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Inflammation, vitamin D status, and mother's education influence Filipino children's IQ scores

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Abstract

Background: The present study examined the association of nutritional status, presence of inflammation, and mother's educational level with Filipino school children's intellectual ability. The objectives were to: 1) characterize cognitive function in a group of apparently healthy schoolchildren enrolled in kindergarten and first grade in public schools in Metro Manila; 2) determine the association of IQ scores with inflammation and micronutrient status (i.e., vitamins D, C, riboflavin, and iron), and 3) determine the contribution of inflammation status and serum micronutrient levels to the variance in IQ scores after controlling for child age, sex, BMI-for-age, height-for-age, and mother's educational attainment.

Methods: Intelligence Quotient (IQ) was measured using the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) – IV. Inflammation was assessed using qualitative C-reactive protein test. Serum 25(OH)D and plasma riboflavin were measured using mass spectrometry. Vitamin C was measured using colorimetric analysis. Differences in mean overall IQ and individual subtest scores by inflammation and micronutrient status were analyzed using independent samples t-test. Multiple linear regression analysis was used to identify factors that contributed to the variance in children's overall IQ scores.

Results: Majority of children possessed average and below average levels of overall intellectual ability based on their IQ scores. Children with vitamin D deficiency had significantly higher mean IQ scores than those with sufficient vitamin D. In the individual subtests, children with vitamin D deficiency scored significantly higher in Verbal Comprehension Index and Visual Spatial Index tests. While children with no inflammation and adequate vitamin D status performed significantly faster in the Processing Speed test. Mother's educational attainment, but not inflammation or micronutrient status, contributed significantly to the variance in children's overall IQ scores, with increasing maternal education predicting higher scores.

Conclusion: Good nutrition is important to improve children's intellectual ability, but it is also necessary to equip mothers with sufficient physical and mental skills to raise intelligent children. The Philippine government should intensify its efforts to improve the health and education of women and girls if it wishes to increase the quality of the country's human resources and overcome poverty.

Keywords: School children; Intelligence; Micronutrients; Inflammation; Urban; Mothers.

Introduction

Cognitive impairment has been associated with physiological factors such as inflammation and poor nutritional status, particularly micronutrient status [1,2]. Micronutrients shown to be important for brain development and cognitive function include iron and vitamin D [3-5]. Other factors shown to be associated with IQ in children are anthropometric measurements and maternal education level [2].

The present study seeks to determine the association of nutritional status, presence of inflammation, and mother's educational level with Filipino schoolchildren's intellectual ability using the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) – IV. The objectives are to: 1) characterize cognitive function in a group of apparently healthy schoolchildren enrolled in kindergarten and first grade in public schools in Metro Manila; 2) determine the association of IQ scores with inflammation and micronutrient status (i.e., vitamins D, C, riboflavin, and iron), and 3) determine the contribution of inflammation status and serum micronutrient levels to the variance in IQ scores after controlling for child age, sex, BMI-for-age, height-for-age, and mother's educational attainment.

Materials and methods

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Region II Trauma and Medical Center Philippines (protocol code R2TMC-IRB Protocol No. 2022:102 dated July 28, 2022). The methods below have been described earlier [6].

Sampling method: Two public elementary schools in low-income communities within Metro Manila were selected based on geographic location (i.e., one in the north and another in the south). In both schools, parents of the entire population of kindergarten and first grade children were invited to a meeting wherein researchers explained the study objectives and methods. Parents were given consent forms to take home after the meeting. They were asked to decide if they would allow their children to participate in the study, and if so, return the signed consent form to the child's teacher. Out of a total of approximately 800 children, 166 parents whose children were apparently healthy (i.e., with no known or current co-morbidities e.g. fever, cough etc. and actively attending class) gave signed consent forms. These children comprised the study sample.

Sample collection and analysis*:* An accredited diagnostic laboratory in Metro Manila collected [7] and analyzed [7,8] the blood samples. Approximately 12 mL venous blood was extracted. Hemoglobin (iron) was obtained from a Complete Blood Count (CBC) using fully automated hematology analyzers (Sysmex, Alinity). Qualitative serum C-reactive protein was determined by immunoturbidimetric method on an Alinity system. Serum vitamin D was determined using LC-MS/MS (liquid chromatography tandem mass spectrometry) technique. Briefly, the sample was subjected to protein precipitation followed by solid phase extraction. The resulting sample solution was then placed in the LC-MS/MS system. The generated calibration curves of both 25(OH)D_2 and 25(OH)D_3 were used to compute for the vitamin D concentration.

