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Expanding the Model: Would it be Possible to Consume Enough Low-Alcoholic Beer to Reach the UK Legal Driving Limit?

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Abstract
In a previous paper it was found that 51 litres or 115 cans of low-alcoholic beer would be required to reach the UK legal alcohol limit for drivers [1]. However, the model employed was too simple. This paper explores whether it would be possible to consume the volume required by considering the rate of metabolism of alcohol to determine what volume would be required to reach the limit and maintain it within 1 hour. This was found to ~53 litres, which is more than 25 times larger than the average drinking speed of an average UK male.

Introduction
In order to be classified as non-alcoholic beer in the UK, the beer must have a %ABV less than 0.05% [2]. As a consequence the small amount of alcohol makes it theoretically possible to reach the UK alcohol limit for drivers, defined at 80mg of ethanol per 100 ml of blood [3].

A previous paper used a simple model to determine the volume of non-alcoholic beer required to do this and was found to be 51 litres [1]. However this model was too simple as it did not account for many variables involved in determining the blood-alcohol content, such as the rate at which alcohol gets metabolised and the capacity of the gastrointestinal tract (GI tract).

This paper explores the effect of alcohol metabolism on the model used by Chandla and Harwood in their previous work [1].

Alcohol Metabolism
There are various catabolic mechanisms employed by the liver to remove ethanol from the blood. The two main pathways under which this occurs however are the alcohol dehydrogenase pathways and the cytochrome P450 pathway (CYP2E1) [4].

The alcohol dehydrogenase pathway utilises two main groups of enzymes, the alcohol dehydrogenases; which catalyse the oxidation of alcohol to acetaldehydes, and the aldehyde dehydrogenases; which catalyse oxidation of acetaldehyde to acetate, a carboxylic acid. These carboxylic acids can be further metabolised at other sites within the body.

The cytochrome P450 family of enzymes are involved in the deactivation of many drugs in the liver. The CYP2E1 is a specific member of this family that facilitates the metabolism of alcohol using a similar mechanism to the alcohol dehydrogenase system.

The CYP2E1 enzyme plays an important role in alcohol tolerance, and those found to be deficient, such as many in East Asian populations can have difficulties in metabolising alcohol. Increased exposure to alcohol usually increases the availability of this enzyme [5, 6].

It is known that the rate at which the liver can metabolise alcohol is 1 unit of alcohol per hour. 1 unit of alcohol is the equivalent of 10ml of ethanol consumed. Using the density of ethanol, 789 kgm^{-3} [4], the mass eliminated per hour can be determined:

$$Mass = Density \times Volume$$

$$Mass = 789 \times (1.0 \times 10^{5})$$

$$Mass = 7.89 \times 10^{-3}\ kg$$

The rate at which alcohol is eliminated from the blood is 7.89 g hour^{-1} or 789 mg hour^{-1}.

Model with Alcohol Metabolism

Expanding the model to include the rate at which alcohol is metabolised by the body allows the rate at which the volume of non-alcoholic beer needs to be consumed in order to reach the legal driving limit in the UK.

In the previous paper it was found that 20,000 mg of ethanol were required to reach the UK legal driving limit, in terms of ethanol concentration in the blood. This was based on values for an average 75 kg male [1, 7].

Using this value, and the calculated rate of alcohol elimination the rate at which the non-alcoholic beer needs to be consumed can be calculated. The time taken to consume the volume of non-alcoholic beer is important due to the constant elimination of alcohol from the blood. For this model it is assumed the limit must be reached by the consumption of non-alcoholic beer within 1 hour.

The minimum rate of ethanol consumption per hour is given by:

$$20000 = M_{ethanol} + 789,$$

where $M_{ethanol}$ is the mass of ethanol in mg. This results in requiring a net consumption of 20789 mg of ethanol per hour.

Using calculations from the previous paper [1], this is equivalent to 52697 ml of non-alcoholic beer per hour. This would be the volume of beer required in order to reach the UK driving limit within an hour and subsequently maintain it, if this rate of drinking continued.

Comparing this to the average drinking speed of a 75 kg male, 1948.32 ml per hour, based on 1 pint every 17.5 minutes [8], shows that it is not possible to consume this volume of non-alcoholic beer in such a time frame that the concentration of ethanol ever reaches 80 mg per 100 ml of blood.

Conclusion

Expanding the model presented in [1] gives a larger volume of non-alcoholic beer required to be consumed at ~53 litres per hour. This occurs in order to combat the effects of catabolic processes removing alcohol from the body.

Comparing this to the average rate of drinking by an average 75 kg UK male shows that it is not possible to reach the UK legal limit for drivers as the required rate is more than 25 times as large.

References

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