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Relationship between nutrition and cognitive processes that affect academic performance in adolescent students

Relación entre nutrición y procesos cognitivos que inciden en el rendimiento académico en estudiantes adolescentes

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ABSTRACT

The study focuses on determining the relationship between nutrition and cognitive processes that affect academic performance in adolescent students. It is a non-experimental, quantitative, descriptive and cross-sectional research. 189 students, with an average age of 15, were selected as a sample. years. The dependent variable is made up of the school performance of the study population, determined through the Saber Tests and grade sheets and indirectly through neuropsychological tests, such as the TMT Test A and B, which measures the cognitive process of attention. and the Wisconsin test that measures executive functions and the Auditory Memory test that measures the memory process. The main independent variable of this study will be the anthropometric nutritional status of the students, determined through the calculation of BMI and hemoglobin. It is concluded that the relationship between BMI and hemoglobin with the different tests is weak, as is BMI and hemoglobin with the grades and results of the Saber Tests. Although the participating students present a high risk of acquiring eating habits that result in nutritional deficiencies. The results obtained show that the BMI in the majority is within normal ranges as well as hemoglobin, they also have good sleeping habits and the results of academic performance measured by grades and Test Saber are not as low as initially expected.

Palabras clave:
adolescentes, hábitos alimenticios, nutrición, procesos cognitivos, rendimiento académico.

RESUMEN

El estudio se centra en determinar la relación entre nutrición y procesos cognitivos que inciden en el rendimiento académico en estudiantes adolescentes, siendo una investigación no experimental, cuantitativa, descriptiva y de corte transversal, se seleccionaron como muestra a 189 alumnos, con edad promedio de 15 años.

La variable dependiente está constituida por el rendimiento escolar de la población en estudio, determinada a través de las Pruebas Saber y las planillas de notas e indirectamente a través de tests neuropsicológicos, tales como el Test TMT A y B que mide el proceso cognitivo de atención y el test de Wisconsin que mide las funciones ejecutivas y el test de Memoria Auditiva que mide el proceso de memoria. La principal variable independiente de este estudio será el estado nutricional antropométrico de los estudiantes, determinado a través del cálculo del IMC y de la

hemoglobina. Se concluye que la relación entre el IMC y la hemoglobina con los diferentes test es débil al igual que el IMC y la hemoglobina con las notas y los resultados de las Pruebas Saber. Aunque los estudiantes participantes presentan un alto riesgo de adquirir hábitos alimenticios que redundan en deficiencias nutricionales. Los resultados obtenidos demuestran que el IMC en la mayoría está dentro de rangos normales al igual que la hemoglobina, igualmente tienen hábitos de sueño bueno y los resultados del rendimiento académico medidos por las notas y Prueba Saber no son tan bajos como se esperaba inicialmente.

Introduction

Adolescence is characterized by an accelerated growth rate, changes in body composition, appearance of secondary sexual characteristics, and emotional and psychosocial maturation. These characteristics influence both the dietary recommendations for this stage of life and the eating habits of young people.

Often the young person does not agree with the eating habits of the family, including attempts to follow special diets (e.g. vegetarian diet), with the independence that is generated at this specific age stage there is an increase in activities outside the home; alterations in eating schedules, skipping some meals (breakfast, lunch) and increased consumption of fast food, sweets and energy drinks. At the same time, decrease the consumption of dairy products, fruits and vegetables, dinner can become the main meal of the day. In addition to these eating habits, sedentary lifestyles increase the risk of obesity and other chronic diseases.

The interest in investigating the relationship between nutritional status and cognitive processes involved in academic performance is situated within the framework of the Sustainable Development Goals (SDGs) and arises from experiences lived in the institution in which students come, mostly from low-income families, exposed to the consumer society that preaches the neoliberal model, so they present a high risk of acquiring eating habits that result in nutritional deficiencies; in turn, this condition is reflected in a level of academic performance below what is required for these adolescents to compete successfully in the labor market.

From the teaching practice it has been possible to observe that in the institution under study there is a low academic performance in 9th grade students, who are mostly adolescents. The causes may be multiple, since there is a clear interdependent relationship between biological, cognitive and contextual factors, but it has been identified that most students come from low-income families, which hinders their development. This problem of low performance is not exclusive to this social sector, as it can be found in the general student population.

The particularity identified as a possible causal factor of the low academic performance in the aforementioned population is the state of malnutrition in which the students can be observed, given the food environment in which they develop. As the population is primarily adolescent, it can be understood that this stage of life is one in which physical and psychosocial development and adequate nutrition are not only essential for present well-being but also for future health and prosperity.

In addition, the adolescent experiences variations in academic performance due to the pressures of evaluations and even more so due to the exhortation of vocational determination. It is in adolescence that the maturation process of the executive functions is defined or culminates, so that the individual becomes an adult with adequate cognitive tools to perform in the real context. To this end, the socio-demographic and economic characterization of the study population, as well as their eating habits, was initially carried out. The anthropometric nutritional status of the 9th grade students of the

institution under study was estimated through the body mass index. Additionally, the hemoglobin concentration of 9th grade students is determined. The results obtained in the application of the TMT, logical thinking, auditory memory, M-WCST and school performance tests are presented.

The relationship between nutritional status and cognitive processes measured through the tests in the study population is clarified. The relationship between the biochemical indicator hemoglobin and the cognitive processes measured through the tests in the study population is evaluated.

Finally, the relationship between the nutritional status of the 9th grade students of the institution studied in relation to their academic performance is established. And finally, the relationship between nutritional status and the biochemical indicator of hemoglobin in the blood of the 9th grade students studied in relation to their academic performance is compared.

Method

The study is quantitative, descriptive and cross-sectional. According to Valdés, P. (2006), quantitative research is reduced to measuring variables in terms of a given magnitude or quantity; the aspects that characterize quantitative research are measurement subject to mathematical criteria and numerical reproduction of the relationships between subjects and phenomena.

Likewise, quantitative research has great value in external validity, because with a representative sample of the population it is possible to infer the results of the study in that sample to the population from which it comes (Valdés, P., 2006). This type of research tries to investigate the forces of association or correlation between variables and generalizes the results through those obtained in a sample, so the results of this type of research have validity to generalize them to the population (Valdés, P., 2006)

For Hernández et al. (2014) with descriptive studies "we seek to specify the properties, characteristics and profiles of people, groups, communities, processes, objects, or any other phenomenon that is subjected to analysis, which means that it only aims to measure or collect information independently or jointly on the concepts or variables to which they refer" (p. 103)

It is cross-sectional due to the data collection, which was carried out in a single time period, coinciding with Tamayo and Tamayo (2010) who express that the purpose of a cross-sectional research is to describe conditions in order to analyze their incidence and interrelation at a specific time.

