



Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1203475420902047
journals.sagepub.com/home/cms



Canadian Burden of Skin Disease From 1990 to 2017: Results From the Global Burden of Disease 2017 Study

Alanna C. Bridgman¹, Christina Fitzmaurice^{2,3,4},
Robert P. Dellavalle^{5,6,7}, Chante Karimkhani Aksut^{6,7},
Ayman Grada⁸, Mohsen Naghavi², Navid Manafi^{9,10},
Andrew T. Olagunju^{11,12}, Tinuke O. Olagunju¹³, Ranjani Somayaji^{14,15},
and Aaron M. Drucker^{16,17}

Abstract

Background: Skin diseases can have high morbidity that can be costly to society and individuals. To date, there has been no comprehensive assessment of the burden of skin disease in Canada.

Objectives: To evaluate the burden of 18 skin and subcutaneous diseases from 1990 to 2017 in Canada using the Global Burden of Disease (GBD) data.

Methods: The 2017 GBD study measures health loss from 359 diseases and injuries in 195 countries; we evaluated trends in population health in Canada from 1990 to 2017 using incidence, prevalence, mortality, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs). Data are presented as rates (per 100 000), counts, or percent change with the uncertainty interval in brackets.

Results: From 1990 to 2017 for all skin diseases, DALY rates increased by 8% to 971 per 100 000 (674–1319), YLD rates increased by 8% to 897 per 100 000 (616–1235), YLL rates increased by 4% to 74 per 100 000 (53–89), and death rates increased by 18% to 5 per 100 000 (3–6). DALY rates for melanoma increased by 2% to 54 per 100 000 (39–68), for keratinocyte carcinoma by 14% to 17 per 100 000 (16–19), and for skin and subcutaneous disease by 8% to 900 per 100 000 (619–1233). The observed over expected ratios were higher for skin and subcutaneous disease (1.37) and keratinocyte carcinoma (1.17) and were lower for melanoma (0.73).

Conclusions: The burden of skin disease has increased in Canada since 1990. These results can be used to guide health policy regarding skin disease in Canada.

Keywords

skin disease, disability, prevalence, incidence

Introduction

Accurate and up-to-date data on disease burden at the population level are crucial for understanding the important causes of death and disability. While mortality from skin disease is rare, many skin diseases are chronic and associated with substantial morbidity.^{1–4} There are estimates of incidence and prevalence of specific diseases such as psoriasis, atopic dermatitis, and melanoma, but to date, there has been no comprehensive study of the burden of skin diseases and their associated disability in Canada.^{5–7}

The Global Burden of Disease (GBD) study aims to provide estimates of the fatal and nonfatal burden of disease. Metrics such as disability-adjusted life years (DALYs) can capture this burden, improving our understanding of skin

disease and informing future research efforts and public policy. Skin disease was the 18th leading cause of global disease burden according to GBD 2015.⁸ The 2017 iteration of the GBD study measures health loss from death or disability resulting from 359 diseases and injuries in 195 countries and more than doubles the number of data sources compared with GBD 2010.⁹ GBD data provides a unique opportunity to understand the burden of skin disease in Canada. Herein, we present GBD 2017 results on morbidity, mortality, incidence,

Corresponding Author:

Aaron M. Drucker, Division of Dermatology, Women's College Hospital,
76 Grenville St, Toronto, ON M5S1B2, Canada.
Email: aaron.drucker@wchospital.ca

and prevalence for 18 skin and subcutaneous diseases, including skin cancers, in Canada from 1990 to 2017. Based on an aging and growing population,¹⁰ we hypothesized that the incidence, prevalence, burden, and mortality of these skin diseases will have increased in Canada from 1990 to 2017.

Materials and Methods

We used GBD 2017 to evaluate Canadian trends in epidemiological patterns from 1990 to 2017. Detailed GBD 2017 methods have been described previously.^{9,11,12} Rates and numbers of deaths, incident cases and prevalence, years of life lost (YLLs) as a result of premature mortality, years lived with disability (YLDs), and DALYs are reported here for both sexes and all age groups in Canada. Rates are age-standardized according to world population estimates by the GBD 2017 study.¹³ The 95% uncertainty intervals (UIs) are reported for all estimates except for total skin disease and includes all sources of uncertainty such as measurement error, systematic biases, and modeling differences from prior iterations of GBD. GBD is conducted in accordance with the Guidelines for Accurate and Transparent Health Estimates Reporting.^{14,15}

Data Sources

The GBD study uses the International Classification of Diseases (ICD) to maximize comparability between diseases worldwide. For Canada, data are obtained from administrative records, vital registrations, census reports, disease registries, government and nongovernmental reports, the scientific literature, surveys (such as the Canada World Poll 2016), and vital statistics. For squamous cell carcinoma, GBD uses the cause of death data from vital registrations in Canada and calculates squamous cell carcinoma incidence based on the mortality incidence ratio. For basal cell carcinoma, GBD

uses claims and hospital data from Ontario. Information on Canadian data sources can be found online at the Global Health Data Exchange <http://ghdx.healthdata.org/geography/canada>.

Classification of Skin Disease

Skin diseases were selected by the GBD study and were defined by the ninth and 10th revision codes of the ICD,^{16,17} resulting in 18 categories of skin and subcutaneous disease based on disease prevalence, data adequacy, and standardized disease definitions: (1) acne vulgaris, (2) alopecia areata, (3) atopic dermatitis, (4) cellulitis, (5) contact dermatitis, (6) decubitus ulcer, (7) fungal skin diseases, (8) malignant skin melanoma, (9) basal cell carcinoma, (10) squamous cell carcinoma, (11) pruritus, (12) psoriasis, (13) pyoderma, (14) scabies, (15) seborrheic dermatitis, (16) urticaria, (17) viral skin diseases, and (18) other skin and subcutaneous diseases, such as pigmentary and atrophic skin disorders.

Cause of Death

GBD attributes the cause of death to a single disease that initiated the ultimate cause of death, with coding following ICD-10 principles. The GBD cause of death hierarchy is divided into 4 levels. Level 1 represents all-cause mortality divided into communicable, maternal, neonatal, and nutritional diseases; noncommunicable diseases; and injuries. Level 2 distinguishes these categories into 21 cause groups (ie, cardiovascular disease). Level 3 distinguishes these causes further by cause (ie, stroke). Finally, Level 4 represents diseases that may be further disaggregated (ie, drug-resistant tuberculosis).¹¹ To assess YLLs and deaths, we used data from Levels 3 and 4 of the cause of death hierarchy.

