RESEARCH

# Global Burden of Disease Study trends for Canada from 1990 to 2016

Justin J. Lang PhD, Samiah Alam MSc, Leah E. Cahill PhD, Aaron M. Drucker MD ScM, Carolyn Gotay PhD, Jeanne F. Kayibanda PhD, Nicole Kozloff MD SM, Kedar K.V. Mate MSc, Scott B. Patten MD PhD, Heather M. Orpana PhD

Cite as: *CMAJ* 2018 November 5;190:E1296-304. doi: 10.1503/cmaj.180698

*CMAJ* Podcasts: author interview at https://soundcloud.com/cmajpodcasts/180698-res

## ABSTRACT

**BACKGROUND:** The Global Burden of Disease Study represents a large and systematic effort to describe the burden of diseases and injuries over the past 3 decades. We aimed to summarize the Canadian data on burden of diseases and injuries.

**METHODS:** We summarized data from the 2016 iteration of the Global Burden of Disease Study to provide current (2016) and historical estimates for all-cause and cause-specific diseases and injuries using mortality, years of life lost, years lived with disability and disability-adjusted life years in Canada. We also compared changes in life expectancy and health-adjusted life expectancy between Canada and 21 countries with a high sociodemographic index.

**RESULTS:** In 2016, leading causes of all-age disability-adjusted life years were neoplasms, cardiovascular diseases, musculoskeletal diseases, and mental and substance use disorders, which together accounted for about 56% of disability-adjusted life years. Between 2006 and 2016, the rate of all-cause age-standardized years of life lost declined by 12%, while the rate of all-cause age-standardized years lived with disability remained relatively stable (+1%), and the rate of all-cause age-standardized disability-adjusted life year declined by 5%. In 2016, Canada aligned with countries that have a similar high sociodemographic index in terms of life expectancy (82 yr) and health-adjusted life expectancy (71 yr).

**INTERPRETATION:** The patterns of mortality and morbidity in Canada reflect an aging population and improving patterns of population health. If current trends continue, Canada will continue to face challenges of increasing population morbidity and disability alongside decreasing premature mortality.

In 2015, for the first time in history, Canadians aged 65 years and older formed a larger proportion of the population than those aged 14 years and younger.[1] As with other high-income countries that have undergone the epidemiologic transition, noncommunicable diseases are driving morbidity and mortality in Canada.[2] Previous studies have provided detailed insight into cause-specific patterns of disease in the Canadian population[3,4] using broad summary estimates of population health, such as health-adjusted life expectancy.[5] However, a comprehensive historical account of health loss across diseases and injuries in Canada, through metrics such as disability-adjusted life years, has not yet been reported. This type of information could help inform decision-making in Canada by providing a better understanding of the diseases and injuries driving health loss in this country.

The Global Burden of Disease (GBD) Study provides a unique platform enabling the examination of health status by country, synthesizing data on a set of 333 diseases and injuries by age and sex, comparable across time (1990–2016) and among 195 countries and territories. The GBD Study also reports disability-adjusted life years, a variable that summarizes both mortality and morbidity and is a useful metric for understanding the relative burden of specific diseases and injuries. The GBD Study accomplishes these activities through the efforts of more than 3000 collaborators from more than 135 countries, led by the Institute for Health Metrics and Evaluation at the University of Washington, Seattle.[6] The GBD estimates are being used to inform health policy in several countries, including the United States, the Philippines, India, New Zealand and the United Kingdom.[7–9] As such, the GBD Study's methodologic innovations could add value to estimates available from established national data systems.

Canadian GBD estimates of disease burden can be found online through the GBD data visualization tool and in supple-

mentary tables of the GBD capstone publications,[10–12] but the estimates have not yet been summarized and interpreted. Here, we present current (2016) and historical (1990 and 2006) estimates for Canada of all-cause and cause-specific mortality, years lived with disability, years of life lost and disability-adjusted life years, as well as cumulative percent changes from 2006 to 2016 for all estimates. We also provide estimates of life expectancy and health-adjusted life expectancy for Canada and 21 comparable countries in North America, Western Europe and Australasia for both 2006 and 2016.

## Methods

The GBD Study uses comprehensive data and methods to summarize and compare disease burden by age, sex, country, cause and year. The methods of the GBD Study have been reported in detail elsewhere.[10–12] In brief, global, regional and national estimates for disease prevalence, incidence, mortality, years of life lost, years lived with disability, disability-adjusted life years, life expectancy and health-adjusted life expectancy were published in the 2016 capstone papers, along with detailed methods for each set of estimates.[10–12] All GBD methods, data, codes and estimates are publicly available through interactive tools and visualizations at the online Data Visualization Hub (https://vizhub.healthdata.org/gbd-compare/). The GBD methodology is updated annually and is compliant with the Guidelines for Accurate and Transparent Health Estimates Reporting (also known as GATHER).[13] Members of the author group for the current paper are all GBD collaborators.

### Data sources

Data obtained for the GBD Study were identified through comprehensive reviews of published studies reporting data for specific conditions and risk factors, unpublished national sources, international databases and additional data sources provided by GBD collaborators.[10–12] The 2016 iteration of the GBD Study incorporated data for Canada from 619 data sources (available from http://ghdx.healthdata.org/gbd-2016/data-input-sources).

