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Mathematical Model of Celebrity Worship Tendency Among K-Pop Fans in South Sulawesi

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Abstract. Celebrity worship is a form of almost obsessional participation in which people idolize and even start to "worship" their favorite celebrities. Twitter reveals that in 2021, Indonesia was ranked fourth as the country with the most number of Korean Pop (K-Pop) fans. In this study, we constructed a SEIRS mathematical model of celebrity worship tendency among K-Pop fans (CWKF) because there have not been specific mathematical models built on the problem of celebrity worship tendency among K-Pop fans. The CWKF free equilibrium point (E_0), endemic equilibrium point (E_1), and using the Next Generation Matrix for the Basic Reproduction Number (R_0) are calculated through analysis. Using the Routh-Hurwitz criteria for equilibrium analysis, we found that E_0 is locally asymptotically stable if $R_0 < 1$, and E_1 is locally asymptotically stable if $R_0 > 1$. Secondly, we conduct numerical simulations using Maple software, and research data consisting of 204 individuals from various regions in South Sulawesi serves as the basis for this mathematical analysis. The numerical simulation obtained supports the dynamic analysis results that the number of individuals who are K-Pop fans will decrease in the population and disappear within a certain period, even without any special treatment.

1 Introduction

Use the Korean "fever" (Hallyu) is currently affecting other nations, including Indonesia. This is because the Korean wave has spread internationally thanks to the informational media [1-2]. As a result of the Hallyu phenomenon during the past ten years, Korean pop music (K-pop) has become a worldwide sensation. K-pop is a music genre that heavily relies on visuals, as evidenced by the eye-catching clothing, the meticulously made music videos, and the coordinated choreographies [3]. K-Pop fans use K-Pop culture as a behavior to mimic their idols excessively, this attitude is shown such as following them wherever they go, waiting hours at an airport to see their idols, lodging at the same hotel as their idols, and even purchasing an excessive amount of expensive items [4-5].

Twitter reveals a list of the top 10 most talked about K-Pop artists in 2020. In 1 year, Indonesia is ranked fourth as the country with the most number of K-Pop fans [6]. According to IDN Times survey results in 2019, 40.7% of K-Pop fans in Indonesia come from 20-25

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years old, 38.1% are 15-20 years old, 11.9% are over 25 years old and the lowest percentage comes from 10-15 years old at 9.3% [7].

Celebrity worship is a form of almost obsessional participation in which people idolize and even start to "worship" their favorite celebrities [8]. Sheridan et al. (2007) found positive statistical associations between celebrity worship and addiction [9]. The higher the level of a person's addiction to a celebrity, the higher the level of worship and the higher the level of involvement with the idol figure. According to a three-dimensional model that McCutcheon et al. (2002) proposed, there are several degrees of celebrity adoration: (1) *The borderline-pathological* dimension reflects extreme attitudes and behaviors that are thought to be maladaptive forms of attraction to a celebrity. (2) The *entertainment-social* dimension refers to a healthy enthusiasm and appreciation towards a famous person. (3) The *intense-personal* dimension represents compulsive feelings toward a celebrity [10]. There is some intuitive reason to believe that irresponsible behavior is linked to the two more problematic levels of celebrity infatuation. In two different samples, narcissism was positively related to celebrity worship, especially for the intense-personal and borderline-pathological subscales [11].

Mathematical modeling plays an important role in comprehending and providing useful techniques to predict and control the dynamics of infectious disease. There have been many studies on the infectious disease dynamics model in social problems, such as social media addiction [12-13], game addiction [14-18], tobacco addiction [19], alcoholic and drug addiction [20-22] and Korean related topic [23-24]. These studies have not built SEIRS mathematical models on the problem of celebrity worship tendency in K-Pop fans, so this study will examine the Mathematical Model of Celebrity Worship Tendency among K-Pop Fans (CWKF) in South Sulawesi.

2 Method

The methods used in this study combine a literature review with applied methods. They look at theories relating to the celebrity worship tendency among K-Pop fans and mathematical modeling, then use the model to determine how many individuals are currently hooked on K-Pop idols and how many will be in the future. Suspect, Expected, Infected, Recovered, and Suspended (SEIRS) models, equilibrium analysis of the model using the Routh-Hurwitz criterion [25] method, simulation models using Maple software, and research data consisting of 204 individuals from various regions in South Sulawesi serve as the basis for this mathematical analysis of CWKF. Probability sampling, also known as proportionate stratified random sampling or proportional stratified random sampling by simple random sampling, was the sampling method utilized in this study [26]. The instrument used in this study is a *Celebrity Attitude Scale* (CAS) consisting of three dimensions of celebrity worship tendency, and additional items were added to suit the research objectives [27].

