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The Impact of Added Sugar Consumption on Short-Term and Working Memory in Online Graduate Nutrition Students Attending King's College

A Cross-Sectional Study

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Abstract

This cross-sectional study examines the impact of added sugar consumption on short-term and working memory among 9 graduate nutrition students attending King's College online. Data was collected for this study from May to June of 2024. A food frequency questionnaire (FFQ), was used to collect dietary intake data from participants, categorized as consuming either high or low amounts of added sugars. Cognitive performance was assessed through standardized Digit Span and Stroop tests. Statistical procedures included t-tests, logistical regression, and Pearson correlation. Preliminary findings suggest that students with a high added sugar diet show decreased cognitive function, poor memory performance, and higher risk of cognitive impairment compared to individuals consuming a low sugar diet. These findings indicate a potential negative impact of added sugar on cognitive function, which is crucial for students' academic success.

Introduction / Background

The consumption of added sugar has raised significant public health concern due to its widespread prevalence and chronic effects on various aspects of health. Previous analyses found added sugar intake among U.S. adults is high. [2] In 2017 to 2018 mean added sugar intake among U.S. adults aged 20 years and older was 17 teaspoons a day (tsp/d), 19 tsp/d for men, and 15 tsp/d for women which is much higher than what the American Heart Association recommends. [2] They suggest consuming less than 9 tsp/d for men and 6 tsp/d for women. [2] Added sugars, which are added to foods during processing, are found in a wide range of commonly consumed products such as sugar from syrups and honey, foods packaged as sweeteners, and sugars from concentrated fruit or vegetable juice.[2] Short-term and working memory are vital cognitive functions that people rely on for daily tasks ranging from simple activities to learning complex processes. These memory types are essential for a students' academic success and their future occupational performance. This underscores the importance of proper dietary habits and the promotion of well-balanced eating among online graduate nutrition students, and the population in general.

Research purpose

The purpose of this cross-sectional study is to investigate the relationship between the consumption of added sugar and cognitive performance, specifically short term and working memory among graduate nutrition students attending King's College online. By focusing on this group, the goal is to understand how dietary habits impact cognitive functions that are essential for academic success and daily activities. Attempting to establish a connection between added sugar consumption, short term memory, and working memory, will give insight as to how added sugar may negatively impact cognition. Due to graduate students' demanding schedules, they may be vulnerable to dietary influences that affect cognitive performance. Understanding how diets high in added sugar affect cognitive function may provide graduate nutrition students with guidance on how to modify their diet for improved cognition.

Objective

Our objective is to assess the effect of added sugar on short-term and working memory. Comparing the cognitive performance test scores of graduate students with high consumption of added sugar to graduate students with low consumption of added sugar in their diet. Dietary intake was gathered and assessed using the FFQ and cognitive performance was evaluated through the Stroop and Digit Span tests.

Literature review

Evidence suggests that diets high in added sugar can negatively impact brain function, specifically memory processes.[1] By examining the relationship between added sugar intake on short-term and working memory, the data gathered will provide a foundational understanding into how dietary choices may influence cognitive performance in the academic setting. Existing literature indicates that some cases of high sugar consumption can impair cognitive functio highlighting the need for dietary guidelines and recommendations that support optimal brain health.

Added Sugar Intake and Cognition

The type, structure, and sweetness level of sugar consumed may moderate the effect of cognitive outcomes.[3] Frank et al. and Smeets et al., demonstrated these factors influence cognitive function differently. Neuroimaging data showed caloric and noncaloric sweeteners activate different brain regions despite having similar sweetness levels and taste.[3] Specifically, Smeets et al., found that non-caloric sweeteners stimulated the amygdala more than caloric sweeteners, which is critical for processing emotions and memory.[3, 4] Additionally, Opstal et al., indicated that glucose deactivates the hypothalamus immediately after ingestion, an effect that continues for about 12 minutes.[3] The hypothalamus plays a pivotal role in controlling appetite and energy homeostasis, indirectly affecting cognitive function by influencing energy availability in the brain.[5]

