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The association between caffeine intake and BMI

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Abstract. Caffeine, a widely consumed psychoactive substance, has attracted interest because of its potential effects on body weight. This study examines the relationship between caffeine intake and Body Mass Index (BMI) across genders and obesity subgroups using data of 4,937 adult participants from the NHANES examination. The findings indicate that there is a significant positive correlation between caffeine intake and BMI in both male and female groups respectively. This suggests that higher caffeine consumption is associated with increased BMI. The association remains consistent within the normal BMI range but becomes less pronounced among individuals classified as obese. However, due to the limitations of the cross-sectional design and the exclusion of certain variables, this model still needs to be further refinement. This study highlights needs for further research into the association between caffeine consumption and body weight, with relevant implications for individuals and the health and wellness industry.

Keywords: BMI, caffeine, health.

1. Introduction

Body Mass Index (BMI), a commonly used indicator of an individual's body weight in relation to height, serves as a important tool in assessing the risk of various health conditions, including cardiovascular diseases, diabetes, metabolic disorders, joint problems, and sleep apnea. Caffeine, a naturally occurring psychoactive substance, is prominently found in popular beverages such as coffee, tea, soft drinks, and energy drinks. Its stimulant properties are known to enhance alertness and reduce fatigue, making it a widely consumed substance.

Researchers have been intrigued by the potential relationship between caffeine intake and BMI, particularly with regard to its effect on body weight and composition. However, the body of evidence remains diverse and at times contradictory. Several studies have suggested that caffeine's influence on weight might be twofold. On one hand, it has been postulated in both rats and humans that caffeine could enhance weight loss by stimulating thermogenesis and promoting the oxidation of fats. These mechanisms might contribute to increased energy expenditure and a potential reduction in body weight[1,2,3,4,5,6]. Conversely, some investigations have indicated a positive correlation between caffeine intake and BMI. This perspective suggests that caffeine consumption might lead to weight gain. Anyway, caffeine is considered to interact with individual metabolic processes in a way that influences body weight differently among various individuals[7,8,9].

The potential association between caffeine consumption and BMI continues to be an area of ongoing investigation. The complexity of this relationship underscores the importance of conducting further

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research to untangle the various factors that contribute to the diverse outcomes observed in different studies.

2. Method

We used NHANES data[10] to analyze and evaluate correlations between Body Mass Index (BMI) and the intake of caffeine, and linear regression analysis was conducted with the formula BMI ~ Intake of Caffeine. A total of 178 variables from the diet table were considered for analysis, and the most critical elements need to be picked out. To examine the linear relationships between these variables and BMI, we used multiple regression analysis rather than methods like random forests. Techniques like forward selection or lasso regression, which automatically help us find the important variables, can also be applied when using multiple regression analysis.

We could use mathematical formulas to define multiple regression analysis:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon$$

Where Y is the dependent variable (BMI), $X_1 \ldots X_n$ are independent variables such as caffeine intake, protein intake, vitamin B2 intake, etc., β_0 is the intercept, β_1, $\beta_2 \ldots \beta_n$ are the regression coefficients of the variables, and ϵ is the error term.

We established a significance level of $p<0.005$. Utilizing forward selection, we identified and selected more than 40 variables that displayed significant relationships with BMI. Further improvement of the model was achieved by narrowing down the variables. Based on their p-values, we selected 12 variables with the smallest p-values for inclusion.

Then, lasso regression, known for its automatic feature selection capability, was introduced. We could use mathematical formulas to define the ordinary Lasso regression:

$$\hat{\beta}(LASSO) = arg\ min \left\| y - \sum_{i=1}^{n} x_i \beta_i \right\|^2 + \lambda \sum_{i=1}^{n} |\beta_i|$$

The parameter y refers to the dependent variable BMI, and x refers to independent variables like caffeine. β is the coefficient of each independent variable x. λ refers to the sparsity parameter, which penalizing the sum of the absolute values of the coefficients β. [11]This technique deals with datasets containing many features, for it will make many coefficients to be zero.

The culmination of our analysis resulted in the final multiple linear regression model. The selected variables for this model were caffeine intake, protein intake, vitamin B2, vitamin D, theobromine, and the age.

