The Journal of EMERGING SCIENTISTS

SSIS
SAIGON SOUTH INTERNATIONAL SCHOOL

Scientific Student Research Journal

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To ensure compliance with safeguarding protocols, student last names have been omitted from this journal. Schools or institutions seeking to verify the authenticity of any entry or its publisher are encouraged to contact our high school office directly.

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Foreword

Welcome to the *Journal of Emerging Scientists.* This issue is a testament to the dedication, curiosity, and hard work of the first cohort of SSIS students taking Independent Science Research. Within these pages, you will find a collection of research endeavors they have undertaken since August 2024.

This issue represents more than just the culmination of months of hard work; it embodies the spirit of scientific inquiry that we strive to cultivate at SSIS. Each piece herein reflects a journey of exploration, from formulating insightful questions to designing methodologies, meticulously collecting data, and thoughtfully analyzing findings. These students have embraced the challenges inherent in independent research, navigating the complexities of their chosen topics with remarkable initiative and perseverance.

Within the *Journal of Emerging Scientists,* you will encounter a diverse range of investigations, reflecting the varied interests and growing expertise within our program. From topics related to Materials Science and Biochemistry to Environmental Science and Behavior Science, their projects offer a glimpse into the exciting frontiers of scientific discovery.

These students exhibited remarkable commitment to scientific excellence and an undeniable willingness to contribute to the body of research and knowledge. Their work not only demonstrates a mastery of scientific principles but also highlights the critical thinking and problem-solving skills essential for future success in STEAM fields.

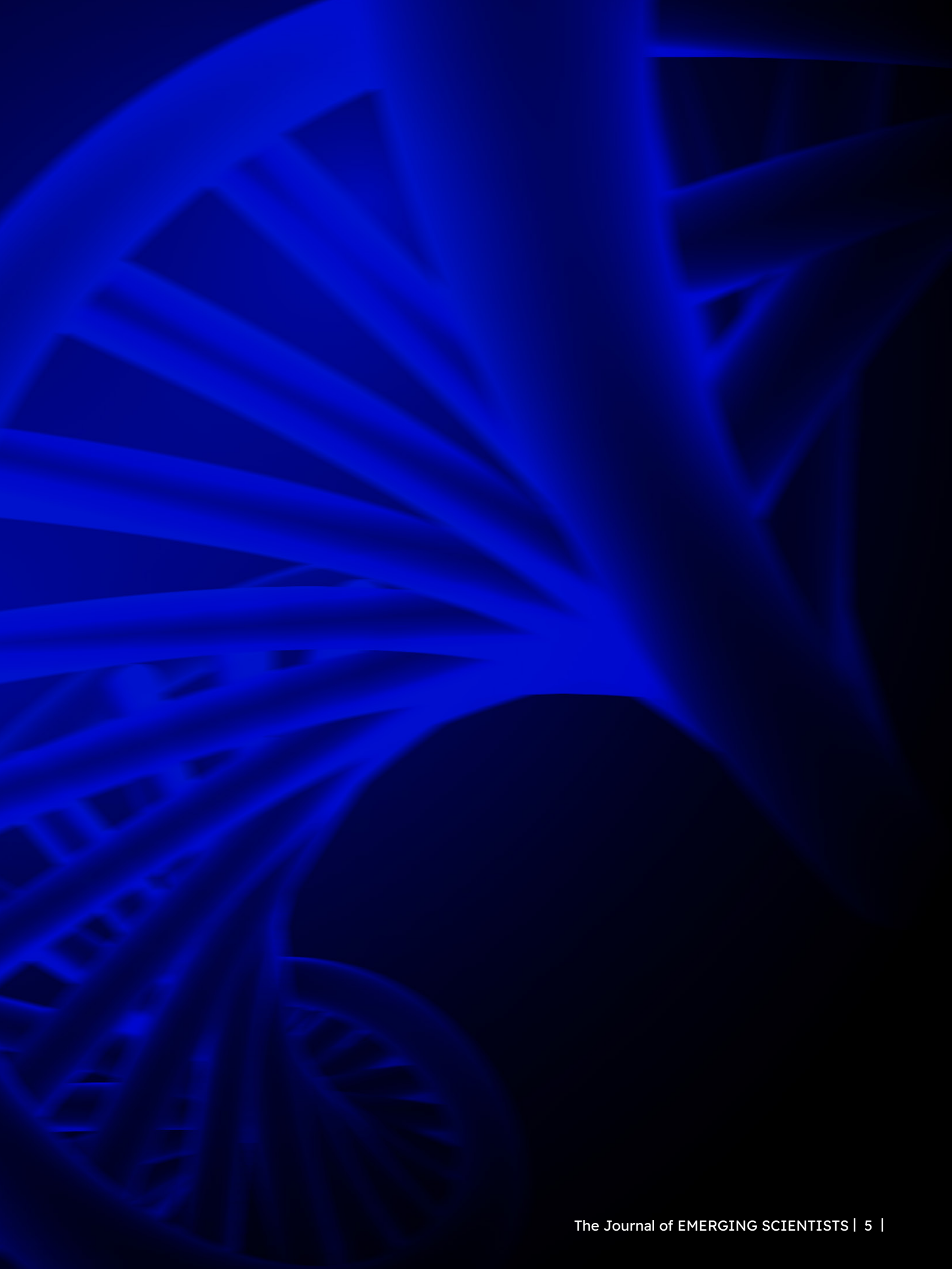
The *Journal of Emerging Scientists* serves as a platform to celebrate their achievements and to inspire future generations of scientists. We encourage you to delve into their findings, engage with their methodologies, and appreciate the valuable contributions they have made.

The editorial team extends its sincere gratitude to the faculty mentors who have guided these students with their expertise and support, as well as to the other individuals who made this issue possible.

We hope you find this issue of the *Journal of Emerging Scientists* informative and inspiring. It offers a compelling snapshot of the vibrant scientific exploration taking place within our Independent Science Research program.

Happy reading!

The Editorial Team



Students' Bios

Naomi is a senior at SSIS. She's currently taking Independent Science Research along with Explorations in Data Science and Environmental Science. Naomi's goal is to become a wildlife veterinarian, which has guided both her academic and personal goals. For her research project, **she compared the foundational neural structures and long-term memory processing between human babies (18–24 months) and two-week-old chickens.** While Naomi has always loved animals, she often finds their unpredictable and complex behaviors difficult to understand. This study pushed her to persevere when her experiments did not go as predicted. To prepare for veterinary school, Naomi intends to major in Biology at university. This will allow her to continue studying animals in greater depth, offering her a solid foundation for a future career in wildlife veterinary medicine.

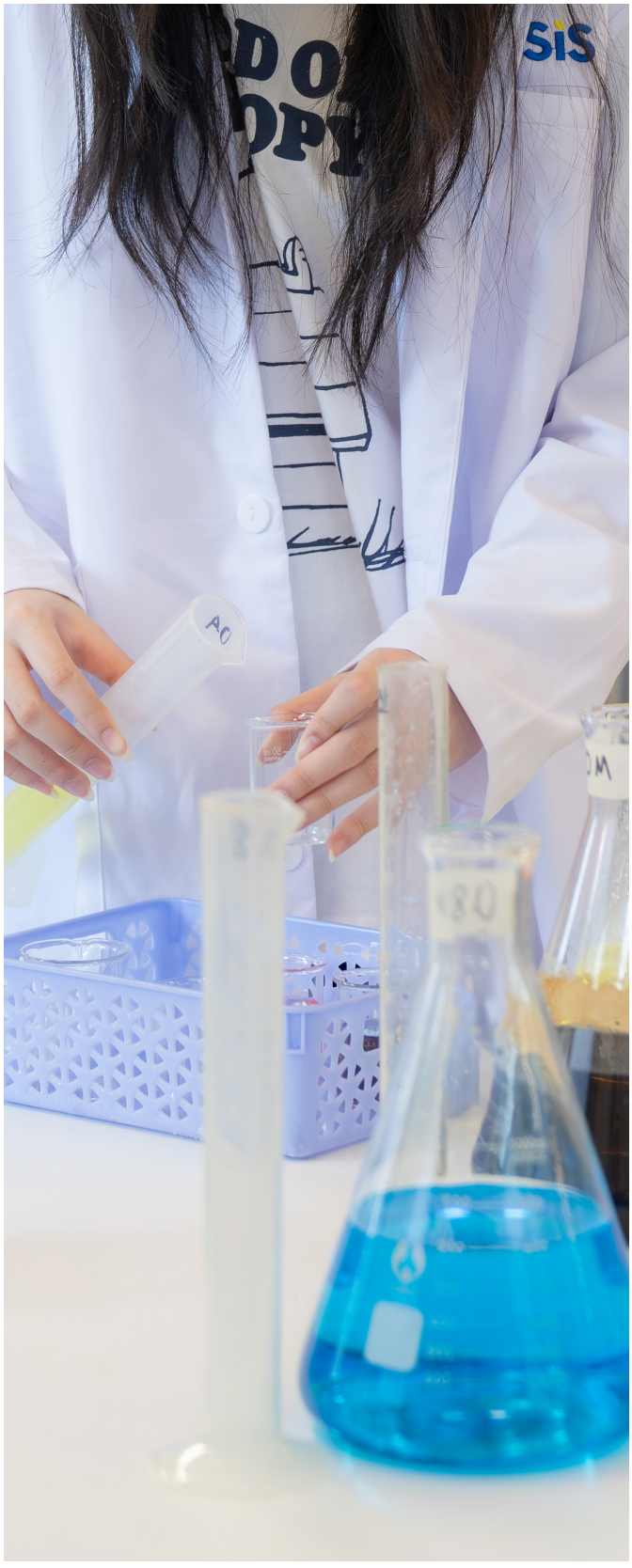
Duc is in grade 11. Along with Independent Scientific Research, he is also taking AP Chemistry. Believing that sports can be a distracting or a motivating factor in the success of high school students, Duc's scientific investigation focused on **determining whether there is an increased level of psychological distress among high school student-athletes at SSIS.** While conducting his investigation, his research process did not go smoothly, which taught him perseverance and patience. Duc has previously competed in Global Link Singapore, a social science competition. His future aspirations are to study psychology and the science behind human behavior. He wants to improve his "scientific research skills beyond high school and take STEAM-related subjects." Duc confides that he tends to get impatient when conducting research, but he's developed resilience by becoming more patient and calmer when things don't go his way during an investigation.

Shannon is a senior who took AP Chemistry and AP Physics before enrolling in the Independent Science Research course. Her project focuses on **optimizing electrochemical CO_2 reduction, a process that could help reduce pollution and greenhouse gas emissions.** She was inspired to pursue this topic through her deep interest in environmental issues and our planet's need for sustainable solutions. Shannon plans to study Chemical Engineering at UCLA in the fall and hopes to continue environmental research at the university level.

Van is in grade 12. In addition to Independent Scientific Research, she has previously taken AP Biology, AP Psychology, and Applied Physics, and she is currently enrolled in AP Chemistry and AP Statistics. Her project examines **how perceived stress affects calorie intake among AP and IB students during exam periods, inspired by her personal experiences and a strong interest in student nutrition.** Despite challenges with participant responses, her research has strengthened her passion for exploring the connection between stress and dietary habits. Outside the classroom, she enjoys baking and cooking, often experimenting with nutrient-rich recipes to create meals that are both healthy and delicious. Van plans to continue her research on stress and food science as a neurobiology major at the University of California, Davis.

Marcie is a senior. She has completed AP Biology, Chemistry, and Physics 1, 2, and C. **Her research focuses on nutrition, specifically analyzing the caloric needs of students at SSIS,** partly because she loves food. Marcie faced challenges with collecting and analyzing her experiment data and learned that one cannot generalize survey results to an entire population without accounting for self-selection bias. She loves LEGO® and puzzles, and says that "scientific research feels like solving a big puzzle where every piece leads to something exciting." This fall, Marcie is heading to the University of Toronto to study engineering and explore innovations in materials and sustainability.

Sybila is graduating from SSIS this year. She is a passionate science student who has completed AP Biology, AP Chemistry, AP Psychology, and Data Exploration and Science. Her independent research is on the **health risks of lead in lipsticks through bioaccumulation into the human body,** inspired by her curiosity about the growing formulation industry and chemistry. Through this project, she has become more confident in her problem-solving skills and has developed resilience when things do not go as planned. She is eager to apply the knowledge she has gained as she enters university.



Assessing the Nutritional Adequacy of School Lunches at Saigon South International School based on Students' Total Daily Energy Expenditure (TDEE)

ABSTRACT

This study investigates whether the caloric content of school lunches provided at Saigon South International School (SSIS) meets the estimated caloric needs of high school students (ages 14–18) based on their Total Daily Energy Expenditure (TDEE). Students' caloric needs were estimated using survey data and calculated with the Mifflin-St Jeor equation, adjusted by self-reported activity levels. Lunch options were analyzed using Cal AI, with assumed portion sizes standardized to average observed school servings. An independent sample t-test was performed to compare the average caloric needs of students to the average caloric content of school lunches. Results showed that lunch provided sufficient calories for students in the Sedentary/Lightly Active group. However, meals were significantly inadequate for Moderately Active and Very Active/Extra Active students, highlighting a need for either increased portions or supplemental intake beyond lunch.

INTRODUCTION

Adolescents' Nutrition

Adolescence is defined as the period between ages 10–19 years old (National Cancer Institute, 2011). During adolescence, the body undergoes rapid development in all domains–biological, cognitive, psychosocial, and emotional (Backes & Bonnie, 2020). Proper nutrition is essential for maintaining a healthy weight (American Heart Association, 2024), supporting normal pubertal growth, cognitive development, and physical activity (Soliman et al., 2022). On the other hand, insufficient caloric intake during adolescence can reduce intellectual capacity (Soliman et al., 2022), delay growth, and increase the risk of chronic diseases in adulthood (Lassi et al., 2017).

Total Daily Energy Expenditure (TDEE)

Total Daily Energy Expenditure (TDEE) reflects daily energy needs and is a critical variable in human health and physiology (Pontzer et al., 2021). TDEE includes multiple components that account for energy used at rest and during physical activity:

- **Resting Energy Expenditure (REE)**: the amount of energy the body requires to maintain vital physiological functions while at rest. It includes maintaining heartbeat, breathing, brain function, and other essential processes (von Loeffelholz & Birkenfield, 2022). REE is composed of:
    - **Basal Metabolic Rate (BMR):** refers to the minimum number of calories your body needs to function at a basic level (Cleveland Clinic, 2024).
- **Non-resting Energy Expenditure (NREE):** the energy expended above resting levels that is not related to the thermic effect of food. It includes all energy used for physical activities and movements outside of rest and digestion. NREE is composed of:
    - **Non-exercise Activity Thermogenesis (NEAT):** refers to the energy expended through everyday activities that are not specifically the result of voluntary exercise (von Loeffelholz & Birkenfield, 2022).

- **Thermic Effect of Food (TEF):** refers to the energy your body uses to digest, absorb, metabolize, and store the nutrients from food (Barclay, 2022).
- **Exercise Activity Thermogenesis (EAT**): refers to the energy expended during structured, purposeful physical exercise (von Loeffelholz & Birkenfield, 2022).

TDEE was chosen for this study because it not only accounts for calories burned at rest but also digestion and activity level, providing a more comprehensive estimate of students' caloric needs.

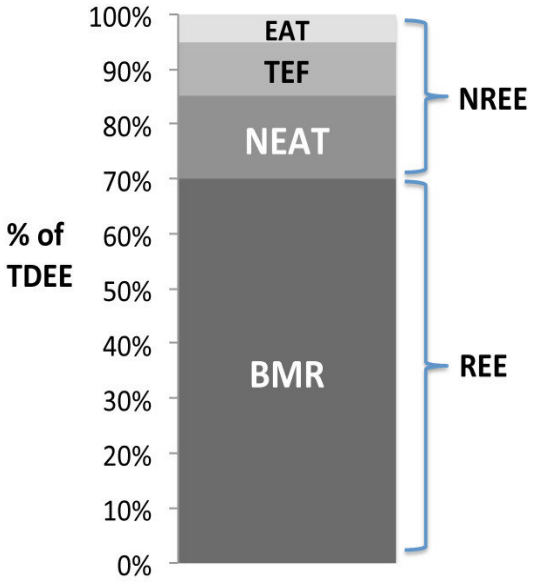


Figure 1. *Components of TDEE: BMR, NEAT, TEF, EAT, REE, and NREE (BioMed Central, 2014)*

Nutritional Labeling at SSIS

Currently, SSIS does not provide detailed nutritional labeling, ingredient composition, or portion size information for its kiosk meals, resulting in limited access to dietary information for students. According to a preliminary survey distributed for this study, the statement "You have enough information about the nutritional content of the food offered at school" received an average student rating of 2.56 on a 5-point scale, indicating a perceived information gap. When asked whether the school lunch "provides enough nutrients to meet your daily needs," the average rating was 3.22 on a 5-point scale. These results reflect students' perceptions, as no objective nutritional benchmarks were available to assess the accuracy of these beliefs. These observations led to the formulation of the following research question: ***"To what extent does the caloric content of school lunch options offered at Saigon South International School meet the average high school student's (ages 14–18) needs based on their TDEE?"***

This study tested this question using the following hypotheses:

- **Null hypothesis (H_0):** SSIS school lunches provide enough calories to meet the lunchtime caloric needs of high school students as estimated by their TDEE.
- **Alternative hypothesis (H_a)**: SSIS school lunches do not provide enough calories to meet the lunchtime caloric needs of high school students as estimated by their TDEE.

MATERIALS AND METHODS

Study Design

This study utilized a quantitative approach to determine whether the nutritional content of school lunch options offered by SSIS meets its high school students' (ages 14–18) caloric needs based on their TDEE. Data collection consisted of two primary components (1) surveying students via Google Forms to collect some of their body measurements and physical activity level (2) analyzing the caloric content of school lunch options using photo documentation and food scanning software. The data were analyzed statistically to assess the adequacy of school lunches in satisfying the students' needs.

Participants and Students Survey

Participants (ages 14–18) were recruited via school email to complete a Google Forms survey. All students had an equal opportunity to participate. While convenient, the survey method might lead to a non-representative sample and skewness (Choi & Pak, 2004), as those who chose to participate may differ systematically from those who did not—for example, more health-conscious or engaged students may have been more likely to respond, potentially biasing the data toward individuals with greater awareness or concern about nutrition. Nonetheless, the survey method was chosen for its feasibility in ensuring broad sample reach while maintaining participant confidentiality. Demographic and anthropometric data collected included biological sex, age, height, weight, and self-reported activity level. The survey also included items assessing students' perceptions of school lunch nutrition.

A total of 92 students responded, of which 9 incomplete responses were removed, resulting in a final sample of 83 participants. While data were collected across all high school grade levels and genders, no effort was made to ensure proportional representation. Therefore, certain age groups or genders may be over- or underrepresented in the sample.

Age	Male (n)	Female (n)	Total (n)
14	3	6	9
15	12	18	30
16	9	13	22
17	8	10	18
18	3	1	4
Total (n)	35	48	83

Table 1. *Distribution of Student Participants by Grade Level and Gender*

Ethical Consideration

Participants provided informed consent by continuing in the survey. They were informed about the purpose of the study and the use of data before they began. All data remained anonymous and accessible only to the research team.

