Disability-Adjusted Life Year conversion

CASE STUDY #3: TUBERCULOSIS CASES TO DALYS

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AIM

The objective of this study is to convert disease-specific health outcomes (i.e., tuberculosis [TB] cases) reported in economic evaluations to disability-adjusted life years (DALYs), a standardized health outcome measure that captures both longevity and morbidity. We estimated DALYs attributable to TB cases among a cohort of 15,000 people living with HIV in high-burden settings according to the results of an analysis conducted by Adelman and colleagues [1]. Since this paper reported both TB cases and DALYs, it was a suitable candidate for a case study to illustrate the conversion process and calibrate the DALY estimation from our online calculator.

METHODS

PARAMETERS

We extracted relevant information from Adelman et al.'s 2018 paper "Cost-effectiveness of WHO-Recommended Algorithms for TB Case Finding at Ethiopian HIV Clinics". [1] The target population was a simulated cohort of 15,000 people living with HIV attending an HIV Clinic in Addis Ababa, Ethiopia in 2013. Outcomes of the study were reported in DALYs as well as the number of TB cases under both the intervention, which was implementation of the WHO-recommended TB symptom screen (Xpert diagnostic algorithm) for people living with HIV, and the comparator, the current recommended practice algorithm (CRPA diagnostic algorithm). We aimed to use the number of TB cases to recreate DALYs and compare the estimated DALYs from our calculator to the reported estimate. Life expectancy at age of premature death was derived from the Global Burden of Disease Study (GBD) 2016, [2] and years lived with disease was calculated as the sum of the age of disease onset and the duration of disease. The duration of disease was extracted from a previous study. [3] A full list of parameters can be found in Table 1.

ONLINE CALCULATOR

The online DALY calculator is a Web app that, on individual and population levels estimates years of life lost (YLL), years lived with disease (YLD), and total DALYs attributable to a particular disease. Further details regarding the DALY calculator are published elsewhere. [4] To add precision to the original calculator, we updated the original standard life expectancy table with country- and gender-specific life expectancy. As users are not able to specify custom disability weights and life expectancy inputs, the

expectation was that the calculator would provide an approximate estimate for this conversion; the goal was to explore and calibrate its accuracy and usability. TB disease options among persons living with HIV with disability parameters closest to those reported in the original article were selected to estimate YLLs for each disease stage.

CUSTOM R CODE

The function underlying the online DALY calculator can be imported into the statistical package R [5] and used with custom parameter inputs. To improve usability of the online calculator, disability weights and life expectancy at death are fixed parameters pulled from standardized data sources [2, 6, 7] depending on disease, country, gender and age of death input by a user. These standardized values, however, do not exactly match the parameters used by Adelman et al. The disability weights for each disease state used in our calculator [6] are different from those in the source paper. The disability weight was 0.053 for HIV, TB (-); 0.399 for HIV, untreated TB; 0.1 for HIV, treated drug susceptible TB; 0.2 for HIV, treated MDR-TB as reported by Adelman et al. We applied the disability weight for AIDS with antiretroviral treatment (0.078) to the HIV, TB (-) and HIV, treated drug susceptible states; the disability weight for TB (0.333) to HIV untreated TB and HIV, treated MDR-TB states. We therefore overestimated DALYs for HIV, TB negative and HIV, treated MDR-TB states and underestimated DALYs for HIV, untreated TB and HIV, treated drug-susceptible TB states by our calculator compared those reported by Adelman et al. To address these differences, we used the underlying code from the online calculator tool to customize disability values to match exactly those reported in the paper by Adelman et al. This code can be found in Appendix 1.

ESTIMATE CALCULATION

Adelman et al. categorized their study cohort according to four different disease stages, to which different disability weights are attached. We estimated DALYs for each disease stage and summed the four DALY estimates to arrive at the total DALYs for the WHO-recommended symptom screen (Xpert). We repeated the process to calculate the DALYs for the current recommended practice algorithm (CRPA).

