The Influence of Education Campaign on Control Spread of Hepatitis B Virus Disease: A Case Study in Phuket Province, Thailand

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Abstract

This research aims to study and analyze the stability of mathematical models for controlling the spread of hepatitis B virus disease in the Education Campaign in Phuket Province, Thailand. We analyze the model using standard methods, focusing on the equilibrium point, the stability of these points, and analytical solutions. The rate of Education Campaigns for the spread of the hepatitis B virus in mathematical modelling and numerical solutions is studied. The results of the mathematical model analysis revealed that the rate of Education Campaigns for the spread of hepatitis B virus is a factor that affects the basic reproductive number on mathematical modelling, and the rate of Education Campaigns with higher values results in a lower basic reproductive number. Therefore, the rate of Education Campaigns is the factor affecting mathematical modelling, if the population has an Education Campaign and follows the hypothesis, then the spread of the hepatitis B virus decreases until there is no epidemic.

Keywords: Hepatitis B Virus, Mathematical Models, Education Campaign

Introduction

It is possible to learn about the epidemic and the model's output by studying mathematical models of epidemics. Assist researchers in comprehending the variables that can regulate the disease's spread. include being accurately aware of how the illness is spread. The study also highlights the advantages of a mathematical model that can modify an epidemic's features. By examining the model's data, this model can effectively comprehend how an epidemic develops and how to comprehend disease management strategies, as a result, the findings of this study have a significant positive impact on infection risk reduction. Controlling epidemics and the spread of infections. Hepatitis B virus (HBV) should receive particular attention because it can infect humans. Hepatitis viruses A, B, C, D, and E are among the different types of hepatitis viruses. They are more likely to develop severe cirrhosis, chronic hepatitis, and liver cancer in the end. One of the primary causes of hepatitis is hepatitis B, which increases your risk of liver cancer and cirrhosis. According to the World Health Organization, in 2015, more than 240 million people worldwide suffered from chronic hepatitis B, and every year more than 600,000 people with HBV die from complications caused by HBV. Chronic hepatitis B, including cirrhosis and liver cancer. In Phuket, the vast majority of liver cancer patients, approximately 90%, have a history of hepatitis.

Most infected individuals won't know they have an infection because they don't exhibit any symptoms. Because the disease progresses so slowly, some people may have fever or pains. Deceptive upper body Maybe I just have the flu. There are two forms of hepatitis B: acute and chronic. Immunisations are initiated at a young age in the Phuket region; nonetheless, certain populations within the province are disease carriers and have the ability to spread the illness. Even

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if the afflicted individual shows no symptoms, the illness will nonetheless continue to worsen. The infection may spread because of patients' poor self-care, early lack of appropriate medical care, ignorance of disease prevention, and other factors.

By simulating people at risk of infection, pathogens, and vectors, the study of mathematical models demonstrates the function and advantages of mathematical models in resolving the ongoing problem of numerous diseases. Treat and prevent disease in accordance with actual needs as quickly and appropriately as possible; Bring disease and infection by turning the data into a mathematical equation to describe the nature of the outbreak and disease progression without requiring researchers to go directly to human studies, which may endanger the lives of researchers and patients. As a result of the above, the researcher realized and saw the benefits and researched a mathematical model for controlling the spread of the hepatitis B virus on the Education Campaign. The researcher studied the Education Campaign to control the spread of the hepatitis B virus in Phuket, it is an important factor in studying mathematical models to create a mathematical model for hepatitis B prevention and control with higher efficiency.

The benefit of this research is to draw up a mathematical model for the effects of the hepatitis B epidemic. In addition, to be applied to control the outbreak of the disease in Phuket and other provinces, as well as to use mathematical knowledge to explain the epidemic to be easier to understand and the results of the research can be used as preliminary information on disease prevention to reduce the number of patients. Furthermore, they can be used as academic information to the surveillance units of the Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health and bring the research results that have been presented to the public health authorities to take measures to control and prevent hepatitis B by campaigning to educate people in Phuket and the general public at risk of infection.

Model Formulation

In our model, we assume that the human population one constant because the birth rates the death rate of human population are equal. The total number of human populations denote by the human N population are divided into four classes; the susceptible human (S), the exposed human (E), the infected human (I) and the recovered human (R). The diagram of four classes of human population and the crucial parameters are used which represented the dynamics model of Hepatitis B Virus Disease. The transitions between model classes can be now expressed by the following system of first-order differential equations:

$$\frac{dS}{dt} = \Omega N - (1-\Delta)\psi SI - \mu S \qquad (1)$$

$$\frac{dE}{dt} = (1-\Delta)\psi SI - \nu E - \mu E \qquad (2)$$

$$\frac{dI}{dt} = \nu E - \phi I - \beta I - \mu I \qquad (3)$$

$$\frac{dR}{dt} = \phi I - \mu R \qquad (4)$$

With $N = S + E + I + R$

From equation (1) - (4), the researcher conducted a mathematical model analysis by reducing the equation form variable S,E,I,R to $\bar{S}=S/N$, $\bar{E}=E/N$, $\bar{I}=I/N$ and $\bar{R}=R/N$ to facilitate analysis as follows:

$$\frac{d\bar{S}}{dt}=\Omega-[(1-\Delta)\psi N\bar{S}\bar{I}+\mu\bar{S}] \qquad (5)$$

$$\frac{d\bar{E}}{dt}=(1-\Delta)\psi N\bar{S}\bar{I}-\bar{E}(\nu+\mu) \qquad (6)$$

$$\frac{d\bar{I}}{dt}=\nu\bar{E}-\bar{I}(\phi+\beta+\mu) \qquad (7)$$

$$\bar{R}=1-(\bar{S}+\bar{E}+\bar{I}) \qquad (8)$$

Where;

$S(t)$: Susceptible human populations at time t

$E(t)$: Exposed human populations at time t

$I(t)$: Infected human populations at time t

$R(t)$: Recovered human populations at time t

N : Total number of human populations

Ω : Birth rate of human populations

μ : Natural death rate of human populations

ψ : Probability that virus transmitted from infected human to susceptible human

ν : Proportional rate for people exposed to the infected human

ϕ : Recovery rate of infected human

β : Mortality rate from the disease

Δ : Rate of Education Campaign

Model Analysis

Since the model monitors human population, all the associated parameters and state variables are non-negative is $t\geq 0$. It is easy to show that the state variables of the model remain non-negative for all non-negative initial conditions (Anderson, R.M., and May, R.M., 1991). The biological feasible region

$$\Gamma=\left\{(S,E,I,R)\in R_{+}^{4}:N\rightarrow(\Omega-\mu-\frac{\beta I}{N})\right\}$$

Lemma 1. The closed Γ is positively invariant and attracting.

