# Global Burden of Chronic Myeloid Leukemia:
# A Systematic Analysis for the Global Burden of Disease Study 2017

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

University of Washington

2020

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Program Authorized to Offer Degree:

Health Services

University of Washington

## Abstract

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**Introduction:** Chronic myeloid leukemia (CML) is a clonal hematopoietic stem cell disorder characterized by the presence of the Philadelphia chromosome. Current pharmacotherapeutic modalities can induce long-term durable remissions through treatment with tyrosine-kinase inhibitors (TKIs). Access to specialized care and TKIs globally have improved outcomes in CML. A comprehensive description of the global burden of CML can further direct health policy, resource allocation, access, research, and patient care.

**Objective:** To describe the burden of CML for 21 world regions and 195 countries and territories from 1990 to 2017.

**Design and Setting:** We report incidence, mortality, and disability-adjusted life-year (DALY) estimates for CML derived from the Global Burden of Disease (GBD) 2017 study. Data sources for the GBD study include vital registration systems and cancer registries. We also analyzed changes in age-standardized incidence and death rates from 1990 to 2017 and 2007 to 2017 globally, by region, and by sociodemographic index (SDI).

**Main Outcomes and Measures:** CML incidence; mortality; and DALYs by age, sex, country, and year.

**Results:** Globally, there were 39,846 (95% uncertainty interval [UI], 36,909 to 42,842) incident cases of CML in 2017 with an age-standardized incident rate (ASIR) of 0.5 cases (95% UI, 0.47 to 0.54) per 100,000 person-years. There were 24,055 deaths (95% UI, 22,233 to 26,072) attributed to CML with an age-standardized death rate (ASDR) of 0.31 deaths (95% UI, 0.28 to 0.33) per 100,000 person-years. In 2017, CML contributed 654,984 DALYs (95% UI, 594,727 to 712,948). The three world regions with the highest ASIRs were Australasia, Western Europe, and Eastern Sub-Saharan Africa. The three world regions with the highest ASDRs were Eastern Sub-Saharan Africa, Central Sub-Saharan Africa, and South Asia. From 1990 to 2017, the global ASIR and ASDR has decreased by 42.4% (95% UI, 39% to 46%) and 48% (95% UI, 46% to 51%), respectively. All SDI regions saw a decline in ASIR and ASDR since 1990; however, the largest decline in ASIR and ASDR were seen in High SDI countries.

**Conclusions and Relevance:** Incidence and mortality of CML is variable among countries but has largely declined since 1990. The largest declines were seen in High SDI countries; however, lack of access to confirmatory testing may underreport CML incidence in low- and middle-income

countries (LMICs). Collaborative efforts have been implemented to overcome educational, access, and socioeconomic barriers. Global health priorities for CML should be directed to expand these efforts and improve upon existing or build data reporting systems. Research priorities should focus on assessing the impact of these efforts.

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# ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to Dr. Christina Fitzmaurice for her flexibility, guidance, and patience throughout the research and thesis writing process. It hasn't been easy balancing career and academics but Dr. Fitzmaurice was always willing to make the time to advise and guide, even when I was residing on the East Coast.

I would also like to thank Dr. Ali Mokdad for graciously agreeing to serve as my Thesis Chair. I appreciate his willingness to serve in this capacity as I work towards this degree. Without him, none of this would be possible.

Lastly, I would like to thank my family and friends for supporting me through the entirety of this degree program. Their guidance and subtle but gentle reminders of when I was going to finally graduate were instrumental in pushing me forward.

# INTRODUCTION

Chronic myeloid leukemia (CML) is a clonal hematopoietic stem cell disorder characterized by the presence of the Philadelphia (Ph) chromosome, a reciprocal translocation of the long arm of chromosome 9 and chromosome 22 resulting in the formation of the BCR-ABL1 oncogene [1]. ABL1 encodes a non-receptor tyrosine kinase that is critical for cellular activities such as proliferation, loss of stromal adhesion, and resistance to apoptosis [1]. Although the creation of the BCR-ABL1 fusion gene results in uncontrolled autoactivation of these pathways leading to clonal proliferation, it also presents a unique biomarker for diagnosis and target for drug therapy [1]. Patients with CML can present in three distinct phases: chronic, accelerated, and blast crisis [1]. Most patients present in chronic phase (CP) where prognosis is excellent with treatment with tyrosine kinase inhibitors (TKIs) and long-term clinical monitoring [2]. Patients presenting or progressing into accelerated or blast crisis have poorer outcomes.

Prior to the development of TKIs, conventional cytotoxic chemotherapy and interferon were the primary treatment options with allogeneic hematopoietic stem cell transplantation as the only curative modality [2]. Response rates with conventional treatments were suboptimal and allogeneic hematopoietic stem cell transplantation with suitable donors were only available in more “developed” countries and came with significant risks [2]. In 2001, imatinib mesylate (Gleevec®, Novartis) was the first FDA-approved TKI for CML and has revolutionized the management of the disease [3]. Since then, four additional TKIs (dasatinib [Sprycel®, Bristol-Meyers Squibb]; nilotinib [Tasigna®, Novartis]; bosutinib [Bosulif®, Pfizer Oncology]; ponatinib [Iclusig®, Takeda]) and generic alternatives to Gleevec® have entered the

marketplace. With five different TKIs approved for the treatment of CML, the choice of first-line agent remains controversial. No agent has demonstrated convincing superiority over the other and guideline recommendations do not specify specific products [4,5]. Response assessments at 3, 6, and 12 months is recommended to guide treatment modifications, if necessary [4,5]

CML remains a relatively uncommon malignancy. Based on estimates from the Cancer Incidence in Five Continent (CI5) project, age-standardized incidence rates (ASIRs) of CML range from 0.3 per 100,000 person-years for females to 1.8 per 100,000 person-years for males [15]. Treatment with TKIs have transformed CML from a once fatal disease to one that can be managed more as a chronic disease state. While the incidence is low, prevalence is on the rise due treatment advances. In a study published in 2012, the prevalence of CML in the US was expected to rise from an estimated baseline of 70,000 in 2010 to 181,000 by 2050 [7]. Registry analysis from Sweden have noted that overall survival (OS) for CML patients treated on TKIs are approaching those of the general population [8]. However, global disparities are large. In high income countries (HIC), adherence to guideline-supported clinical monitoring recommendations outside of the clinical trial setting is variable, potentially compromising response rates and durable remissions [9]. In many low- and middle-income countries (LMICs), access to complex testing and newer generation TKIs remains problematic. In India, response rates with imatinib for those adherent to therapy are similar to those in HIC [10]. However, patient adherence and access to advanced diagnostic testing and newer generation TKIs continues to be challenging [10]. A similar situation has also been reported in Tunisia where lack of advanced testing and access to newer generation TKIs remain barriers to appropriate care [11].

Despite these global challenges, progress is being made to expand access to advanced testing and pharmacotherapy options. In 2017, the Max Foundation, in continued partnership with Novartis, formed the CMLPath to Care™ program that connects patients in LMICs with effective treatments, medical care, and access to clinical specialists [12]. This program was an evolution of the already successful Glivec International Patient Assistance Program (GIPAP) that was formed in 2002 [13]. These programs are particularly noteworthy due to several international registry studies showing that patients in countries of lower socioeconomic status often present with more advanced disease despite availability of treatment, which may be attributed to the lack of access to critical molecular and cytogenetic testing [10,11,14].

With rising CML prevalence due to advances in clinical care, an accurate understanding of the global burden of CML is critical in order to inform current and future health policies and programs. There is currently limited data in the published literature on the global epidemiology of CML. In 2018, researchers from France published a population-based study describing the epidemiological patterns of major leukemia subtypes in 184 countries using data extracted from Cancer Incidence in Five Continents Volume X (CI5-X) and the GLOBOCAN database [15]. The study found geographical disparities in leukemia incidences that may be partly attributed to the quality or access of health systems [15]. Data for this study included the years 2003 to 2007. To build upon this data, the aim of this study is to specifically describe the global burden of CML in terms of incidence, mortality, and disability-adjusted life years from 1990 to 2017 by age, sex, and socioeconomic index (SDI) (a summary indicator of income per capita, educational

attainment, and fertility) in order to help direct current and future health policies, resource allocations, and interventions

# METHODS

Methods for GBD studies have been described in detail in previous publications [6,16-18]. For this study, we describe methods and results specific to GBD 2017 estimation for CML. The GBD study includes estimates for CML mortality, incidence, and disability-adjusted life-years (DALYs). To estimate CML mortality, vital registration (VR) system and cancer registry (CR) data were used. Data sources can be found in the 2017 GBD source tool (http://ghdx.healthdata.org/gbd-2017/data-input-sources). VR and CR data were further processed in multiple steps with adjustments made to include redistribution of undefined codes ("garbage codes") or codes that cannot be considered to refer to underlying causes of death. *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* (ICD-10) codes 92.1 (chronic myeloid leukemia, BCR/ABL-positive) and 92.2 (atypical chronic myeloid leukemia, BCR/ABL-negative) were mapped to the GBD cause for "chronic myeloid leukemia." A separately modeled mortality-to-incidence ratio (MIR) was used to transform incidence data from cancer registries to mortality estimates. These mortality estimates were added to mortality data from vital registration systems and this input was used in an ensemble model (CODEm) to determine mortality estimates for every location, age group, both sexes, from 1990 to 2017 [19]. Final CML mortality estimates were then adjusted using "CodCorrect", an algorithm that scales single causes of death to independently estimated all-cause mortality and child causes to parent causes (in this case CML to the parent cause "leukemia") [17]. Years of life lost (YLLs) were calculated by estimating the difference between a standard life expectancy

and age of death [20]. Incidence estimates were obtained by taking final CML mortality estimates and dividing by the MIR. Correlations between the MIR and survival data from the Surveillance, Epidemiology, and End Results (SEER) program were used to estimate CML survival for all GBD locations [23]. DALYs were calculated as the sum of YLDs and YLLs. [18]. All rates are reported per 100,000 person-years with a 95% uncertainty interval (UI) in parentheses. For the age standardization, the GBD world population standard was used [21].

For stratification of CML incidence and mortality based on SDI, the same methods as described in the GBD 2015 study were used to calculate SDI [22]. In summary, three indicators (income per capita, educational attainment, and fertility) were rescaled between 0 and 1 and weighted equally in a composite index. The composite SDI was then calculated using the mean of all three individual indicators, with a composite SDI of 1.0 indicating a location with the highest per capital income, highest educational attainment, and lowest fertility rate. For this study, locations were organized into similar groups or quintiles based on their SDI values from 2016 (see Table 5).

Detailed flowcharts describing this process of estimating mortality, incidence, prevalence, years lived with disability (YLDs), years of life lost (YLLs), and disability-adjusted life-years (DALYs) can be found in the Appendix (see Figure 1).