TDEE Calculation

Basal Metabolic Rate (BMR) for each participant was estimated using the Mifflin-St Jeor equation. While the equation is technically designed for resting metabolic rate (RMR), it can be used as a substitute for BMR for simplicity. BMR refers to the number of calories the body needs to maintain basic life functions such as breathing, circulation, and cell production while at complete rest. RMR is a closely related concept but is measured under less strict conditions and may include additional factors like digestion and minimal muscle activity, making it slightly higher than BMR (McMurray et al., 2014). Despite these differences, the terms are often used interchangeably in applied settings due to their conceptual similarity and the practical challenges of measuring true BMR.

The Mifflin-St Jeor equation has been shown to predict RMR within 10% of measured values more accurately than other equations, including Harris-Benedict and Owen, particularly in healthy individuals (Frankenfield et al., 2005). Furthermore, the formula only requires basic inputs–weight, height, age, and sex–without needing complex measurements like body fat percentage or lean body mass, which can be impractical for the study's scope.

Each participant's BMR was estimated using the following equations (TDEE Calculator | Calories Burned per Day | ATHLEAN-X, 2024):

BMR (male) = (10 x weight [kg]) + (6.25 x height [cm]) - (5 x age [years]) + 5
BMR (female) = (10 x weight [kg]) + (6.25 x height [cm]) - (5 x age [years]) - 161

TDEE was calculated by multiplying BMR by a self-reported activity level multiplier (Hwu, 2005). The following activity levels were used. (The activity level descriptions were adapted to account for both exercise intensity and duration, as no standardized scale adequately captured both dimensions.)

Activity Level	Multiplier
Sedentary: Little to no physical movement/exercise, spending most of your day sitting/lying down	BMR x 1.2
Lightly active: Engage in light exercise or recreational activities a few times a week	BMR x 1.375
Moderately active: Engage in regular, moderate-intensity workouts or sports on most days of the week	BMR x 1.55
Very active: Have intense fitness routines that require strenuous effort most days	BMR x 1.725
Extra active: Vigorous athletic training, engage in intense workouts twice a day	BMR x 1.9

Table 2. *Descriptions and corresponding factors used to calculate Total Daily Energy Expenditure (TDEE) from Basal Metabolic Rate (BMR)*

Self-reported activity level was selected over objective measurement, justified by feasibility and the correlation between perceived exertion and food intake (Porter et al., 2025).

Each participant's lunch caloric requirement was estimated by dividing their TDEE by three, based on the common dietary assumption that individuals consume three main meals per day (breakfast, lunch, and dinner) of roughly equal caloric value. While actual meal distributions may vary, this method provides a standardized and practical benchmark for analyzing whether the school-offered lunch alone meets one-third of daily energy needs.

Nutritional Content of School Lunches Analysis

SSIS offers a variety of lunch options through its cafeteria and café. For the purpose of this study, only meals provided by the kiosk were analyzed: Set Lunch, Noodle Soup, Hot Plate, Salad and Wrap, and Pasta Kitchen. These selections were chosen because they represent the core offerings most frequently consumed by students and are standardized enough to allow for consistent caloric analysis.

A total of 31 lunch options were collected from different kiosk stations for evaluation. Caloric data were first obtained using MyFitnessPal (mean = 581.14 kcal) and verified using Cal AI (mean = 615.19 kcal). Although the mean difference between the two tools was not significant, Cal AI was used for final calculations because it avoids user-submitted variability and processes bulk data faster.

Since the SSIS kiosk does not use standardized measurements for portion sizes, meals are prepared without the use of weighing tools. As a result, the quantity of food served may vary slightly between students, across different days, or depending on who is serving. To account for this, average portion sizes were estimated through consistent daily observations, providing a reasonable basis for caloric analysis based on the most typical serving size.

Statistical Analysis

To determine whether school lunches met the caloric needs of students, an independent sample t-test was conducted using the Social Science Statistics online calculator to compare the average lunch caloric values with students' average TDEE across different activity levels. This test was chosen because the two means—students' average lunch TDEE and the average caloric value of school lunch—were assumed to be independent. Assumptions for the independent sample t-test included:

1) Normality: Central Limit Theorem applied as the sample sizes exceed 30 participants or histogram analysis (2) Independence: Assumed between students' TDEE and school lunches' caloric content (3) Random sample: Not achieved due to self-selected bias, so generalizations are limited.

Additionally, to satisfy assumptions for subgroup analysis, students were grouped by activity level (combining Sedentary and Lightly Active, and combining Very Active and Extra Active). These groupings were made because individuals within each combined category had relatively similar caloric needs, and grouping also increased sample sizes to meet normality conditions required for statistical testing.

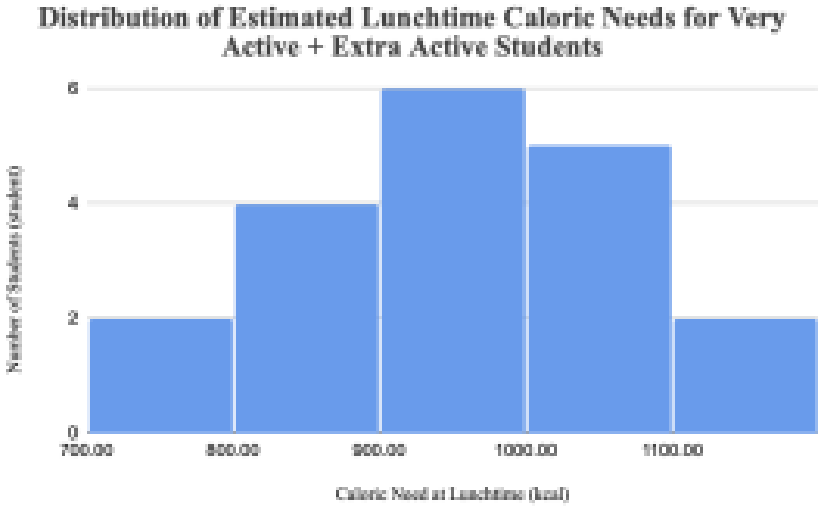


Figure 2. *Histogram of caloric needs distribution for Very Active + Extra Active group showing approximate normality*

RESULTS

Group	Sample Size (n)	Mean, $\bar{x}$ (kcal)	Standard Deviation, s (kcal)	Margin of Error 95%, $1.960_{s_{\bar{x}}}$
Lunch options	31	615.2	128.5	615.2 ± 45.2 (± 7.35%)
Sedentary + Lightly Active	30	599.2	63.2	599.2 ± 22.6 (± 3.77%)
Moderately Active	34	796.7	129.9	796.7 ± 43.7 (± 5.48%)
Extra Active + Very Active	19	956.3	114.1	956.3 ± 51.3 (± 5.37%)

Table 3. *Sample sizes, means, standard deviations, and 95% confidence margins for the caloric needs of each student activity group and for school lunch options*

Group	Sample Size (n)	Mean TDEE (kcal)	*t*-value	*p*-value	Significance
Sedentary + Lightly Active	30	599.2	-0.61	0.5419	Not significant
Moderately Active	34	796.7	5.65	< 0.00001	Statistically significant
Very Active + Extra Active	19	956.3	9.49	< 0.00001	Statistically significant
All Students In The Sample	83	761.9	4.29	0.000038	Statistically significant

Table 4. *Independent sample t-test results comparing student activity groups' caloric needs to lunch offerings, generated using the Social Science Statistics online calculator*

The results showed that the average lunch offering (615.2 kcal) met the caloric needs of Sedentary + Lightly Active students (599.2 kcal), as no significant difference was found ($t = -0.61$, $p = 0.5419$). However, caloric needs of Moderately Active students (796.7 kcal) and Very/Extra Active students (956.3 kcal) were significantly greater than the calories provided by school lunch ($p < 0.00001$ for both groups). These findings validate the claim that SSIS lunches fall short for more active students. Overall, students' mean caloric need at lunch was 761.9 kcal ($t = 4.29$, $p = 0.000038$) and was significantly higher than the mean caloric content of school lunch options.

CONCLUSION

The hypothesis that SSIS school lunches may not adequately meet students' caloric needs was partially supported. While lunches provided sufficient energy for Sedentary + Lightly Active students ($t = -0.61$, $p = 0.5419$), they were significantly insufficient for students who were Moderately Active ($t = 5.65$, $p < 0.00001$) and Very Active + Extra Active ($t = 9.49$, $p < 0.00001$). These results support the claim that the current lunch options do not meet the nutritional demands of more active students. Given the importance of adequate adolescent nutrition for growth and performance (*Adolescent Nutrition | Centre for Adolescent Health,* n.d.), this study highlights the need for SSIS to consider portion customization or nutritional transparency to better align meals with varying student energy requirements. These findings reaffirm the study's initial concern and suggest areas for improvement in school meals.

EVALUATION

Strengths

This study had several strengths that enhanced the reliability of its findings. The combination of student-specific data–height, weight, age, and activity level–allowed for a customized calculation of caloric needs, specifically for SSIS. Statistical tests were appropriate and assumptions, such as normality and independence, were either met or addressed through subgrouping and histogram validation. Additionally, caloric values of lunch items were analyzed using two tools (MyFitnessPal and Cal AI), with the latter selected for its consistency and ability to handle bulk data without user-submitted variability.

Limitations

However, the study also faced several limitations that could have impacted the accuracy of its results. The results cannot be inferred to the entire SSIS student population due to lack of random sampling. The use of the Mifflin-St Jeor equation also introduces limitations. Though generally reliable and accurate within about 10% for many people, its accuracy decreases in obese individuals and certain ethnic or age groups that were underrepresented in validation studies (Stubelj et al., 2019). Since the sample was students aged 14-18, it was below the recommended age range for calculation. Mifflin-St Jeor is also designed to measure RMR, not BMR.

Self-reported activity level introduces subjectivity, which could affect TDEE accuracy, as students may overestimate or underestimate the frequency, duration, or intensity of their physical activity. This can lead to inflated or deflated TDEE estimates, thereby affecting the validity of the comparison between caloric needs and lunch offerings. Furthermore, while the Mifflin-St Jeor equation accounts for sex biologically by using different formulas for males and females, it does not consider individual differences in body composition such as muscle mass or fat distribution. These factors influence metabolic rate and caloric needs. As a result, even students of the same age, height, and weight may require different energy intakes. Although it is recognized that boys generally require more calories than girls due to higher average muscle mass and metabolic rate, no subgroup analysis by gender was conducted in this study due to time constraints.

While Cal AI improved accuracy compared to MyFitnessPal by removing crowd-sourced variability, limitations remain. The app may struggle to identify mixed dishes with hidden ingredients, especially in culturally diverse meals like those served at SSIS. Meal portion sizes were assumed based on observed averages, which may vary daily and were not confirmed by kitchen staff.

These limitations highlight that while the findings are statistically significant, the exact extent to which students' energy needs are unmet may be overestimated or underestimated. Nonetheless, the study offers compelling evidence that current school lunches may inadequately support students with higher physical demands and invites further refinement in both data collection methods and school nutrition planning.

ACKNOWLEDGEMENTS

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REFERENCES

Adolescent nutrition | Centre for Adolescent Health. (n.d.). Blogs.rch.org.au. https://blogs.rch.org.au/cah/2023/08/15/adolescent-nutrition/

American Heart Association. (2024, September 24). *Dietary recommendations for healthy children*. https://heart.org/en/healthy-living/healthy-eating/eat-smart/nutrition-basics/dietary-recomm endations-for-healthy-children

Backes, E. P., & Bonnie, R. J. (Eds.). (2020). Adolescent development. In *The promise of adolescence: Realizing opportunity for all youth* (pp. 1–44). National Academies Press. https://ncbi.nlm.nih.gov/books/NBK545476/

Barclay, A. (2022, January). *The thermic effect of food.* Glycemic Index Foundation. https://glycemicindex.com/2022/01/the-thermic-effect-of-food/

BioMed Central. (2014, February 27). *Components of total daily energy expenditure (TDEE). BMR = basal...* ResearchGate; ResearchGate. https://researchgate.net/figure/Components-of-total-daily-energy-expenditure-TDEEBMRb asal-metabolic-rate_fig1_260397860

Choi, B. C., & Pak, A. W. (2004). A Catalog of Biases in Questionnaires. *Preventing Chronic Disease, 2*(1). https://pmc.ncbi.nlm.nih.gov/articles/PMC1323316/

Cleveland Clinic. (2024, November 20). *BMR (Basal Metabolic Rate): What It Is & How To Calculate It*. https://my.clevelandclinic.org/health/body/basal-metabolic-rate-bmr

Frankenfield, D., Roth-Yousey, L., & Compher, C. (2005). Comparison of predictive equations for resting metabolic rate in healthy nonobese and obese adults: A systematic review. *Journal of the American Dietetic Association*, 105(5), 775–789. https://pubmed.ncbi.nlm.nih.gov/15883556/

Hwu, A. (2005). *Physical Activity and Controlling Weight.* https://k-state.edu/paccats/Contents/PA/PDF/Physical%20Activity%20and%20Controlling %20Weight.pdf

Lassi, Z. S., Moin, A., & Bhutta, Z. A. (2017). Nutrition in middle childhood and adolescence. In *Disease control priorities (3rd ed.): Volume 8, child and adolescent health and development* (pp. 147–160). World Bank. https://ncbi.nlm.nih.gov/books/NBK525242/

McMurray, R. G., Soares, J., Caspersen, C. J., & McCurdy, T. (2014). Examining variations of resting metabolic rate of adults. *Medicine & Science in Sports & Exercise,* 46(7), 1352–1358. https://doi.org/10.1249/MSS.0000000000000232

National Cancer Institute. (2011, February 2). Adolescent. https://cancer.gov/publications/dictionaries/cancer-terms/def/adolescent

Pontzer, H., Yamada, Y., Sagayama, H., Ainslie, P. N., Andersen, L. F., Anderson, L. J., Arab, L., Baddou, I., Bedu-Addo, K., Blaak, E. E., Blanc, S., Bonomi, A. G., Bouten, C. V. C., Bovet, P., Buchowski, M. S., Butte, N. F., Camps, S. G., Close, G. L., Cooper, J. A., & Cooper, R. (2021). Daily energy expenditure through the human life course. *Science, 373*(6556), 808–812. https://doi.org/10.1126/science.abe5017

Porter, A., Jago, R., Robles, L. A., Cawley, E., Rogers, P. J., Ferriday, D., & Brunstrom, J. M. (2025). Investigating the psychology of eating after exercise – a scoping review. *Journal of Nutritional Science*, 14. https://doi.org/10.1017/jns.2024.99

Soliman, A., Alaaraj, N., Hamed, N., Alyafei, F., Ahmed, S., Shaat, M., Itani, M., Elalaily, R., & Soliman, N. (2022). Nutritional interventions during adolescence and their possible effects. *Acta Bio Medica: Atenei Parmensis,* 93(1), e2022087. https://doi.org/10.23750/abm.v93i1.12789

Stubelj, M., Teraž, K., & Poklar Vatovec, T. (2019). Predicting equations and resting energy expenditure changes in overweight adults. *Slovenian Journal of Public Health, 59*(1), 33–41. https://doi.org/10.2478/sjph-2020-0005

TDEE Calculator | Calories Burned Per Day | ATHLEAN-X. (2024, December 26). ATHLEAN-X. https://learn.athleanx.com/calculators/tdee-calculator

von Loeffelholz, C., & Birkenfeld, A. (2022). *The Role of Non-exercise Activity Thermogenesis in Human Obesity* (K. R. Feingold, B. Anawalt, A. Boyce, G. Chrousos, K. Dungan, A. Grossman, J. M. Hershman, G. Kaltsas, C. Koch, P. Kopp, M. Korbonits, R. McLachlan, J. E. Morley, M. New, L. Perreault, J. Purnell, R. Rebar, F. Singer, D. L. Trence, & A. Vinik, Eds.). PubMed; MDText.com, Inc. https://ncbi.nlm.nih.gov/books/NBK279077/

To what extent does increasing the voltage range affect the extent of CO_2 reduction in an electrolysis reaction?

ABSTRACT

This research investigates the relationship between applied voltage and the electrochemical reduction of carbon dioxide (CO_2) in a silver nitrate solution. According to Chai et al. (2023), post-combustion CO_2 capture remains one of the most efficient strategies, particularly when using chemical absorption, solid adsorption, or membrane separation. Building on this, electrochemical CO_2 conversion offers a renewable, electricity-driven pathway to transform CO_2 into useful compounds like carbonic acid.

This experiment evaluates how different voltages influence CO_2 reduction by measuring changes in pH and conductivity before and after electrolysis. The hypothesis was that moderate voltages would enhance ionic product formation and increase solution acidity, indicating optimal CO_2 conversion. The data showed that voltages between 3.0V and 6.0V produced the most significant pH drops and conductivity increases. These results are consistent with Detz et al. (2023), who highlighted the role of applied voltage in improving component efficiency and product yield in electrochemical systems.

However, based on the voltage-efficiency relationship reported by Niu et al. (2019), excessive voltage led to anomalies likely caused by competing reactions or system instability. Overall, this study supports the development of CO_2 capture and utilization (CCU) technologies, contributing to future clean energy and carbon recycling solutions.

INTRODUCTION

Vietnam has seen a **triple increase in CO_2 emissions from 2000 to 2020**, largely due to industrial expansion and fossil fuel reliance (World Bank, 2022). This inspired me to explore sustainable CO_2 reduction strategies, particularly those powered by renewable electricity. One promising solution is **electrochemical CO_2 reduction,** which uses electrical energy to convert carbon dioxide into useful chemicals like formic acid, methanol, or carbonate ions. This process can help close the carbon loop if powered by green energy sources. The efficiency of CO_2 reduction depends on several variables, including electrode type, electrolyte composition, and applied voltage. Past research has shown that increasing voltage accelerates reaction rates, but excessive voltage may trigger side reactions like hydrogen evolution or metal ion reduction (Chai et al., 2023). **This study aims to determine the optimal voltage range for efficient CO_2 conversion,** using pH and conductivity as indirect indicators of ionic product formation and acidification.

METHODOLOGY

Materials and Preparation

- **Sodium Bicarbonate Solution:** 2g of $NaHCO_3$
- **Hydrochloric Acid:** 10 mL of 1M HCl
- **Silver Nitrate Solution:** 30mL of 0.1M $AgNO_3$
- **Beakers:** 5.3 cm diameter × 7 cm height (2)
- **Copper Electrodes:** 4 cm × 10 cm strips (2)
- **pH and Conductivity Pen:** Used to measure solution properties pre- and post-reaction
- **Distilled Water:** Used to rinse beakers and materials between trials to prevent cross-contamination

Experimental Setup

Figure 1: *Illustrates the pH and conductivity pens used.*

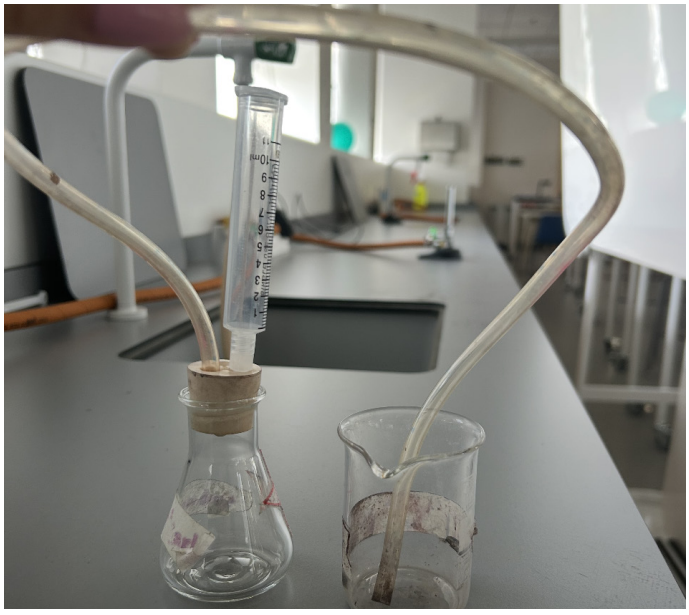


Figure 2: *Depicts the gas transfer and electrode configuration used to conduct electrolysis.*

Electrode Configuration

Copper strips were attached to the rim of the silver nitrate beaker and connected to a power supply using alligator clips. This setup allowed for a consistent current flow through the electrolyte.