### GBD cause hierarchy

For mortality and nonfatal outcomes, the GBD hierarchy is organized into 4 levels, which are mutually exclusive and collectively exhaustive.[10–12] Sixty-eight of these causes are sources of disability but not death, whereas 5 are causes of death but not disability.[12] Level 0 includes all causes. Level 1 causes represent 3 major categories: communicable, maternal, neonatal and nutritional diseases; noncommunicable diseases; and injuries. Level 2 includes 21 broad cause groups within the level 1 categories, such as cardiovascular disease and noncommunicable diseases. Level 3 includes individual causes within the level 2 groups, such as cerebrovascular disease within cardiovascular disease. Finally, level 4 of the hierarchy includes sub-causes for some level 3 causes, such as hemorrhagic stroke within cerebrovascular disease. Here, we generally present data from level 0 to level 2; in only a few instances are level 3 data presented, to increase clarity (e.g., for HIV/AIDS and tuberculosis).

### Statistical analysis

#### Mortality and nonfatal health loss

We modelled mortality estimates for diseases and injuries using the Cause of Death Ensemble model (CODEm)[14] or custom models for certain diseases. Detailed methods for the modelling procedures for mortality are provided elsewhere.[10] In brief, CODEm generates mortality estimates for each location-year, age and sex, through a standardized modelling process that combines covariable selection and out-of-sample validity analyses. We modelled nonfatal diseases using Disease Modelling-Meta-Regression II (DisMod-MR 2.1)[11] or custom models for certain diseases. DisMod-MR 2.1 uses Bayesian meta-regression to synthesize available data sources and produce internally consistent estimates of incidence, prevalence, remission and excess mortality. We estimated nonfatal sequelae and comorbidities separately for each age group, sex, location and year through microsimulation. We applied disability weights to nonfatal causes by severity, using the same weights as in the 2013 and 2015 iterations of the GBD Study.[12]

#### Years of life lost, years lived with disability and disability-adjusted life years

We calculated years of life lost as the sum of each death multiplied by a standard life expectancy at each age.[10] We calculated the standard life expectancy for all countries from the lowest observed risk of mortality in each 5-year age group within populations greater than 5 million, which was 86.6 years in 2016. We calculated years of life lived with disability by multiplying the prevalence of a sequela by the disability weight for the corresponding health state.[11] We calculated disability-adjusted life years as the sum of years of life lost and years lived with disability for each cause; this variable was the cause-specific burden of a disease or injury, accounting for life lost and disability.[12] We used the GBD time-invariant, world population age standard to calculate age-standardized rates for all measures.[15] Detailed descriptions of the methods used to calculate these measures of disease burden have been desribed elsewhere.[10–12]

#### Life expectancy

We calculated life expectancy using life tables that use age- and sex-specific mortality rates to calculate period life expectancy at birth and at different ages.[16] We calculated health-adjusted life expectancy using the Sullivan approach, which incorporates age- and sex-specific mortality rates, disease prevalence and associated disability weights for all disease sequelae, as well as comorbidity in the population.[17]

#### International comparisons

We used the GBD sociodemographic index, which summarizes per capita income, mean years of education in the population aged 15 and older, and total fertility rate to identify relevant comparator countries.[12] In this paper, we compared Canada with other countries in North America, Western Europe and Australasia in the top quintile of the 2016 sociodemographic index.

**Table 1 (part 1 of 2): All-age years lived with disability counts and rates of age-standardized years lived with disability per 100 000 for diseases and injuries in Canada in 2016, and cumulative percent changes for 2006 to 2016 (both sexes combined)**

| | All-age YLD | | | Age-standardized YLD rate, per 100 000 | | |
|---|---|---|---|---|---|---|
| Cause (disease or injury) | 2016 count (95% UI) | Rank in 2016 (count)* | % change, 2006 to 2016 | 2016 rate (95% UI) | Rank in 2016 (rate)* | % change, 2006 to 2016 |
| All causes | 4 512 880 (3 365 754–5 796 010) | NA | 17 | 10 598 (7886–13 701) | NA | 1 |
| Communicable, maternal, neonatal and nutritional diseases | 133 545 (95 133–180 056) | NA | 21 | 396 (283–535) | NA | 10 |
| HIV/AIDS and tuberculosis (combined) | 10 252 (4710–18 670) | 16 | 30 | 23 (10–42) | 16 | 13 |
| HIV/AIDS† | 9895 (4435–18 311) | NA | 31 | 24 (11–43) | NA | 14 |
| Tuberculosis† | 357 (234–500) | NA | 12 | 1 (1–1) | NA | –3 |
| Diarrhea, lower respiratory and other common infectious diseases | 54 780 (35 565–80 418) | 11 | 12 | 165 (106–243) | 9 | 1 |
| Neglected tropical diseases and malaria | 112 (61–240) | 21 | –2 | 0 (0–1) | 21 | –16 |
| Maternal disorders | 524 (326–783) | 20 | 7 | 2 (1–2) | 19 | –4 |
| Neonatal disorders | 44 210 (31 048–61 791) | 12 | 37 | 132 (92–184) | 11 | 25 |
| Nutritional deficiencies | 17 663 (11 563–26 518) | 15 | 16 | 58 (38–88) | 15 | 8 |
| Other communicable, maternal, neonatal and nutritional diseases | 5803 (3479–9608) | 18 | 14 | 15 (9–25) | 17 | 3 |
| Noncommunicable diseases | 4 013 355 (2 972 963–5 157 859) | NA | 17 | 9408 (6953–12 139) | NA | 1 |
| Neoplasms | 67 454 (49 603–88 406) | 10 | 28 | 125 (92–164) | 12 | 0 |
| Cardiovascular diseases | 240 834 (176 513–313 325) | 7 | 21 | 437 (319–570) | 7 | –5 |
| Chronic respiratory diseases | 145 961 (106 939–193 068) | 8 | 7 | 378 (269–512) | 8 | –7 |
| Cirrhosis and other chronic liver diseases | 7222 (5062–10 060) | 17 | 24 | 15 (11–21) | 18 | 2 |
| Digestive diseases | 27 658 (19 623–37 770) | 13 | 17 | 61 (43–84) | 14 | –0 |
| Neurologic disorders | 411 060 (280 011–554 154) | 4 | 8 | 994 (670–1352) | 4 | –5 |
| Mental and substance use disorders | 930 422 (674 147–1 194 375) | 2 | 14 | 2453 (1782–3160) | 1 | 3 |
| Diabetes mellitus, urogenital, blood and endocrine diseases | 326 535 (230 823–435 543) | 5 | 22 | 659 (464–883) | 5 | –0 |
| Musculoskeletal disorders | 1 035 204 (758 579–1 339 935) | 1 | 22 | 2265 (1652–2948) | 2 | 3 |
| Other noncommunicable diseases | 821 004 (562 807–1 153 821) | 3 | 18 | 2022 (1393–2854) | 3 | 1 |
| Injuries | 365 980 (242 373– 521 636) | NA | 21 | 795 (524–1142) | NA | 1 |
| Transport injuries | 74 222 (48 641–106 679) | 9 | 10 | 164 (107–237) | 10 | –7 |