Dietary Sugars and Brain Function

Giles et al., conducted a study to investigate the independent and interactive effects of sugar intake in the form of high fructose corn syrup and sugar expectation on mood and cognition.[6] This study used amounts of sugar similar to what is found in a can of soda, making the findings relevant to everyday consumption. The soda used in the study contained a mix of sugars, mostly fructose.[6]

It was observed that participants felt more tension following sugar intake which may be caused simply by the expectation of consuming sugar.[6] Bucher et al. and Siegrist et al., reported elevated tension may be linked to health perceptions of soda as these beverages are commonly seen as unhealthy.[6] On the cognitive side, sugar intake enhanced attention span, but Meikle et al., noted that this benefit is only apparent when participants expected to consume sugar.[6] So, while high fructose corn syrup and glucose in doses equivalent to a can of soda seem to improve attention, the role of expectation remains unclear. [6]

No significant effects were observed in other cognitive areas such as verbal memory, working memory, and selective attention.[6] After completing the Stroop test, there was no difference in performance based on whether participants had sugar or expected to have sugar.[6] The soda used (Sprite) contained a mix of 60% fructose, 39% glucose, and 1% maltose.[6] This lower glucose dose compared to past research raises concern about how the glucose to fructose ratio may influence cognitiion.[6]

Effects of Sweeteners on Cognitive Function

Lopez-Mesa et al., aimed to investigate the effects of frequent short-term consumption of commercial sweeteners on central nervous system (CNS) activity and cognitive function.[8] The study used a combination of neuropsychological testing for analysis of sensory and information processing. Research focused on healthy adults with normal body mass index (BMI), divided into three experimental groups based on the type of sweetener supplemented.[8] The study provided evidence that frequent consumption of both nutritive and non-nutritive sweeteners over a six-week period led to changes in cognitive function.[8] The effects varied, specifically in overall memory, encoding memory, and executive functions, depending on the type of sweetener.[8]

The steviol glycosides group remained consistent before and after supplementation with no significant changes.[8] The sucrose group displayed decreased encoding memory performance post treatment, although the neurophysiological tests did not show significant changes.[8] Encoding memory involves the conversion of sensory data into mental representations, crucial for storing and retrieving information.[8] The sucralose group showed significant declines in overall memory, encoding memory, and executive functions including a detrimental effect on brain function related to problem solving.[8]

There was significant excess theta wave absolute power (AP) in the frontotemporal regions of the sucralose group post supplementation, with a tendency for decrease in alpha and beta AP posterior leads.[8] The study's results showed a direct correlation between increased theta activity and decreased cognitive performance in the sucralose group, highlighting the potential negative impact of sucralose on brain activity and health.[8]

Lopex-Meza et al., indicated frequent consumption of non-nutritive sweeteners, particularly sucralose, is linked to significant changes in CNS activity and cognitive functions.[8] These results highlight the importance of considering the type and quantity of sweeteners consumed, as they may play a crucial role in cognitive dysfunction under certain conditions.

Role of added sugars and Cognition

Overall, the presented studies suggest that the type of sugar consumed can significantly affect cognitive function. Some results suggest glucose has a beneficial impact on cognitive performance. Higher blood glucose levels resulted in faster decision times and increased acetylcholine synthesis.[3] Ginieis et al., found that glucose significantly improved cognitive response times compared to fructose, sucrose, and sucralose.[3] However, other studies reported no improvement or negative effect of glucose on cognitive function.[3]

