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How brain chemistry shapes intelligence: the role of dopamine and beta-endorphins in school students

Najla Abbood Kamel [1*], **Muthanna Mohammed Awad** [1], **Fuaad Mohammed Freh** [2]

[1] Department of Biology, College of Education for Pure Science, University of Anbar, Anbar, Iraq
[2] Department of Educational and Psychological Sciences, College of Education for Humanities, University of Anbar, Anbar, Iraq

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Corresponding author
Najla Abbood Kamel
najlaaboud28@gmail.com

ABSTRACT

Scientific evidence suggests that intelligence is shaped by various biological factors and is among the most prominent cognitive abilities influencing academic performance. This study aimed to investigate neurochemical influences on intelligence among school-aged students. A total of 90 male students from three types of schools (public, distinguished, and high-achieving) participated. The Standard Progressive Matrices (SPM) test was used to assess mental age and IQ before any intervention, while both SPM and Advanced Progressive Matrices (APM) were administered before and after a 15-day nutritional intervention involving walnuts and dark chocolate. Dopamine and beta-endorphin levels were also measured to assess physiological influences.

Before the intervention, significant differences were observed among the three groups in both mental age and IQ. Post-intervention results showed a notable improvement in the public school group, particularly in APM scores. The distinguished group improved mainly in the SPM test, while the high-achievers group showed no significant changes. Dopamine levels differed significantly among the groups, with higher levels in distinguished and high-achieving students than in public school students. In contrast, beta-endorphin levels did not differ significantly. Overall, the findings indicate that biological factors, particularly dopamine, may contribute to differences in cognitive performance among student groups. Moreover, the nutritional intervention appeared to improve performance among students with initially lower cognitive scores, especially in public schools.

Keywords: *β-endorphin, Dopamine, Intelligence, Mental age, Raven's test*

1 INTRODUCTION

Cognitive abilities are a set of mental processes that include receiving, processing, and using information in various tasks [1]. Intelligence, in particular, is an important ability for students from which other cognitive abilities emerge, such as logical thinking, perception, learning, memory, and problem-solving [2]. The literature shows that intelligence is influenced by multiple neurological and psychological factors [3]. Recently, studies have indicated an important role for neurotransmitters and neurochemicals, such as dopamine and beta-endorphin, in regulating higher mental processes, the reward system, and working memory [4]. Dopamine, a neurotransmitter produced in the brain and released by the hypothalamus, plays a crucial role in various cognitive functions, including intelligence [5]. In contrast, beta-endorphin can affect mental performance through learning and memory processes, reducing stress, and improving mood [6].

Dopamine also influences motivation, attention, and reward-related learning. Higher dopamine levels have been linked to improved executive functions and working memory, which are critical for academic success. Conversely, lower dopamine levels are often associated with reduced motivation and difficulties in sustaining cognitive effort [7, 8]. Similarly, beta-endorphin, an endogenous opioid peptide, plays a role in regulating mood and stress responses. It may also indirectly influence learning by improving emotional well-being and reducing anxiety during cognitive tasks. Although its role is less directly tied to executive functions than dopamine, balanced beta-endorphin levels are important for maintaining optimal mental performance [9, 10].

Despite studies examining the influence of neurotransmitters and neurohormones on cognitive abilities, the impact of these factors on intelligence levels among students across different educational systems has received limited attention. Recent research also indicates that nutritional, behavioral, and lifestyle factors, such as the consumption of certain foods that enhance neurotransmitter activity, may contribute to improved mental performance in students [11, 12]. Nutritional interventions are increasingly recognized as strategies to support cognitive function. Foods rich in omega-3 fatty acids, polyphenols, and essential micronutrients can modulate neurotransmitter synthesis and activity. Walnuts, for instance, contain omega-3 fatty acids, antioxidants, and vitamins that may contribute to neuronal membrane stability and neurogenesis. Dark chocolate, particularly varieties with at least 70–85% cocoa, is abundant in flavonoids and methylxanthines, which have been reported to enhance cerebral blood flow and improve memory and attention [13, 14]. Together, these foods may provide a safe, cost-effective way to support students' mental performance and well-being.

Therefore, the current study aims to investigate the effect of dopamine and beta-endorphin on intelligence and mental age among students from public, distinguished, and high-achieving schools. This study uses Raven's tests (SPM and APM) as pre- and post-tests, along with a nutritional intervention based on dark chocolate and walnuts.