# RESULTS

*Global Incidence, Mortality, and DALYs*

In 2017, the global incident cases of CML were 39,846 (95% UI, 36,909 to 42,842), with an age-standardized incident rate (ASIR) of 0.5 per 100,000 person-years (95% UI, 0.47 to 0.54). There were more incident cases in males (22,550 cases [95% UI, 20,364 to 24,316]) than in females (17,297 cases [95% UI, 15134 to 19527]). The ASIR for males was 0.61 per 100,000 person-years (95% UI, 0.56 to 0.66) compared with 0.41 per 100,000 person-years (95% UI, 0.36 to 0.47) in females. In 2017, there were 24,055 deaths attributed to CML (95% UI, 22,233 to 26,072), with an age-standardized death rate (ASDR) of 0.31 per 100,000 person-years (95% UI, 0.28 to 0.33). By gender, mortality in 2017 was slightly higher in males than females, with 12,916 deaths estimated in males (95% UI, 11,645 to 14,091) compared with 11,139 (95% UI, 9,683 to 12,732) in females. The ASDR in males was 0.36 per 100,000 person-years (95% UI, 0.33 – 0.39) compared with 0.26 per 100,000 person-years (95% UI, 0.23 – 0.30) in females. Globally, CML was responsible for 654,984 DALYs (95% UI, 594,727 – 712,948). From 1990 to 2017, the ASIR and ASDR decreased by 42% (95% UI, 39% to 46%) and 48% (95%UI, 46% to 51%), respectively from 0.75 (95% UI, 0.71 to 0.8) to 0.43 (95% UI, 0.4 to 0.46) per 100,000 person-years and from 0.59 (95% UI, 0.56 to 0.63) to 0.31 (95% UI, 0.28 to 0.33) per 100,000 person-years. From 2007 to 2017, the ASIR and ASDR decreased by 15.9% (95% UI, 13.2% to 18.8%) and 19.9 (95% UI, 17.6% to 22.2%).

*GBD Region Incidence and Mortality*

Stratifying by GBD region (see Table 4 for descriptions of each GBD region), the three regions with the highest incident cases of CML in 2017 were South Asia with 8,730 cases (95% UI,

7,517 to 9,949), Western Europe with 8,070 cases (95% UI, 7,578 to 8,590), and East Asia with 4,162 cases (95% UI, 3,544 to 4,850). The three regions with the highest ASIRs were Australasia with 1.03 cases per 100,000 person-years (95% UI, 0.88 – 1.2), Western Europe with 0.94 cases per 100,000 person-years (95% UI, 0.88 to 1.00), and Eastern Sub-Saharan Africa with 0.85 cases per 100,000 person-years (95% UI, 0.66 to 1.04). The three regions with the highest mortality from CML in 2017 were South Asia (6,660 deaths [95% UI, 5,713 to 7,651]), Western Europe (4,245 [95% UI, 4,025 to 4,487]), and Southeast Asia with 1,652 deaths (95% UI, 1,302 to 1,992). The three regions with highest ASDRs were Eastern Sub-Saharan Africa (0.77 deaths per 100,000 person-years [95% UI, 0.59 to 0.94]), Central Sub-Saharan Africa with 0.54 deaths per 100,000 person-years (95% UI, 0.39 to 0.67), and South Asia (0.49 deaths per 100,000 person-years [95% UI, 0.43 to 0.57]).

The regions with the most significant decreases in ASIR from 1990 to 2017 were Western Europe (-61% [95% UI, -58% to -64%]), High-Income North America (-61% [95% UI, -58% to -64%]), and High-Income Asia-Pacific (-55% [95% UI, -48% to -61%]). The regions with increases in ASIR were Central Sub-Saharan Africa (+12% [95% UI, -11% to 40%]), Andean Latin America (+8% [95% UI, -9% to 27%]), and Southeast Asia (+2% [95% UI, -22% to 18%]). From 2007 to 2017, the regions with the most significant decreases in ASIR were Central Europe (-32% [95% UI, -27% to -37%]), Tropical Latin America (-30% [95% UI, -27% to -34%]), and Southern Sub-Saharan Africa (-29% [95% UI, -18% to -39%]). The regions with least improvement in ASIR were Andean Latin America (+4% [95% UI, -9% to 17%]), East Asia (+2% [95% UI, -6% to 11%]), and Central Sub-Saharan Africa (-1% [95% UI, -14% to 14%]). With respect to changes in ASDR over time, from 1990 to 2017, the regions with largest

decreases were High-Income Asia-Pacific (-73% [95% UI, -70% to -74%]), High-Income North America (-68% [95% UI, -66% to -69%]), and Australasia (-64% [95% UI, -58% to -68%]). The regions with least amount of change over this time period were Central Sub-Saharan Africa (+10% [95% UI, -12% to 35%]), Western Sub-Saharan Africa (-6% [95% UI, -21% to 13%]), and Andean Latin America (-10% [95% UI, -23% to 4%]). From 2007 to 2017, the regions with the most significant decreases were Southern Latin America (-32% [95% UI, -25% to -39%]), Western Europe (-32% [95% UI, -28% to -36%]), and High-Income Asia-Pacific (-31% [95% UI, -27% to -36%]). The regions with the lowest improvement were Andean Latin America (-0.2% [95% UI, -11% to 11%]), Central Sub-Saharan Africa (-1% [95% UI, -14% to 13%]), and Western Sub-Saharan Africa (-2% [95% UI, -12% to 10%).

*Country Incidence and Mortality*

The countries with the highest incident cases of CML in 2017 were India (6,974 cases [95% UI, 5,885 to 7,986]), China (3,887 cases [95% UI, 3,288 to 4,568]), and the United States of America (2,108 cases [95% UI, 2,108 to 2343]). The countries with the highest mortality from CML in 2017 were India (5,372 deaths [95% UI, 4,512 to 6,189]), the United States of America (1,390 deaths [95% UI, 1,332 to 1,463]), and Germany (1,115 deaths [95% UI, 988 to 1,258]). The countries with the highest ASIRs were Ethiopia (2.08 cases per 100,000 person-years [95% UI, 1.46 to 2.69], Slovenia (1.99 cases per 100,000 person-years [95% UI, 1.67 to 2.39], and Brunei (1.81 cases per 100,000 person-years [95% UI, 1.50 to 2.18]. The countries with the highest ASDR were Ethiopia (1.89 deaths per 100,000 person-years [95% UI, 1.33 to 2.48], Brunei (1.09 deaths per 100,000 person-years [95% UI, 0.93 to 1.31], and Honduras (0.96 deaths per 100,000 person-years [95% UI, 0.68 to 1.28]. From 1990 to 2017, the countries with the highest decrease

in ASIR were Hungary (-71% [95% UI, -64% to -75%]), Germany (-70% [95% UI, -63% to -76%]), and Israel (-67% [95% UI, -59% to -73%]). From 2007 to 2017, the countries with the highest decrease in ASIR were Kyrgyzstan (-47% [95% UI, -36% to -55%]), Bulgaria (-41% [95% UI, -30% to -51%]), and Israel (-41% [95% UI, -30% to -51%]). Examining changes in ASDR from 1990 to 2017, the countries with the largest decrease were Singapore (-76% [95% UI, -72% to -79%]), Japan (-75% [95% UI, -73% to -77%]), and Hungary (-72% [95% UI, -69% to -75%]). From 2007 to 2017, the countries with the largest decrease were Lithuania (-51% [95% UI, -43% to -57%]), Slovakia (-50% [95% UI, -40% to -58%]), and Kyrgyzstan (-47% [95% UI, -38% to -55%]). Conversely, the countries with the least improvement in ASIRs from 1990 to 2017 were Jamaica (+95% [95% UI, 43% to 168%]), El Salvador (+72% [95% UI, 18% to 131%]), and Philippines (+62% [95% UI, 28% to 101%]). From 2007 to 2017, the countries that appeared to have the least improvement were Georgia (+98% [95% UI, 60% to 141%]), Jamaica (+29% [95% UI, -2% to 65%]), and Mauritius (+25% [95% UI, 3% to 51%]). With respect to ASDRs, the countries with the least improvement from 1990 to 2017 were Jamaica (+68% [95% UI, 27% to 124%]), El Salvador (+42% [95% UI, 0% to 89%]), and Zimbabwe (+42% [95% UI, -2% to 110%]). From 2007 to 2017, the countries with the least improvement in ASDRs were Georgia (+107% [95% UI, 75% to 142%]), Jamaica (+27% [95% UI, 0% to 61%]), and Ecuador (+21% [95% UI, 5% to 40%]).

*SDI Incidence, Mortality, and DALYs*

Among SDI regions, the crude incident cases of CML was highest in High and Middle SDI countries with the lowest crude incidence seen in Low SDI countries. Crude mortality was highest again in High and Middle SDI regions with the lowest crude mortality seen in High-

middle SDI countries. The ASIR was highest in Low and High SDI countries with the lowest ASIR in Middle SDI countries. Lastly, the highest ASDR was seen in Low and Low-middle SDI countries with the lowest ASDR seen in High-Middle SDI countries. From 1990 to 2017, High SDI countries saw the most significant improvements in both ASIRs and ASDRs while Low-Middle and Middle SDI countries saw the least improvement in ASIRs and Low and Low-Middle SDI countries saw the least improvement in ASDRs, respectively (see Figures 4 and 5).

# DISCUSSION

The results of this study build upon previously reported data on global incidence of CML and, to our knowledge, is the first study to describe global mortality attributed to CML as well as analyzing trends in incidence and mortality since 1990 [15]. In comparison with other cancers, CML remains a relatively uncommon malignancy in the global population and as such, mortality attributed to CML remains low [24]. Consistent with other epidemiologic studies, higher incidence and death rates were seen in males [15,25,26]. Among all GBD world regions, the regions with the highest ASIRs were Australasia, Western Europe, and Eastern Sub-Saharan Africa while the regions with the lowest ASIRs were Southern Sub-Saharan Africa, East Asia, and High-Income Asia-Pacific. These results support the concerns reported in previous studies noting challenges of under-ascertainment of CML cases [15]. In a study looking at regional variations in diagnosis of CML in LMICs, only 9.4% of patients in the study were from the African continent [25]. Among SDI groups, time trends for all groups showed a decline in ASIR since 1990, although with varying degrees of decline. The sharpest decline in ASIR since 1990 was seen in the High SDI group. Given the lack of a strong etiological risk factor for CML, it is unclear how this significant decline should be interpreted. A possible explanation may be the

inclusion of other myeloproliferative cases in calculating ASIRs for CML earlier in the study period with a decline in ASIRs paralleling the adoption of confirmatory testing for CML. From 2007 to 2017, the decline in ASIR has decreased indicating a plateauing; thus, more recent ASIR data may be more reflective of the true ASIR in High SDI countries. The time trend for the Low SDI group was also surprising to note. In 1990, the ASIR was almost double that of other SDI groups, with the exception of the High SDI group, despite healthcare infrastructure and testing challenges [16]. In 2017, the ASIR in the Low SDI group was essentially similar to that of the High SDI group. For the other SDI groups, ASIRs in 1990 were much lower compared with the High and Low SDI group and time trends showed variable declines over time. The High-Middle SDI group showed the most significant decline in this group with the Low-Middle and Middle SDI groups showing marginal declines since 1990. While a comprehensive analysis of differences in incidence and time trends among these groups is beyond the scope of this study, it is likely that some of the differences may be attributed to methodological challenges since incidence estimates in the GBD study depend on accurate estimation of the mortality to incidence ratio, which is being modeled in the GBD study. The model depends on matching incidence and mortality data and performance can be poor if data is sparse as is the case in CML. Current testing measures include complete blood counts to detect persistent leukocytosis, bone marrow aspiration and analysis, and confirmatory cytogenetic and molecular studies to identify the presence of BCR-ABL1 transcript [1,3]. While it is not surprising to see high incidence rates in the High SDI group, most likely due to wide availability of diagnostic testing and established healthcare infrastructure, it is interesting to see similar ASIR in 2017 in the Low SDI group but lower ASIRs in the other SDI groups. One possible explanation is that the higher ASIR in 2017 in the Low SDI group may be reflective of the work being done by access programs connecting

patients in low socioeconomic areas to critical testing and medical expertise [12,13,25]. More variable access to advanced diagnostic testing has been documented in countries like China and India and this may reflect the lower incidence rates seen in Middle and Low-Middle SDI groups [10,27].

