Mathematical Modeling of Communicable Diseases with Yoga as Control Strategy

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Abstract

The purpose of this paper is to formulate and analyze the abstract behavior of diseases dynamics. The formulation of the problem in the paper is inspired by ethnographies from different social setting and ancient cultural practices related to human health problems. Many people have been worried for communicable diseases caused by virus due to their complexities and dearth of knowledge. They have been a major cause of morbidity and mortality among humans all over the world. Yoga Sadhak compartment (Y) is added to SIR model. A new SYIR model is developed which contains four governing differential equations to describe the transmission dynamics of these disease. These equations were analyzed. Effectiveness and efficiency of yoga pranayama is calculated. Reproduction number is estimated and sensitivity analysis of parameters used in the model is studied. A distinction is made between infection in naïve susceptible and Yoga Sadhak susceptible individuals. Using the model, association between prevalence of infection and immunity by Yoga Pranayama is analyzed. It is found that Yoga Pranayama induce immunity power in individuals which help to reduce transmission rate of diseases. The model shows that eradication depends on Yoga Pranayama coverage as well as on yoga Pranayama efficacy. This study definitely answers the questions regarding the effectiveness of Yoga Pranayama. Further studies are needed to formulate the model and establish causal relationship between parameters involved in the model.

Key Words: Transmission dynamics, Pranayama, Immunity power, Epidemic equilibrium.

Introduction

Background of study

Mathematical modeling is powerful tool of scientific method in which we identify a real world and a conceptual world. In Real world, (we call external world) in which we observe various phenomena and behaviors in their natural form or produced by artifacts. The conceptual world is the world of the mind where we live when we try to understand what is going on in that real (external) world. The conceptual world can be viewed as having three stages: observation, modeling and prediction. In the observation part of the scientific method we measure what is happening in the real world. We gather empirical evidence and facts on the ground. Observations may be direct where we use our senses or indirect in which case some measurements are taken to indicate through some other reading that an event has taken place. Mathematical models describe the behavior or results observed, explain why that behavior and results occurred or allow us to predict future behaviors or results that are yet unseen or unmeasured. In the prediction part of the scientific method, we exercise our models to tell us what will happen in a yet to be conducted experiment or in an anticipated set of events in the real world. These predictions are then followed by observations that serve either to validate the model or to suggest reasons that the model is inadequate. We build models and use them to predict events that can confirm or deny the models (Antman et al., 2003; Elizbeth S. Allman; John A.Rhodes, 2004; Welty et al., 2016).

Communicable diseases have been a cause of global concern throughout the history of mankind. Its outbreak affects the morbidity and mortality rates across the world. Daniel Bernoulli (1760) formulated and solved a mathematical model for smallpox. In his model, he evaluated the effectiveness of vaccination inoculating healthy people against the smallpox virus. The conclusions from this model showed that universal inoculation against smallpox would increase the life expectancy from 26 years 7 months to 29 years 9 months(Moore et al., 2020; Sangam et al., 2015) Hamer 1906 formulated and analyzed a discrete-time model for measles. Hamer proposed that the spread of infection should depend on the number of susceptible individuals and the number of infective individuals. Ross developed a differential equation model for malaria a vector-borne disease. Dr. Ross was awarded the second Nobel Prize in Medicine for his demonstration of the dynamics of the transmission of malaria between mosquitoes and humans. Kermac and Mc Kendric extended Rosse's model for plague studied in Mumbai in (1926) and obtained the epidemic threshold results. This model also gives the relationship between susceptible, infected and recovered. Lotka (1913) and Volterra (1926) proposed the predator-prey model Reed-Frost (1928) describes the relationship between susceptible, infected, and immune individuals in a population. Hethcote H.W. (1976-1980) developed SIS,SIR model for communicable diseases with vital dynamics and without vital dynamics and published various papers(Day, 2009; Martcheva, 2013; Mathematics, 2008; Pokharel, 2020; Sangam et al., 2015).