Initial Measurements

The pH and conductivity of the $AgNO_3$ solution were recorded before introducing CO_2. These values served as baseline data for later comparison.

CO_2 Generation and Transfer

To generate CO_2, 10 mL of HCl was slowly added to the beaker containing 2g of sodium bicarbonate. The gas released was directed via a gas transfer tube into the beaker containing silver nitrate. This approach ensured controlled and immediate exposure of the electrolyte to CO_2 gas.

Reaction:

$NaHCO_3 + HCl \longrightarrow NaCl + CO_2\uparrow + H_2O$

Electrolysis Procedure

After CO_2 was bubbled into the $AgNO_3$ solution, electrolysis was initiated by turning on the power supply. The reaction was monitored and allowed to run until gas bubbles stopped forming in the CO_2-generating beaker, signaling completion.

Electrochemical Reactions:

$CO_2 + H_2O \rightleftharpoons H_2CO_3$

$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$

Final Measurements and Trials

Post-reaction, pH and conductivity were measured again. The experiment was conducted at voltages of 0V, 1.5V, 3.0V, 4.5V, 6.0V, 9.0V, and 12.0V, with two trials at each voltage for consistency.

RESULTS

Effect of Applied Voltage on pH and Conductivity Before and After Electrolysis in Silver Nitrate Solution

Trial	Voltage (V)	Conductivity of $AgNO_3$ (ppt)	Conductivity of Electrolysis (ppt)	pH of $AgNO_3$	pH of Electrolysis
1	0	3.94	5.95	6.1	6.0
2	1.5	2.76	4.74	4.5	4.2
3	1.5	5.7	6.5	4.9	4.9
4	3.0	4.4	6.17	5.6	5.1
5	3.0	5.57	2.55	5.1	4.8
6	4.5	4.5	6.07	5.6	4.6
7	6.0	3.03	6.42	4.5	4.5
8	6.0	3.81	2.28	5.0	6.7
9	9.0	3.03	5.14	4.5	4.3
10	9.0	6.78	4.45	5.1	4.8
11	12.0	3.03	5.97	5.5	4.1
12	12.0	2.9	3.5	5.5	4.8

Table 1: *Experimental Data Table of Voltage, Conductivity, and pH Before and After Electrolysis. This table summarizes the results of the trials to show the applied voltage, the conductivity, and pH levels of $AgNO_3$ before and after electrolysis.*

DATA ANALYSIS

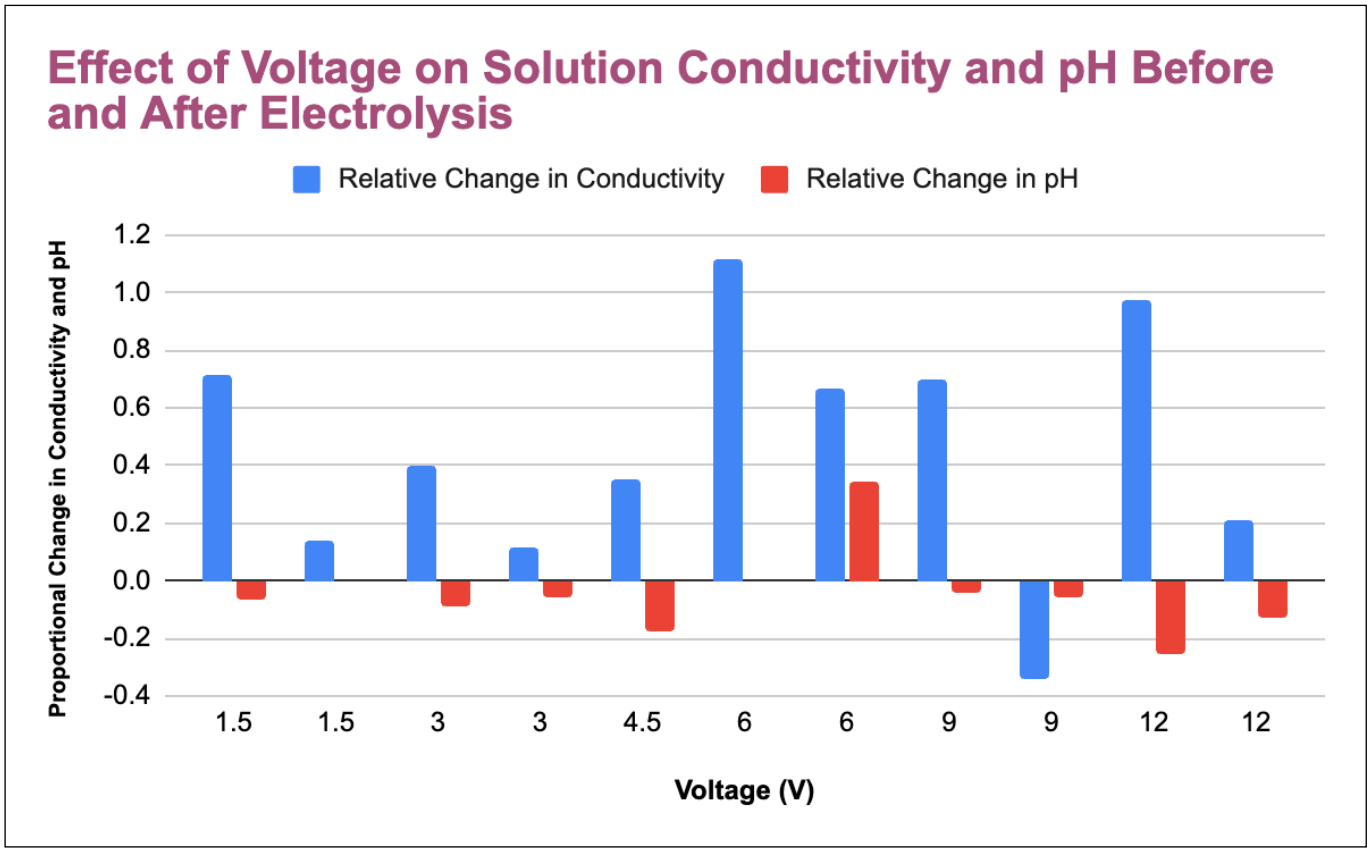


Table 2: *Effect of Voltage on Solution Conductivity and pH Before and After Electrolysis. This bar graph shows the proportional change in conductivity (blue) and pH (red) of the silver nitrate solution before and after electrolysis at voltages from 1.5V to 12.0V.*

Conductivity Analysis

Conductivity reflects the concentration of ions in the solution. An increase in conductivity after electrolysis suggests that the reaction produced new ionic species, which enhances ion flow and indicates active electrochemical CO_2 conversion.

Across most trials, especially between 3.0V and 6.0V, conductivity increased significantly, up to +112% relative change, as shown in Table 2. This supports the idea that CO_2 is being converted into bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions via the intermediate formation of carbonic acid (H_2CO_3). These negatively charged ions increase the ionic strength of the solution, thereby raising conductivity.

The largest relative increase occurred at 6.0V, which aligns with the hypothesis that moderate voltages optimize CO_2 reduction. In contrast, inconsistencies such as the decrease in conductivity observed at 9.0V (Trial 2) may be due to competing reactions, such as the reduction of Ag^+ ions or interference from excessive current disrupting the electrochemical environment.

pH Analysis

The pH trend provides insight into the formation of acidic products. A decrease in pH was observed in most trials, which suggests the generation of carbonic acid (H_2CO_3) as CO_2 dissolves and reacts with water. This supports the successful electrochemical activation of CO_2.

Voltages between 3.0V and 4.5V showed consistent pH drops, further reinforcing this interpretation. The largest increase in pH occurred at 6.0V (Trial 2), which is a notable outlier. This may reflect a side reaction that may temporarily produce hydroxide ions and raise pH.

Summary of Patterns

- Conductivity $\uparrow$ —> Indicates formation of ionic CO_2-reduction products (HCO_3^-, CO_3^{2-}).
- pH $\downarrow$ —> Suggests acidification from carbonic acid formation.
- Optimal range: 3.0V–6.0V for both trends.
- Outliers: Irregular results at 6.0V (Trial 2), 9.0V (Trial 2), and 12.0V suggest reduced efficiency or interference.

CONCLUSION

This investigation demonstrates that electrolysis can effectively facilitate the conversion of CO_2 into acidic and ionic products, particularly when operated at moderate voltages between **3.0V and 6.0V.** This supports the hypothesis that increasing voltage enhances CO_2 reduction up to an optimal point.

The **evidence** lies in the proportional increases in conductivity and decreases in pH observed across multiple trials within this range. These changes are consistent with the formation of **carbonic acid (H_2CO_3)** and its dissociation into **bicarbonate (HCO_3^-)** and **carbonate (CO_3^{2-}),** all of which increase ion concentration and acidity. However, the results became less consistent at higher voltages (9.0V and 12.0V), which is likely due to side reactions. This pattern aligns with findings by Detz et al. (2023), who emphasized the importance of identifying voltage thresholds to optimize energy efficiency in electrochemical CO_2 conversion systems.

The results suggest that electrochemical CO_2 reduction, when powered by **renewable electricity,** could become a scalable and sustainable strategy for mitigating greenhouse gas emissions and car/motorbike pollution. For future applications, this method could be expanded to:

- Convert captured CO_2 into **fuel precursors** like methanol (as seen in USC's methanol synthesis studies)
- Support **on-site emission reduction** at industrial facilities

Further research should explore alternative electrodes, real-world gas mixtures, and system scaling to evaluate the feasibility of these systems in a practical setting. This study provides a foundational step toward understanding how voltage can optimize electrochemical CO_2 conversion.

EVALUATION AND LIMITATIONS

This investigation successfully demonstrated that electrolysis influences the reduction of CO_2, as indicated by notable changes in pH and conductivity. However, several limitations must be considered when interpreting the results.

Potential Sources of Error and Interference

1. **Reduction of Ag+ Ions:**
   The use of silver nitrate as the electrolyte may have introduced competing redox reactions. Silver ions (Ag^+) could be reduced at the cathode independently of CO_2 reduction, contributing to increased conductivity unrelated to CO_2 conversion.

2. **Inconsistencies Across Trials:**
   Some trials, such as the second trial at 6.0V and 9.0V, showed unexpected trends (pH increase or conductivity drop). These anomalies may reflect unstable gas delivery, uneven electrode contact, or variations in solution mixing.

3. **Measurement Limitations:**
   The experiment relied solely on **pH and conductivity** as indirect indicators of CO_2 reduction. While useful, these do not directly confirm product identity or quantity. More precise methods could be explored.

Control Experiment: Confirming the Role of Electrolysis

To verify that the observed changes were due to electrolysis and not just the presence of CO_2, a control experiment was performed without applying any voltage. After CO_2 was introduced to the silver nitrate solution, the pH only dropped from 6.1 to 6.0, and conductivity increased slightly from 3.94 to 5.95 ppt (+2.01). These minor shifts indicate that **CO_2 alone does not significantly alter the solution.** Therefore, the substantial changes observed in the main trials can be attributed to **electrochemically driven reactions,** not passive CO_2 absorption.

Ways to Improve the Investigation

1. **Repeat Trials:** Conduct at least 3 trials per voltage to minimize the impact of outliers and increase statistical reliability.

2. **Use Alternative Electrolytes**: Replacing silver nitrate with an electrolyte like sodium sulfate could prevent unwanted metal ion reduction.

3. **Quantify Products Directly**: Introduce other methods to measure the concentration of bicarbonate or carbonate ions formed.

REFERENCES

Chai, Yee Ho, et al. "Basic Principles of CO_2 Capture and Conversion Technologies." *Nanomaterials for Carbon Dioxide Capture and Conversion Technologies*, Elsevier, 2023, www.sciencedirect.com/science/article/pii/B9780323898515000068. Accessed 3 Dec. 2024.

Detz, Remko J., et al. "Electrochemical CO_2 Conversion Technologies: State-of-the-Art and Future Perspectives." *Sustainable Energy & Fuels, The Royal Society of Chemistry,* 25 Oct. 2023, https://pubs.rsc.org/en/content/articlelanding/2023/se/d3se00775h Accessed 3 Dec. 2024.

Niu, Guanghui, et al. "Investigation of CO_2 Splitting Process Under Atmospheric Pressure Using Multi-Electrode Cylindrical DBD Plasma Reactor." *Plasma Chemistry and Plasma Processing,* vol. 39, 2019, pp. 939–954. Springer, https://doi.org/10.1007/s11090-019-09955-y. Accessed 3 Dec. 2024.

"Influence of Discharge Voltage on CO_2 Conversion and Energy Efficiency." *ResearchGate,* www.researchgate.net/figure/Influence-of-discharge-voltage-on-CO2-conversion-and-energy-efficiency-CO2-flow-rate_fig4_331209058. Accessed 3 Dec. 2024.

"Turning Air into Fuel: USC Scientists Turn Carbon Dioxide into Methanol." *USC Today, University of Southern California*, https://today.usc.edu/turning-air-into-fuel-usc-scientists-turn-carbon-dioxide-into-methanol/. Accessed 3 Dec. 2024.

"Crafting a Superstar Enzyme That Turns CO_2 Emissions into Useful Products." *USC Viterbi School of Engineering*, 2023, https://viterbischool.usc.edu/news/2023/03/crafting-a-superstar-enzyme-that-turns-co2-emissions-into-useful-products/. Accessed 3 Dec. 2024.

Olah, George A., et al. "Chemical Recycling of Carbon Dioxide to Methanol and Dimethyl Ether: From Greenhouse Gas to Renewable, Environmentally Carbon Neutral Fuels and Synthetic Hydrocarbons." *The Journal of Organic Chemistry,* vol. 74, no. 2, 2009, pp. 487–498. https://doi.org/10.1021/jo801260f.

National Renewable Energy Laboratory. "CO_2 Conversion Pathways." *NREL,* https://www.nrel.gov/research/co2-conversion.html. Accessed 3 Dec. 2024.

Leclaire, Julien, et al. "Reversible Chemical Fixation of CO_2." *Chemical Society Reviews,* vol. 41, no. 11, 2012, pp. 4165–4180. https://doi.org/10.1039/C2CS15384B.

To what extent do the number of sports participation contribute to the higher psychological distress among high school SSIS Student-athletes using the K10 Distress scale?

ABSTRACT

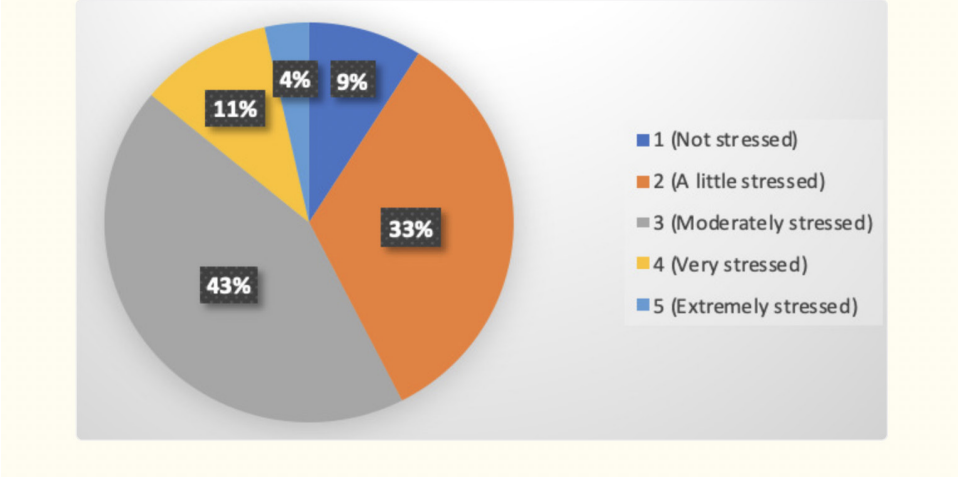
There have been trends towards raising mental health awareness among all. However, there has specifically been a focus on a particular group, students. Students face countless struggles and difficulties throughout their time as scholars. These may include academics, family, social media, and athletics factors. This study focuses on determining to what extent do the number of sports participation contribute to the higher psychological distress among high school SSIS Student-athletes using the K10 Distress Scale. This research focuses on Saigon South International School, a college preparatory school located in Ho Chi Minh City, Vietnam. The school has 260 student athletes who participate in at least one sport at school out of the total 488 students, accounting for 53.28% of the school population. A form was sent out through multiple media channels, such as mail and social media, to high school students. This form entices a K10 questionnaire to evaluate the student's psychological well-being. A one-way ANOVA test was used to determine whether the results support the conclusion that the number of sports played significantly influences psychological distress levels. It showed that the conclusion was supported due to the p value being significantly lower than the 0.05 threshold, indicating strong evidence against the null hypothesis.

Keywords: Mental health, Psychological Distress, Student-Athletes

BACKGROUND INFORMATION

Anxiety & Depression

Figure 1. Stress level due to sports.



Tavish Ward, Thor Stead, Rohan Mangal, Latha Ganti. (2023 Feb 21). Figure 1. Stress level due to sports [Photograph]. PubMed. https://pubmed.ncbi.nlm.nih.gov/36844646/. Accessed 3 May 2025.

This study found that 91% of the high school athletes experienced some type of stress, and approximately 60% experienced a moderate to an extreme level of stress due to their sport. The study used an anonymous online survey conducted with 200 high school athletes, aged 16 to 17, to explore the relationship between stress and sports. The participants included both male and female athletes from diverse sports backgrounds, geographic locations, and ethnicities (1). Since the 2010s, there has been an increase in the rate of depression amongst high school students as a whole. In the United States, post COVID-19, these issues continued to rise. Statistically speaking, "39.7% of students experienced persistent feelings of sadness and hopelessness, 28.5% experienced poor mental health, 20.4% seriously considered attempting suicide, and 9.5% attempted suicide" (2). More specifically, student-athletes tend to have increasing psychological distress. According to PMC PubMed central, research conducted on U.S. high school student athletes has found that "around 60% of all high school athletes experienced a moderate to an extreme level of stress due to their sport, and a quarter reported stress negatively affecting their performance" (1).

K10 Scale

The K10 Scale, also known as the Kessler Psychological Distress Scale, is a measure of psychological distress. This scale involves 10 questions about a person's emotional state over the past 30 days, each with a five-level response scale. Once the participant has completed the survey, a score out of 50 will be calculated. Low scores indicate low levels of psychological distress, while high scores indicate high levels of psychological distress. Scores from 10-19 are categorized as "likely to be well", 20-24 as "likely to have a mild disorder, 25-29 as "likely to have a moderate disorder", and 30-50 as "likely to have a severe disorder, according to the 2001 Victorian Population Health Survey (3).