We also describe changes in age-adjusted death rates (ASDRs) attributed to CML. In 2017, the world regions with the lowest ASDRs were East Asia, Southern Sub-Saharan Africa, and High-Income Asia-Pacific. The world regions with highest ASDRs were Eastern Sub-Saharan Africa, Central Sub-Saharan Africa, and South Asia. Among SDI groups, ASDRs were highest in the Low SDI group. Analyzing time trends since 1990, the largest declines in ASDRs were seen in High and High-Middle SDI groups, with the sharpest decline seen in the High SDI group. While it is outside the scope of this study to show correlations between access to effective treatments and improvement in ASDRs, it is likely that the increased use of TKIs and utilization of high-risk procedures such as allogeneic stem cell transplantation for more aggressive or refractory disease may be attributed to the sharp decline in CML-associated mortality in high socioeconomic areas [28]. A report from the Swedish Cancer Registry showed life expectancy for patients with CML approaching the general population, highlighting the impact of effective medical treatment on mortality [8]. Our results showed declines in ASDRs for all SDI groups since 1990, although there was significant heterogeneity in the magnitude of decline. However, socioeconomic disparities, variability in practice, and access to appropriate medical care may be preventing further improvement in outcomes. Ethnic minorities in High SDI regions are underrepresented in cancer registry studies and lower socioeconomic status or advanced age have been correlated with poorer outcomes [29-31]. Despite data showing clinical effectiveness of

TKIs, universal adoption of TKIs is variable among higher SDI countries, especially among the elderly population, and merits further investigation [29,32-34]. The underutilization of TKIs in the elderly population is particularly noteworthy given the median age of CML in higher socioeconomic areas ranges in the 6$^{th}$ to 7$^{th}$ decades of life [29, 32-34]. While higher SDI regions saw significant declines in ASDRs, lower SDI regions showed modest improvements. Of particular interest, the Low SDI group saw the most appreciable decline in ASDR since 1990 among the LMICs. Reasons for this improvement merits further investigation. It is unclear if recent efforts to increase access to appropriate medical care in Low SDI countries had any effect on mortality rates; however, the change in ASDR since 2007 was modest. Therefore, improvement since 1990 cannot be entirely attributed to increased access to TKIs as these programs started in 2007. Although time to treatment with TKIs, a negative risk factor for outcomes, has shortened in LMICs, the median age of diagnosis appears to be much younger in LMICs compared with higher SDI countries [25]. Further investigation is warranted to assess the impact of a younger disease demographic on healthcare systems in these areas.

*Limitations and Future Directions*

As described in previous GBD and other large-scale epidemiological studies, quality data reporting at the local level is critical in our efforts to accurately characterize disease burden. Where data is low or unavailable, GBD estimates fill in the gaps leading to wide uncertainty intervals in data reporting. Additionally, CML presentation can be triphasic, with more aggressive disease presenting similarly to other acute leukemias. Lack of access to advanced diagnostic and molecular testing to confirm diagnosis of CML can lead to underreporting of CML cases. Other challenges remain including differences in data collection and reporting

methods as well as heterogeneity in coding practices. In order to improve the accuracy of disease burden characterization, it is critical that more support and resource allocation is directed towards the improvement and standardization of data collection and reporting at a local and regional level.

Despite these challenges, there are a number of collaborations and initiatives striving to overcome socioeconomic barriers and expand access to care in LMICs. To date, the CMLPath to Care™ program through The Max Foundation in collaboration with Novartis Oncology has connected over 75,000 patients in over 75 low- and middle-income countries with effective treatments and clinical expertise [12]. The Max Foundation has also pioneered a novel patient-centered care delivery program called Max Access Solutions to provide comprehensive clinical care, operational logistics, and support for patients in LMICs [35]. In an effort to overcome diagnostic barriers where confirmatory testing is either unavailable or cost-prohibitive, The Max Foundation in partnership with Dr. Jerry Radich at the Fred Hutchinson Cancer Research Center have developed a low-cost, paper-based method to detect CML [36]. The initiative, called Spot on CML, has provided testing to over 500 patients in 19 countries since its inception in 2017 [36]. Lastly, the International Chronic Myeloid Leukemia Foundation has created the Emerging Regions Support and Partnership Program (ERSAP) to provide education and diagnostic support for clinicians in emerging regions by connecting them with CML experts in the global oncology community [37].

# CONCLUSION

While the incidence and mortality for CML has declined since 1990, the magnitudes in decline have varied depending on SDI classification. Lack of access to confirmatory testing and incident reporting systems make estimating the true burden of CML difficult, especially in low- and middle-income countries. Novel collaborations have implemented methods and programs to overcome access and socioeconomic barriers; however, greater reach is needed to ensure every patient has access to comprehensive clinical care. Further research is needed to link all of these efforts in order to improve the global characterization of disease burden for CML.

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# APPENDIX

Table 1: 2017 CML incidence and deaths at the global level, by region, and by SDI quintile