Epidemiology describes patterns of health, illness and associated factors at the population level. The word "epidemiology" is derived from the Greek terms epi, which means "upon," demos, which means "people," and logos, which means "study." This etymology implies that the subject of epidemiology applies only to human populations. The role of father of epidemiology is often assigned to the Greek physician Hippocrates (460–377 B.C.E.), who described the connection between disease and environment. **T**he term "epidemiology" appears to have first been used to describe the study of epidemics in 1802 by the Spanish physician de Villalba in Epidemiologia Espanola (Martcheva, 2013). Epidemiological studies were mostly concerned with infectious diseases. But nowadays, a central concern of epidemiology is to study diseases such as stroke and coronary heart disease**,** positioning diseases that do not transmit from one person to another as an infectious diseases. These diseases are dominating worldwide spreading infectious disease such as pneumonia, dengue, influenza and HIV(Martcheva, 2013; Pokharel, 2020).Epidemiology is a branch of medical science dealing with disease incidence, distribution and control in a population. It identifies risk factors, assesses treatment and health services modalities, and provides opportunities for the prevention, treatment, planning and improvement of health services effectively. The ultimate aim of any epidemiological study is to eliminate or reduce health problems thereby promoting the health and well-being of the society as a whole. Epidemiological studies are useful because it provides relevant information on disease in a given population, facilitates diagnosis of disease at a community level, promotes planning and evaluation of health care facilities and programs and risk assessment of individual. Epidemiology provides a framework to endure the basic tenet of addressing the determinants of infectious diseases and its distribution in specified population and helps in the control of health related problems (Mathematics, 2008).

The term yoga is derived from Sanskrit root yuj which means contemplation (Samadhi; trance) and is characteristics of the mind pervading all its planes. It is a psycho-somatic spiritual discipline for achieving union and harmony between our mind (puroosh) and body (prakriti) and the ultimate union of our individual consciousness with the universal consciousness. It is mind-body cinque which involves relaxation, meditation and a set of physical exercises performed in sync with breathing. It is the best means for achieving physical, mental, social and spiritual well being of the practitioners. This can be achieved by systematic and disciplined practice of ashtang (eight-limbed) yoga described by sage Patanjali. The eight limbs of yoga are yama (abstinences), niyama (observances), asana (yoga postures), pranayama (breath control), pratyahara (withdrawal of the senses), dharana (concentration), dhyana (meditation) and samadhi (absorption).The first two limbs yam and niyam which are ethical code and personal discipline for the development of our moral, spiritual and social aspects. Third and fourth limbs asana and pranayama help in our physical development and improvement of physiological functions. Fifth and sixth limbs pratyahar and dharna controls our senses and making our mind one-pointed, calm and alert. The final two limbs dhyan and samadhi result in inner peace, ecstasy, higher level of consciousness and the ultimate union of our individual consciousness with the universal consciousness resulting in realization of power of the universe. The result is unfoldment of a unique spiritual personality that is a blessing for the whole humanity (Maehle, 2012; Usharbuddh Arya, 1986; Yogini, 2006).Yoga helps in developing our total personality in an integrated and holistic manner. In this paper fourth limb of Yoga Pranayama is considered as control strategy of Communicable diseases .This fourth Anga or limb of Ashtanga Yoga Pranayama regulates breath or controls Prana by stopping of inhalation and exhalation, which follows after securing that steadiness of posture. Healthy life can be considered as a by-product of practicing yogic techniques since it has been observed that yoga practitioners are physically and mentally healthier and have better coping skills to stressors (victim) than the normal population(Ann Swanson, 2019; Clennell, 2007; Maehle, 2012). So Yoga is widely practiced and globally accepted health promoting tool in our society. Healthy people as well as patients may inquisitively approach medical professionals to take consultation about Yoga. If this knowledge about yoga invokes interest in the medical professionals and they practice it themselves, it might open up new avenue in bringing together our traditional heritage of yoga and today's objective knowledge of modern medicine. Documented scientific evidence strongly indicates that yoga has promotive, preventive as well as curative potential. It can be used as an effective lifestyle adjunct to medical treatment to reduce drug dosage and improve quality of life of the patients. It is to be emphasized that yoga is very effective for prevention as well as management of all pervading health problems and health-related disorders. Modern medicine is very effective in controlling infections, performing surgeries and managing diseases. However, it has limited role in controlling infectious diseases caused by virus, stress-based diseases, chronic degenerative, old age and lifestyle related disorders which are the bane of modern society. Yoga has been found to be very effective in these conditions. Our public health delivery system is under-staffed, fund-starved and reeling under severe economic burden. Knowledge of inexpensive, effective and easily administrable yogic techniques will go a long way in helping us to achieve the WHO goal of providing "Physical, mental, spiritual and social health" to the society(Estrada-hernandez, 2020). Yoga can help to regulate enzymes, increase immunity and maintains three imperfections Kaph, Bata and Pitta (Swami Satyananda Saraswati, 1995). So professionals are seeking to establish Yoga Pranayama as an independently viable healing practice as well as integrate it into the current modern medical model. It will aid health care providers and fitness professionals in recommending the most beneficial yoga practice to their patients'. It can have a clearly positive influence, where disease propagation is minimized or fully stopped (Sardhana & Singh, 2016; Swami Satyananda Saraswati, 1995).Research has been completed in various fields of yoga, Mathematical modeling of communicable diseases with Yoga as control strategies has not been studied yet. In this paper we try to solve such problem.