2 MATERIALS AND METHODS

2.1 Study sample

The study sample consisted of 90 male students aged 17–20 years (mean = 17.7, SD = 0.87) selected from three schools in Anbar province, Iraq. All students were in high school (sixth-grade science), equivalent to twelfth grade (Grade 12) in most international educational systems. The sample included three types of schools: the Distinguished School, which included 17 students and required general intelligence tests for admission, although none of its students had previously taken the Raven test; the High-Achievers School, which included 28 students and required achievement tests for admission; and the Public School, which included 45 students, required no tests for admission, and represented the general category of students from public schools.

2.2 Group equivalence

Group equivalence was first verified using a questionnaire that included several relevant demographic variables, including nutritional program (vegetarian, non-vegetarian, or vegan), exercise (exerciser or non-exerciser), socioeconomic status (high, medium, or low), consumption of drinks (tea, coffee, or soft drinks), and smoking (smoker or non-smoker). Student responses were analyzed using the chi-square test to determine whether statistically significant differences were present between the groups. The results showed that the groups were equivalent in most variables, as shown in Table 1.

2.3 Experimental design

The total sample consisted of 90 students from three schools (distinguished, high-achievers, and public). The sample included all students from the available classes in the three schools at the time of the study. Before implementing any nutritional intervention, the Raven Standard Progressive Matrices (SPM) test was administered to participants to provide a baseline comparison across the three schools. Subsequently, a subsample of 44 students was selected to undergo an experimental nutritional program, including 17 students from the distinguished school and five students from the high-achievers school (all of whom belonged to schools that required pre-admission tests [intelligence or achievement]) and 22 students from the public school, which does not require pre-admission tests.

The pre-test (SPM) was administered on February 13, 2025, in a suitable environment with untimed administration. The APM test was then administered on February 20, 2025, with a 7-day interval between the two tests to avoid mental fatigue.

Regarding the nutritional program, each student received 100 g of walnuts and 70 g of dark chocolate (85% cocoa) daily for 15 days.

The post-test, which included the APM test, was

Table 1 Equivalence of three groups in demographic variables

Category	Subcategory	Distinguished	HighAchievers	Public	Total	Pearson ChiSquare	Degrees of Freedom (df)	p-value (Asymptotic Significance)
Food Regime	Vegetarian	<5	<5	<5	5			
	Non-vegetarian	14	22	45	81	3.120	4	0.539
	Vegan	<5	<5	<5	<5			
Exercises	Non-exerciser	7	19	11	37	4.105	2	0.128
	Exerciser	10	9	34	53			
Socioeconomic Status	High	<5	<5	<5	7			
	Medium	13	24	39	76	2.510	4	0.643
	Low	<5	<5	<5	7			
Drinks	Tea	5	<5	<5	11			
	Coffee	<5	5	<5	13			
	Soft drinks	<5	6	<5	12	9.834	12	0.628
	Tea and Soft drinks	<5	<5	8	11			
	Coffee and Soft drinks	<5	<5	5	8			
	Tea and Coffee	<5	<5	12	16			
	All of them	<5	9	10	19			
Smoking	Nonsmoker	16	26	37	79	1.225	2	0.542
	Smoker	<5	<5	8	11			

conducted on March 9, 2025, in a suitable environment similar to the pre-test conditions, with untimed administration. The APM test was then administered again on March 16, 2025.

2.4 Intelligence tests

2.4.1 Raven's progressive matrices test

Raven's Progressive Matrices, developed by John C. Raven in 1939 [15], assesses general intelligence in individuals aged 5 years and above. The test involves identifying the missing element in increasingly difficult visual matrices. This study used two versions: the Standard Progressive Matrices (SPM), which includes five sets of 12 items each and covers a wide range of abilities, and the Advanced Progressive Matrices (APM), which includes 36 items and assesses higher cognitive levels [16].

Materials Provided:A test booklet containing matrices, answer sheets, and pens.

2.4.2 Raven's test (apm and spm) administration and instructions

The principal researchers administered the APM and SPM tests in a calm, controlled environment. Participants received clear instructions to examine each matrix and select the correct missing element from multiple-choice options, and all procedures were explained beforehand.

