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## Association between alcohol consumption and overweight in adults: brief notes on biological plausibility

Luís Paulo Souza e Souza <sup>1,\*</sup> and Silas Augusto Marquito Rocha <sup>2</sup>

<sup>1</sup> *Department of Medicine, Federal University of Amazonas, Brazil.*

<sup>2</sup> *Department of Medicine, Faculty of São Carlos Metropolitan, Brazil.*

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### Abstract

Authors debate that alcohol would be a food, providing calories to those who consume it. And when this consumption is exacerbated, there is a risk of weight gain. When assessing the risk factors for being overweight, especially in the consumption of alcoholic beverages, studies have shown positive, negative, and null associations. In this text, we sought to discuss the evidence of the association between alcohol consumption and overweight in adults. From the analysis, the studies observed the effect of alcohol on both metabolic pathways and the modulation of neurotransmitters that regulate appetite and hunger. The literature has pointed out that light to moderate consumption would not be a risk factor for being overweight, but only excessive consumption would be related. Authors emphasize that people who consume alcohol in a mild to moderate way have better lifestyle habits involving physical exercise and healthier food intake. Thus, they could present better protection against weight gain. Because obesity and overweight are multifactorial diseases, it is difficult to investigate the independent influence of alcohol consumption on the risk of these diseases. It reinforces the importance of studies that analyze and advance in the understanding of the relationship between alcohol consumption and overweight, especially by evaluating the total volume consumed, consumption patterns, and types of drinks so that the results support the creation of strategies for health promotion, prevention and control of these diseases among the population.

**Keywords:** Alcoholic beverages; Overweight; Obesity; Epidemiology; Health Surveillance.

### 1. Introduction

In recent years, many studies have emerged on the consumption of alcoholic beverages and, despite the scientific interest related to the effects on the central nervous system, it is important to reinforce that alcohol provides calories because of the natural process resulting from the fermentation of foods containing sugar. Thus, it can be considered a nutrient [1].

When studies assess the risk factors for being overweight, they evidence the excess food intake, low frequency of physical activity, and the use of substances such as alcohol and tobacco. Especially regarding the consumption of alcoholic beverages, the data from the studies are positively, negatively, or not at all associated [2-5].

However, when considering that one (01) gram of alcohol provides, on average, 7.1 kilocalories (kcal), this substance has energy value and, therefore, can meet the daily caloric needs of an individual or lead him to excess weight, depending on the amount, frequency and mode of consumption [1, 5-6].

\* Corresponding author: Luís Paulo Souza e Souza

Scholars debate that the energy consumed in alcohol is additive to other dietary sources and that the increase in energy intake with the consumption of alcoholic substances can probably promote a positive energy balance and thus favor weight gain [4-12]

A study by Yeomans [6], which investigated alcohol intake as a risk factor for the development of obesity, found that the analyzed research showed that the energy consumed in the form of alcohol is additive to that of other dietary sources, leading to excess short-term passive energy consumption. Alcohol consumed before or with meals tends to increase food intake, probably by increasing the short-term rewarding effects of food. These findings were found in the short-term studies based in laboratories on the effects of alcohol on appetite and energy balance. When analyzing long-term epidemiological studies, Yeomans [6] found that moderate alcohol intake may protect against obesity, particularly in women. However, when alcohol is consumed in excess (without considering alcohol dependence), there is an increased risk of obesity.

Considering articles published between 1984 and 2010, the authors of another systematic review study observed contradictory findings. The global analysis did not clearly confirm the positive association between alcohol consumption and weight gain. However, when this consumption was in excess, the positive association remained. Also, according to the authors, the research showed that individuals who drank more intensely or heavily had a higher proportion of obesity concerning those who drank lightly or moderately. Research has also shown that light to moderate consumption can sometimes protect against weight gain, especially when the drink consumed is the wine [5].

