Data for Heroin Model
Tricia Phillips
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- The following are the **number of individuals initially in each class** for Tennessee:

  *__Susceptibles__: (Total population in 2015-size of four other classes= $6,590,726 - 1,819,581 - 48,000 - 14,000 - R_0$ =FILL IN) [17]

  Although this number does not explicitly state it is for individuals 12 and older, we assume it is since it comes from the Tennessee Department of Health; if it does include individuals under 12, we assume that number is negligible.

  *__Opioid addicts__, 2015/2016 average for "Pain Reliever Use Disorder" for individuals 12 and older: 48,000 [15]
  We note that their definition of pain reliever use disorder includes those who meet the American Psychiatric Association criteria for dependence or abuse. Here, opioid dependence is classified as having "signs and symptoms that reflect compulsive, prolonged self-administration of opioid substances that are used for no legitimate medical purpose or...are used in doses that are greatly in excess of the amount needed for pain relief...regular patterns of compulsive drug use that daily activities are typically planned around obtaining and administering opioids." This definition falls under our definition of opioid addiction. Opioid abuse, on the other hand, they consider to be less severe than dependence, and would not lead to the development of withdrawal symptoms. This latter definition does not fall under our characterization of addiction, but we make a note of this to say that this estimate for those with a pain reliever use disorder may be overestimated for what we are concerned with, but is an acceptable approximation [1].

  *__Heroin/fentanyl addicts__, 2015/2016 average for "Past Year Heroin Use" for individuals 12 and older: 14,000 [15]
  Although this number includes those who may have used heroin once or twice in the past year, we are under the assumption that the majority of these individuals are addicts and that very few, if any, individuals use heroin recreationally. In addition, the number of heroin users does not include fentanyl users explicitly, but we are under the assumption that those who take fentanyl are a subset of those who use heroin, and therefore, would mostly be included in these numbers. We admit the values may be slightly too low, for the cases of individuals who do fentanyl and not heroin, but data has not been found for fentanyl addicts only. Therefore, we are working under the assumption that it would be a negligible population that takes fentanyl without heroin. Overall, these two assumptions may work to balance one another out.

  **Recovering addicts*: *won't be able to find because we do not know the total of*

individuals total that have been in treatment ever in the past for our time frame

- For Tennessee, the **total number of individuals taking prescription opioids** for pain [13]:
  2013: 1,845,144
  2014: 1,824,342
  2015: 1,819,581
  2016: 1,761,363
  2017: 1,636,374

  Although this number does not explicitly state it is for individuals 12 and older, we assume it is since it comes from the Tennessee Department of Health; if it does include individuals under 12, we assume that number is negligible.

- For Tennessee individuals 12 and older, **the number of treatment admissions for non-heroin opiates/synthetics** as the primary substance of abuse to facilities that receive state/public funding (generally referring to funding by the state substance abuse agency) [9]:
  2005: 1,578
  2006: 1,529
  2007: 1,743
  2008: 2,022
  2009: 2,464
  2010: 3,384
  2011: 3,884
  2012: 4,203
  2013: 4,485
  2014: 4,530
  2015: 4,326

  We are under the assumption that if one were addicted to heroin in addition to prescription opioids, their heroin problem would be the primary reason for going to treatment and would be included in the following numbers.

- For Tennessee individuals 12 and older, **the number of treatment admissions for heroin** as the primary substance of abuse to facilities that receive state/public funding (generally referring to funding by the state substance abuse agency) [9]:
  2010: 199
  2011: 240
  2012: 390
  2013: 555
  2014: 743
  2015: 1,083

  Again, these numbers do not include fentanyl users explicitly, but we are under the assumption that those who take fentanyl are a subset of those who use heroin, and

therefore, would mostly be included in these numbers. We admit the values may be slightly too low, for the cases of individuals who do go to treatment with the primary substance of abuse being fentanyl, but there is not data available for those numbers currently.

