The Study of Nonlinear Model of The Effect of Awareness Program by Mass Media on Alcoholism in Thailand

Piyada Wongwiwat*

Applied Statistics Department, Faculty of science and Technology, Suan Sunandha Rajabhat University

Received : 19 February 2018
Accepted : 28 March 2018
Published online : 29 March 2018

Abstract

A nonlinear model of alcoholism is developed in this research by using the SS,AM model to study the alcoholism transmission considering the effect of mass media. This nonlinear model was constructed by applying a standard dynamical modeling method. The stability of the model was determined by using Routh-Hurwitz criteria. The results were shown for supporting the new model. Also, the graphical representations were provided to qualitatively support the analytical results. The model implies that the mass media is an effective way to prevent and control the spread of alcoholism in Thailand.

Keywords : nonlinear model, alcoholism, media, basic reproductive number

*Corresponding author. E-mail : piyada.wo@ssru.ac.th
Introduction

Alcohol abuse is the leading cause of death of world population up to 3.3 million people died each year or around 5.9% of total death in the world. From World Health Organization (WHO, 2014), the figure of alcohol consumption in Thailand is the fifth in the world and the trend of this consumption has climbed up rapidly. In year 1989, the alcohol consumption in Thailand was 20.2 liter per person per year while it increased triple to 58.0 liters per person per year in year 2003. Many countries aware of alcohol drinking especially in the university life because the consumption of alcohol can be the Gateway Drugs leading to another drug addiction (Steinberg, 1996).

Mass Media is a significant force in modern life that can be accessed from many sources; for example, Television, Internet, Radio, Billboard and Magazine etc. When people get information easily anywhere at any time, the mass media can play an important role to form people personality and knowledge. Undoubtedly, the mass media is very effective tool to deliver the message to raise awareness of alcoholism and prevent the widespread and fetal effect of alcohol abuse. There were several researches such as Tchuenche et al. (2011), Greenhalgh et al. (2015) and Wongwiwat (2015) investigating of the role of media to infectious diseases and the results of studies showed that the mass media has a significant effect on disease control.

To study the dynamic of infectious diseases, the nonlinear model is very useful tool to apply. The analytical solution, numerical solution and simulation are one of various mathematical methods used to analyze the harmful diseases without researching in the real environment that may infect the researchers, Swarnali and Samanta (2013), Bhunu (2012), Kaur et al. (2014), Zuo and Liu (2014) and Greenhalgh et al. (2015). Several researches mainly studied on the impact of awareness programs on and infectious diseases outbreak.

Thus, the new nonlinear model is applied to analyze the alcoholism transmission in order to understand the effect of mass media on the dynamic of the alcoholism in Thailand.

Methods

As the SSₐAM model, we consider effect of mass media the reduction of transmission level of this disease, then we separated susceptible class to susceptible class have no disease information and susceptible class have disease information. And both classes can be infective class. In this paper, we applied the structure of transfer diagram of model system from Swarnali and Samanta (2013), Kaur (2014) to suitable with the Alcoholism in Thailand. The population assumed that the human population is constant and divided into five compartments as follows: S, Sₐ, A and M represent the number of susceptible class, Alcoholism class, susceptible class acknowledge from content of media and the cumulative density of the mass media in that region at time t respectively. The transmission dynamics of the alcoholism in Thailand are described by the compartment diagram, Figure1.
The transmission dynamics of the alcoholism in Thailand are described by the following systems of nonlinear ordinary differential equations:

\[
\frac{dS}{dt} = \Lambda - (\beta A + \omega S M + d)S + \sigma S_M + (1 - p) \gamma A \tag{1}
\]

\[
\frac{dS_M}{dt} = \omega S M - (\alpha + \beta A) + \sigma + d)S_M + p \gamma A \tag{2}
\]

\[
\frac{dA}{dt} = (S + \alpha S_M) \beta A - (\gamma + d)A \tag{3}
\]

\[
\frac{dM}{dt} = \mu + \mu A - \mu_i M \tag{4}
\]