Methodology

We construct a deterministic mathematical model using a system of ordinary differential equations where the total population, denoted by N(t), is divided into four mutually exclusive sub-populations according to their epidemiological (or disease) status: susceptible, Infected and infectious , Yoga Sadhak and recovered. We analyze the model qualitatively to determine the criteria for containing an epidemic/pandemic of communicable disease like influenza, COVID-19 with the presence of Yoga Pranayama. Epidemic threshold is computed. A sensitivity analysis on the key parameters is also performed. Variables /Parameters are numerically analysed.

We evaluate the possibility that the disease may take-off in the absence of Yoga awareness and classical basic reproduction number denoted by R_0 is calculated. With this threshold, the qualitative mathematical properties of the model are studied, and the epidemiological consequences are discussed. If the parameter R_0 is less than unity ($R_0 < 1$), then the disease cannot spread in the population but, if $R_0 > 1$, then, the spread of the disease in the population is always possible. R_0 is calculated using the next generation operator method. This epidemiological quantity measures the average number of new cases generated by an infectious individual for the duration of his/her infectiousness in a completely susceptible population.

Formulation of model

We divide the total population (N) into four classes to build the model. Namely, S_1 the naive susceptible individuals(non-Yoga Sahak);Y_1 the Yoga Sadhaka individuals performing Pranayama which produce immunity and lost after a certain period of time if practice is left.; I_1 infected individuals which contain both infectious Yoga Sadhak and non-Shadak .

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Finally R_1 the recovered individuals. The model contains constant population and considered that the natural mortality rate and natural death rate are constant so that it balances the total population to be of constant size N. Interaction occurs between the classes as they mix with each other naturally. Interested non-Yoga Sadhaka susceptible individuals S_1 are shifted to Yoga Sadhaka class Y_1 at a rate m if they perform yoga Pranayama daily. The naive susceptible individuals S_1 become infectious and move to class I_1 .The incidence is the infection rate of susceptible individuals through their contact with infective such that the number of primary infectious individuals produced by adequate contact $\frac{\beta S_1 I_1}{N}$ where β is the transmission coefficient of the disease infection of non- yoga Sadhaka individuals. It is realistically assumed that the Yoga Pranayama induces protection from natural infection and the immunity so induced produce a class of Yoga Sadak susceptible individuals Y_1. These susceptible individuals develop immunological memory. So they are able to elicit very quickly an immune response, so their infection rate is lower than that of the naive susceptible individuals S_1 or they have no infection. In such a situation, the number of new infectious produced by adequate contacts is $\frac{\rho_1 Y_1 I_1}{N}$ N where $\rho_1 = \sigma\beta$ is the transmission coefficient of the disease infection in Yoga Sadhaka and $0 \leq \sigma \leq 1$. Parameter σ illustrates the effect of immunity produced by Yoga Pranayama, so it is the factor that reduces the risk of infection and reinfection. if $\sigma = 0$,then, the Yoga Pranayama is useless and if σ =1, the Yoga Pranayama is 100% effective, From now on we make the realistic assumption that Yoga Pranayama brings out immune response, but it fail to offer long-lasting protection against infection and reinfection, that is, $0 < \sigma < 1$.Induced immunity against infection are assumed to be lost at per capita rate ρ_2.Thus, after recovery, they may have chance to become infected.ρ_1 is the rate at which the Yoga Pranayama sadhak become infected and move to infected class and ρ_2 is the rate at which the recovered individuals (natural protection decreases) again move to susceptible class. The average duration of immune protection acquired either by Pranayama or infection is $d_2 = \frac{1}{\rho_2}$.This duration is predicted to evolve asymptotically towards infinity in reality it is of course finite. The model assumes that infectious individuals recover with rate constants $\gamma > 0$. The recovering period of the Yoga Sadhaka infectious individuals may be shorter than that of the non-Yoga Sadhaka one .But here we take average recovery period. The recovered individuals move back to classes S_1 by decreasing protection. Finally, we assume that individuals may either inter to Yoga Sadhaka Class Y_1 at same rate m or remain to class S_1.