Proof. Adding (1)-(4) give the rate of change of the total population.

$$\frac{dN}{dt}=\Omega N-(1-\Delta)\psi SI-\mu S+(1-\Delta)\psi SI-\nu E-\mu E+\nu E-fI-\beta I-\mu I+fI-\mu R$$

$$\frac{dN}{dt} = \Omega N - \mu S - \mu E - \beta I - \mu I - \mu R$$
$$\frac{dN}{dt} = (\Omega - \mu)N - \beta I$$
$$\int \frac{1}{(\Omega - \mu)N} dN \leq \int dt - \int \frac{\beta I}{(\Omega - \mu)N} dt$$
$$\frac{1}{(\Omega - \mu)} \ln N \leq t - \frac{\beta I}{(\Omega - \mu)N} t + c$$
$$N \leq e^{[(\Omega - \mu) - \frac{\beta I}{N}]t + c}$$
$$N(t) \leq N_0 e^{[(\Omega - \mu) - \frac{\beta I}{N}]t}$$

Thus, the total human population (N) are bounded by $(\Omega - \mu - \frac{\beta I}{N})$, so that $\frac{dN}{dt} = 0$ whenever $\Omega = \mu$. It can be shown that $N(t) \leq N_0 e^{[(\Omega - \mu) - \frac{\beta I}{N}]t}$, if $N_0 e^{[(\Omega - \mu) - \frac{\beta I}{N}]t} > 0$ hence, the region Γ is positively invariant and attracts all solution in R_+^4

1) Basic Reproductive Number

The basic reproductive number (R_0) is defined as the expected number of secondary cases produced by a single infection in a completely susceptible population, by using the next generation method and used spectral radius (Van den Driessche and Watmough, 2002). We have rewritten the system in matrix form $\frac{dx}{dt} = F(x) - V(x)$

Here F(x) gives the rate of appended of new infections in a compartment and V(x) gives the transfer of individuals. We obtained,

$$x = \begin{bmatrix} S \\ E \\ I \\ R \end{bmatrix}, \ F(x) = \begin{bmatrix} 0 \\ (1-\Delta)\psi SI \\ 0 \\ 0 \end{bmatrix}, \text{ and } V(x) = \begin{bmatrix} -\Omega N + (1-\Delta)\psi SI + \mu S \\ \nu E + \mu E \\ -\nu E + \phi I + \beta I + \mu I \\ -\phi I + \mu R \end{bmatrix}$$

Where:

$$F(x)=\begin{bmatrix} \frac{\partial[0]}{\partial S} & \frac{\partial[0]}{\partial E} & \frac{\partial[0]}{\partial I} & \frac{\partial[0]}{\partial R} \\ \frac{\partial[(1-\Delta)\psi SI]}{\partial S} & \frac{\partial[(1-\Delta)\psi SI]}{\partial E} & \frac{\partial[(1-\Delta)\psi SI]}{\partial I} & \frac{\partial[(1-\Delta)\psi SI]}{\partial R} \\ \frac{\partial[0]}{\partial S} & \frac{\partial[0]}{\partial E} & \frac{\partial[0]}{\partial I} & \frac{\partial[0]}{\partial R} \\ \frac{\partial[0]}{\partial S} & \frac{\partial[0]}{\partial E} & \frac{\partial[0]}{\partial I} & \frac{\partial[0]}{\partial R} \end{bmatrix}$$

$$F(x)=\begin{bmatrix} 0 & 0 & 0 & 0 \\ (1-\Delta)\psi I & 0 & (1-\Delta)\psi S & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

and

$$V(x)=\begin{bmatrix} \frac{\partial[-\Omega N+(1-\Delta)\psi SI+\mu S]}{\partial S} & \frac{\partial[-\Omega N+(1-\Delta)\psi SI+\mu S]}{\partial E} & \frac{\partial[-\Omega N+(1-\Delta)\psi SI+\mu S]}{\partial I} & \frac{\partial[-\Omega N+(1-\Delta)\psi SI+\mu S]}{\partial R} \\ \frac{\partial[\nu E+\mu E]}{\partial S} & \frac{\partial[\nu E+\mu E]}{\partial E} & \frac{\partial[\nu E+\mu E]}{\partial I} & \frac{\partial[\nu E+\mu E]}{\partial R} \\ \frac{\partial[-\nu E+\phi I+\beta I+\mu I]}{\partial S} & \frac{\partial[-\nu E+\phi I+\beta I+\mu I]}{\partial E} & \frac{\partial[-\nu E+\phi I+\beta I+\mu I]}{\partial I} & \frac{\partial[-\nu E+\phi I+\beta I+\mu I]}{\partial R} \\ \frac{\partial[-\phi I+\mu R]}{\partial S} & \frac{\partial[-\phi I+\mu R]}{\partial E} & \frac{\partial[-\phi I+\mu R]}{\partial I} & \frac{\partial[-\phi I+\mu R]}{\partial R} \end{bmatrix}$$

$$V(x)=\begin{bmatrix} (1-\Delta)\psi I+\mu & 0 & (1-\Delta)\psi S & 0 \\ 0 & \nu+\mu & 0 & 0 \\ 0 & -\nu & \phi+\beta+\mu & 0 \\ 0 & 0 & -\phi & \mu \end{bmatrix}$$

