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The Clinical Effects of Consuming Enough Low-Alcoholic Beer to Reach the UK Legal Driving Limit

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Abstract
51 litres or 115 cans of low-alcoholic beer would be required to reach the UK legal alcohol limit for drivers [1]. This paper explores the physiological and potential pathophysiological effects of consuming such a volume with respect to Na^+, by modelling the non-alcoholic beer as a solution of ethanol in deionised water. It is found that consuming such a volume would cause serum Na^+ to drop to 13.21 mEq/L. This is classified as severe hyponatraemia, with the most likely consequence being death.

Introduction

In the UK non-alcoholic beer is defined to be any beer that has a %ABV of alcohol of less than 0.05%. As there is a small amount of alcohol present within these beverages, it is theoretically possible to reach the UK alcohol limit for drivers, which is defined as 80 mg of ethanol per 100 ml of blood [2].

In a previous paper, a simple model was used to determine the volume of non-alcoholic beer that was required to be consumed to reach the UK legal driving limit [1]. This was found to be 51 litres.

This paper explores the physiological and potential pathophysiological effect of consuming such a large volume of non-alcoholic beer by considering normal fluid balance and the concentration of Na^+ ions within the blood.

Fluid Balance

Fluid balance is the homeostatic process that maintains the volume of fluid in the human body. This is done by balancing fluid inputs and output into the body using a tightly regulated system, controlled primarily by the renal system.

The main source of fluid input into the body is through drinking, a process dependent on thirst. This response is triggered when an increased extracellular fluid osmolarity is detected by osmoreceptors within the supraoptic crest of the brain. Thirst enables humans to engage in the voluntary activity of consuming fluid [3].

Fluid output systems in the body include through urine, perspiration and faeces. The control of these output systems is more complex, as it relies on the actions of Anti-diuretic Hormone (ADH) and the Renin-Angiotensin-Aldosterone system (RAAS) [3].

An increase in ADH occurs during fluid deficiency, and is triggered by the same receptors that activate thirst. ADH is produced in the posterior pituitary gland but has its main effects in the kidneys, where it acts to increase water retention [3].

Activation of RAAS causes the distal convoluted tubules (DCT) and cortical collecting ducts (CCD) to reabsorb water and Na^+ from the urine, by secreting K^+ into the tubules in order to reabsorb the sodium ions [3].

Model

In order to determine the effect of consuming such a large volume of non-alcoholic beer on the serum Na^+ concentration, assumptions need to be made. These assumptions are that every 330 ml bottle of non-alcoholic beer contains 6 mg of Na^+ [4] and as the beer is being absorbed into the blood the volume and Na^+ concentration are allowed to reach equilibrium, with the movement of the volume of beer and Na^+ ions occurs via diffusion.

Typically in a clinical setting the serum Na^+ levels are determined using sodium blood tests, with the concentration of Na^+ typically given in the units of mEq/L. An Equivalent (*Eq*) is defined as the amount of a substance required to supply 1 mole of electrons in a redox reaction [5]. As sodium is univalent, this equates to the number of moles of sodium, and can thus be converted into a mass of Na^+ through the use of the equation:

$$Mass = Moles \times Molar\ Mass$$

The consequence of this is that the mEq/L can be converted into the units of mg/ml, the units used in this model.

The normal reference range for serum sodium levels is 135–145 mEq/L, this equates to 3.105 to 3.335 mg/ml [3]. For the purpose of this model, the normal serum Na^+ concentration is taken as the midpoint of this range, 140 mEq/L or 3.22 mg/ml.

The concentration of Na^+ in non-alcoholic beer is 0.018 mg/ml. Assuming the volume of blood circulating in an average 75 kg male is 5 L, the following equation can be used to determine the serum Na^+ concentration once the blood and beer in the intestines reach equilibrium:

$$V_{beer}[Na^+]_{beer} + V_{blood}[Na^+]_{blood} = V_{Eq}[Na^+]_{Eq}$$

As the volume of fluid on either side of the endothelium and the concentration of Na^+ is the same the total volume can be used as V_{Eq}.

Evaluating this equation gives:

$$(51000 \times 0.018) + (5000 \times 3.22) = V_{Eq}[Na^+]_{Eq}$$

$$V_{Eq}[Na^+]_{Eq} = 56000 \times [Na^+]_{Eq} = 17027.27$$

$$[Na^+]_{Eq} = \frac{17027.27}{56000}$$

$$[Na^+]_{Eq} = 0.304\ mg/ml$$

To put this concentration into context it can be converted back to the units of mEq/L in order to be classified. This results in a serum Na^+ concentration of 13.21 mEq/L.

Severe hyponatraemia is defined as a serum Na^+ level below 120 mEq/L, which would define the serum Na^+ in this case. As the pathophysiological process in this case would be acute, the most probable presentation of a patient who had attempted this would be with convulsions.

Hyponatraemia

Hyponatraemia is defined as a serum Na^+ below the normal reference range (135–145 mEq/L). It can be further classified by the severity of the condition.

This classification is based upon the Na^+ concentration, with 'mild' hyponatraemia within the range of 130–135 mEq/L, 'moderate' at between 125 and 129 mEq/L and 'profound' or 'severe' at below 125 mEq/L [6].

There are a range of symptoms associated with this condition, which include nausea, headaches lethargy and decreased levels of consciousness [6]. In severe cases these symptoms also include seizures and coma.

Very low serum Na^+, considered to be < 115 mEq/L is also associated with neurological symptoms and brain oedema, due to the changes in osmolarity in blood and intracranial fluid [6]. Acute cases with serum Na^+ below this level has potential to cause death in patients [7].

Conclusion

Using the model outlined above, consuming the 51 L of non-alcoholic beer required to reach the UK legal driving limit would cause rapid depletion of serum Na^+, from a concentration of ~140 mEq/L to 13.21 mEq/L. This serum Na+ concentration would be considered to be severe hyponatraemia, and would be fatal.

References

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