Ways and Suggestions for Drivers to Avoid Risks After Drinking

Yingrui Zhang[1(✉)] and Jiang Qiuyan[2]

[1] School of Mathematical Sciences, Luoyang Normal University, Luoyang 471022, China
zhangyingruicn@126.com
[2] Library of Hunan Institute of Science and Technology, Yongzhou 425013, China

Abstract. Through the analysis of the problem of drinking and driving, and through the chamber model, it is concluded that if you drink three bottles of beer in a relatively short period of time, the alcohol content in your blood will reach the maximum after 1.2496 h, and it will be in line with the national standard after 18 h. If you drive every day and want to drink, you'd better drink in the evening and drink moderately.

Keywords: compartment model · pharmacokinetics · drinking and driving · ordinary differential equation

1 Introduction

According to the relevant knowledge of physiology, we know that alcohol will go through two stages after entering the human body:

(1) Rapid diffusion stage: alcohol is quickly absorbed by the blood after entering the intestines and stomach;
(2) Elimination stage: Most of the alcohol in the blood is converted into acetaldehyde by the liver, and then oxidized into acetic acid, which is oxidized into carbon dioxide and water when it enters the tissue, and at the same time releases a certain amount of heat. Among them, 5% to 10% of the alcohol in the blood is directly excreted with breath, sweat and urine [1].

2 Model Assumptions

(1) The alcohol content of each bottle of beer is the same;
(2) The blood volume of each person is the same;
(3) The rate of blood alcohol transfer from the gastrointestinal tract is directly proportional to the concentration of alcohol in the gastrointestinal tract;
(4) In the case of drinking for a long time, alcohol enters the body at a uniform rate during drinking [2].

M. F. b. Sedon et al. (Eds.): SSHA 2023, ASSEHR 752, pp. 661–664, 2023.
https://doi.org/10.2991/978-2-38476-062-6_84

Symbol description

V: Body fluid volume (ml);

$X(t)$: Moment t the amount of alcohol in the stomach (mg), ($m = 0$, i.e., that time to start drink), $X(0) = H$;

$C(t)$: Moment t the amount of alcohol in that body fluid (mg), $C(0) = 0$;

$D(t)$: Moment t alcohol concentration in body fluid ($mg/100$ ml);

$\gamma(t)$: Rate of transfer of alcohol to body fluids.

3 Model Establishment and Solution

Drinking a lot of alcohol is very harmful to the human body:

(1) liver damage: fat accumulation in the liver may cause fatty liver;
(2) gastric ulcer: excessive drinking can cause gastrorrhagia and even endanger life;
(3) nervous system damage: such as peripheral neuropathy;
(4) cerebral cortex atrophy;
(5) alcoholic fetal syndrome;

all these are harmful to the human body can not be underestimated.

Drinking alcohol for a short time is equivalent to a process of absorbing alcohol into the blood before it enters the ventricle. Based on the analysis of pharmacokinetics, we can decompose it into an absorption chamber and a central chamber [3].

If one drinks it quickly, A Milliliters of alcohol, assuming that the alcohol concentration in the body at the beginning is D, after drinking t The mass of alcohol in the absorption chamber at the moment is $x(t)$, that follow equation can be established [4]:

$$\begin{cases} \frac{dx(t)}{dt} = -kx(t) \\ x(0) = D \end{cases} \tag{1}$$

To solve this ordinary differential equation, we can obtain by separation of variables and integration:

$$\frac{dx(t)}{dt} = f(t) - mx(t) \tag{2}$$

Among:

$f(t)$ is the rate at which alcohol enters the central chamber.

$x(t)$ and blood concentration $c(t)$ atrioventricular volume V the following relationship exists:

$$x(t) = Vc(t)$$

Integrate and solve again to get

$$c(t) = \frac{kD}{V(m-k)}e^{-kt} + c(0)e^{-mt} \tag{3}$$

k, m, D, V It's all constant. So we can simplify it as follows:

$$c(t) = Ae^{-kt} - Be^{-mt} \tag{4}$$

The data were fitted by MAILAB programming. A, k The values of are: $A = 190.1285$, $k = 0.2316$ then:

$$c(t) = 190.1285e^{-0.2316t}$$

Similar available the values of B, m are respectively $B = 130.4252$, $m = 0.4775$ So you can get the blood alcohol content and time when you drink three bottles of wine quickly. The relationship of t is:

$$c(t) = 190.1285e^{-0.2316t} - 130.4252e^{-0.4775t} \tag{5}$$

It is calculated that if the alcohol is drunk in a very short time, the blood alcohol content in the seventeenth hour is 20.5031 mg/100 ml, greater than 20 mg/100 ml still exceeding the state standard for driving under the influence; the blood-alcohol level was 18.7591 mg/100 ml at the 18th hour, meet the national standards for drinking and driving.

If the alcohol is consumed over a long period of time (say, three hours), the process is similar to a constant rate of intravenous infusion [5], and here we assume that the alcohol in the blood enters the central chamber over a long period of time and at a constant rate of $f(t) = k$, and assume $c(0) = 0$.

Then it can be obtained from the differential equation:

$$c(t) = \frac{f(t)}{Vm}\left(1 - e^{-mt}\right) \tag{6}$$

It can be seen from the assumption that: $f(t-3) = 0$.

Further solving the differential equation, we can get:

$$c(t-3) = \frac{f(t)}{Vm}e^{-m(t-3)} \tag{7}$$

Therefore, in the case of drinking three bottles of beer or half a kilogram of liquor over a long period of time (such as three hours), the relationship between alcohol content and time is as follows:

$$c(t) = \begin{cases} \frac{f(t)}{Vm}\left(1 - e^{-mt}\right) & (0 < t \le 3) \\ \frac{f(t)}{Vm}\left(1 - e^{-3m}\right)e^{-m(t-3)} & (t > 3) \end{cases} \tag{8}$$

Then the data can be fitted by MAILAB programming:

$$c(t) = \begin{cases} 217.04\left(1 - e^{-0.231t}\right) & (0 < t \le 3) \\ 217.04\left(1 - e^{-3m}\right)e^{-0.2316(t-3)} & (t > 3) \end{cases} \tag{9}$$

Calculations are available $c(16) = 20.5312 > 20$ at this time, it exceeds the national standard of drinking and driving. $c(17) = 18.7838 < 20$ at this time, it meets the national standard, so if you drink three bottles of beer for a long time (such as within three hours), you need to drive after 17 h to meet the national standard for drinking and driving.

References

1. Jiang Qiyuan. Mathematical Model [M], Beijing: Higher Education Press, 2013.
2. Zhou Zhe, He Yan. Medical Mathematics Experiment [M]. Beijing: Science Press, 2011.
3. Duan Shiming. Drug metabolism and pharmacokinetics of intravenous drugs [M]. Beijing: People's Medical Publishing House, 2010.
4. Lei Tianli, Yang Shenghong. Mathematical model of blood alcohol concentration change [J], Science and Technology Economic Market, 2016, 7, 35-36.
5. Ji Huifang, Xie Lin, Wang Jian. Determination of olanzapine in human plasma and its pharmacokinetics [J]. Journal of China Pharmaceutical University, 2012, 33 (5): 397–400.