In turn, Traversy and Chaput [4], in an updated article, showed that in the analysis of research on this relationship, prospective studies showed that light to moderate alcohol intake did not remain associated with weight gain, but excessive consumption maintained a positive association. Experimental studies found the same data. However, the authors reinforce that it is necessary to consider that some characteristics of individuals may make them more prone to weight gain in the face of alcohol use. Those people who consume in a mild to moderate way, for example, tend to have better life habits, in general, which favors protection against obesity [4].

An article from a comprehensive review study that included systematic reviews, meta-analyses, observational studies, randomized clinical trials, and experimental research found that the consumption of alcoholic beverages can favor overweight and obesity, since there is an increase in energy consumed in liquid form [11]. Alcohol has more energy per gram than protein or carbohydrates. For the author, the total energy content of a drink varies depending on the form in which it is presented. Basically, they are separated into three groups: fermented beers and cider, fermented wine, and distilled spirits. In this way, the alcohol content by volume varies, as does the total energy content [11].

Authors debate that it is important to worry about alcohol consumption in conjunction with overweight or obesity, as there is a risk of developing liver disease, although the literature is not yet fully consistent. A systematic review study showed that the combination of high alcohol consumption and being overweight may be associated with a significantly increased risk of chronic liver disease, reinforcing that the risk increases with body mass index (BMI) greater than 25 and alcohol consumption greater than 14 units/112 grams per week [13].

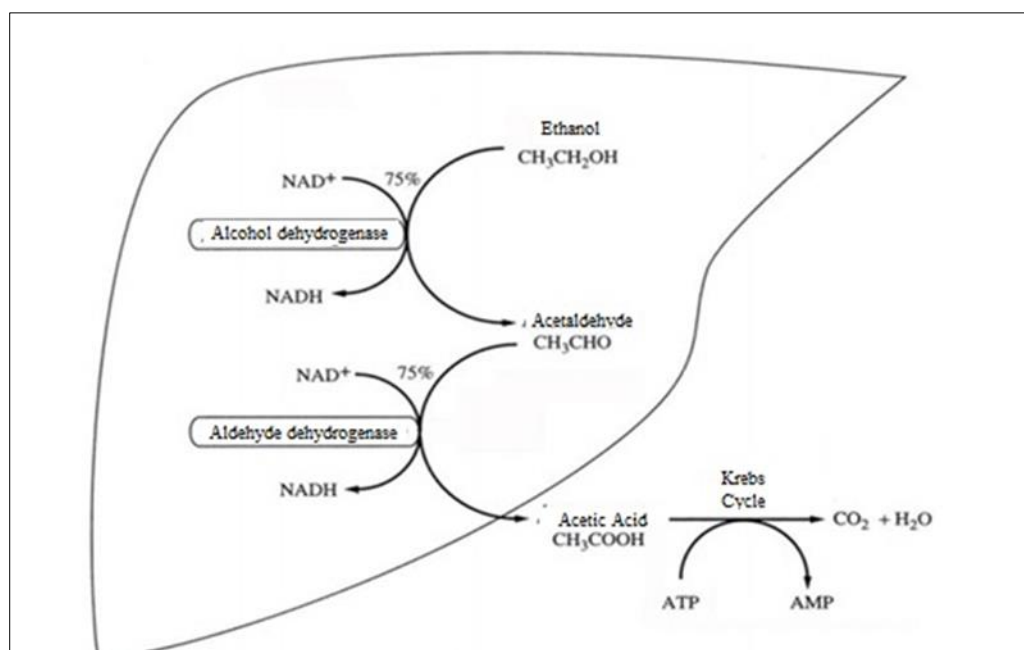
Before moving forward, it is worth mentioning what would be the "standard dose" of alcohol consumed, which is the unit of measurement that defines the amount of pure ethanol contained in alcoholic beverages. In general, a standard dose is equivalent to the same amount of alcohol, corresponding to larger or smaller volumes, depending on the alcohol content of the drinks. Although there is no international consensus on the exact size of a dose of alcoholic beverage, the World Health Organization (WHO) recommends that a standard dose contains approximately 10 grams (g) of pure alcohol, but recognizes that this definition differs between countries [14].