2.4.3 Scoring of raven's test (spm and apm)

The researchers scored the SPM test by awarding one point for each correctly solved matrix within a set. Raw scores were used to calculate the total number of correct answers across all sets.

2.4.4 Converting raw scores to mental age

After correcting the Raven tests (SPM and APM) and calculating the raw score, the researchers compared these scores with standard tables used in recent studies [17–20]. Each raw score was matched to the average age reflecting the same level of performance, and each student's mental age was then estimated based on this match. The traditional and widely accepted Raven's manual (Raven, Court, & Raven, 1998) was also used as a secondary source.

2.4.5 Calculating intelligence quotient (iq)

After determining mental age, the researchers calculated the intelligence quotient (IQ) for each subject using the following traditional equation:

$$\frac{\text{Mental age}}{\text{Chronological age}} \times 100$$

This equation is used to determine an individual's intelligence level by comparing cognitive development with their actual age.

2.4.6 Determining percentile rank

The researchers used standard tables from the official manual used in the study to calculate the percentile reflecting each student's position among peers of the same age.

2.5 Collection of blood samples

On March 16, 2025, 5 mL of blood was drawn from each participant and transferred into gel tubes for serum extraction. The samples were allowed to clot for 30 min at room temperature and then centrifuged at 3000 rpm. After transfer into white tubes, the serum was used for physiological examinations.

2.6 Laboratory measurements

Serum dopamine and beta-endorphin levels were measured using a commercial ELISA kit (SunLong Biotech Co., LTD, China), according to the manufacturer's instructions. This kit is based on the principle of specific antigen–antibody interaction. Optical density was read at 450 nm using an ELISA microplate reader.

2.7 Statistical analysis

Statistical analysis was conducted using SPSS version 27. The equivalence of demographic variables among the three groups was verified using the chi-square test. To analyze pre-test differences among the three schools before implementing the nutritional program (sample size = 90), a one-way analysis of variance (ANOVA) was used. To measure the effect of the nutritional program on the subsample (n = 44), a paired-samples t-test was used for normally distributed variables, and a Mann–Whitney U test was used for non-normally distributed variables. A one-way ANOVA was also used to analyze changes in dopamine and beta-endorphin levels after implementation. Results were considered statistically significant at $p < 0.05$, highly significant at $p < 0.01$, and very significant at $p < 0.001$.

3 RESULTS

After analyzing all data, the one-way ANOVA showed statistically significant differences in mental age among the three schools (public, distinguished, and high-achievers), with an F value of 9.792 and a p-value of 0.0001. Statistically significant differences in IQ were also found among the same groups, with an F value of 16.48 and a p-value of <0.0001. According to the mean ± standard error values, students in the distinguished school had the highest mean mental age (18.62 ± 0.30), followed by the high-achievers school (16.71 ± 0.39) and the public school (16.57 ± 0.22). For IQ, the highest mean was recorded in the distinguished school (107.7 ± 2.150), followed by the high-achievers school (95.84 ± 2.460) and the public school (90.85 ± 1.320), as shown in Table 2

Table 2 SPM testing of 90 students before nutritional interventions, using ANOVA test

Parameter	Group type	Count	Mean ± Std. Error of Mean	F-test	P-value
Mental age	Public schools	45	16.57 ± 0.2226	9.792	0.0001***
	Distinguished Schools	17	18.62 ± 0.3107		
	High-Achieving Schools	28	16.71 ± 0.3988		
IQ	Public schools	45	90.85 ± 1.320		<0.0001* ***
	Distinguished Schools	17	107.7 ± 2.150	16.48	
	High-Achieving Schools	28	95.84 ± 2.460		

The results of the SPM test for public school students (n = 22) showed statistically significant differences between the pre- and post-tests in both mental age and IQ. Mean mental age increased from 16.64 to 17.45 after the nutritional program, with a mean difference of 0.80 (±1.06), and this increase was statistically significant (t = 3.546, df = 21, p = 0.002). The mean IQ also increased from 91.23 to 95.20, with a mean difference of 3.96 (±6.22), and this increase was also statistically significant (t = 2.989, p = 0.007). For the APM test within the same group, there was a significant increase in mental age from 17.02 to 18.68, with a mean difference of 1.66 ± 1.03, and the difference was highly significant (t = 7.570, p < 0.001). In addition, the IQ increased from 92.88 to 101.93, with a mean difference of 9.05 ±5.69, indicating a statistically significant improvement (t = 7.470, p < 0.001).