**Table 1 (part 2 of 2): All-age years lived with disability counts and rates of age-standardized years lived with disability per 100 000 for diseases and injuries in Canada in 2016, and cumulative percent changes for 2006 to 2016 (both sexes combined)**

| | All-age YLD | | | Age-standardized YLD rate, per 100 000 | | |
|---|---|---|---|---|---|---|
| Cause (disease or injury) | 2016 count (95% UI) | Rank in 2016 (count)* | % change, 2006 to 2016 | 2016 rate (95% UI) | Rank in 2016 (rate)* | % change, 2006 to 2016 |
| Unintentional injuries | 265 651 (176 916–384 718) | 6 | 25 | 567 (374–822) | 6 | 3 |
| Self-harm and interpersonal violence (combined) | 25 548 (16 941–36 576) | 14 | 17 | 62 (41–88) | 13 | 2 |
| Self-harm† | 7197 (4659–10 316) | NA | 13 | 17 (11–24) | NA | –3 |
| Interpersonal violence† | 18 350 (12 205–26 530) | NA | 19 | 45 (30–65) | NA | 4 |
| Forces of nature, conflict and terrorism, and executions and police conflict | 562 (156–1519) | 19 | 37 | 1 (0–4) | 20 | 18 |

Note: NA = not applicable, UI = uncertainty interval, YLD = years lived with disability.
*Ranks are provided for level 2 causes of the Global Burden of Disease (GBD) cause hierarchy, in descending order, with the leading cause being ranked number 1.
†Represents level 3 causes of the GBD cause hierarchy.

### Uncertainty intervals

We calculated uncertainty intervals for all estimates, taking a number of factors into account, such as adjustment, standardization and uncertainty in model parameters, depending on the estimate. When calculation of GBD estimates required multiple steps, the uncertainty associated with each step is propagated through the entire calculation. The 95% uncertainty intervals for all estimates are reported in the tables.

### Ethics approval

Ethics approval was not sought because this study was a secondary data analysis of published results.

## Results

### Mortality and years of life lost

In 2016, the largest proportion of deaths was caused by noncommunicable diseases, with an estimate of 243 553 deaths (see Table A1 in Appendix 1, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.180698/-/DC1), with neoplasms and cardiovascular diseases as the leading causes. Communicable, maternal, neonatal and nutritional diseases accounted for 13 184 deaths, and injuries for 15 999 deaths. From 2006 to 2016, the age-standardized mortality rate decreased by 12%. The largest proportional cause-specific changes in age-standardized mortality rates between 2006 and 2016 were in the categories of forces of nature, conflict and terrorism, and executions and police conflict (–72%), HIV/AIDS and tuberculosis (–40%), transport injuries (–20%) and cardiovascular diseases (–19%). The only level 2 age-standardized mortality rate that increased during this period was that for mental and substance use disorders, with an increase of 11%. Tables A1 to A3 in Appendix 1 present estimates for Canadian mortality, years of life lost, years lived with disability and disability-adjusted life years for all GBD level 0 to 3 causes.

More all-age years of life lost were accounted for by neoplasms (1 530 983) and cardiovascular diseases (987 044) than all other causes combined (Table A1 in Appendix 1). From 2006 to 2016, the rate of all-cause age-standardized years of life lost decreased by 12% to 8798 years of life lost per 100 000. During this period, the rates of age-standardized years of life lost for every level 2 cause decreased, except for mental and substance use disorders, which increased by 12% to 244 years of life lost per 100 000.

### Years lived with disability and disability-adjusted life years

In 2016, there were 4 512 880 years lived with disability from all causes (Table 1 and Table A2 in Appendix 1). The leading cause of all-age years lived with disability was musculoskeletal disorders at 1 035 204, closely followed by mental and substance use disorders at 930 422. In contrast to the age-standardized mortality rate, which decreased between 2006 and 2016, the rate of age-standardized years lived with disability remained relatively stable (+1%). Between 2006 and 2016, the largest decline in rates of age-standardized years lived with disability for level 2 causes occurred for neglected tropical diseases and malaria (–16%), and the largest increase was for neonatal disorders (+25%).