3 Result and Discussion

3.1 Model Construction

This study develops the SEIRS model on the social case of online game addiction [14] with another social case, namely celebrity worship tendency among K-Pop fans with the assumption that individuals in the Infected compartment can cause other individuals to be infected, and individuals in the Exposed compartment can enter the Recovered compartment, namely individuals who stopped being K-Pop fans before becoming possessive fans because they are aware of the negative impact of liking K-Pop idols excessively.

This model divides the compartment into four. Susceptible individuals (S) are individuals who have the potential to become K-Pop fans. Exposed individuals (E) or novice fans are those who are at the entertainment-social level. Infected individuals (I) or possessive fans are individuals who have the intense-personal feelings or borderline-pathological levels. Recovered individuals (R) are individuals who stopped being K-Pop fans. Compartment diagram and variables are served in Fig.1. and Table 1.

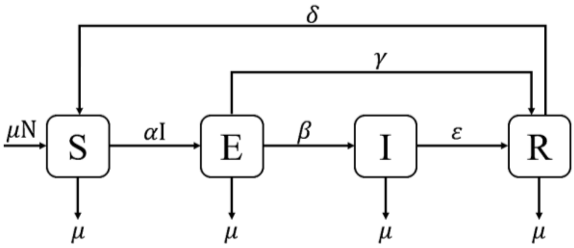

Fig. 1. Compartmental diagram for the transmission dynamics of CWKF.

Table 1. Variables and Parameters used in this model.

Symbol	Definition
N	Sample size of individuals aged 10-29 years
S	Number of individuals who are susceptible to becoming K-Pop fans
E	Number of individuals who became novice K-Pop fans
I	Number of individuals who are possessive K-Pop fans
R	Number of individuals who stopped being K-Pop fans
μ	Rate of individuals who know what K-Pop is or are not interested in K-Pop
α	Rate of individuals who started liking K-Pop (novice fans)
β	Rate of individuals who are possessive K-Pop fans
γ	Rate of individuals who stopped being fans before becoming possessive fans
ε	Rate of individuals who stopped being possessive fans
δ	Rate of recovered individuals who are susceptible to becoming fans again due to environmental influences

Setting the above considerations together, the flow diagram shown in Figure 1 and scaling to the proportion of the number of individuals in a subpopulation to the total population, the following system of nonlinear differential equations describes the dynamics of CWKF in human population:

$$\frac{ds}{dt} = \mu + \delta r - \alpha si - \mu s = \mu + \delta r - (\alpha i + \mu)s \quad (1)$$

$$\frac{de}{dt} = \alpha si - \beta e - \gamma e - \mu e = \alpha si - (\beta + \gamma + \mu)e \quad (2)$$

$$\frac{di}{dt} = \beta e - \varepsilon i - \mu i = \beta e - (\varepsilon + \mu)i \quad (3)$$

$$\frac{dr}{dt} = \varepsilon i + \gamma e - \delta r - \mu r = \varepsilon i + \gamma e - (\delta + \mu)r \quad (4)$$

with the initial condition $s(t) + e(t) + i(t) + r(t) = 1$.

3.2 Equilibrium Point of SEIRS Model

The (s, e, i, r) points are equilibrium points of the system of equations (1)-(4) if they satisfy the equation $\frac{ds}{dt}, \frac{de}{dt}, \frac{di}{dt}, \frac{dr}{dt} = 0$. There are two equilibrium points in the system of equations, namely the free equilibrium point and the endemic equilibrium point. So that the following equation is obtained:

$$\mu + \delta r - (\alpha i + \mu)s = 0 \quad (5)$$

$$\alpha si - (\beta + \gamma + \mu)e = 0 \quad (6)$$

$$\beta e-(\varepsilon+\mu)i=0 \tag{7}$$
$$\varepsilon i+\gamma e-(\delta+\mu)r=0 \tag{8}$$