and

$$V^{-1}(E_0)=\begin{bmatrix} \frac{1}{\mu} & \frac{-\nu(1-\Delta)\psi N}{\mu(\nu+\mu)(\phi+\beta+\mu)} & \frac{-(\nu+\mu)(1-\Delta)\psi N}{\mu(\nu+\mu)(\phi+\beta+\mu)} & 0 \\ 0 & \frac{1}{\nu+\mu} & 0 & 0 \\ 0 & \frac{\nu}{(\nu+\mu)(\phi+\beta+\mu)} & \frac{1}{\phi+\beta+\mu} & 0 \\ 0 & \frac{\nu\phi}{\mu(\nu+\mu)(\phi+\beta+\mu)} & \frac{\phi}{\mu(\phi+\beta+\mu)} & -\frac{1}{\mu} \end{bmatrix}$$

There fore:

$$FV^{-1}(E_0)=\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & (1-\Delta)\psi N & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} \frac{1}{\mu} & \frac{-\nu(1-\Delta)\psi N}{\mu(\nu+\mu)(\phi+\beta+\mu)} & \frac{-(\nu+\mu)(1-\Delta)\psi N}{\mu(\nu+\mu)(\phi+\beta+\mu)} & 0 \\ 0 & \frac{1}{\nu+\mu} & 0 & 0 \\ 0 & \frac{\nu}{(\nu+\mu)(\phi+\beta+\mu)} & \frac{1}{\phi+\beta+\mu} & 0 \\ 0 & \frac{\nu\phi}{\mu(\nu+\mu)(\phi+\beta+\mu)} & \frac{\phi}{\mu(\phi+\beta+\mu)} & -\frac{1}{\mu} \end{bmatrix}$$

$$FV^{-1}(E_0)=\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & \frac{(1-\Delta)\psi\nu N}{(\nu+\mu)(\phi+\beta+\mu)} & \frac{(1-\Delta)\psi N}{\phi+\beta+\mu} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

and Spectral Radius from $FV^{-1}(E_0)$, that is

$$\rho\left(FV^{-1}(E_0)\right)=\max\left\{0,\ 0,\ 0,\ \frac{(1-\Delta)\psi\nu N}{(\nu+\mu)(\phi+\beta+\mu)}\right\}$$

We have the basic reproductive number as shown, $R_0=\dfrac{(1-\Delta)\psi\nu N}{(\nu+\mu)(\phi+\beta+\mu)}$

2) Stability Analysis

In this section, the stability of equilibrium can be analyzed by using the Jacobian matrix of the model at the disease free equilibrium. Referring to the results of Vanden Driessche and Watmough (2002), the stability of this system as shown in the follow theorem.

Theorem 1: The disease free equilibrium of the system about the equilibrium E_0, is local asymptotically stable if R_0 >1 and unstable if R_0 <1.

Proof. The Jacobian matrix of the model (Eqs.1-4) evaluated a $E_0(S,E,I,R)=E_0(N,0,0,0)$ is obtained the local stability of equilibrium point is determined from the Jacobian matrix of the system of ordinary differential equation. The equation (1)-(4) evaluated at the equilibrium point. The Jacobian matrix is

$$J_0=\begin{bmatrix} -\mu & 0 & -(1-\Delta)\psi N \\ 0 & -(\nu+\mu) & (1-\Delta)\psi N \\ 0 & \nu & -(\phi+\beta+\mu) \end{bmatrix}$$

$$\det(J_0-\lambda I)=\begin{vmatrix} -\mu-\lambda & 0 & -(1-\Delta)\psi N \\ 0 & -(\nu+\mu)-\lambda & (1-\Delta)\psi N \\ 0 & \nu & -(\phi+\beta+\mu)-\lambda \end{vmatrix}$$

$$\det(J_0-\lambda I)=(-\mu-\lambda)\begin{bmatrix} \lambda^2+\lambda(\phi+\beta+\nu+2\mu) \\ +(\nu+\mu)(\phi+\beta+\mu) \\ -(1-\Delta)\nu\psi N \end{bmatrix}$$

The eigenvalues of the Jacobian matrix J_0 are obtained by solving $\det(J_0-\lambda I)=0$, then the characteristic equation as follows:

$$0=(-\mu-\lambda)\left[\lambda^2+\lambda(\phi+\beta+\nu+2\mu)+(\nu+\mu)(\phi+\beta+\mu)-(1-\Delta)\nu\psi N\right]$$

where; $\lambda_1=-\mu$ and $\lambda_{2,3}=\dfrac{-A\pm\sqrt{A^2-4B}}{2}$, The two roots of $\lambda^2+A\lambda+B=0$ will be negative real part if they satisfy the Routh-Hurwitz criteria , $A=\phi+\beta+\nu+2\mu$ and $B=(\nu+\mu)(\phi+\beta+\mu)-(1-\Delta)\nu\psi N$, $A>\sqrt{A^2-4B}$ and $A>0,\ B>0$

Theorem 2: The endemic equilibrium of the system Eqs. (5)-(7) for the equilibrium

$$E_1(\bar{S}^*,\bar{E}^*,\bar{I}^*)=\left(\frac{\Omega}{(1-\Delta)\psi N\bar{I}^*+\mu},\frac{\Omega}{(\nu+\mu)}-\frac{\mu(\phi+\beta+\mu)}{(\nu+\mu)(1-\Delta)\psi N\nu},\frac{\nu\Omega}{(\nu+\mu)(\phi+\beta+\mu)}-\frac{\mu}{(\nu+\mu)(1-\Delta)\psi N}\right)$$

is local asymptotically stable if R_0 >1, and unstable if R_0 <1.