| Location | Incidence cases, No. | | | ASIR, both sexes (per 100,000 person-years) | | | Deaths, No. | | | ASDR, both sexes (per 100,000 person-years) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | Both | Female | Male | Both | Female | Male | Both | Female | Male | Both |
| Global | 17297 (15134 to 19527) | 22550 (20364 to 24316) | 39846 (36909 to 42842) | 0.41 (0.36 to 0.47) | 0.61 (0.56 to 0.66) | 0.50 (0.47 to 0.54) | 11139 (9683 to 12732) | 12916 (11645 to 14091) | 24055 (22233 to 26072) | 0.26 (0.23 to 0.30) | 0.36 (0.33 to 0.39) | 0.31 (0.28 to 0.33) |
| High SDI | 5061 (4731 to 5432) | 7933 (7516 to 8396) | 12994 (12403 to 13589) | 0.46 (0.43 to 0.49) | 0.88 (0.84 to 0.94) | 0.65 (0.62 to 0.68) | 3003 (2816 to 3238) | 4064 (3886 to 4254) | 7067 (6797 to 7386) | 0.23 (0.21 to 0.24) | 0.42 (0.40 to 0.44) | 0.31 (0.30 to 0.32) |
| High-Middle SDI | 2705 (2442 to 3063) | 4139 (3618 to 4687) | 6843 (6279 to 6279) | 0.3 (0.27 to 0.34) | 0.5 (0.44 to 0.57) | 0.39 (0.36 to 0.43) | 1406 (1312 to 1570) | 1987 (1799 to 2220) | 3392 (3181 to 3707) | 0.15 (0.14 to 0.17) | 0.25 (0.23 to 0.28) | 0.20 (0.18 to 0.21) |
| Low SDI | 3039 (2285 to 3831) | 2596 (2069 to 3146) | 5634 (4742 to 6381) | 0.72 (0.55 to 0.91) | 0.66 (0.53 to 0.80) | 0.69 (0.58 to 0.78) | 2413 (1833 to 3036) | 2055 (1633 to 2485) | 4467 (3772 to 5065) | 0.62 (0.48 to 0.77) | 0.58 (0.46 to 0.70) | 0.60 (0.50 to 0.68) |
| Low-Middle SDI | 3221 (2531 to 3981) | 2939 (2496 to 3527) | 6159 (5369 to 7178) | 0.47 (0.37 to 0.58) | 0.48 (0.40 to 0.56) | 0.47 (0.41 to 0.54) | 2391 (1868 to 2961) | 2121 (1783 to 2526) | 4512 (3907 to 5247) | 0.37 (0.29 to 0.46) | 0.38 (0.31 to 0.45) | 0.37 (0.32 to 0.43) |
| Middle SDI | 3236 (2674 to 3696) | 4883 (4152 to 5336 | 8118 (7024 to 8700) | 0.28 (0.23 to 0.32) | 0.45 (0.39 to 0.49) | 0.36 (0.31 to 0.39) | 1913 (1577 to 2203) | 2667 (2257 to 2930) | 4579 (3964 to 4907) | 0.17 (0.14 to 0.19) | 0.26 (0.22 to 0.29) | 0.21 (0.18 to 0.23) |
| High-Income Asia Pacific | 426 (367 to 492) | 768 (677 to 873) | 1193 (1083 to 1320) | 0.25 (0.20 to 0.30) | 0.51 (0.44 to 0.59) | 0.37 (0.33 to 0.41) | 235 (211 to 262) | 367 (341 to 394) | 601 (564 to 641) | 0.09 (0.08 to 0.10) | 0.21 (0.19 to 0.22) | 0.14 (0.13 to 0.15) |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Western Europe | 3187 (2903 to 3505) | 4883 (4511 to 5336) | 8070 (7578 to 8590) | 0.66 (0.60 to 0.72) | 1.29 (1.19 to 1.41) | 0.94 (0.88 to 1.00) | 1892 (1737 to 2066) | 2353 (2198 to 2523) | 4245 (4025 to 4487) | 0.33 (0.30 to 0.36) | 0.58 (0.54 to 0.62) | 0.44 (0.41 to 0.46) |
| Andean Latin America | 101 (77 to 121) | 143 (112 to 174) | 243 (198 to 281) | 0.34 (0.26 to 0.41) | 0.51 (0.40 to 0.62) | 0.42 (0.35 to 0.49) | 62 (47 to 72) | 85 (68 to 101) | 146 (120 to 165) | 0.21 (0.16 to 0.25) | 0.32 (0.25 to 0.37) | 0.26 (0.21 to 0.29) |
| Central Latin America | 560 (507 to 621) | 889 (814 to 967) | 1449 (1358 to 1544) | 0.43 (0.39 to 0.48) | 0.78 (0.72 to 0.85) | 0.60 (0.56 to 0.63) | 333 (304 to 367) | 523 (485 to 564) | 856 (807 to 903) | 0.26 (0.24 to 0.29) | 0.48 (0.45 to 0.52) | 0.36 (0.34 to 0.38) |
| Southern Latin America | 154 (132 to 181) | 222 (191 to 258) | 376 (335 to 421) | 0.36 (0.30 to 0.42) | 0.63 (0.55 to 0.73) | 0.48 (0.43 to 0.54) | 100 (87 to 115) | 130 (113 to 148) | 229 (206 to 252) | 0.21 (0.19 to 0.25) | 0.37 (0.32 to 0.42) | 0.28 (0.25 to 0.31) |
| Tropical Latin America | 370 (341 to 409) | 541 (508 to 577) | 911 (865 to 958) | 0.29 (0.27 to 0.32) | 0.50 (0.48 to 0.54) | 0.39 (0.37 to 0.41) | 259 (241 to 283) | 339 (323 to 357) | 597 (574 to 630) | 0.20 (0.19 to 0.22) | 0.33 (0.32 to 0.35) | 0.26 (0.25 to 0.28) |
| North Africa and Middle East | 889 (665 to 1187) | 1332 (1047 to 1570) | 2220 (1844 to 2606) | 0.36 (0.27 to 0.48) | 0.56 (0.44 to 0.67) | 0.46 (0.39 to 0.53) | 508 (376 to 666) | 725 (557 to 848) | 1232 (1013 to 1436) | 0.22 (0.17 to 0.29) | 0.35 (0.27 to 0.41) | 0.28 (0.23 to 0.32) |
| High-Income North America | 1084 (1003 to 1190) | 1460 (1356 to 1576) | 2543 (2416 to 2682) | 0.38 (0.35 to 0.42) | 0.60 (0.56 to 0.65) | 0.48 (0.46 to 0.51) | 673 (634 to 729) | 889 (835 to 943) | 1561 (1498 to 1643) | 0.20 (0.19 to 0.22) | 0.34 (0.32 to 0.36) | 0.26 (0.25 to 0.27) |
| Oceania | 34 (22 to 53) | 25 (17 to 37) | 58 (43 to 82) | 0.74 (0.51 to 1.13) | 0.5 (0.35 to 0.71) | 0.62 (0.47 to 0.84) | 25 (17 to 39) | 17 (12 to 25) | 41 (31 to 56) | 0.59 (0.41 to 0.87) | 0.36 (0.26 to 0.52) | 0.47 (0.37 to 0.62) |
| Central Sub-Saharan Africa | 233 (131 to 307) | 152 (106 to 201) | 384 (280 to 480) | 0.68 (0.39 to 0.90) | 0.53 (0.35 to 0.68) | 0.61 (0.44 to 0.76) | 185 (106 to 243) | 119 (82 to 153) | 303 (222 to 375) | 0.60 (0.35 to 0.79) | 0.47 (0.31 to 0.61) | 0.54 (0.39 to 0.67) |
| Eastern Sub-Saharan Africa | 889 (638 to 1162) | 842 (626 to 1067) | 1731 (1323 to 2103) | 0.84 (0.61 to 1.08) | 0.88 (0.65 to 1.13) | 0.85 (0.66 to 1.04) | 724 (524 to 858) | 674 (500 to 858) | 1398 (1071 to 1695) | 0.75 (0.56 to 0.97) | 0.80 (0.59 to 1.03) | 0.77 (0.59 to 0.94) |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Central Asia | 160 (135 to 187) | 165 (135 to 194) | 324 (284 to 365) | 0.34 (0.29 to 0.40) | 0.44 (0.37 to 0.51) | 0.38 (0.34 to 0.43) | 99 (86 to 113) | 100 (82 to 115) | 198 (176 to 220) | 0.22 (0.19 to 0.25) | 0.29 (0.24 to 0.34) | 0.25 (0.22 to 0.27) |
| Southern Sub-Saharan Africa | 33 (24 to 41) | 21 (15 to 29) | 53 (40 to 66) | 0.09 (0.06 to 0.11) | 0.08 (0.06 to 0.10) | 0.08 (0.06 to 0.10) | 22 (16 to 28) | 16 (12 to 22) | 38 (29 to 46) | 0.06 (0.04 to 0.08) | 0.06 (0.05 to 0.09) | 0.06 (0.05 to 0.08) |
| Western Sub-Saharan Africa | 520 (334 to 699) | 518 (418 to 705) | 1037 (835 to 1320) | 0.40 (0.25 to 0.55) | 0.49 (0.40 to 0.64) | 0.44 (0.36 to 0.56) | 394 (255 to 531) | 394 (322 to 525) | 787 (628 to 990) | 0.32 (0.21 to 0.44) | 0.43 (0.35 to 0.56) | 0.37 (0.30 to 0.47) |
| East Asia | 1395 (1136 to 1745) | 2767 (2196 to 3290) | 4162 (3544 to 4850) | 0.14 (0.12 to 0.18) | 0.28 (0.23 to 0.33) | 0.21 (0.18 to 0.25) | 400 (321 to 508) | 780 (624 to 937) | 1179 (995 to 1391) | 0.04 (0.03 to 0.05) | 0.08 (0.07 to 0.10) | 0.06 (0.05 to 0.07) |
| South Asia | 4594 (3577 to 5663) | 4136 (3384 to 4855) | 8730 (7517 to 9949) | 0.62 (0.48 to 0.76) | 0.59 (0.49 to 0.70) | 0.60 (0.51 to 0.69) | 3542 (2764 to 4419) | 3119 (2544 to 3687) | 6660 (5713 to 7651) | 0.50 (0.40 to 0.63) | 0.49 (0.40 to 0.57) | 0.49 (0.43 to 0.57) |
| Southeast Asia | 1127 (806 to 1552) | 1633 (1243 to 1938) | 2760 (2182 to 3207) | 0.34 (0.24 to 0.46) | 0.55 (0.42 to 0.65) | 0.43 (0.34 to 0.50) | 706 (502 to 1025) | 946 (722 to 1140) | 1652 (1302 to 1992) | 0.22 (0.16 to 0.32) | 0.35 (0.27 to 0.42) | 0.28 (0.22 to 0.33) |
| Australasia | 126 (101 to 154) | 304 (249 to 363) | 429 (368 to 498) | 0.60 (0.46 to 0.75) | 1.52 (1.23 to 1.84) | 1.02 (0.88 to 1.20) | 61 (52 to 74) | 153 (132 to 179) | 214 (189 to 244) | 0.23 (0.20 to 0.28) | 0.69 (0.59 to 0.81) | 0.44 (0.39 to 0.50) |
| Caribbean | 151 (129 to 182) | 221 (193 to 254) | 371 (333 to 418) | 0.57 (0.49 to 0.69) | 0.92 (0.81 to 1.06) | 0.74 (0.66 to 0.83) | 104 (89 to 126) | 142 (125 to 162) | 245 (222 to 274) | 0.39 (0.33 to 0.47) | 0.60 (0.53 to 0.68) | 0.48 (0.44 to 0.54) |
| Central Europe | 267 (241 to 298) | 623 (575 to 678) | 890 (833 to 951) | 0.26 (0.23 to 0.29) | 0.76 (0.70 to 0.83) | 0.47 (0.44 to 0.51) | 216 (195 to 239) | 427 (399 to 460) | 643 (607 to 684) | 0.18 (0.16 to 0.20) | 0.50 (0.47 to 0.54) | 0.31 (0.29 to 0.33) |
| Eastern Europe | 1007 (878 to 1142) | 914 (810 to 1028) | 1920 (1756 to 2092) | 0.57 (0.49 to 0.66) | 0.74 (0.66 to 0.83) | 0.64 (0.58 to 0.70) | 609 (553 to 665) | 629 (597 to 667) | 1238 (1172 to 1310) | 0.30 (0.28 to 0.33) | 0.50 (0.48 to 0.53) | 0.38 (0.36 to 0.40) |

Table 2: CML incidence, deaths, and changes at the global and regional levels, and by SDI quintiles, both sexes, 1990 to 2017