3.2.1 CWKF Free Equilibrium Point

CWKF free equilibrium point (E_0) is a state where there are no K-Pop fans in the population. This point can be determined by assuming $e=0$ and $i=0$ which means that no individual is a K-Pop fan. From the system of equations (5)-(8), the addiction-free equilibrium point obtained is

$$E_0=(s,e,i,r)=(1,0,0,0) \tag{9}$$

3.2.2 The Endemic Equilibrium Point

The endemic equilibrium point (E_1) is a state where there are K-Pop fans in the population. This point can be determined by finding the solution, with $s,e,i,r\neq 0$. From system of equations (5)-(8), the endemic equilibrium point is obtained as follows

$$\begin{aligned}E_1&=(s,e,i,r)\\&=\left(\frac{(\varepsilon+\mu)(\beta+\gamma+\mu)}{\alpha\beta},\frac{\alpha\beta\varepsilon\delta+\alpha\beta\delta\mu+\alpha\beta\varepsilon\mu+\alpha\beta\mu^2-\beta\delta\varepsilon^2-2\beta\delta\varepsilon\mu-\beta\delta\mu^2-\beta\varepsilon^2\mu-2\beta\varepsilon\mu^2-\beta\mu^3-\delta\varepsilon^2\gamma-\delta\varepsilon^2\mu-2\delta\varepsilon\gamma\mu-2\delta\varepsilon\mu^2-\delta\gamma\mu^2-\delta\mu^3-\varepsilon^2\gamma\mu-\varepsilon^2\mu^2-2\varepsilon\gamma\mu^2-2\varepsilon\mu^3-\gamma\mu^3-\mu^4}{\alpha\beta(\beta\delta+\beta\varepsilon+\beta\mu+\delta\varepsilon+\delta\mu+\varepsilon\gamma+\varepsilon\mu+\gamma\mu+\mu^2)},\right.\\&\left.-\frac{(\mu^2+(\beta+\gamma+\varepsilon)\mu+\varepsilon(\beta+\gamma)-\alpha\beta)(\delta+\mu)}{\alpha(\mu^2+(\beta+\delta+\gamma+\varepsilon)\mu+(\beta+\delta+\gamma)\varepsilon+\beta\delta)},-\frac{(\beta\varepsilon+\gamma(\varepsilon+\mu))((\beta+\gamma+\mu)(\varepsilon+\mu)-\alpha\beta)}{\alpha\beta((\beta+\gamma+\mu)(\varepsilon+\mu)+\delta(\varepsilon+\mu)+\beta\delta)}\right)\end{aligned} \tag{10}$$

Basic Reproduction Number (R_0)

To determine the level of spread of an infectious disease in an area can be indicated by the value of the basic reproductive number (R_0). This also applies to know the level of distribution of individual K-Pop fans who behave in celebrity worship. The basic reproduction number is obtained by utilizing the Next Generation Matrix method and is calculated at the CWKF free equilibrium point (E_0). In this model, the system of equations that constitute the infected sub-population are compartments E and I in the system. Based on equations (2) and (3), E and I can be written as

$$\frac{de}{dt}=\alpha si-(\beta+\gamma+\mu)e$$
$$\frac{di}{dt}=\beta e-(\varepsilon+\mu)i$$
$$\begin{bmatrix}\frac{de}{dt}\\ \frac{di}{dt}\end{bmatrix}=\begin{bmatrix}\alpha si\\ 0\end{bmatrix}-\begin{bmatrix}(\beta+\gamma+\mu)e\\ -\beta e+(\varepsilon+\mu)i\end{bmatrix}$$

Then, the Jacobi matrix of the two matrices will be formed as F and V, and then determine the inverse of matrix V. The next generation matrix is determined, namely $K=FV^{-1}$, then look for its eigenvalue

$$K=\begin{bmatrix}\frac{\alpha\beta s}{(\beta+\gamma+\mu)(\varepsilon+\mu)} & \frac{\alpha s}{(\varepsilon+\mu)}\\ 0 & 0\end{bmatrix}\text{, we found }\lambda=0\text{ and }\lambda=\frac{\alpha\beta s}{(\beta+\gamma+\mu)(\varepsilon+\mu)}$$

Substitute $s=1$ from E_0, the basic reproduction number is found

$$R_0=\frac{\alpha\beta s}{(\beta+\gamma+\mu)(\varepsilon+\mu)} \tag{11}$$

3.3 Local Stability Analysis of Equilibrium Point of SEIRS Model

The concept of system behaviour at the equilibrium point is known as equilibrium point stability which is information to describe the behaviour of the system. The stability analysis is obtained based on the eigenvalues of the Jacobian matrix through the linearization method. Based on the system of equations (1)-(4), the following Jacobian matrix is obtained

$$J(f(\bar{x})) = \begin{bmatrix} -(\alpha i+\mu) & 0 & -\alpha s & \delta \\ \alpha i & -(\beta+\gamma+\mu) & \alpha s & 0 \\ 0 & \beta & -(\varepsilon+\mu) & 0 \\ 0 & \gamma & \varepsilon & -(\delta+\mu) \end{bmatrix} \quad (12)$$

Let $x = \beta + \gamma + \mu$, $y = \varepsilon + \mu$ and $z = \delta + \mu$.