¹School of Medicine, Queen's University, Kingston, ON, Canada

²Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA, USA

³Division of Hematology, University of Washington, Seattle, WA, USA

⁴Department of Health Metrics Sciences, School of Medicine, University of Washington, Seattle, WA, USA

⁵School of Medicine, University of Colorado Denver, Aurora, CO, USA

⁶Dermatology Service, US Department of Veterans Affairs (VA), Denver, CO, USA

⁷Department of Dermatology, University of Colorado School of Medicine, Denver, CO

⁸School of Medicine, Boston University, Boston, MA, USA

⁹Ophthalmology Department, Iran University of Medical Sciences, Tehran, Iran

¹⁰Ophthalmology Department, University of Manitoba, Winnipeg, MB, Canada

¹¹Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, ON, Canada

¹²Department of Psychiatry, University of Lagos, Lagos, Nigeria

¹³Department of Pathology and Molecular Medicine, McMaster University, Hamilton, ON, Canada

¹⁴Department of Medicine, University of Calgary, Calgary, AB, Canada

¹⁵Department of Medicine, University of Washington, Seattle, WA, USA

¹⁶Division of Dermatology, University of Toronto, Toronto, ON, Canada

¹⁷Women's College Research Institute, Women's College Hospital, Toronto, ON, Canada

Mortality and YLLs

Age-specific and sex-specific mortality are available for 6 of the 18 skin and subcutaneous diseases (cellulitis, decubitus ulcer, melanoma, squamous cell carcinoma, other skin and subcutaneous diseases, and pyoderma)¹¹ and are modeled using the Cause of Death Ensemble model (CODEm).¹¹ CODEm combines numerous modeling techniques to best predict age-specific and sex-specific mortality estimates by cause while taking temporal and spatial trends into consideration and using predictive covariates.¹¹ The GBD study calculates YLLs as a measure of cause-specific premature mortality. Age-standardized mortality and YLL rates are calculated using the GBD world standard population.¹¹

Years Lived with Disability

Disease modeling meta-regression 2.1 (DisMod-MR 2.1) is used to calculate prevalence for each disease taking into account data on incidence, prevalence, remission, mortality, and disease duration.^{12,18} The prevalence estimates are multiplied by disability weights to calculate YLDs resulting from a specific cause. Disability weights were derived from surveys evaluating the level and progression of disability associated with specific causes.¹² The prevalence of different disease sequelae is used to model comorbidity using a micro-simulation approach.¹²

Disability-Adjusted Life Years

DALYs were calculated using the GBD 2017 results for YLLs and YLDs, combined.^{9,11} In GBD, DALYs are used as the primary measure to compare disease burden across time and between age and sex groups. The GBD world population age standard is used to calculate age-standardized rates for DALYs, YLLs, and YLDs.⁹ Rates are calculated and presented per 100 000 person-years.

Observed Over Expected Ratio

The observed over expected (O/E) ratio is based on a nation's socio-demographic index (SDI) and age-standardized DALYs. The expected value of a disease is based solely on the SDI, which does not vary over time for a specific region. The SDI is a composite average of the rankings of average educational attainment, annual income, and fertility rates across all areas in the GBD study, expressed on a scale of 0-1.¹¹ The O/E ratio is therefore a method of comparing regions.

Uncertainty Intervals

GBD uses Bayesian estimation methods; every estimate is calculated 1000 times to give 95% UIs. The width of the UI is reflective of data availability, sample size, and consistency

of data across multiple sources.^{9,11} If the calculation of GBD estimates requires multiple steps, the uncertainty associated with each step is propagated throughout the entire calculation.¹⁹ UIs are calculated for percentage change for each disease, though UIs for total skin disease including cancers are unavailable.

Results

Prevalence and Incidence

In Canada, in 2017, skin and subcutaneous diseases had an age-standardized incidence rate of 37 898 cases per 100 000 (95% UI 36 776-39 096) (Table 1) and an age-standardized prevalence rate of 28 409 cases per 100 000 (27 917-28 872) (Table 2), an increase of 4% and 7%, respectively, from 1990. Incidence and prevalence rates are subcategorized by sex in supplemental Tables S1-S4. Of all skin diseases since 1990, keratinocyte carcinomas (basal and squamous cell carcinomas), had the largest rise in both incidence rate by 748% (546%-944%) to 90 per 100 000 (63-124) and prevalence rate by 1147% (749%-1751%) to 54 per 100 000 (37-74). The incidence and prevalence rates for melanoma have increased by 68% (39%-93%) to 15 per 100 000 (11-19) and by 81% (53%-108%) to 130 per 100 000 (96-160), respectively. Incidence and prevalence rates were similarly increased among males and females from 1990 to 2017, though males had a greater relative increase in the prevalence (8 per 100 000 [6-12] to 76 per 100 000 [50-113]) and incidence (8 per 100 000 [6-11] to 63 per 100 000 [43-98]) of squamous cell carcinoma compared with females (5 per 100 000 [4-7] to 34 per 100 000 [20-56] and 4 per 100 000 [3-6] to 28 per 100 000 [17-46], respectively).

Mortality and YLLs

Age-standardized rates and all-age death counts are summarized in Tables 3 and 4 and are subcategorized by sex in supplemental Tables S5-S8. From 1990 to 2017, the death rate for all skin diseases in Canada increased by 18% to 5 per 100 000 (95% UI 3-6). All skin diseases were responsible for 2281 deaths [1597-2684], an increase of 136% compared with 1990, and 42 127 YLLs (30 346-50 573), an increase of 85%. Melanoma caused the most deaths among skin diseases (49% of total deaths from skin disease and 0.4% of all deaths in Canada). Melanoma was also the largest contributor to YLLs, representing 60% of total YLLs from skin disease, and 0.6% of all-cause YLLs. Since 1990, age-standardized female and male death rates for melanoma have remained stable at 1 per 100 000 (0.9-2) and 2 per 100 000 (1-3), respectively. Age-standardized YLL rates for females for all skin diseases increased by 6% to 51 per 100 000 (33-71), while YLL rates for males remained stable at 99 per 100 000 (60-128), though males had a higher absolute YLL rate.

Table 1. All-Age and Age-Standardized Incidence Rates Per 100 000 for Skin and Subcutaneous Disease in Canada in 1990 and 2017 and Cumulative Percentage Changes for 1990-2017 for Both Sexes Combined.