Proof.

$$J_1=\begin{bmatrix} -(1-\Delta)\psi N\bar{I}^*-\mu & 0 & -(1-\Delta)\psi N\bar{S}^* \\ -(1-\Delta)\psi N\bar{I}^* & -(\nu+\mu) & (1-\Delta)\psi N\bar{S}^* \\ 0 & \nu & -(\phi+\beta+\mu) \end{bmatrix}$$

$$\det(J_1-\lambda I)=0=\begin{vmatrix} -(1-\Delta)\psi N\bar{I}^*-\mu-\lambda & 0 & -(1-\Delta)\psi N\bar{S}^* \\ -(1-\Delta)\psi N\bar{I}^* & -(\nu+\mu)-\lambda & (1-\Delta)\psi N\bar{S}^* \\ 0 & \nu & -(\phi+\beta+\mu)-\lambda \end{vmatrix}$$

The eigenvalues of the Jacobian matrix J_1 are obtained by solving $\det(J_1-\lambda I)=0$, we provided the characteristic equation as follows:

$$0=\lambda^3+\lambda^2((1-\Delta)\psi N\bar{I}^*+\nu+\phi+\beta+3\mu)$$
$$+\lambda\left[((1-\Delta)\psi N\bar{I}^*+\nu+2\mu)(\phi+\beta+\mu)+((1-\Delta)\psi N\bar{I}^*+\mu)(\nu+\mu)-((1-\Delta)\psi N\nu\bar{S}^*\right]$$
$$+((1-\Delta)\psi N\bar{I}^*+\mu)(\nu+\mu)(\phi+\beta+\mu)-(1-\Delta)\psi\nu N\bar{S}^*\mu$$

The three roots of $\lambda^3+A\lambda^2+B\lambda+C=0$ will be negative real part if they satisfy the Routh-Hurwitz criteria.

1) $A=(1-\Delta)\psi N\bar{I}^*+\nu+\phi+\beta+3\mu$
2) $B=((1-\Delta)\psi N\bar{I}^*+\nu+2\mu)(\phi+\beta+\mu)+((1-\Delta)\psi N\bar{I}^*+\mu)(\nu+\mu)-((1-\Delta)\psi N\nu\bar{S}^*$
3) $C=((1-\Delta)\psi N\bar{I}^*+\mu)(\nu+\mu)(\phi+\beta+\mu)-(1-\Delta)\psi\nu N\bar{S}^*\mu$
4) $AB>C$

Remark 1. The case $R_0 = 1$ is a critical threshold point where the disease free equilibrium E_0 loses its asymptotic stability and simply becomes (neutrally) stable. Moreover, it becomes unstable immediately $R_0 > 1$ and this will lead to the existence of a stable endemic equilibrium E_1. Note that $R_0 = 1$ can literarily be viewed as a transcritical bifurcation point where stability is exchanged between E_0 and E_1.

Numerical Analysis

In this section, we would like to present the numerical simulation of our model. Numerical analysis is the consideration of finding the appropriate parameter values that make the Disease-Free Equilibrium Point (DEP) and Endemic Equilibrium Point (EEP) that make the system of nonlinear differential equations Local Asymptotically Stable to find the numerical solution by simulating as follows.

$$S_{(m+1)}=\frac{h\Omega N+S_{(m)}}{(1+h(1-\Delta)\psi I_{(m)}+h\mu)} \tag{9}$$

$$E_{(m+1)}=\frac{h(1-\Delta)\psi S_{(m+1)}I_{(m)}+E_{(m)}}{(1+h\nu+h\mu)} \tag{10}$$

$$I_{(m+1)}=\frac{h\nu E_{(m+1)}+I_{(m)}}{(1+h(\phi+\beta+\mu))} \tag{11}$$

$$R_{(m+1)}=\frac{h\phi I_{(m+1)}+R_{(m)}}{(1+h\mu)} \tag{12}$$

Numerical analysis using the parameter values obtained from the survey of the hepatitis B epidemic to substitute values in equations (9)-(12), which have the parameter values that we used in the numerical simulation are given in Table 1.

Table 1: Parameters values used in numerical simulation at disease free state.

Description	Parameters	Values
The total number of human populations	N	1,000 pesons
The proportional rate for people exposed to the infected human populations	ν	0.329 day^{-1}
The birth rate of human populations	Ω	0.0000526 day^{-1}
The probability that virus transmitted from infected human to susceptible human	ψ	0.009 day^{-1}
The recovery rate of infected human populations	ϕ	0.247 day^{-1}
The mortality rate from the disease	β	0.00000000274 day^{-1}
The natural death rate of human populations	μ	0.0000118 day^{-1}
The rate of Education Campaign	Δ	0 - 1

By solving the system of differential equations. The numerical results showed the relationship between the parameters of Education Campaign rate and basic reproductive Number in Table 2.

Table 2: The relationship between the parameters of effectiveness of Education Campaign and Basic Reproductive Number

Δ	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
R_0	32.844	29.194	25.545	21.896	18.246	14.597	10.948	7.299	3.649

The analysis model found that the stability of equilibrium points and the Education Campaign rate affect the mathematical model. It concluded that when the value of the Education Campaign rate decreases, The basic reproductive number increases. On the other hand, when the value of the Education Campaign increases, The basic reproductive number decreases.

1) Stability of Endemic Equilibrium Point

The study found that the rate of hepatitis B epidemic Education Campaign was one factor influencing the change in the hepatitis B epidemic control mathematical model. We changed the values of Education Campaign Δ = 0.5 - 0.9. Also, kept the values of the other values of parameters to be those given in Table 1, we have the eigenvalues and basic reproductive numbers are: $\lambda^3 + A\lambda^2 + B\lambda + C = 0$, λ_1=-0.0000181, λ_2= -0.2217 และ λ_3=-

0.9292. Since all of eigenvalues have been negative, the endemic equilibrium point will be local asymptotically stable (Fred Brauer, Pauline den Driessche and Jianhong Wu, 2008) as shown in Fig. 1-5.