Saigon South International School

Saigon South International School (SSIS), is a college preparatory school in Ho Chi Minh City, Vietnam, that is involved in sports like basketball, volleyball, soccer, badminton, swimming, cross country and track & field. SSIS is a founding member of the Mekong River International Schools Association (MRISA), that involves international schools in countries such as Thailand, Cambodia, Laos, and Vietnam. In addition, SSIS is the only school in Vietnam to be a member of the South East Asia Student Activities Conference (SEASAC), which hosts 24 events at 16 schools throughout the region. Moreover, SSIS is also a part of Saigon International Schools Athletic Conference (SISAC), a local inter-school league with over 15 schools. At SSIS High School, there are 260 students who participate in at least one activity, out of the total 488 students. This accounts for 53.28% of all high school students (4). In terms of academics, SSIS is the only school in Ho Chi Minh City that offers both the International Baccalaureate Diploma Program (IBDP) and Advance Placement (AP). SSIS offers 21 Advance Placement (AP) courses, and 43 International Baccalaureate (IBDP) Higher Level and Standard Level courses. SSIS requires students to earn a minimum of 24 credits across all subjects, such as English, Math, Science, Social Studies, Modern World Languages, Fine and Performing Arts, Physical Education & Health and Electives. Each credit is earned for successful completion for a one-year course that meets for an average 210 minutes per week.

One-Way ANOVA Test

ANOVA, which stands for Analysis of Variance, is a statistical method used to compare the average values across three or more groups. This test examines how much variation exists both within each group and between all of the different groups. The main objective is to determine whether the differences in group average are greater than what would be expected by chance. If the variation between the groups is significantly greater than the variation within them, it indicates that the group differences are likely meaningful (7).

Key Terms:

Psychological Distress: "Psychological distress" can be measured using validated tools such as the Kessler Psychological Distress Scale (K10) or the General Health Questionnaire (GHQ). This term captures symptoms like anxiety, stress, and emotional discomfort, which are quantifiable and commonly studied in relation to injury and recovery.

Student-Athlete: An individual who pursues academic and athletic endeavors. This student participates in at least one sport at school.

Hypothesis: High school student-athletes experience significantly higher psychological distress, as measured by the K10 Distress Scale, compared to non-athlete students due to factors such as performance pressure, time demands, and physical strain.

H_0 (Null Hypothesis): There is no relationship between the number of sports played and the psychological distress as any difference is not significant.

H_a (Alternative Hypothesis): The more sports that are played by the student-athletes, the higher the psychological distress as measured by the higher K10 score.

PROCEDURE:

Independent Variable (IV): Participation in athletics (Student-athletes vs. Non-athletes)
Dependent Variable (DV): Psychological distress (measured by the K10 Distress Scale)

This paper is a combination of literature review and surveys. Combining the K10 Distress Scale with several personal questions on identifying one's athletic activities, the form is sent out to all sports teams at Saigon South International School (SSIS). These sports teams include basketball, softball, tennis, badminton, etc. Once these questionnaires are collected, further analysis will be done to analyze common trends and identify whether there are correlations. The research question was iterated several times. At the beginning, the question was trying to determine whether several factors, such as familial factors, social media, and academics contribute to the higher psychological distress amongst high school student athletes. However, after talking SSIS's school psychologist, as well as literature reviews, the question was changed to determine whether athletics contribute to the higher psychological distress among high school student athletes. To be able to send this form, I sent it to the athletes over social media and over mail. However, I mainly sent the form through social media platforms as the emailing method yielded little to no responses. The K10 was chosen as it was the most appropriate scale because the K10 entices all distresses, such as anxiety and depression. To further analyze the data, I will do the one-way ANOVA for this study because it is the most suitable statistical test for comparing the average K10 scores across more than two independent variables based on the number of sports played. This method allows me to detect significant differences between group means while controlling the risk of Type I error which happens when a true null hypothesis is mistakenly rejected by the researcher.

RISKS & CONSIDERATIONS:

Participation

Research showed that "more than one third (36%) of adults over the age of 16 never discuss their mental health, representing 19.6 million people (5). There is a common stigma around mental health, and getting participants to complete the form may bring difficulties. So, I did a more personal route, sending the forms through social media platforms instead of GMail. I was able to go from 10 participants to 100 in under 12 hours. This was because I asked my friends to send it to their friends. Thus, I was able to get many participants. Although distributing the form via social media introduced a potential selection bias, it was found more effective than email - which yielded no responses - as I employed a snowball sampling method by asking the recipients to share the form with their own networks, significantly increasing participation. By doing so, I received more than 100 responses within 6 hours.

Honesty

Sharing about one's vulnerabilities to a high school student through a Google form can be difficult for some. There is a mental barrier that is placed in students about sharing their weaknesses. Therefore, if these students do share, is it the truth? So, to acknowledge these problems, the solution was that I sent these forms personally through social media to my friends, and asked the friends to send it to their friends. I found that this way was more effective than sending this survey via email as students do not regularly respond to email messages immediately. This then led me to use social media.

Confidentiality

An important consideration is confidentiality. When the participants complete the SSIS Student Athlete K10 Scale, they would want their information not to be shared with anyone. Therefore, a solution would be hiding their emails and names when they complete the form, as well as deleting the data at the end to avoid any leaks on personal information.

RESULTS

During the last 30 days, about how often did you feel tired out for no good reason?	During the last 30 days, about how often did you feel nervous?
None of the time	Most of the time
Some of the time	A little of the time
Some of the time	Some of the time
Most of the time	Some of the time
Some of the time	Some of the time
Some of the time	A little of the time
Most of the time	A little of the time
Most of the time	Some of the time
Some of the time	Some of the time
Some of the time	A little of the time
Most of the time	A little of the time
Most of the time	None of the time
Some of the time	Some of the time
A little of the time	A little of the time
Some of the time	A little of the time
A little of the time	A little of the time
Most of the time	Some of the time
A little of the time	Some of the time

Figure 1: *K10 Scores for High School Students*

This image shows a brief overview of the form responses. Automatically, after the students complete the K10 Survey on Google Forms, there will be a connected Google Sheets that displays the questions, answers, and times for each individual. Due to confidentiality, the form did not collect name, grade or email to ensure that the students' responses were kept confidential.

PROCESSED DATA

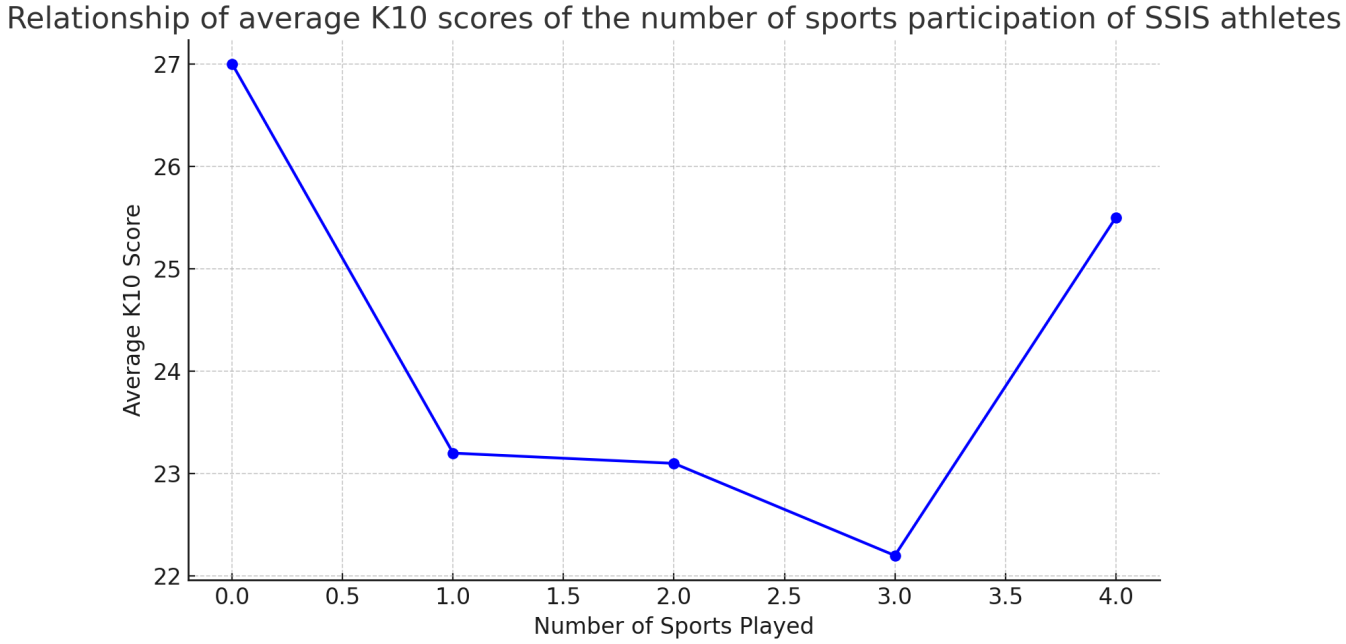


Figure 2: *Relationship of Average K10 Scores of the Number of Sports Participation of SSIS Athletes*

Before starting this chart, each of the response options were replaced with their numerical values. According to the K10 scale, "None of the time" was assigned 1, "A little of the time" was assigned 2, "Some of the time" was assigned 3, "Most of the time" was assigned 4, and "All of the time" was assigned 5. After, a mean was calculated for the number of sports played. This line chart shows the score distribution between the 101 participants of the Google Form survey. Out of the 101 participants, here are the following distributions of the amount of sports played. There were 28 participants who didn't participate in any athletic teams, 40 who participated in one sport, 23 who participated in 2 sports, 8 who participated in 3 sports, and 2 who participated in 4 sports. After completing the survey, the form showed that out of the students who participated in no athletic activity, they recorded an average K10 Score of 26.96. On the K10 scale, a high number shows high levels of psychological distress. According to the ABS (6), a "high" score ranges from 22-29. Initially, engagement in sports appears beneficial; individuals who played one to three sports consistently reported lower average K10 scores, suggesting reduced psychological distress. The most significant drop is observed from 0 sports played (K10 =26.96) to one sport played (K10 = 23.2), indicating that even minimal involvement in physical activity can have a positive impact on mental health. This trend continues until it reaches three sports played, where the lowest average score was recorded at 22.13. However, an important reversal occurred when the number of sports played reached four, where the K10 score increased sharply to 25.5.

After looking at the line graph, I did a one-way ANOVA test to see if there is a statistically significant difference in average K10 scores across the different groups based on the number of sports played. In the ANOVA, the F-statistic compares the variance between groups to the variance within groups. A higher F-value suggests a greater difference between group means. The key value to interpret is the p-value, telling us the probability that the observed differences occurred by chance. After doing the test, the p-value was extremely small, 2.89×10^{-81}, significantly below the conventional threshold of 0.05. A small p-value, which is less than 0.05, indicates strong evidence against the null hypothesis. This means that it is highly unlikely that all group means are the same.

On the other hand, a large p value , $p \geq 0.05$, suggests that any observed differences are likely due to random variation. In conclusion, the results support the conclusion that the number of sports played significantly influences psychological distress levels. The H_a was supported whereas the H_0 was rejected.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	101	118	1,16831683	0,98138614
Column 2	101	2444	24,1980198	50,400396

ANOVA

Source of Variati	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Gro	26783,5446	1	26783,5446	1042,53077	2,88978E-81	3,88837472
Within Group	5138,17822	200	25,6908911			
Total	31921,7228	201				

Figure 2: *ANOVA: Single Factor Test with Processed Results*

SAMPLE ANALYSIS K10

K10 Question Keywords	Response
Fatigue	**None of the time**
Nervous	**Most of the Time**
So nervous	**None of the time**
Hopeless	**None of the time**
Restless/Fidgety	**None of the time**
So Restless	**A little of the time**
Depressed	**None of the time**
So Depressed	**Most of the time**
Lack of Energy	**None of the time**
Worthless	**None of the time**

Table 1: *Sample Analysis of Student A (Raw Data)*

This was the response that was given by this student who played one sport. Then, after receiving the data, each of the response options were replaced with their numerical values. According to the K10 scale, "None of the time" was assigned 1, "A little of the time" was assigned 2, "Some of the time" was assigned 3, "Most of the time" was assigned 4, and "All of the time" was assigned 5. Therefore, this table was derived.

K10 Question Keywords	Response
Fatigue	**1**
Nervous	**4**
So nervous	**1**
Hopeless	**1**
Restless/Fidgety	**1**
So Restless	**2**
Depressed	**1**
So Depressed	**4**
Lack of Energy	**1**
Worthless	**1**

Table 2: *Sample Analysis of Student A (Processed Data)*

Therefore, this student had a total score of 17, which according to the K10 Scale means that they are "likely to be well".

Standard Deviation Calculation

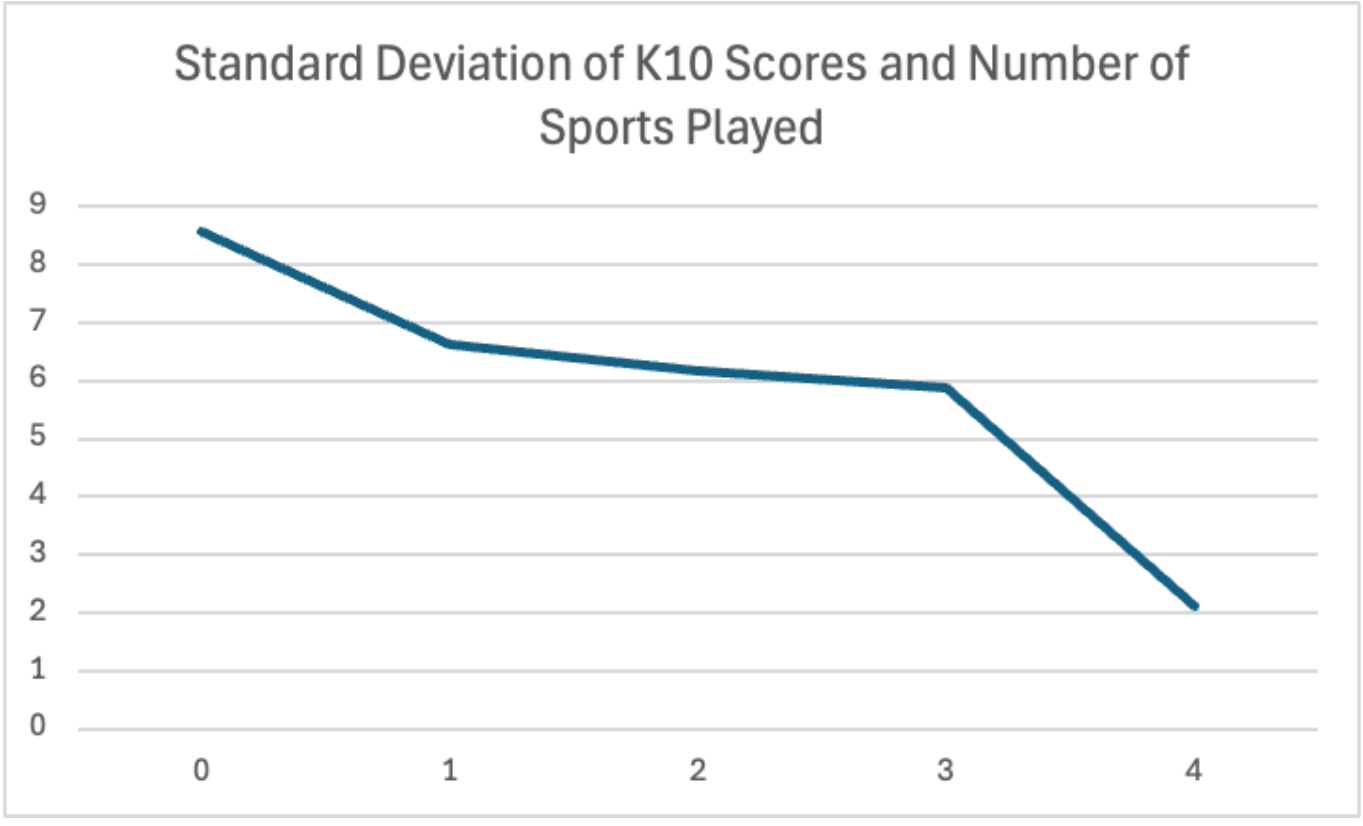


Figure 4: *Standard Deviation of K10 Scores and Number of Sports Played*

After putting the graph in Microsoft Excel, the graph shows a clear downward trend in the variability of K10 scores as the number of sports played increases. At 0 sports played , the standard deviation is 8.57, which indicates a large spread in mental distress levels - some individuals might be experiencing very high levels of distress, while others are not. As the number of sports played increases, the standard deviation steadily decreases: 6.61 for 1 sport, 6.18 for 2 sports, and 5.89 for 3 sports. This suggests that while psychological distress still varies, it becomes more consistent among students with moderate sport participation. Most notably, at 4 sports played, the standard deviation drops sharply to 2.12, meaning that the athletes who are highly involved in sports tend to have very similar (and likely more stable) mental health outcomes. Overall, the decreasing trend in standard deviation shows that higher levels of sports participation are associated not just with potentially better mental health on average, but also with more predictable and less varied K10 scores among the SSIS student-athletes.

APPLICATION

Conclusion

The H_a is supported as shown by the evidence. After collecting data and doing a one-way ANOVA test, the p-value was extremely small, 2.89×10^{-81}, significantly below the conventional threshold of 0.05. A small p-value, which is less than 0.05, indicates strong evidence against the null hypothesis. This means that it is highly unlikely that all group means are the same. In conclusion, the results support the conclusion that the number of sports played significantly influences psychological distress levels. This aligns with the literature review as a significant portion of the participants experienced a certain level of psychological distress.

EVALUATION

Limitations

Sample size

The survey was sent to a relatively small sample size with unequal distributions among categories of sports played. There were groups such as students playing 3 sports with only 2 responses. Therefore, if this study were to sample all student-athletes, then it would give a more accurate depiction of psychological well-being. To address this issue in the future, this form will be sent out to all athletes during the season, instructed by their coaches, to make sure that all athletes complete the form.

After seeing the trends in sports played and psychological distress, the next logical step is to reach out to administrators to figure out how certain rules or guidelines can be set to improve the general well-being of these student athletes. Potential solutions can be: time management training, access to mental health resources, such as sports psychologists, or safe space and peer support.

School

After analyzing the data set for this research, I plan on meeting with the SSIS headmaster to discuss the findings, as well as potentially new solutions that could lower the stress for student-athletes. Being balanced in life is one of SSIS's core values, and through the findings of the form, we can determine how we can go about it in the future. These studies are from athletes and non-athletes, thus giving a more rounded perspective.

Personal

After doing this research first hand, I am able to analyze the data set for myself and understand what challenges I am facing, as well as how I can overcome them. Similarly to the other students, I am also a student-athlete, thus I am able to connect with them on a deeper level. This research not only helps me, but others.

Student-Athletes

Since these student-athletes are the main subject of my research, they will be most directly affected by my research. Based on my findings, they are able to determine whether there is a correlation to their increased psychological distress due to the amount of athletics they do. Therefore, they are able to see how they can solve this issue and improve their mental well-being.

REFERENCES

L;, Ward T;Stead T;Mangal R;Ganti. "Prevalence of Stress amongst High School Athletes (V2)." *Health Psychology Research,* U.S. National Library of Medicine, 21 Feb. 2023, https://pubmed.ncbi.nlm.nih.gov/36844646/ Accessed 4 Feb 2025.