Regarding the research design, the ninth grade students of the institution in question will be integrated into the study once they have given their voluntary acceptance to participate and informed consent has been received from their parents or legal guardians and also from the school establishment in question. Every day there is more interest in the knowledge that leads to the practice of healthy lifestyle habits, among which physical activity and proper nutrition stand out, as an essential basis for maintaining the balance of a healthy life.

Sample

A sample of 189 students was selected, with an average age of 15 years, distributed in both sexes, i.e. females and males. Among the inclusion criteria, one hundred percent of the ninth grade students in the study sample of the institution studied were taken, who

have the indicated authorization, that is, those students whose parents have signed the participation form in the research and who voluntarily commit themselves to participate in a responsible manner for as long as the research requires it.

As a criterion for exclusion, the voluntary and individual refusal of each student and/or his/her guardian or representative was established, in order to comply with the informed consent rules that apply in these cases. In addition, the exclusion criteria were students or their legal representatives who did not attend the educational sessions about the research process and, on the other hand, students who, although they attended the training given, did not follow the necessary or required recommendations and instructions. Finally, students or their legal representatives who did not sign the acceptance or informed consent form were also unable to participate.

Variables

The dependent variable of this research project is constituted by the school performance of the study population, which was measured directly through the Saber Tests and report cards and indirectly through neuropsychological tests, such as the TMT A and B test that measures the cognitive process of attention, the Wisconsin test that measures the executive functions and the Auditory Memory test that measures the memory process.

The main independent variable in this study is the anthropometric nutritional status of the students, determined by calculating body mass index (BMI) and hemoglobin. In addition, covariates such as logical thinking and cognitive processes were analyzed to explain the topic studied.

Analytical Research Instruments and Tests

For the characterization of the students, we inquired about gender, age, stratum, type of housing in which they live, parents' schooling and income, number of hours of sleep, number of hours of screen time and physical activity.

The Questionnaire, adolescents "Promoting Eating at School", was applied to inquire about food consumption patterns and perceived health of snacks, school recess activities, eating and shopping behavior during school hours and about the money spent per week to buy food or beverages outside the school area.

The Consumption Frequency Questionnaire (CFC) IASE (Healthy Eating Index) was used, in which questions are asked about the frequency of consumption of cereals, vegetables, fruits, milk and dairy products, meats, legumes, sweet sausages, soft drinks and fats. In order to know how healthy the food consumed by the students is, the instrument entitled "Harvard Plate" was applied, in which an image of 100% of their lunch is presented, and the students must indicate what percentage of the plate they consume of vegetables, fruits, whole grains and healthy protein.

In relation to the BMI assessment, height was measured using a wall measuring rod and weight was measured using a digital scale.

To investigate the development of cognitive processes, the Trail Making Test, better known as TMT, which consists of two parts A and B, was used. The examiner starts counting the execution time of part A and part B as soon as the instructions have been given and the participant has been told that he/she can start. In addition, the Logical Thinking Test was applied, which consists of ten tasks designed to evaluate five formal logical-mathematical reasoning schemes such as proportionality, control of variables, probability, correlation and combinatorics.

Additionally, the assessment of logical, numerical and associative memory was performed by applying the Immediate Auditory Memory Test (MAI). This test consists of

the following three parts: presentation of two paragraphs in order to know to what extent the student remembers the details of the news item "event", presentation of digits to be repeated in the same order and inversely and pairs of associated words (3 repetitions). The student's task is to remember which word was associated with one of the pair presented (Cordero, 1978)

Executive functions were assessed using the Wisconsin Card Sorting Test (WSCT). This version of the test was created after eliminating the 80 of the 128 response cards of the original WCST that shared more than one attribute, which is why this test is composed of 48 response cards and 4 model cards. According to Schretlen (2019) Schretlen (2019) this test allows the assessment of executive function, requires strategic planning, organized search, use of environmental information to change cognitive set, goal-oriented behavior and inhibition of impulsive responses.

For the measurement of the dependent variable (academic performance), the measurement instruments used were the teachers' report cards in the different subjects and the results of the Saber Tests, as well as the cognitive process evaluation tests. According to the Ministry of Education (2022), the Saber Tests evaluate the basic competencies formulated by the Ministry of National Education in the Basic Competency Standards. The Saber 9 tests evaluate Language, Mathematics, Natural Sciences and Citizenship Competencies.

Data Analysis

A descriptive analysis of the variables of interest was performed in which the categorical characteristics were described as percentages and their respective 95% confidence intervals (95% CI). Continuous variables were expressed as means and their corresponding Standard Deviation (SD) and as medians and their interquartile range according to their distribution.

The data analytical approach was based on the statistical comparison of the results of the nutritional variables with the data of the academic performance variables of the population referred to in the present study.

The data were recorded in Microsoft Office Excel and then exported to Stata version 15 for data processing and analysis of the results.

Results

Forty-four percent of the students who participated in the study belonged to the female gender and 56% to the male gender. One percent of the students who participated in the study are between 10 and 13 years old, 75% are between 14 and 16 years old, and 24% are between 17 and 21 years old. Sixty-two percent of the participating students belong to stratum 1, 30% to stratum 2, 6% to stratum 3, 1% to stratum 4 and another 1% to stratum 5. Forty-one percent of the participating students reside in rented housing, 29% in housing shared with other family members, and 31% reside in their own housing.

Forty-six percent of the parents of the participating students have primary schooling. 60% of the parents of the participating students have a low income level. The low educational level of parents has a negative effect on children's academic performance. It is related to poverty, lifestyles, family communication patterns, linguistic communication in the home, and children's educational expectations. In it, a minimum of

nutritious food is purchased, leading to poor nutritional quality, which has an impact on school performance.

Most adolescents need approximately 8 to 10 hours of sleep per night. Getting the right amount of sleep is essential for anyone who wants to do well in exams or perform well in sports. But, unfortunately, many teenagers don't get enough sleep. In this regard, 62% of the participating students sleep 8 hours, 8% of the participating students sleep 9 hours and only 2% of the participants sleep more than 9 hours.

When children reach adolescence, they may lose interest in physical activity. Between school, homework, friends and even a part-time job, teens have to juggle many interests and responsibilities. But regular physical activity can help teens feel more energetic, improve concentration and look better. And regular physical activity can help your child maintain a healthy weight and prevent heart disease, diabetes and other health problems in the future. In this regard, 90% of the participating students do engage in physical activity and 10% of the participating students do not engage in physical activity. 26% of participating students spend less than 2 hours on screen and 32% of participating students spend 2 hours on screen. Therefore, it is recommended that young people can participate in sports and structured physical activities that involve musculoskeletal activities. Lifting under the supervision of a qualified adult can improve strength and help prevent sports injuries. Given the opportunity and interest, teens can improve their health through almost any activity, such as skateboarding, yoga, swimming, dancing or hitting the road. Adolescents can incorporate physical activity into their daily routines, such as walking to school, running errands, or finding an active part-time job.