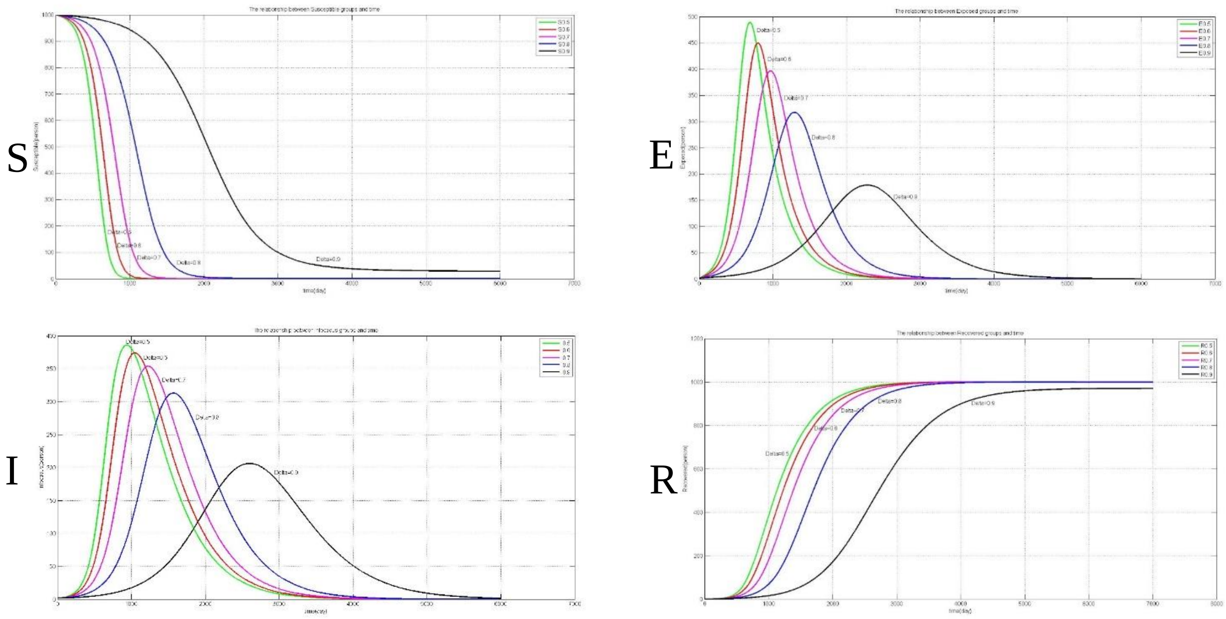

Figure 1: Time series (S) Susceptible human, (E) Exposed human, (I) Infected human, (R) Recovered human. The solutions approach the endemic equilibrium state to the disease-free state, Education Campaign 0.5 - 0.9

From Figure 1, the study found that the rate of Education Campaigns is one of the factors affecting the change of the mathematical model of hepatitis B epidemic control. When the rate of hepatitis B Education Campaigns increases in the mathematical model, the results are as follows:

1) The rate of change of the Susceptible human group (S) will gradually decrease and change slowly.

2) The rate of change of the Exposed human group (E) will decrease significantly.

3) The rate of change of the Infected human group (I) will decrease significantly. It was found that the peak of the Infected human group (I) changed significantly.

4) The number of the infected population changed to a group that recovered from the disease faster. Because the number of infected people decreased, it resulted in a decrease in the epidemic.

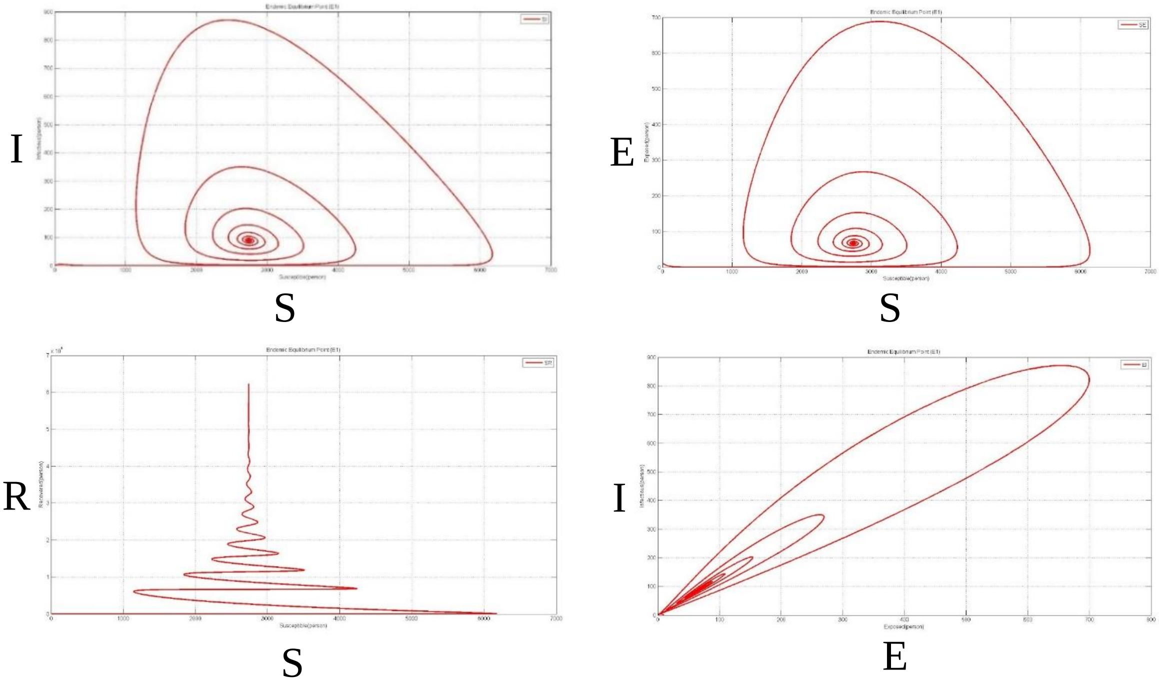

Figure 2: The relationship between (S) Susceptible human and (I) Infected human, The relationship between (E) Exposed human and (S) Susceptible human, The relationship between (R) Recovered human and (S) Susceptible human, The relationship between (I) Infected human and (E) Exposed human. The solutions approach the endemic equilibrium state to the disease-free state.