| Location | Incident cases, No. | | Deaths, No. | | ASIR | | Overall Change ASIR, % | ASDR | | Overall Change ADSR, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2017 | 1990 | 2017 | 1990 | 2017 | | 1990 | 2017 | |
| Global | 35250 (32830 to 37820) | 39846 (36909 to 42842) | 24198 (22633 to 26109) | 24055 (22233 to 26072) | 0.83 (0.78 to 0.88) | 0.50 (0.47 to 0.54) | -42.4 (-39.2 to -45.9) | 0.59 (0.56 to 0.63) | 0.31 (0.28 to 0.33) | -48.2 (-45.6 to -51.1) |
| High SDI | 18431 (17859 to 19036) | 12994 (12403 to 13589) | 11587 (11265 to 11905) | 7067 (6797 to 7386) | 1.51 (1.46 to 1.55) | 0.65 (0.62 to 0.68) | -60.3 (-57.7 to -62.6) | 0.92 (0.90 to 0.95) | 0.31 (0.30 to 0.32) | -66.4 (-64.8 to -67.8) |
| High-Middle SDI | 5757 (5030 to 6429) | 6843 (6279 to 6279) | 3935 (3519 to 4345) | 3392 (3181 to 3707) | 0.57 (0.50 to 0.63) | 0.39 (0.36 to 0.43) | -32.4 (-23.4 to -39.5) | 0.40 (0.36 to 0.44) | 0.20 (0.18 to 0.21) | -51.6 (-46 to -56) |
| Low SDI | 3373 (2680 to 4290) | 5634 (4742 to 6381) | 2854 (2304 to 3573) | 4467 (3772 to 5065) | 0.84 (0.69 to 1.04) | 0.69 (0.58 to 0.78) | -20.1 (-6.7 to -33.1) | 0.77 (0.64 to 0.95) | 0.60 (0.50 to 0.68) | -22.4 (-9.9 to -34.1) |
| Low-Middle SDI | 3401 (2950 to 4323) | 6159 (5369 to 7178) | 2762 (2418 to 3496( | 4512 (3907 to 5247) | 0.50 (0.44 to 0.63) | 0.47 (0.41 to 0.54) | -10.9 (-23.4 to 1.8) | 0.44 (0.39 to 0.56) | 0.37 (0.32 to 0.43) | -16.2 (-4.7 to -28.8) |
| Middle SDI | 4216 (3726 to 4920) | 8118 (7024 to 8700) | 3018 (2715 to 3529) | 4579 (3964 to 4907) | 0.37 (0.33 to 0.42) | 0.36 (0.31 to 0.39) | -9.2 (-0.6 to 19.5) | 0.29 (0.26 to 0.33) | 0.21 (0.18 to 0.23) | -25.8 (-19.4 to -34.5) |
| High-Income Asia Pacific | 1753 (1611 to 1906) | 1193 (1083 to 1320) | 1033 (997 to 1074) | 601 (564 to 641) | 0.88 (0.81 to 0.96) | 0.37 (0.33 to 0.41) | -55 (-47.5 to -61.4) | 0.52 (0.50 to 0.54) | 0.14 (0.13 to 0.15) | -72.5 (-70.4 to -74.4) |
| Western Europe | 11322 (10828 to 11778) | 8070 (7578 to 8590) | 6755 (6483 to 7015) | 4245 (4025 to 4487) | 2.04 (1.95 to 2.12) | 0.94 (0.88 to 1.00) | -61.1 (-57.6 to -64.3) | 1.17 (1.13 to 1.21) | 0.44 (0.41 to 0.46) | -62.7 (-60.6 to -64.9) |
| Andean Latin America | 92 (77 to 105) | 243 (198 to 281) | 71 (59 to 81) | 146 (120 to 165) | 0.35 (0.29 to 0.40) | 0.42 (0.35 to 0.49) | -7.9 (-9.3 to 26.6) | 0.29 (0.25 to 0.33) | 0.26 (0.21 to 0.29) | -10.3 (-23.1 to 4) |
| Central Latin America | 756 (726 to 790) | 1449 (1358 to 1544) | 558 (536 to 583) | 856 (807 to 903) | 0.72 (0.69 to 0.75) | 0.60 (0.56 to 0.63) | -26 (-20.8 to -31.6) | 0.57 (0.55 to 0.60 | 0.36 (0.34 to 0.38) | -36.6 (-32.5 to -41) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Southern Latin America | 424 (389 to 459) | 376 (335 to 421) | 322 (297 to 347) | 229 (206 to 252) | 0.90 (0.82 to 0.97) | 0.48 (0.43 to 0.54) | -52.2 (-45.1 to -58.2) | 0.69 (0.63 to 0.74) | 0.28 (0.25 to 0.31) | -59.1 (-54 to -63.6) |
| Tropical Latin America | 780 (745 to 818) | 911 (865 to 958) | 581 (559 to 605) | 597 (574 to 630) | 0.71 (0.68 to 0.74) | 0.39 (0.37 to 0.41) | -49.7 (-46.2 to -52.9) | 0.56 (0.54 to 0.59) | 0.26 (0.25 to 0.28) | -53.7 (-51 to -56.3) |
| North Africa and Middle East | 1268 (926 to 1540) | 2220 (1844 to 2606) | 966 (703 to 1171) | 1232 (1013 to 1436) | 0.62 (0.45 to 0.74) | 0.46 (0.39 to 0.53) | -34.2 (-18.7 to -43.3) | 0.51 (0.37 to 0.62) | 0.28 (0.23 to 0.32) | -44.7 (-31.4 to -52.9) |
| High-Income North America | 3983 (3857 to 4113) | 2543 (2416 to 2682) | 2840 (2769 to 2920) | 1561 (1498 to 1643) | 1.18 (1.14 to 1.22) | 0.48 (0.46 to 0.51) | -60.7 (-57.5 to -63.7) | 0.81 (0.79 to 0.83) | 0.26 (0.25 to 0.27) | -67.8 (-65.7 to -69.4) |
| Oceania | 35 (26 to 46) | 58 (43 to 82) | 27 (20 to 34) | 41 (31 to 56) | 0.80 (0.63 to 1.03) | 0.62 (0.47 to 0.84) | -24.1 (-5.6 to -38.9) | 0.66 (0.52 to 0.84) | 0.47 (0.37 to 0.62) | -28.4 (-12.5 to -41) |
| Central Sub-Saharan Africa | 155 (103 to 199) | 384 (280 to 480) | 129 (88 to 163) | 303 (222 to 375) | 0.53 (0.37 to 0.66) | 0.61 (0.44 to 0.76) | 11.7 (-10.9 to 39.5) | 0.49 (0.34 to 0.61) | 0.54 (0.39 to 0.67) | 10.1 (-12 to 34.5) |
| Eastern Sub-Saharan Africa | 1139 (839 to 1546) | 1731 (1323 to 2103) | 975 (734 to 1309) | 1398 (1071 to 1695) | 1.14 (0.88 to 1.53) | 0.85 (0.66 to 1.04) | -27.1 (-2.8 to -50.8) | 1.06 (0.83 to 1.41) | 0.77 (0.59 to 0.94) | -27 (-4.4 to -49.4) |
| Central Asia | 280 (239 to 320) | 324 (284 to 365) | 202 (172 to 230) | 198 (176 to 220) | 0.50 (0.43 to 0.57) | 0.38 (0.34 to 0.43) | -28.6 (-18.2 to -36.1) | 0.37 (0.32 to 0.43) | 0.25 (0.22 to 0.27) | -34.3 (-24.6 to -40.9) |
| Southern Sub-Saharan Africa | 35 (27 to 44) | 53 (40 to 66) | 27 (21 to 34) | 38 (29 to 46) | 0.10 (0.08 to 0.13) | 0.08 (0.06 to 0.10) | -20.4 (-7.9 to -30.8) | 0.08 (0.06 to 0.10) | 0.06 (0.05 to 0.08) | -23.9 (-11.7 to -33.9) |
| Western Sub-Saharan Africa | 493 (390 to 619) | 1037 (835 to 1320) | 405 (318 to 508) | 787 (628 to 990) | 0.45 (0.35 to 0.56) | 0.44 (0.36 to 0.56) | -3.5 (-19 to 16.6) | 0.40 (0.31 to 0.50) | 0.37 (0.30 to 0.47) | -5.7 (-20.5 to 12.7) |
| East Asia | 2758 (2109 to 3420) | 4162 (3544 to 4850) | 1494 (1191 to 1859) | 1179 (995 to 1391) | 0.24 (0.19 to 0.29) | 0.21 (0.18 to 0.25) | -13.3 (-30.4 to 3.6) | 0.14 (0.11 to 0.17) | 0.06 (0.05 to 0.07) | -55.8 (-48.9 to -64.2) |
| South Asia | 4638 (3924 to 5719) | 8730 (7517 to 9949) | 3865 (3296 to 4799) | 6660 (5713 to 7651) | 0.66 (0.56 to 0.82) | 0.60 (0.51 to 0.69) | -13 (-25.6 to 0.06) | 0.60 (0.51 to 0.76) | 0.49 (0.43 to 0.57) | -18 (-5.4 to -30.9) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Southeast Asia | 1326 (1083 to 1887) | 2760 (2182 to 3207) | 992 (824 to 1465) | 1652 (1302 to 1992) | 0.42 (0.35 to 0.60) | 0.43 (0.34 to 0.50) | 1.7 (-22.1 to 18.4) | 0.34 (0.29 to 0.50) | 0.28 (0.22 to 0.33) | -18.5 (-6 to -35.8) |
| Australasia | 452 (415 to 491) | 429 (368 to 498) | 287 (274 to 300) | 214 (189 to 244) | 1.92 (1.76 to 2.08) | 1.02 (0.88 to 1.20) | -49.4 (-37.5 to -59.9) | 1.21 (1.15 to 1.26) | 0.44 (0.39 to 0.50) | -63.7 (-58.2 to -68.2) |
| Caribbean | 300 (274 to 329) | 371 (333 to 418) | 224 (206 to 245) | 245 (222 to 274) | 1.06 (0.96 to 1.16) | 0.74 (0.66 to 0.83) | -34.4 (-25.5 to -42.2) | 0.81 (0.75 to 0.89) | 0.48 (0.44 to 0.54) | -40.5 (-32.5 to -46.7) |
| Central Europe | 1251 (1180 to 1324) | 890 (833 to 951) | 976 (926 to 1032) | 643 (607 to 684) | 0.87 (0.82 to 0.92) | 0.47 (0.44 to 0.51) | -51.5 (-47.2 to -55.4) | 0.67 (0.63 to 0.70) | 0.31 (0.29 to 0.33) | -53.3 (-49.8 to -56.5) |
| Eastern Europe | 2020 (1808 to 2310) | 1920 (1756 to 2092) | 1480 (1345 to 1677) | 1238 (1172 to 1310) | 0.74 (0.66 to 0.84) | 0.64 (0.58 to 0.70) | -7.4 (-21.8 to 8.5) | 0.53 (0.48 to 0.60) | 0.38 (0.36 to 0.40) | -28.3 (-19.9 to -36.6) |

Table 3: CML incidence and trends at the global and regional levels, and by SDI quintiles, both sexes, 2007 to 2017