Verlenden JV, Fodeman A, Wilkins N, et al. "Mental Health and Suicide Risk among High School Students and Protective Factors - Youth Risk Behavior Survey, United States, 2023." *Centers for Disease Control and Prevention, Centers for Disease Control and Prevention*, 8 Oct. 2024, www.cdc.gov/mmwr/volumes/73/su/su7304a9.htm. Accessed 4 Feb 2025.

Kessler RC, Barker PR, Colpe LJ, Epstein JF, Gfroerer JC, Hiripi E, et al. "Screening for serious mental illness in the general population". Arch Gen Psychiatry. 2003 Feb;60(2):184-9. https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0010/22240/kessler-psychological-distress-scale-k101.pdf. Accessed 4 Feb 2025.

"Athletics." *Saigon South International School,* www.ssis.edu.vn/student-life/athletics. Accessed 5 Feb. 2025.

1 in 4 Adults Don't Talk about Mental Health – Mind." *COVER Magazine*, 30 Jan. 2024, https://www.covermagazine.co.uk/news/4073444/adults-talk-about-mental-health-mind. Accessed 2 Feb. 2025.

Australian Bureau of Statistics. National Health Survey: *Mental Health,* 2007–08. https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4817.0.55.001Chapter92007-08. Accessed 3 Feb. 2025

ANOVATest – Definition, Examples." *DataCamp,* https://www.datacamp.com/tutorial/anova-test. Accessed 2 May 2025.


SSIS
Fresh Box
For Baking
Nutrition Facts

Naomi

To what extent do the early stages of brain maturation and cognitive development in a two-week-old *Gallus gallus domesticus* and *Homo sapiens* infant (6 to 24 months old) exhibit similarities within the context of short-term and long-term memory processing?

ABSTRACT

Memory processing is a vital and recognizable part of the way humans function. Research on long-term memory processing in humans has previously only been conducted on mice or primates. There is a preconceived notion on the intelligence of chickens—that they have limited cognitive abilities. For instance, the term "bird brain" originated from the misconception of the telencephalic regions of birds and are therefore unintelligent because of a small brain.[1] In this paper, I am evaluating, **"To what extent do the early stages of brain maturation and cognitive development in a two-week-old *Gallus gallus domesticus* and *Homo sapiens* infant (6 to 24 months old) exhibit similarities within the context of short-term and long-term memory processing?"** To evaluate this and back up my research, I constructed a maze in order to implement positive reinforcement to teach the two-week old chickens the maze. While there are notable differences in the pace and extent of brain maturation and cognitive development between two-week-old chickens and human newborns, there are also significant similarities, particularly in the functions of foundational hippocampal development that are associated with memory processing. My overall conclusion is that baby chickens are able to develop their hippocampus to have similar functionalities to human babies' development of short-term and long-term memory, particularly navigation and spatial memory. My maze experiment illustrates that young chickens are capable of learning to navigate throughout environments and encode object location.

BACKGROUND

In all species, memory is a multifaceted cognitive function that depicts an individual's acquisition, storage, and retrieval of information,[2] which is the essential basis for survival and cognitive processes. Memory allows both mammals and avian species to learn about their environment, including food sources, reproduction, and predators. The capacity of memory has evolved over several species, with different types of memories (e.g. spatial, short- and long-term memory). Short-term memory refers to the limited, temporary storing of information from a recent time period, while long-term memory is a more permanent store of information with essentially unlimited capacity.[3] These distinct memory processes are also stored in different regions of the brain. Short-term memories are frequently preserved in the prefrontal cortex, a region that handles decision-making, reasoning, planning, and managing emotions. Long-term memories, on the other hand, are processed and stored in three brain regions: the hippocampus, cerebrum, and amygdala. Spatial memory is the ability to remember the locations of objects, directions, and the layout of an environment. It helps animals and humans navigate through space by forming mental maps based on previous experiences. The hippocampus is responsible for the formation and organization of new long-term memories, particularly those related to spatial navigation and declarative information. The cerebrum, mainly the cerebral cortex, contributes and aids in the storage of long-term memories across sensory and motor regions. The amygdala is primarily involved in emotional learning and attaches emotional significance to memories, especially related to fear and reward.

[1] *Anton Reiner, The Avian Brain Nomenclature Forum: Terminology for a New Century in Comparative Neuroanatomy (2009)*
[2] *Sruthi Sridhar, Cognitive neuroscience perspective on memory: overview and summary (2023)*
[3] *Nelson Cowan, What are the differences between long-term, short-term, and working memory? (2008)*

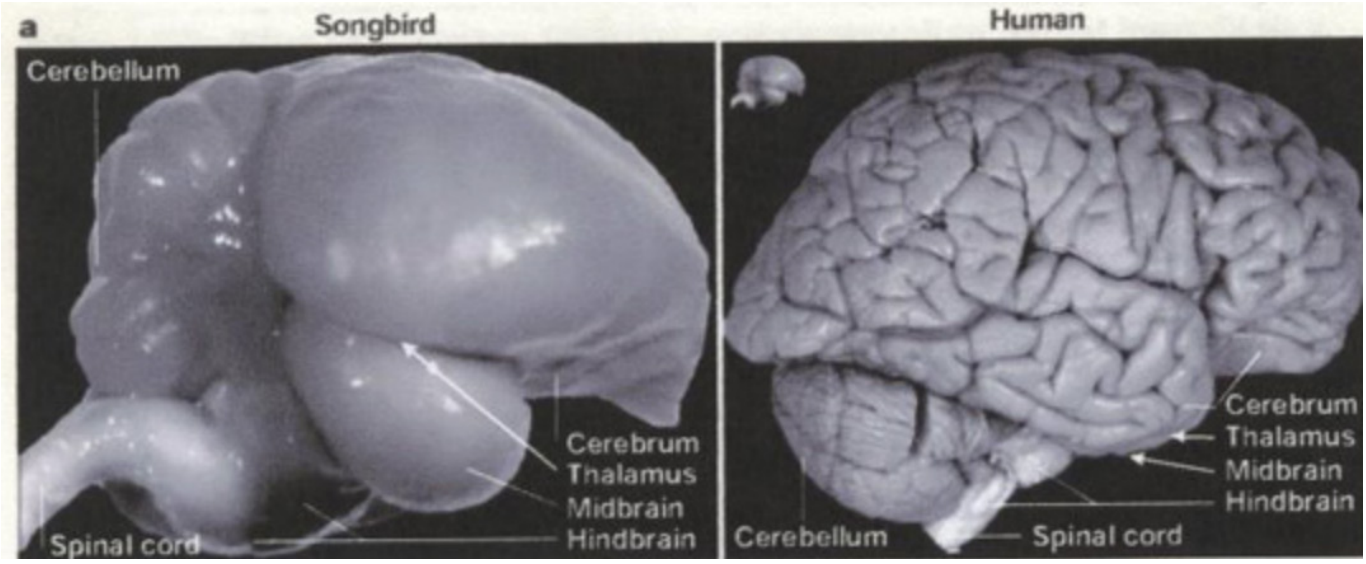


Figure 1:[4] *Side views of Zebra Finch and* Homo sapiens *brain*

Early memory development in newborns begins early in life, with both short-term and long-term memory functions developing over time. Around six to eight months of age, newborns start to exhibit short-term memory signs when they learn to retain and process small amounts of information. Their long-term memory starts developing even earlier; by six months, they can remember information for up to twenty-four hours, and by nine months, they can remember up to a few weeks. They can start recalling events from as long as a year ago by the time they are 20 months old.[5] This demonstrates how quickly and early both memory processes develop in infancy.

Chickens, like many avian species, develop cognitive abilities related to memory phenomenally early in life. In fact, many of their cognitive functions begin to emerge even within hours of hatching, emphasizing the extent and preocity of their neural development. Research shows that short-term memory in chickens is functional within the first few days after hatching. For instance, depending on the adverse stimuli, it has been demonstrated that day-old chickens can retain sensory information, such as unpleasant flavors, for anywhere from 15 minutes to several hours. Additionally, chickens have the capacity to remember and utilize information over brief periods of time by being able to recall the location of food sources as soon as they are exposed.[6] After hatching, long-term memory capacities start to develop. In one study, two-day-old chickens were trained to navigate a barrier to get to other chickens, and after only one session, they were able to retain this acquired spatial behavior for at least 24 hours.[7] Long-term memory is present early in development, as shown by other research that has demonstrated that chickens may recall taught actions for longer lengths of time after repeated training.[8] These highlight that both short-term and long-term memory processes in chickens are not only present from a very young age but are also critical for their ability to learn about their environment and interact with it in adaptive ways.

For several decades, neuroscience has depended on mice and primates as models. Mice are ideal for studying memory formation, neurogenesis, and hippocampus function because they have a relatively simple and well-conserved brain structure, along with genetic accessibility. Due to primates' close evolutionary relationship to humans have provided deeper understanding into more advanced cognitive abilities and the complexities of memory structures.[9] Mice and primates have shaped scientists' understanding of memory encoding, consolidation, and retrieval across

[4] *Figure 1. Side views of Zebra Finch & human brains. Inset (next to human brain) is the Zebra Finch brain to the same scale (From: Jarvis et al. 2005)*
[5] *Thanujeni Pathman, Patricia J. Bauer, Memory and Early Brain Development (2020)*
[6] *Lori Marino, Thinking chickens: a review of cognition, emotion, and behavior in the domestic chicken (2017)*
[7] *Lucia Regolin, Steven P.R Rose, Long-term memory for a spatial task in young chicks (1999)*
[8] *John R. Jakupi, Nikki S. Rickard. Evidence of a Time-Dependent Long-Term Stage of Memory for a Spatial Learning Task in the Chick (Callus Gallus) (2004)*
[9] *Smithsonian National Museum of Natural History, Human origins (2024)*

various brain regions, especially the hippocampus. Birds have memory and spatial navigation skills that are equivalent with or better than those of many mammals, despite having very distinct brain structure on the surface. This raises the debate on the idea of deep evolutionary conservation. Despite having 300 years of divergence from mammals, birds may have inherited similar brain features related to memory from a common ancestor. For instance, avian research has revealed similarities between mammals and their advanced behaviors, such as spatial memory, suggesting that birds are capable of high-level cognitive functions.

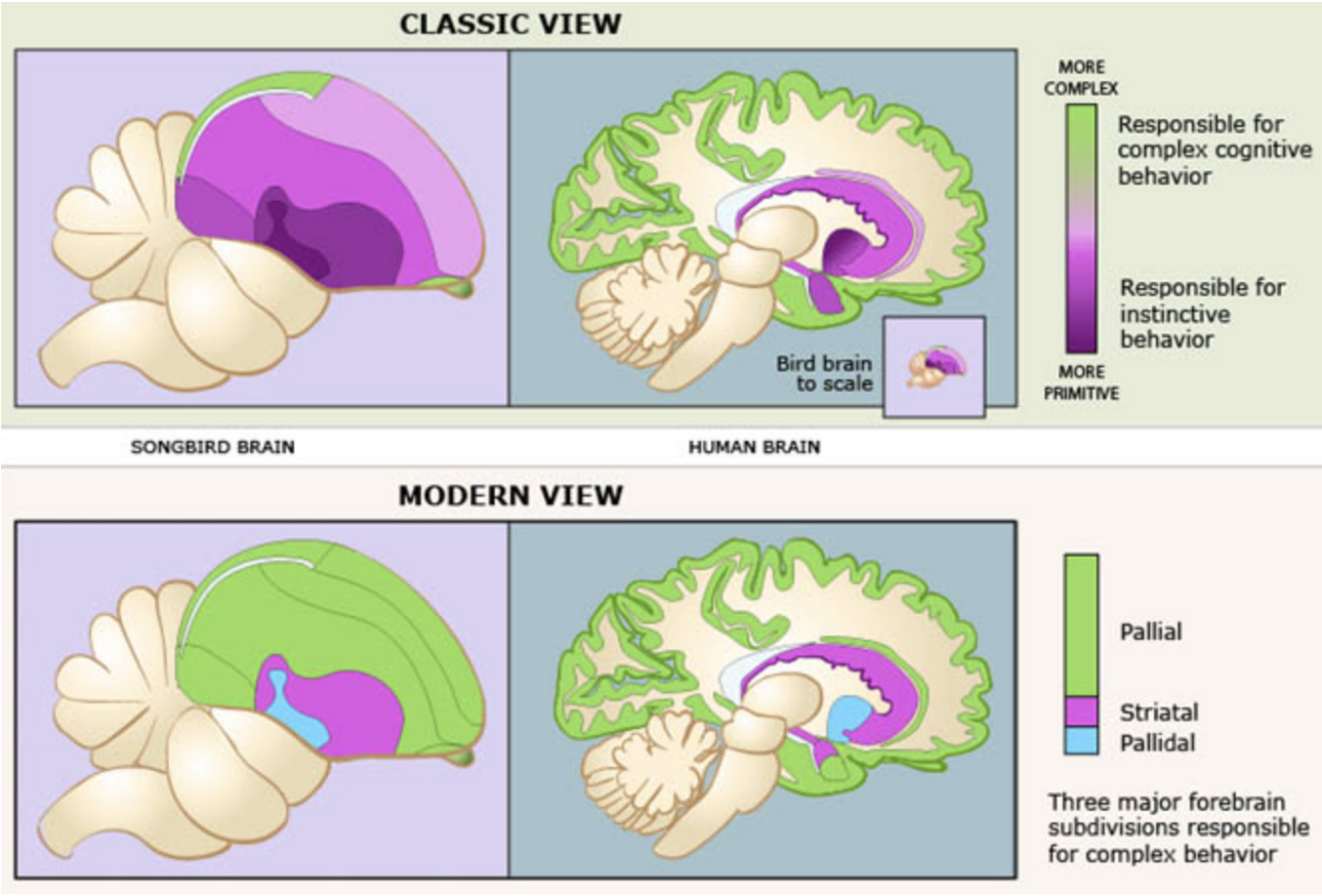


Figure 2:[10] *Comparative Views Between Songbird brain and* Homo sapiens *brain structures: Classic versus Modern Understanding*

The research study, titled "Defining structural homology between the mammalian and avian hippocampus through conserved gene expression patterns observed in the chick embryo," investigated whether chickens share developmental traits with mammals regarding the hippocampus.[11] Researchers discovered that genes crucial to hippocampus development in mammals, such as Prox1 and NeuroD, are also active in specific regions of the chicken hippocampus. These are transcription factors, with Prox1 primarily affecting lymphatic and neural development, and NeuroD playing an important role in nervous system and pancreatic development. They discovered that the ventral V-shaped region in chickens closely resembles the dentate gyrus in mice, showing an analogous structure. The dentate gyrus is a part of the hippocampus, it plays a role in spatial memory and mood regulation. Chicken hippocampal neurons migrate from a designated neurogenic zone, which is similar to the pattern seen in mammals. These findings indicate a deeply conserved developmental structure and support the concept that chickens, and other birds, can be beneficial models for understanding the evolution of memory systems.

[10] *Figure 2: Zina Deretsky, NSF,* via http://avianbrain.org
[11] *Sandeep Gupta, Defining structural homology between the mammalian and avian hippocampus through conserved gene expression patterns observed in the chick embryo (2012)*

METHODOLOGY

The primary training method that was utilized in this experiment to examine memory processing in newborn chickens was positive reinforcement. Positive reinforcement in psychology refers to the addition of a favorable stimulus after a desired behavior, in order to increase the likelihood of repetition. The hippocampus is a brain region that has a considerable impact on these cognitive functions: memory, learning, and emotions. It supports a variety of memory types, including spatial, short-term and long-term memory. Memory development in chickens normally becomes the most prominent around two weeks, making it an ideal period to assess cognitive abilities such as maze navigation.

The experiment is designed to assess how quickly and effectively the newborn chickens can learn to navigate a maze through a multitude of repeated training sessions. The independent variable in this study is the number of training sessions, which reflects the exposure each chicken has to the maze. The dependent variables include the number of trials required for a chick to complete the maze independently and the time it takes to complete the maze. Several control variables are maintained to ensure consistency across trials. This includes using a controlled type of positive reinforcement (e.g., food incentives), the same maze design throughout the experiment, and controlled environmental conditions such as lighting, temperature, and noise. The chickens used are also started at the same age, and a consistent training method involving the use of gentle guidance is applied throughout the training sessions.

To begin, the maze was made of lightweight foam boards with walls being 10 inches tall, twice the height of an average young chicken (~4 inches). It was 1 meter by 1 meter and remained unchanged throughout all the trials. As previously found during the pretesting tests, the chickens had a tendency to jump out of the maze, so a modification was made to the final experimentation. A transparent plastic sheet—equal in size—was created to thumbtack[12] onto the boards to prevent escape. Each trial was recorded by an iPhone 12, mounted by an iPad stand. Before the final testing, the chickens were given time to explore the maze in a quiet, naturally lit, enclosed room to minimize stress, from sound and visual stimulation, and allow them to become familiar with the environment without human interference. Positive reinforcement was used as a controlled variable in the experiment. Along the correct path, five specific squares, including the exit, were designated to provide a pleasant stimulus. Inside each of these squares, 0.5 grams of poultry feed was placed to reward the chicken and encourage movement while reducing the time spent at each square. Training involved guided runs where each chicken was placed at the maze's entrance and directed through the maze using cues such as floor tapping, shaking the feed bottle (sound), or gentle nudges. When the chick crossed a wall or took the correct turn, it was faced with positive reinforcement. These training runs were repeated three to four times per session, with the time recorded from release to the moment they reached the last square. Over time, help was gradually removed, allowing the chickens to make independent decisions inside the maze.

12 *Image of maze used during final training experimentation*

RESULTS

There were three training sessions altogether. The first session was held on February 23, 2025, and the second on March 13, 2025, placed two weeks apart to evaluate whether the chickens could retain and encode what they had learned, demonstrating evidence of long-term memory processing when they returned. The three-hour space between the second and third sessions was to allow the baby chickens to take a rest and also familiarize with the maze layout while disregarding the food incentive. Providing time between these training sessions and trials was crucial, since it lowered the influence of outliers caused by temperamental difficulties or coincidences. It also considered memory consolidation and retention—Were they processing this information and encoding it for future usage?

In the first training session, Chicken A, informally known as Chicken A, showed the most dramatic improvement. Her time dropped from 3 minutes and 13 seconds in Trial 1 to just 6 seconds by Trial 3. This rapid decline represents around a 96.89% improvement in time, suggesting that she quickly learned the path through the maze again and was able to recall it from before. The percent change formula is used in this study to calculate the different changes in the time taken to accomplish the maze. Chicken B's, time also decreased, though not as sharply, from 25 seconds in Trial 1 to 16 seconds in Trial which showed a 36% improvement. These results from the first training session indicate that both chickens were beginning to recognize patterns and develop a short-term memory of the maze's pathway.

$$Percentage\ Change\ =\ (\frac{New\ Value-Original\ Value}{Original\ Value})\times 100$$

$$\text{(Chicken A) } Percentage\ Change\ =\ (\frac{6\ seconds-193\ seconds}{193\ seconds})\times 100\approx\ -\ 96.89\%$$

$$\text{(Chicken B) } Percentage\ Change\ =\ (\frac{16\ seconds-25\ seconds}{25\ seconds})\times 100\approx\ -\ 36\%$$

In the second training session, tested two weeks later, an obstacle was hit as Chicken A seemed to show more inconsistent performance. Chicken A completed the maze in 1 minute and 23 seconds during her first trial and 5 seconds by the fourth one, but showed a longer time in the middle trials (Trial 2: 2 minutes and 2 seconds, Trial 3: 2 minutes and 23 seconds). These alternating times display possible issues that occurred like short distractions or environmental factors. However, her last trial showed another drastic drop to 5 seconds, which suggests that Chicken A retained a memory of the maze layout. Chicken B's times in this session were 1 minute and 31 seconds, 1 minute and 15 seconds, 46 seconds, and 7 seconds, showing a stable trend of improvement across all three trials. Although her first three trials in the second training session appeared to be slower than her trials in the first session, this was a result of Chicken B's growing comfortability with the maze. She explored the maze and tried to discover different paths to the exit in lieu of going on the laid-out path. The ability to relearn and improve within a session that occurred after a two-week break suggests signs of long-term memory retrieval and reconsolidation.