During adolescence, a "growth spurt" occurs, which requires maintaining a daily intake of calcium and protein to help build muscle and bone, as well as healthy fats to promote optimal hormonal development. The results show that 61% of the participating students never or less than one day a week eat breakfast.

48% of participating students 1-6 days a week eat lunch and 48% of participating students 7 days a week eat lunch.

Seventy-one percent of participating students consume two snacks per day.

53% of the participating students consume three glasses of sugar-sweetened beverages per day. Eighty percent of participating students report consuming unhealthy snacks.

81% of participating students state that they spend school recess and lunch breaks with other students. 84% of participating students spend school recess and lunch breaks usually in other spaces. 51% of participating students state that what they eat at school is usually brought from home, bought at the school canteen and also bought elsewhere.

37% of participating students spend more than $7,000 per week on food or beverages from their school cafeteria. 50% of participating students once a week or less buy food or beverages outside the school area. 63% of participating students spend $3,000 per week to purchase food or beverages outside the school area.

Fifty-six percent of participating students daily consumed soft drinks, 24% 3 or more times per week, 14% 1 or 2 times per week, 4% less than once per week, and 3% never or almost never consumed soft drinks.

The healthy eating index indicates that 32% 1 or 2 times a week never or almost never consume cereals. 35% 1 or 2 times a week, 23% less than once a week and 21% never or almost never consume vegetables. Thirty-three percent consume fruit less than once a week and 19% never or almost never consume fruit.

Most students consume milk and its derivatives less than once a week, as well as meat and legumes. Most students consume sausages and most students consume sweets

on a daily basis. Most of the participating students consume soft drinks and fats on a daily basis.

Taking into account the information gathered through the Harvard Plate methodology, it is possible to conclude that students consume few fruits, vegetables, cereals and in greater proportion in some of the plate is composed of protein. Through the data obtained it is possible to affirm that most of the students belong to low strata such as stratum 1 and stratum 2, likewise most of the students' parents have low incomes, do not have any level of education or have schooling levels such as only elementary school.

Regarding eating habits, most students never or less than one day a week eat breakfast, which means that according to Keski-Rahkonen et al. (2003) skipping breakfast reflects more than just meal timing preference, it appears to be a component of often concomitant health-compromising behaviors.

It is highlighted that 71% of the students consume snacks daily, being snacks products with high levels of sugars and fats, likewise, most of the students consume three times a day sugary drinks and in a very low percentage some of the students consume healthy snacks.

At their school breaks, students gather with their peers, but at lunchtime most students are alone at home or with other students, i.e. they do not have adult supervision to instill healthy eating. In addition, the money that students have to buy food is spent buying food and sugary drinks in the institution or sometimes they also buy them in other places.

The high consumption of sausages, sweets, soft drinks and fats per week by most of the students stands out. Additionally, it was found that most students spend more than two hours a day on the screen and do not play sports in their free time; in their free time they prefer to check social networks or spend time with their friends.

According to Martín-Aragón (2008), the foods that the human body needs are formative, energetic and regulatory, but most students consume milk and its derivatives less than once a week, as well as meats and legumes, while the consumption of sausages is 3 or more times a week. Sweets are consumed on a daily basis

According to Harvard University, red meat should be limited and processed meats such as bacon and sausages should be avoided, but most students consume sausages and most students also consume sweets on a daily basis. Most of the participating students consume soft drinks and fats on a daily basis. In addition, Harvard University stresses that most meals should contain vegetables and fruits ½ of the plate, whole grains ¼ of the plate, protein value ¼ of the plate such as fish, chicken, legumes and nuts are healthy and versatile protein sources, can be mixed in salads and combine well with vegetables in a dish, healthy plant oils, in moderation, drink water, coffee or tea, omit sugary drinks limit milk and dairy products to one or two servings a day and limit juice or juice to one small glass a day, but it is possible to conclude that students consume in low proportions fruits, vegetables, cereals and in higher proportions in some of the plate is composed of protein.

Harvard University also indicates to stay active, perform physical activity to control weight, but 3l, 90% of students do not perform physical activity.

To estimate the relationship between nutritional status and the cognitive processes measured through the tests, the correlation coefficient and the R^2 were calculated for each of the variables. Table 1 shows the relationship between BMI and TMT results.

Table 1

Relationship between BMI and TMT scores

CORRELATION COEFFICIENT	Part A	0,13149091
	Part B	-0,0952514
COEFFICIENT R^2	Part A	0,01728986
	Part B	0,00907282

BMI and TMT part A have a very weak positive relationship. The slope of the regression equation of +0.02 implies that for each unit increase in BMI, the average TMT A-time increases by 0.02 seconds. BMI and TMT part B present a very weak positive relationship. The slope of the regression equation of +0.13 implies that for each unit increase in BMI, the average TMT time B increases by 0.013 seconds, which is observed in Figure 1.

Figure 1

Relationship between BMI and TMT scores

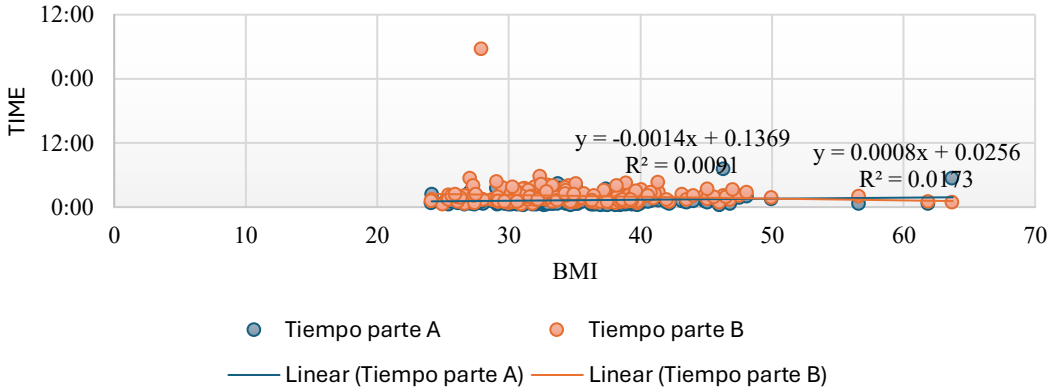


Table 2 shows the relationship between BMI and the Logical Thinking Test. BMI and logical thinking test results show a weak positive relationship.

Table 2

Relationship between BMI and the Logical Thinking Test

CORRELATION COEFFICIENT	0,07728886
COEFFICIENT R2	0,00597357

The slope of the regression equation of +3.27 implies that for each unit increase in BMI, the logical thinking test scores increase by 3.27 points. See Figure 2.