	All-age incidence rate (per 100 000) (95% UI)			Age-standardized incidence rate (per 100 000) (95% UI)		
	1990	2017	% change	1990	2017	% change
All skin disease	37 959 (36 716-39 191)	44 612 (43 084-46 273)	18	36 377 (35 243-37 523)	38 004 (36 850-39 239)	5
Melanoma	11 (8-14)	23 (16-27)	109 (72-141)	9 (7-12)	15 (11-19)	68 (39-93)
Keratinocyte carcinoma	13 (10-16)	160 (110-221)	1151 (856-1460)	11 (8-14)	90 (63-124)	748 (546-944)
BCC	6 (4-9)	79 (40-129)	1215 (745-1719)	5 (3-8)	46 (25-73)	816 (485-1135)
SCC	7 (5-9)	81 (55-114)	1095 (780-1416)	6 (4-7)	44 (30-63)	686 (487-881)
Skin/subcutaneous disease	37 935 (36 698-39 160)	44 430 (42 958-46 024)	17 (16-19)	36 357 (35 228-37 497)	37 898 (36 776-39 096)	4 (4-5)
Acne vulgaris	1461 (1340-1597)	1655 (1532-1797)	13 (9-17)	1607 (1460-1780)	2193 (2016-2415)	37 (31-42)
Alopecia areata	731 (706-757)	724 (701-750)	-1 (-2 to 0)	667 (644-690)	665 (643-689)	0 (0-0)
Bacterial skin disease	4425 (4236-4618)	4816 (4597-5029)	9 (6-11)	4386 (4203-4575)	4441 (4246-4626)	1 (-1 to 3)
Cellulitis	3080 (2892-3268)	3480 (3263-3692)	13 (9-17)	2958 (2781-3138)	3008 (2814-3192)	2 (-1 to 4)
Pyoderma	1345 (1306-1383)	1337 (1301-1373)	-1 (-2 to 1)	1428 (1387-1473)	1432 (1391-1478)	0 (-2 to 2)
Decubitus ulcer	122 (107-140)	203 (178-237)	66 (56-77)	102 (91-116)	109 (96-126)	6 (0 to 12)
Dermatitis	6571 (5905-7249)	6917 (6233-7600)	5 (2-9)	6227 (5587-6897)	6230 (5583-6903)	0 (0 to 0)
Atopic	437 (412-461)	425 (404-449)	-3 (-6 to 1)	488 (456-520)	490 (459-524)	0 (-3 to 5)
Contact	5333 (4642-6008)	5684 (5002-6394)	7 (3-11)	4964 (4314-5634)	4965 (4314-5631)	0 (0-0)
Seborrheic	803 (744-859)	808 (755-862)	1 (-1 to 3)	775 (718-829)	775 (719-830)	0 (0-0)
Fungal skin diseases	9505 (8534-10 508)	11 539 (10 253-12 805)	21 (17-26)	8758 (7913-9619)	8481 (7628-9361)	-3 (-4 to -2)
Other ^a	9905 (9654-10 163)	13 613 (13 252-13 997)	37 (35-40)	8939 (8707-9169)	10 100 (9852-10 363)	13 (11-15)
Pruritus	625 (551-711)	721 (635-823)	15 (10-21)	582 (514-656)	596 (527-675)	2 (-1 to 5)
Psoriasis	192 (185-199)	225 (217-233)	17 (14-20)	188 (182-195)	215 (208-222)	14 (12-17)
Scabies	1373 (1204-1570)	1242 (1102-1405)	-9 (-13 to -6)	1476 (1286-1704)	1445 (1256-1660)	-2 (-5 to 1)
Urticaria	1480 (1308-1675)	1390 (1235-1574)	-6 (-8 to -3)	1595 (1395-1818)	1595 (1395-1819)	0 (0-0)
Viral skin diseases	1546 (1482-1611)	1384 (1330-1440)	-11 (-11 to -10)	1829 (1743-1915)	1829 (1742-1914)	0 (0-0)

Abbreviations: BCC, basal cell carcinoma; SCC, squamous cell carcinoma.

^aOther refers to other skin and subcutaneous disease.

Table 2. All-Age and Age-Standardized Prevalence Rates Per 100 000 for Skin and Subcutaneous Disease in Canada in 1990 and 2017 and Cumulative Percentage Changes for 1990-2017 for Both Sexes Combined.

	All-age prevalence rate (per 100 000) (95% UI)		Age-standardized prevalence rate (per 100 000) (95% UI)		% change
	1990	2017	1990	2017	
All skin disease	26 794 (26 385-27 256)	30 590 (30 019-31 156)	26 591 (26 121-27 058)	28 593 (28 049-29 106)	8
Melanoma	83 (63-107)	184 (134-225)	72 (54-91)	130 (96-160)	81 (53-108)
Keratinocyte carcinoma	5 (4-7)	103 (71-139)	4 (3-6)	54 (37-74)	1147 (749-1751)
BCC	1 (1-2)	12 (6-20)	1 (1-2)	7 (3-12)	724 (426-1022)
SCC	8 (6-10)	99 (66-134)	6 (5-9)	53 (36-73)	729 (507-986)
Skin/subcutaneous disease	26 705 (26 259-27 142)	30 304 (29 815-30 792)	26 515 (26 064-26 961)	28 409 (27 917-28 872)	7 (6-8)
Acne vulgaris	3124 (2907-3348)	3492 (3271-3737)	3310 (3061-3579)	4317 (4099-4775)	33 (28-39)
Alopecia areata	415 (400-429)	412 (400-427)	377 (364-390)	376 (363-389)	0 (-2-3)
Bacterial skin disease	176 (164-188)	191 (178-204)	177 (164-190)	180 (168-193)	2 (-7 to 11)
Cellulitis	116 (109-124)	131 (123-139)	111 (104-119)	114 (106-121)	2 (-1 to 5)
Pyoderma	65 (63-67)	65 (64-67)	70 (68-72)	71 (69-73)	2 (0-4)
Decubitus ulcer	33 (29-38)	55 (48-64)	28 (24-31)	30 (26-34)	7 (0-13)
Dermatitis	7385 (7046-7730)	7288 (6951-7648)	7880 (7548-8225)	7898 (7563-8257)	0 (-2 to 3)
Atopic	4718 (4548-4916)	4409 (4250-4575)	5399 (5183-5638)	5416 (5188-5655)	0 (-2 to 3)
Contact	2353 (2066-2659)	2513 (2198-2864)	2215 (1945-2515)	2216 (1946-2515)	0 (0-0)
Seborrheic	480 (447-514)	537 (502-575)	440 (409-470)	441 (411-471)	0 (0-0)
Fungal skin diseases	2706 (2416-2995)	3259 (2906-3642)	2504 (2251-2771)	2417 (2162-2681)	-3 (-4 to -3)
Other ^a	9549 (9303-9806)	13 135 (12 789-13 508)	8597 (8375-8816)	9709 (9465-9963)	13 (11-15)
Pruritus	805 (721-920)	926 (820-1050)	744 (666-846)	764 (685-865)	3 (-1 to 7)
Psoriasis	2446 (2361-2526)	3140 (3030-3249)	2271 (2195-2348)	2662 (2577-2747)	17 (15-20)
Scabies	462 (401-531)	418 (367-479)	495 (429-573)	485 (420-561)	-2 (-5 to 1)
Urticaria	843 (740-962)	794 (701-904)	907 (794-1035)	906 (793-1035)	0 (0-0)
Viral skin diseases	2752 (2662-2846)	2523 (2446-2604)	3085 (2981-3199)	3085 (2981-3199)	0 (0-0)

Abbreviations: BCC, basal cell carcinoma; SCC, squamous cell carcinoma.
^aOther refers to other skin and subcutaneous disease.

Table 3. All-Age Death Counts and Age-Standardized Death Rates Per 100 000 for Skin and Subcutaneous Disease in Canada in 1990 and 2017 and and Cumulative Percentage Changes for 1990-2017 for Both Sexes Combined.