We categorized the data based on two key factors: Gender and Obesity status.The classification resulted in four distinct groups:

1) Female, Not Obese (BMI < 28)
2) Female, Obese (BMI >= 28)
3) Male, Not Obese (BMI < 28)
4) Male, Obese (BMI >= 28)

This grouping allowed us to analyze the impact of caffeine intake on BMI within each subgroup.

A scatter plot was created for each of the four groups. The x-axis represented caffeine intake, while the y-axis represented BMI. For each group, a regression line was included to depict the trend in the data. The regression line visually demonstrated the general relationship between caffeine intake and BMI within the specific group.

We conducted a multiple linear regression analysis for each group. This involved fitting a linear model to the data of each group to ascertain the influence of caffeine intake on BMI, considering other relevant variables.

3. Result

Of the 9813 participants studied in the NHANES examination, data were available from 4,937 participants, due to the remainders have missing data or data out of range. Out of the total 4,937 participants, 3,490 individuals reported caffeine intake, constituting 70.69% of the sample. Within this

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group, 1,636 were female, representing 67.24% of the female participants, and 1,854 were male, accounting for 74.04% of the male participants. Also, among all the participants, 814 individuals were classified as obese, constituting 33.46% of the female group, while 1,229 males were classified as obese, making up 49.08% of the male group. As shown in graph 1,the average BMI among females who consume caffeine was found to be 25.90, while among females who do not consume caffeine, it was notably lower at 22.71. Among males who reported caffeine consumption, the mean BMI was 25.81, whereas for males who did not consume caffeine, the mean BMI was 23.14. These findings suggest that both male and female caffeine consumers tend to have higher BMIs compared to their non-caffeine-consuming counterparts, with females generally exhibiting a greater difference in mean BMI between the two groups.

3.1. Comparison of BMI Across Different Caffeine Consumption Groups

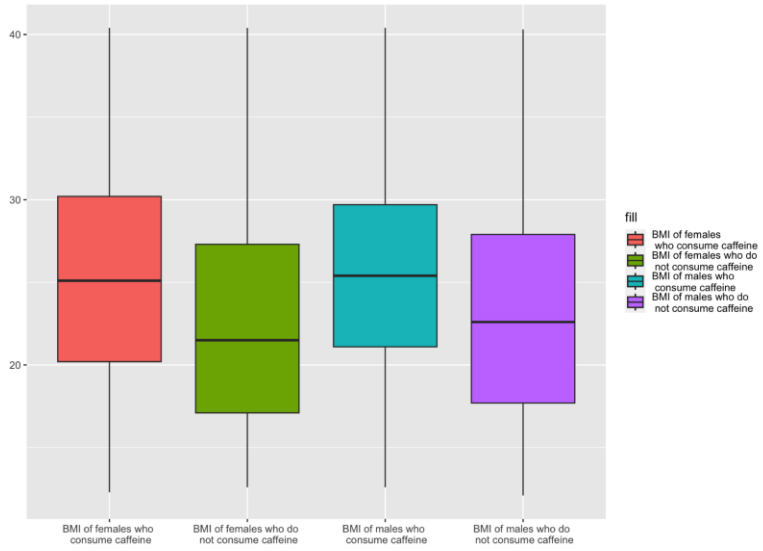

Figure 1. This figure presents a comparison of BMI (Body Mass Index) among different caffeine consumption groups. Each boxplot visualizes the distribution of BMI within each group and both of the male and female groups who consume caffeine are significantly greater than the group who do not consume caffeine.

Both the male and female groups exhibit a positive correlation between caffeine intake and BMI. When considering caffeine as the sole variable, the coefficient is 1.67×10^{-2}. However, after excluding the influence of protein, vitamin B2, vitamin D, and theobromine while accounting for age, the caffeine coefficient decreases to 8.110×10^{-3}.