3.3.1 CWKF Free Equilibrium Point

Eigenvalues of the Jacobian matrix $J(E_0)$ determined $|\lambda I - J(E_0)| = 0$

$$\Leftrightarrow \left| \lambda \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} -\mu & 0 & -\alpha & \delta \\ 0 & -x & \alpha & 0 \\ 0 & \beta & -y & 0 \\ 0 & \gamma & \varepsilon & -z \end{bmatrix} \right| = 0$$

$$\Leftrightarrow (\lambda+\mu)(\lambda+z)(\lambda^2 + a\lambda + b) = 0 \quad (13)$$

where $a = x + y$ and $b = xy - \alpha\beta$.

We obtain $\lambda = -\mu$, $\lambda = -(\delta+\mu)$ and $\lambda^2 + a\lambda + b = 0$ (14)

To see the negativity of roots, we used Routh-Hurwitz criteria and by the principle equation (14) has a strictly negative real root if $H_1, H_2 > 0$.

- $H_1 = |a| = a = x + y = (\beta+\gamma+\mu) + (\varepsilon+\mu) > 0$
- $H_2 = \left| \begin{bmatrix} a & 0 \\ 1 & b \end{bmatrix} \right| = ab$

Due to $H_1, H_2 > 0$ after all of the calculations, all eigenvalues of $J(E_0)$ are negatives when $R_0 < 1$, then E_0 is stable [28]. E_0 is locally asymptotically stable if $R_0 < 1$ and unstable otherwise [12].

3.3.2 The Endemic Equilibrium Point

Eigenvalues of the Jacobian matrix $J(E_1)$ determined $|\lambda I - J(E_1)| = 0$

$$\Leftrightarrow \left| \lambda \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} -(\alpha i+\mu) & 0 & -\alpha s & \delta \\ \alpha i & -x & \alpha s & 0 \\ 0 & \beta & -y & 0 \\ 0 & \gamma & \varepsilon & -z \end{bmatrix} \right| = 0$$

$$\Leftrightarrow (\lambda+\mu)(\lambda^3 + a\lambda^2 + b\lambda + c) = 0 \quad (15)$$

where $a = 3\mu + \alpha i + \beta + \delta + \varepsilon + \gamma$

$b = 3\mu^2 + 2\alpha i\mu + 2\beta\mu + 2\delta\mu + 2\varepsilon\mu + 2\gamma\mu + \alpha i\beta - \alpha\beta s + \alpha i\delta + \alpha i\varepsilon + \alpha i\gamma + \delta\beta + \beta\varepsilon + \delta\varepsilon + \delta\gamma + \gamma\varepsilon$

$c = \mu^3 + \alpha i\mu^2 + \beta\mu^2 + \delta\mu^2 + \varepsilon\mu^2 + \gamma\mu^2 + \alpha i\beta\mu - \alpha\beta s\mu + \alpha i\delta\mu + \alpha i\varepsilon\mu + \alpha i\gamma\mu + \delta\beta\mu + \beta\varepsilon\mu + \delta\varepsilon\mu + \delta\gamma + \gamma\varepsilon\mu + \alpha i\delta\beta - \alpha\beta\delta s + \alpha i\beta\varepsilon + \alpha i\delta\varepsilon + \alpha i\gamma\varepsilon + \delta\beta\varepsilon + \delta\gamma\varepsilon$

we get $\lambda = -\mu$ and $\lambda^3 + a\lambda^2 + b\lambda + c = 0$ (16)

To see the negativity of roots, we used Routh-Hurwitz criteria and by the principle equation (16) has a strictly negative real root if $H_1, H_2, H_3 > 0$.

- $H_1 = |a| = a = \alpha i + x + y + z > 0$
- $H_2 = \left| \begin{bmatrix} a & c \\ 1 & b \end{bmatrix} \right| = ab - c > 0$

- $H_3 = \left\| \begin{bmatrix} a & c & 0 \\ 1 & b & d \\ 0 & a & c \end{bmatrix} \right\| = abc - c^2 = c(ab - c\,) = cH_2$

Due to $H_1, H_2, H_3 > 0$ after all of the calculations, all eigenvalues of $J(E_1)$ are negatives, then E_1 is stable [28]. E_1 is locally asymptotically stable if $R_0 > 1$ and unstable otherwise [12].