	All-age deaths (count) (95% UI)			Age-standardized death rate (per 100 000) (95% UI)		
	1990	2017	% Change	1990	2017	% Change
All skin disease	969 (797-1287)	2281 (1597-2684)	136	4 (3-6)	5 (3-6)	18
Melanoma	562 (455-771)	1118 (790-1328)	99 (44-126)	2 (1-2)	2 (1-2)	3 (-24 to 17)
SCC	261 (251-271)	639 (594-690)	145 (125-167)	0.8 (0.8-0.8)	0.9 (0.8-0.9)	10 (1-20)
Skin/subcutaneous disease	146 (91-245)	525 (213-666)	259 (94-385)	0.4 (0.3-0.7)	0.7 (0.3-0.9)	57 (-13 to 110)
Bacterial skin disease	91 (62-178)	430 (159-556)	374 (108-634)	0.3 (0.2-0.5)	0.6 (0.2-0.8)	110 (-7 to 218)
Cellulitis	40 (24-79)	218 (70-297)	440 (120-763)	0.1 (0.1-0.2)	0.3 (0.1-0.4)	140 (-1 to 279)
Pyoderma	50 (32-106)	213 (77-306)	321 (85-579)	0.2 (0.1-0.3)	0.3 (0.1-0.4)	85 (-16 to 192)
Decubitus ulcer	42 (16-71)	61 (27-123)	44 (7-135)	0.1 (0.1-0.2)	0.1 (0.0-0.2)	-40 (-55 to -4)
Other ^a	13 (5-20)	33 (10-48)	152 (62-230)	0.04 (0.02-0.1)	0.05 (0.02-0.1)	11 (-22 to 45)

Abbreviations: SCC, squamous cell carcinoma; UI, uncertainty interval.

^aOther refers to other skin and subcutaneous disease.

Years Lived with Disability

From 1990 to 2017, age-standardized YLD rates for all 18 skin and subcutaneous diseases increased by 8% to 897 per 100 000 (95% UI 616-1235). These are summarized in Table 5 and subcategorized by sex in supplemental Tables S9 and S10. Since 1990, keratinocyte carcinomas had the largest increase in YLD rates by 673% (459%-938%) to 2 per 100 000 (1-4). In 2017, in Canada, skin and subcutaneous diseases, including skin cancer, were responsible for 318 029 YLDs (222 690-437 915) or 7% of all-cause YLDs. In 2017, psoriasis was responsible for the largest number of YLDs (97 046 [68 760-127 164]) followed by atopic dermatitis (69 065 [37 470-114 020]), an increase of 68% (61%-76%) and 22% (18%-27%), respectively, since 1990. Age-standardized YLD trends from 1990 to 2017 were mostly similar across skin conditions between males and females, though males had a larger increase of 735% (449%-1165%) in YLD rate for squamous cell carcinomas (3 per 100 000 [2-6])

compared with an increase of 553% (338%-871%) in females (2 per 100 000 [1-3]).

Disability-Adjusted Life Years

From 1990 to 2017, age-standardized DALY rates for all skin and subcutaneous diseases increased by 8% to 971 per 100 000 (95% UI 645-1320) and are summarized in Table 6 and subcategorized by sex in supplemental Tables S11 and S12. Figure 1 presents DALY rates for specific age groups with separate estimates for females and males in supplemental Figures S1 and S2, respectively. In Canada, all skin diseases were responsible for 360 156 all-age DALYs in 2017 (256 470-485 451), or 4% of all-cause all-age DALYs, an increase of 15% since 1990. In 2017, psoriasis was responsible for the most all-age DALYs at 97 046 (68 760-127 164). Basal cell carcinoma had the greatest percentage increase in total all-age DALYs from 1990 to 2017 by 1410% (781%-2191%),

Table 4. All-Age YLL Counts and Age-Standardized YLL Rates Per 100 000 for Skin and Subcutaneous Disease in Canada in 1990 and 2017 and and Cumulative Percentage Changes for 1990-2017 for Both Sexes Combined.

	All-age YLLs (count) (95% UI)			Age-standardized YLL rate (per 100 000) (95% UI)		
	1990	2017	% Change	1990	2017	% Change
All skin disease	22 737 (18 252-29 874)	42 127 (30 346-50 573)	85	71 (57-94)	74 (53-89)	4
Melanoma	15 401 (11 964-20 181)	25 333 (18 284-30 861)	64 (29-83)	48 (37-63)	47 (34-57)	-4 (-24 to 6)
SCC	4805 (4607-5009)	9482 (8716-10 310)	97 (81-115)	15 (14-15)	15 (14-16)	0 (-8 to 9)
Skin/subcutaneous disease	2532 (1681-4684)	7312 (3345-9403)	189 (63-292)	8 (5-15)	12 (6-16)	54 (-12 to 107)
Bacterial skin disease	1692 (1232-3532)	6178 (2627-7888)	265 (72-459)	5 (4-11)	10 (5-14)	93 (-9 to 192)
Cellulitis	756 (474-1589)	3246 (1159-4344)	329 (84-592)	2 (2-5)	5 (2-7)	125 (-3 to 257)
Pyoderma	935 (605-2091)	2931 (1198-4280)	213 (54-392)	3 (2-7)	5 (2-8)	67 (-16 to 155)
Decubitus ulcer	588 (241-999)	671 (317-1315)	14 (-15-78)	3 (0.8-3)	1 (0.6-2)	-39 (-54 to -6)
Other ^a	252 (112-416)	463 (173-730)	84 (25-135)	0.8 (0.4-1)	0.9 (0.4-1)	5 (-21 to 35)

Abbreviations: SCC, squamous cell carcinoma; UI, uncertainty interval; YLL, years of life lost.

^aOther refers to other skin and subcutaneous disease.

Table 5. All-Age YLD Counts and Age-Standardized YLD Rates Per 100 000 for Skin and Subcutaneous Disease in Canada in 1990 and 2017 and Cumulative Percentage Changes for 1990-2017 for Both Sexes Combined.

	All-age YLDs (count) (95% UI)		Age-standardized YLD rate (per 100 000) (95% UI)		% Change
	1990	2017	1990	2017	
All skin disease	219 304 (151 133-301 250)	318 029 (222 690-437 915)	828 (565-1154)	897 (616-1235)	8
Melanoma	1374 (874-2024)	3853 (2384-5776)	4 (3-6)	7 (5-11)	73 (42-102)
Keratinocyte carcinoma	98 (59-160)	1527 (873-2502)	0.3 (0.2-0)	2 (1-4)	673 (459-938)
BCC	1 (0.4-3)	17 (6-41)	0.003 (0.001-0.009)	0.03 (0.01-0.1)	701 (374-1087)
SCC	97 (58-159)	1510 (863-2481)	0.3 (0.2-0.5)	2 (1-4)	673 (455-941)
Skin/subcutaneous disease	217 832 (150 200-299 066)	312 649 (219 433-429 637)	824 (562-1147)	888 (610-1220)	8 (5-10)
Acne vulgaris	18 139 (10 922-29 253)	26 736 (16 112-42 872)	71 (42-114)	94 (57-152)	33 (25-42)
Alopecia areata	3684 (2334-5512)	4819 (3083-7146)	12 (8-18)	12 (8-18)	0 (-7 to 8)
Bacterial skin disease	1860 (1228-2625)	2736 (1808-3900)	7 (4-9)	7 (4-10)	2 (-11 to 16)
Cellulitis	1760 (1170-2494)	2603 (1714-3678)	6 (4-9)	6 (4-9)	2 (-12 to 17)
Pyoderma	101 (40-210)	132 (53-279)	0.4 (0.2-0.8)	0.4 (0.2-0.9)	1 (-12 to 17)
Decubitus ulcer	1386 (956-1890)	3019 (2057-4151)	4 (3-6)	5 (3-6)	7 (-6 to 23)
Dermatitis	74 226 (44 188-115 828)	94 069 (56 348-146 852)	300 (176-471)	301 (175-472)	0 (-3 to 4)
Atopic	56 433 (30 273-93 327)	69 065 (37 470-114 020)	238 (129-396)	239 (129-399)	0 (-4 to 5)
Contact	16 036 (10 458-23 586)	22 426 (14 727-32 773)	56 (36-82)	56 (36-83)	0 (-4 to 5)
Seborrheic	1757 (1004-2732)	2577 (1451-4075)	6 (3-9)	6 (3-9)	0 (-6 to 7)
Fungal skin diseases	4081 (1656-8414)	6419 (2598-13 221)	14 (6-29)	13 (6-28)	-4 (-6 to -1)
Other ^a	14 212 (6773-26 021)	25 649 (12 371-47 427)	47 (22-87)	53 (26-99)	13 (11-15)
Pruritus	2326 (1095-4383)	3513 (1670-6585)	8 (4-15)	8 (4-16)	3 (-3 to 8)
Psoriasis	57 814 (40 867-76 088)	97 046 (68 760-127 164)	198 (140-262)	232 (164-305)	17 (12-23)
Scabies	3251 (1802-5320)	3863 (2139-6375)	13 (7-21)	13 (7-20)	-2 (-8 to 4)
Urticaria	13 772 (9076-19 321)	16 994 (11 084-24 172)	55 (36-78)	55 (36-78)	0 (-6 to 6)
Viral skin diseases	23 081 (14 819-33 956)	27 787 (17 919-40 948)	95 (61-142)	95 (61-141)	0 (-3 to 4)

