Disability-Adjusted Life Year conversion

CASE STUDY #1: HIV CASES TO DALYS

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AIM

This study aims to convert disease-specific health outcomes (e.g., HIV cases) reported in economic evaluations into disability-adjusted life years (DALYs), a health outcome measure comparable across various disease areas. In this case study, we attempted to estimate DALYs attributable to a single HIV case based on information presented by Vassall et al. [1]. Because this study presented the outcomes of their model in terms of both HIV cases averted and DALYs averted, we used this case study to calibrate our DALY estimation from our online calculator.

METHODS

PARAMETERS

To populate our DALY equations, we used information from Vassall et al.'s 2014 paper titled "Cost-effectiveness of HIV prevention for high-risk groups at scale: an economic evaluation of the Avahan programme in south India" and related publications. [1, 2] The target population reached was 154,425 high risk group members, including female sex workers (FSWs), men who have sex with men (MSM), and injecting drug users, in 22 Indian districts with high HIV prevalence, focusing on the years 2004-2008. Outcomes of the study were reported in DALYs averted and HIV cases averted, which we divided to calculate DALYs attributable to each HIV case for this population. This DALY/HIV case estimate is the number we aimed to recreate with this conversion. No parameters were sourced externally. 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 in disease (YLD), and total DALYs attributable to a particular disease. Further methodology regarding the DALY calculator is published elsewhere. [3] As users are not able to specify custom utility and life expectancy inputs, the calculator was only used as a rough estimation for this conversion to calibrate its accuracy and usability. HIV disease options with utility 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 [4] and used with custom parameter inputs. To improve usability of the online calculator, disability weight and life expectancy at death are fixed parameters pulled from standardized data sources [5, 6] depending on disease and age of death input but a user. These standardized values, however, do not exactly match the parameters used by Vassell et al.

The online calculator's life expectancy at premature death when the age of death is 49.25 is higher than those reported in the paper (38.54 years in the calculator vs. 26.5 years in the paper). Our online calculator sources from global average life expectancies [6], while Vassell et al. use life expectancies specific to their target population. Secondly, the utilities weights used in our calculator [5] are higher than those in the source paper. Both differences result in inflated DALY estimates by our calculator compared those reported by Vassell et al. To address these differences, we used the underlying code from the online calculator tool to customize utility values and life expectancies to match exactly those reported in the paper by Vassell et al. This code can be found in Appendix 1.

ESTIMATE CALCULATION

Because HIV has multiple progressive disease stages to which different disability weights are attached, for those not undergoing treatment, we first estimated the YLDs (i.e. the influence on quality of life during this disease stage) accrued during each disease stage (i.e., early/asymptomatic HIV, symptomatic HIV, AIDS without treatment). Then, we separately calculated the YLLs due to early death from AIDS. This process is displayed in Figure 1.

We made some assumptions concerning age of onset and age of death due to HIV. Based on the median duration of HIV stages reported in the paper (Table 1), we assumed that the age of death due to AIDS without treatment was 9.75 years (117 months) since the onset of the HIV.

For those who receive antiretroviral therapy (ART), we estimated DALYs averted due to the treatment as number of DALYs accrued by an individual without treatment minus DALYs accrued by an individual with ART. We used disability weights for HIV with ART and applied additional 9.5 years of life gained based on the report (Table 1).

Finally, we conducted subgroup analyses for each age group specified in the paper (25-29 years old; 30-34; 35-39; 40-44; 45-49; 50-54). We varied life expectancy at early death for each age group, though disease length remained the same for all groups.

RESULTS

Estimated DALYs per HIV case in this population can be found in Table 2. The original paper reported 61,744 HIV cases and 1,061,255 DALYs were averted due to their intervention, resulting in 17.2 DALYs attributable to each HIV case. The number of DALYs attributable to each case of HIV estimated by our online calculator was 23.65, and by our custom R code was 19.42. DALYs averted due to ART was 9.43 per HIV case. DALYs imposed with and without treatment, as well as DALYs averted by ART per each age group is reported in Table 3.