Since the population of \( N = S + S_M + A \); where \( \Lambda \) is the recruitment rate of human; \( \beta \) is the transmission rate of susceptible, \( d \) is the natural mortality rate, \( \gamma \) is the quitting rate of alcohol drinking \( \sigma \) is the return rate of quitted drinker to consume alcohol again. \( \omega \) is the dissemination rate of awareness among susceptible due to media awareness program, \( \alpha \) is decreasing rate of educated people becomes alcohol drinker, \( \kappa \) is the rate constant corresponding to regular media coverage, \( \mu \) is the rate constant corresponding to regular media coverage, \( \mu_i \) is the natural decay rate constant of media coverage/awareness programs, \( \mu_i \) is the rate constant influenced by number of infects, \( p \) is the probability of media accessibility and \( N \) is total population, respectively.

**Figure 1** The dynamics model of the alcoholism in Thailand
Step 1: Equilibrium Analysis; To begin with the disease free equilibrium, the endemic equilibrium and the basic reproductive number, respectively.

Step 2: Stability Analysis; To check the local stability of an equilibrium points is determine from the Jacobian matrix of the ordinary differential equation evaluated at \( E_0 \) and the endemic equilibrium points \( E_1 \).

Step 3: Numerical Simulation; To demonstrated data to validate the performance of the nonlinear models by using Maple software.

Results and Discussion

1. Equilibrium Analysis

To begin with the disease free equilibrium, the endemic equilibrium and the basic reproductive number, respectively.

1.1) The disease free equilibrium (DEF): The system has two equilibrium points; a disease free equilibrium point and an endemic equilibrium point.

\[
E_0(S, S_m, V, I, M) = E_0\left(\frac{\mu_S A}{\omega + \mu_V(v_i + d)}, \frac{\omega \mu_S A}{\mu_A}, \frac{\nu_2 \omega \mu_A Q_2}{\mu_0}, \frac{\nu_3 \omega \mu_A Q_2}{\mu_0}, \frac{\nu_2 \omega \mu_A Q_2}{\mu_0} \right)
\]

1.2) The endemic equilibrium:

\[
E_1\left(\frac{\mu_S A}{\omega (1 - \delta_m) + \omega + \mu_V(v_i + d)} + \frac{\omega \mu_S A}{(1 - \delta_m) + \omega + \mu_V(v_i + d)}, \frac{Q_1 I^{\nu} + Q_1 I^{\nu} + Q_1 I^{\nu}}{Q_1 I^{\nu} + Q_1 I^{\nu} + Q_1 I^{\nu}}, \frac{\mu + \mu I^{\nu}}{\mu} \right)
\]

1.3) The basic reproductive number:

The basic reproductive number is obtained by the next generation matrix. We start with \( \frac{dX}{dt} = F(x) - V(x) \)

where, \( F \) is the matrix of new infectious and \( V \) is the matrix of the transfers between the compartments in the infective equations. We obtained

\[
F(x) = \begin{bmatrix}
0 \\
0 \\
0 \\
\beta (1 - \delta_m)(S + a_u S_m) + \beta_S V I \\
\beta (1 - \delta_m)(S + a_u S_m) + \beta_S V I
\end{bmatrix}, \\
V(x) = \begin{bmatrix}
\beta (1 - \delta_m)I + \lambda M + v_i + d \end{bmatrix} - \begin{bmatrix}
\beta a_m (1 - \delta_m)I + v_i + d \end{bmatrix} S - A - \begin{bmatrix}
\beta a_m (1 - \delta_m)I + v_i + d \end{bmatrix} S_m - \omega S M \\
(\gamma + \gamma_m + d)I \\
\mu M - \mu - \mu I
\end{bmatrix}.
\]
Hence, basic reproductive number \( R_0 \) is \( R_0 = \sqrt{\frac{\beta (1 - \delta_m) S + \beta (1 - \delta_m) a_M S_m + \beta V}{\gamma + \gamma_m + d}} \).