Yilamez et al., investigated cognitive effect and reaction of four dietary sugars, glucose, fructose, sucrose, and saccharin compared to a placebo group (water).[7] Overall, the results demonstrated that fasting had a negative effect on cognitive performance and reaction tests.[7] Yilamez et al., found the slowest reaction time was observed in the control group, while the fastest time was in the glucose group.[7] The mean score differed significantly between all conditions. Glucose consumption had a remarkable positive effect on cognitive performance and reaction time compared to other dietary sugars.[7] Suggesting that glucose might have unique properties that enhance cognitive function and reaction speed over short-term.[7] Negative effects of fasting status on cognitive and response performance were highlighted, expressing the importance of nutritional status when evaluating cognitive function and reaction time, as fasting can impair cognitive processes. Interestingly, the study also observed saccharin, a non-caloric sweetener, appeared to improve test results compared to fructose and sucrose, despite saccharin causing no increase to blood sugar levels.[7] This finding suggests that saccharin may have cognitive enhancing properties independent of its effects on blood sugar.[7]

Ginieis et al., conducted a series of computerized cognitive tests to evaluate the impact of different sugars on cognitive function.[9] The following three computerized tests were used: the simple response time task, arithmetic processing, and the Stroop task.[9] These tasks were designed to assess various cognitive functions such as information processing, executive function, and selective attention, primarily linked to the prefrontal lobe of the brain.[9] Each task was done before consumption of the test drink. The study reported significant changes in blood glucose levels post ingestion of glucose and sucrose with no significant interaction between the time points and fasting status.[9] Glucose and sucrose conditions showed elevated blood glucose levels compared to fructose and the placebo.[9]

For the simple response time task, glucose ingestion resulted in significantly slower response times compared to fructose and sucralose, regardless of fasting status.[9] There were no significant differences between glucose and sucrose conditions.[9] In the Arithmetic task glucose and sucrose ingestion negatively affected performance compared to fructose and the placebo.[9] Regarding the Stroop task response times, participants under the glucose and sucrose conditions were slower than in other conditions with no significant differences in error rates.[9] The findings suggest that glucose and sucrose negatively affect cognitive performance, particularly in tasks requiring rapid response and prevention of automatic processes.[9] These effects were found more pronounced under fasting conditions, indicating that fasting influences cognitive performance and glucose effects.[9]

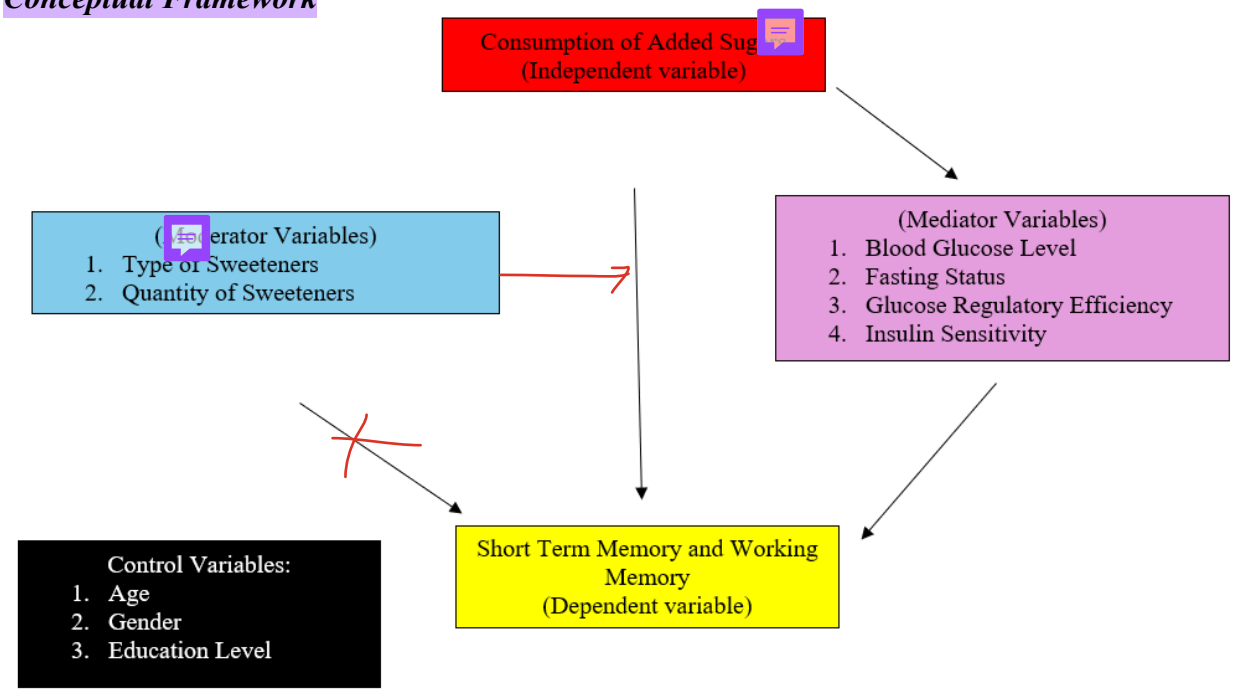
The literature review summarizes the impact of added sugar on cognition showing that the type and amount of sugar consumed can significantly impact cognitive performance. High consumption of added sugar is generally linked to cognitive impairment with specific sugars including fructose and sucrose, which may have negative effects, whereas glucose may show potential cognitive benefits. The findings also highlight the role of individual factors such as glucoregulatory efficiency and psychological expectations having an effect. This review emphasizes the importance of tailored dietary guidelines to optimize cognitive health and address the research question of how added sugar intake influences cognitive performance.