From Figure 2, the researchers found numerical answers to show the relationship between the Susceptible human group (S) and the Infected human group (I), the relationship between the Susceptible human group (S) and the Exposed human group (E), the relationship between the Susceptible human (S) and the Recovered human group (R), and the relationship between the Exposed human group (E) and the Infected human group (I). It was found that if there are people infected with hepatitis B in Phuket Province and when the Education Campaign rate on the spread of hepatitis B is added to the mathematical model, It found the relationship between the populations of the two groups in each pair mentioned will tend to converge to the equilibrium point. Therefore, the population in each pair mentioned will reach the Endemic Equilibrium Point.

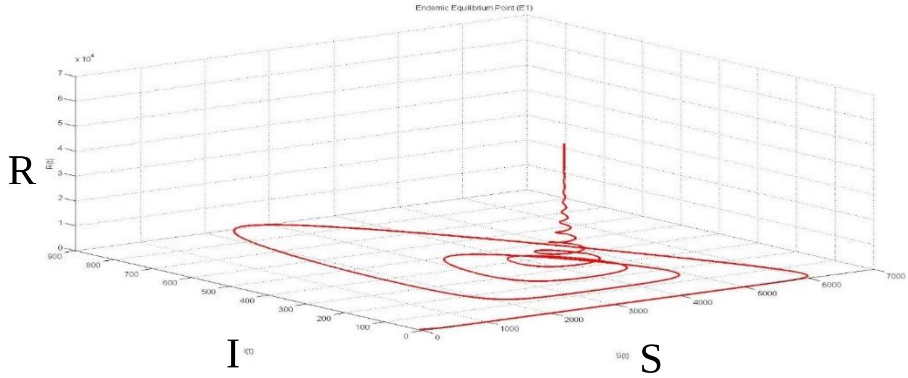

Figure 3: The relationship between (S) Susceptible human, (I) Infected human and (R) Recovered human. The solutions approach the endemic equilibrium state to the disease-free state.

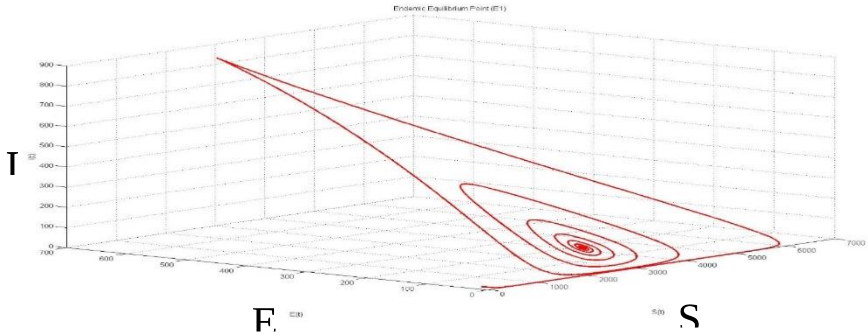

Figure 4: The relationship between (S) Susceptible human, (I) Infected human and (E) Exposed human. The solutions approach the endemic equilibrium state to the disease-free state.

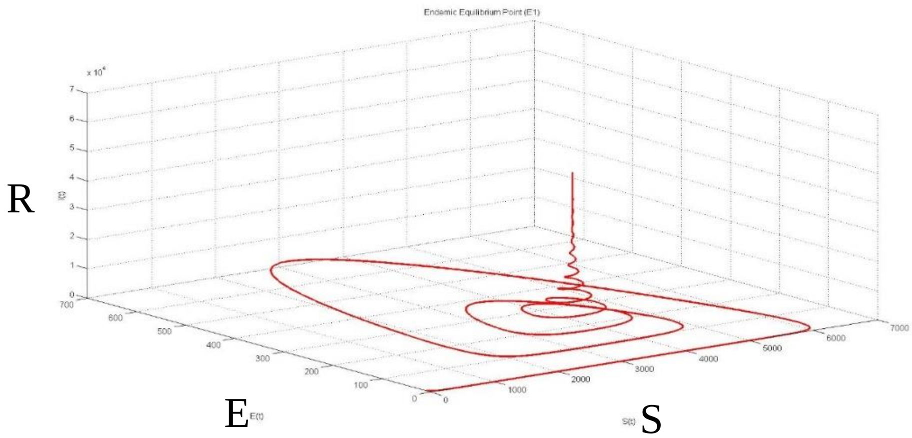

Figure 5: The relationship between (S) Susceptible human, (R) Recovered human and (E) Exposed human. The solutions approach the endemic equilibrium state to the disease-free state.

From Figure 3-5, the numerical answer shows the relationship of the 4 groups in a three-dimensional graphical comparison at the equilibrium point with disease. It was found that if in Phuket province there are people infected with Hepatitis B virus and the rate of campaigning for knowledge of the spread of Hepatitis B virus by 99% is added to the mathematical model, over time the three population groups will tend to converge to the equilibrium point and the disease will spread. Therefore, the 4 groups enter the Endemic Equilibrium Point.