For plasma riboflavin, the sample was subjected to protein precipitation and the resulting supernatant subjected to the LC-MS/MS system. The resulting peak areas of samples were processed against peak areas of calibration solutions.

Vitamin C in serum sample was determined using a plate-based colorimetric assay. Using a microplate reader, a dose-response curve correlating absorbance units to concentration of ascorbic acid in the sample was generated. The vitamin C concentration of sample was computed by subtracting sample absorbance from blank and comparing against that of the calibrator. All solutions were protected from light during the sample preparation to prevent degradation of biomarkers. Reference values for the different micronutrients are shown in Table 1.

Table 1: Reference values for micronutrients examined.

Micronutrient	Reference values	
	Normal	Insufficient/Deficient
Vitamin D (serum 25(OH)D_3)	>20 ng/mL (>50 nmol/L)	<20 ng/mL (<50 nmol/L)
Vitamin C (serum ascorbic acid)	6.00-20.00 mg/L	Below 6.00 mg/L
Riboflavin (plasma riboflavin)	1.00-19.00 mcg/L	Below 1.00 mcg/L
Iron (hemoglobin)	100-140 g/L	Below 100 g/L

Anthropometric assessment

Weight and height were measured by two trained nutritionists using a standard Detecto weighing scale with height rod. Weighing scales were calibrated with known weights prior to use during each weighing session. Two readings were obtained and the average was taken. Height-for-age and BMI-for-age z-scores were determined using WHO AnthroPlus software [9] which used the 2007 WHO Growth Reference for classification [10]. Cut-offs for height-for-age were: stunted <-2 z-score, not stunted ≥2 z-score. Cut-offs for BMI-for-age were: low BMI <-2 z-score, normal BMI ≥-2 to ≤+1 z-score, high BMI >+1 z-score.

Intelligence test

The Wechsler Preschool and Primary Scale of Intelligence (WPPSI)-IV tests were administered individually by four licensed psychologists. WPPSI-IV consists of 10 subsets. One subset consists of a Verbal IQ (Information, Comprehension, Arithmetic, Vocabulary and Similarities) and the other subset consists of a Performance IQ (Object Assembly, Geometric Design, Block Design, Mazes and Picture Completion [11]. The Verbal IQ and Performance IQs are combined to give a Full-Scale IQ (FSIQ), which is defined as the average of all cognitive abilities and is widely recognized as a good measure of general intelligence [11].

Statistical analysis

The percentile distribution of FSIQ scores was determined using SPSS v. 26. Independent samples t-test was used to assess differences in mean FSIQ score between groups. Multiple linear regression (full model was reduced through backward elimination) was used to identify serum micronutrients that contributed to the variance in FSIQ scores after controlling for child age, sex, BMI-for-age, height-for-age, and mother's educational attainment.

Results

Characteristics of the study sample

Table 2 shows the characteristics of the study sample. There were slightly more males than females. The proportion of overweight and obese children exceeded that of thin children (19.4% vs. 15.1%, respectively). Six percent of children were stunted. None of the children were anemic and all had sufficient riboflavin. Twenty-nine percent had low (insufficient/deficient) vitamin D while 19.8 percent had low vitamin C. Majority (58.6%) of mothers had high school or below educational attainment.

Table 2: Characteristics of the study sample.

Child age in years (mean ±SD)	6.25 ± 0.86	
	No.	%
Male	94	56.6
Female	72	43.4
Total	166	100.0
BMI-for-age z-score		
Severe thinness	8	4.8
Moderate thinness	17	10.3
Normal	108	65.5
Overweight	18	10.9
Obese	14	8.5
Total	165	100.0
Height-for-age z-score		
Severely stunted (< -3)	2	1.2
Moderately stunted (≥ -3 to ≤ -2)	8	4.8
Normal height (≥ -2 to ≤ +3)	154	93.3
Tall (> 3)	1	0.6
Total	165	100.0
Child C-reactive protein (qualitative)		
Negative	143	88.8
Positive	18	11.2
Total	161	100.0
Serum 25(OH)D		
Deficient (<20 ng/mL)	7	4.3
Insufficient (20-29 ng/mL)	40	24.8
Sufficient (≥30 ng/mL)	114	70.8
Total	161	100.0
Serum Vitamin C		
Deficient	26	19.8
Normal	105	80.2
Total	131	100.0
Plasma Riboflavin		
Normal	121	77.1
High	36	22.9
Total	157	
Hemoglobin		
Normal	147	92.5
High	12	7.5
Total	159	
Mother's education		
Below high school	13	8.0
High school graduate	84	50.6
College level/vocational	45	27.8
College graduate	20	12.3
Total	162	100.0

Cognitive function of kindergarten and first grade Filipino children using WPPSI-IV

Table 3 shows the distribution of Full-Scale IQ (FSIQ) scores of the study sample. The median (most frequent) FSIQ score was 88. The cut-off score for average IQ is 90 -109 [12]. Sixty percent of children had IQ scores below 93 while 90 percent had scores below 103, indicating that average and below average IQ are common in this sample.