Neoplasms, cardiovascular disease, musculoskeletal disorders, and mental and substance use disorders were the top 4 causes of all-age disability-adjusted life year counts in Canada in 2016, accounting for about 56% of the total 8 824 288 disability-adjusted life years (Table 2 and Table A3 in Appendix 1). Figure 1 shows the rank of all-age cause-specific disability-adjusted life years in 1990, 2006 and 2016. Neoplasms surpassed cardiovascular disease as the top cause of all-age disability-adjusted life years between 1990 and 2006, and these ranks were maintained in 2016. During this period, musculoskeletal disorders surpassed mental and substance use disorders to become the third leading cause of all-age disability-adjusted life years. The rate of all-cause, age-standardized disability-adjusted life years decreased by 5% between 2006 and 2016,

**Table 2 (part 1 of 2): All-age disability-adjusted life year counts and rates of age-standardized disability-adjusted life years per 100 000 for diseases and injuries in Canada in 2016, and cumulative percent changes for 2006 to 2016 (both sexes combined)***

| | All-age DALYs | | | Age-standardized DALY rate, per 100 000 | | |
|---|---|---|---|---|---|---|
| Cause (disease or injury) | 2016 count (95% UI) | Rank in 2016 (count)† | % change, 2006 to 2016 | 2016 rate (95% UI) | Rank in 2016 (rate)† | % change, 2006 to 2016 |
| All causes | 8 824 288 (7 638 096–10 121 267) | NA | 14 | 19 396 (16 598–22 491) | NA | –5 |
| Communicable, maternal, neonatal and nutritional diseases | 371 574 (328 284–421 247) | NA | 11 | 1109 (966–1265) | NA | –5 |
| HIV/AIDS and tuberculosis (combined) | 24 360 (18 687–32 855) | 16 | –19 | 58 (44–77) | 17 | –28 |
| HIV/AIDS‡ | 22 013 (16 401–30 491) | NA | –20 | 53 (40–72) | NA | –28 |
| Tuberculosis‡ | 2347 (2099–2617) | NA | –9 | 5 (4–5) | NA | –24 |
| Diarrhea, lower respiratory and other common infectious diseases | 172 959 (151 182–200 033) | 12 | 16 | 393 (330–470) | 13 | –5 |
| Neglected tropical diseases and malaria | 342 (273–480) | 21 | –0 | 1 (1–1) | 21 | –10 |
| Maternal disorders | 2431 (2076–2810) | 19 | –4 | 7 (6–8) | 19 | –11 |
| Neonatal disorders | 133 459 (110 825–156 834) | 13 | 12 | 545 (456–639) | 12 | –2 |
| Nutritional deficiencies | 21 194 (15 043–30 075) | 17 | 15 | 64 (44–95) | 16 | 6 |
| Other communicable, maternal, neonatal and nutritional diseases | 16 831 (14 126–20 713) | 18 | 10 | 42 (35–53) | 18 | –3 |
| Noncommunicable diseases | 7 614 897 (6 564 561–8 764 722) | NA | 14 | 16 243 (13 739–18 981) | NA | –5 |
| Neoplasms | 1 598 437 (1 531 426–1 665 479) | 1 | 14 | 3008 (2878–3134) | 1 | –10 |
| Cardiovascular diseases | 1 227 878 (1 146 628–1 309 432) | 2 | 8 | 2179 (2032–2324) | 5 | –16 |
| Chronic respiratory diseases | 335 299 (293 354–384 957) | 9 | 10 | 714 (600–856) | 9 | –10 |
| Cirrhosis and other chronic liver diseases | 110 087 (101 389–119 034) | 14 | 14 | 213 (197–230) | 14 | –7 |
| Digestive diseases | 109 791 (95 018–124 265) | 15 | 16 | 212 (183–243) | 15 | –7 |
| Neurologic disorders | 687 440 (549 979–838 011) | 6 | 15 | 1474 (1145–1845) | 6 | –4 |
| Mental and substance use disorders | 1 030 496 (775 745–1 295 117) | 4 | 15 | 2697 (2023–3406) | 2 | 4 |
| Diabetes mellitus, urogenital, blood and endocrine diseases | 563 635 (470 739–675 776) | 7 | 16 | 1114 (924–1345) | 7 | –7 |
| Musculoskeletal disorders | 1 053 138 (777 459–1 358 990) | 3 | 21 | 2300 (1686–2984) | 4 | 3 |
| Other noncommunicable diseases | 898 697 (643 118–1 233 063) | 5 | 16 | 2333 (1700–3160) | 3 | –1 |
| Injuries | 837 816 (714 075–1 004 250) | NA | 7 | 2044 (1768–2418) | NA | –8 |
| Transport injuries | 209 744 (181 775–245 581) | 11 | –6 | 554 (490–637) | 11 | –17 |

**Table 2 (part 2 of 2): All-age disability-adjusted life years counts and rates of age-standardized disability-adjusted life years per 100 000 for diseases and injuries in Canada in 2016, and cumulative percent changes for 2006 to 2016 (both sexes combined)***

| | All-age DALYs | | | Age-standardized DALY rate, per 100 000 | | |
|---|---|---|---|---|---|---|
| Cause (disease or injury) | 2016 count (95% UI) | Rank in 2016 (count)† | % change, 2006 to 2016 | 2016 rate (95% UI) | Rank in 2016 (rate)† | % change, 2006 to 2016 |
| Unintentional injuries | 389 289 (299 348–508 564) | 8 | 19 | 859 (660–1121) | 8 | –2 |
| Self–harm and interpersonal violence (combined) | 237 440 (201 557–263 231) | 10 | 4 | 627 (534–696) | 10 | –5 |
| Self-harm‡ | 192 398 (155 047–215 915) | NA | 4 | 503 (406–564) | NA | –5 |
| Interpersonal violence‡ | 45 042 (34 689–58 523) | NA | 7 | 125 (97–163) | NA | –3 |
| Forces of nature, conflict and terrorism, and executions and police conflict | 1343 (745–2363) | 20 | –53 | 4 (2–6) | 20 | –60 |