Variables and parameters so defined are given in the following table.

Variables/Parameters	**Description**
$S_1(t)$	Naive susceptible individuals at time t
$Y_1(t)$	Yoga Sadhak class at time t
$I_1(t)$	Infected(infectious) class at time t
$R_1(t)$	Recovered class at time t
Λ	Recruitment rate of individuals into the population
β	Disease transmission rate i.e. Contact rate
γ	Recovery rate
σ	Yoga Pranayama efficacy ($\sigma \in [0, 1]$)
m	Rate at which susceptible individuals are becoming Yoga Sadak
ρ_1	Rate at which the Yoga Sadhak become infected ($\rho_1 = (1 - \sigma)\beta$)
ρ_2	Rate of wanning immunity induced by infection

The model is governed by the system of ordinary differential equations:

$$\frac{dS_1}{dt} = \Lambda N - \beta \frac{S_1 I_1}{N} - (m+\mu)S_1 + \rho_2 R_1$$

$$\frac{dY_1}{dt} = mS_1 - \frac{\rho_1 Y_1 I_1}{N} - \mu Y_1$$

$$\frac{dI_1}{dt} = \frac{\beta S_1 I_1}{N} + \frac{\rho_1 Y_1 I_1}{N} - (\gamma+\mu)I_1$$

$$\frac{dR_1}{dt} = \gamma I_1 - (\rho_2+\mu)R_1$$

Non-negative initial conditions are $N(0) > 0$ and $S_1 + Y_1 + I_1 + R_1 = N$

Above System is well posed, since solutions remain non-negative for non- negative initial conditions. The demographic equation for the dynamics of the total population size remain constant as birth rate is considered equal to death rate. So that the total population remains constant N. Since the model is homogeneous of degree one, the variables can be normalized by setting

$$S = \frac{S_1}{N},\ Y = \frac{Y_1}{N},\ I = \frac{I_1}{N},\ R = \frac{R_1}{N}$$

It leads to the following normalized system of ordinary differential equations.