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. The difference between the DALY estimate created by our methods

and that reported by Vassell et al. is likely because a dynamic transmission model calculates DALYs differently than a stagnant calculation. The model incorporates demographic data, particularly differing age groups between three populations, which will create more precise DALY estimates than our calculator, which relies on average ages per individual.

Table 1: Parameters sourced from Vassell et al.

	Description	Number	Source reported in article
Utility weight	Early and asymptomatic HIV	0	Salomon et al (2012) [5]
	Late-stage HIV infection	0.22	
	AIDS	0.55	
	ART	0.053	
Life expectancy	Without HIV, 25-29 years	43.8	WHO Life expectancy tables 2009
	Without HIV, 30-34 years	39.3	
	Without HIV, 35-39 years	34.9	
	Without HIV, 40-44 years	30.7	
	Without HIV, 45-49 years	26.5	
	Without HIV, 50-54 years	22.6	
	Extra LE with ART if HIV+	9.5	Creese et al (2002); Mills et al (2011); Freedberg et al (2007)[7-9]
Age of onset	Assumed from article supplement: overall median age of age groups	39.5	
Age of death	Average duration of HIV stages (months, reported as uniform distribution):		Kumarasamy et al (2003) [10]
	Early HIV	2-6 (median: 4)	
	Asymptomatic HIV	70-91 (median: 80.5)	

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	Late-stage HIV	6-18 (median: 12)	
	AIDs phase no treatment	11.6-29.4 (median: 20.5)	
	Additional LY due to ART	9.5 YEARS	Citations 22-25: Creese et al (2002); Mills et al (2011); Freedberg et al (2007) [7-9]
	Assumed from article: Without treatment	89.6-144.4 months post-onset (median: 117) (9.75 years)	
	With treatment (based off median above)	231 months post-onset (19.25 years)	
Discount rate	3%		
Age weighting	Not used		

Figure 1: DALY calculation with progressive HIV disease

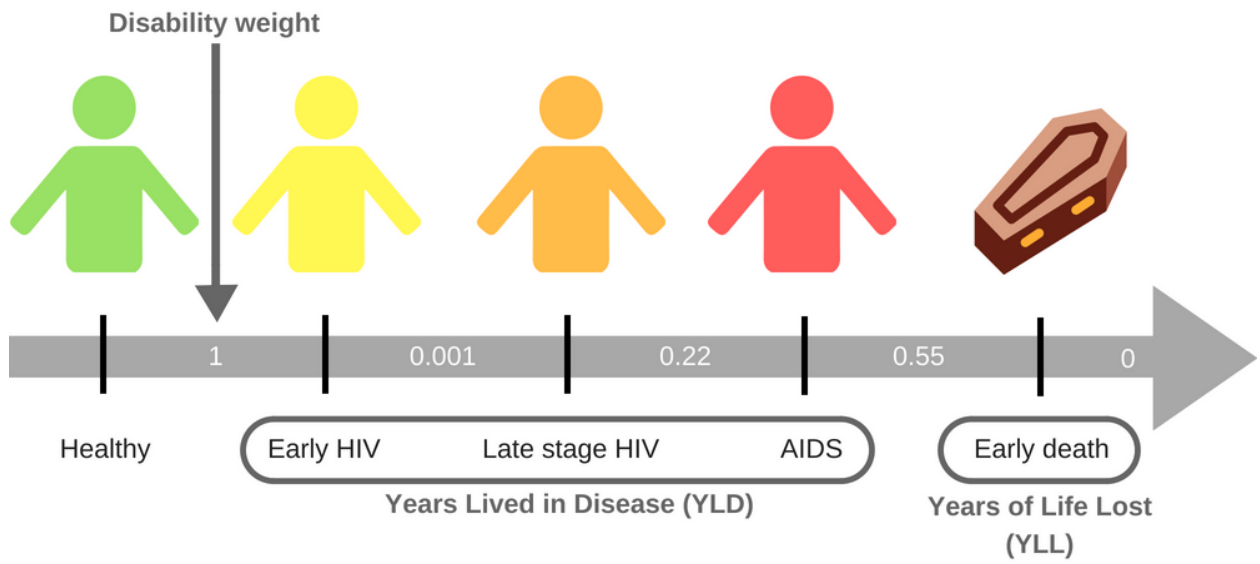**Table 2: Outcomes of DALY conversion calculation on online calculator and with custom R code**

