Mathematical and Computer Modelling 52 (2010) 999–1003

Contents lists available at ScienceDirect

Mathematical and Computer Modelling

journal homepage: www.elsevier.com/locate/mcm

Alcohol consumption in Spain and its economic cost: A mathematical modeling approach

Francisco-José Santonja [a,*], Emilio Sánchez [b], María Rubio [c], José-Luis Morera [c]

[a] *Departamento de Estadística e Investigación Operativa, Universidad de Valencia, Spain*
[b] *Unidad de Conductas Adictivas de Catarroja, Agencia Valenciana de Salud, Spain*
[c] *Instituto de Matemática Multidisciplinar, Universidad Politécnica de Valencia, Spain*

ARTICLE INFO

Article history:
Received 24 September 2009
Received in revised form 12 February 2010
Accepted 22 February 2010

Keywords:
Alcohol consumption
Economic cost
Differential equation system
Modeling

ABSTRACT

In this paper, a mathematical model for alcohol consumption in Spanish population is proposed. Its parameters are estimated by fitting the model to real data from Spanish Ministry of Health. Predictions about the future behavior of the alcohol consumption in Spain are presented using this model. Results are applied to estimate the economic costs (sanitary and non-sanitary) assumed by Spanish society that are derived from this consumption.

1. Introduction

Alcohol consumption is growing at a fast rate in developed and developing countries and it is becoming a serious problem not only from the individual health point of view but also from the public socioeconomic one, motivated by the high cost of the Health Public Care System due to the assistance expenditure of people suffering diseases related with this consumption [1,2]. It has been estimated that the alcohol consumption derived cost is around 3800 millions of Euros per year in Spain [3]. In this paper, we analyze the evolution of alcohol consumption in Spain (see Table 1 [3]) and estimate the economic quantification of the impact of this alcohol consumption in the next few years.

In this article, we present an epidemiological-type mathematical model to study the transmission dynamics and evolution of the alcohol consumption in Spanish population. Additionally, we present estimations of the economic costs of this consumption. These types of epidemiological models also have been used in the study of ecstasy or heroin addiction [4,5] and in the approach to another topics that spread by social contact like obesity or extreme behaviors [6,7].

This paper is organized as follows. In the next section the mathematical model is presented and the model parameters are estimated. Once the mathematical model is established Section 3 contains numerical simulations of the model with consumption predictions for the next few years. In Section 4, we present the economic cost estimations. Section 5 is devoted to the conclusions.

2. Mathematical model

2.1. Building the model

In this paper we assume the proposal showed in [8,9] and treat alcohol consumption as a disease that spreads by social

* Corresponding address: Instituto de Matemática Multidisciplinar, Edificio 8G, piso 2, Ciudad Politécnica de la Innovación, Universidad Politécnica de Valencia, 46022 Valencia, Spain.
E-mail address: franciscosantonja@hotmail.com (F.-J. Santonja).

0895-7177/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mcm.2010.02.029

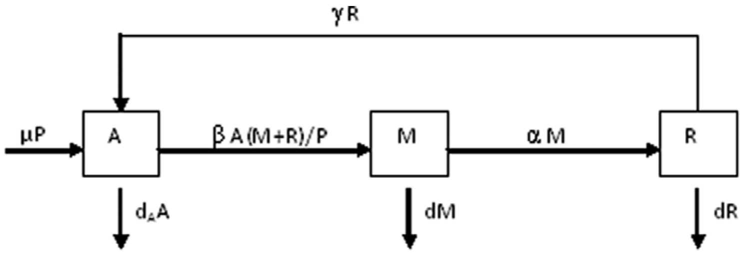

Fig. 1. Flow diagram of the mathematical model for the dynamics of alcohol consumption in Spain.

contact. We suppose that these contacts influence in the probability of transmission of the consumption habits. This fact leads us to propose an epidemiological-type model to study the epidemic evolution.

For model building, 15–64 years old Spanish population is divided into three subpopulations [10]:

- $A(t)$: Non-consumers, individuals that have never consumed alcohol or they infrequently have alcohol consumption.
- $M(t)$: Non-risk consumers, individuals with regular low consumption. To be precise, men who consume less than 50 cc of alcohol every day and women who consume less than 30 cc of alcohol every day.
- $R(t)$: Risk consumers, individuals with regular high consumption, i.e., men who consume more than 50 cc of alcohol every day and women who consume more than 30 cc of alcohol every day.

Furthermore, we consider the following assumptions:

1. We assume population homogeneous mixing. That is, each individual can contact with any other individual [11].
2. The transitions between the different subpopulations are determined as follows:
   - We consider that the new recruited 15 years old individuals become members of the $A(t)$ subpopulation.
   - Once an individual starts regular alcohol consumption he/she becomes a non-risk consumer, $M(t)$. If this person increases his/her consumption habit he/she can become a risk consumer, $R(t)$.
   - Individuals of subpopulation $R(t)$ becomes a member of subpopulation $A(t)$ if the alcohol consumption is reduced at an appropriate rate.
3. The transitions described above can be modeled as follows:
   - An individual in $A(t)$ transits to $M(t)$ because people in $M(t)$ or $R(t)$ transmit the alcohol consumption habit by social contact at rate β. Therefore, this is a nonlinear term modeled by $\beta A(t)(M(t) + R(t))/P(t)$. We consider $P(t) = A(t) + M(t) + R(t)$.
   - An individual in $M(t)$ transits to $R(t)$ at rate α proportionally to the size of $M(t)$ if his/her alcohol consumption increases. Hence, this is a linear term modeled by $\alpha M(t)$.
   - An individual in $R(t)$ transits to $A(t)$ when decides to give up the alcohol consumption and to go into therapy. An individual in $R(t)$ transits to $A(t)$ at rate γ proportionally to the size of $R(t)$. Hence, this is a linear term modeled by $\gamma R(t)$.

Under the above assumptions, dynamic alcohol consumption model for Spanish population is given by the following nonlinear system of ordinary differential equations:

$$A'(t) = \mu P(t) + \gamma R(t) - d_A A(t) - \beta A(t) \frac{[M(t) + R(t)]}{P(t)} \tag{1}$$

$$M'(t) = \beta A(t) \frac{[M(t) + R(t)]}{P(t)} - dM(t) - \alpha M(t) \tag{2}$$

$$R'(t) = \alpha M(t) - \gamma R(t) - dR(t) \tag{3}$$

$$P(t) = A(t) + M(t) + R(t) \tag{4}$$

where the constant parameters of the model are:

- μ, birth rate in Spain.
- γ, rate at which a risk consumer becomes a non-consumer.
- d_A, death rate in Spain.
- β, transmission rate due to social pressure to increase the alcohol consumption (family, friends, marketing, TV, etc.).
- d, augmented death rate due to alcohol consumption. Accidents at work, traffic accidents and diseases derived by alcohol consumption are considered.
- α, rate at which a non-risk consumer moves to the risk consumption subpopulation.

Fig. 1 shows the diagram for the dynamic alcohol consumption model. The boxes represent the subpopulations and the arrows represent the transitions between the subpopulations. Arrows are labeled by the parameters of the model.