PICO Question

"What is the effect of the consumption of a diet high in added sugar as measured by the food frequency questionnaire compared to a diet low in added sugar on short term and working memory in graduate nutrition students attending King's College online?

Methods

Conceptual Framework



Study context and design

The study was conducted online through King's College, focusing on graduate nutrition students. The study's design is cross-sectional, using self-reported dietary intake data and cognitive function assessments. The study will explore the relationship between dietary sugar consumption and cognitive function. Participants completed the study by remotely filling out FFQs to report their dietary intake, including the consumption of added sugar. The cognitive performance of participants was assessed using a self–administered online cognitive test known as the Stroop test, measuring cognitive flexibility and attention. [11] Participants were required to name the color of the word being displayed, which can be contradictory of the word itself, for example, the word yellow printed in green ink. [11] The Stroop test assessed the ability to stop cognitive interference and maintain focus on a task.[11]

Study population and sampling

The study population consisted of graduate nutrition students attending King's college online. Participants were selected using convivence sampling based on specific inclusion criteria as follows: currently enrolled graduate students in the nutrition program aged 18 to 65 years. Participants needed to be currently enrolled in the graduate nutrition online course. Health status was also considered with participants having no history of neurological disorders or cognitive impairments. Lastly, dietary habits were controlled by categorizing the frequency of high sugar food consumption to analyze its specific effect on cognitive performance. All eligible students who met the inclusion criteria and agreed to the consent process were included in this study.

Data collection tools and techniques

Participants filled out food frequency questionnaires online to provide detailed information about their dietary habits including a question that asked about how often high sugar foods were consumed. The options were 0, 1-3, 4-6, and 7-12 times a month or 1, 2-3, and >3 times a day. Additionally, online Digit Span and Stroop tests were administered to assess cognitive performance. These tests were designed to be self-administered and completed by participants in their own time.

Variables Assessed

Independent variable

The independent variable was the level of added sugar consumed in the diet categorized into low and high added sugar groups. This categorization will allow the study to determine if there is a direct effect of sugar and cognitive performance after comparing the amount of added sugar consumed to the cognitive tests.

Dependent variable

The dependent variables being assessed are short-term and working memory. These cognitive outcomes were measured to determine the impact of the independent variable.

Control variable

To ensure that cognitive performance could be attributed to dietary sugar intake the study controlled several factors. The control variables included age, with a range of 18 to 65 years, gender, and education level.