Figure 2

Relationship between BMI and the Logical Thinking Test

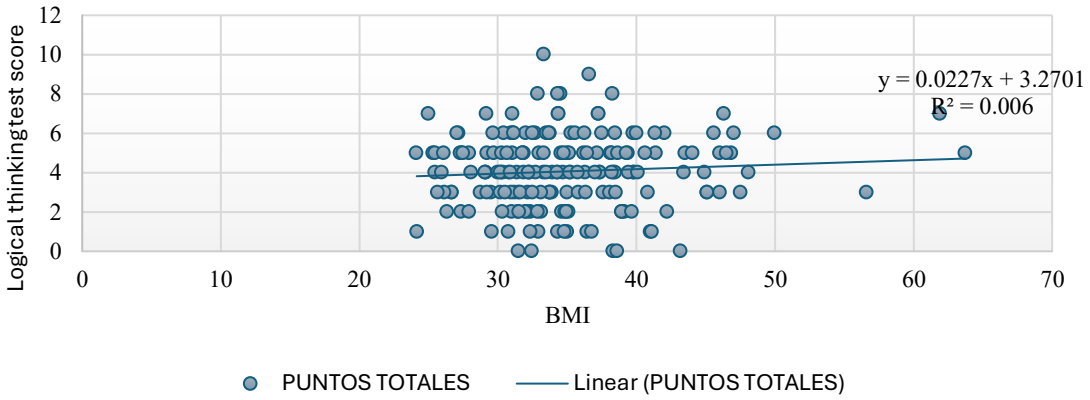


Table 3 shows the relationship between BMI and the Auditory Memory Test.

Table 3

Relationship between BMI and the Auditory Memory Test

CORRELATION COEFFICIENT	0,01090912
COEFFICIENT R2	0,00011901

BMI and auditory memory test results do not show a relationship, the correlation coefficient and R^2 are very close to zero. The slope of the regression equation of +54.17 implies that for each unit increase in BMI, the logical thinking test scores increase 54.17 points, as shown in Figure 3.

Figure 3

Relationship between BMI and the Auditory Memory Test

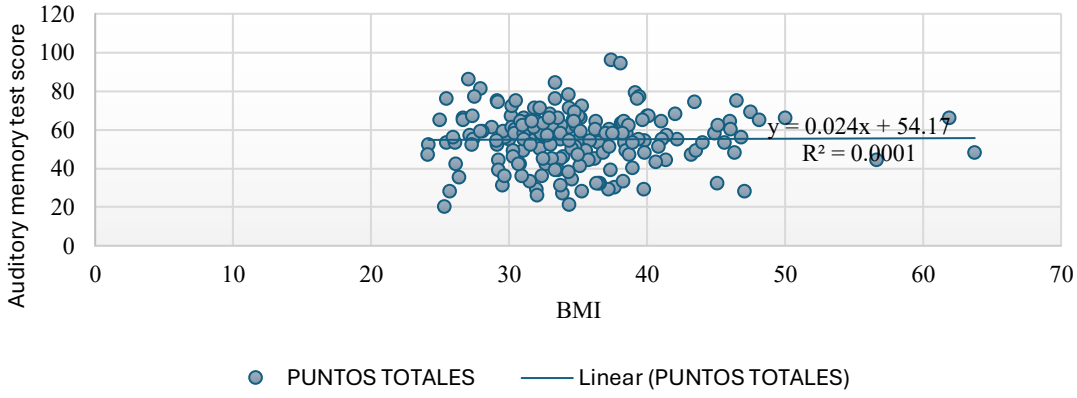


Table 4 shows the relationship between BMI and the Wisconsin M-WCST.

Table 4

Relationship between BMI and the Wisconsin M-WCST test

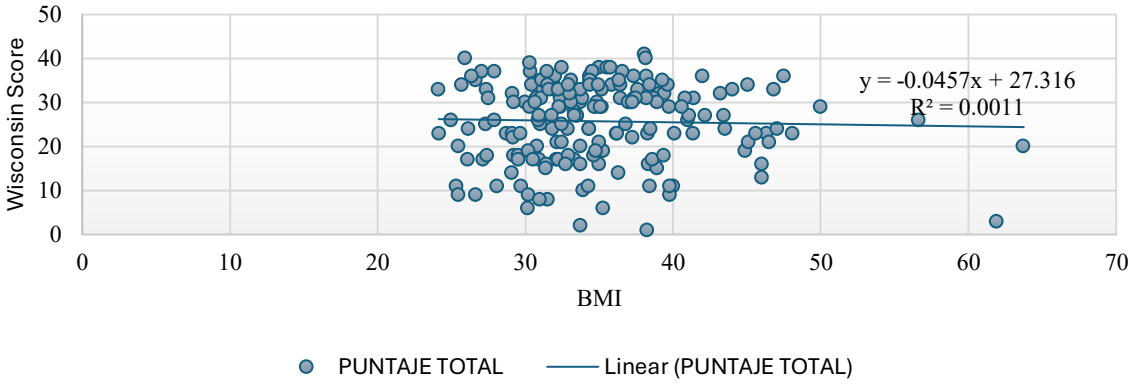
CORRELATION COEFFICIENT	-0,0324574

COEFFICIENT R2	0,00105348

The BMI and the results of the Wisconsin M-WCST test by means of the correlation coefficient indicate that it could have a negative relationship, but this is weak and by means of the R^2 they do not present a relationship. The slope of the regression equation of +27.31 implies that for each unit increase in BMI, the logical thinking test scores increase by 27.31 points. See Figure 4.

Figure 4

Relationship between BMI and the Wisconsin M-WCST test



To estimate the relationship between the biochemical indicator of hemoglobin and the cognitive processes measured through the tests, the correlation coefficient and the R^2 were calculated.

Hemoglobin and TMT part A considering R^2 present a weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. Hemoglobin and TMT part B considering R^2 present a weak positive relationship. The correlation coefficient analysis shows a low negative relationship. Table 5 shows the relationship between hemoglobin and the TMT test.

Table 5

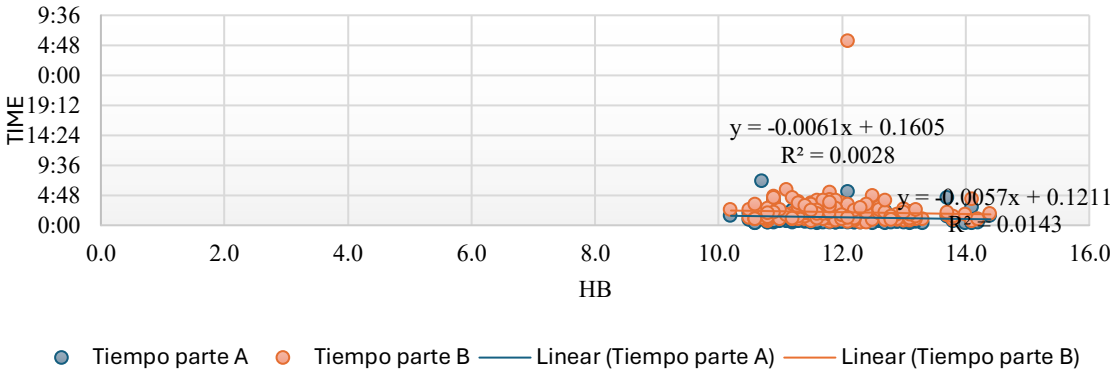
Relationship between hemoglobin and the TMT Test

CORRELATION COEFFICIENT	Part A	-0,1197744
	Part B	-0,0533067
COEFFICIENT R2	Part A	0,01434591
	Part B	0,00284161

The slope of the regression equation of +0.012 implies that for each unit increase in hemoglobin, the mean TMT A-time increases by 0.012 seconds. The slope of the regression equation of +0.16 implies that for each unit increase in hemoglobin, the mean TMT B-time increases by 0.16 seconds, which is seen in Figure 5.

