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Research Article

Drug Availability is the Most Important Factor in Controlling Substance Abuse

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Abstract

Modelling has been commonly used in studying substance abuse and recently, an extensive 11 compartment model with 40 different parameters of single substance abuse has been published. However, there is no sensitivity analysis performed to elucidate the relative importance of these parameters. In this study, we perform a one-factor-a-time (OFAT) sensitivity analysis by reducing each parameter to 10% its default value individually and simulated. Our results suggest that substances/drugs availability to be the most important factor, more crucial than the push from drug sellers and policing efforts. Reducing drug availability by 90% reduces the prevalence of drug users (including active users, users in treatment, and ex-users in remission) by 72.7%. Proportional reduction of contact between drug sellers and susceptible populations results in 30.5% reduction in prevalence while proportional reduction in policing efforts results in 10.6% increase in prevalence. This may have an impact on law enforcement and education efforts.

Keywords: Substance Abuse; Modelling; Sensitivity Analysis

Introduction

Substance abuse is an public health issue for most of human history [1]. These substances range from legal substances to non-prescription products [2,3] to prescription medications [4,5] to illegal substances [6]. Hence, the terms "drug" and "substance" are interchangeable. Several recent studies suggest notable prevalence in substance abuse. Mansoor., *et al*. [7] report 68.1% of 8734 adult patients hospitalized in West Virginia, USA, between 2006 and 2016, were tested positive on urine drug screen. Abate., *et al*. [8] conduct a meta-analysis on 29 articles and estimate 32.28% overall prevalence of psychoactive drug abuse in 22012 Ethiopian students aged 18 to 25. Chapagain., *et al*. [9] report that 18.1% of 1125 surveyed East Nepalian higher secondary school students in 2018 were current drug users. Even in a country such as Singapore which is known for its strict drug laws, Subramaniam., *et al*. [10] estimate a 2.3% lifetime prevalence of consuming illegal drugs. A review by Bryson [11] in 2018 suggest a disturbing trend that prevalence of substance abuse in anaesthesiologists is higher than in general population and is increasing since 2000. Hence, drug/substance abuse can be considered an epidemic.

Since Mackintosh and Steward [12] introduce mathematical modelling into the study of substance abuse epidemiology in 1979, multiple models have been formulated to study different aspects [13] under varying assumptions. A systematic review by Wang., *et al*. [13] in 2022 present 24 models using ordinary differential equations (ODE). Yap., *et al*. [14] combine all 24 ODE models presented in Wang., *et al*. [13] using Tang and Ling's model [15] as foundation, which was in turn based on Njagarah and Nyabadza's model [16] – one of the 24 models reviewed by Wang., *et al*. [13]. The resulting model by Yap., *et al*. [14] consist of 11 compartments with 40 parameters. However, the relative importance of these 40 parameters are not examined by Yap., *et al*. [14]. In this study, we examine the relative importance of these 40 parameters using one-factor-a-time (OFAT) sensitivity analysis [17,18] to elucidate the most critical factor in controlling substance use within a population. Our results suggest that the availability of substances/drugs to be the most important factor, more crucial than the push from drug sellers and policing efforts.

Methods

Yap., *et al*. [14] model, which consist of 11 compartments with 40 parameters; were examined using one-factor-a-time (OFAT) sensitivity analysis [17,18], where each of the 40 parameters were reduced to 10% its default value one at a time and simulated. The parameter reduced model and the model with default parameter value were simulated for 10 timesteps at the default 0.00274 timestep, resulting in 3650 time-points. The impact of a parameter were determined using root mean square error (RMSE) [19] from the simulation results by comparing the 11 compartments between the default model and the parameter reduced model across 3650 time-points. The importance of a parameter is directly proportional to the RMSE value.

Results and Discussion

Sensitivity analysis is a method to determine the robustness of an assessment by examining the extent to which results are affected by changes in methods, models, values of unmeasured variables, or assumptions by identifying the results that are most dependent on questionable or unsupported assumptions [18,20]. Hence, sensitivity can rank the relative importance of the 40 parameters in Yap., *et al*. [14] substance abuse model.

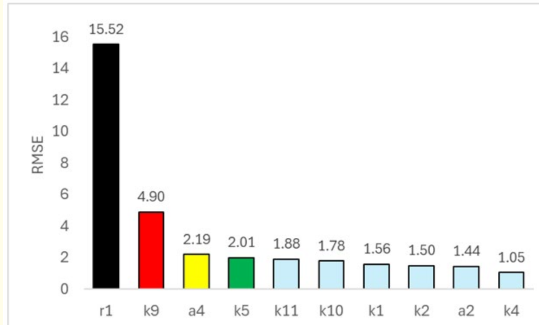

Figure 1: Root-Mean-Square Error (RMSE) of Top 10 Most Sensitive Parameters. Black bar (r1) is per capita mortality rate of population. Red bar (k9) is the availability of drugs in the system. Yellow bar (a4) is the contact rate between drug sellers and susceptible population with health education. Green bar (k5) is the intensity of policing/police search.

