Alcohol and Your Body

Student Materials: Reading Assignment

Introduction

Drinking has been a widely accepted part of western culture for generations. In our society, it is associated with social occasion from weddings to wakes. For many people, moderate drinking enhances the quality of social interactions as well as fine meals.

Nevertheless, misuse of alcohol in this country exacts a heavy toll on society. It has been estimated that the abuse of alcohol in the United States costs us in excess of 100 billion dollars a year in lost wages and medical care. The personal costs in terms of emotional pain and destroyed relationships cannot be calculated. Alcohol has been demonstrated to be a contributing factor in 40% to 55% of all alcohol related traffic fatalities, 50% of homicides, and 30% of suicides every year.

Although numbers vary, it has been estimated that one out of every eight adults who drink will develop the disease of alcoholism. Until very recently, this number was estimated to be one in 10. What is becoming even clearer is that there is a very large number of individuals who abuse alcohol on a regular basis who do not meet the traditional criteria for alcoholism but are clearly problem drinkers. According to one recent estimate, 20% of American adults are problem drinkers. Another study estimates that there are 40 million problem drinkers in the United States.

In spite of the well publicized risks and costs of drinking in our society, the vast majority of Americans choose to drink alcohol on a fairly regular basis. As we are all aware, the misuse of alcohol cannot be attributed solely to alcoholics or problem drinkers. Although public campaigns by Mothers Against Drunk Driving, Students Against Drunk Driving, Sober Ride, and designated driver awareness have all helped reduce the incidence of alcohol related driving fatalities, it is very clear that drinking and driving continues to be a major problem in our society. Recent estimates suggest that one out of every two Americans is likely to be involved in an alcohol related accident at some point in their life. It goes without saying that one does not have to be an alcoholic in order to get into trouble with drinking and driving. In fact, there is some evidence to suggest that social drinkers are more likely to get into trouble with drinking and driving on the rare occasion when they might exceed a reasonable alcohol consumption level. This increased risk has been attributed to the fact that social drinkers typically have a lower tolerance for alcohol than problem drinkers and alcoholics, and are thus more likely to be impaired at fairly low blood alcohol levels.

The Biology

In recent years there has been a considerable amount of scientific research on the effects of alcohol on memory, reflexes, coordination, depth perception and a host of other

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cognitive and psychomotor processes. In these studies, as well as in the legal arena, blood alcohol levels are presented as a percentage of alcohol per volume of blood.

A blood alcohol level (BAC) of 0.10 is defined as 1 gram per kg of blood, meaning that alcohol is 0.10% or one one-thousandth of the blood. There is now a considerable amount of research which has demonstrated that significant impairment in reflexes, depth perception, and reaction time occur with BACs as low as 0.05. While many states have set 0.10 as the cut-off for the legal definition of Driving While Intoxicated (DWI), this research has in part influenced a national movement to reduce the BAC level for a DWI from 0.10 to 0.08. A person weighing 150 pounds with 34 grams of alcohol in the body, the amount of alcohol from two and a half beers, would have an 0.08 BAC. The same person with 210 grams of alcohol in the body would have an 0.50 BAC and would be at risk of going into a coma or even dying.

It has also been demonstrated that the probability of being involved in an alcohol related accident increases dramatically as the BAC increases. It has been estimated that an individual with a BAC between 0.10 and 0.14 is 48 times more likely to be involved in a motor vehicle accident than an individual who has not been drinking.

The BAC of an individual is determined by three primary factors which include body weight, amount of alcohol consumed, and the amount of elapsed time from the first drink until a breath and/or blood sample is taken. As an example, a 180 pound man who consumes seven drinks over a three hour period of time will have a BAC of around 0.10. In contrast, a 110 pound man who consumes the same seven beers over three hours will have a BAC of around 0.20. One drink, which is defined as one ounce of liquor, five ounces of wine or one 12 ounce beer, consists of approximately 14 grams of alcohol.

Alcohol is absorbed into the body primarily through the lining of the stomach. For this reason, a BAC peak is usually reached within 20 minutes of the last drink.

Our bodies deal with chemicals in the blood stream mainly via two key processes. The first is elimination by the kidneys. The second is the breakdown of chemicals by enzymes from the liver.

When the kidneys eliminate a chemical, they tend to eliminate a certain proportion each time period. For example, the average person eliminates about 13% of the caffeine in his or her body each hour. Thus, if the person has 100 mg of caffeine in the body (about the amount from one cup of coffee), then the body will eliminate 13 mg over the next hour. If the person has 200 mg in the body, about 26 mg will be eliminated. Where a is the amount of caffeine in the person's body at the beginning of an hour and y is the amount of caffeine eliminated during the next hour,

$$y = 0.13a.$$

The percent of caffeine removed from a person's body per hour can vary greatly from person to person. The number we used, 13%, is an average.