$$\frac{dS}{dt} = \Lambda - \beta SI - (m+\mu)S + \rho_2 R$$

$$\frac{dY}{dt} = mS - \rho_1 Y I - \mu Y$$

$$\frac{dI}{dt} = \beta SI + \rho_1 YI - (\gamma+\mu)I$$

$$\frac{dR}{dt} = \gamma I - (\rho_2+\mu)R$$

Where each variable denotes a fraction of the total individuals so that

$S + Y + I + +R = 1$ .This is illustrated in following diagram

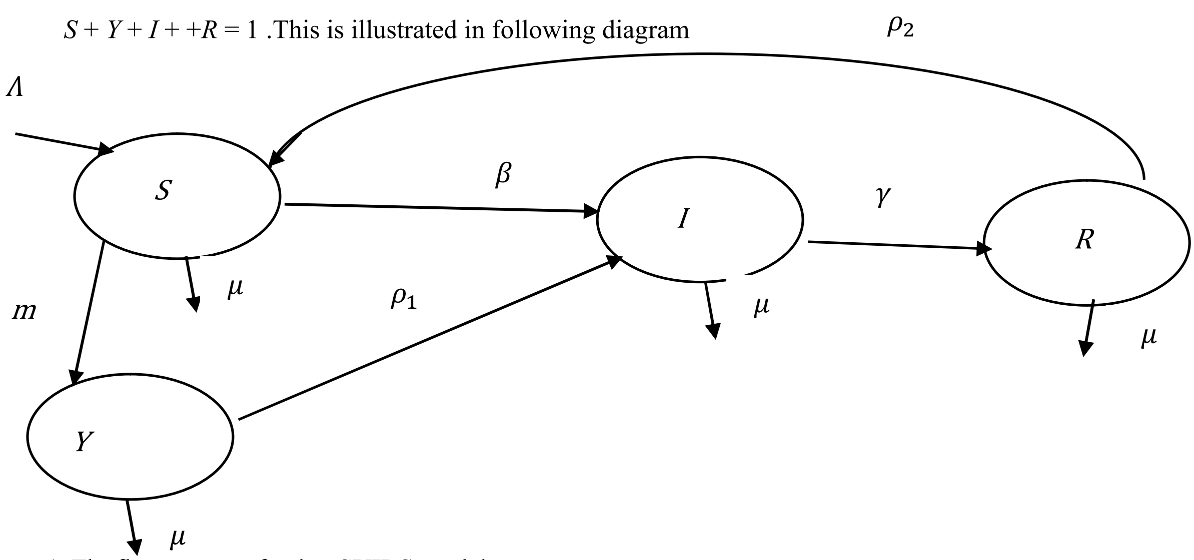

Figure 1: The flow diagram for the SYIRS model

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Result

Analysis of Model

Above Systems includes modeling equations of transmission dynamics of communicable diseases which predicts diseases control strategy and changes in qualitative behavior of people by performing Yoga Pranayama To develop the framework for predicting disease control strategy yoga classes, Yoga chautari, online classes, yoga champs etc. are conducted and yoga sadhak whose are conducting yoga regularly for long time are considered. The systems of equations together with these yoga schedules will be qualitatively analyzed so as to find the conditions for existence and stability of a disease free equilibrium point. The analysis allows us to determine the optimal yoga coverage level needed for disease control and to find the basic reproduction number denoted by R_0 in mathematical epidemiology which is the average number of infected individuals produced by one infected individual introduced in a population completely susceptible. Thus, if $R_0 < 1$, the disease dies out and if $R_0 > 1$, the disease spreads in the population and goes to an endemic level. For a disease that confers immunity in which the susceptible population is yoga sadhak, it has been demonstrated that under certain parameter conditions there is a dependence of the reproductive number on the pranayama rate. In such a case, the reproduction ratio R_p which is the basic reproduction ratio R_0 modified by pranayama must be reduced below one in order to ensure that the disease dies out. If there is no yoga sadhaka performing pranayama, then $R_p = R_0$.Therefore the aim of the yoga campaigns against communicable diseases must be to reduce R_p below one and to provide prolonged protection against both clinical disease and natural infection and reinfection.

Positivity and boundedness

The variables involve in the model must be positive and bounded. We first assume that all the parameters in the model are positive.

From above first equation

$$\frac{dS}{dt} = \Lambda - \beta SI - (m+\mu)S + \rho_2 R \geq 0$$

$$\frac{dS}{dt} \geq -\beta SI - (m+\mu)S$$

$$S = S_0 \exp\left(-\int_0^t (\beta I + m + \mu)dt\right)$$

This means $S \geq 0$ Similarly $I \geq 0$; $Y \geq 0$; $R \geq 0$

Adding all above equations; $\frac{dS}{dt} + \frac{dY}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = 0$

On integrating ,we get $S + Y + I + R = 1$ .So the system is bounded.

Reproduction Number

Basic Reproduction Number

The concept of basic reproduction number R_0 introduced by Ross in 1909 is defined in epidemiological modeling as the average number of infected individuals produced by one infected individual introduced in a popula-tion completely susceptible. The basic reproduction number (R_0) is used to measure the transmission potential of a disease. For example, if the R_0 for measles in a population is 12, then we would expect each new case of measles to produce 12 new secondary cases (assuming everyone around the case was susceptible). R_0 excludes new cases produced by the secondary cases.

Effective Reproduction Number

A population will rarely be totally susceptible to an infection in the real world. Some individuals will be immune due to prior infection which has conferred life-long immunity, or as a result of previous immunization or some protective majors. Therefore, all individuals will not become infected and the average number of secondary cases per infectious case will be lower than the basic reproduction number. The effective reproductive number (R_e) is the average number of secondary cases per infectious case in a population made up of both susceptible and non-susceptible hosts. Effective reproduction number is the number of people in a population who can be infected by an individual at any specific time. It changes as the population becomes increasingly immunized, either by individual immunity following infection or vaccination or Yoga. if $R_e < 1$, the disease dies out and if $R_e > 1$,the disease spreads in the population and goes to an endemic level such as at the start of an epidemic.