Statistical analysis plan

Participant age was summarized using means and standard deviations; gender, education level, and high sugar intake were summarized using frequencies and percentages. All statistical calculations were completed using Jamovi software.[10] Independent sample T-tests were used to

compare Stroop test scores across gender, education level, and high sugar intake. Pearson correlation was used to assess the relationship between Stroop test scores and age, which serves as a continuous variable. A linear regression analysis was conducted to control for potential confounding variables and adjust the effects of age, gender, education level, and high sugar intake on the Stroop test scores. Using this statistical analysis plan, researchers demonstrated and assessed relationships between the independent variable and the dependent variable while also considering any confounding variables.

Ethical considerations and approval

Prior to data collection, participants were interviewed individually by a research team member. The interview was held on zoom and was recorded as evidence of the verbal consent process. During the interview participants were first invited to join the study, then they were provided with a brief description of the study's purpose as well as a description of study procedures that read as follows:

"1. Complete an online questionnaire about your typical dietary intake, food preferences, and eating habits. This questionnaire should take approximately 15 minutes to complete.

2. Take part in online video cognitive assessments that will measure aspects such as memory, attention, and problem-solving skills. These tests are expected to take about 30 minutes.

3. Provide demographic information including age, gender, educational background, and general health status. This questionnaire should take approximately 15 minutes to complete."

Participants were also told their participation was voluntary and the possible benefits, risks, and discomfort were minimal due to the researcher's design. Participants were ensured their data would remain confidential and were assigned an ID number to ensure anonymity. The interview ended with researchers giving participants time to ask questions. Afterwards all participants gave their verbal consent and submitted an online form to ensure digital consent.

Results

Table 1: Descriptive Statistics of the Study Population (Age, Overall Stroop test score, Gender, Education level, Frequency of High Sugar Intake)

Variables	**Total (N9)**
Continuous variable	**mean±SD**
Age	28.778±7.049
Overall Stroop test score*	22.229±5.32
Categorical variable	**N (%)**
Gender identity	
Female	6 (75)
Male	2 (25)
Education	
Bachelor (BA. BSc)	8 (88.9)
Masters (MA, MS, MBA)	1 (11.1)
High sugar intake	
≤7-12x/mon	6 (66.7)
≥ 1x/daily	3 (33.3)

Table 1 provides a categorical breakdown of participants. Using the data obtained from the FFQ, participants were separated into 3 categories with two groups each, those being gender identity, education level, and sugar intake. The age of participants ranged from 21.729 years to 35.827, with the average being 28 years and 9.3 months. Of the 9 participants, 1 chose not to provide their gender identity. Those who did provide their gender identity were 75% female and 25% male. All 9 participants shared their education level, with 1 achieving a previous master's degree. All participants presented their frequency of sugar intake in the FFQ.

The main independent variable is high sugar intake with the cutoff for the high sugar group defined as consuming foods with added sugar ≥ 1 time per day. 3 out of the 9 participants (33.3%) fell into the high sugar intake category with the remaining 66.7% of the group consuming foods with added sugar ≤ 7-12 time per month. The dependent variable, Stroop test, found all 9 participants who participated submitted their test scores. The scores of the Stroop test ranged from 16.909 and 27.549 points with an average score of 22.229 points.

Table 2: Mean Differences of High Sugar Intake Frequency on Cognitive Performance According to Stroop Test Scores

Variable	Stroop test Mean±SD	Mean diff	t	P[#]
Mean difference[$]				
Gender identity				
Female	22.612±5.558	2.095	0.425	0.686
Male	20.517±8.028			
Education				
Bachelor (BA. BSc)	23.153±4.863	8.313	1.612	0.151
Masters (MA, MS, MBA)	14.840±00			
High sugar intake				
=<7-12x/mon	22.661±6.425	1.297	0.324	0.755
>= 1x/daily	21.365±2.931			
Correlation[$$]				
Age	-0.209	----		0.991

*** Stroop test** *(outcome variable)- Higher score indicates better short term and working memory*
[#] *P significant at <0.05*
[$] *Independent sample 't' test*
[$$] *Pearson (r) correlation*

The independent sample T-test was included to determine the relationship between the groups of each categorical variable (IV) and their respective performances on the Stroop test. Using the t-test the mean outcome was determined of the Stroop test by the categorical variable. On average females performed better by 2.095 points on the Stroop when compared to males. However, the P value indicated no statistical significance. On average, participants with a bachelor's degree outperformed their counterpart with a master's by 8.313 points. Although, the average difference was not statistically significant.