The liver eliminates chemicals by breaking them down with enzymes. However, the liver may not break down a constant proportion each hour. Instead, the percent of the chemical being broken down can depend on the amount of the chemical that is in the body, as is the case for alcohol. What happens is that as the amount of alcohol in the body increases, the proportion of the alcohol the body can deal with (eliminate) decreases. For alcohol, the **proportion** p of the alcohol broken down in a given hour is approximated by the formula

$$p = \frac{10}{4.2 + a}$$

where a is the number of grams of alcohol in the body at the beginning of the hour. This is an example of what is called **capacity-limited metabolism**, in which the amount of the chemical metabolized depends on the amount of the chemical in the body. (Note that this formula is an average. For any individual person, the numbers 10 and 4.2 may vary considerably.)

1. Find the proportion of alcohol eliminated from the body during the next hour if there are 14, 28, and 42 grams of alcohol in the body at the beginning of the hour. (One drink consists of approximately 14 grams of alcohol.)

2. The function

$$p = \frac{10}{4.2 + a}$$

is only approximate and can be used only for a-values within a certain range. For example, if a person weighing 150 pounds (about 70 kg.) has more than 210 grams of alcohol, the person could die; thus, the body would no longer eliminate alcohol. As another example, if $a = 0.8$ grams, then $p = 2$, meaning the proportion of alcohol eliminated would be 200%. But the body cannot eliminate more alcohol than there is. For what amount of alcohol, would the body eliminate 100%? (The formula is only useful for a-values above this number.)

3. Graph the function p. What does the graph say about the proportion of alcohol eliminated when a, the amount of alcohol in the body, is relatively large? How does this relate to the horizontal asymptote for this function? Use TRACE to estimate for which a-values the body would eliminate less than 10% of the alcohol per hour.

Alcohol and Your Body
Classroom materials, part 1

The Process of Elimination

To answer the following questions, you will need the information in the "Alcohol and Your Body" Reading Assignment.

Let a represent the amount of alcohol in the body at the beginning of an hour. Let y represent the amount of alcohol eliminated from the body during that hour. To find the **amount** of alcohol eliminated during that hour, multiply the proportion eliminated by the amount in the body at the beginning of the hour, giving the formula

$$y = p\,a = \left(\frac{10}{4.2 + a}\right)a \qquad \text{or} \qquad y = \frac{10a}{4.2 + a}.$$

For example, suppose someone has 50 grams of alcohol in their body at 8:00 p.m. Then, during the next hour, their body will eliminate

$$y = \frac{10 \times 50}{4.2 + 50} = 9.2$$

grams of alcohol from their body. So at 9:00 p.m., they would have $50 - 9.2 = 40.8$ grams of alcohol in their body. During the next hour, their body would eliminate

$$y = \frac{10 \times 40.8}{4.2 + 40.8} = 9.1$$

grams of alcohol from their body. So at 10:00 p.m., they would still have $40.8 - 9.1 = 31.7$ grams of alcohol in their body.

4. How much alcohol is eliminated during an hour if the body began with 14, 28, and 42 grams? Compare your results to the results of problem 1. This demonstrates that as the amount of alcohol, a, in the body goes up (from 14 to 28 to 42 grams), the proportion, p, of alcohol eliminated decreases, but the actual amount of alcohol eliminated, y, increases.

5. Graph the function y and find its horizontal asymptote, both graphically and algebraically. What does this asymptote say about the amount of alcohol eliminated from the body for someone with a large amount a of alcohol already in the body?

6. Suppose a 150 pound man has 160 grams of alcohol in his body. Use your knowledge of the asymptote to the function

$$y = \frac{10a}{4.2 + a}$$

to **estimate** how long he should wait before driving. Remember that 34 grams of alcohol in his body gives a BAC of 0.08. Is this estimate an underestimate or overestimate and why? (Hint: Look at the graph and the asymptote.)

The main result of this horizontal asymptote is to imply that for some chemicals, such as alcohol, the body eliminates a **constant amount** each hour, at least when the levels, a, are reasonably large. This is in contrast to other chemicals, such as caffeine, in which the body eliminates a **constant proportion** each hour.

It should be pointed out that recent research demonstrates that the rate at which alcohol is processed differs for men and women. It has been determined that women have fewer enzymes to break down alcohol and typically a lower percentage of body fat. This means that the function y for amount of alcohol eliminated is approximately accurate only for men. The correct function for women would have an even smaller horizontal asymptote, meaning that if a man and a woman are the same weight and drink the same amount, the woman will have more alcohol in her body and it will take her longer to eliminate the alcohol from her body.