Abbreviations: BCC, basal cell carcinoma; SCC, squamous cell carcinoma; UI, uncertainty interval; YLD, years lived with disability.
^aOther refers to other skin and subcutaneous disease.

Table 6. All-Age DALY Counts and Age-Standardized DALY Rates Per 100 000 for Skin and Subcutaneous Disease in Canada in 1990 and 2017 and Cumulative Percentage Changes for 1990-2017 for Both Sexes Combined.

	All-age DALYs (count) (95% UI)			Age-standardized DALY rate (per 100 000) (95% UI)		
	1990	2017	% Change	1990	2017	% Change
All skin disease	242 042 (170 083-328 283)	360 156 (256 470-485 451)	49	899 (626-1239)	971 (674-1320)	8
Melanoma	16 775 (12 958-21 882)	29 187 (20 811-35 646)	74 (37-93)	53 (41-69)	54 (39-68)	2 (-17 to 13)
Keratinocyte carcinoma	4903 (4706-5110)	11 009 (9983-12 302)	125 (104-150)	15 (14-16)	17 (16-19)	14 (3-27)
BCC	1 (0.4-3)	17 (6-41)	1410 (781-2191)	0.004 (0.001-0.009)	0.03 (0.01-0.1)	701 (374-1087)
SCC	4901 (4705-5108)	10 991 (9968-12 295)	124 (103-150)	15 (14-16)	17 (16-19)	14 (3-26)
Skin/subcutaneous disease	220 364 (152 419-301 292)	319 960 (225 675-437 503)	45 (41-50)	832 (571-1155)	900 (619-1233)	8 (6-11)
Acne vulgaris	18 139 (10 922-29 253)	26 736 (16 112-42 872)	47 (38-57)	71 (42-114)	94 (57-152)	33 (25-42)
Alopecia areata	3684 (2334-5512)	4819 (3083-7146)	31 (22-40)	12 (8-18)	12 (8-18)	0 (-7 to 8)
Bacterial skin disease	3552 (2620-5468)	8913 (5116-11 291)	151 (59-244)	12 (9-18)	17 (11-22)	43 (-4 to 88)
Cellulitis	2516 (1807-3531)	5850 (3447-7697)	133 (56-216)	9 (6-12)	12 (7-16)	36 (-1 to 75)
Pyoderma	1036 (693-2169)	3064 (12 830-4380)	196 (52-352)	3 (2-7)	6 (2-8)	60 (-15 to 136)
Decubitus ulcer	1974 (1437-2590)	3689 (2653-4975)	87 (58-120)	6 (4-8)	6 (4-8)	-7 (-20 to 9)
Dermatitis	74 226 (44 188-115 828)	94 069 (56 348-146 852)	27 (23-31)	300 (176-471)	301 (175-472)	0 (-3 to 4)
Atopic	56 433 (30 273-93 327)	69 066 (37 470-114 020)	22 (18-27)	238 (129-397)	239 (129-399)	0 (-4 to 5)
Contact	16 036 (10 458-23 586)	22 426 (14 727-32 773)	40 (31-49)	56 (36-82)	56 (36-83)	0 (-4 to 5)
Seborrheic	1757 (1004-2733)	2579 (1451-4075)	47 (37-57)	6 (3-9)	6 (3-9)	0 (-6 to 7)
Fungal skin diseases	4081 (1656-8414)	6419 (2598-13 221)	57 (51-64)	14 (6-29)	13 (6-28)	-4 (-6 to -1)
Other ^a	14 464 (71 13-26 269)	26 112 (12 893-47 852)	81 (77-85)	48 (24-87)	54 (27-99)	13 (10-15)
Pruritus	2327 (1095-4383)	3513 (1670-6585)	51 (42-61)	8 (4-15)	8 (4-16)	3 (-3 to 8)
Psoriasis	57 814 (40 867-76 088)	97 046 (68 760-127 164)	68 (61-76)	198 (140-262)	232 (164-305)	17 (12 to 23)
Scabies	3251 (1802-5320)	3863 (2139-6375)	19 (12-27)	13 (7-21)	13 (7-20)	-2 (-8 to 4)
Urticaria	13 772 (9076-19 321)	16 994 (11 084-24 172)	23 (16-31)	55 (36-78)	55 (36-78)	0 (-6 to 6)
Viral skin diseases	23 081 (14 819-33 956)	27 787 (17 919-40 948)	20 (17-25)	95 (61-142)	95 (61-141)	0 (-3 to 4)

Abbreviations: BCC, basal cell carcinoma; DALY, disability-adjusted life year; SCC, squamous cell carcinoma; UI, uncertainty interval.

^aOther refers to other skin and subcutaneous disease.