	Without treatment		With treatment	
	Description	**Number**	**Description**	**Number**
Vassall et al.	NA		DALYs per HIV case	17.18
Online Calculator	YLDs (Early HIV)	0.08	YLDs (AIDS with ART)	1.13
	YLDs (Symptomatic HIV)	0.27	YLLs with treatment	11
	YLDs (AIDS)	1.13	DALYs	12.13
	YLLs without treatment	22.17	DALYs averted due to treatment	11.52
	DALYs	23.65		
Custom R code	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	0.78
	YLDs (Late stage HIV)	0.22	YLLs with treatment	9.2
	YLDs (AIDS)	0.92	DALYs	9.99
	YLLs without treatment	18.28	DALYs averted due to treatment	9.43
	DALYs	19.42		

Table 3: Outcomes of DALY conversion calculation with custom R code, age sub-categories

Age group	Without treatment		With treatment	
	Description	Number	Description	Number
25-29 years	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	1.03
	YLDs (Late stage HIV)	0.22	YLLs with treatment	6.88
	YLDs (AIDS)	0.92	DALYs	11.04
	YLLs without treatment	20.80	DALYs averted due to treatment	10.89
	DALYs	21.93		
30-34 years	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	0.78
	YLDs (Late stage HIV)	0.22	YLLs with treatment	9.21
	YLDs (AIDS)	0.92	DALYs	9.99
	YLLs without treatment	19.62	DALYs averted due to treatment	10.77
	DALYs	20.76		
35-39 years	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	0.78
	YLDs (Late stage HIV)	0.22	YLLs with treatment	9.21
	YLDs (AIDS)	0.92	DALYs	9.99
	YLLs without treatment	18.30	DALYs averted due to treatment	9.44
	DALYs	19.43		
40-44 years	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	0.78
	YLDs (Late stage HIV)	0.22	YLLs with treatment	9.21
	YLDs (AIDS)	0.92	DALYs	9.99
	YLLs without treatment	16.90	DALYs averted due to treatment	8.05
	DALYs	18.03		
45-49 years	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	0.78
	YLDs (Late stage HIV)	0.22	YLLs with treatment	9.21
	YLDs (AIDS)	0.92	DALYs	9.99
	YLLs without treatment	16.90	DALYs averted due to treatment	8.05
	DALYs	18.03		
50-54	YLDs (Early/asymptomatic HIV)	0.0006	YLDs (HIV on ART)	0.78
	YLDs (Late stage HIV)	0.22	YLLs with treatment	9.21
	YLDs (AIDS)	0.92	DALYs	9.99
	YLLs without treatment	16.40	DALYs averted due to treatment	7.54
	DALYs	17.53		

