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Tobacco epidemics: Effect of marketing bans and awareness programs on its spread

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ABSTRACT

Tobacco, an anathema for the mankind is expected to increase its death toll to 1 billion people in 21st century in the recent report of World Health Organization (WHO). It has been lime lighted in the report that articulated awareness programs, to aware people about the harmful effects of tobacco consumption can decrease in the death toll. Therefore in this paper, a non-linear mathematical model has been proposed and analyzed to study the effects of media and awareness programs on the spread of tobacco epidemics. Four different cases were studied. Policies focusing on tobacco users at a constant rate were found to be most productive in reducing tobacco epidemics. We also determined that not only internal factors but also external factors can play an important role in determining best policy. The model analysis shows that the spread of tobacco epidemics can be controlled by conducting awareness programs by media but tobacco epidemics remains endemic due to immigration and birth. The simulation analysis of the model is also carried out to confirm the analytical results.

1. Introduction

Merriam-Webster defines an epidemic as something that affects a disproportionately large number of people within a population, community, or region at the same time. In present times, tobacco use is growing fastest in low-income countries which are least equipped to deal with the smoking-diseases and resulting deaths. In case, even when these countries are well equipped, morbidity and mortality will still be high because the treatment is not within the reach of the common people. Even in the developed countries, it is one of the major factors contributing in the premature death. According to the WHO report, more than 80 percent of global tobacco-related deaths will be in low and middle-income countries by the year 2030 [1]. The severe health problems caused by tobacco use include cancer in lungs and mouth, heart and respiration problems in children and adults, pregnancy complications in women, etc. [2]. Several product factors such as ventilation holes, additives, host factors like intention of using these tobacco products, environmental factors in the form of environmental laws and activities of tobacco manufacturing companies also influence initiation and cessation of tobacco [2,3]. The need for enforcing these measures is very high as the tobacco-related diseases kill some 6 million people each year [1].

Increased price of tobacco products, effective mass media strategies, effective rules and regulations by the government bodies could become a useful tool in promotion of quitting the tobacco products and to protect nonsmokers [2,3]. Information transmission also has an important effect in controlling tobacco epidemics [4]. We can understand it by simple example that the demand for condoms rises in areas where AIDS is prevalent and condom use has been linked to the awareness of the

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mass [5]. Proper implementation of effective tobacco-control strategies will ensure the consumption of tobacco to a minimum level in a minimum time [6]. On closer inspection, it is not so much the presence of the disease itself that will prompt humans to change their behavior, as awareness of the presence of the disease. This challenges us to study the importance of awareness programs in the spread of tobacco epidemics [7].

A number of modeling efforts have been made recently in the field of epidemic outbreaks (case of infectious diseases) and population response to the information transmission as well as awareness programs [5,8–15]. But, the tobacco epidemic is different from the infectious diseases considering that the spread of infectious diseases depends only on the interaction between infective and susceptible [9,16], while tobacco related diseases also spread through the advertisements made by tobacco companies as a part of their promotion which requires no interaction [17,18]. It has been made clear in the WHO report that banning marketing campaigns of the tobacco companies or putting graphical warning on the tobacco products will control the spread of tobacco epidemics [19]. In a study Saffer and Chaloupka [20] draw some important conclusions indicating that limited bans are not effective in reducing tobacco consumption since it will ultimately result in a substitution of advertising from the banned resources to those that are still allowed and that comprehensive bans are effective in reducing consumption [20]. Regulating advertising and promotion can reduce both the prevalence and initiation of smoking. Based on an analysis of tobacco use before and after the introduction of advertising bans, it is estimated that comprehensive advertising bans reduce smoking initiation. Therefore, complete advertising bans are essential in reducing the health burden of tobacco use [21].

There exists several modeling studies addressing tobacco epidemics [22,25,26], but they all seem to miss all few of the important characteristics of tobacco epidemics. For eg., Garsow et al. presented several basic mathematical models including basic infection model, non-linear relapse model and model emphasizing on rehab programs effectiveness. They conducted stability analysis as well as numerical simulations of the model [22]. On the same note, Bhunu and Mushayabasa [25] developed a mathematical model to study the dynamics of smoking and alcoholism together. They found that targeting moderate smokers to quit smoking is more effective strategy than targeting smoking addicts. Important factors such as recruitment by advertisement campaigns, inclusion of dynamic media awareness programs still need to be included and studied. Few of these studies also study the impact of constant awareness programs targeting smokers only on the tobacco epidemics. It will be very interesting to study what happens if these programs are targeted towards non-smokers, or both smokers and non-smokers simultaneously. Therefore, in this paper, we propose a nonlinear SIRS mathematical model that takes care of the diffusion of health information and bad effects of tobacco smoke through media and awareness programs among an active host population that can respond to it by taking measures or seeking treatment to avoid spreading of the tobacco related diseases. The proposed SIRS model has its similarities and differences with the 3D Lotka–Voterra model [23,24]. 3D Lotka–Voterra models consider predation of prey through first predator only similar to our model where susceptibles are also converted by infectives only. The differences can be visualized in terms of growth of second predator (aware class in our model) and rate of predation of first predator (infectives in our model).

In this model, we assume that the population is susceptible to the risk of becoming tobacco users but only a certain proportion chooses to respond appropriately by trying to limit their probability of becoming one or seeking treatment early. We show that if the dissemination of information through awareness programs is fast enough, the number of tobacco users decrease resulting in the decrease in the mortality rate due to tobacco. We also derive the full characterization of the global behavior of the model.

2. Mathematical model

We consider that the total population is $N(t)$ at time t for a subjected region, with combined birth rate and immigration of non-tobacco users (susceptible population) with a constant rate A. The total population is divided into three classes; the susceptible population $X(t)$, the infective population (*i.e.*, tobacco users/smokers) $Y(t)$ and the aware population $R(t)$. In further consideration, the cumulative density of awareness programs driven by media and other sources in that region at time t is denoted by $M(t)$.

In the modeling process, it is assumed that consumers of tobacco increase due to contacts between non-tobacco users and tobacco users as well as due to the first-hand observation effect on non-tobacco users (advertisement of tobacco products). The cumulative growth rate of the media awareness programs impacting the susceptible and infective population is assumed to be proportional to the total number of non-tobacco and tobacco users. It is further assumed that due to media awareness programs, aware people constitute a separate class named by "aware class" and avoid the contact with the tobacco users. Furthermore in the model, aware population is assumed to relapse and they become susceptible again. All the classes in the model have a natural death rate while tobacco users have an extra-mortality rate in their class due to diseases caused by the consumption of tobacco.

In view of the above factors and by assuming a simple interaction, a SIRS model is proposed as follows:

$$\begin{aligned} dX/dt &= A - \alpha X - \alpha_1 XY - \beta_1 XM + \beta R - dX, \\ dY/dt &= \alpha X + \alpha_1 XY - \beta_2 YM - \alpha_2 Y - dY, \\ dR/dt &= \beta_1 XM + \beta_2 YM - \beta R - dR, \\ dM/dt &= \mu_1 X + \mu_2 Y - \mu_0 M, \end{aligned} \tag{2.1}$$