2) Analysis of Education Campaign Rates

The study found that the rate of hepatitis B epidemic Education Campaign was one factor influencing the change in the hepatitis B epidemic control mathematical model as follows:

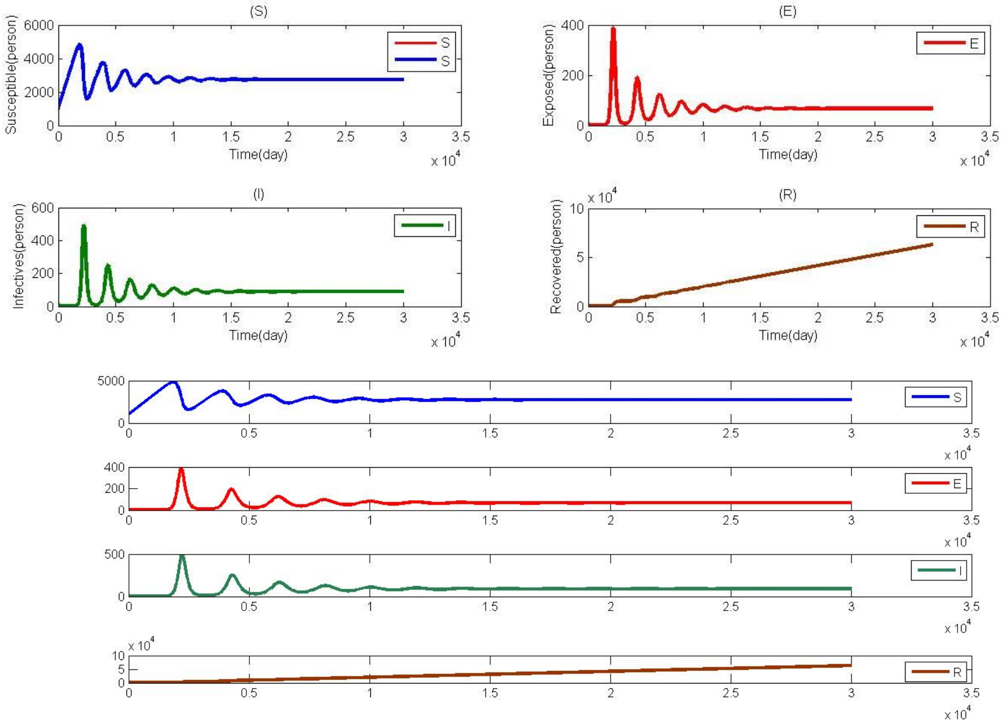

Figure 6: Time series (S) Susceptible human, (E) Exposed human, (I) Infected human, (R) Recovered human. The solutions approach the endemic equilibrium state to the disease-free state, Education Campaign 99 %.

From Figure 6, the numerical solution shows the relationship between the Susceptible human group (S), the Exposed human group (E), the Infected human group (I), and the Recovered human group (R). All of them are graphs of the stability of the equilibrium point with the disease. It was found that if in Phuket province there are people infected with the hepatitis B virus and the education campaigns of the spread of hepatitis B virus by 99% in the mathematical model, the population of all four groups will tend to converge to the equilibrium point and the spread of the disease will occur. Therefore, the susceptible human group (S) compared to the exposed human group (E), the infected human group (I), and the recovered human group (R) enter the endemic equilibrium point.

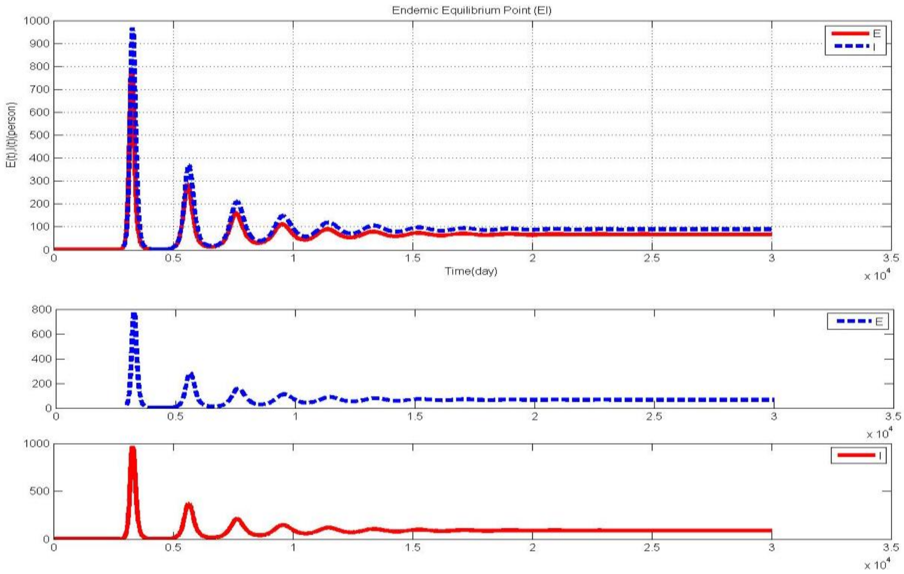

Figure 7: Time series the Exposed human group (E) compared to the Infected human group (I) at the stable equilibrium point with disease.

From Figure 7, the numerical answer shows the relationship between the number of Exposed human groups (E) and the Infected human groups (I). It is a graph of the stability of the equilibrium point with disease. It was found that if in Phuket province there are people infected with hepatitis B virus and increase the Education Campaigns about the spread of hepatitis B virus by 99% in the mathematical model, when time passes, the population of the Exposed human group (E) and the Infected human group (I) will tend to converge to the equilibrium point and the spread of the disease will occur. Therefore, the numbers of the Exposed human group (E) and the Infected human group (I) enter the endemic equilibrium point.

