E12.

51. Pitre LD, Linford G, Pond GR, McWhirter E, Seow H. Is Access to Care Associated With Stage at Presentation and Survival for Melanoma Patients? J Cutan Med Surg. 2019;23(6):586-94.

52. Di Quinzio ML, Dewar RA, Burge FI, Veugelers PJ. Family physician visits and early recognition of melanoma. Can J Public Health. 2005;96(2):136-9.

53. Singh SD, Ajani UA, Johnson CJ, Roland KB, Eide M, Jemal A, et al. Association of cutaneous melanoma incidence with area-based socioeconomic

indicators-United States, 2004-2006. J Am Acad Dermatol. 2011;65(5 Suppl 1):S58-68.

54. Ortiz CA, Goodwin JS, Freeman JL. The effect of socioeconomic factors on incidence, stage at diagnosis and survival of cutaneous melanoma. Med Sci Monit. 2005;11(5):RA163-72.

55. Pearce J, Barnett R, Kingham S. Slip! Slap! Slop! Cutaneous malignant melanoma incidence and social status in New Zealand, 1995-2000. Health Place. 2006;12(3):239-52.

56. Idorn LW, Wulf HC. Socioeconomic status and cutaneous malignant melanoma in Northern Europe. Br J Dermatol. 2014;170(4):787-93.

57. Davis LE, Mahar AL, Strumpf EC. Agreement between individual and neighborhood income measures in patients with colorectal cancer in Canada. J Natl Cancer Inst. 2023;115(5):514-22.

58. Joshua AM. Melanoma prevention: are we doing enough? A Canadian perspective. Curr Oncol. 2012;19(6):e462-7.

59. Statistics Canada. Canadian Community Health Survey - Annual Component (CCHS). updated 2023-01-03. [Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226]

60. Statistics Canada. Canadian Community Health Survey (CCHS) Annual component User guide. 2017.

61. Sibley, L.M., Weiner, J.P. An evaluation of access to health care services along the rural-urban continuum in Canada. BMC Health Serv Res 11, 20 (2011).