Figure 5

Relationship between hemoglobin and the TMT Test



Regarding hemoglobin and its relationship with the results of the Logical Thinking Test, the R^2 presents a very weak positive relationship. But analyzing the correlation coefficient, these variables show a low negative relationship. Table 6 shows this relationship.

Table 6

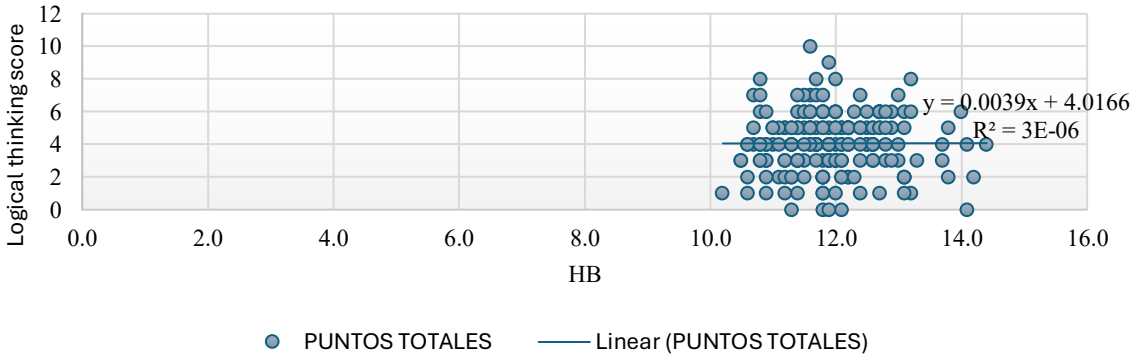
Relationship between hemoglobin and the Logical Thinking Test

CORRELATION COEFFICIENT	-0,0125957
COEFFICIENT R2	0,00015865

The slope of the regression equation of +4.01 implies that for each unit increase in hemoglobin, the logical thinking test scores increase by 4.01 points. See Figure 6.

Figure 6

Relationship between hemoglobin and the Logical Thinking Test



Hemoglobin and the results of the Auditory Memory Test taking into account the R^2 present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low positive relationship. See Table 7.

Table 7

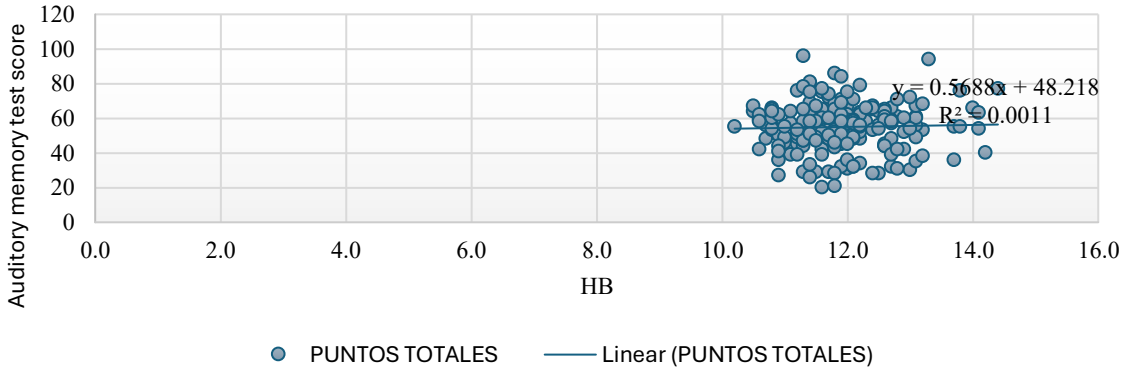
Relationship between hemoglobin and the Auditory Memory Test

CORRELATION COEFFICIENT	0,02312889
COEFFICIENT R2	0,00053495

The slope of the regression equation of +48.21 implies that for each unit increase in hemoglobin, the Auditory Memory Test scores increase 48.21 points, as shown in Figure 7.

Figure 7

Relationship between hemoglobin and the Auditory Memory Test



Hemoglobin and the results of the Wisconsin M-WCST test, taking into account the R^2, show a very weak positive relationship. However, if we analyze the correlation coefficient, the correlation coefficient shows a low positive relationship, as shown in Table 8.

Table 8

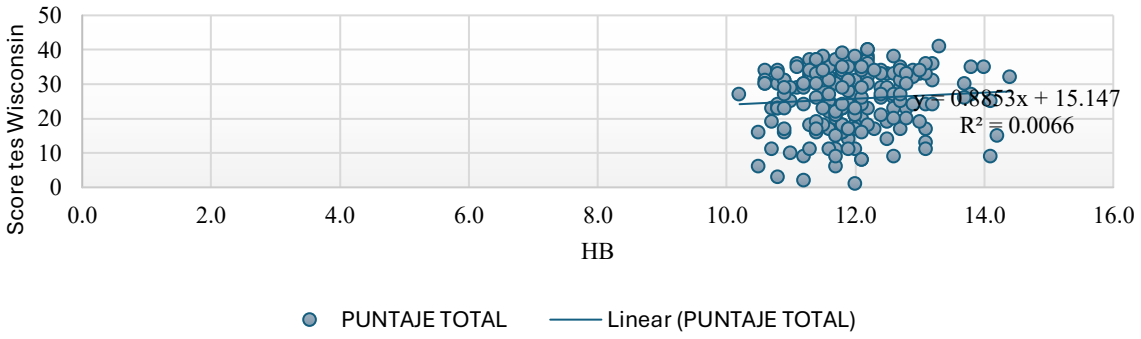
Relationship between hemoglobin and the Wisconsin M-WCST test

CORRELATION COEFFICIENT	0,0685562
COEFFICIENT R2	0,00469995

The slope of the regression equation of +15.14 implies that for each unit increase in hemoglobin, Wisconsin M-WCST scores increase by 15.14 points.

Figure 8

Relationship between hemoglobin and the Wisconsin M-WCST test



To estimate the relationship between BMI and grades, the correlation coefficient and R^2 were calculated, as shown in Table 9. The BMI and the results obtained in the grades taking into account the R^2 present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship.