Note: DALY = disability-adjusted life years, NA = not applicable, UI = uncertainty interval.
*This table presents disability-adjusted life year estimates, which combine years of life lost and years lived with disability.
†Ranks are provided for level 2 causes of the Global Burden of Disease (GBD) cause hierarchy, in descending order, with the leading cause being ranked number 1.
‡Represents level 3 causes of the GBD cause hierarchy.

with the rates for only nutritional deficiencies, mental and substance use disorders, and musculoskeletal disorders increasing during this period (Table 2). In 1990, 45% of total all-cause disability-adjusted life years were from years lived with disability; this proportion grew to 50% in 2006 and 52% in 2016. This change indicates a shift from premature mortality to morbidity contributing to overall health loss in Canada. As shown in Appendix 2 (available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.180698/-/DC1), peak age-specific disability-adjusted life years were in the 60- to 64-year age group for both males and females.

### Life expectancy and healthy life expectancy at birth across countries with high sociodemographic index

In 2006, Canada's life expectancy at birth — 81 years — was ranked eighth among the 21 comparator countries, with life expectancies in this group ranging from 78 years in the US and Denmark to 83 years in Andorra (Table 3). In 2016, Canada's life expectancy increased to 82 years, which ranked tenth. In 2006, Canada's health-adjusted life expectancy — 70 years — was ranked sixth among the 21 countries with a high sociodemographic index; in 2016, Canada ranked seventh with a health-adjusted life expectancy of 71 years.

## Interpretation

We identified several important findings in this study. All-age mortality is increasing, but age-standardized mortality is declining across most causes. This pattern reflects an aging population combined with improved population health. In addition, there is a general shift in the burden of health loss from premature mortality to disability, as shown by years lived with disability accounting for 52% of total disability-adjusted life years in 2016, a proportion that increased from 45% in 1990. Rankings in cause-specific all-age disability-adjusted life years seem to have stabilized in recent years, with only minor changes in the rankings of level 2 GBD causes between 2006 and 2016. Finally, improved population health has translated into gains in life expectancy and health-adjusted life expectancy that have kept pace with those of other high-income countries.

We have highlighted notable reductions in age-standardized disability-adjusted life years, mortality and years of life lost for cardiovascular diseases, reductions that were larger than those seen for neoplasms. As a result, cardiovascular diseases are now the second leading cause of disease burden in Canada, consistent with findings for some other high-income countries.[18] In contrast, increasing age-standardized rates for mental and substance use disorders were observed for all measures of burden. Mortality associated with drug use disorders was a primary contributor to this increase. This trend is likely to continue, given the large increases observed in opioid-related mortality in Canada in 2016 and 2017,[19,20] similar to trends observed in the US.[21] Between 2006 and 2016, musculoskeletal disorders had a higher disability burden than mental and substance use disorders, and were the leading cause of years lived with disability and the third leading cause of all-age disability-adjusted life years, similar to a global pattern.[22] Overall, the burden of disease in Canada is shifting from premature mortality, measured by years of life lost, to a greater burden resulting from years lived with disability. This shift is consistent with other high-income countries, including the US.[9] Further exploration of changes at levels 3 and 4 of the GBD hierarchy is needed to unpack some of the observed trends, including further exploration of how changing patterns of risk and protective factors influence these patterns.[23]

### Limitations

The estimates presented here were modelled through the GBD Study, and results may differ from those reported by Canada's