For the distinguished school (n = 17), the SPM test results showed statistically significant differences between the pre- and post-tests in both mental age and IQ. The mean mental age increased from 18.62 to 19.52, with a mean difference of 0.90 ±1.73, and this increase was statistically significant (t = 2.140, df = 16, p = 0.048). The mean IQ also increased from 107.73 to 112.92, with a mean difference of 5.18 ±10.05, and this difference was statistically significant (t = 2.128, p = 0.049). The APM test results in the same group showed a slight increase in mental age, from 18.83 to 19.04, with a mean difference of 0.21 ±1.34; however, the difference was not statistically significant (t = 0.651, p = 0.524). Despite an increase in IQ from 108.94 to 110.15, with a mean difference of 1.20 ±7.91, the difference was not statistically significant (t = 0.628, p = 0.539).

In the high-achievers school (n = 5), the SPM test showed no statistically significant differences between the pre- and post-tests. Mean mental age increased from 16.50 to 17.10, with a mean difference of 0.60 (±3.89) (t = 0.344, df = 4, p = 0.748). The IQ also increased from

94.78 to 97.14, with a mean difference of 2.36 (±20.60), but the difference did not reach the statistical significance level (t = 0.256, p = 0.810). For the APM test in this group, mental age increased from 17.20 to 17.50, with a mean difference of 0.30 (±0.45), but was not statistically significant (t = 1.50, p = 0.208). IQ also increased from 98.86 to 100.54, with a mean difference of 1.68 (±2.48), but the difference was not statistically significant (t = 1.516, p = 0.204). (As shown in Table 3)

Table 3 Comparison of pre- and post-test results of SPM and APM for the nutritional program sample (N=44) using the t-test for related samples

Test type	N	Group type	Variables	Mean		Mean Difference	Std. Deviation of Difference	Std. Error Mean	t	d f	Sig. (2tailed)
				Pre	Post						
SPM	22	Public school	Mental age	16.64	17.45	0.80455	1.06435	0.226 92	3.54 6	2 1	0.002
			IQ	91.23	95.20	3.96364	6.22151	1.326 43	2.98 8	2 1	0.007
SPM	17	Distinguished school	Mental age	18.61 76	19.51 76	0.90000	1.73421	0.420 61	2.14 0	1 6	0.048
			IQ	107.7 294	112.9 176	5.18824	10.05061	2.437 63	2.12 8	1 6	0.049
SPM	5	HighAchiever's School	Mental age	16.50 00	17.10 00	0.60000	3.89551	1.742 13	0.34 4	4	0.748
			IQ	94.78 00	97.14 00	2.36000	20.60141	9.213 23	0.25 6	4	0.810
APM	22	*Public school	Mental age	17.02	18.68	1.66	1.03	0.22	7.57 0	2 1	p < . 001
			IQ	92.88	101.9 3	9.05	5.69	1.21	7.47 0	2 1	p < . 001
APM	17	Distinguished school	Mental age	18.83 53	19.04 71	0.21176	1.34065	0.325 16	0.65 1	1 6	0.524
			IQ	108.9 471	110.1 529	1.20588	7.91948	1.920 75	0.62 8	1 6	0.539
APM	5	HighAchiever's School	Mental age	17.20	17.50	0.30	0.45		1.50 0	4	0.208
			IQ	98.86	100.5 4	1.68	2.48		1.51 6	4	0.204

For the public school group (n = 22), the SPM test results in this analysis showed a statistically significant difference between the pre- and post-tests for mental age, with the mean increasing from 18.66 to 26.34 (U = 157.50, Z = -1.992, p = 0.046), indicating statistical significance in favor of the post-test. For IQ, the mean increased from 19.14 to 25.86, but the difference did not reach statistical significance (U = 168.00, Z = -1.741, p = 0.082). For the same group, the APM test showed statistically significant differences in both mental age and IQ. Mental age increased from 15.70 to 29.30, with a highly significant difference (U = 92.50, Z = -3.568, p < 0.001). IQ also increased from 16.98 to 28.08, with a statistically significant difference (U = 120.50, Z = -2.878, p = 0.004).