We identified parameters from external sources concerning age of death due to TB among persons living with HIV and life expectancy at premature death. Age of death was the sum of age of disease onset and length of time from disease onset to death. The latter was not reported in the original paper; we therefore extracted it from a separate paper that used a population-based estimate from the same country [3]. We conducted two set of calculations using different life expectancy at premature death: GBD standard life expectancy (Japan estimate) and Ethiopia-specific life expectancy.

RESULTS

Estimated DALYs in this population can be found in Table 2. The original paper reported 30,300 DALYs associated with the Xpert screening algorithm and 30,500 DALYs associated with CRPA screening algorithm, resulting in 200 DALYs averted due to the

WHO recommended symptom screen. By using GBD life expectancy for an idealized population (Japan estimate), our online calculator estimated 31,140 DALYs associated with the Xpert screening algorithm and 31,317 DALYs associated with CRPA screening algorithm, resulting in 177 DALYs averted. Using our custom R code, we estimated that 30,789 DALYs were associated with the Xpert screening algorithm and 30,974 DALYs associated with CRPA screening algorithm, resulting in 185 DALYs averted. DALYs associated with Xpert and CRPA, as well as DALYs averted by using Ethiopia specific life expectancy, are reported in Table 2.

The difference between the number of DALYs estimated by the online calculator and the custom R code stems from the use of standardized disability weights and life expectancy estimates in the online calculator versus custom parameters in the custom R code. Differences between population-based DALY estimates created by our methods and those reported by Adelman et al. are less than 5%. While this translates into larger percentage differences in terms of DALYs averted, the absolute differences are small and unlikely to change conclusions regarding cost-effectiveness. The remaining differences are likely because the uncertainty of the exact figure for life expectancy and rounding mechanisms throughout the calculation process used in the paper.

In summary, the use of both the DALY calculator and customized R code produced estimates of DALYs that were comparable to those used in an original, published cost-effectiveness evaluation of a targeted algorithm for TB case finding among persons living with HIV in Ethiopia. Future validation efforts will focus on a variety of disease areas, including non-communicable disease.

Table 1: Parameters

	Description	Number		Source reported in article	Source externally
Disability weight	HIV, TB negative	0.053		Salomon et al (2012) [5]	
	HIV, untreated TB	0.399			
	HIV, treated drug-susceptible TB	0.1		Andrew et al (2012) [8]	
	HIV, treated MDR-TB	0.2			
Life expectancy	Idealized population	49.88			GBD [2]
	Ethiopia population	39.29			GBD [7]
Age of onset		38		Adelman et al (2015) [9]	
Age of death	Age of onset plus length of infection to death	38.583			Asgedom et al (2018) [3]
		Xpert	CRPA		
Incident cases	HIV, TB negative	14100	14100	Adelman et al (2018) [1]	
	HIV, untreated TB	434	442		
	HIV, treated drug-susceptible TB	452.952	445.176		
	HIV, treated MDR-TB	13.048	13.048		
Incident deaths	HIV, TB negative	705	705	Adelman et al (2018) [2]	
	HIV, untreated TB	434	442		
	HIV, treated drug-susceptible TB	47.560	46.743		
	HIV, treated MDR-TB	2.610	2.691		
Discount rate	3%				
Age weighting	Not used				

Table 2: Outcomes of DALY conversion calculation on online calculator and with custom R code