The third training session, three hours after the second, was meant to gauge memory retention over a short period of time while also allowing the chickens to become comfortable in the maze without disturbances or stress factors. Chicken A finished the maze in 1 minute and 25 seconds, 1 minute and 16 seconds, and 56 seconds over three trials, demonstrating a more consistent learning curve than the second session. Chicken B's times were 1 minute and 1 second, 31 seconds and 9 seconds displaying another session of consistent growth. These findings imply that the chickens were not only able to recall previously learned information, but also refine and reinforce their memory of the maze through repeated exposure.

When the chickens were first placed in the maze, I noticed that both Chicken A and B were very jumpy and anxious. Instead of utilizing their senses and following the path laid out for them, they would run around. To improve this, the chickens were given time inside the maze without the food incentives to calm down and explore. After a few minutes of exposure is when the experiment would begin, and they would be placed at the start. After being calmed down, the chickens always seemed hesitant to explore in the first trial and would hide in corners. By the second or third trial, the chickens began moving more quickly through the maze, appearing to remember the location of the food reward. The chickens consistently followed the same path, suggesting they had learned the efficient pathway. Both chickens were fidgety, but Chicken A was more anxious compared to Chicken B. This was seen when she would be reluctant to follow the path and try to jump out, but also hide and stay in corners for more than 10 seconds. Since this was always occurring in the first trial, I would offer guidance to help the chicken move. Even after being removed from the maze for several hours, both chickens were able to retrace the correct path without trial-and-error, indicating signs of short-term memory retention. When tested in the next training session, both chickens were still capable of navigation, suggesting longer-term memory processing.

Overall, both Chicken A and Chicken B showed clear signs of short-term and long-term memory across all three sessions, ten trials total. The decrease in time over repeated trials supports the presence of short-term memory. While the capacity to improve their performance after time between the training sessions provides validity to the idea that they were encoding information in long-term memory. Positive reinforcement played an important role in this process. The introduction of food in the maze motivated the chickens to engage in the activity and encouraged repeated trials. This increased the connection between completing the maze and earning a reward. This reinforcement additionally helped the chickens stay focused, but also increased the probability that the maze would be stored and recalled later. This suggests that even at a young age, chickens are capable of memory consolidation and recall.

Recorded Training Trial Data for Three Sessions

First Training Session: February 23, 2025 @12:35		
	Time for Chicken A (minutes, seconds)	Time for Chicken B (minutes, seconds)
Trial 1	3:13 ±1 second	0:25 ±1 second
Trial 2	0:43 ±1 second	0:20 ±1 second
Trial 3	0:06 ±1 second	0:16 ±1 second

Second Training Session: March 13, 2025 @10:15		
	Time for Chicken A (minutes, seconds)	Time for Chicken B (minutes, seconds)
Trial 1	1:23 ±1 second	1:31 ±1 second
Trial 2	2:02 ±1 second	1:15 ±1 second
Trial 3	2:23 ±1 second	0:46 ±1 second
Trial 4	0:05 ±1 second	0:07 ±1 second

Third Training Session: March 13, 2025 @13:15		
	Time for Chicken A (minutes, seconds)	Time for Chicken B (minutes, seconds)
Trial 1	1:25 ±1 second	1:01 ±1 second
Trial 2	1:16 ±1 second	0:31 ±1 second
Trial 3	0:56 ±1 second	0:09 ±1 second

CONCLUSION

This research explores the question: **"To what extent do the early stages of brain maturation and cognitive development in a two-week-old *Gallus gallus domesticus* and *Homo sapiens* infant (6 to 24 months old) exhibit similarities within the context of short-term and long-term memory processing?"** Despite differences in structure between the human and avian brains, both species have brain areas, such as the hippocampus and cerebrum, that perform similar cognitive processes. According to the results, along with research on their primary forebrain areas, young chickens showed evident signs of both short-term and long-term memory, similar to what is shown in human infants. My maze experiment indicated that young chickens were capable of picking up navigation skills, remember where objects were located, and eventually retain that knowledge. The similarities show that some cognitive processes, like short-term and long-term memory, are not specific to mammals and could be the result of deep evolutionary conservation. The results provide support to my claim that memory systems can develop from different species' brain regions and still yield comparable results, particularly in the areas of spatial memory and basic skills for learning. This rejects the common misconceptions about bird intelligence and demonstrates that similar cognitive development can take place in completely different brains.

EVALUATION

Although this experiment provided meaningful insight into early memory development in chickens and infants, I came across a number of factors that may have influenced my results, which are important to reflect on for future improvements. During the beginning of my research, I struggled with direct comparison between *Gallus gallus domesticus* (domestic chickens) and *Homo sapiens* infants due to differences in developmental timelines. Chickens are precocial animals, which mean that they are hatched in an already matured state where they can function independently shortly after hatching. Their brain development and sensory abilities also progress earlier on. On the other hand, human infants are altricial and grow much slower postnatal development, with memory and cognitive abilities gradually developing over months and years. As a result, behaviors that appear similar between a two-week-old chicken and a human infant may actually reflect different stages of neurological and cognitive maturity. This made it difficult to directly compare the two while considering biological and developmental differences. Even though both chickens and humans demonstrate early memory processing, the speed and extent to which they develop and may divert into various paths likely differ, which should be acknowledged when examining the results.

Another limitation is the specific breed of bird used in the experiment. Instead of using a common domestic chicken breed, the chickens involved were a cross between chickens and quails. This hybrid introduces more genetic differences that may have influenced their behavior and cognitive development. Crossbreeds have unique traits that they inherit from both parent species, such as differences in temperament, sensory processing, and brain development. Because quails are more skittish, as seen by the observed results, than domestic chickens, these characteristics may have influenced the chickens' reactions during the maze trials. This makes it unfair and difficult to generalize the findings to all domestic chickens, as the observed behavior may not accurately represent purebred *Gallus gallus domesticus.* Future replications of this study would benefit from using a common chicken breed, such as the Rhode Island Red or Leghorn, to mitigate the differences caused by hybrid genetics.

APPLICATION

Comparing human infants and baby chickens provides a meaningful way to explore how memory and learning begin to develop at an early age. Even though humans and chickens are very different species, both show signs of memory processing soon after birth or hatching. These early presented capabilities help them respond to their surroundings and adapt to new environments. Looking at both species side by side in comparison can help us understand whether similar cognitive skills can develop from different brain structures. While humans have a layered cerebral cortex and chickens have a more clustered pallial neuron organization, both seem entirely capable of forming long-term memories very early in life. However, there is still a large gap in research because not many studies have directly compared early memory development between avians and mammals, specifically chickens and humans. By evaluating how memory works in both humans and chickens, scientists can better understand whether learning systems are shaped by shared evolutionary origins or by diverted paths that lead to similar outcomes. Additionally, chickens provide a valuable opportunity for studying deep evolutionary conservation, which argues that some cognitive and neurological qualities may have been retained over hundreds of millions of years. Chickens are ideal for examining the relationships between brain development, gene expression, and behavior because they are more accessible than many other birds. This makes chickens important not only for evolutionary comparisons, but can also be models for neuroscience research in the future.

REFERENCES

Reiner, Anton, et al. "The Avian Brain Nomenclature Forum: Terminology for a New Century in Comparative Neuroanatomy." *PubMed,* 1 Jan. 2004, https://pmc.ncbi.nlm.nih.gov/articles/PMC2713747/

Sridhar, Sruthi, et al. "Cognitive Neuroscience Perspective on Memory: Overview and Summary." *Frontiers in Human Neuroscience,* vol. 17, 26 July 2023, https://pmc.ncbi.nlm.nih.gov/articles/PMC10410470/#:~:text=Memory%20is%20an%20essential%20cognitive,%2C%20olfactory%2C%20or%20tactile%20inputs ., https://doi.org/10.3389/fnhum.2023.1217093

Cowan, Nelson. "Chapter 20 What Are the Differences between Long-Term, Short-Term, and Working Memory?" *Progress in Brain Research,* 2008, pp. 323–338, https://pmc.ncbi.nlm.nih.gov/articles/PMC2657600/, https://doi.org/10.1016/s0079-6123(07)00020-9.

"Parts of the Brain Involved with Memory | Introduction to Psychology." *Lumenlearning.com,* 2025, https://courses.lumenlearning.com/waymaker-psychology/chapter/parts-of-the-brain-involved-with-memory/.

"Memory and Early Brain Development | Encyclopedia on Early Childhood Development." *Encyclopedia on Early Childhood Development*, June 2020, https://www.child-encyclopedia.com/brain/according-experts/memory-and-early-brain-development

Marino, Lori. "Thinking Chickens: A Review of Cognition, Emotion, and Behavior in the Domestic Chicken." *Animal Cognition,* vol. 20, no. 2, 2 Jan. 2017, pp. 127–147, https://pmc.ncbi.nlm.nih.gov/articles/PMC5306232?, https://doi.org/10.1007/s10071-016-1064-4.

REGOLIN, LUCIA, and STEVEN P.R ROSE. "Long-Term Memory for a Spatial Task in Young Chicks." *Animal Behaviour,* vol. 57, no. 6, 1 June 1999, pp. 1185–1191, https://pubmed.ncbi.nlm.nih.gov/10373250/ , https://doi.org/10.1006/anbe.1999.1097

Jakupi, John R., and Nikki S. Rickard. "Evidence of a Time-Dependent Long-Term Stage of Memory for a Spatial Learning Task in the Chick (Callus Gallus)." *Behavioral Neuroscience,* vol. 118, no. 3, 2004, pp. 569–574, https://pubmed.ncbi.nlm.nih.gov/15174934/

Gupta, Sandeep, et al. "Defining Structural Homology between the Mammalian and Avian Hippocampus through Conserved Gene Expression Patterns Observed in the Chick Embryo." *Developmental Biology*, vol. 366, no. 2, June 2012, pp. 125–141, https://pubmed.ncbi.nlm.nih.gov/22537492/, https://doi.org/10.1016/j.ydbio.2012.03.027.

"Genetics." *The Smithsonian Institution's Human Origins Program*, 3 Jan. 2024, https://humanorigins.si.edu/evidence/genetics#:~:text=Primate%20Family%20Tree,about%2025%20million%20years%20ago

An investigation of concentrations of lead in lipstick and bioaccumulation health risk

ABSTRACT

This study investigates the contaminant, lead, in lipsticks. Prolonged exposure to lead in microdoses through the bioaccumulation of lipstick can lead to hormonal fluctuations, decreased IQ and ability to learn, and cardiovascular issues. This article evaluates the risk of lead exposure through lipsticks in small doses using mathematical risk assessment models to estimate lead buildup and the amount transported into the bloodstream. Although the lead content in individual lipsticks often remains within recommended safety limits, cumulative exposure across years, especially when expedited with lead from other environmental sources, poses a significant public health concern. These results highlight the urgent need for stricter regulatory standards on lead content in cosmetics.

INTRODUCTION

In recent years, the makeup industry has expanded rapidly to become one of the largest, holding a global net worth of $646 billion. The exceptional growth has driven increased research into improving product formulations, however, the potential toxicity of cosmetic ingredients has received comparatively little attention. Specifically, lead concentrations must be investigated in cosmetic products due to lead's severe health risks. Lead is found in makeup as a contaminant from natural minerals especially iron oxides to be used in the creation of pigments. Lead can penetrate the blood-brain barrier (BBB), a network of cerebral blood vessels that prevents toxins and other dangerous compounds from reaching the brain, which acts as the brain's protective barrier, However, lead disrupts neurotransmitter signaling by mimicking and interfering with calcium, a key regulator of cellular function. This leads to and blocks vital channels voltage-dependent on calcium, decreasing motor ability, hormone signalling, and causing permanent brain damage. Lead similarly attacks the cardiovascular system by micking calcium, which the heart heavily depends on, disrupting normal rhythmic heart contractions, as well as damaging cells that control blood pressure and clotting, all of which can lead to heart disease, high blood pressure, reduced ability of transporting oxygen around the body and blocking blood flow which can result in death. Lanphear and colleagues state that lead accounts for more than 400,000 deaths annually in the USA. The author additionally states that previous estimates have produced lower numbers because those analyses assumed that lead does not affect mortality at amounts of lead in blood below 5 ppmL (parts per milliliter), thus, they did not consider the effects of lower exposures (The Lancet Public Health). Lead is dangerous even at low levels, such as in cosmetics, because of its ability to bioaccumulate in the body. Lead can build and store itself in the bones and teeth, meaning with repeated exposure, even at small doses, lead will accumulate to larger amounts over time and, in turn, circulate through the body to the vital organs, potentially causing increased blood pressure, kidney damage, comas, seizures, and strokes.

Lipsticks are applied directly to the mucous membrane and the lips. The mucous membrane is lined with epithelial cells and serves as a barrier between the internal system of the body, including the lungs and intestines, and the surroundings. The mucous membrane functions by producing mucus to prevent foreign substances from traveling through the barrier by binding and trapping harmful pathogens and subsequently clearing them before their penetration and absorption across the epithelium. Lead in lipstick can diffuse through the mucous membrane due to its small molecular size, allowing fat-soluble compounds to more easily penetrate or be absorbed. The outer lips are the thinnest layer of skin, lacking a strong barrier, making it especially permeable for small molecules. When applying lipstick, the waxes, fragrances, and alcohol strip the lips of any protective moisture, and in turn, metal ions can pass through into the internal system. Lead is also absorbed directly by oral ingestion through

simply licking lips or drinking water. On average, women use about 4 to 9 pounds of lipstick over their lifetime. Lead is heavily regulated across several industries. For example, in drinking water, a limit of 15 ppb (parts per billion) is enforced legally, whilst for paint it is 90 ppm (parts per million), which raises the question as to why cosmetics are held to a non-binding recommendation from the U.S. FDA (Food and Drug Administration) to not exceed 10 ppm.

There is no amount of lead deemed safe; however, as of 2012, the Centers for Disease Control and Prevention (USA) have set the standard that adult blood lead levels of 10 ppm, or children blood levels of 5 ppm to be considered a health risk even if no symptoms are showing (National Library of Medicine). According to the UCSF, lead blood levels between 40 and 80 ppm are considered extremely dangerous and risk serious health damage occurring.

RESEARCH QUESTION

To what extent is lead concentration in lipsticks, measured in parts per million (ppm), assessed as dangerous to human health through bioaccumulation formulas to not exceed the 10ppm regulatory limit, based on a meta-analysis of previous studies?

Table 1: *Lead Regulation Limits and Market Values of the Lipstick Industry by Country*

Country	Organization	Production Value	Regulation
USA	FDA	$6.2 billion	10 ppm
Korea	MFDS	$7.2 billion	20 ppm
China	CSAR	$3.8 billion	10 ppm
Europe	Annex II of Regulation (EC)	$12 billion	10 ppm

The regulation allowing 10 ppm of lead in cosmetics, such as lipstick, is designed to prevent immediate, acute harm by ensuring that the amount of lead per use is small enough not to cause measurable health issues. However, this regulation primarily focuses on single exposure levels and does not take into account the long-term risk of bioaccumulation. Lead, even in small amounts, can accumulate in the body over time, especially with regular, daily exposure from products like lipstick. Therefore, even low levels of lead could build up in tissues, such as bones and teeth, and eventually be circulated to vital organs via the bloodstream.

This issue can be further understood through the formula shown below, which measures how much lead will be accumulated or absorbed into the body per unit of time, in this case, 1 year. This formula uses the ingestion rate, which is a constant of how much lead concentration from the total sample of lipstick will be absorbed or ingested.

$$D = C_{Pb} \times I$$

D = Lead absorption per day
C_{Pb} = Concentration of lead
I = Ingestion Rate - Constant of 24 mg/day for adults
D 365 = Lead accumulation per year

However, the above formula does not account for the fact that the body does not retain all of the lead ingested and will eliminate lead concentration at a certain rate by excretion of sweat, urine and faeces. The true value of bioaccumulation is calculated using the formula below.

$$A = D \frac{1 - e^{d \times t}}{d}$$

D = Lead absorption (from the previous formula)
t = time in years
d = decay constant

The decay constant (d) is derived from the half-life of lead in the body. Lead has a half-life of about 20 years in humans. (phys.libretexts.org)

$$d = \frac{In(2)}{20} = 0.0347 per\ year$$

The equation presented above quantifies the amount of lead retained within the body following its initial absorption from our previous calculation. By factoring in these physiological processes, the calculation provides a more precise estimation of the cumulative lead accumulation in the body over time.

The calculated values above provide a true estimation of the total bioaccumulation of lead over time. Only approximately 10% of the accumulated lead travels into the bloodstream at any given time to reach the vital organs. Therefore, to assess the potential health risks relative to our established benchmarks, which are defined as 5 ppm for children and 10 ppm for adults according to the National Library of Medicine, it is necessary to divide the total accumulation value by 10, in order to estimate bloodstream concentrations.

The following data was collected by Sciencedirect and Scieolo; both articles were also investigating the potential risks of lead and lipstick, in which data was collected from the years 2018 and 2020. Both sources use a form of spectroscopy, a technique that measures how matter interacts with electromagnetic radiation to identify and quantify elements. Spectroscopy is widely regarded as the most accurate technique for determining the concentrations of specific elements. It is approved by the FDA, EPA, and WHO, ensuring its reliability and precision in measuring heavy metal concentrations.

Tables 2 and 3: *Concentrations of lead found in different samples of lipstick*

Origin Country	Pb Concentration (ppm)
China	2.07±0.06
China	2.36±0.07
China	3.37±0.13
China	4.17±0.10
China	4.54±0.05
China	3.18±0.02
China	3.72±0.10
USA	0.51±0.10
USA	0.27±0.05

Source 1: (ScienceDirect) - Concentration of lead found in different samples of lipstick

Origin Country	Pb Concentration (ppm)
France	1.1775
Usa	1.2000
Usa	1.5559
China	1.8247

Source 2: (scielo.org) - Concentration of lead found in different samples of lipstick

HYPOTHESIS

If the bioaccumulation of lead in lipsticks exceeds the regulatory limit of 10 ppm in blood flow, then the resulting exposure through regular use poses a significant health hazard, including potential neurotoxicity, reproductive harm, and an increased cancer risk, as demonstrated through mathematical risk assessment. The bioaccumulation of lead is further exacerbated by preexisting lead concentrations in the body from other sources, such as drinking water, other cosmetics, and paints, etc.