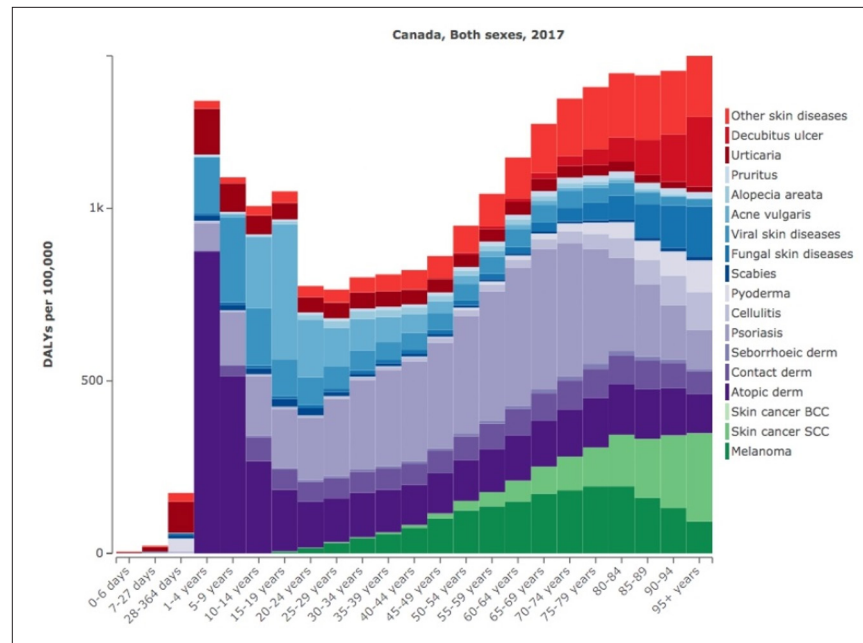


Figure 1. Disability-adjusted life year (DALY) rates (per 100 000) for 18 skin diseases in Canada in 2017. BCC, basal cell carcinoma; SCC, squamous cell carcinoma.

from 1 (0.4-3) to 17 (6-41). There is a higher overall age-standardized burden of melanoma in males (67 per 100 000 [35-87]) relative to females (43 per 100 000 [31-60]) that has remained stable since 1990. The age-standardized DALY rate for melanoma remained relatively stable at 54 per 100 000 (39-68), increased for keratinocyte carcinoma by 14% (3%-27%) to 17 per 100 000 (16-19), and increased for skin and subcutaneous disease by 8% (6%-11%) to 900 per 100 000 (619-1233). Age-standardized DALY rates for keratinocyte carcinomas increased by 47% (23%-78%) in females to 6 per 100 000 (5-8) but remained relatively stable in males at 29 per 100 000 (26-33) and appears to be largely due to a 46% (23%-77%) increase in squamous cell carcinoma rates in females to 6 per 100 000 (5-8) that is not seen in males. However, the overall burden of keratinocyte carcinoma is still higher in males than in females. Finally, there is a somewhat higher overall burden of nonmalignant skin and subcutaneous disease in females (1001 per 100 000 [687-1377]) compared with males (801 per 100 000 [552-1098]) with increases of 8% (5%-12%) since 1990 in both sexes.

Observed Over Expected

The O/E ratios for 1990 and 2017 are presented in Table 7; supplemental Tables S13 and S14 are based on age-standardized DALY rates for each disease. In 2017, Canada had more DALYs than expected for keratinocyte carcinoma (O/E: 1.17) and overall skin and subcutaneous diseases (O/E: 1.37). For melanoma, Canada had a lower burden compared with expected (O/E: 0.73). The overall higher burden of skin disease compared with expected is explained in part by chronic

inflammatory skin diseases including atopic dermatitis (O/E: 1.33) and psoriasis (O/E: 1.73). Findings were fairly consistent for males and females, with the exception that males had a lower burden from basal cell carcinoma than expected (O/E: 0.75) whereas it was higher for females (O/E: 1.38).

Discussion

The present study is the first to comprehensively report on the burden of 18 skin diseases in Canada. These results can be used to inform resource allocation and health systems responses to skin disease in Canada. We report an overall increase in the burden of all skin diseases since 1990.²⁰ All-age total DALYs for all skin diseases (including skin cancers) account for 4% of DALYs in Canada. This places skin diseases 10th among all causes of DALYs in Canada, behind neoplasms, cardiovascular disease, and diabetes, and ahead of substance use disorders and digestive diseases. Skin and subcutaneous diseases, including skin cancers, are the eighth leading cause of age-standardized DALY rates in Canada, behind substance use disorders and ahead of diabetes and kidney diseases and unintentional injuries.¹⁶

As noted above, the overall burden of skin and subcutaneous disease has been steadily increasing since 1990 possibly reflecting Canada's aging population.²¹ It is also possible that this increase is due to secular changes in surveillance, detection, and statistical recording of skin diseases, particularly skin cancer.²²⁻²⁴ Other factors may contribute to individual disease burdens such as antimicrobial resistance and sun safety behaviors. YLD rates have increased nearly sevenfold for

Table 7. O/E Ratios Based on Age-Standardized DALY Rates for Skin and Subcutaneous Diseases in Canada from 1990 to 2017 for Both Sexes Combined.

	1990			2017			% Change for O/E
	Observed (95% UI)	Expected	O/E	Observed (95% UI)	Expected	O/E	
Melanoma	53 (41-69)	51	1.03	54 (39-68)	74	0.73	-29
Keratinocyte carcinoma	15 (14-16)	16	0.91	17 (16-19)	15	1.17	29
BCC	0.004 (0.001-0.009)	0.02	0.17	0.03 (0.01-0.1)	0.03	1.05	517
SCC	15 (14-16)	16	0.91	17 (16-19)	15	1.17	29
Skin/subcutaneous disease	832 (571-1155)	643	1.29	900 (619-1233)	657	1.37	6
Acne vulgaris	71 (42-114)	59	1.20	94 (57-152)	71	1.32	10
Alopecia areata	12 (8-18)	9	1.43	12 (8-18)	9	1.35	-6
Bacterial skin disease	12 (9-18)	13	0.95	17 (11-22)	11	1.58	66
Cellulitis	9 (6-12)	5	1.68	12 (7-16)	5	2.41	44
Pyoderma	3 (2-7)	8	0.46	6 (2-8)	6	0.91	98
Decubitus ulcer	6 (4-8)	6	0.97	6 (4-8)	6	0.95	-2
Dermatitis	300 (176-471)	206	1.46	301 (175-472)	209	1.44	-1
Atopic	238 (129-397)	177	1.35	239 (129-399)	179	1.33	-2
Contact	56 (36-82)	29	1.94	56 (36-83)	29	1.95	1
Seborrheic	6 (3-9)	1	8.76	6 (3-9)	1	6.35	-28
Fungal skin diseases	14 (6-29)	46	0.30	13 (6-28)	41	0.33	10
Other ^a	48 (24-87)	49	0.99	54 (27-99)	50	1.09	10
Pruritus	8 (4-15)	10	0.83	8 (4-16)	9	0.94	13
Psoriasis	198 (140-262)	110	1.80	232 (164-305)	130	1.78	-1
Scabies	13 (7-21)	12	1.03	13 (7-20)	6	2.04	98
Urticaria	55 (36-78)	62	0.88	55 (36-78)	54	1.02	16
Viral skin diseases	95 (61-142)	61	1.55	95 (61-141)	61	1.55	0

Abbreviations: BCC, basal cell carcinoma; DALY, disability-adjusted life year; O/E, observed over expected; SCC, squamous cell carcinoma; UI, uncertainty interval.