2. Stability Analysis

The local stability of an equilibrium points is determine from the Jacobian matrix of the ordinary differential equation evaluated at \( E_0 \).

\[
J_0 = \begin{bmatrix}
- (\omega M + v_i + d) & 0 & 0 & -\beta (1 - \delta_m) S & -\omega S_m \\
\omega M & - (v_i + d) & 0 & -\beta a_a (1 - \delta_m) S & -\omega S_m \\
v_i & v_i & - (\gamma + d) & -\beta V & 0 \\
0 & 0 & 0 & \beta (1 - \delta_m) (S + a_m S_m) + \beta V - (\gamma + \gamma_m + d) & 0 \\
0 & 0 & 0 & -\mu_i & -\mu_i \\
\end{bmatrix}
\]

The eigenvalues value of \( J_0 \) are obtained by solving \( \det (J_0 - \lambda I) \). And we obtain the characteristic equation,

\[
(-\gamma + d) - \lambda (-v_i + d) - \lambda (-\omega M + v_i + d) - \lambda (- (1 - \delta_m) (S + a_m S_m) + \beta V - (\gamma + \gamma_m + d) - \lambda) (-\mu_i - \lambda) = 0
\]

where;

\[
\lambda_1 = -(\gamma + d), \quad \lambda_2 = -(v_i + d), \quad \lambda_3 = -(\omega M + v_i + d), \quad \lambda_4 = -(\gamma + \gamma_m + d) + \beta (1 - \delta_m) (S + a_m S_m) + \beta V, \quad \lambda_5 = -\mu_i
\]

Next, we consider the stability of the endemic equilibrium points \( E_i \), we examine the eigenvalue of Jacobian matrix at \( E_i \), which is

\[
J_0 = \begin{bmatrix}
-B_3 & 0 & 0 & -B_6 & -\omega S \\
\omega S & -B_3 & 0 & -B_4 & -\omega S \\
v_i & v_i & -B_4 & -\beta V & 0 \\
B_2 & B_4 & \beta I & -B_4 & 0 \\
0 & 0 & 0 & \mu_i & -\mu_i \\
\end{bmatrix}
\]

The eigenvalues value of \( J_0 \) are obtained by solving \( \det (J_0 - \lambda I) \). And we obtain the characteristic equation,

\[
1^3 + C_1 I^3 + C_1 I^3 + C_1 I^3 + C_1 I + C_1 = 0
\]
By Routh-Hurwitz criteria, equilibrium points are locally asymptotically stable if all conditions are satisfied:

1) \( c_1c_2c_3 > c_1^2 + c_3^2 c_4 \)

2) \( (c_1c_4 - c_3)(c_1c_2c_3 - c_1^2c_4) > c_1(c_1c_4 - c_3)^2 + c_1c_3^2 \).

1.3 Numerical Simulation

In this section, we present several scenarios using demonstrated data to validate the performance of the nonlinear models using the parameters obtained from literatures of Kaur et al. (2014). The parameters that were not available in literatures were estimated. The software used for computation is Maple. First, we consider stability of disease free state using set of parameter values of study the system of nonlinear ordinary differential equations (1-4). We found that, the eigenvalues corresponding to the equilibrium point \( E_0 \) and basic reproductive number are following: \( \lambda_1 = -0.0166 < 0, \lambda_2 = -0.0299 < 0, \lambda_3 = -0.1012 < 0, \lambda_4 = -6.0176 < 0, R_0 = 0.2461 < 1. \)

Since all eigenvalues corresponding to \( E_0 \) be negative, thus \( E_0 \) is locally asymptotically stable and basic reproductive number less than 1. Further, to illustrate the stability of endemic free state, shown that the results: \( \lambda_1 = -0.000046, \lambda_2 = -0.005518, \lambda_3 = -0.001000, \lambda_4 = -0.082327, \lambda_5 = -0.142932, R_0 = 1.3183 > 1. \) The same, all eigenvalues to be negative and basic reproductive number is greater than 1, the equilibrium state will be the endemic state, \( E_1 \). The disease free equilibrium (\( E_0 \)) will be local asymptotically stable, as follows:

![Figure 2](image_url)

Figure 2: Time series of susceptible class, susceptible class acknowledge from content of media, alcoholism class and the cumulative density of the mass media, respectively.