For the distinguished school group (n = 17), the SPM test showed a statistically significant difference in mental age between the pre- and post-tests. Mean scores increased from 14.00 to 21.00 (U = 85.00, Z = -2.075, p = 0.038). IQ increased from 14.82 to 20.18, but the difference was not statistically significant (U = 99.00, Z = -1.580, p = 0.122). The APM test results for the same group showed no statistically significant differences in either mental age or IQ. Mental age increased from 16.12 to 18.88 (U = 121.00, Z = -0.843, p = 0.400), and IQ increased from 16.29 to 18.71 (U = 124.00, Z = -0.720, p = 0.472).

Furthermore, the results showed no statistically significant differences in any of the variables for the high-achiever school group (n = 5). On the SPM test, mental age increased from 5.30 to 5.70, a slight, non-significant difference (U = 11.50, Z = -0.213, p = 0.831). IQ remained stable at 5.50 in both measurements, with no statistically significant difference (U = 12.50, Z = 0.000, p = 1.000). For the APM test, mental age increased from 17.20 to 17.50, but the difference was not statistically significant (U = 11.00, Z = -0.328, p = 0.841). IQ also increased from 98.86 to 100.54, with a non-significant increase (U = 10.00, Z = -0.532, p = 0.690), as shown in Table 4. A one-way ANOVA

Table 4 Analysis of the differences between the results before and after the nutritional program for a sample of students (N=44) using the Mann-Whitney test

Test type	N	Group type	Variables	Mean		Sum of ranks		MannWhitney U	Wilcoxon W	Z	Asymp. Sig. (2tailed)
				Pre	Post	Pre	Post				
SPM	22	Public school	Mental age	18.66	26.34	410.50	579.50	157.500	410.500	-1.992	0.046 **
			IQ	19.14	25.86	421.00	569.00	168.000	421.000	-1.741	0.082
SPM	17	Distinguished school	Mental age	14.00	21.00	238.00	357.00	85.000	238.000	-2.075	0.038
			IQ	14.82	20.18	252.00	343.00	99.000	252.0	-1.58	0.114
SPM	5	High-Achievers School	Mental age	5.30	5.70	26.50	28.50	11.500	26.500	-0.213	0.831
			IQ	5.50	5.50	27.50	27.50	12.500	27.500	0.000	1.000
APM	22	Public school	Mental age	15.70	29.30	345.50	644.50	92.500	345.500	-3.568	0.000
			IQ	16.98	28.08	373.50	616.50	120.500	373.500	-2.878	0.004
APM	17	Distinguished school	Mental age	16.12	18.88	274.00	321.00	121.000	274.000	-0.843	0.400
			IQ	16.29	18.71	277.00	318.00	124.000	277.000	-0.720	0.472
APM	5	High-Achievers School	Mental age	17.20	17.50	26.00	29.00	11.000	26.00	-0.328	0.841
			IQ	98.86	100.54	25.00	30.00	10.000	25.00	-0.532	0.690

was conducted to examine differences in dopamine levels among students from public, distinguished, and high-achievers schools. The analysis showed highly significant differences among the groups, with an F value of 73.53 and a p-value of <0.0001 (Table 5 and Figure 1). Table 6 presents the mean endorphin levels (± standard error) for students from three different school group types: public schools, distinguished schools, and high-achievers schools. The F-test result (F = 0.02240, P = 0.9779) indicates no statistically significant difference in endorphin levels among the three groups.

Table 5 Comparison of dopamine levels (pg/ml) among public, distinguished, and high-achievers schools

parameter	Group type	Count	Mean ± Std. Error	F-test	P-value
Dopamine (pg/ml)	Public School	45	10.04 ± 0.5777	73.53	$P < 0.0001$****
	Distinguished	17	24.12 ± 0.6532		
	High-Achievers	28	19.76 ± 1.179		

Table 6 Comparison of classification results

parameter	Group type	Count	Mean	F-test	P-value
Endorphin	Public schools	45	94.46	0.02240	0.9779 ns*
	Distinguished Schools	17	87.34		
	High-Achieving Schools	28	87.66		