Thus, in this article, we sought to discuss the evidence on the association between alcohol consumption and overweight in adults, bringing the findings of different types of studies, in addition to discussing the biological plausibility of the relationship between these two outcomes.

### **1.1. Alcohol metabolism and weight gain**

Because it is a toxic substance, alcohol becomes an energy source different from all others since it needs to be eliminated as quickly as possible. In this way, alcohol has priority in metabolism, altering other metabolic pathways [1]. After being ingested, alcohol is absorbed by the stomach and then the intestine (on average, 75% is absorbed by the small intestine; the rest is absorbed by the mucosa of the mouth, esophagus, stomach and large intestine) [11].

The liver is the organ that is subject to higher concentrations since it receives the ethanol absorbed by the stomach and intestine, and it is in it that most of the metabolization of this substance occurs. The metabolic breakdown of alcohol in the liver occurs mainly by the activity of two enzymes: alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH) (Figure 1).



Source: Translated and adapted from Julien [17].

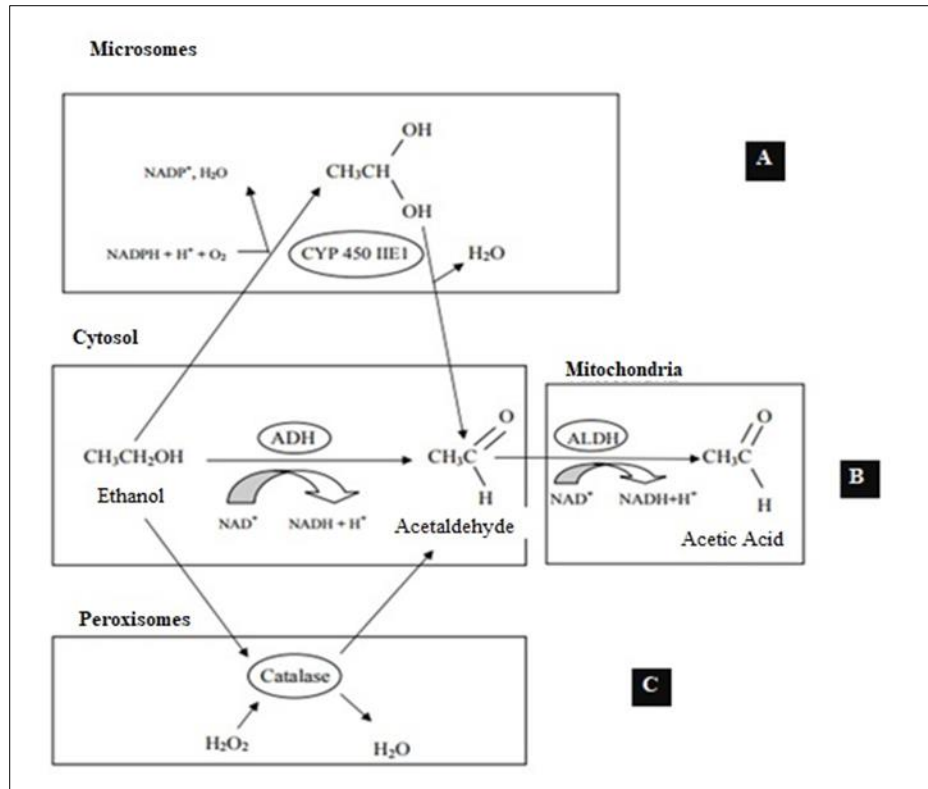
**Figure 1** Metabolism of ethanol in the liver using the main enzymes: alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH).