From Figure 2, we found that the values of parameters are in the text and \( R_0 < 1 \). We see that the solutions converge to disease free state. And we found that the values of parameters are in the text and \( R_0 > 1 \). We see that the solutions converge to endemic free state following Figure 3.
Time series of susceptible class, susceptible class acknowledge from context of media, alcoholism class and the cumulative density of the mass media, respectively.

The effects of parameter $\omega$, $\sigma$ and $\alpha_\infty$ respectively.

From Figure 4, the effects of parameter $\omega$, $\sigma$ and $\alpha_\infty$ present that the more providing information to the high risk drinker is the less number of alcoholism reduces. While, when the awareness of threat of alcohol decreases, the number of alcoholism will increase a lot.

Table 1 The Basic reproduction number under effects of parameter $\omega$, $\sigma$ and $\alpha_\infty$ respectively.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$A$</th>
<th>$R_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>142</td>
<td>4.123</td>
</tr>
<tr>
<td>0.3</td>
<td>47</td>
<td>3.729</td>
</tr>
<tr>
<td>0.5</td>
<td>27</td>
<td>3.430</td>
</tr>
<tr>
<td>0.9</td>
<td>15</td>
<td>3.000</td>
</tr>
<tr>
<td>$\sigma$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>594</td>
<td>4.312</td>
</tr>
<tr>
<td>0.3</td>
<td>1457</td>
<td>4.350</td>
</tr>
<tr>
<td>0.5</td>
<td>2167</td>
<td>4.359</td>
</tr>
<tr>
<td>0.9</td>
<td>3267</td>
<td>4.365</td>
</tr>
<tr>
<td>$\alpha_\infty$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>2314</td>
<td>4.527</td>
</tr>
<tr>
<td>0.3</td>
<td>2662</td>
<td>4.921</td>
</tr>
<tr>
<td>0.5</td>
<td>2988</td>
<td>5.286</td>
</tr>
<tr>
<td>0.9</td>
<td>3579</td>
<td>5.949</td>
</tr>
</tbody>
</table>
The analytical result from this research told that if the rate of knowledge transferred to the alcohol risk takers by the awareness program increases, the index of alcoholism transmission and the number of alcohol addicts will reduce. Also, if we reduce the rate of return to addicts in the group of used-to-be addicted group, the index of alcoholism transmission and the number of alcohol addicts will decrease. On the other hand, if the rate of awareness program to alcohol risk takers is reduced, the index of alcoholism transmission and the number of alcohol addicts will be increased.

In conclusion, those parameters, the rate of knowledge transferred to the alcohol risk takers by the awareness program \( \omega \), the rate of return to addicts in the group of used-to-be addicted group \( \sigma \), the rate of awareness program to alcohol risk takers \( \alpha_m \) directly affect the dynamic of alcoholism. When the alcohol risk takers get a lot of information from the media \( R_0 < 1 \), there is no alcoholism transmission and vice versa.

Conclusions

The spread of Alcoholism by considering effect of mass media to the reduction of transmission level of this disease is analyzed. The study started from analytical solution, numerical solution and then simulation of the nonlinear model. The result are summarized in Figure 2 to Figure 4 and Table 1 by presenting the important values and the model system shown that the disease free equilibrium is stable until, the basic reproduction number, \( R_0 < 1 \). The disease free equilibrium becomes unstable for \( R_0 > 1 \), which leads to the existence of an endemic equilibrium.

\[
\frac{dS}{dt} = \Lambda - [\beta A + \omega M + d]S + \gamma S + (1 - \mu)\gamma A \tag{1}
\]

\[
\frac{dS_m}{dt} = \omega S M - \alpha S \beta A + \sigma + d)S_m + \mu \gamma A \tag{2}
\]

\[
\frac{dA}{dt} = (S + \alpha S_m) \beta A - (\gamma + d)A \tag{3}
\]

\[
\frac{dM}{dt} = \mu + \mu_A - \mu_M \tag{4}
\]

Therefore, the model clearly shows that the mass media significantly causes the reduction in transmission and infection of alcoholism in Thailand.
Acknowledgements

The first author is also thank you to my colleagues in Suan Sunandha Rajabhat University for grant and Dr. Plawut Wongwiwat for their help and support.

References