| Location | Incident cases, No. | | Deaths, No. | | ASIR | | Overall Change ASIR, % | ASDR | | Overall Change ASDR, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2017 | 2007 | 2017 | 2007 | 2017 | | 2007 | 2017 | |
| Global | 38185 (35320 to 40536) | 39846 (36909 to 42842) | 23294 (21487 to 24901) | 24055 (22233 to 26072) | 0.61 (0.56 to 0.64) | 0.50 (0.47 to 0.54) | -15.9 (-13.2 to -18.8) | 0.38 (0.35 to 0.41) | 0.31 (0.28 to 0.33) | -19.9 (-17.6 to -22.2) |
| High SDI | 14771 (14350 to 15154) | 12994 (12403 to 13589) | 8051 (7902 to 8202) | 7067 (6797 to 7386) | 0.89 (0.87 to 0.92) | 0.65 (0.62 to 0.68) | -26.2 (-22.3 to -29.7) | 0.45 (0.44 to 0.46) | 0.31 (0.30 to 0.32) | -30.6 (-27.7 to -33.1) |
| High-Middle SDI | 7021 (6360 to 7452) | 6843 (6279 to 6279) | 3740 (3488 to 3945) | 3392 (3181 to 3707) | 0.49 (0.45 to 0.52) | 0.39 (0.36 to 0.43) | -16.2 (-10.5 to -20.7) | 0.27 (0.25 to 0.29) | 0.20 (0.18 to 0.21) | -28 (-23.9 to -30.8) |
| Low SDI | 4582 (3762 to 5304) | 5634 (4742 to 6381) | 3699 (3048 to 4290) | 4467 (3772 to 5065) | 0.74 (0.61 to 0.86) | 0.69 (0.58 to 0.78) | -8.3 (-1.8 to -14.2) | 0.66 (0.54 to 0.77) | 0.60 (0.50 to 0.68) | -9.1 (-2.7 to -15.3) |
| Low-Middle SDI | 5095 (4494 to 5905) | 6159 (5369 to 7178) | 3855 (3387 to 4474) | 4512 (3907 to 5247) | 0.50 (0.44 to 0.57) | 0.47 (0.41 to 0.54) | -8 (-2 to -14) | 0.41 (0.36 to 0.47) | 0.37 (0.32 to 0.43) | -9.6 (-4 to -15.9) |
| Middle SDI | 6623 (5806 to 7193) | 8118 (7024 to 8700) | 3912 (3450 to 4299) | 4579 (3964 to 4907) | 0.37 (0.33 to 0.41) | 0.36 (0.31 to 0.39) | -3.3 (-7.9 to 1.4) | 0.24 (0.21 to 0.26) | 0.21 (0.18 to 0.23) | -10.4 (-6.1 to -14.4) |
| High-Income Asia Pacific | 1353 (1238 to 1469) | 1193 (1083 to 1320) | 658 (638 to 681) | 601 (564 to 641) | 0.50 (0.45 to 0.55) | 0.37 (0.33 to 0.41) | -27.6 (-17.9 to -36.6) | 0.21 (0.20 to 0.22) | 0.14 (0.13 to 0.15) | -31.3 (-27 to -35.7) |
| Western Europe | 9563 (9188 to 9912) | 8070 (7578 to 8590) | 5069 (4939 to 5185) | 4245 (4025 to 4487) | 1.33 (1.28 to 1.38) | 0.94 (0.88 to 1.00) | -27.8 (-22.1 to -32.7) | 0.64 (0.63 to 0.66) | 0.44 (0.41 to 0.46) | -32.3 (-28.3 to -35.6) |
| Andean Latin America | 170 (141 to 190) | 243 (198 to 281) | 108 (90 to 120) | 146 (120 to 165) | 0.39 (0.32 to 0.43) | 0.42 (0.35 to 0.49) | 3.8 (-8.8 to 16.9) | 0.26 (0.22 to 0.29) | 0.26 (0.21 to 0.29) | -0.2 (-11.2 to 11.1) |
| Central Latin America | 1237 (1188 to 1288) | 1449 (1358 to 1544) | 757 (730 to 782) | 856 (807 to 903) | 0.68 (0.66 to 0.71) | 0.60 (0.56 to 0.63) | -15.3 (-9.6 to -20.4) | 0.45 (0.43 to 0.46) | 0.36 (0.34 to 0.38) | -18.5 (-13.4 to -23.5) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Southern Latin America | 426 (397 to 455) | 376 (335 to 421) | 275 (261 to 288) | 229 (206 to 252) | 0.66 (0.61 to 0.71) | 0.48 (0.43 to 0.54) | -28.8 (-19 to -37.1) | 0.42 (0.40 to 0.44) | 0.28 (0.25 to 0.31) | -32.4 (-24.7 to -39) |
| Tropical Latin America | 978 (939 to 1024) | 911 (865 to 958) | 639 (621 to 664) | 597 (574 to 630) | 0.54 (0.52 to 0.57) | 0.39 (0.37 to 0.41) | -30.2 (-26.8 to -33.9) | 0.38 (0.37 to 0.39) | 0.26 (0.25 to 0.28) | -30.6 (-27.6 to -33.7) |
| North Africa and Middle East | 1852 (1469 to 2101) | 2220 (1844 to 2606) | 1123 (875 to 1270) | 1232 (1013 to 1436) | 0.53 (0.42 to 0.59) | 0.46 (0.39 to 0.53) | -16.6 (-7.8 to -23.2) | 0.35 (0.28 to 0.40) | 0.28 (0.23 to 0.32) | -20.5 (-11.9 to -26.5) |
| High-Income North America | 2478 (2389 to 2577) | 2543 (2416 to 2682) | 1542 (1508 to 1586) | 1561 (1498 to 1643) | 0.55 (0.54 to 0.58) | 0.48 (0.46 to 0.51) | -17.8 (-12.4 to -23.4) | 0.32 (0.31 to 0.33) | 0.26 (0.25 to 0.27) | -18.2 (-14.6 to -21.7) |
| Oceania | 47 (35 to 65) | 58 (43 to 82) | 33 (25 to 46) | 41 (31 to 56) | 0.68 (0.52 to 0.89) | 0.62 (0.47 to 0.84) | -9.3 (-23 to 6.3) | 0.53 (0.41 to 0.69) | 0.47 (0.37 to 0.62) | -9.6 (-21.2 to 5) |
| Central Sub-Saharan Africa | 280 (201 to 354) | 384 (280 to 480) | 225 (161 to 283) | 303 (222 to 375) | 0.60 (0.43 to 0.76) | 0.61 (0.44 to 0.76) | -0.9 (-13.8 to 13.5) | 0.54 (0.40 to 0.69) | 0.54 (0.39 to 0.67) | -1.3 (-14.1 to 12.7) |
| Eastern Sub-Saharan Africa | 1420 (1125 to 1671) | 1731 (1323 to 2103) | 1170 (933 to 1386) | 1398 (1071 to 1695) | 0.95 (0.76 to 1.13) | 0.85 (0.66 to 1.04) | -11.4 (-2.9 to -20.2) | 0.87 (0.69 to 1.04) | 0.77 (0.59 to 0.94) | -11.7 (-3.2 to -20.1) |
| Central Asia | 327 (287 to 360) | 324 (284 to 365) | 211 (187 to 230) | 198 (176 to 220) | 0.48 (0.42 to 0.52) | 0.38 (0.34 to 0.43) | -23.5 (-16 to -30.6) | 0.33 (0.29 to 0.35) | 0.25 (0.22 to 0.27) | -24.3 (-17.9 to -30.8) |
| Southern Sub-Saharan Africa | 60 (48 to 70) | 53 (40 to 66) | 43 (35 to 51) | 38 (29 to 46) | 0.11 (0.09 to 0.13) | 0.08 (0.06 to 0.10) | -28.8 (-17.5 to -39.1) | 0.09 (0.07 to 0.10) | 0.06 (0.05 to 0.08) | -29.6 (-20.6 to -38.9) |
| Western Sub-Saharan Africa | 773 (623 to 982) | 1037 (835 to 1320) | 599 (485 to 759) | 787 (628 to 990) | 0.44 (0.36 to 0.55) | 0.44 (0.36 to 0.56) | -1.6 (-11.5 to 10.2) | 0.38 (0.31 to 0.48) | 0.37 (0.30 to 0.47) | -2 (-12.1 to 9.7) |
| East Asia | 3912 (3324 to 4532) | 4162 (3544 to 4850) | 1229 (1059 to 1453) | 1179 (995 to 1391) | 0.24 (0.21 to 0.28) | 0.21 (0.18 to 0.25) | 1.8 (-5.9 to 10.7) | 0.08 (0.07 to 0.09) | 0.06 (0.05 to 0.07) | -24.1 (-18.7 to -29.2) |
| South Asia | 6910 (5969 to 7911) | 8730 (7517 to 9949) | 5417 (4721 to 6264) | 6660 (5713 to 7651) | 0.62 (0.54 to 0.72) | 0.60 (0.51 to 0.69) | -6.2 (-13.1 to 1.1) | 0.54 (0.47 to 0.62) | 0.49 (0.43 to 0.57) | -7.8 (-0.7 to -15.2) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Southeast Asia | 2281 (1781 to 2753) | 2760 (2182 to 3207) | 1467 (1154 to 1857) | 1652 (1302 to 1992) | 0.46 (0.36 to 0.56) | 0.43 (0.34 to 0.50) | -4.6 (-12.8 to 3.9) | 0.32 (0.25 to 0.41) | 0.28 (0.22 to 0.33) | -13.3 (-6.8 to -20.1) |
| Australasia | 468 (424 to 519) | 429 (368 to 498) | 230 (218 to 248) | 214 (189 to 244) | 1.39 (1.26 to 1.55) | 1.02 (0.88 to 1.20) | -24.8 (-10 to -38.1) | 0.62 (0.59 to 0.66) | 0.44 (0.39 to 0.50) | -29 (-19.8 to -37.1) |
| Caribbean | 332 (306 to 366) | 371 (333 to 418) | 221 (204 to 243) | 245 (222 to 274) | 0.80 (0.74 to 0.88) | 0.74 (0.66 to 0.83) | -8.2 (-17 to 1.5) | 0.54 (0.50 to 0.59) | 0.48 (0.44 to 0.54) | -10 (-1.4 to -18.1) |
| Central Europe | 1115 (1061 to 1174) | 890 (833 to 951) | 792 (765 to 822) | 643 (607 to 684) | 0.65 (0.62 to 0.69) | 0.47 (0.44 to 0.51) | -32.2 (-27.3 to -36.8) | 0.44 (0.43 to 0.46) | 0.31 (0.29 to 0.33) | -29.5 (-25.3 to -33.1) |
| Eastern Europe | 2214 (2066 to 2374) | 1920 (1756 to 2092) | 1495 (1442 to 1546) | 1238 (1172 to 1310) | 0.76 (0.71 to 0.82) | 0.64 (0.58 to 0.70) | -12.5 (-2.3 to -21.6) | 0.49 (0.47 to 0.50) | 0.38 (0.36 to 0.40) | -22.2 (-17 to -26.6) |

Table 4: GBD Regions

| **GBD Region** | **Countries** |
|---|---|
| High-Income Asia Pacific | Brunei, Japan, Singapore, South Korea |
| Western Europe | Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom |
| Andean Latin America | Bolivia, Ecuador, Peru |
| Central Latin America | Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Venezuela |
| Southern Latin America | Argentina, Chile, Uruguay |
| Tropical Latin America | Brazil, Paraguay |
| North Africa and Middle East | Afghanistan, Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Palestine, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, United Arab Emirates, Yemen |
| High-Income North America | Canada, Greenland, United States |
| Oceania | American Samoa, Federated States of Micronesia, Fiji, Guam, Kiribati, Marshall Islands, Northern Mariana Islands, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu |
| Central Sub-Saharan Africa | Angola, Central African Republic, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon |
| Eastern Sub-Saharan Africa | Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Somalia, South Sudan, Tanzania, Uganda, Zambia |
| Central Asia | Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan |
| Southern Sub-Saharan Africa | Botswana, Lesotho, Namibia, South Africa, Swaziland, Zimbabwe |
| Western Sub-Saharan Africa | Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Togo |
| East Asia | China, North Korea, Taiwan |
| South Asia | Bangladesh, Bhutan, India, Nepal, Pakistan |
| Southeast Asia | Cambodia, Indonesia, Laos, Malaysia, Maldives, Mauritius, Myanmar, Philippines, Sri Lanka, Seychelles, Thailand, Timor-Leste, Vietnam |
| Australasia | Australia, New Zealand |
| Caribbean | Antigua and Barbuda, The Bahamas, Barbados, Belize, Bermuda, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Puerto Rico, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Virgin Islands, U.S. |
| Central Europe | Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia |
| Eastern Europe | Belarus, Estonia, Latvia, Lithuania, Moldova, Russia, Ukraine |