Table 9

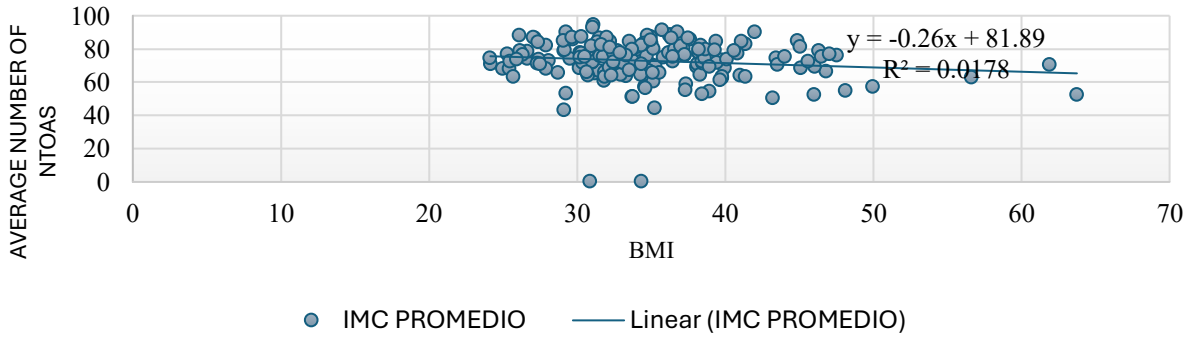
Relationship between BMI and grades

CORRELATION COEFFICIENT	-0,1334177
COEFFICIENT R2	0,01780027

The slope of the regression equation of +81.89 implies that for each unit increase in BMI, grade scores increase 81.89 points. See Figure 9.

Figure 9

Relationship between BMI and grades



To estimate the relationship between BMI and the Saber Tests, the correlation coefficient and the R^2 were calculated. The BMI and the results obtained in the saber tests, taking into account the R^2, present a very weak positive relationship. However, if we analyze the correlation coefficient, the correlation coefficient shows a low negative relationship, as shown in Table 10.

Table 10

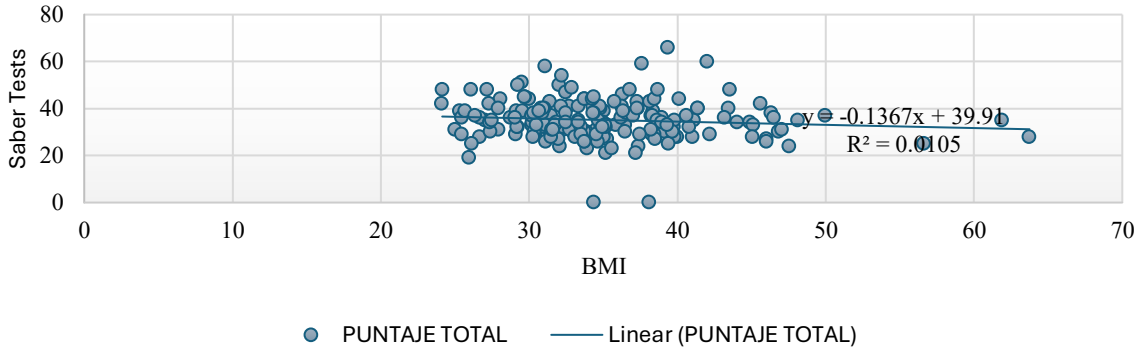
Relationship between BMI and Saber Tests

CORRELATION COEFFICIENT	-0,1024591
COEFFICIENT R2	0,0104979

The slope of the regression equation of +39.91 implies that for each unit increase in BMI, test scores on the Saber exams increase by 39.91 points. See Figure 10.

Figure 10

Relationship between BMI and Saber Tests



To estimate the relationship between the biochemical hemoglobin indicator and the grades, the correlation coefficient and the R^2 were calculated. Hemoglobin and the results obtained in the grades taking into account the R^2 present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. This is shown in Table 11.

Table 11

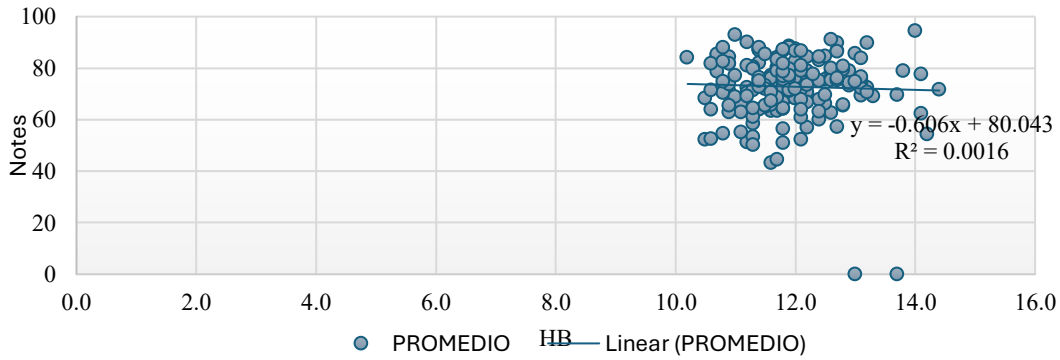
Relationship between hemoglobin and grades

CORRELATION COEFFICIENT	-0,0397424
COEFFICIENT R2	0,00157946

The slope of the regression equation of +80.04 implies that for every unit increase in hemoglobin, grade scores increase 80.04 points, which is observed in Figure 11.

Figure 11

Relationship between BMI and grades



To estimate the relationship between the biochemical hemoglobin indicator and the Saber Tests, the correlation coefficient and the R^2 were calculated. Hemoglobin and the results of the Saber Tests, taking into account the R^2, show a very weak positive relationship. But analyzing from the correlation coefficient, they present a low positive relationship. See Table 12.

Table 12

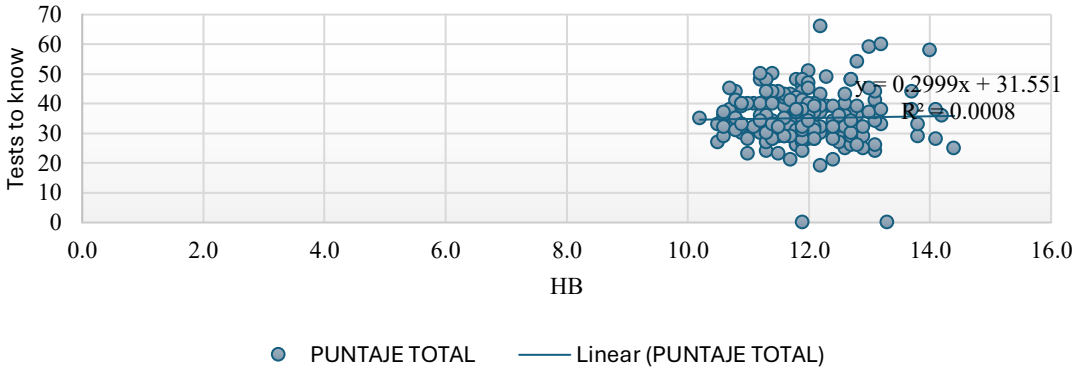
Relationship between hemoglobin and scores

CORRELATION COEFFICIENT	0,07277475
COEFFICIENT R2	0,00529616

The slope of the regression equation of +31.55 implies that for each unit increase in hemoglobin, Saber Test scores increase 31.55 points, as shown in Figure 12.