* *ns = not significant.*

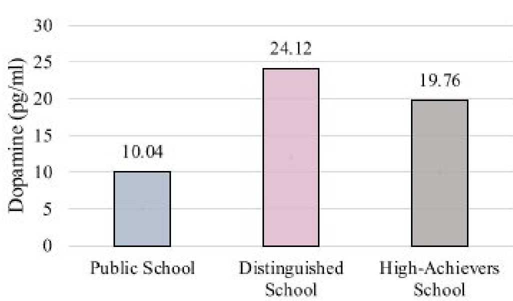

Fig. 1 Dopamine levels (pg/ml) across public, distinguished, and high-achievers schools

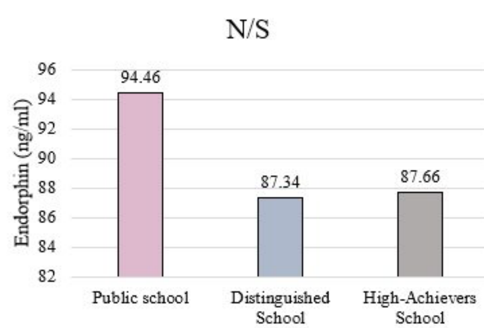

Fig. 2 Endorphin-β levels (pg/ml) across public, distinguished, and high-achievers schools

4 DISCUSSION

The results of the SPM test, conducted before the nutritional program, showed statistically significant differences in both mental age and IQ. Students from the distinguished school had the highest mean mental age (18.62±0.30), followed by students from the high-achievers school (16.71±0.39), whereas students from the public school had the lowest mean mental age (16.57±0.22). Distinguished-school students also recorded the highest mean IQ (107.7±2.150), compared with students from the high-achievers school (95.48±2.460) and the public school (90.85±1.320). These results are consistent with the literature [21], which indicates that an educational environment enriched with intellectual challenges and psychological support improves students' mental performance. However, these results are not consistent with [22], which found no significant differences among schools in students' mental abilities before educational interventions. This difference may be attributed to variation in sample characteristics or the nature of the curricula in that study.

The findings of the present study indicate that the educational environment in Distinguished Schools is characterized by advanced curricula, interactive teaching, diverse teaching methods, ongoing psychological support, and various school activities, which may significantly enhance students' mental abilities. The admissions system adopted in these schools, which includes IQ tests, may also explain their higher mean mental ages and IQs compared with other groups.

For public school students, the SPM test showed statistically significant differences between pre- and post-tests in both mental age and IQ, indicating a markedly positive impact of the nutritional program. Mean mental age increased from 16.64 to 17.45 by a statistically significant difference of 0.80. The mean IQ also increased from 91.23 to 95.20, with a statistically significant difference of 3.96. In the APM test conducted after the nutritional program, the results showed significant improvement. Students' mean mental age increased from 17.02 to 18.68 (a difference of 1.66), and IQ increased from 92.88 to 101.93 (a statistically significant difference of 9.05). This improvement could be attributed to the role of proper nutrition, particularly walnuts and dark chocolate, in improving cognitive performance and neurological functions related to attention and memory, especially among school students. These findings are consistent with [23], who reported that walnuts and dark chocolate can make a noticeable difference in attention and concentration, thereby improving brain health and overall mental abilities.

In contrast, the distinguished school showed statistically significant differences on the SPM test, with students from this school recording limited improvement. The mean mental age on the SPM increased from 18.62 to 19.52, a difference of 0.90. An increase in mean IQ from 107.73 to 112.92 was also observed, with a difference of 5.18. Both were statistically significant but less pronounced than in the public school. However, the APM test differences were not statistically significant, although the mean mental age increased from 18.83 to 19.04, and IQ increased from 108.94 to 110.15. These results are in line with the literature. A study [24] indicated that students with high cognitive performance may not show increases in mental age or IQ from nutritional interventions because of their already high cognitive level. However, [25] indicated that specially designed nutritional programs can be effective even for individuals with high intelligence. This may be explained by the fact that students in this group already had high cognitive levels before the program, making improvement limited and making it difficult to record significant increases in performance within the upper range of the test.