In the first phase, the ADH enzyme converts alcohol to acetaldehyde, using nicotinamide adenine dinucleotide (NAD) as a hydrogen acceptor, which is reduced to NADH. This reaction provides a high energy content from NADH, generating 16 adenosine triphosphate (ATP)/mol of ethanol via oxidative phosphorylation. The acetaldehyde converted by ADH is a very reactive and highly toxic compound. However, its concentration in the body is minimal as it is quickly transformed into acetic acid by ALDH, which passes into the bloodstream and can be taken up by cells to be combined with coenzyme A, originating the acetyl-coenzyme A. Subsequently, it enters the citric acid cycle (Krebs' circle) to be oxidized, forming  $\text{CO}_2$  (eliminated in respiration),  $\text{H}_2\text{O}$  (eliminated in urine), and energy. In social drinkers, because they consume light to moderate amounts, there is greater availability of NAD since it will not be necessary to be captured to be converted into NADH [15-16].

On the other hand, in excessive drinkers and chronic alcoholics, in which ADH activity can be blocked, the metabolization pathway is the mitochondrial ethanol oxidizing system (MEOS). This pathway is in the smooth endoplasmic reticulum of hepatocytes and uses cytochrome P-450, NADPH-cytochrome reductase, and phospholipids, having as hydrogen acceptor NADP (Scheme A of Figure 2). However, in this pathway, there is energy expenditure in the form of ATP and use of oxygen and NADPH (nicotinamide adenine dinucleotide phosphate) in its reduced form, not generating energy-forming components such as NADH [1, 8, 16]. Another pathway used in heavy drinkers and chronic alcoholics is the catalase pathway (Diagram C of Figure 2), which has small participation in the process since it metabolizes only 10% of the alcohol ingested. And like the MEOS pathway, it does not generate ATP [18].

The three ways present (Schemes A, B, and C of Figure 2), as a product, the acetaldehyde, which will be oxidized into acetate or acetic acid and water by an enzyme that is present in the matrix and in the outer mitochondrial membrane, in the microsome and in the cytosol of hepatocytes, called aldehyde dehydrogenase (ALDH). After that, acetate is converted to coenzyme A, displacing ATP to adenosine monophosphate (AMP). In turn, AMP can then be converted back into ATP or purines and uric acid. Acetyl coenzyme A will enter the Krebs' cycle and will be transformed into carbon dioxide and water [1, 18].

At the end of the metabolism, acetate is an ideal form of energy and inhibits lipid oxidation or fat breakdown, which saves energy, and thus can cause liver steatosis and increase body fat, generating obesity [1, 15].



Source: Adapted from Pivetta [19].

**Figure 2** Ethanol metabolism demonstrates the three metabolization pathways, highlighting the pathways used in excessive drinkers. (A): Mitochondrial Ethanol Oxidizing System - MEOS; (B): most common pathway in the liver - ADH and ALDH; (C): catalase pathway.

Some authors point out that even if alcohol has no nutritional value, each gram of metabolized ethanol provides the body, on average, seven calories [15]. Other researchers clarify that each gram of metabolized ethanol forms 7.1 kcal/g, and when compared to other substances, this energy source gains prominence (carbohydrates: 4 kcal/g; proteins: 4 kcal/g; lipids: 9 kcal/g) [20]. Also, for the authors [20], people who consume high doses of alcohol frequently would not take advantage of all their calories since the metabolization pathway used in these cases would be MEOS. However, not all people harness the calories of alcohol in the same way. Thus, people with higher body mass index (BMI) tend to make more efficient use of calories when compared to leaner people, which could further contribute to weight gain.

Thus, given the text presented so far, the literature points out that light to moderate alcohol consumption is less likely to be a risk factor for being overweight than excessive alcohol consumption.

### 1.2. Effects of alcohol on appetite and satiety

Alcohol can stimulate food intake, with individuals eating more food after consuming the alcohol. In the analyses of studies already published, it is not so clear whether alcohol promotes food intake in the absence of hunger. However, they affirm that alcohol can increase the perception of individuals about appetite in response to food stimuli [6].