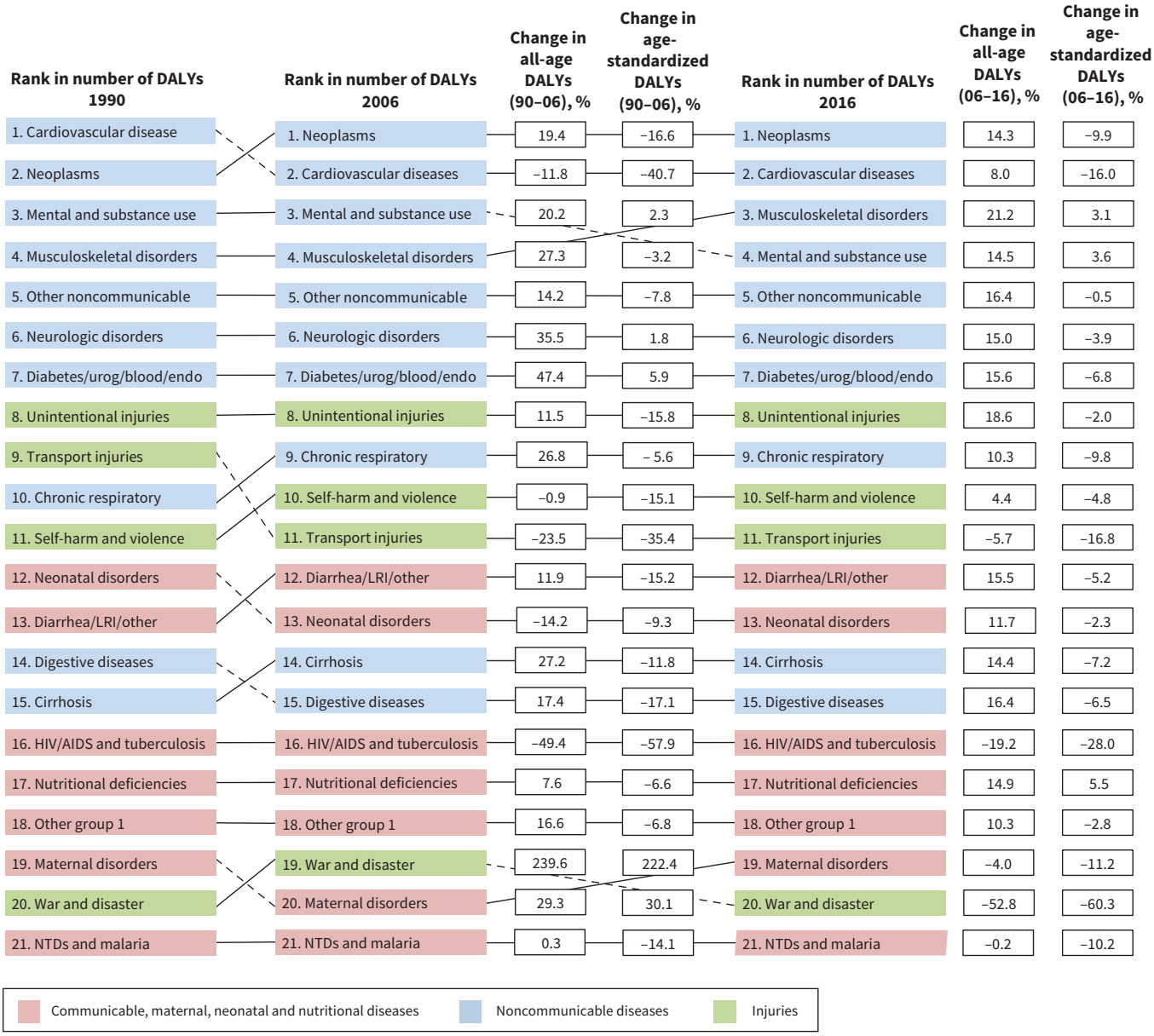


**Figure 1:** Rank of disability-adjusted life years (DALYs) and percent change for diseases and injuries in 1990, 2006 and 2016 for both sexes combined, showing percent change of counts and age-standardized rates per 100 000. The line connecting a box for a disease or injury type in one year to the corresponding box in a later year is solid if the rank rose or did not change; the line is dashed if the rank declined. endo = endocrinologic, LRI = lower respiratory infection, NTD = neglected tropical diseases, urog = urogenital; "other group 1" includes sexually transmitted diseases excluding HIV, hepatitis and other infectious diseases.

data systems. The GBD estimates are strengthened by a consistent approach to data cleaning and standardization and by comparability across causes, over time and between countries; as such, our findings complement existing Canadian estimates and provide additional information about years lived with disability and disability-adjusted life years for a comprehensive list of causes. The GBD Study does not model subnational (provincial/territorial or regional) or other important subpopulation (e.g., Indigenous people, people living with low income) estimates for Canada, which may be important, given that previous research has identified variability in disease estimates across Canada.[24,25] These limitations may be addressed in future iterations of the GBD Study. The 2016 estimates provided here do not incorporate the most current vital statistics because of the time lag in releasing data, which means that our results may not reflect any recent and important changes such as the opioid epidemic.[19]

## Conclusion

We have presented internationally recognized and systematic estimates describing the burden of disease and injury in Canada, with a focus on the period from 2006 to 2016. Estimates from the GBD Study for mortality, years of life lost, years lived with disability and disability-adjusted life years in Canada highlight declining age-standardized mortality and disability-adjusted life year rates, as well as gains in life expectancy and health-adjusted life expectancy between 2006 and 2016 that have kept pace with those in similar

**Table 3: Life expectancy and health-adjusted life expectancy at birth, for both sexes combined, in 2006 and 2016 for countries in North America, Western Europe and Australasia with a high sociodemographic index**