In the high-achievers school, although there was a slight improvement in mental age and IQ, statistical significance was absent across all measures. Mental age on the SPM increased from 16.50 to 17.10 ($p = 0.748$), and IQ increased from 94.78 to 97.14 ($p = 0.810$). These results are consistent with [26]. Small samples reduce statistical power, increasing the likelihood that differences will not be detected even if they exist. While [27] noted that a small sample size reduces test power, it also observed that, with sufficiently large sample sizes, a statistically significant difference can be observed even with low precision. The main reason is likely the small sample size (n = 5), which weakens statistical power and makes it difficult to detect differences even if they exist.

In the non-parametric analysis using the Mann–Whitney U test, the results were consistent with the t-test findings, enhancing the reliability of the statistical differences and confirming the impact and clarity of the nutritional program, regardless of the data distribution. Dopamine levels for 90 participants differed significantly among the three schools ($p < 0.0001$**). The distinguished school recorded the highest mean (24.12), followed by the high-achievers school (19.76), while the public school had the lowest mean (10.04). According to [28], dopamine plays a pivotal role in regulating executive cognitive performance and working memory, as well as the reward system. Moreover, [29] found that low dopamine levels are associated with decreased academic performance. Dopamine is a motivating neurotransmitter, particularly in school environments characterized by encouragement and student motivation, which may explain its higher levels among students in the distinguished school. In contrast, the noticeable decrease among students in the public school may reflect a weaker environment and a lack of psychological support, both of which may reduce motivation to learn and participate.

As for beta-endorphin, the results showed no statistically significant differences among the three groups ($p = 0.977$), despite slight variation in the means. Reference [30] also indicated that beta-endorphin is more affected by mood and physical activity than by cognitive changes. [6] explains that endorphins contribute to reducing pain, psychological stress, and tension; thus, they are more closely related to mental health than dopamine, which showed clear differences as an effect closely related to cognitive abilities, especially intelligence. This stability in endorphin levels suggests that beta-endorphin is more closely related to mood and emotional and affective aspects than to cognitive performance, making it less affected by variation in mental performance.

Limitations and Future Work: The nutritional program was implemented in only 44 of the 90 students because of differences in administrative cooperation between schools at the time of the study, particularly the high-achievers' school. Participant numbers were unequal across the three schools, with limited enrollment in the distinguished and high-achievers institutions. In addition, the lack of parental consent for some students and difficulties in adhering to the nutritional program further restricted participation. The short intervention duration (15 days), constrained by school timelines and academic schedules, limited the ability to evaluate long-term effects. Finally, the age-specific focus narrows the generalizability of the findings to other age groups.

Future research should expand the sample to include larger numbers of students from different regions with a balanced distribution across educational stages and extend the duration of the nutritional program to evaluate long-term effects on mental age and intelligence metrics. It would also be valuable to examine the relationships among mental age, IQ, and additional hormones, such as serotonin, and to implement various nutritional interventions (e.g., omega-3-rich meals or antioxidant-rich diets) to assess their cognitive and physiological effects.

5 CONCLUSION

It can be concluded that students' scores before the nutritional intervention showed statistically significant differences on the SPM test, with the distinguished school recording higher scores than the high-achievers and public schools. The nutritional program (100 grams of walnuts and 70 grams of 85% dark chocolate daily for 15 consecutive days) also resulted in significant improvement in some cognitive indicators among school students, particularly in the public school compared with the distinguished and high-achievers schools. Statistical analyses showed that improvements in the APM and SPM tests were statistically significant among public school students in mental age and IQ after the nutritional intervention. However, students in the distinguished and high-achievers schools recorded less pronounced differences because of their higher baseline cognitive levels before starting the program. On the physiological level, dopamine levels differed significantly among the three schools, with the distinguished school recording the highest level, followed by the high-achievers schools and then the public schools [6]. Our results reinforce the need to conduct pre-tests without interventions, as well as pre- and post-intervention tests, to monitor the impact of any potential intervention.

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Author contributions

NAK: Conceptualization, experimental design, data collection, biochemical analysis, writing – original draft. MMA: Statistical analysis, data interpretation, review, and editing of the manuscript.FMF: Psychological assessments, participant coordination, and interpretation of cognitive testing results. All authors reviewed the manuscript.

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Data availability

N/A

DECLARATIONS

Conflict of interest

The authors declare no conflict of interest.

Consent to publish

N/A

Ethical approval

The study was approved by the Scientific Research Ethics Committee at Anbar University (Approval No. 18, dated 18/01/2025).

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