Information for moving from recovery to opioid addiction or heroin/fentanyl addiction, σ_A and σ_H:

We consider here the number of individuals in Tennessee age 12 and older who dropped out of treatment and assume that dropping out would result in an individual going back into addiction since they did not successfully complete treatment. The number of drop-outs from medication-assisted opioid detox programs and outpatient medication-assisted opioid programs was reported as essentially zero for Tennessee in 2012, 2013, and 2015, and 3 or fewer for 2011 and 2014, which does not seem realistic [4, 7, 8, 10, 11]. Therefore, to get an estimate for what this value may look like, we took the total number of admissions into all drug treatment programs for each year and calculated the drop-out rates for each of those years:
2011: 2,910/13,422=.217 [2, 4]
2012: 3,127/13,525=.231 [3, 7]
2013: 3,273/14,476=.226 [5, 8]
2014: 3,164/14,909=.212 [6, 10]
2015: 3,039/14,916=.204 [9, 11]

We take the average of these drop out rates and extrapolate this to be an estimate for those dropping out of opioid-related therapies: .218. (SEEMS WAY TOO LOW).

- We use data on the number of prescription opioid overdose deaths which include natural, semi-synthetic, and synthetic opioids; however, we subtract out the number of fentanyl overdoses (fentanyl is classified as a synthetic prescription opioid), since those overdoses are counted for in their own category. This results in the following **total number of prescription opioid overdose deaths** [14]:
  2013:(637-53=) 584
  2014: (697-69=) 628
  2015: (848-169=) 679
  2016: (1,009-294=) 715

  Although this number does not explicitly state it is for individuals 12 and older, we assume it is since it comes from the Tennessee Department of Health; if it does include individuals under 12, we assume that number is negligible.

  Had note that it was a good thing methadone was pulled out separately from this data; why is that important? Because it's used for treatment?

- We add together the heroin and fentanyl overdoses from the years 2013-2016 for the state of Tennessee. The **total number of heroin and fentanyl overdoses** for these four years are:
  2013: (63+53=) 116

2014: (147+69=) 216
2015: (205+169=) 374
2016: (260+294=) 554 [14].

Although this number does not explicitly state it is for individuals 12 and older, we assume it is since it comes from the Tennessee Department of Health; if it does include individuals under 12, we assume that number is negligible.

- Taking the total number of deaths and subtracting out overdose deaths for respective years results in the **total number of deaths, excluding overdoses** for individuals in Tennessee [16]:
  2013: (63,199-584-116=) 62,499 out of an estimated total population of 6490795
  2014: (64,559-628-216=) 63,715 out of an estimated total population of 6540007
  2015: (66,329-679-374=) 65,276 out of an estimated total population of 6590726
  2016: (67,924-715-554=) 66,655 out of an estimated total population of 6649404

  How adjust that this is entire population and not just 12 and older? Can't find numbers of population under 12.

  Total number of deaths includes those under 12; how adjust?

- **Total population** estimated in Tennessee each year [17]:
  2013: 6,490,795
  2014: 6,540,007
  2015: 6,590,726
  2016: 6,649,404

- **Relationship among θ_1, θ_2, and θ_3:** Since we could not find data for values of θ_1, θ_2, or θ_3 for Tennessee, we consider a national study of individuals 12 and older to establish a relationship among these three rates. For a national study consisting of 609,000 participants, "the recent heroin incidence rate was 19 times higher among those who reported prior non-medical pain reliever (NMPR) use (0.39%) than among those who did not report NMPR use (0.02%) [12]. Thus, we will extrapolate this information to say that the rate that prescription opioid users and opioid addicts move to heroin use is 19 times greater than the rate at which susceptibles move to heroin use (i.e. $\theta_2 + \theta_3 > 19\theta_1$). Although θ_2 is going from P to H and consists of prescription opioid users who do not misuse their prescription, we will make the assumption that those who misuse are much more likely to be the ones to move to heroin use.

References

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