Figure 12

Relationship between hemoglobin and the Saber Tests



Discussion and Conclusions

According to the results observed in relation to the demographic and socioeconomic classification of the participating students, 44% of the students belong to the female gender and 56% to the male gender. One percent of the students are between 10 and 13 years old, 75% are between 14 and 16 years old and 24% are between 17 and 21 years old. Therefore, there is a higher percentage of male students, although the difference is not so marked. On the other hand, most of the students are in their middle adolescence.

As for the socioeconomic stratum, 62% of the participating students belong to stratum 1, that is, the majority, and only 1% to stratum 5. There is also a high percentage, 41% of students residing in rented housing.

In relation to the educational level of the parents, 46% of the parents of the participating students have primary schooling. On the other hand, 60% of the students' parents have a low income level.

Through the data obtained it is possible to affirm that most of the students belong to low strata such as stratum 1 and stratum 2, likewise most of the students' parents have low incomes, do not have any level of education or have low levels of schooling.

The low educational level of parents has a negative effect on children's academic performance. It is related to poverty, lifestyles, family communication patterns, linguistic communication in the home, and children's educational expectations. In these family environments, a minimum of nutritious food is purchased, leading to poor nutritional quality, which affects school performance.

Regarding sleep, most adolescents need approximately 8 to 10 hours of sleep per night. Getting the right amount of sleep is essential for anyone who wants to do well in exams or perform well in sports. In this regard, 62% of the participating students sleep 8 hours, so the majority of students sleep the required hours.

In relation to physical activity, when children reach adolescence, they may lose interest in physical activity. Between school, homework, friends and even a part-time job, teens have to juggle many interests and responsibilities. But regular physical activity can help teens feel more energetic, improve concentration and look better.

In addition, regular physical activity can help maintain a healthy weight and prevent heart disease, diabetes and other health problems in the future. In this regard, 90% of the participating students do engage in physical activity, that is to say, a large part of the students. Additionally, it was found that most students spend more than two hours a day on the screen and do not play sports in their free time; in their free time they prefer to check social networks or spend time with their friends.

Due to the rapid growth of adolescents, it is necessary to maintain a daily intake of calcium and protein for muscle and bone development, as well as healthy fats that promote optimal hormonal development. The results show that 61% of the participating students never or 1 day a week eat breakfast. The consumption of dairy products such as a glass of milk, yogurt or cream cheese, and the consumption of whole-grain carbohydrates such as two slices of whole-grain toast, sliced tomato and a slice of good quality ham, chicken or some white meat, are necessary in certain proportions depending on the daily physical activity and the condition of the adolescent.

In terms of eating habits, most students never or sometimes 1 day a week eat breakfast, which, as mentioned, is detrimental to adolescents in their physical, emotional and academic dimensions, mainly.

Regarding the frequency with which they eat lunch, 48% of the participating students eat lunch between 1-6 days a week and 48% eat lunch 7 days a week, which means that almost half of the students maintain an adequate frequency.

In relation to the consumption of snacks, sugary drinks and snacks, 71% of the participating students consumed two snacks per day, 53% consumed three glasses of sugary drinks per day and 80% of the students stated that they consumed unhealthy snacks. It is highlighted that 71% of the students consume at least 2 snacks per day, being the snacks products with high levels of sugars and fats; likewise, most of the students consume 3 times a day sugary drinks and in a very low percentage some of the students consume healthy snacks. The high consumption of sausages, sweets, sodas and fats per week by most students stands out, so these three parameters show that most students consume unhealthy foods.

Regarding school break, 81% of participating students state that they spend school recess and lunch breaks with other students. In addition, 84% of students spend school recess and lunch breaks usually in other spaces, so a large percentage of students share their time with their peers and do so in spaces other than the school restaurant. At their school breaks, students gather with their peers, but at lunchtime most students are alone at home or with other students, i.e. they do not have adult supervision to instill healthy eating.

On the other hand, 37% of students spend more than $7,000 per week on food or beverages from their school cafeteria and 63% spend $3,000 per week on purchasing food or beverages outside the school area. Additionally, 50% of the students, half of them, which is a significant number, buy food or beverages outside the school area, once a week or less. This is why the money that students have to buy their food, they spend it buying food and sugary drinks in the institution or sometimes they also buy them in other places.

In relation to the consumption of soft drinks, it is important to consider that 56% of the students consume soft drinks daily, that is, more than half of the students.

According to the results obtained in the healthy eating index, 35% of the students consume cereals 1 or 2 times a week and 33% consume cereals less than once a week,

which indicates that almost two thirds of the students consume cereals only a few days a week.

The foods that the human body needs are formative, energetic and regulatory, but most students consume milk and its derivatives less than once a week, as well as meat and vegetables; while the consumption of sausages is 3 or more times a week and the consumption of sweets, sodas and fats is done on a daily basis

Taking into account the information gathered through the Harvard Plate methodology, it is possible to conclude that students consume few fruits, vegetables, cereals and protein. According to Harvard University, most meals should contain vegetables and fruits ½ of the plate, whole grains ¼ of the plate, protein value ¼ of the plate such as fish, chicken, legumes and nuts are healthy and versatile protein sources, but it is possible to conclude that students consume in few proportions fruits, vegetables, cereals and the most remarkable is that in a low percentage of students the plate is composed of protein.

Harvard University also suggests staying active, engaging in physical activity to control weight. According to the BMI estimation, the majority of students are within the normal weight range and only 1% have type II obesity.

In the differentiation by gender, most of the female students are within the normal weight range and only 4% have type I obesity. As for the male students, approximately two thirds of the males are within the normal weight range and only 1% have type II obesity. In general, most of the students are within the normal weight range and a small proportion are obese.

Regarding the oxygen transporting protein or hemoglobin, the study shows that 45% of the female students have normal hemoglobin levels (greater than 12 g/dL), that is, no anemia, and 42% of the female students have mild anemia since they have slightly decreased hemoglobin levels (less than 12 g/dL) and 13% have moderate anemia, that is, lower hemoglobin levels (less than 11 g/dL).

As for male adolescents, 77% of male students had mild anemia, i.e., hemoglobin levels below 13 g/dL and 13% had moderate anemia, due to hemoglobin levels below 11 g/dL. It is important to emphasize that none of the students had severe anemia, i.e. hemoglobin levels below 8 g/dL, so it is concluded that all students have a normal oxygen carrying capacity.