The Pearson (r) correlation was used to determine the relationship between age and Stroop test due to age being a continuous variable. The correlation between age and participants' Stroop tests score was -0.209, indicating a weak negative relationship. With such a high P value, the correlation between age and test score was not statistically significant suggesting no significant relationship.

T-tests were also used to test the relationship between the main independent variable, high sugar intake, and Stroop test scores. The independent t-test revealed participants who consume high sugar foods less often (≤ 7-12 times per month) outscored their counterparts by an average of 1.297 points. Yet again, there was a high P value, indicating no significant effect of sugar intake on Stroop test performance.

Overall, the t-tests and Pearson (r) correlation model showed none of the variables that were analyzed (age, gender, education, and sugar intake) showing a statistically significant effect on Stroop test performance. Due to the P values presented, the null hypothesis is accepted

Table 3 Linear regression Analysis

Variable	ß estimates	SE	Confidence interval		P#
			Low	Upper	
Age (yrs)	0.063	0.380	-0.993	1.118	0.877
Gender identity					
Female	REFERENCE				
Male	2.339	8.121	-23.507	28.185	0.792
Education					
Masters (MA, MS, MBA)	REFERENCE				
Bachelor (BA. BSc)	11.373	10.823	-23.072	45.818	0.371
High sugar intake					
>= 1x/daily	REFERENCE				
=<7-12x/mon	2.487	6.007	-16.629	21.603	0.707

*** Stroop test** *(outcome variable)- Higher score indicate*
[#] *P significant at <0.05'*

The linear regression model was used to estimate the differences in Stroop test scores by different groups. Regarding age, it was found for every 1-year increase in age there was an increase the Stroop test outcome by 0.063 points controlling for gender, education and high sugar intake in the past 30 days. The coefficient for age however suggests only a small positive association and was not shown to be statistically significant. When using females as the reference group, it was found that men, on average, perform 2.339 points higher when controlling for age, education, and high sugar intake in the past 30 days. The linear regression model showed a confidence interval including zero, indicating no statistical significance. Participants with bachelor's degrees but not master's degree had an average increase of 11.373 points on test performance when compared to the participant who previously achieved their master's when controlling for age, gender, and sugar intake in the past 30 days.

The primary independent variable, high sugar intake, proved to have a negative impact on short term and working memory, with those in the low sugar intake category achieving an average of 2.487 points above participants with high sugar intake when controlling for age, gender, and education level. The confidence interval however includes zero, so high sugar intake was shown to have no significant effect by the linear regression model. The linear regression model showed none of the independent variables (age, gender, education, and sugar intake) had a statistically significant effect on the dependent variable. Due to the P values presented the null hypothesis is accepted.

Discussion

The findings from this cross-sectional study indicate a potential negative impact of a high added sugar diet on short-term and working memory among graduate nutrition students attending King's college online. However, the results did not reach statistical significance, suggesting that

while there are observable trends, these findings should be interpreted with caution due to the small sample size and other study limitations.

Participants with high added sugar intake performed slightly worse on the Stroop test compared to those with low sugar consumption. Specifically, individuals consuming high sugar foods less frequently (<7-12 times per month) had an average Stroop test score of 1.297 points higher than those consuming high sugar foods more frequently (>1 time daily). Despite this trend, the P value was not statistically significant, indicating it cannot be conclusively stated that high sugar intake negatively impacts short term and working memory based on this study alone.