Given all of the information we have regarding the dangers of alcohol, what can one do to be a responsible drinker? Moderation for social drinkers is the key. We know from the horizontal asymptote that the body oxidizes approximately ten grams of pure alcohol per hour. Once an individual becomes intoxicated, the only significant factor in becoming sober is <u>time</u>. The old myths about taking a cold shower or drinking black coffee are dangerous. While they may prevent a drunk person from falling asleep at the wheel, they will not improve reflexes, depth perception, or judgment.

Designated drivers, the use of public transportation, hosting responsible parties, and moderation all will help insure the safe use of alcohol. For individuals who have crossed the line into problem drinking or alcoholism, total abstinence is the only reasonable alternative.

Alcohol and Your Body
Classroom materials, part 2

Equilibrium

Suppose a person is periodically ingesting some amount of a chemical, such as alcohol or caffeine. During each time period, the body is also eliminating some amount. If the body eliminates more than the person consumes during some time period, then the amount of that chemical in the body drops. If the body eliminates less than the person consumes, then the amount of the chemical in the body increases.

Sometimes a person consumes exactly the amount that the body eliminates during a time period. In this case, we say that the amount of the chemical in the body is at **equilibrium**. This means that the amount of the chemical, alcohol in this study, in the body remains constant.

Recall that a represents the amount of alcohol in the body at the beginning of an hour and

$$y = \frac{10a}{4.2 + a}$$

represents the amount of alcohol **eliminated** from the body during that hour. We will now deal with the situation in which a person continues to drink. Let d represent the amount this person drinks each hour. Thus, the amount of alcohol in the body would be at equilibrium if

$$\text{the amount consumed} = \text{the amount eliminated}$$

or

$$d = \frac{10a}{4.2 + a}.$$

7. Solve for a as a function of d, the number of grams of alcohol being consumed each hour. This function gives the equilibrium amount of alcohol in a person's body if they continue to drink d grams of alcohol each hour. It may take some time for this person's body to reach the equilibrium amount.

For the following problems, you might use the information that a person weighing 150 pounds 1) usually first feels the effects of alcohol when they have 10 grams in the body, 2) is considered intoxicated with 34 grams of alcohol, and 3) is at risk of dying with 210 grams of alcohol.

8. Find the equilibrium amount of alcohol in the body when a person drinks 7 grams of alcohol (about one-half of a beer) each hour. What can you say about this person's level of intoxication over an extended period of time if the person weighs 150 pounds?

9. Find the amount a of alcohol in the body at equilibrium when a person drinks 9, 9.5, and 9.9 grams of alcohol each hour. What can you say about the level of intoxication over an extended period of time for each of these three drinking rates?

10. Graph the function for a in terms of d. Where is its vertical asymptote and what does it say about a person's level of intoxication?

Your graph should show that for d greater than the vertical asymptote, the a-value is negative. There is no positive equilibrium value if a person drinks more than a certain amount each hour. Instead, the amount of alcohol in this person's system would continue to increase until they stopped drinking or went into a coma. In your group, discuss this result in relation to the fact that the standard drink (one beer, one glass of wine, or one mixed drink) contains 14 grams of alcohol.

11. From the formula, compute the number of grams of alcohol consumed per hour that achieves an equilibrium level of alcohol of:

a. $a = 140$ grams.

b. $a = 210$ grams. (At this level, there is risk of death for a person weighing 150 pounds.)

You should have found in problem 11 that the difference between the amount of alcohol consumed per hour that achieves a high level of intoxication and the amount that puts this 150 pound person at risk of death is about one tenth of one gram of alcohol, the amount of alcohol in half of a teaspoon of beer. This means that when the consumption level d is near the vertical asymptote, small changes in d result in **large** changes in the equilibrium amount in your body. Because of other factors, such as variable sizes of drinks and variability in the human body that cause the numbers 10 and 4.2 in the formula to be only approximate, it is impossible to consume a fixed amount of alcohol per hour to achieve an equilibrium level of alcohol in the body that maintains a moderate to high level of intoxication. The following problem gives another demonstration of this fact.

12. Someone, preferring stupor to awareness, decides to try to achieve an equilibrium level of 80 grams of alcohol in the body. They use the formula

$$d = \frac{10a}{4.2 + a}$$

to find that they should consume $d = 9.5$ grams of alcohol per hour. Recall that this formula may vary from person to person. For example, the 10 in the numerator might be 9 or 11 or some other number "reasonably" close to 10. Suppose that in reality, the formula for the person in this problem is actually

$$d = \frac{9.6a}{4.2 + a}.$$

What is the true equilibrium level of alcohol in this person's body, given the consumption rate of $d = 9.5$ grams per hour? Is this person at risk of dying?

For more information on problems related to alcohol consumption, we recommend **Under the Influence**, by James Milam.

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