	Xpert screening (treatment)		CRPA screening (comparison)		Differences
	Description	**DALYs**	**Description**	**DALYs**	**DALYs averted**
Adelman et al.		30,300		30,500	200
Online Calculator (Idealized population)	HIV, TB (-)	18782	HIV, TB (-)	18,782	
	HIV, untreated TB	11,038	HIV, untreated TB	11,241	
	HIV, treated drug-susceptible TB	1,240	HIV, treated drug-susceptible TB	1,214	
	HIV, treated MDR-TB	80	HIV, treated MDR-TB	80	
	Total	**31,140**	**Total**	**31,317**	**177**
(Ethiopia population)	HIV, TB (-)	16,872	HIV, TB (-)	16,872	
	HIV, untreated TB	9,862	HIV, untreated TB	10,043	
	HIV, treated drug-susceptible TB	1,110	HIV, treated drug-susceptible TB	1,087	
	HIV, treated MDR-TB	71	HIV, treated MDR-TB	71	
	Total	**27,915**	**Total**	**28,073**	**158**
Custom R code	HIV, TB (-)	18,353	HIV, TB (-)	18,353	
	HIV, untreated TB	11,132	HIV, untreated TB	11,337	
	HIV, treated drug-susceptible TB	1,235	HIV, treated drug-susceptible TB	1,214	
	HIV, treated MDR-TB	68	HIV, treated MDR-TB	70	
	Total	**30,789**	**Total**	**30,974**	**185**

REFERENCES

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Appendix 1: Custom R code used to calculate DALYs

```
library('devtools')
install_github('TuftsCEVR/DALYCalculator')
library('DALYcalculator')

#Adelman 2018: Tuberculosis

#POPULATION LEVEL
#TREATMET: XPERT
  #DALYs estimates for each disease state among PLHIV
  #HIV,TB(-):
    T_TBNeg_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03, beta=0,
a_death=38.58, a_disability=38, YLL_L=49.16, D=0.053 ,incident_cases = 14100,
incident_deaths = 705)[3]
    T_TBNeg_DALY
  #HIV,untreated TB:
    T_TBuntreated_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03,
beta=0, a_death=38.58, a_disability=38, YLL_L=49.16, D=0.399 ,incident_cases =
434, incident_deaths = 434)[3]
    T_TBuntreated_DALY
  #HIV, treated drug-susceptible TB:
    T_DSTB_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03, beta=0,
a_death=38.58, a_disability=38, YLL_L=49.16, D=0.1,incident_cases = 453,
incident_deaths = 48)[3]
    T_DSTB_DALY
  #HIV, MDR-TB:
    T_MDRTB_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03, beta=0,
a_death=38.58, a_disability=38, YLL_L=49.16, D=0.2,incident_cases = 13,
incident_deaths = 3)[3]
    T_MDRTB_DALY
  #add together to get full DALY estimate
    T_DALY_PLHIVTB<- T_TBNeg_DALY+T_TBuntreated_DALY+T_DSTB_DALY+T_MDRTB_DALY
    T_DALY_PLHIVTB

#COMPARISON: CRPA
  #DALYs estimates for each disease state among PLHIV
  #HIV,TB(-):
    C_TBNeg_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03, beta=0,
a_death=38.58, a_disability=38, YLL_L=49.16, D=0.053 ,incident_cases = 14100,
incident_deaths = 705)[3]
    C_TBNeg_DALY
  #HIV,untreated TB:
    C_TBuntreated_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03,
beta=0, a_death=38.58, a_disability=38, YLL_L=49.16, D=0.399 ,incident_cases =
442, incident_deaths = 442)[3]
    C_TBuntreated_DALY
  #HIV, treated drug-susceptible TB:
    C_DSTB_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03, beta=0,
a_death=38.58, a_disability=38, YLL_L=49.16, D=0.1,incident_cases = 443,
incident_deaths = 45)[3]
    C_DSTB_DALY
  #HIV, MDR-TB:
    C_MDRTB_DALY<-DALYcalculator::f_DALYpop(K=0, C = 0.16243, r=0.03, beta=0,
a_death=38.58, a_disability=38, YLL_L=49.16, D=0.2,incident_cases = 13,
incident_deaths = 3)[3]
    C_MDRTB_DALY
  #add together to get full DALY estimate
    C_DALY_PLHIVTB<- C_TBNeg_DALY+C_TBuntreated_DALY+C_DSTB_DALY+C_MDRTB_DALY
    C_DALY_PLHIVTB
```

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