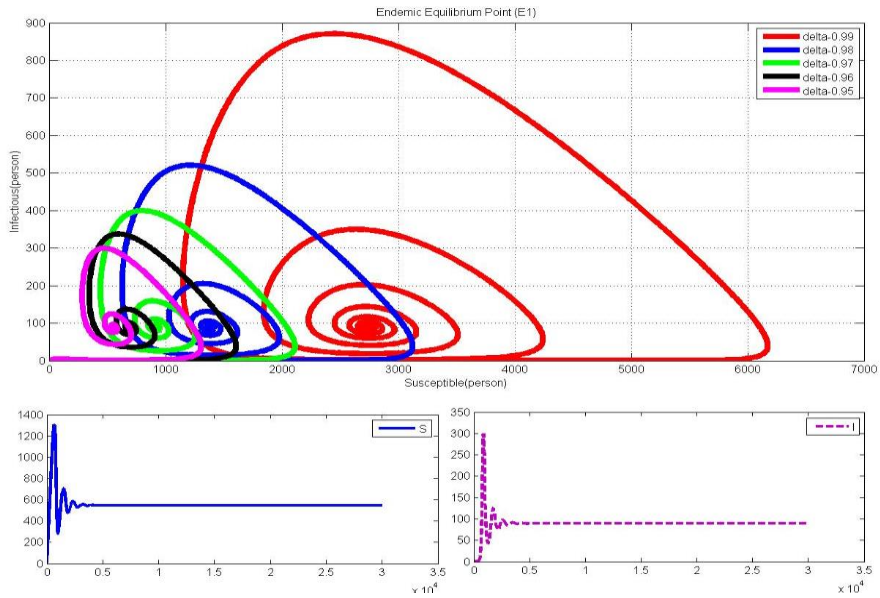

Figure 8: The relationship between (S) Susceptible human and Infected human group (I). The solutions approach the endemic equilibrium state to the disease-free state, Education Campaign 95%-99 %.

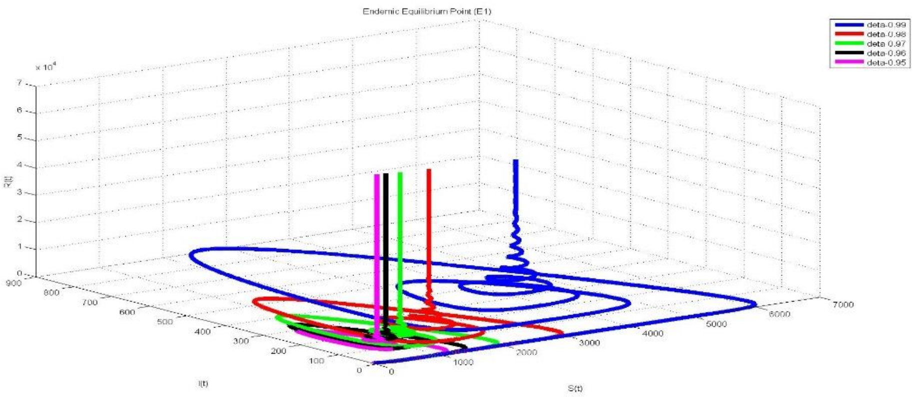

Figure 9: The relationship between (S) Susceptible human, Infected human group (I) and (R) Recovered human. The solutions approach the endemic equilibrium state to the disease-free state, Education Campaign 95%-99 %.

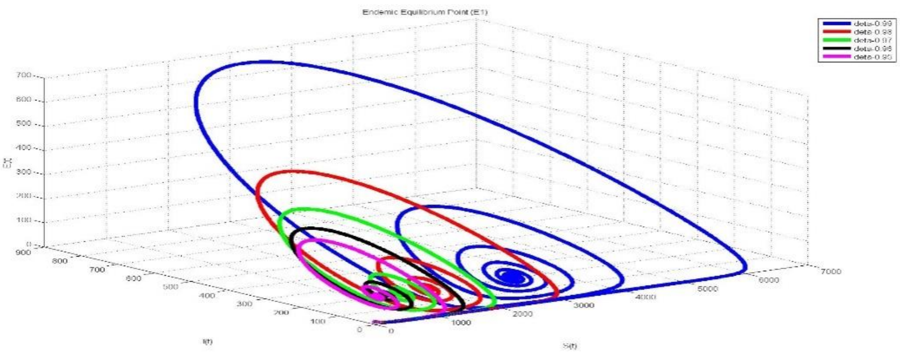

Figure 10: The relationship between (S) Susceptible human, Infected human group (I) and (E) Exposed human. The solutions approach the endemic equilibrium state to the disease-free state, Education Campaign 95%-99 %.

The numerical answer presented in Figure 8-10 illustrates the relationship between the four groups in a three-dimensional graphical comparison at the equilibrium point with the disease. It was found that if in Phuket province there are people infected with Hepatitis B virus and the rate of Education Campaign 95%-99% of Hepatitis B virus is added to the mathematical model, over time the three population groups will tend to converge to the equilibrium point and the disease will spread. Therefore, the 4 groups enter the endemic equilibrium point.

Conclusions

Numerical analysis revealed that both equilibrium points were Local Asymptotical Stable at the disease-free equilibrium. Therefore, the rate of hepatitis B epidemic Education Campaigns was higher, resulting in a decrease in the basic reproductive numbers. The study found that the rate of hepatitis B epidemic Education Campaigns influenced the change in the hepatitis B epidemic control mathematical model. For example, an Education Campaign found that if Susceptible human groups had less knowledge about hepatitis B prevention, the spread of the disease would increase. If the Susceptible human group has more knowledge about hepatitis B prevention, the spread of the disease will be reduced until there is no epidemic of

Hepatitis B. The study also found that the rate of hepatitis B epidemic Education Campaigns influenced the infection level value of changes in the epidemic control mathematical model Hepatitis B if the rate of hepatitis B epidemic Education Campaign was higher resulting in a decrease in infection level.

The researchers found that the Education Campaigns about the spread of hepatitis B and prevention of hepatitis B among the Susceptible human groups in Phuket province is very important and necessary because most patients with cirrhosis and liver cancer have a history of hepatitis B. When the Susceptible human groups are infected with the virus from the Infected human group, most of them are unaware because they do not show any symptoms. Therefore, the disease progresses silently. Infected human group can easily spread the virus. Thus, the method to reduce patients in Phuket province must be proactive measures by Education Campaigns about the spread of hepatitis B. Including campaigning for people to get regular checkups from doctors, and the government should set both short-term and long-term measures to set policies for preventing Hepatitis B, publicize to people in Phuket and other provinces, and follow up seriously and continuously.

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