On the effects of satiety, the alcohol showed to influence several hormones linked to satiety. Røjdmark, Calissendorff, and Brismar [21], in a study conducted with 14 healthy, non-obese subjects of both sexes, suggested that alcohol may influence energy intake by inhibiting the effects of leptin or glucagon-like peptide-1 (GLP-1). Traversy and Chaput [4] clarify that there is still no clear evidence that alcohol increases appetite through the action of peptide YY (PYY), ghrelin, gastric inhibitory peptide (GIP), or cholecystokinin (CCK).

In a study conducted with eight healthy, non-obese men in Stockholm, Sweden, authors found that alcohol did not increase plasma levels of neuropeptide Y (NPY), which is the principal stimulant of hunger [22]. However, animal studies have shown that central NPY levels increase after alcohol consumption [7].

In addition to the points already mentioned, the authors highlight that alcohol can still affect some hormones. Chart 1 has some of those effects on hormones or neurotransmitters involved in appetite and central neurological pathways in humans. Although the research cited in Chart 1, Traversy and Chaput [4] emphasize that further studies are needed to elucidate the precise biochemical mechanism that drives food intake after alcohol consumption since the interaction between Central and peripheral satiety signals is complex.

**Table 1** Effects of alcohol on various hormones or peripheral neurotransmitters and central neurotransmitter systems related to hunger and energy consumption.

	<b>Hormone / Neurotransmitter</b>	<b>Effect on hunger / Energy consumption</b>	<b>Effect of alcohol intake on hormonal/ neurotransmitter response</b>	<b>References</b>
Peripheral signals	Cholecystokinin (CCK)	Suppression	Increase	[23-24]
	Leptin	Suppression	Decreases	[21]
	Glucagon-like peptide-1 (GLP-1)	Suppression	Decreases	[21]
	Gastric inhibitor peptide (GIP)	Suppression	No effect	[21]
	Peptide YY (PYY)	Suppression	No effect	[22]
	Neuropeptide Y (NPY)	Stimulation (being inhibited by leptin)	No effect	[22]
	Ghrelin	Stimulation	Decreases	[22]
Central neurotransmitter systems	Gamma-aminobutyric acid (GABA)	Stimulation	Agonist	[25]
	Opioids	Stimulation	Increases	[26-27]
	Serotonin	Suppression	Decreases	[7]

### 1.3. Factors influencing the association between alcohol consumption and being overweight

Lifestyle is a factor that can influence the association of alcohol consumption with overweight. The literature has pointed out that mild to moderate use would not be a risk factor for being overweight, but only excessive consumption would be related [29-32]. Authors emphasize that people who consume alcohol in a mild to moderate way often have better lifestyle habits involving physical exercise and healthier food intake, which would confer a greater protection to weight gain [4, 31]. In addition, individuals who drink beer and spirits have poorer eating habits than those who drink wine [33]. The types of drinks also have health impacts since the total energy content of a drink varies depending on the way it is presented [29-31, 34].

Another point that deserves attention when analyzing such an association is sex. The relationship between alcohol consumption and body weight is generally stronger in men than in women, mainly due to the amount and type of alcohol consumed by men [32]. Authors also reinforce that men are more likely to drink beer, which is rich in carbohydrates, providing more energy than wine per standard dose. The woman's body has lower levels of enzymes responsible for metabolizing alcohol, making the substance take longer to be eliminated. In addition, women have less water leading to the fact that ethanol is more concentrated in their bodies, worsening the effects [6, 32]

On the other hand, physical activity is another factor that deserves attention in the association analysis. Authors emphasize that the level of physical activity can increase energy expenditure, counterbalancing with increased energy intake through alcohol consumption [35-36].

Therefore, it is relevant to consider the various factors (intake, expenditure, and lifestyle habits) to avoid confusion in the analyses [1, 4, 29-31]. One study found that insufficient sleep was associated with increased alcohol consumption and overweight in adults. For the authors, sleeping less than 6 hours per night would be associated with higher alcohol consumption and a higher BMI. In addition, it observed that people who had short sleep duration had excessive eating behaviors associated with higher alcohol intake and overweight [4].

