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ORIGINAL ARTICLE

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Optimal Implementation of Intervention Strategies for Elderly People with Ludomania

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Abstract

Objectives: Now-a-days gambling is growing especially fast among older adults. To control the gratuitous growth of gambling, well-analyzed scientific strategies are necessary. We tried to analyze the adequacy of the health of society mathematically through immediate treatment of patients with early prevention.
Methods: The model from Lee and Do was modified and control parameters were introduced. Pontryagin's Maximum Principle was used to obtain an optimal control strategy.
Results: Optimal control can be achieved through simultaneous use of the control parameters, though it varies from society to society. The control corresponding to prevention needed to be implemented in full almost all the time for all types of societies. In the case of the other two controls, the scenario was greatly affected depending on the types of societies.
Conclusion: Prevention and treatment for elderly people with ludomania are the main intervention strategies. We found that optimal timely implementation of the intervention strategies was more effective. The optimal control strategy varied with the initial number of gamblers. However, three intervention strategies were considered, among which, preventing people from engaging in all types of gambling proved to be the most crucial.

1. Introduction

Problem gambling or ludomania is a type of disorder that consists of an urge to continuously gamble despite harmful negative consequences or a desire to stop and that is associated with both social and family costs. Problem gambling and wider gambling-related harm constitute a significant health and social issue [1]. To study problems associated with gambling, Shaffer and Korn [2] used the classic public health model for communicable disease, which examines the interaction among host, agent, environment, and vector. Moreover, some sociologists [3–6] have shown that a significant predictor of the occurrence of ludomania is peer pressure; in the sense that the occurrence depends on the number of individuals involved, the number of individuals who might be involved, as well as the frequency, duration, priority, and intensity of association with peers. Therefore, ludomania might be considered as a contagious disease. Recently, from the point of view of a communicable disease, Lee and Do [7,8] used a mathematical modeling approach to study the dynamics of problem gambling.

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In this study, we adopted the optimal control theory to their model and tried to find optimal strategies for intervention. A variety of policies and services have been developed with the intent of preventing and reducing problem gambling and related harm. The prevalence and consequences of problem gambling as well as approaches to treatment can be found in the book by Petry [9]. We considered a basic model [7] to incorporate some important epidemiological features, such as time-dependent control functions. The extended model can then be used to determine cost-effective strategies for combating the spread of problem gambling in a given population; a mathematical modeling approach to study the dynamics of problem gambling.

2. Materials and methods

2.1. Basic model

We considered the model of Lee and Do [7] without demographic effect as follows:

$$\begin{aligned}
\frac{dS}{dt} &= -\alpha S\frac{L+P}{N}\\
\frac{dL}{dt} &= \alpha S\frac{L+P}{N} - \beta L\frac{P}{N} - \phi L + \psi P\\
\frac{dP}{dt} &= \beta L\frac{P}{N} + \phi L - \psi P - \gamma P\frac{H}{N} - \theta P + \tau H\\
\frac{dH}{dt} &= \gamma P\frac{H}{N} + \theta P - \tau H
\end{aligned} \tag{1}$$

The whole population $N(t)=S(t)+L(t)+P(t)+H(t)$ consisting of older adults aged 65–80 years was divided into four classes: susceptible $S(t)$, latent gamblers $L(t)$, pathological gamblers $P(t)$, and treated gamblers $H(t)$. The susceptible population $S(t)$ was a class of individuals who had never gambled more than five times in a single year in their life time. Using the per capita transition rate α, susceptible people entered the second compartment $L(t)$, which was composed of individuals who gamble frequently but had two or less symptoms of problem gambling in the previous year. The transition rate α might be understood as the peer pressure from people in $L(t)$ and $P(t)$. Latent people were pathological gamblers, with the peer pressure transition rate β from people in $P(t)$, or with the natural progression rate ϕ. The class of excessive gamblers $P(t)$ consisted of problem and pathological gamblers. When problem or pathological gamblers sought help, they transited to class $H(t)$ of individuals who were in treatment, with the peer pressure rate γ from people in$H(t)$, or with the voluntary transition rate θ. By attending several types of psychotherapy, including Gamblers Anonymous, cognitive behavioral therapy, behavioral therapy, psychodynamic therapy, and family therapy [10], people in $H(t)$ may have returned to $P(t)$ with the transition rate τ. The rate τ was closely related to the efficacy of a cognitive–behavioral treatment package for pathological gambling [11].

2.2. Optimal control

Using sensitivity analysis, Lee and Do [7] showed that the best way to reduce gambling problems among elderly people is to minimize the value of α, which is similar to the claim of Shaffer and Korn [2] that primary prevention is most important. We considered three interventions to reduce gambling problems among elderly people: reducing α and β, and urging the pathological gamblers to take medical services, which resulted in increasing θ. Although we may have gained some insights from such constant controlling of the parameters, it is unrealistic to have constant controls to α, β, and θ over time. The goal was to show that it was possible to implement time-dependent control techniques while minimizing the cost of implementation of such control measures.

We formulated an optimal control problem for the transmission dynamics of gambling by adding control terms to the basic model (1) as follows:

$$\begin{aligned}
\frac{dS}{dt} &= -\alpha(1-u_1(t))S\frac{L+P}{N}\\
\frac{dL}{dt} &= \alpha(1-u_1(t))S\frac{L+P}{N} - \beta(1-u_2(t))L\frac{P}{N} - \phi L + \psi P\\
\frac{dP}{dt} &= \beta(1-u_2(t))L\frac{P}{N} + \phi L - \psi P - \gamma P\frac{H}{N}\\
&\quad -(\theta+\rho u_3(t))P + \tau H\\
\frac{dH}{dt} &= \gamma P\frac{H}{N} + (\theta+\rho u_3(t))P - \tau H
\end{aligned} \tag{2}$$

Here, we noted that $N(t)=S(t)+L(t)+P(t)+H(t)$ was constant.

The control variables $u_1(t)$, $u_2(t)$, and $u_3(t)$ represent the amount of intervention related to the parameters α, β, and θ at time t, respectively. The factor of $1-u_1(t)$ and $1-u_2(t)$ reduced the per capita transition rate α from S to L and β from L to$P$, respectively. It was also assumed that the per capita transition rate θ from P to H increased at a rate proportional to $u_3(t)$; where $\rho > 0$ was a rate constant.

We defined our control set to be:

$$U=\{(u_1(t),u_2(t),u_3(t)) : u_i(t) \text{is Lebesgue measurable on } [0,T], 0\le u_i(t)\le 1, i=1,2,3\}.$$

An optimal control problem with the objective cost functional can be given by

$$J(u_1,u_2,u_3)=\int_0^T\Big(A_L L(t)+A_P P(t)+\frac{B_1}{2}u_1^2(t)+\frac{B_2}{2}u_2^2(t)+\frac{B_3}{2}u_3^2(t)\Big)dt \tag{3}$$