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3.2. Scatter Plot of BMI against Caffeine Intake with Weighted Linear Regression Line in Female Group

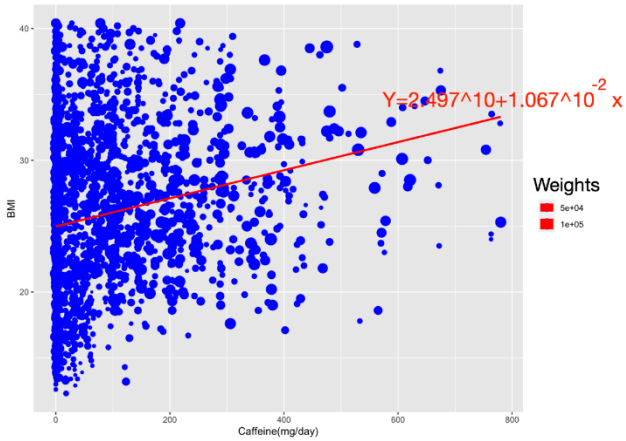

Figure 2. This figure displays a scatter plot illustrating the positive correlation between BMI and caffeine intake in the female group. The initial coefficient of the relationship between caffeine intake and BMI is 1.67×10^{-2}, while the modified coefficient is 8.110×10^{-3}.

We conducted a similar analysis for the male group. When considering only caffeine as a variable, the coefficient was 8.849 × 10^-3. However, after eliminating the influence of protein, vitamin B2, vitamin D, and theobromine while accounting for age, the caffeine coefficient decreased to 8.364 × 10^-3, which is a little higher than the female group.

3.3. Scatter Plot of BMI against Caffeine Intake with Weighted Linear Regression Line in Male Group

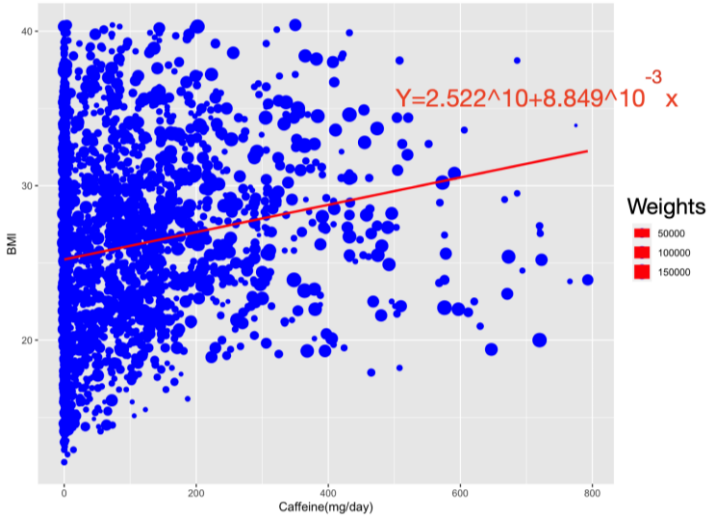

Figure 3. This figure displays a scatter plot illustrating the positive correlation between BMI and caffeine intake in the male group. The initial coefficient of the relationship between caffeine intake and BMI is 8.849×10^{-3}, while the modified coefficient is 8.364×10^{-3}.

The results also demonstrate a positive correlation between BMI and caffeine intake in non-obese groups. When considering caffeine as the only variable, the coefficient for the female group is 9.456×10^{-3}, and it decreases to 7.7×10^{-3} after adjusting for other factors. In the male group, the coefficient is initially 7.201 × 10-3, and it decreases to 6.45×10^{-3} after the adjustment, which is lower than the coefficient observed in the female group. However, no significant correlation is observed between BMI and caffeine intake of both genders in the obese groups.