Genetic aspects may also play a role in predisposing individuals to gain weight resulting from alcohol consumption. A study conducted with 1,301 Japanese male alcoholics observed that the genotype of the enzyme alcohol dehydrogenase-1B (ADH1B) is a strong determinant of body weight in alcoholics. Thus, genetic polymorphisms affect susceptibility to alcoholism and may affect body weight through gene-associated differences in fuel utilization [37].

Finally, in addition to the aspects already mentioned, the relationship of the role of alcohol in promoting overweight presents multiple factors, such as type, frequency, and amount of alcohol consumed; consumption pattern; symptoms of depression; psychosocial problems; chronic diseases; use of medication; disinhibition behavior; history of alcohol consumption; propensity to gain weight; predisposition to binge eating; anxiety [4]. It is also noteworthy that alcohol concentrations can also vary according to sex, age, dose, phase of the menstrual cycle (for women), concomitance of consumption with food and with the use of drugs [38-39].

Studies show that the absorption of ethanol is faster when the drink has an alcohol concentration of 20 to 30% and also when the stomach is empty (foods, especially those rich in carbohydrates, slow down absorption). In addition, beverages with an alcohol content close to 20% raise the concentration of ethanol in the blood faster than beverages with a concentration of 3 to 8%. They also debate that the concentrations in tissues and blood are higher in women since they have more subcutaneous tissue (rich in fats) and lower blood volume than men. In addition, women may also have lower levels of dehydrogenases (enzymes that metabolize ethanol) [38-39]. It is necessary to highlight that a recently published study conducted with adults in Brazil through the National Health Survey, a robust home sample survey, did not find an association between binge drinking (or episodic heavy drinking) and obesity in the investigated adults [40].

On the other hand, recent studies conducted by a group of researchers from Minas Gerais, a state in the southeastern region of Brazil, in the Cohort of Minas Gerais Universities (CUME) project, identified that, at baseline (2016), participants presented a prevalence of binge drinking (BD) (characterized by the intake of 4 or more doses of alcohol on a single occasion, for women, and 5 or more for men, in the last 30 days) and overweight equal to 41.3% and 40.8%, respectively. BD increased the prevalence of overweight by 19%, and BD exposure on 5 or more days in the month increased by 31% [29]. The second study evaluated the daily consumption of alcoholic beverages in total grams (alcohol) and the second type (beer, wines, and spirits) in milliliters. Alcohol intake was associated with being overweight, with a tendency to increase in prevalence the higher the daily consumption. There was a significant tendency to increase the prevalence of overweight when there was a higher consumption of beer (trend  $p = 0.038$ ), a fact not observed for the other types of drinks ( $p < 0.05$ ). Such results reinforce the need to reduce the widely accepted view that light to moderate alcohol consumption is not harmful to health, in the sense of adopting caution in this proposition. Thus, public health and alcohol control policies should consider the influence of alcohol intake on weight gain [30].

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## 2. Conclusion

Considering that obesity and overweight are multifactorial diseases, it is difficult to investigate the independent influence of alcohol consumption on the risk of being overweight. Observational studies are limited by the possibility of residual confusion due to unmeasured variables and, in turn, experimental studies are restricted by the short follow-up period, in addition to the difficulty of control for all lifestyle habits in free-living conditions.

Because they present relationships among themselves and constitute risk factors for non-communicable diseases and conditions, which are the principal causes of morbidity and mortality in the adult population, generating expenses for health systems worldwide, overweight and alcohol consumption are important topics to be investigated. Thus, research must investigate and help in understanding the relationship between alcohol consumption and overweight, mainly by evaluating the total volume consumed, consumption patterns - with emphasis on BD, and types of alcoholic beverages so that the results support the creation of strategies for health promotion, prevention and control of these diseases among the population.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that there is no conflict of interest in publishing this paper.

### *Statement of ethical approval*

The study did not require approval from the Ethics Committee because it did not involve data with humans and animals, but followed all ethical assumptions in the writing of a scientific article.

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