References

1.	Vassall, A., et al., *Cost-effectiveness of HIV prevention for high-risk groups at scale: an economic evaluation of the Avahan programme in south India.* The Lancet Global Health, 2014. 2(9): p. e531-e540.
2.	Pickles, M., et al., *Assessment of the population-level effectiveness of the Avahan HIV-prevention programme in South India: a preplanned, causal-pathway-based modelling analysis.* The Lancet Global Health, 2013. 1(5): p. e289-e299.
3.	David Kim, J.E., Disability Adjusted Life Years (DALY) Calculator: Methodology. 2018, Center for the Evaluation of Value and Risk in Health, Tufts Medical Center.
4.	Team, R.C., R: *A language and environment for statistical computing.* 2013, R Foundation for Statistical Computing: Vienna, Austria.
5.	Salomon, J.A., et al., *Common values in assessing health outcomes from disease and injury: disability weights measurement study for the Global Burden of Disease Study 2010.* The Lancet, 2012. 380(9859): p. 2129-2143.
6.	Wang, H., et al., *Global, regional, and national under-5 mortality, adult mortality, age-specific mortality, and life expectancy, 1970–2016: a systematic analysis for the Global Burden of Disease Study 2016.* The Lancet, 2017. 390(10100): p. 1084-1150.
7.	Creese, A., et al., *Cost-effectiveness of HIV/AIDS interventions in Africa: a systematic review of the evidence.* The Lancet, 2002. 359(9318): p. 1635-1642.
8.	Freedberg, K.A., et al., *Clinical impact and cost-effectiveness of antiretroviral therapy in India: starting criteria and second-line therapy.* AIDS (London, England), 2007. 21(Suppl 4): p. S117.
9.	Mills, E.J., et al., *Life expectancy of persons receiving combination antiretroviral therapy in low-income countries: a cohort analysis from Uganda.* Annals of internal medicine, 2011. 155(4): p. 209-216.
10.	Kumarasamy, N., et al., *Natural history of human immunodeficiency virus disease in southern India.* Clinical Infectious Diseases, 2003. 36(1): p. 79-85.

Appendix 1: Custom R code used to calculate DALYs

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

#Vassell 2014: HIV

#INDIVIDUAL LEVEL
#NO TREATMENT
  #assign YLD estimates per each phase of HIV to variables
  #early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
    asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03,
beta=0, a_death=46.54167, a_disability=39.5, YLL_L=26.5, D=0.0001)[2]
    asymptomaticearly_YLD
  #late stage HIV, lasts 12 months (1 year)
    latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=47.54167, a_disability=46.54167, YLL_L=26.5, D=0.22)[2]
    latestage_YLD
  #AIDS, lasts 20.5 months (1.71 years)
    AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=49.25, a_disability=47.54167, YLL_L=26.5, D=0.55)[2]
    AIDS_YLD
  #YLL estimate
    YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=49.25,
a_disability=47.54167, YLL_L=26.5, D=0.55)[3]
    YLL
  #add together to get full DALY estimate
    DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
    DALY_HIVcase

#TREATMENT
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=58.75,
a_disability=39.5, YLL_L=22.6, D=0.053)

#BY AGE CATEGORY
  #25-29
    #no tx
#assign YLD estimates per each phase of HIV to variables
#early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=34.04166666666667, a_disability=27, YLL_L=43.8, D=0.0001)[2]
asymptomaticearly_YLD
#late stage HIV, lasts 12 months (1 year)
latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=35.04166666666667, a_disability=34.04166666666667, YLL_L=34.9, D=0.22)[2]
latestage_YLD
#AIDS, lasts 20.5 months (1.71 years)
AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=36.75,
a_disability=35.04166666666667, YLL_L=34.9, D=0.55)[2]
AIDS_YLD
#YLL estimate
YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=36.75,
a_disability=27, YLL_L=34.9, D=0.55)[3]
YLL
#add together to get full DALY estimate
DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
DALY_HIVcase
    #tx (19.25 years)
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=46.25, a_disability=27, YLL_L=26.5, D=0.053)

  #30-34
    #no tx
```

```r
#assign YLD estimates per each phase of HIV to variables
#early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=39.04166666666667, a_disability=32, YLL_L=34.9, D=0.0001)[2]
asymptomaticearly_YLD
#late stage HIV, lasts 12 months (1 year)
latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=40.04166666666667, a_disability=39.04166666666667, YLL_L=30.7, D=0.22)[2]
latestage_YLD
#AIDS, lasts 20.5 months (1.71 years)
AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=41.75,
a_disability=40.04166666666667, YLL_L=30.7, D=0.55)[2]
AIDS_YLD
#YLL estimate
YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=41.75,
a_disability=32, YLL_L=30.7, D=0.55)[3]
YLL
#add together to get full DALY estimate
DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
DALY_HIVcase
    #tx (19.25 years)
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=51.25,
a_disability=32, YLL_L=22.6, D=0.053)