^aOther refers to other skin and subcutaneous disease.

keratinocyte carcinoma, with smaller increases for skin and subcutaneous diseases. The largest relative increase in death rate is attributable to bacterial skin diseases such as pyoderma and cellulitis possibly due to an immunologically weaker and aging population with more comorbidities²⁵ as well as antibiotic misuse and resistance.^{26,27} As populations age, outcomes of nonfatal diseases are slowly becoming a larger component of the global burden of disease. Decreased mortality rates for most of the 359 diseases studied in GBD 2017 have not been matched with a similar decline in age-standardized YLD rates, likely due to a global aging population.²⁰

While incidence and prevalence rates for all skin diseases have modestly increased, rates for keratinocyte carcinomas have increased eightfold to 11-fold since 1990 and have increased by 68% (39%-93%) and 81% (53%-108%) for melanoma, respectively. The reason for this disproportionately large increase in the burden of keratinocyte carcinomas in Canada is likely multifactorial. The GBD 2017 cancer study found keratinocyte carcinomas to be the leading global cause of cancer in 2017, with an increase in incident cases of 33% over the past decade—20% of which is attributable to a change in the population age structure and 13% to population growth.²⁸ The much larger increase in incidence and burden in Canada may also be due to changes in data sources and increased detection and surveillance.^{22,23} The approximately equal incidence of basal cell carcinoma and squamous cell carcinoma seen in our study is compatible with recent estimates from the United States.^{29,30}

There was a higher overall burden of skin cancers in males and a higher burden of nonmalignant skin and subcutaneous disease in females. The sex differences in keratinocyte carcinoma burden are likely multifactorial and could be related to sun safety behaviors,³¹ health resource utilization,³²⁻³⁴ and tumor stage at presentation.^{34,35}

Some of the trends in our data are comparable to those in other populations. Age-standardized malignant melanoma incidence rates in light-skinned individuals in the United States, Sweden, Australia, New Zealand, Norway, and the United Kingdom have been steadily increasing by 3% each year from 1982 to 2011 and are projected to increase through 2031.³⁶ Since 1990, age-standardized melanoma incidence rates have increased by 40%-68% in the United States, Canada, and Australia.¹⁶ Age-standardized keratinocyte carcinoma incidence rates have increased in Canada by 748% (546%-944%) and in the United States by 15% (-10% to 59%), while rates have decreased in Australia by 20% (-4% to 36%), though the incidence rates of all skin cancers in Australia are much higher overall¹⁶ possibly due to differences in climate and therefore time spent outdoors without sun protection. It is unclear why keratinocyte carcinoma incidence rates have increased so dramatically in Canada compared with other high-income nations, as Canadian and Australian populations are aging at similar rates.³⁷

Limitations

GBD does not collect subnational data for Canada; provincial, territorial, and regional estimates would be beneficial to fully understand the skin and subcutaneous disease burden in Canada, as there is variability in disease and risk factor estimates across Canada, and there have been changes in data collection methods over time which may impact the results.^{38,39} It would also be beneficial for future iterations of the GBD to include different categories of skin disease, such as acute vs. chronic urticaria and wounds/ulcers. The 2017 estimates do not use current vital statistics due to the lag time in the release of reported data, and the DALY metric for skin diseases does not consider disability from related systems—for example, mental health comorbidity in atopic dermatitis.⁴⁰⁻⁴³ Misclassification of disease is possible, particularly when relying on administrative coding of diagnoses. Future iterations of GBD ought to disaggregate DALYs and YLLs attributable to differences in latitude and sunlight exposure.

Conclusion and Future Directions

The disease, including skin cancer, has been steadily increasing in Canada since 1990 and is responsible for 4% of DALYs nationally. Incidence rates have significantly increased since 1990, especially for keratinocyte carcinomas and melanoma. Subnational estimates of the burden of skin disease in future GBD iterations may give more targeted estimates. While our study cannot determine the causes of the temporal changes observed, Canada's aging population likely plays a major role. This data can be used to inform government policy and advocacy initiatives that aim to reduce the burden of skin disease in Canada, particularly targeting sun-protection practices, early diagnosis, and public education.

Acknowledgments

We would like to extend our thanks to Danny Colombara, a modeler for Global Burden of Disease, who assisted us in this work.

Declaration of Conflicting Interests


The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article. In the last 3 years, Dr Drucker served as an investigator and has received research funding from Sanofi and Regeneron and has been a consultant for Sanofi, RTI Health Solutions, Eczema Society of Canada, and Canadian Agency for Drugs and Technology in Health. He has received honoraria from Prime Inc, Spire Learning, CME Outfitters, and Eczema Society of Canada. His institution receives education grants from Sanofi.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Bill & Melinda Gates Foundation.

ORCID iDs

Alanna C. Bridgman  <https://orcid.org/0000-0002-5274-1527>

Christina Fitzmaurice  <https://orcid.org/0000-0002-6802-3394>

Ayman Grada  <https://orcid.org/0000-0002-5321-0584>

Supplemental Material

Supplemental material for this article is available online.

References

1. Lim HW, Collins SAB, Resneck JS, et al. The burden of skin disease in the United States. *J Am Acad Dermatol*. 2017;76(5):958-972. doi:10.1016/j.jaad.2016.12.043
2. Bridgman AC, Block JK, Drucker AM. The multidimensional burden of atopic dermatitis: an update. *Ann Allergy Asthma Immunol*. 2018;120(6):603-606. doi:10.1016/j.anai.2018.03.009
3. Bridgman AC, Eshtiaghi P, Cresswell-Melville A, Ramien M, Drucker AM. The burden of moderate to severe atopic dermatitis in Canadian children: a cross-sectional survey. *J Cutan Med Surg*. 2018;22(4):443-444. doi:10.1177/1203475418761859
4. Hay RJ, Johns NE, Williams HC, et al. The global burden of skin disease in 2010: an analysis of the prevalence and impact of skin conditions. *J Invest Dermatol*. 2014;134(6):1527-1534. published Online First: 2013/10/30. doi:10.1038/jid.2013.446
5. Barbarot S, Auziere S, Gadkari A, et al. Epidemiology of atopic dermatitis in adults: results from an international survey. *Allergy*. 2018;73(6):1284-1293. doi:10.1111/all.13401
6. Eder L, Widdifield J, Rosen CF, et al. Trends in the prevalence and incidence of psoriasis and psoriatic arthritis in Ontario, Canada: a population-based study. *Arthritis Care Res*. 2019;71(8):1084-1091. doi:10.1002/acr.23743
7. Ghazawi FM, Cyr J, Darwich R, et al. Cutaneous malignant melanoma incidence and mortality trends in Canada: a comprehensive population-based study. *J Am Acad Dermatol*. 2019;80(2):448-459. doi:10.1016/j.jaad.2018.07.041
8. Karimkhani C, Dellavalle RP, Coffeng LE, et al. Global skin disease morbidity and mortality: an update from the global burden of disease study 2013. *JAMA Dermatol*. 2017;153(5):406-412. doi:10.1001/jamadermatol.2016.5538
9. GBD 2017 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2018;392(10159):1859-1922. doi:10.1016/S0140-6736(18)32335-3
10. Statistics Canada. Population projections for Canada (2018 to 2068), provinces and territories (2018 to 2043); 2019.
11. Roth GA, Abate D, Abate KH, GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2018;392(10159):1736-1788. doi:10.1016/S0140-6736(18)32203-7
12. James SL, Abate D, Abate KH, GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2018;392(10159):1789-1858. doi:10.1016/S0140-6736(18)32279-7
13. GBD 2017 Population and Fertility Collaborators. Population and fertility by age and sex for 195 countries and territories, 1950-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2018;392(10159):1995-2051. doi:10.1016/S0140-6736(18)32278-5
14. Stevens GA, Alkema L, Black RE, et al. Guidelines for accurate and transparent health estimates reporting: the gather statement. *PLoS Med*. 2016;13(6):e1002056. doi:10.1371/journal.pmed.1002056
15. Stevens GA, Alkema L, Black RE, et al. Guidelines for accurate and transparent health estimates reporting: the gather statement. *Lancet*. 2016;388(10062):e19-e23. doi:10.1016/S0140-6736(16)30388-9
16. Global Burden of Disease. 2017. <http://ghdx.healthdata.org/gbd-results-tool>
17. GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2018;392(10159):1789-1858. doi:10.1016/S0140-6736(18)32279-7
18. Barendregt JJ, Van Oortmarssen GJ, Vos T, Murray CJL. A generic model for the assessment of disease epidemiology: the computational basis of DisMod II. *Popul Health Metr*. 2003;1(1):4. published Online First: 2003/05/30. doi:10.1186/1478-7954-1-4
19. GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2018;392(10159):1736-1788. doi:10.1016/S0140-6736(18)32203-7
20. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the global burden of disease study 2016. *Lancet*. 2017;390(10100):1211-1259. doi:10.1016/S0140-6736(17)32154-2
21. Verma J, Samis S. Canada's population is aging. *Healthc Pap*. 2011;11(1):3-5. published Online First: 2011/04/06.
22. Caliendo AM, Gilbert DN, Ginocchio CC, et al. Better tests, better care: improved diagnostics for infectious diseases. *Clin Infect Dis*. 2013;57(Suppl 3):S139-S170. doi:10.1093/cid/cit578