While the results showed a slight effect on the Stroop test score (DV), it was unable to demonstrate any statistical significance. Mean changes in the score were most likely due to chance or an outside uncontrolled factor. As mentioned above, education level does not have an equal distribution of participants into the two categories. This unequal distribution creates greater possibility for human error to affect Stroop test score rather than education level itself. The other two categories also had an unequal distribution of participants, however not as glaring as that of education level. The 1 year (unit) increase in age will increase the short-term memory scale by 0.165 unit, indicating a higher retention of memory. The 1 year (unit) increase changes the IV categories and causes an increase or decrease in short-term memory by 0.165 units.

The inability to reach statistical significance should not deter future researchers from conducting studies looking at the relationship between high sugar intake and cognition. High sugar foods are readily available in most parts of the world and may contribute to negative physiological health outcomes, but their psychological effect has room to be studied. Future research should aim to address the limitations of this study by increasing the sample size, ensuring a more balanced distribution of demographic variables, and employing a longitudinal design to assess cognitive changes over time. Additionally, upcoming investigation studying cognitive assessments should provide a more extensive evaluation of the impact of added sugars on various cognitive areas. Also, future analysis should explore the cognitive effects across various sweeteners, standardizing energy levels and sweetness to isolate the cognitive impacts of different dietary sugars.[9] Finally, studies need to examine if other cognitive areas, such as memory provide an understanding of sugar's influence on the brain and cognitive activity.

Understanding the relationship between diet and cognitive performance is crucial, especially for students' whose academic success depends on all aspects of their memory. Promoting healthy dietary habits with reduced added sugar intake could be beneficial for maintaining optimal cognitive health and academic performance among students. This study highlights the importance of dietary guidelines that support brain health advocating for further research to reduce added sugar consumption in diets.

Several limitations must be considered when interpreting the results of this study. The small sample size of nine participants is a primary limitation. With such a limited number of subjects the study lacks statistical power to detect significant differences or establish strong conclusions. Furthermore, the unequal distribution in the education level category (with only one participant holding a master's degree) weakens the studies ability to generalize findings across different educational backgrounds. The decision to assess the relationship between education and

cognition was most likely negatively impacted by this chosen sample. Only one participant had achieved a master's degree, therefore not providing an adequate sample of participants who fit into this category.

Another limitation is the use of self-reported data for dietary intake, which may introduce bias. Participants may underreport or overreport their actual sugar consumption leading to inaccurate high and low sugar intake groups. The study's cross-sectional design means that it can only establish associations rather than casual relationships. Longitudinal studies should be conducted to determine if high sugar intake directly leads to cognitive decline over time. The FFQ used to assess participant intake provided researchers with limited information about participants sugar intake. The questionnaire also neglected to ask participants what type of sugar they consume. Researchers had limited data on actual sugar consumption leading to the creation of categories used in the tables above.

Moreover, the cognitive performance assessment relied solely on the Stroop test, which is useful for measuring cognitive flexibility and attention, but may not fully capture the complexities of short term and working memory.[2] Including a variety of cognitive tests could provide a more comprehensive understanding of how added sugar affects different aspects of cognitive function. Despite the limitations, the observed trends align with most of the existing literature, suggesting that high sugar diets may impair cognitive function. Previous studies have shown that diets high in added sugar are associated with poorer memory performance and an increased risk of cognitive decline. This study contributes to the growing body of evidence by focusing on a specific population of graduate nutrition students, highlighting the potential dietary influence of added sugar on cognitive performance.

Conclusion

The study found no statistically significant relationship between the independent variables age, gender, education, sugar intake, and Stroop test performance. Some trends were observed including females, and those with a bachelor's degree performed slightly better. Finally, lower sugar intake was associated with better scores, but these differences were not significant and likely due to the small sample size and unequal distribution of participants across categories. Researchers accepted the null hypothesis.

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