EVALUATION

Original Lead concentration in lipstick	Daily intake calculation	Calculated Bioaccumulation risk (2 years) (ppm)	Calculated Bioaccumulation risk (4 years) (ppm)	Blood Stream circulation predicted value (2 years)	Blood Stream circulation predicted value (4 years)
2.07±0.06	2.07 × 0.024 = 0.04968	27.45	42.29	2.7	4.2
3.72±0.10	3.72 × 0.024 = 0.08928	49.37	76.85	4.9	7.6
1.5559	1.5559 × 0.024 = 0.03734	20.65	32.16	2.0	3.2
0.51±0.10	0.51 x 0.024 = 0.0036	9.48	15.97	0.9	1.5

The values calculated above represent the total amount of lead accumulated in the body's tissues over time of years 2 and 4, rather than directly reflecting the concentration in the bloodstream with our known danger levels of 20-40 ppm circulation. This distinction is important because the lead stored in tissues will eventually be released as the body eliminates metal over time. From this, we can assume that blood levels will be significantly lower than the calculated values above. Lead accumulates in tissues like the bones and teeth before it enters the bloodstream. The bone-to-blood ratio is essential as lead must travel through the bloodstream to reach vital organs such as the brain, kidneys, and heart, which are particularly susceptible to lead toxicity. Typically, 90% of the lead is stored within the teeth and bone, with 10% circulating in the bloodstream at any given time. Therefore, for 2.07±0.06 over 2 years, only 2.7 would circulate the bloodstream; however, after 4 years, with the same amount and chronic use, the circulation would double to 4.2.

CONCLUSION

From the data, it can be concluded that with chronic use of lipsticks, the bioaccumulation increases seen in trial 2 of 2.7 circulation in 2 years to a 4.2 circulation within 4 years and that consequently bloodstream circulation increases, with all points of the data table supporting this claim supports my hypothesis partially. Therefore, if the bioaccumulation of lead in lipsticks exceeds the regulatory limit of 10 ppm in blood flow, then the resulting exposure through regular use poses a significant health hazard.

Although the lead concentrations in the lipsticks themselves are not high enough to pose a threat as not all the lead from the lipstick sample will be absorbed by the body and a smaller amount will circulate through the body, the repeated use of lipsticks over several years will eventually accumulate enough to reach the critical level threshold of 10 ppm with trial 2 at concentrations of 3.72±0.10 well below the regulatory limit of 10 ppm already reaching circulation levels of 7.6 lead to blood ratio within 4 years proves that alone the concentrations of lead in lipstick within multiple years can cause lead related health hazards. Especially with other factors adding to lead concentrations, such as foods, paint, and other cosmetic products, the critical level is expected to be reached much sooner. The evidence proves that no amount of lead in cosmetics can be deemed safe or acceptable. Lead poisoning is a gradual process, and repeated exposure from seemingly harmless products like lipsticks contributes to a dangerous, cumulative toxic load. Therefore, the accumulation of lead in the body, especially through regular use of cosmetic products, should be considered a serious health hazard, warranting stricter regulations and increased public awareness.

LIMITATIONS

The data in Table 1 can be misleading because of two factors. Firstly, the product value does not equate to the amount produced. For instance, China exported 1.6 million tons of cosmetics in 2023, leading globally, whilst the US had approximately 547,000 tons in 2024. However, the US actually had more production value than China, as seen in the table, clearly showing that the export value does not reflect the exact amount of products produced, and this discrepancy makes it difficult to assess which specific products are circulating in the market. This is significant because different countries have varying production norms and regulations that they must abide by. As such, the value of exports does not provide a clear representation of the actual cosmetic products in circulation, nor does it reflect the potential risks associated with those products.

This research is subject to several limitations that may affect the accuracy and generalizability of its findings. Notably some of the formulas used to estimate lead decay and accumulation were adapted from a physics textbook focused on radioactive half-life, which may not be entirely applicable to the context of cosmetics. The presence of preservatives and stabilizers in lipstick formulations could significantly influence the chemical behavior and bioavailability of lead, potentially altering the accuracy of these models. Additionally, constraints in available testing equipment and resources may have limited the precision or sensitivity of the measurements. Future research should consider using chemical models more tailored to cosmetic compounds, expand the sample pool across a wider range of brands and countries, and investigate the long-term bioaccumulation of lead in human tissue to better assess potential health risks.

REFERENCES

Alqahtani, Alaa M, et al. "Determination of Lead and Cadmium Concentration in Cosmetic Products in the Saudi Market." *Journal of Umm Al-Qura University for Applied Sciences,* 15 Nov. 2023, https://doi.org/10.1007/s43994-023-00088-9.

"Bioaccumulation Factor - an Overview | ScienceDirect Topics." *Sciencedirect.com,* 2015, www.sciencedirect.com/topics/agricultural-and-biological-sciences/bioaccumulation-factor.

Bressler, Joseph P., and Gary W. Goldstein. "Mechanisms of Lead Neurotoxicity." *Biochemical Pharmacology,* vol. 41, no. 4, Feb. 1991, pp. 479–484, https://doi.org/10.1016/0006-2952(91)90617-e.

Corliss, Julie. "Lead Exposure and Heart Disease." *Harvard Health,* 5 Apr. 2019, www.health.harvard.edu/blog/lead-exposure-and-heart-disease-2019040516296.

Dang, Peizhu, et al. "Chronic Lead Exposure and Burden of Cardiovascular Disease during 1990-2019: A Systematic Analysis of the Global Burden of Disease Study." *Frontiers in Cardiovascular Medicine,* vol. 11, 2024, p. 1367681, pubmed.ncbi.nlm.nih.gov/38655496/, https://doi.org/10.3389/fcvm.2024.1367681.

"Did You Know Women Eat 9 LBS of Lipstick in a Lifetime?" *Beauty Bakerie Cosmetics Brand,* 16 May 2017, www.beautybakerie.com/blogs/ice-cream-social/why-wearing-beauty-bakerie-will-prevent-you-from-eating-9-pounds-of-lipstick?srslti-d=AfmBOoq1aqLRt-vbxOisvAJpU_m9GLHJLFugRgj0Q1wba-M5wkmhwISV. Accessed 28 Apr. 2025.

Feizi, Rozhan, et al. "Evaluation of Lead and Cadmium Concentrations in Lipstick and Eye Pencil Cosmetics." *Environmental Health Engineering and Management,* vol. 6, no. 4, 6 Dec. 2019, pp. 277–282, ehemj.com/article-1-558-en.pdf, https://doi.org/10.15171/ehem.2019.31. Accessed 26 Apr. 2022.

"Lead Levels Blood." Ucsfhealth.org, www.ucsfhealth.org/medical-tests/lead-levels---blood.

Li, Yanan, et al. "Trace Metal Lead Exposure in Typical Lip Cosmetics from Electronic Commercial Platform: Investigation, Health Risk Assessment and Blood Lead Level Analysis." *Frontiers in Public Health*, vol. 9, 17 Nov. 2021, https://doi.org/10.3389/fpubh.2021.766984.

LibreTexts. "10.4: Radioactive Decay." *Physics LibreTexts*, 1 Nov. 2016, https://phys.libretexts.org/Bookshelves/University_Physics/University_Physics_(OpenStax)/University_Physics_III_-_Optics_and_Modern_Physics_(OpenStax)/10%3A__Nuclear_Physics/10.04%3A_Radioactive_Decay

"Lipstick Contaminated with Lead?" NutritionFacts.org, 23 Mar. 2023, https://nutritionfacts.org/blog/lipstick-contaminated-with-lead/.

Liu, Sa, et al. "Concentrations and Potential Health Risks of Metals in Lip Products." *Environmental Health Perspectives,* vol. 121, no. 6, June 2013, pp. 705–710, https://doi.org/10.1289/ehp.1205518.

Mayo Clinic. "Lead Poisoning - Symptoms and Causes." *Mayo Clinic,* 21 Jan. 2022, www.mayoclinic.org/diseases-conditions/lead-poisoning/symptoms-causes/syc-20354717.

Mo, Chuiyan. "Heavy Metals Regulations in the European Union: An Overview." *Compliance Gate*, 4 Sept. 2020, www.compliancegate.com/heavy-metal-regulations-european-union/.

Monnot, Andrew D., et al. "An Exposure and Health Risk Assessment of Lead (Pb) in Lipstick." *Food and Chemical Toxicology*, vol. 80, June 2015, pp. 253–260, https://doi.org/10.1016/j.fct.2015.03.022.

Nourmoradi, H., et al. "Assessment of Lead and Cadmium Levels in Frequently Used Cosmetic Products in Iran." *Journal of Environmental and Public Health,* vol. 2013, 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3794557/, https://doi.org/10.1155/2013/962727. Accessed 21 May 2020.

Olufemi, Adejoke Christianah, et al. "Potential Health Risks of Lead Exposure from Early Life through Later Life: Implications for Public Health Education." *International Journal of Environmental Research and Public Health*, vol. 19, no. 23, 30 Nov. 2022, p. 16006, https://doi.org/10.3390/ijerph192316006.

Raza-Naqvi, Syed Ali, et al. "TOXICOLOGY of HEAVY METALS USED in COSMETICS." *Journal of the Chilean Chemical Society*, vol. 67, no. 3, Sept. 2022, pp. 5615–5622, https://doi.org/10.4067/s0717-97072022000305615.

Saah, Selina Ama, et al. "Human Health Risks of Lead, Cadmium, and Other Heavy Metals in Lipsticks." *Heliyon,* vol. 10, no. 23, Dec. 2024, p. e40576, https://doi.org/10.1016/j.heliyon.2024.e40576.

---. "Human Health Risks of Lead, Cadmium, and Other Heavy Metals in Lipsticks." *Heliyon*, vol. 10, no. 23, Dec. 2024, p. e40576, https://doi.org/10.1016/j.heliyon.2024.e40576.

Soares, Aline Rodrigues, and Clésia Cristina Nascentes. "Development of a Simple Method for the Determination of Lead in Lipstick Using Alkaline Solubilization and Graphite Furnace Atomic Absorption Spectrometry." *Talanta,* vol. 105, Feb. 2013, pp. 272–277, www.sciencedirect.com/science/article/pii/S0039914012007771, https://doi.org/10.1016/j.talanta.2012.09.021. Accessed 9 Feb. 2019.

Team, ChemLinked, and ChemLinked Team. "South Korea Functional Cosmetic Regulation | ChemLinked." *ChemLinked*, chemlinked, 2022, https://cosmetic.chemlinked.com/cosmepedia/south-korea-functional-cosmetic-regulation

US EPA, OCSPP. "Lead Laws and Regulations." *US EPA*, 12 Feb. 2013, https://epa.gov/lead/lead-laws-and-regulations.

To what extent do grade 12 AP and IB students' food intake during a non-exam week (low stress environment) differ from an AP and IB mock exam week (high stress environment)?

ABSTRACT

Eating healthy is a crucial part of maintaining a healthy diet on a daily basis, especially in a high stress environment such as AP and IB mocks. Although students continue to strive to balance their diet, that factor is still heavily neglected amongst 12th graders at Saigon South International School (SSIS)–either through over or under consumption.

The purpose of this study serves as an investigation on the extent of diet fluctuations among grade 12 students in non stressful environments compared to stressful environments.

This cross-sectional study utilizes the Princeton perceived stress indicator via a survey, a calorie calculator and a t-statistical test. Although this dataset heavily relies on a stress meter from a previous study, our analyses provide reliability in making inferences about the Senior population within SSIS based on a sample through hypothesis testing.

Findings indicate that IB students' stress level and calorie intake have no significant difference between a normal school week(low stress environment) and mock examination week (high stress environment) with p-value of 0.510 for calorie intake and p-value of 0.799 for students' perceived stress level. Whereas, AP students displayed a s ignificant difference in calorie intake between high and low stress environments, as the p-value for a non-exam week is 0.0001. However, AP students' perceived stress level showed no significance between the two environments with a p-value of 0.052.

These results suggest that there are various other factors that could contribute to the fluctuating data, such as college applications and personal issues. However, it is still important to prioritize one's health in order to have the energy to succeed and think in stressful environments.

INTRODUCTION

Our bodies are able to adapt and adjust to various environments through the help of the nutrients our body consumes given by food. Having a balanced diet is essential to guarantee that our well-being has the energy it needs for daily activities. Consumption of either too little or too high of nutrients can lead to deterioration of an individual's health and stagnate performance (Njomza Gashi- 05.24). A person's appetite can be impacted by various factors–through genetics, gender, peer pressure, age, sleep and health. Food choices are made according to the public market based on nutritional factors and economics, therefore understanding motivational attributes would support in strengthening a diet while under pressure (Suha Said Al-Naimi- 09.24).

Stress is a fundamental biological process intrinsic to living organisms; however, it is also recognized as a potential contributing factor to the onset of numerous pathological conditions. It encompasses the organism's generalized, non-specific physiological and psychological responses to stimuli that threaten or disrupt homeostatic balance. These stimuli, commonly referred to as stressors, may arise from both internal and external sources. Alternatively, stressors can be classified into environmental, biological, and psychological domains, depending on their origin

and nature. (NIH). Most frequently seen in high school students, their overwhelming school schedule overlaps with an individual's spare time– limiting them to exploring hobbies and interests to a fixed routine of "school, extracurricular, homework and sleep" (NYU) – creating a gradual build up of stress overtime and the idea of not having enough time in one's day to complete deadlines. Likewise, this phenomenon elevates cortisol levels for a prolonged period of time, such as during repeated and constant stressors, causing an increase in food consumption and high levels of fats and calories (Johns Hopkins Medicine), this is to subsidies for overworking. This occurrence can happen in reverse as epinephrine helps trigger the body's fight-or-flight response, a revved-up physiological state that temporarily puts eating on hold (Harvard Health). According to a recent Kuwaiti study, students who are under a lot of stress over their grades often eat more foods high in calories and fat (Ahmed et al., 2014). Additionally, a study among Egyptian university students revealed a substantial correlation between higher perceived stress scores and a lower intake of fruits and vegetables for both genders. According to a recent study done in 2020, students who felt a lot of stress show unhealthier eating habits, such that they were seen eating pre-cooked and microwavable meals (Choi, 2020).

This similar concept can be applied to students in rigorous curriculums such as the International Baccalaureate (IB) diploma program and College Board's Advanced Placement (AP). Both programs offer an exhaustive schedule that demands an individual's full attention, leading to students developing stress through their own perspective– whether it is the inability to make time for hobbies or even take care of oneself throughout the day–especially during exam season (University of South Florida). In order to cope and handle a students' pressure their body starts to depend on overeating or neglecting food as a whole as a way to decrease the feeling of work piling up each day. However, this has the potential to severely impact an individual's diet as this habit could turn into a permanent diet. Through this observation, a comparison between AP and IB students was made to observe the extent of how much academic rigor impacts a student's dietary habit to determine fluctuations in perceived stress and calorie intake.

METHODOLOGY

This study was carried out with grade 12 students from the IB and AP curriculum at Saigon South International School (SSIS) in Ho Chi Minh City, Vietnam. The data were collected through a survey created by the researcher where the randomly selected students, via a random number generator, were asked to anonymously answer a series of questionnaires inspired by a previous study by Princeton to determine their stress level at their current time (Princeton Perceived Questionnaire). Additionally, the students are asked to note down their total daily calorie intake at the end of the survey. This process is split into 2 stages, first is the control where AP and IB students are surveyed on an average school week and the second is during their respective mock week.

After the results are collected, a t-statistical test is applied on AP and IB stress and calorie numbers from before and after the mock exam week then compared to one another to analyze the difference in stress and calorie patterns. If the distribution is normal then a t-test is safe to use freely regardless of sample size and compared to a confidence interval of =0.05 against a statistical hypothesis test–the null states that "There will be no significant difference in Grade 12 IB students and Grade 12 AP students' caloric intake in stressful environments and non stressful environments." This statement holds true if the p-value of the data is larger than =0.05, whereas, when alpha is larger we will fail to reject the alternative hypothesis being "there will be a significant difference in Grade 12 IB students and Grade 12 AP students' caloric intake in stressful environments and non stressful environments." However, if the distribution is skewed, it can be manipulated to normal through transformation of data in order to use the t-test. In order to determine a student's stress level, a perceived stress level between 20-26 would be moderate stress and 27-40 would be considered high perceived stress (State of New Hampshire Employee Assistance Program).

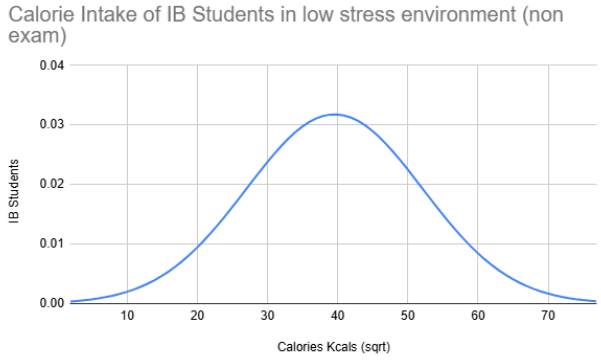
RESULTS

In the current study, a total of 33 participants within the grade 12 body, encompassing both AP and IB students, participated. These students were chosen via random sampling and split into the following: 9 full diploma IB respondents from a population sample of 38 Senior IB and 12 AP students from a population sample of roughly 63 full AP Seniors. The original data for grade 12 IB calorie intake in a controlled environment (non exam week) and exam week was heavily skewed, so it had to be square rooted. After performing an independent t-test, shown by the equation below.

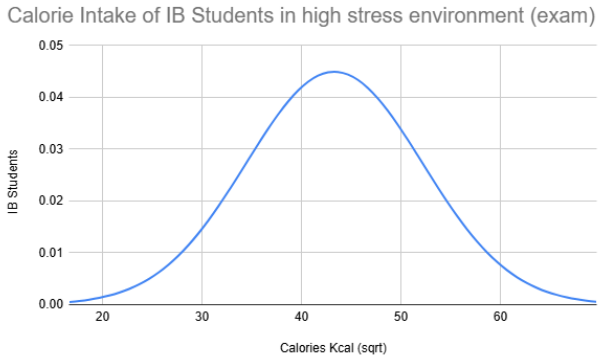
$$t = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Condition	Sample Size (n)	Mean Caloric Intake	Standard Deviation
High Stress (IB)	6	43.31	8.88
Low Stress (IB)	9	39.57	12.55

Table 1: *Calorie intake of grade 12 IB students in high and low stress environments*



Graph 1: *Distribution of grade 12 IB calorie intake in a non-exam environment*



Graph 2: *Distribution of grade 12 IB calorie intake in an exam environment*

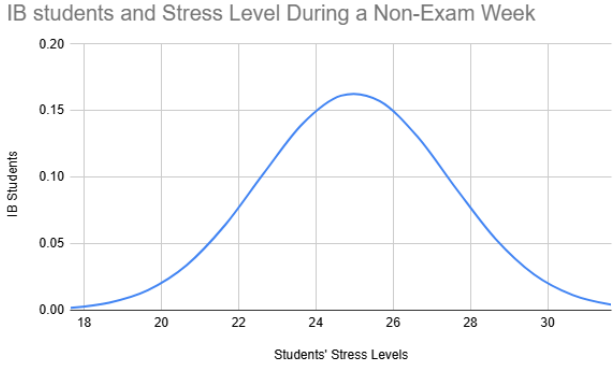
The results indicate a p-value of 0.510 and a t-statistic of 0.678, since the p-value exceeds the 0.05 significance threshold, we fail to reject the null hypothesis. The analysis displays that there is no statistically significant difference in the caloric intake of Grade 12 IB students between high-stress and low-stress environments. This indicates that their diet prior to their mock examination week has not fluctuated during their examination week, in short remained the same. After students have answered the survey, their qualitative answers were then changed into numerical values. Similar results were produced when measuring individual students' perceived stress yielding a p-value of 0.799 which is beyond bigger than =0.05 indicating that we fail to reject the null hypothesis. This means that there is not enough evidence that there is any statistically significant difference in grade 12 IB students' perceived stress in pre-mock week and mock week, indicating that they are equally stressed in both environments due to studying and the idea of doing well in the exam.