| | Life expectancy at birth, yr | | | | | Health-adjusted life expectancy at birth, yr | | | | | Proportion of life in unhealthy state | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | | 2016 | | | 2006 | | 2016 | | | | |
| Country | Estimate (95% UI) | 2006 rank | Estimate (95% UI) | 2016 rank | % change, 06 to 16 | Estimate (95% UI) | 2006 rank | Estimate (95% UI) | 2016 rank | % change, 06 to 16 | 2016 estimate, % | 2016 rank |
| Andorra | 83 (81–84) | 1 | 83 (81–84) | 2 | –0 | 71 (68–74) | 1 | 71 (68–74) | 7 | 0 | 14 | 20 |
| Australia | 81 (81–82) | 4 | 83 (82–83) | 2 | 2 | 71 (67–73) | 4 | 72 (68–74) | 4 | 1 | 13 | 12 |
| Austria | 80 (80–80) | 12 | 82 (81–82) | 13 | 2 | 70 (67–72) | 12 | 71 (68–74) | 10 | 2 | 13 | 6 |
| Belgium | 79 (79–80) | 17 | 81 (80–82) | 18 | 2 | 69 (66–72) | 18 | 70 (67–73) | 19 | 2 | 13 | 13 |
| Canada | 81 (80–81) | 8 | 82 (82–82) | 10 | 2 | 70 (67–73) | 6 | 71 (68–74) | 7 | 1 | 13 | 7 |
| Denmark | 78 (78–79) | 21 | 81 (80–82) | 21 | 3 | 68 (65–71) | 21 | 70 (67–73) | 21 | 3 | 14 | 16 |
| Finland | 79 (79–79) | 20 | 82 (81–82) | 11 | 3 | 68 (65–71) | 20 | 71 (67–74) | 16 | 3 | 14 | 21 |
| France | 81 (80–81) | 7 | 82 (82–83) | 4 | 2 | 70 (67–73) | 5 | 72 (69–75) | 3 | 2 | 13 | 3 |
| Germany | 80 (79–80) | 15 | 81 (80–82) | 18 | 2 | 69 (66–72) | 16 | 70 (67–73) | 18 | 2 | 13 | 11 |
| Greece | 80 (80–80) | 12 | 81 (80–82) | 17 | 1 | 70 (67–72) | 10 | 71 (68–73) | 15 | 1 | 13 | 2 |
| Iceland | 81 (81–82) | 3 | 82 (82–83) | 4 | 1 | 71 (68–73) | 2 | 72 (68–74) | 4 | 1 | 13 | 8 |
| Ireland | 79 (79–80) | 19 | 81 (80–82) | 16 | 2 | 69 (66– 72) | 17 | 70 (67–73) | 17 | 2 | 13 | 10 |
| Italy | 81 (81–81) | 5 | 82 (82–83) | 4 | 2 | 71 (68–73) | 2 | 72 (69–75) | 2 | 2 | 13 | 1 |
| Luxembourg | 80 (80–81) | 9 | 82 (81–83) | 7 | 2 | 70 (66–72) | 13 | 71 (68–74) | 9 | 2 | 14 | 17 |
| Malta | 80 (79–80) | 15 | 81 (80–83) | 15 | 2 | 69 (67–72) | 14 | 71 (68–74) | 10 | 2 | 13 | 4 |
| Netherlands | 80 (80–80) | 12 | 82 (81–82) | 12 | 2 | 69 (66–72) | 15 | 71 (68–74) | 14 | 2 | 13 | 14 |
| New Zealand | 80 (80–80) | 11 | 82 (81–82) | 13 | 2 | 70 (67–72) | 10 | 71 (68–74) | 13 | 2 | 13 | 9 |
| Norway | 80 (80–81) | 9 | 82 (81–83) | 7 | 2 | 70 (67–73) | 8 | 72 (69–74) | 4 | 2 | 13 | 5 |
| Sweden | 81 (81–81) | 6 | 82 (81–83) | 9 | 2 | 70 (67–73) | 9 | 71 (68–74) | 10 | 1 | 14 | 18 |
| Switzerland | 82 (81–82) | 2 | 83 (81–85) | 1 | 2 | 70 (67–73) | 6 | 72 (68–75) | 1 | 2 | 14 | 19 |
| United Kingdom | 79 (79–80) | 17 | 81 (81–81) | 18 | 2 | 69 (66–72) | 18 | 70 (67–73) | 20 | 2 | 14 | 15 |
| United States | 78 (78–78) | 22 | 79 (79–79) | 22 | 1 | 67 (64–70) | 22 | 68 (65–71) | 22 | 1 | 14 | 22 |
| Japan* | 82 (82–82) | NA | 84 (84–84) | NA | NA | 72 (69–75) | NA | 71 (68–74) | NA | NA | 15 | NA |

Note: NA = not applicable, UI = uncertainty interval.
*Japan, which is grouped with high-income Asia Pacific countries in the Global Burden of Disease Study, was added here as a benchmark, to highlight one of the leading countries in terms of life expectancy and health-adjusted life expectancy.

high-income countries. There has been a shift in the burden of disease from premature mortality to disability. This shift requires careful health system and public health planning, particularly in light of the major demographic changes that will continue to evolve throughout the coming decades.