Finally, the relationship between BMI and hemoglobin with the different tests is weak, as is the relationship between BMI and hemoglobin with grades and the results of the Saber Tests.

In this regard, it is relevant that for Hermans et al. (2017) it should be noted that adolescents have a low risk perception of unhealthy eating and seek autonomy in their food choices.

These results can be analyzed with those obtained by Lapo and Quintana (2018) by stating that in adolescents no significant relationship was evidenced between nutritional status by BMI with school performance, nor between eating habits with school performance.

In the study by González et al. (2020) also concluded that the dependence between the variables BMI and academic performance is weak.

This may be due to the fact that according to Lamas (2015) factors such as personality, motivation, aptitudes, interests, study habits, self-esteem, relationship with teachers, may cause a gap between academic performance and the performance expected from the student, which may sometimes be linked to didactic teaching methods

Although the participating students present a high risk of acquiring eating habits that result in nutritional deficiencies; which in turn, would be reflected in a

level of academic performance below what is required for these adolescents to be successful; in this regard, the results obtained show that the BMI in most of the participating students is within normal ranges as well as hemoglobin, they also have good sleeping habits and the results of academic performance measured by the grades of the subjects and the Saber Test are not as low as initially expected.

Regarding the interpretation of the neuropsychological tests applied as an instrument to evaluate academic performance in adolescents, it is specified that for example in the case of the TMT Trail Making Test, most students passed Part A of the TMT test and almost all (99%) students passed Part B of the TMT test and only a minimum percentage (1%) of students did not pass Part B of the TMT test, which means that students have developed a good cognitive process of attention.

Through the application of the logical thinking test, out of the 18 possible points to be obtained in the test, only one student obtained 10 points, another student obtained 9 points and four students obtained 8 points. All other students scored less than 8 points.

In the Auditory Memory Test, which measures the memory process, it was observed that only 5 of the 189 students scored above 80 points, indicating that most of the students can improve this function.

Through the application of the Wisconsin M-WCST test, which measures executive functions, it is possible to observe that the number of total errors in most of the students is high, which indicates poorer performance. It should be noted that only 3 of the 189 students participating in the study obtained scores higher than or equal to 40 points, indicating better school performance.

Finally, with respect to the grades of the 14 subjects taken by CIME ninth grade students, 24% of the students had a high grade point average, 67% had a basic grade point average, and only 9% had a low grade point average. None of the students obtained a higher grade point average. Also taken into account were the scores of the Saber exams, which did not have a very high score, reaching only an average score.

BMI and TMT part A have a very weak positive relationship. The slope of the regression equation of +0.02 implies that for each unit increase in BMI, the average TMT A-time increases by 0.02 seconds.

BMI and TMT part B present a very weak positive relationship. The slope of the regression equation of +0.13 implies that for each unit increase in BMI, the average TMT time B increases by 0.013 seconds.

BMI and logical thinking test results show a weak positive relationship. The slope of the regression equation of +3.27 implies that for each unit increase in BMI, the logical thinking test scores increase by 3.27 points.

BMI and auditory memory test results do not show a relationship, the correlation coefficient and R^2 are very close to zero. The slope of the regression equation of +54.17 implies that for each unit increase in BMI, the logical thinking test scores increase 54.17 points.

The BMI and the results of the Wisconsin M-WCST by means of the correlation coefficient indicate that there could be a negative relationship, but this is weak and by means of the R^2 they do not show a relationship. The slope of the regression equation of +27.31 implies that for each unit increase in BMI, the logical thinking test scores increase by 27.31 points.

From these results it is possible to conclude that BMI has a positive relationship with the different tests applied, but it is weak.

Hemoglobin and TMT part A considering R^2 present a weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. The slope of the regression equation of +0.012 implies that for each unit increase in

hemoglobin, the mean TMT A-time increases by 0.012 seconds.

Hemoglobin and TMT part B considering R^2 present a weak positive relationship. The correlation coefficient analysis shows a low negative relationship. The slope of the regression equation of +0.16 implies that for each unit increase in hemoglobin, the mean TMT B time increases by 0.016 seconds.

Hemoglobin and the results of the Logical Thinking Test, taking into account the R^2, present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. The slope of the regression equation of +4.01 implies that for each unit increase in hemoglobin, the logical thinking test scores increase by 4.01 points.

Hemoglobin and the results of the Auditory Memory Test taking into account the R^2 present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low positive relationship. The slope of the regression equation of +48.21 implies that for each unit increase in hemoglobin, the auditory memory test scores increase by 48.21 points.

Hemoglobin and the results of the Wisconsin M-WCST test, taking into account the R^2, show a very weak positive relationship. But analyzing from the correlation coefficient, they present a low positive relationship. The slope of the regression equation of +15.14 implies that for each unit increase in hemoglobin, the Wisconsin M-WCST scores increase by 15.14 points. With these data, it is possible to affirm that hemoglobin, although it has a positive relationship with the tests, is low.

The BMI and the results obtained in the grades taking into account the R^2 present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. The slope of the regression equation of +81.89 implies that for each unit increase in BMI, grade scores increase 81.89 points.

The BMI and the results obtained in the saber tests, taking into account the R^2, present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. The slope of the regression equation of +39.91 implies that for each unit increase in BMI, test scores on the Saber exams increase by 39.91 points.

Therefore, the BMI with students' grades and the Saber Tests, although negatively related, is low.

Hemoglobin and the results obtained in the grades taking into account the R^2 present a very weak positive relationship. But analyzing from the correlation coefficient, they present a low negative relationship. The slope of the regression equation of +80.04 implies that for every unit increase in hemoglobin, grade scores increase 80.04 points.

Hemoglobin and the results of the Saber Tests, taking into account the R^2, show a very weak positive relationship. But analyzing from the correlation coefficient, they present a low positive relationship. The slope of the regression equation of +31.55 implies that for each unit increase in hemoglobin, Saber Test scores increase by 31.55 points. That is, hemoglobin with students' grades and the Saber Tests, although they have a negative relationship, it is low.

Trying to test the relationship that exists between nutrition and cognitive processes that affect academic performance in adolescent students at CIME, it can be deduced that, although there is a close relationship between these two variables, it cannot be concluded that nutrition has the most direct relationship. There is evidence from the reviewed literature that mentions such a relationship, and what is finally affirmed through this research, is that in addition to the

relationship between nutrition and academic performance, there may be multiple causes.

It would remain for future research to study in more depth all this complex understanding of what a true learning process implies based on emotional, physical, psychological and environmental conditions in accordance with what the student should be provided to achieve the objectives of his or her integral formation. All this is worthwhile, if applied to the context of the student with a view to contributing in the long term to the quality of life of people.

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Conflict of Interest

The authors have no conflict of interest related to this publication.

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