Almost	Sometimes	Often	Usually
1	2	3	4

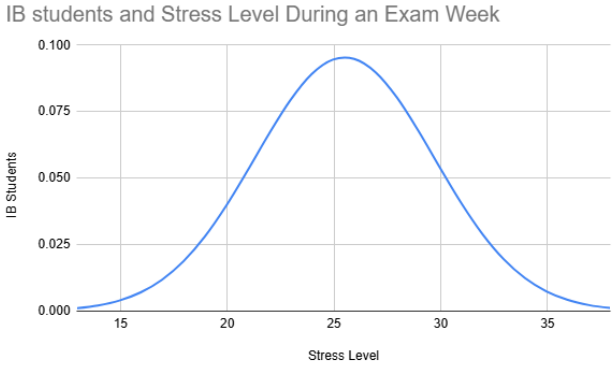
Figure 1: *Perceived stress meter used in experiment from Princeton*

Group	Environment	Sample Size (n)	Mean stress level	Standard Deviation (SD)
Grade 12 IB Students	Non-Stressful (Pre-exam)	9	25.0	2.45
Grade 12 IB Students	Stressful (Exam)	6	25.5	4.18

Table 2: *Perceived stress level of grade 12 IB students in pre-exam and exam environment*



Graph 3: *Perceived stress of grade 12 IB students in low stress environments*



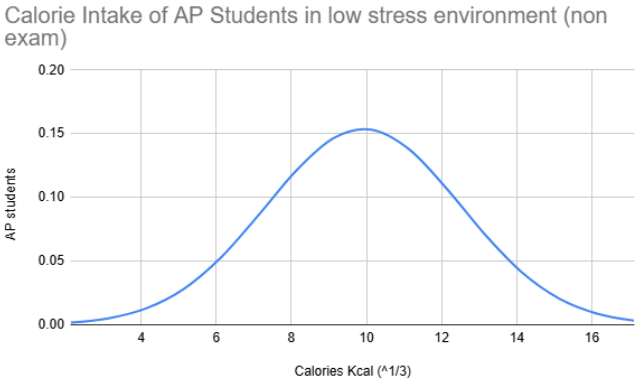
Graph 4: *Perceived stress of grade 12 IB students in high stress environments*

As for AP, the data for non stressful environment calorie intake was heavily skewed so by cube rooting the data gives a normal distribution. As for the data for stressful environment calorie intake, it was also skewed so natural logging (ln) the dataset was able to transform it to normal.

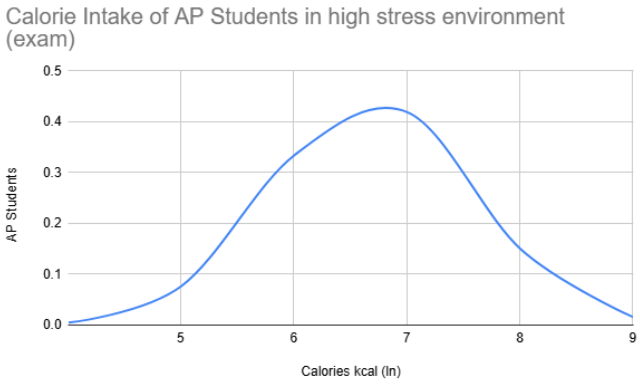
Condition	Sample Size (n)	Mean Caloric Intake	Standard Deviation
High Stress (AP)	9	6.686	0.894
Low Stress (AP)	12	9.922	2.597

Table 3: *Calorie intake of grade 12 AP students in high and low stress environments*

The results indicate a p-value given by the t-test of independence from both data sets is 0.0001 and a t-value of 4.819. Based on the findings our p-value of 0.0001 is smaller than our significance level of 0.05, meaning that we reject the null hypothesis. In conclusion there is enough evidence that there is a significant difference between in Grade 12 AP students' caloric intake in stressful environments and non stressful environments. As seen through the mean of both data and the untransformed data below, there is a decrease in the mean caloric intake of low stress and high stress environments indicating that during mock examination week, AP students started undereating more than an average school week.



Graph 5: *Calorie Intake of grade 12 AP students in low stress environments*



Graph 6: *Calorie Intake of grade 12 AP students in an exam environment*

AP Students	Calories
AP PRE MOCK	450
AP PRE MOCK	1200
AP PRE MOCK	600
AP PRE MOCK	2400
AP PRE MOCK	738
AP PRE MOCK	1150
AP PRE MOCK	1131
AP PRE MOCK	50
AP PRE MOCK	1925
AP PRE MOCK	1800
AP PRE MOCK	1500
AP PRE MOCK	800

Figure 2: *Chart of Calorie Intake of AP 12th Graders Pre-exam*

AP Students	Calories
AP MOCK	200
AP MOCK	900
AP MOCK	1000
AP MOCK	1000
AP MOCK	800
AP MOCK	5000
AP MOCK	300
AP MOCK	900
AP MOCK	700

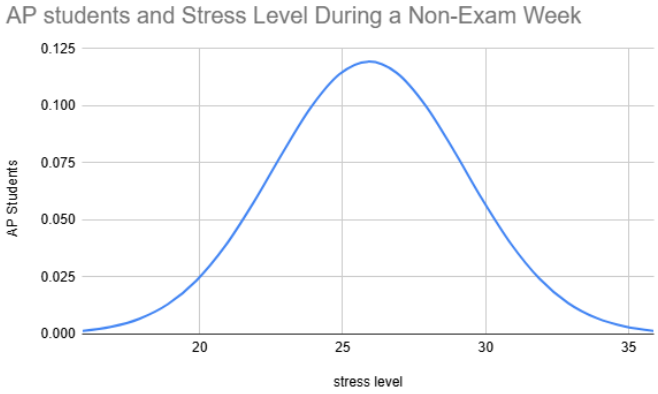
Figure 3: *Chart of Calorie Intake of AP 12th Graders During Exam*

Similar procedures were given to AP students, the randomly selected students were asked to fill out a questionnaire on the survey to determine how stressed they thought they were during the week they were provided. Each individual students' stress was collected below.

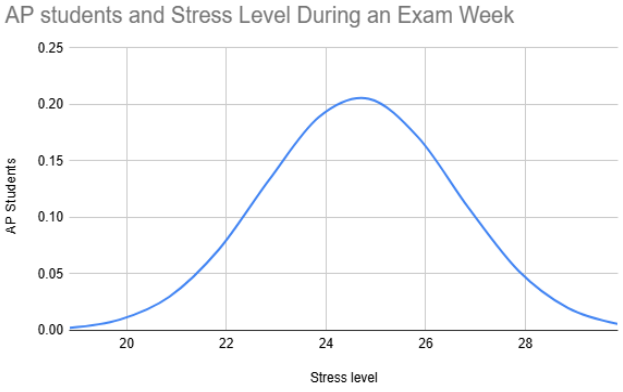
Group	Environment	Sample Size (n)	Mean stress level	Standard Deviation (SD)
Grade 12 AP Students	Non-Stressful (Pre-exam)	12	25.92	3.34
Grade 12 AP Students	Stressful (Exam)	9	24.67	1.94

Table 4: *Perceived Stress of grade 12 AP students in high and low stress environments*

With the given data, it was possible to safely perform a t-test since the data had no major skews. The data yields a p-value of approximately 0.052 being slightly larger than our significance level of =0.05, with a t-statistic of approximately -2.079. Therefore, based on this independent sample t-test, we fail to reject the null hypothesis at the 0.05 significance level. This means that, based on these data, there is not enough statistical evidence to conclude that there is a significant difference in the mean stress levels of AP students between the mock and pre-mock exam periods. While AP students show a fluctuation in calorie intake during strenuous examination week, individual's mean stress remains relatively constant.



Graph 7: *Perceived stress of grade 12 AP students in low stress environments*



Graph 8: *Perceived stress of grade 12 AP students in high stress environments*

AP Students	Stress Level
AP PRE MOCK	25
AP PRE MOCK	24
AP PRE MOCK	28
AP PRE MOCK	34
AP PRE MOCK	24
AP PRE MOCK	28
AP PRE MOCK	26
AP PRE MOCK	25
AP PRE MOCK	24
AP PRE MOCK	26
AP PRE MOCK	20
AP PRE MOCK	27

Figure 4: *Chart of Perceived Stress of AP 12th Graders Pre-exam*

AP Students	Stress Level
AP MOCK	22
AP MOCK	24
AP MOCK	24
AP MOCK	24
AP MOCK	23
AP MOCK	27
AP MOCK	24
AP MOCK	28
AP MOCK	26

Figure 5: *Chart of Perceived Stress of AP 12th Graders During Exam*

DISCUSSION

Our research aimed to investigate the relationship between stress levels and caloric intake among Grade 12 International Baccalaureate (IB) and Advanced Placement (AP) students during periods of academic pressure (mock examination). Specifically, we sought to determine if there were significant differences in these variables between the two student groups and within each group across different levels of academic demand.

Interestingly, our findings suggest a nuanced pattern. When examining stress levels, we observed no statistically significant difference between IB and AP students. This implies that, at least as measured via survey, both groups of high-achieving students report experiencing similar levels of stress during demanding mock examination periods, aligning with a previous research that concluded high-achieving students, regardless of program type, frequently experience elevated but comparable levels of stress due to similar academic expectations and self-imposed performance pressures (Suldo et al., 2008; Conner et al., 2010). Furthermore, within the AP student cohort, our analysis indicated no significant variation in reported stress levels between the examined conditions (e.g., mock exams vs. regular coursework). This could suggest that AP students experience a relatively consistent level of perceived stress, or that our measures were not sensitive enough to detect subtle fluctuations.

However, the picture differs when we consider caloric intake. Our results hinted at no significant difference in caloric intake between IB and AP students overall. This might suggest that despite potentially different curriculum and assessment styles, the average nutritional demands or eating behaviors of these two groups are comparable under academic pressure (Michels et al., 2012).

The most compelling finding emerged when we examined caloric intake within the AP student group. Here, our analysis suggested a statistically significant difference in caloric intake across the different academic conditions we investigated. This implies that while their perceived stress levels might remain relatively stable, the eating habits of AP students do appear to be influenced by the specific academic demands they face (Oliver & Wardle, 1999; Torres & Nowson, 2007). This could manifest as either increased or decreased consumption depending on the nature and intensity of the academic period.

These findings raise several intriguing questions for future research. Why might AP students exhibit significant changes in caloric intake across different academic demands while their reported stress levels remain relatively constant? This could suggest that factors beyond consciously perceived stress, such as workload, time constraints, or altered routines, play a more direct role in their eating behaviors. It's also possible that AP students have developed coping mechanisms that allow them to maintain a consistent perception of their stress, even as their physiological responses (like changes in appetite) fluctuate.

The lack of a significant difference in stress levels between IB and AP students, despite their often-perceived differences in curriculum rigor and assessment styles, warrants further exploration. It could be that both programs cultivate a similar level of academic pressure, or that students self-select into these demanding pathways based on a similar tolerance for stress.

Future research could benefit from employing longitudinal designs to track stress and caloric intake within individual students across various academic periods for more accuracy (Schlotz et al., 2008). Utilizing more objective measures of stress (e.g., cortisol levels) and dietary intake (e.g., food diaries, nutritional analysis) could also provide a more comprehensive understanding of these complex relationships (Livingstone & Black, 2003). It would also be valuable to explore mediating variables such as coping strategies, social support, and time management, which have been linked to both stress and health-related behaviors in adolescents (Compas et al., 2001; Eisenberg et al., 2007). Furthermore this gives way for insight on how different components in food will affect an individual's focus and cognition in processed thinking (Gómez-Pinilla, 2008).

This research had various challenges, with one being that the sample size of each group did not meet the expected original size which was: 10 students in IB and 15 students in AP. Instead the results gave us varying sample sizes throughout the environments with one being less or more than the other. Additionally, the investigation was not as random as intended with some students not responding leading to small results so I had to resort to giving teachers my survey and have the students fill it out during the end of their class time causing the use of data transformation due to skewness. Lastly, the data was originally going to be a t-test of homogeneity with chosen students to fill out the survey in both non exam and exam environments, though it wasn't possible because of everyone's busy schedules or other contributing factors. With all of these limitations accommodated in the following development of this paper, the results will reveal more concise accuracy.

In conclusion, our preliminary findings suggest a dissociation between perceived stress levels and caloric intake, particularly within the AP student population. While both IB and AP students appear to experience similar levels of stress, AP students demonstrate a significant variability in their eating habits across different academic demands. This highlights the need for further investigation into the multifaceted factors influencing nutritional behavior in academically high-achieving students.

REFERENCES

Salihu, Salih, and Njomza Gashi. "Eating Habits of Students during a Typical Exam Period-Case of Kosovo." *International Journal of Public Health Science (IJPHS),* vol. 13, no. 3, 1 Sept. 2024, p. 1386, www.researchgate.net/publication/380824201_Eating_habits_of_students_during_a_typical_exam_period-Case_of_Kosovo, https://doi.org/10.11591/ijphs.v13i3.24227. Accessed 4 May 2025.

Al-Naimi, Suha. "Relationship between Academic Stress and Eating Habits among University of Sharjah Medical Students." *Clinical Psychology Review, vol.* 119, no. 1, Sept. 2024, pp. 1–5, https://doi.org/10.70706/j.cpr.2024.103890.

Stromájer, Gábor Pál, et al. "Stress and Anxiety among High School Adolescents: Correlations between Physiological and Psychological Indicators in a Longitudinal Follow-up Study." *Children,* vol. 10, no. 9, MDPI AG, Sept. 2023, p. 1548, https://doi.org/10.3390/children10091548. Accessed 4 May 2025.

NYU Web Communications. *Nyu.edu,* 2015, www.nyu.edu/about/news-publications/news/2015/august/nyu-study-examines-top-high-school-students-stress-and-coping-mechanisms.html. Accessed 4 May 2025.

"Tips to Manage Stress Eating." *Hopkinsmedicine.org,* 20 June 2024, www.hopkinsmedicine.org/health/wellness-and-prevention/tips-to-manage-stress-eating#:~:text=During%20a%20stressful%20event%2C%20the,fat%20storage%20and%20weight%20gain. Accessed 4 May 2025.

"Why Stress Causes People to Overeat - Harvard Health." Harvard Health, 23 Jan. 2012, www.health.harvard.edu/staying-healthy/why-stress-causes-people-to-overeat#:~:text=In%20the%20short%20term%2C%20stress,temporarily%20puts%20eating%20on%20hold. Accessed 4 May 2025.

Choi, Jinkyung. "Impact of Stress Levels on Eating Behaviors among College Students." *Nutrients,* vol. 12, no. 5, MDPI AG, Apr. 2020, p. 1241, https://doi.org/10.3390/nu12051241. Accessed 4 May 2025.

"Multiyear Study Investigates Stress in IB and AP Students | 2015 | News | about Us | USF College of Education." Usf.edu, 2015, www.usf.edu/education/about-us/news/2015/2015-multiyear-study-stress-ib-ap-students.aspx. Accessed 4 May 2025.

Shahid, Azmeh, et al. "Perceived Stress Questionnaire (PSQ)." STOP, THAT and One Hundred Other Sleep Scales, 2011, pp. 273–74, https://doi.org/10.1007/978-1-4419-9893-4_64.

F, Ahmed, et al. "Association between Stress and Dietary Behaviours among Undergraduate Students in Kuwait Gender Differences." *Journal of Nutrition and Health Sciences,* vol. 1, no. 1, May 2014, https://doi.org/10.15744/2393-9060.1.104. Accessed 20 Aug. 2020.

State of New Hampshire Employee Assistance Program. Perceived Stress Scale. 1983, www.das.nh.gov/wellness/docs/percieved%20stress%20scale.pdf.

Deshpande, Sameer, et al. "Factors Influencing Healthy Eating Habits among College Students: An Application of the Health Belief Model." *Health Marketing Quarterly, vol. 26*, no. 2, Informa UK Limited, May 2009, pp. 145–64, https://doi.org/10.1080/07359680802619834. Accessed 4 May 2025.

Shah, Qasim Ali, et al. "Antecedents and Consequences of Academic Stress on Dietary Habits of University Students: An Exploration of Stress Coping Mechanisms and Health Outcomes." *Journal of Entrepreneurship, Management, and Innovation*, vol. 6, no. 2, June 2024, pp. 152–72, https://doi.org/10.52633/jemi.v6i2.371.

Suldo, Shannon M., et al. "Relationships among Stress, Coping, and Mental Health in High-Achieving High School Students." *Psychology in the Schools,* vol. 45, no. 4, Wiley, Feb. 2008, pp. 273–90, https://doi.org/10.1002/pits.20300. Accessed 18 May 2025.

Michels, Nathalie, et al. "Stress, Emotional Eating Behaviour and Dietary Patterns in Children." *Appetite,* vol. 59, no. 3, Elsevier BV, Aug. 2012, pp. 762–69, https://doi.org/10.1016/j.appet.2012.08.010. Accessed 18 May 2025.

Torres, Susan J., and Caryl A. Nowson. "Relationship between Stress, Eating Behavior, and Obesity." *Nutrition,* vol. 23, no. 11-12, Elsevier BV, Nov. 2007, pp. 887–94, https://doi.org/10.1016/j.nut.2007.08.008. Accessed 18 May 2025.

OLIVER, G., and J. WARDLE. "Perceived Effects of Stress on Food Choice." *Physiology & Behavior,* vol. 66, no. 3, Elsevier BV, May 1999, pp. 511–15, https://doi.org/10.1016/s0031-9384(98)00322-9. Accessed 18 May 2025.

Schlotz, Wolff, et al. "The Perceived Stress Reactivity Scale: Measurement Invariance, Stability, and Validity in Three Countries." *Psychological Assessment,* vol. 23, no. 1, Mar. 2011, pp. 80–94, https://doi.org/10.1037/a0021148.

Livingstone, Barbara E., and Alison E. Black. "Markers of the Validity of Reported Energy Intake." *Journal of Nutrition,* vol. 133, no. 3, Elsevier BV, Mar. 2003, pp. 895S920S, https://doi.org/10.1093/jn/133.3.895s. Accessed 18 May 2025.

"(PDF) Coping, Emotion Regulation, and Psychopathology in Childhood and Adolescence: A Meta-Analysis and Narrative Review." *ResearchGate*, www.researchgate.net/publication/317629455_Coping_Emotion_Regulation_and_Psychopathology_in_Childhood_and_Adolescence_A_Meta-Analysis_and_Narrative_Review.

Gómez-Pinilla, Fernando. "Brain Foods: The Effects of Nutrients on Brain Function." *Nature Reviews Neuroscience,* vol. 9, no. 7, Springer Science and Business Media LLC, July 2008, pp 568–78, https://doi.org/10.1038/nrn2421. Accessed 18 May 2025.

Conner, Kyaien O., et al. "Attitudes and Beliefs about Mental Health among African American Older Adults Suffering from Depression." *Journal of Aging Studies,* vol. 24, no. 4, Dec. 2010, pp. 266–77, https://doi.org/10.1016/j.jaging.2010.05.007.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