Where $R_e = 1$, the disease is endemic. Mathematically the basic reproduction number is defined as

$$R_0 = \frac{Contact\ Rate}{Recovery\ Rate} = \frac{\beta}{\gamma + \mu}$$

We use next generation matrix to find effective reproduction number. From next generation matrix the reproduction number is given by

$$R_e = \frac{\beta S_0 + \rho_1 Y_0}{\gamma + \mu} = \frac{\beta S_0 + (1-\sigma)\beta Y_0}{\gamma + \mu} = \frac{\beta - \sigma\beta Y_0}{\gamma + \mu} = \frac{\beta(1 - \sigma Y_0)}{\gamma + \mu} = R_0(1 - \sigma Y_0)$$

$$\therefore \quad R_e < R_0$$

If there is no Yoga Sadhaka, then $Y_0 = 0$ and hence $R_e = R_0$ .This relation indicates that the more people who are Yoga Sadhak, the less value of R_e . This implies that Yoga Pranayama decreases the value of reproductive number, hence controls the disease. So Yoga Pranayama is effective in controlling the communicable diseases.

Sensitivity Analysis

Mathematical models are widely used to examine, explain and predict the dynamics of infectious disease transmission. Sensitivity analysis characterizes the response of model outputs to parameter variation, helping to allocate resources to follow-up experimentation and field study. Sensitivity analysis enables us to ascertain the effect of a particular parameter in the model on dependent variable.

The sensitivity index on R is given by

$A_p = \frac{\partial R}{\partial P}\frac{P}{R}$ Where R is reproduction number and P is parameter of interest.

(a) sensitivity of β on R_e

$A_\beta = \frac{\partial R_e}{\partial \beta}\frac{\beta}{R_e} = 1$

This indicates that there is direct relation between R and β.

(b) Sensitivity of σ on R_e

$A_\sigma = \frac{\partial R_e}{\partial \sigma}\frac{\sigma}{R_e} = \frac{1}{1 - \frac{1}{\sigma Y_0}} = 1 + \frac{1}{\sigma Y_0} + \frac{1}{\sigma^2 {Y_0}^2} > 1$

Which is also positive and greater than 1 which indicates that R_e is directly related to σ.

(c) Sensitivity Analysis of γ on R_e

$A_\gamma = \frac{\partial R_e}{\partial \gamma}\frac{\gamma}{R_e} = \frac{-\gamma}{\gamma + \mu}$. Similarly μ has opposite effect.

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Stability Analysis

Disease free equilibrium point

The equilibrium condition in the absence of the infection is known as disease free equilibrium condition. S_0 is the initial number of susceptible population and Y_0 is initial number of Yoga Shadhak individuals. At disease free or trivial equilibrium point (DFE), we have $E_0=(S_0, Y_0, 0, 0)$ with the Jacobin matrix of above system evaluated at the DFE is

$$J_0 = \begin{bmatrix} -\mu - m & 0 & \beta S_0 & \rho_2 \\ m & -\mu & -\rho_1 Y_0 & 0 \\ 0 & 0 & \beta S_0 + \rho_1 Y_0 - \gamma - \mu & 0 \\ 0 & 0 & \gamma & -\rho_2 - \mu \end{bmatrix}$$

Now det $(J_0\text{-}KI) = 0$

$$\begin{vmatrix} -\mu - m - k & 0 & \beta S_0 & \rho_2 \\ m & -\mu - k & -\rho_1 Y_0 & 0 \\ 0 & 0 & \beta S_0 + \rho_1 Y_0 - \gamma - \mu - k & 0 \\ 0 & 0 & \gamma & -\rho_2 - \mu - k \end{vmatrix} = 0$$

Solving it ,we get

$$(-\mu - k(\beta S_0 + \rho_1 Y_0 - \gamma - \mu - k)[k^2 + (2\mu + m - \rho_2)k + (\mu^2 - \mu\rho_2 + m\mu - m\rho_2)] = 0$$

From this we four values of k: $k_1 = -\mu; k_2 = \beta S_0 + \rho_1 Y_0 - \gamma - \mu$;

$$k_3 = -(\mu - \rho_2); \quad k_4 = -(\mu + m)$$

Therefore, the system is stable.

Endemic equilibrium point

When the disease is present in the population o then $I^* \neq 0$. There may be several critical points when $I^* \neq 0$, which are the endemic equilibrium points (EEP) of the model. These points will be denoted by

$P^* = (S^*, Y^*, I^*, R^*)$ which are determined from above system as follows

$S^* = \frac{\mu+\gamma+\beta\sigma Y^* - Y^*}{\beta}$; $Y^* = \frac{mS^*}{\rho_1 I^* + \mu}$; Also $I^* = \frac{(\rho_2+\mu)R^*}{\gamma}$ and $I^* = \frac{m}{\rho_1}\frac{S^*}{Y^*} - \frac{\mu}{\rho_1}$

Numerical Analysis

The numerical analysis of the model was done with the parameters of the model fixed at the values indicated in following table. Also, effect of Yoga Pranayama is calculated.