Table 5: Sociodemographic index groupings, based on 2016 values

| **SDI Grouping** | **Locations** |
|---|---|
| High | Andorra, Australia, Austria, Belgium, Brunei, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Puerto Rico, Singapore, Slovakia, Slovenia, South Korea, Sweden Switzerland, Taiwan, United Kingdom, United States, U.S. Virgin Islands |
| High-Middle | Antigua and Barbuda, Argentina, Armenia, Azerbaijan, Barbados, Belarus, Bermuda, Bulgaria, Chile, Cuba, Georgia, Greenland, Guam, Hungary, Iran, Israel, Kazakhstan, Kuwait, Lebanon, Libya, Macedonia, Malaysia, Mauritius, Montenegro, Northern Mariana Islands, Panama, Portugal, Qatar, Romania, Russia, Saudi Arabia, Serbia, Spain, The Bahamas, Trinidad and Tobago, Turkey, Turkmenistan, Ukraine, United Arab Emirates |
| Middle | Albania, Algeria, American Samoa, Bahrain, Bosnia, and Herzegovina, Botswana, Brazil, China, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Fiji, Grenada, Guyana, Indonesia, Jamaica, Jordan, Maldives, Mexico, Moldova, Mongolia, Oman, Paraguay, Peru, Philippines, Saint Lucia, Saint Vincent and the Grenadines, Seychelles, South Africa, Sri Lanka, Suriname, Thailand, Tunisia, Uruguay, Uzbekistan, Venezuela, Vietnam |
| Low-Middle | Bangladesh, Belize, Bhutan, Bolivia, Cambodia, Cameroon, Cape Verde, Congo, Federated States of Micronesia, Gabon, Ghana, Guatemala, Honduras, India, Iraq, Kenya, Kyrgyzstan, Laos, Lesotho, Marshall Islands, Mauritania, Morocco, Myanmar, Namibia, Nepal, Nicaragua, Nigeria, North Korea, Pakistan, Samoa, Sudan, Swaziland, Syria, Tajikistan, Timor-Leste, Tonga, Vanuatu, Zambia, Zimbabwe |
| Low | Afghanistan, Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Cote d'Ivoire, Democratic Republic of Congo, Djibouti, Eritrea, Ethiopia, Guinea, Guinea-Bissau, Haiti, Kiribati, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Palestine, Papua New Guinea, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, South Sudan, Tanzania, The Gambia, Togo, Uganda, Yemen |


Figure 1: Flowchart describing estimation steps for CML incidence, mortality, YLLs, YLDs, DALYs. MI: mortality to incidence, VA: verbal autopsy

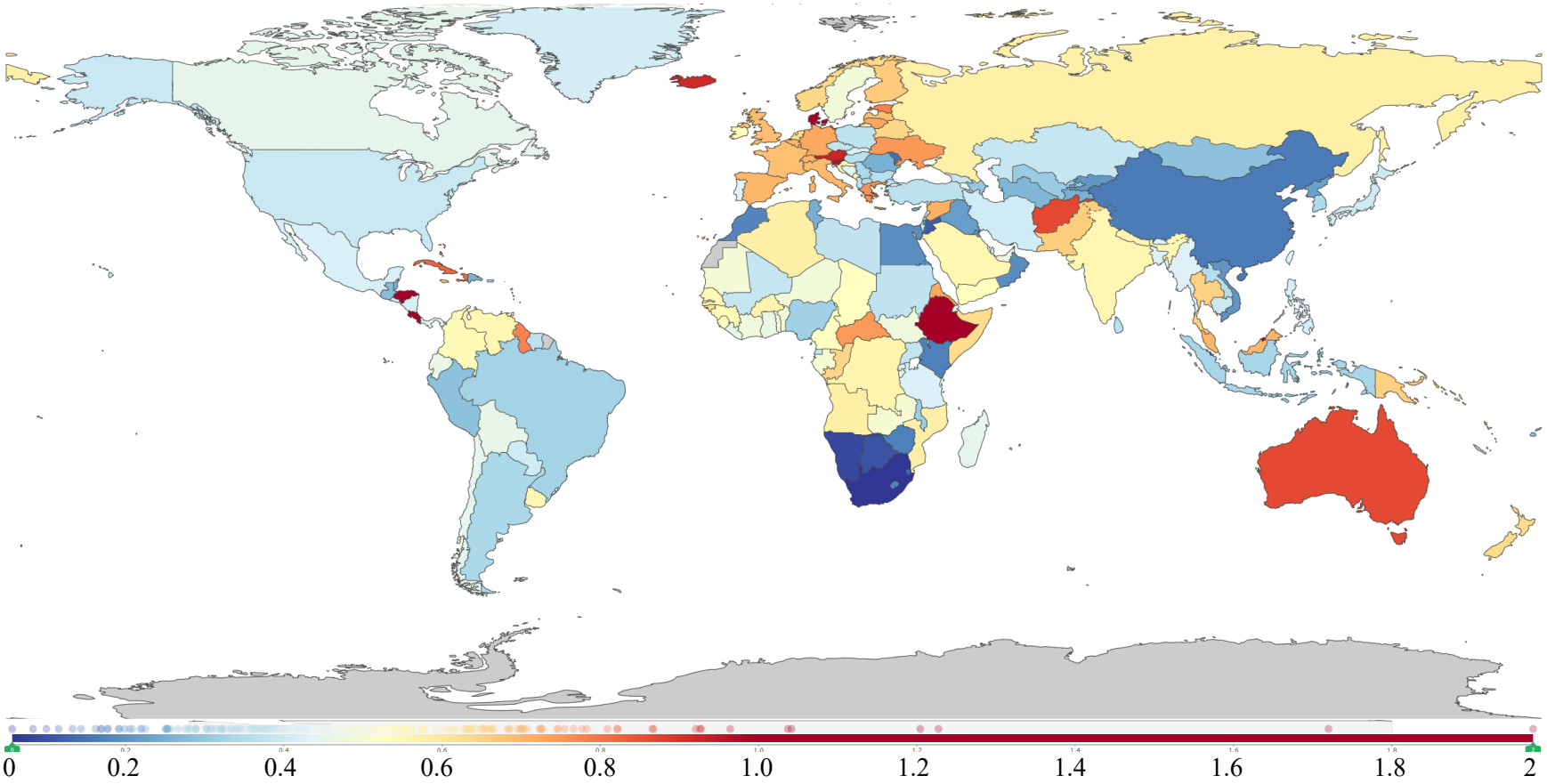


Figure 2: Age-standardized incidence rate of CML, both sexes, 2017 per 100,000 person-years

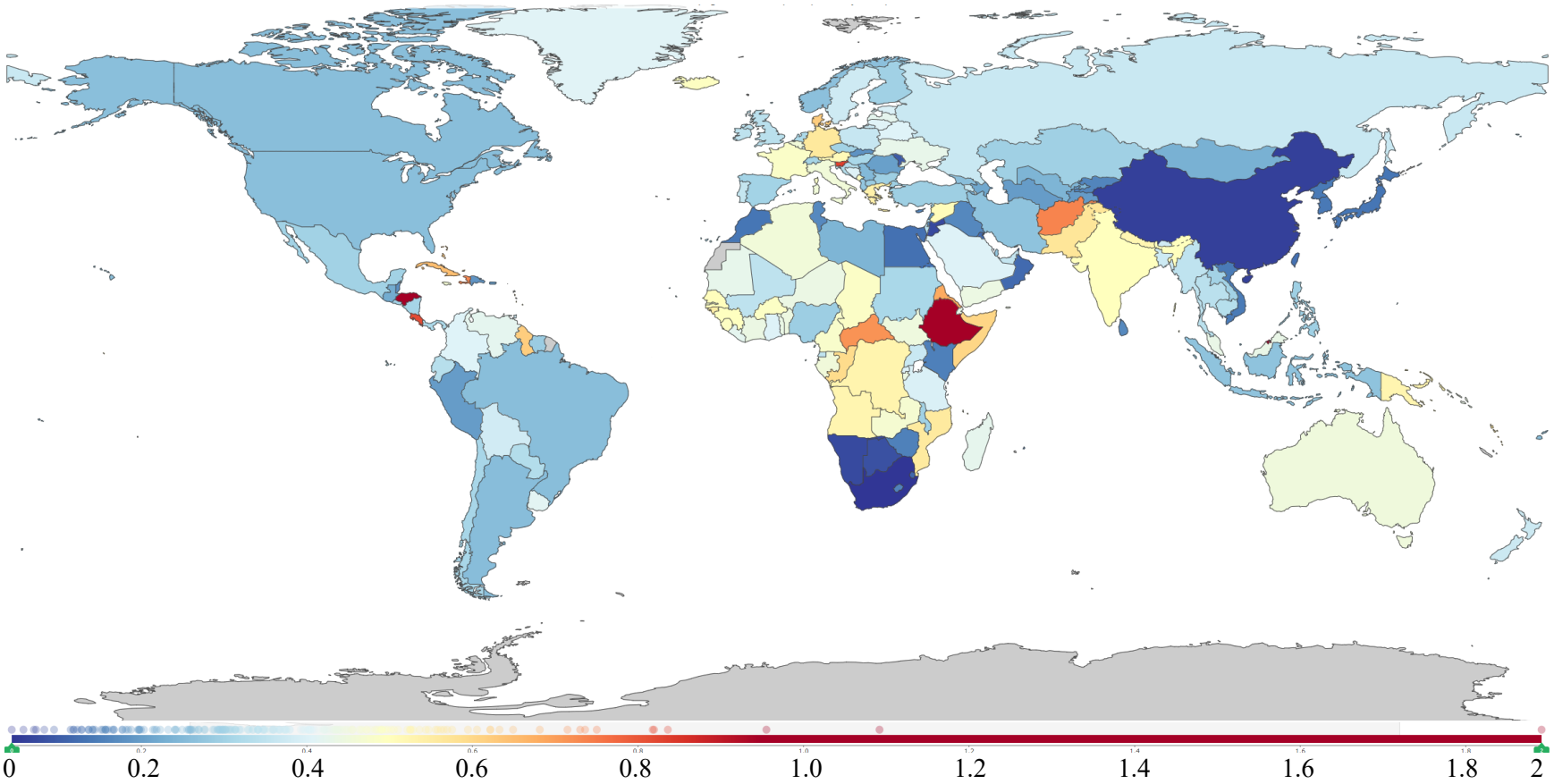


Figure 3: Age-standardized death rate of CML, both sexes, 2017 per 100,000 person-years