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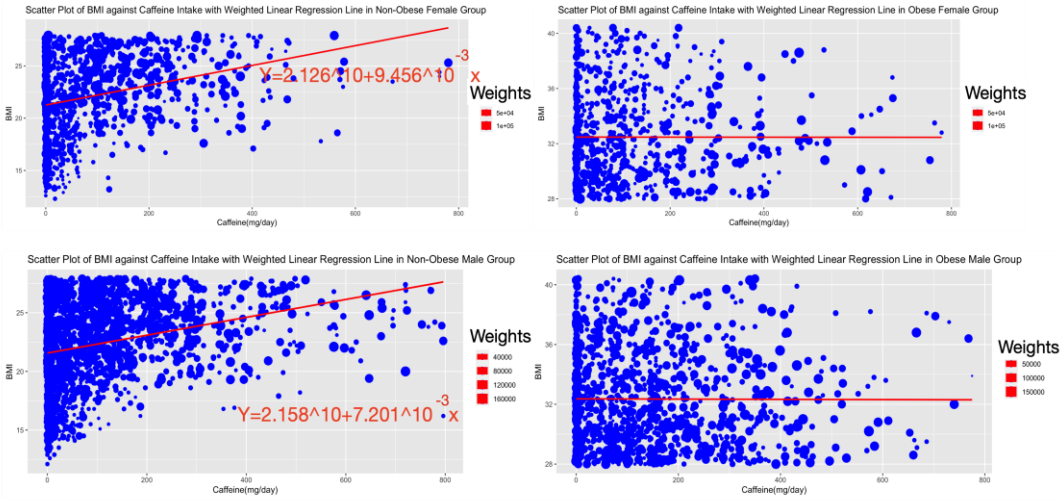

Figure 4. This figure presents a comparative analysis between two genders based on their obesity status and its association with BMI and caffeine intake. The findings reveal a positive correlation between BMI and caffeine intake in non-obese groups. However, no significant correlation is observed between BMI and caffeine intake in the obese groups.

4. Discussion

Our analysis revealed insights into the association between BMI and caffeine intake:

Both male and female groups displayed a significant positive correlation between BMI and caffeine intake. Specifically, the correlation coefficient was 0.008364/mg for males and 0.008110/mg for females. This indicates that as caffeine intake increases, BMI tends to increase as well. The positive correlation between BMI and caffeine consumption was also observed within the normal BMI range for both genders. Interestingly, among the obese population, we observed no significant correlation between BMI and caffeine intake. This implies that the relationship between caffeine and BMI may differ among individuals with obesity.

One study involving mice demonstrated that caffeine was able to reverse the weight gain induced by saccharin consumption in the group following a low-fat diet, but it did not have the same effect in the group on a sweet, high-fat diet[12]. In the human study, it has also been demonstrated that in the obese group, there is almost no change in fat oxidation after caffeine consumption[13].This observation may help explain why caffeine shows a weak correlation with BMI in individuals who are obese.

Another study found a positive association between the number of night shifts worked and caffeine consumption, which in turn was positively associated with BMI. The consumption of caffeinated beverages has been linked to BMI in school-aged children, highlighting the potential broader implications of caffeine on weight[7]. Both examples shows that our findings are consistent with prior research.

Another study suggested that with caffeine, people will feel less sweet with thew same amount of sugar, so they may consume more sugar and more calories as the result.[14] Given the positive association between caffeine intake and BMI, providing healthier alternatives, such as some low-calorie or sugar-free complementary food, could satisfy individuals conscious about their weight.

5. Conclusion

In conclusion, our findings underline the complex association between caffeine intake and BMI across different gender and obesity subgroups. The positive correlation in normal BMI ranges and its absence among the obese population highlight the need for further investigation into the intricate interplay between caffeine and body weight. Our results provide valuable insights for both individuals and businesses in the realm of health and wellness.

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It's essential to acknowledge limitations in our study. As too many features that may affect the association, we only selected the features most likely to be associated with BMI by using forward selection and refining by Lasso regression. By selecting variables with the smallest p-values, we aim to strike a balance between a rather simplified model and remain a strong explanatory power. Still, the final model has a rather low R^2 value, which means the model may have problem with explaining the variance and lack of explanatory power. In this case, other methods like random forests may be applied to get a model with a higher goodness of fit. Also, as our study design is cross-sectional, our ability to establish association between caffeine and BMI is limited. Some important variables, like sleep quality or stress levels, were not included, which might impact the relationship. These limitations must be considered in future experiments.

In recent years, consumers increasingly seek healthier products that also satisfy their need for refreshment during long working hours or other activities. Considering the observed association between caffeine consumption and body mass index (BMI), healthier alternatives are needed to be provided by businesses. These alternatives could include low-calorie beverages or snacks, and sugar-free versions of popular caffeinated drinks. Such an approach matches with current health trends and promotes a lifestyle that harmonizes enjoyment and well-being.

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