Order	Parameter	Description
1	r1	Per capita mortality rate of population.
2	k9	Availability of drugs in the system.
3	a4	Effective contact rate between drug barons (D) and susceptible population with health education (C).
4	k5	Intensity of policing/police search.
5	k11	Rate at which susceptible population with health education (C) become light drug users (L) without the effects of drug barons (D).
6	k10	Rate at which susceptible population without health education (S) accepts health education (C).
7	k1	Rate at which susceptible population without health education (S) become light drug users (L) without the effects of drug barons (D).
8	k2	Rate at which light users (L) escalates to heavy drug use (H).
9	a2	Rate at which light users (L) convert from consumer to seller/promoter (D).
10	k4	Proportion of light drug users (L) exposed to police search.

Table 1: Description of the Top 10 Most Sensitive Parameters.

By reducing each parameter value one at a time to 10% its default value in Yap., *et al*. [14] model, our results show that the per capita mortality rate of population (parameter r1) is the most sensitive (Figure 1, Table 1). However, per capita mortality rate of population is not a usual parameter to vary in substance use epidemic although it relates to the overall health of the population. Hence, we focus on the next most sensitive parameter, which is availability of drugs in the system (parameter k9); suggesting that drug availability can have a high impact to the prevalence of substance abuse. By comparing drug prevalence (Figure 2 and 3) where prevalence is the percentage of heavy and light drug users, drug users in treatment, and drug users in remission, against total population; our results suggest that a 72.7% reduction of drug exposure from the peak drug exposure is 28.11% of the population in default drug availability to about 7.66% of the population when drug availability is reduced to 10% of default. This is consistent with studies showing that substance abuse correlates with availability [21-23]. Availability of abused substances has been an important idea since 1980s [24] but cannot primarily explain substance abuse [25].

More importantly, our results also show that controlling the availability of drug is more important than preventing the contact of drug sellers to susceptible populations, or policing efforts (Figure 2 and 4) even though reducing the contact of drug sellers to susceptible populations may reduce prevalence (Figure 2) from 28.11% in default parameters to 19.55% (30.5% reduction). However, the impact of policing may have an important as our results show that reducing policing efforts increases drug prevalence (Figure 3) from 28.11% in default parameters to 31.08% (10.6% increase) and also increases the proportion of drug users within the population (Figure 4); thereby, underlining the importance of policing in reducing substance abuse [26].

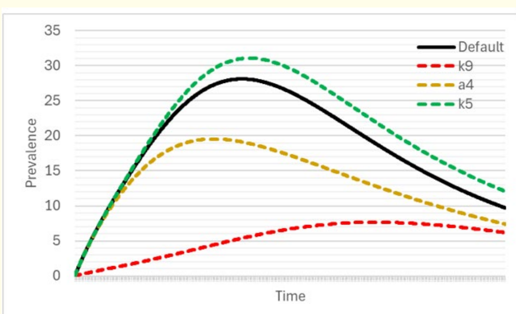

Figure 2: Effects of Reduce Drug Availability to 10% of Default (By Prevalence).

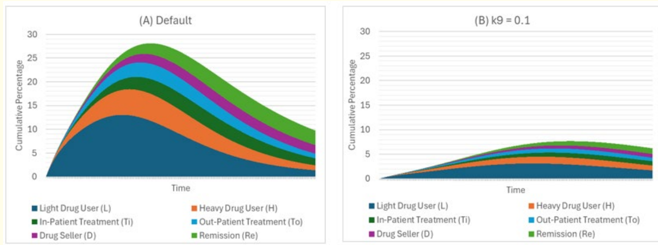

Figure 3: Effects of Reduce Drug Availability to 10% of Default (By Compartments). Panel A shows that peak drug prevalence is 28.11% of the population in default drug availability but when drug availability is reduced to 10% of default (Panel B), the peak drug prevalence is 7.66% the population.

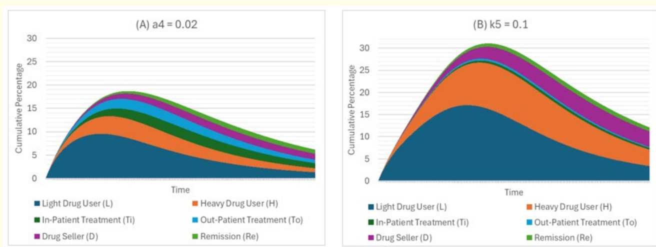

Figure 4: Effects of Contact between Drug Sellers and Susceptible Population, and Policing Efforts. Panel A shows that peak drug prevalence is 19.55% of the population when contact between drug sellers and susceptible population with health education is reduced to 10% of default. Panel B shows that peak drug prevalence is about 31.08% of the population when policing effort is reduced to 10% of default.

Conclusion

Drug availability is the most important factor in the prevalence of substance abuse; followed by encounter of drug sellers with susceptible population, and policing efforts.

Supplementary Materials

Data files for this study can be downloaded from https://bit.ly/SA-SAM.

Conflict of Interest

The authors declare no conflict of interest.

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