3.4 Simulation

The initial values used in the simulation consisted of 204 individuals who were scattered into four compartments, with the parameters listed in Table 2.

Table 2. Values of Variables and Parameters

Variable	Value	Parameter	Value
S	81	μ	0.8578
E	9	α	0.4755
I	84	β	0.3431
R	30	γ	0.0931
-	-	ε	0.0539
Total (N)	204	δ	0.0931

If the parameter values are substituted into equation (11), the value of $R_0 = 0.138 < 1$ is obtained, which means that individual possessive fans do not cause others to become possessive fans. This shows the behavior of the solution which will gradually lead to a CWKF free equilibrium Point (E_0), so it can be said that celebrity worship cases will decrease in the population and disappear within a certain period. Simulation results can be seen in Fig. 2.

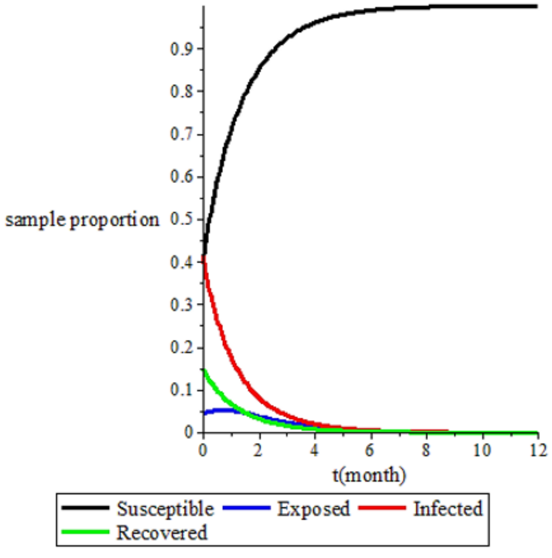

Fig. 2. Simulation results of SEIRS model.

From the graph, the number of individuals who have the potential to become K-Pop fans (black line) increases every month and reaches equilibrium in the 8th month. The number of individuals who are at the entertainment-social level (blue line) had increased until before entering the second month but then decreased. Then the number of individuals who are at the intense-personal feelings or borderline-pathological level (red line) and individuals who stopped being K-Pop fans (green line) decreased every month and reached equilibrium after the 8th month.

This study combines two fields: science (mathematical modeling) and psychology (the celebrity worship behavior of K-Pop fans). The model built is a modification of the SEIRS model from Anwar [14] and applied to the case of celebrity worship tendency among K-Pop fans according to the definition of Cahyani's research [29].

Research on celebrity worship behavior conducted by Cahyani [29] entitled *Celebrity Worship on Early Adult K-Pop Fangirling* obtained the results that the high sense of empathy felt by fans towards their idols made fans feel that they had a special bond with their idol celebrities and even felt what happened to the celebrity. Sheridan et al. (2007) found positive statistical associations between celebrity worship and addiction [9]. The nature of celebrity worshippers (*fangirls*) is similar to the nature of addiction; the higher the addiction to celebrity idols, the higher the level of involvement with the idol figure; this is known as celebrity involvement [30].

Research on mathematical models in social cases has been conducted by Anwar [14] with the title *SEIRS Model Analysis for Online Game Addiction Problem of Mathematics Students*. This study obtained a SEIRS model where the population was divided into four classes, namely Susceptible, Exposed, Infected, and Recovered, and found that the level of online game addiction in students was not an endemic condition, and it was estimated that in the future, the condition of students who were depressed due to online games would not be alarming. In addition, research conducted by Fadhilah [23] with the title *Model Epidemi SEIEDR Perilaku Kecanduan Drama Korea* obtained the result that the greater the value of the individual rate of novice viewers and active viewers who are given education will reduce the population of novice viewers and active viewers of Korean dramas. In line with the results of research by Anwar [14] and Fadhilah [23], this study shows that the number of individuals who are K-Pop fans will decrease in the population and disappear within a certain period of time, even without any special treatment. However, to accelerate the rate towards addiction-free, it can be seen from the value of R_0 by decreasing it.

4 Conclusion

The celebrity worship tendency among K-Pop fans can be explained by the SEIRS mathematics model. The SEIRS model analysis explains the stability and equilibrium point of celebrity worship of K-Pop fans behavior.

Simulation results show that the number of individuals who are K-Pop fans will decrease in the population and disappear within a certain period of time even without any special treatment. This means that, in general, there is a possibility that non-endemic conditions can occur in the system. However, to accelerate the rate towards addiction-free, it can be seen from the value of R_0 by decreasing it.

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