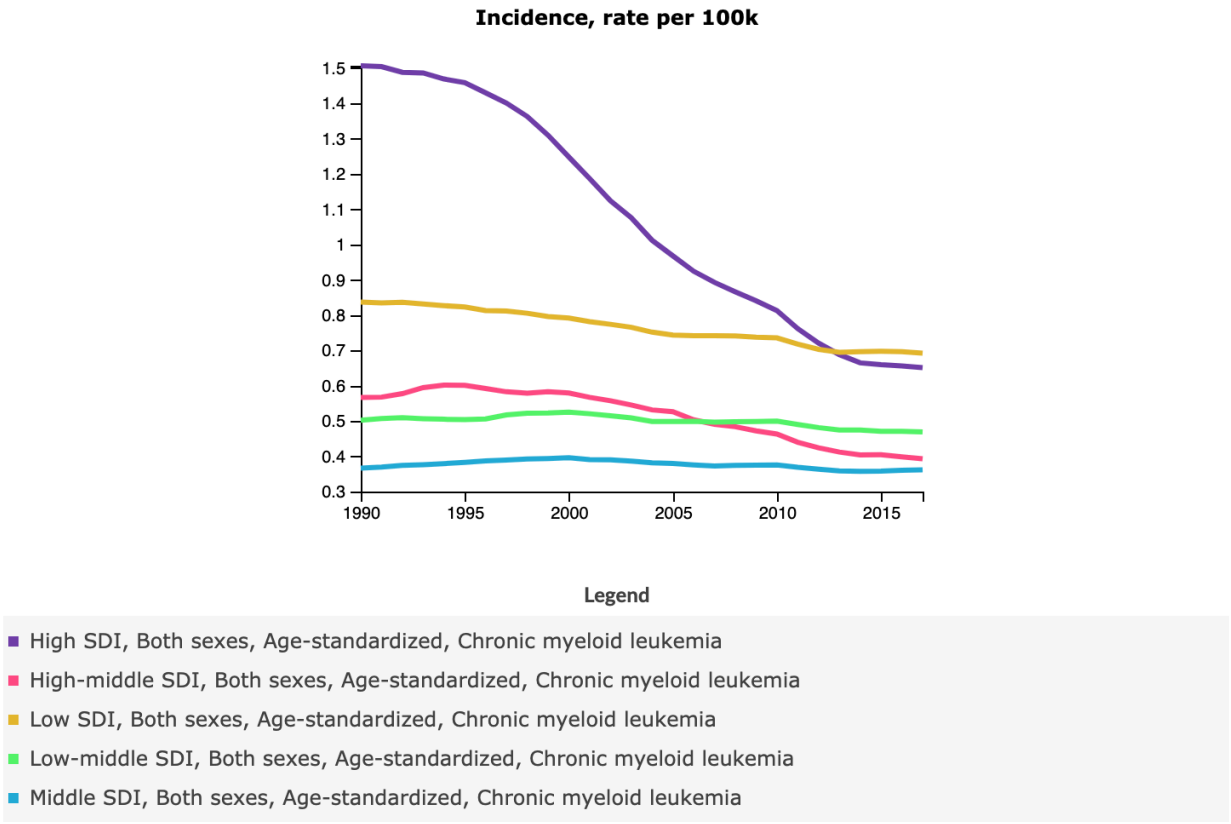


Figure 4: Trends in age-standardized incidence rate of CML by socio-demographic index, both sexes, 1990 – 2017

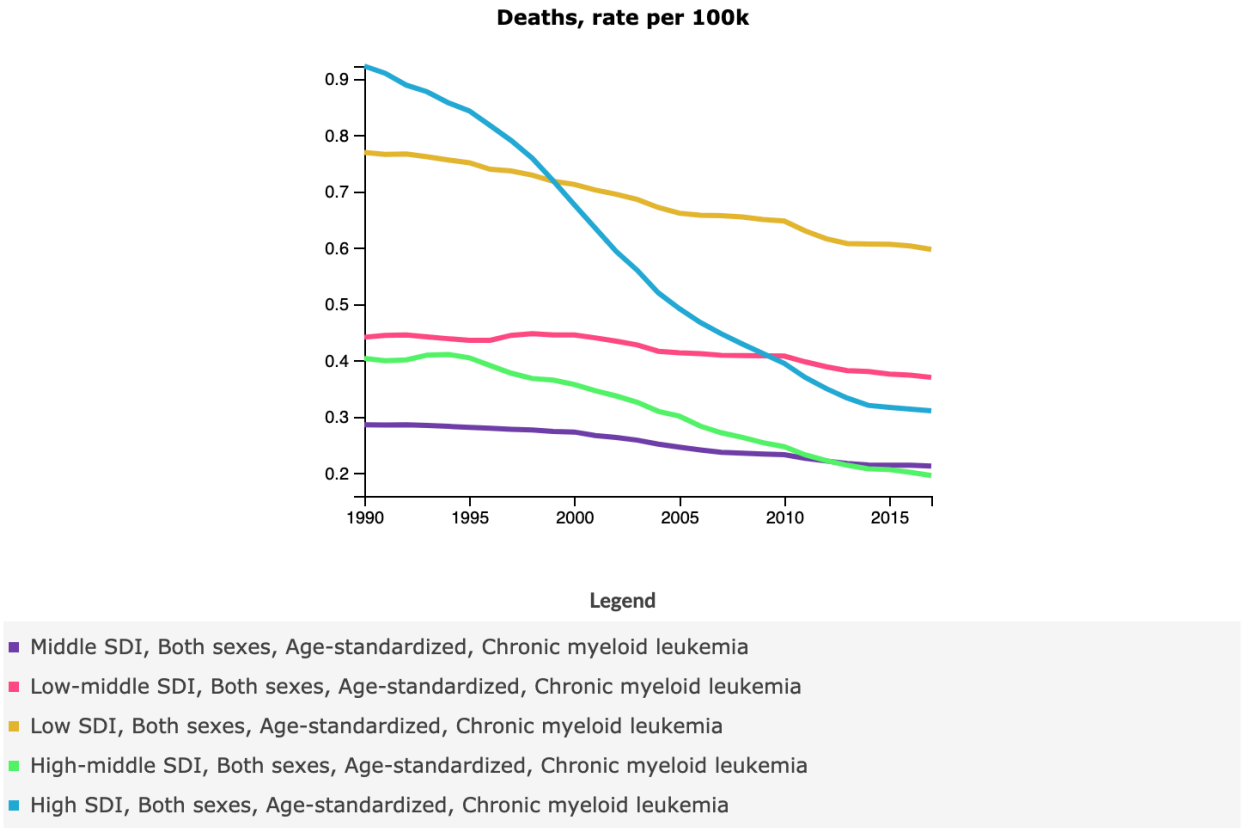


Figure 5: Trends in age-standardized mortality rate of CML by socio-demographic index, both sexes, 1990 – 2017

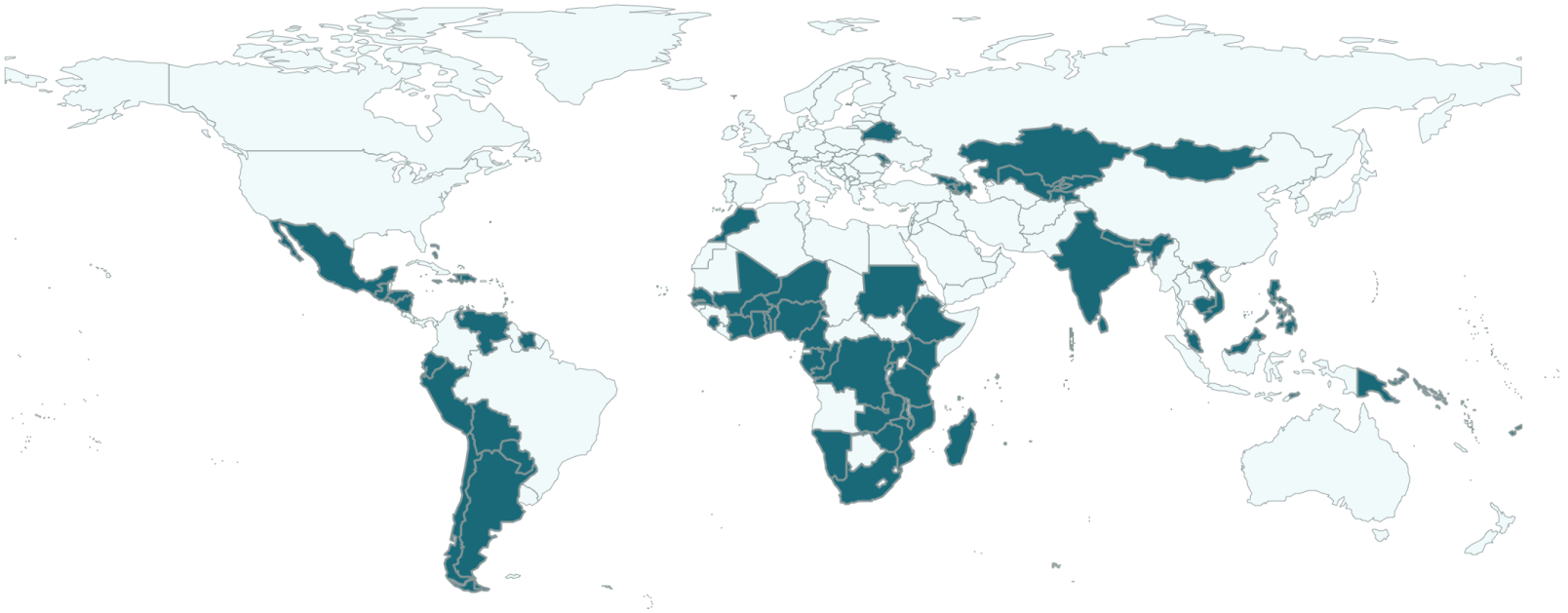

Figure 6: Countries supported by The Max Foundation's Max Access Solutions for Imatinib
Image retrieved from: The Max Foundation. Mapping Our Efforts. https://www.themaxfoundation.org/global/. Updated 2018. Accessed March 08 2020.

# VITA

Prior to enrolling in the Executive Master of Public Health program at the University of Washington School of Public Health, Eric Chow received his Bachelor of Science in Pharmaceutical Sciences in 2010 from the University of North Carolina at Chapel Hill and his Doctor of Pharmacy with Distinction from the University of North Carolina Eshelman School of Pharmacy in 2011. He then went on to complete his Post-Graduate Year 1 (PGY1) Pharmacy Practice Residency and Post-Graduate Year 2 Oncology Pharmacy Residency at UNC Healthcare in Chapel Hill, NC from 2011 to 2013. Upon completing his residency training, Eric has practiced in a variety of roles, including being a clinical pharmacy specialist in malignant hematology and hematopoietic cell transplantation, an oncology investigational drug research pharmacist, and a system oncology manager for a large, community health system. He is currently an oncology medical science liaison for Janssen Biotech.

Eric has also presented, authored, or coauthored numerous presentations, abstracts, and publications in the areas of malignant hematology and hematopoietic cell transplantation, with a specific focus on multiple myeloma and hematopoietic progenitor cell mobilization. He is also an active member in the American Society for Transplantation and Cellular Therapy and the Hematology Oncology Pharmacy Association, having served on and chaired numerous committees.