## References


1. Table 17-10-0005-01: Population estimates on July 1st, by age and sex. Ottawa: Statistics Canada; (modified 2018 Aug. 31). Available: www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501 (accessed 2018 July 24).
2. Omran AR. The epidemiologic transition. A theory of the epidemiology of population change. *Milbank Mem Fund Q* 1971;49:509-38.
3. *Report from the Canadian Chronic Disease Surveillance System: mental illness in Canada, 2015*. Ottawa: Public Health Agency of Canada; 2015. Available: www.canada.ca/content/dam/canada/health-canada/migration/healthy-canadians/publications/diseases-conditions-maladies-affections/mental-illness-2015-maladies-mentales/alt/mental-illness-2015-maladies-mentales-eng.pdf (accessed 2018 May 18).
4. Canadian Cancer Society, Advisory Committee on Cancer Statistics. *Canadian cancer statistics 2017*. Toronto: Canadian Cancer Society; 2017. Available: www.cancer.ca/~/media/cancer.ca/CW/cancer%20information/cancer%20101/Canadian%20cancer%20statistics/Canadian-Cancer-Statistics-2017-EN.pdf (accessed 2017 Nov. 28).
5. Public Health Agency of Canada, Steering Committee on Health-Adjusted Life Expectancy. *Health-adjusted life expectancy in Canada: 2012 report by the Public Health Agency of Canada*. Ottawa: Public Health Agency of Canada; 2012. Available: www.canada.ca/content/dam/canada/health-canada/migration/healthy-canadians/publications/science-research-sciences-recherches/health-adjusted-life-expectancy-canada-2012-esperance-vie-ajustee-fonction-etat-sante/alt/pub-eng.pdf (accessed 2018 May 17).
6. *Global Burden of Disease (GBD)* [website]. Seattle: Institute for Health Metrics and Evaluation. Available: www.healthdata.org/gbd (accessed 2017 Nov. 27).
7. *Health loss in New Zealand 1990–2013: a report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study*. Wellington (New Zealand): Ministry of Health; 2016. Available: www.health.govt.nz/system/files/documents/publications/health-loss-in-new-zealand-1990-2013-aug16.pdf (accessed 2016 Nov. 27).
8. *Namibia: state of the nation's health. Findings from the Global Burden of Disease.* Seattle: Institute for Health Metrics and Evaluation; 2016. Available: www.healthdata.org/sites/default/files/files/policy_report/2016/PolicyReport_Namibia_2016.pdf (accessed 2016 Nov. 27).
9. Department of Health and Human Services. *NIH-wide strategic plan: fiscal years 2016–2020*. Bethesda (MD): National Institutes of Health; 2015.
10. GBD 2016 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017;390:1151-210.
11. 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;390:1211-59.
12. GBD 2016 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017;390:1260-344.
13. Stevens GA, Alkema L, Black RE, et al.; GATHER Working Group. Guidelines for accurate and transparent health estimates reporting: the GATHER statement. *PLoS Med* 2016;13:e1002116.
14. Foreman KJ, Lozano R, Lopez AD, et al. Modeling causes of death: an integrated approach using CODEm. *Popul Health Metr* 2012;10:1.
15. GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016;388:1459-544.
16. Salomon JA, Wang H, Freeman MK, et al. Healthy life expectancy for 187 countries, 1990–2010: a systematic analysis for the Global Burden Disease Study 2010. *Lancet* 2012;380:2144-62.
17. Sullivan DF. A single index of mortality and morbidity. *HSMHA Health Rep* 1971;86:347-54.
18. Araújo F, Gouvinhas C, Fontes F, et al. Trends in cardiovascular diseases and cancer mortality in 45 countries from five continents (1980–2010). *Eur J Prev Cardiol* 2014;21:1004-17.
19. Special Advisory Committee on the Epidemic of Opioid Overdoses. *National report: apparent opioid-related deaths in Canada (January 2016 to June 2017).* Ottawa: Public Health Agency of Canada; 2017. Available: www.canada.ca/en/public-health/services/publications/healthy-living/apparent-opioid-related-deaths-report-2016-2017-december.html (accessed 2018 May 17).
20. Orpana HM, Lang JJ, Baxi M, et al. Canadian trends in opioid-related mortality and disability from opioid use disorder from 1990 to 2014 through the lens of the Global Burden of Disease Study. *Health Promot Chronic Dis Prev Can* 2018;38:234-43.
21. Gomes T, Tadrous M, Mamdani MM, et al. The burden of opioid-related mortality in the United States. *JAMA Network Open* 2018;1:e180217.
22. March L, Smith EUR, How DG, et al. Burden of disability due to musculoskeletal (MSK) disorders. *Best Pract Res Clin Rheumatol* 2014;28:353-66.
23. GBD 2016 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease 2016. *Lancet* 2017;390:1345-422.
24. Feely A, Lix LM, Reimer K. Estimating multimorbidity prevalence with the Canadian Chronic Disease Surveillance System. *Health Promot Chronic Dis Prev Can* 2017;37:215-22.
25. Young TK, Reading J, Elias B, et al. Type 2 diabetes mellitus in Canada's First Nations: status of an epidemic in progress [published erratum in *CMAJ* 2000; 163:1132]. *CMAJ* 2000;163:561-6.


**Competing interests:** Aaron Drucker reports grants and personal fees from Sanofi and Regeneron for activities outside the work reported here. No other competing interests were declared.

This article has been peer reviewed.

**Affiliations:** Centre for Surveillance and Applied Research (Lang, Orpana), Health Promotion and Chronic Disease Prevention Branch, Public Health Agency of Canada; Healthy Active Living and Obesity Research Group (Lang), CHEO Research Institute, Ottawa, Ont.; Departments of Medicine (Alam, Cahill) and of Community Health and Epidemiology (Alam, Cahill), Dalhousie University, Halifax, NS; Department of Nutrition (Cahill), Harvard T.H. Chan School of Public Health, Boston, Mass.; Division of Dermatology, Department of Medicine (Drucker), and Department of Psychiatry (Kozloff), University of Toronto; Division of Dermatology, Department of Medicine (Drucker), Women's College Hospital; Women's College Research Institute (Drucker), Toronto, Ont.; School of Population and Public Health (Gotay), University of British Columbia, Vancouver, BC; Institut de la statistique du Québec (Kayibanda), Québec, Que.; Slaight Family Centre for Youth in Transition (Kozloff), Centre for Addiction and Mental Health, Toronto, Ont.; School of Physical and Occupational Therapy (Mate), McGill University, Montréal, Que.; Departments of Community Health Sciences (Patten) and of Psychiatry (Patten), University of Calgary, Calgary, Alta.; School of Epidemiology and Public Health (Orpana), University of Ottawa, Ottawa, Ont.

**Contributors:** All of the authors are collaborators in the Global Burden of Disease Study. All of the authors contributed to the concept and design of the work presented here and to interpretation of the data. Justin Lang and Heather Orpana drafted the manuscript. All of the authors contributed to critical revision of the manuscript for important intellectual content, approved the final version to be published and agreed to be accountable for all aspects of the work.

**Funding:** The Global Burden of Disease Study was partially funded by the Bill & Melinda Gates Foundation. The funders had no role in the study design, data analysis, data interpretation or writing of the report. Nicole Kozloff is supported by a NARSAD Young Investigator Grant from the Brain and Behavior Research Foundation.

**Acknowledgements:** This research was conducted as part of the Global Burden of Diseases, Injuries, and Risk Factors Study, led by the Institute for Health Metrics and Evaluation. The authors would like to thank Emily Wolfe Phillips for presubmission review of the manuscript.

**Accepted:** Sept. 7, 2018

**Correspondence to:** Justin Lang, Justin.lang@canada.ca