  #35-39
    #no tx
#assign YLD estimates per each phase of HIV to variables
#early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=44.04167, a_disability=37, YLL_L=34.9, D=0.0001)[2]
asymptomaticearly_YLD
#late stage HIV, lasts 12 months (1 year)
latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=45.04167, a_disability=44.04167, YLL_L=26.5, D=0.22)[2]
latestage_YLD
#AIDS, lasts 20.5 months (1.71 years)
AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=46.75167, a_disability=45.04167, YLL_L=26.5, D=0.55)[2]
AIDS_YLD
#YLL estimate
YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=46.75167,
a_disability=37, YLL_L=26.5, D=0.55)[3]
YLL
#add together to get full DALY estimate
DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
DALY_HIVcase
    #tx (19.25 years)
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=56.25,
a_disability=37, YLL_L=22.6, D=0.053)

  #40-44
    #no tx
#assign YLD estimates per each phase of HIV to variables
#early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C =
0.16243, r=0.03, beta=0, a_death=49.04167, a_disability=42,
YLL_L=30.7, D=0.0001)[2]
asymptomaticearly_YLD
#late stage HIV, lasts 12 months (1 year)
latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243,
r=0.03, beta=0, a_death=50.04167, a_disability=49.04167,
YLL_L=26.5, D=0.22)[2]
latestage_YLD
```

```r
#AIDS, lasts 20.5 months (1.71 years)
AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=51.75167, a_disability=50.04167, YLL_L=22.6, D=0.55)[2]
AIDS_YLD
#YLL estimate
YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=51.75167,
a_disability=42, YLL_L=22.6, D=0.55)[3]
YLL
#add together to get full DALY estimate
DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
DALY_HIVcase
    #tx (19.25 years)
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=61.25,
a_disability=42, YLL_L=22.6, D=0.053)

  #45-49
    #no tx
#assign YLD estimates per each phase of HIV to variables
#early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=54.04167, a_disability=47, YLL_L=22.6, D=0.0001)[2]
asymptomaticearly_YLD
#late stage HIV, lasts 12 months (1 year)
latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=55.04167, a_disability=54.04167, YLL_L=22.6, D=0.22)[2]
latestage_YLD
#AIDS, lasts 20.5 months (1.71 years)
AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=56.75167, a_disability=55.04167, YLL_L=22.6, D=0.55)[2]
AIDS_YLD
#YLL estimate
YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=56.75167,
a_disability=47, YLL_L=22.6, D=0.55)[3]
YLL
#add together to get full DALY estimate
DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
DALY_HIVcase
    #tx (19.25 years)
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=66.25,
a_disability=47, YLL_L=22.6, D=0.053)

  #50-54
    #no tx
#assign YLD estimates per each phase of HIV to variables
#early/asymptomatic HIV, lasts 84.5 months (7.04167 years) - made disability
weight very small
asymptomaticearly_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=59.04167, a_disability=52, YLL_L=22.6, D=0.0001)[2]
asymptomaticearly_YLD
#late stage HIV, lasts 12 months (1 year)
latestage_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=60.04167, a_disability=59.04167, YLL_L=22.6, D=0.22)[2]
latestage_YLD
#AIDS, lasts 20.5 months (1.71 years)
AIDS_YLD<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=61.75167, a_disability=60.04167, YLL_L=22.6,
D=0.55)[2]
AIDS_YLD
#YLL estimate
YLL<-DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0,
a_death=61.75167, a_disability=62, YLL_L=22.6, D=0.55)[3]
YLL
#add together to get full DALY estimate
DALY_HIVcase<-asymptomaticearly_YLD+latestage_YLD+AIDS_YLD+YLL
DALY_HIVcase
```

```
    #tx (19.25 years)
DALYcalculator::f_DALY(K=0, C = 0.16243, r=0.03, beta=0, a_death=71.25,
a_disability=52, YLL_L=22.6, D=0.053)
```

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