Symbols	**Description of State Variables/ Parameters**	Base Value	Reference
μ	death rate	.006232	UN ; world population Prospective
B	Disease transmission rate	0.625	Assumed
Σ	effect of immunity produced by Yoga	$0 < \sigma < 1$ i.e. $\sigma = 0.8$	Assumed
Γ	recovery rate	1/7	Assumed

Symbols	**Description of State Variables/ Parameters**	Base Value	Reference
Λ	Birth rate	6.232	Assumed
M	growth rate of Yoga Sadak individuals	0.25	Assumed
ρ_1	Rate of wanning immunity induced by Yoga$i.e.\rho_1 = (1-\sigma)\beta$	0.125	Assumed
ρ_2	Rate of wanning immunity induced by infection	0.10	Assumed
S(0)	Susceptible population	0.98	Assumed
I(0)	Infected population	0.02	Assumed
Y(0)	Yoga Sadhak	0.50	Assumed

Table 1: Parameter values used in simulation

We first estimated the reproduction number from the data . R_0 =4.2 and R_e = $R_0(1 - \sigma Y_0)$=2.48 .If Yoga Pranayama Sadhak are 80% or 0.80 and $\sigma = 0.9$, then R_e is nearly equal to 1 .In this case disease remain as endemic. If $\sigma = 0.9$ and Y_0=0.90, then R_e = 0.798 .In this case diseases is eliminated. Yoga Pranayama is completely effective in controlling diseases.

Conclusion and Discussion

Discussion

This work is based on the formulation and use of a mathematical model for the transmission dynamics of communicable diseases with Yoga Pranayama in a human population. The main part of this work with respect to previous models is that we explicitly consider Yoga Pranayama efficacy where a fraction of susceptible individuals is transferred to Yoga compartment per unit time. Indeed, this model is more appropriate for developing countries where adequate health facilities are not generally available for mass hospitalization, isolation and quarantine. Our proposed incorporates some essential parameters (such as σ, ρ_1) of diseases transmission, which enable the assessment of preventive strategies, and their epidemiological consequences. The model is given in the form of a non-linear ODE, and our analytical results show that the effective reproduction number R_e is reduced whenever Yoga Pranayama is introduced as a control measure (i.e., Re < R0).Also, the Yoga Pranayama *increases immunity.* Thus, concurrent administration of Yoga Pranayama is more adequate in controlling the epidemic.

This is consistent with the fact that control measures are necessary to reduced the value of the basic reproduction number R_0, and if this quantity is less than unity, the disease can be eradicated. Thus, a more than 90% Yoga Sadhak are necessary for more effective controlling of the epidemic. Since it is well-known that infected persons also confer immunity which wan with time. After recovering, they may migrate from recovered class to susceptible class, this is incorporated into our model by assuming that they move at a rate ρ_2.

DFE equilibrium exist and amount of preventive measures can eradicate disease from the population(i.e., prevention is better than cure).We use a continuous Yoga Pranayama program (where a fraction of susceptible individuals move to this class per unit time), We have performed sensitivity analysis on a mathematical model of dynamics of disease transmission to determine the relative importance of model parameters to disease transmission and by computing sensitivity analysis it indices that β, σ, ρ_1 have direct effect on reproduction number of the reproductive numbers where as γ, μ have indirect effect on it.

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Conclusion

Mathematical models are potentially useful tools to aid in the design of control programs for communicable diseases. We developed an epidemiological model of transmission dynamics of communicable disease with Yoga Pranayama and used it to predict trends in infection as well as possible control measures. The model incorporates realistic features including Yoga Pranayama compartment of individuals. The qualitative and quantitative mathematical properties of the models are studied, their biological consequences and some control strategies are discussed, and the results of the models are calculated in the presence of Yoga Pranayama that may wane over time. We find that the disease can be controlled by Yoga pranayama and immunity loss can be balanced increasing Yoga practice. The model incorporates the assumption that the disease does not confer permanent immunity by Yoga and infection, thus reinfection is possible. The important observation from our results is that waning of immunity is a major obstacle to the eradication of infectious diseases with just a Yoga Pranayama.

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