23. Thomas L, Puig S, Dermoscopy PS. Dermoscopy, digital dermoscopy and other diagnostic tools in the early detection of melanoma and follow-up of high-risk skin cancer patients. *Acta Derm Venereol.* 2017;Suppl 218:14-21. doi:10.2340/00015555-2719
24. Welch HG, Kramer BS, Black WC. Epidemiologic signatures in cancer. *N Engl J Med.* 2019;381(14):1378-1386. doi:10.1056/NEJMSr1905447
25. Baibergenova A, Drucker AM, Shear NH. Hospitalizations for cellulitis in Canada: a database study. *J Cutan Med Surg.* 2014;18(1):33-37. doi:10.2310/7750.2013.13075
26. Pallin DJ, Camargo CA, Schuur JD. Skin infections and antibiotic stewardship: analysis of emergency department prescribing practices, 2007-2010. *West J Emerg Med.* 2014;15(3):282-289. doi:10.5811/westjem.2013.8.18040
27. Russo A, Concia E, Cristini F, et al. Current and future trends in antibiotic therapy of acute bacterial skin and skin-structure infections. *Clin Microbiol Infect.* 2016;22(Suppl 2):S27-S36. doi:10.1016/S1198-743X(16)30095-7
28. Global Burden of Disease Cancer Collaborators. Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 29 cancer groups, 1990 to 2017: a systematic analysis for the global burden of disease study. *JAMA Oncol.* 2019;5(12):1749-1768. doi:10.1001/jamaoncol.2019.2996
29. Chahal HS, Rieger KE, Sarin KY. Incidence ratio of basal cell carcinoma to squamous cell carcinoma equalizes with age. *J Am Acad Dermatol.* 2017;76(2):353-354. published Online First: 2017/01/17. doi:10.1016/j.jaad.2016.08.019
30. Rogers HW, Weinstock MA, Feldman SR, Coldiron BM. Incidence estimate of nonmelanoma skin cancer (keratinocyte carcinomas) in the U.S. population, 2012. *JAMA Dermatol.* 2015;151(10):1081-1086. published Online First: 2015/05/01. doi:10.1001/jamadermatol.2015.1187
31. Dodds M, Arron ST, Linos E, Polcari I, Mansh MD. Characteristics and skin cancer risk behaviors of adult Sunless Tanners in the United States. *JAMA Dermatol.* 2018;154(9):1066-1071. published Online First: 2018/07/27. doi:10.1001/jamadermatol.2018.2054
32. Bergenmar M, Törnberg S, Brandberg Y. Factors related to non-attendance in a population based melanoma screening program. *Psychooncology.* 1997;6(3):218-226. doi:10.1002/(SICI)1099-1611(199709)6:3<218::AID-PON265>3.0.CO;2-G
33. de Rooij MJ, Rampen FH, Schouten LJ, Neumann HA. Factors influencing participation among melanoma screening attenders. *Acta Derm Venereol.* 1997;77(6):467-470. published Online First: 1997/12/12. doi:10.2340/0001555577467470
34. Pyne JH, Myint E, Barr EM, Clark SP, Hou R. Basal cell carcinoma: variation in invasion depth by subtype, sex, and anatomic site in 4,565 cases. *Dermatol Pract Concept.* 2018;8(4):314-319. published Online First: 2018/11/28. doi:10.5826/dpc.0804a13
35. Armstrong LTD, Magnusson MR, Guppy MPB. Risk factors for recurrence of facial basal cell carcinoma after surgical excision: a follow-up analysis. *J Plast Reconstr Aesthet Surg.* 2017;70(12):1738-1745. published Online First: 2017/06/06. doi:10.1016/j.bjps.2017.04.006
36. Whiteman DC, Green AC, Olsen CM. The growing burden of invasive melanoma: projections of incidence rates and numbers of new cases in six susceptible populations through 2031. *J Invest Dermatol.* 2016;136(6):1161-1171. published Online First: 2016/02/24. doi:10.1016/j.jid.2016.01.035
37. Hugo G. The changing demographics of Australia over the last 30 years. *Australas J Ageing.* 2013;32(Suppl 2):18-27. published Online First: 2013/11/06. doi:10.1111/ajag.12113
38. 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. published Online First: 2015/12/04. doi:10.1186/s40463-015-0107-1
39. Peters CE, Nicol A-M, Demers PA. Prevalence of exposure to solar ultraviolet radiation (UVR) on the job in Canada. *Can J Public Health.* 2012;103(3):223-226. published Online First: 2012/08/22. doi:10.1007/BF03403817
40. Cheng C-M, Hsu J-W, Huang K-L, et al. Risk of developing major depressive disorder and anxiety disorders among adolescents and adults with atopic dermatitis: a nationwide longitudinal study. *J Affect Disord.* 2015;178:60-65. doi:10.1016/j.jad.2015.02.025
41. Slattery MJ, Essex MJ. Specificity in the association of anxiety, depression, and atopic disorders in a community sample of adolescents. *J Psychiatr Res.* 2011;45(6):788-795. published Online First: 2010/11/30. doi:10.1016/j.jpsychires.2010.11.003
42. Shin J, Choi Y, Park E-C, et al. Psychiatry outpatient visits by atopic dermatitis patients varying in the complexity of their prescriptions: a nationwide cohort study conducted from 2005 to 2013. *Medicine.* 2016;95(49):e5411. published Online First: 2016/12/09. doi:10.1097/MD.00000000000005411
43. Lee C-Y, Chen M-H, Jeng M-J, et al. Longitudinal association between early atopic dermatitis and subsequent attention-deficit or autistic disorder: a population-based case-control study. *Medicine.* 2016;95(39):e5005. published Online First: 2016/09/30. doi:10.1097/MD.00000000000005005