Table 3: Distribution of FSIQ scores.

Median	Range	Minimum	Maximum	Percentiles of FSIQ scores								
				10th	20th	30th	40th	50th	60th	70th	80th	90th
88.00	72.00	48.00	120.00	73.00	78.00	80.00	83.40	88.00	93.00	94.20	98.00	103.00

Table 4 shows the standard score ranges obtained by children. A total of 85 children (52%) had scores below the average cut-off score of 90, confirming the existence of below average cognitive function in majority of the sample population.

Association of IQ scores with inflammation and micronutrient status

Inflammation status & IQ scores: Table 5 shows no difference in overall FSIQ scores among children with and without inflammation. However, specific subtests showed that children who tested positive for inflammation had significantly lower scores in Processing Speed Index (PSI) compared with those who were negative for the condition.

Micronutrients and IQ: Table 5 shows that children with sufficient serum vitamin D levels had significantly lower mean scores in Full Scale IQ (FSIQ), Verbal Comprehension Index (VCI), and Visual Spatial Index (VSI) but had significantly better scores in Processing Speed Index (PSI) than those with low serum levels. Conversely, children with low vitamin D levels had significantly lower scores in Processing Speed but scored significantly higher in overall IQ, VCI, and VSI than those with sufficient vitamin D.

No associations were found for vitamin C status and IQ scores. None of the children were deficient in iron and riboflavin hence no comparisons were made.

The contribution of inflammation status and micronutrient levels to the variance in FSIQ score controlled for child age, sex, BMI for age, height-for-age, and mother's educational attainment

Table 6 shows that mother's educational attainment predicted FSIQ score – i.e., child FSIQ score increased with increasing maternal education. Nutritional status (serum micronutrients, anthropometric measures) and inflammation did not predict children's IQ score. The full model was reduced to find the significant predictors through backward elimination linear regression.

The backward elimination procedure confirmed that information on maternal education has sufficient statistical evidence of explaining the variation in children's FSIQ score (Table 7).

Table 4: WPPSI-IV standard score ranges of Filipino school children aged 5 to 9 years.

FSIQ standard score ranges	Indication of scores [12]	No.	%
Extremely low (below 70)	Scores in this range represent less than 2% of the population. Children scoring in this range may have significant cognitive delays or intellectual disabilities. They may require specialized educational support and could benefit from individualized education plans (IEPs) or special education programs.	7	4
Borderline (70-79)	Students who test in this range may have a learning disability and should review their subtest scores to identify specific areas of cognitive weakness. Children who score in this range may face learning challenges or have potential learning disabilities. Their abilities are below average, and they may struggle with academic work. Further analysis of their subtest scores can help identify specific areas of cognitive weakness that can be addressed through targeted intervention strategies.	40	25
Low average (80-89)	This is slightly lower than the mean score of 100, but still able to perform as expected in the classroom. Scores in this range are slightly below the average but are still within the normal range. Children in this range are typically able to perform as expected in the classroom, but may need additional support in certain areas to keep up with their peers.	38	23
Average (90-109)	The vast majority of children tested will score in this range with a mean (averaged) score of 100; the highest possible score on the WPPSI-IV is 160. Children in this range are typically performing at or around grade level and have the cognitive abilities necessary to succeed in a standard academic environment.	74	45
High average (110-119)	This typically indicates a stronger cognitive ability in one or more areas (review your child's subtest scores to see where these strengths are indicated).	4	2
Superior (120-129)	A score like this indicates your child is gifted in many areas required for school and testing success. These children often excel in the classroom and may benefit from advanced or enriched educational programs.	1	1
Very superior (130++)	If your child scores in this range, he or she typically will be accepted into most gifted and talented programs or private schools. They are often considered highly gifted and may be eligible for admission into specialized gifted and talented programs or selective private schools.	0	0
Total		163	100.0

Table 5: WPPSI-IV scores by inflammation (CRP) status and micronutrient status.

		Inflammation status			Vitamin D status			Vitamin C status		
		CRP (-) (n=139)	CRP (+) (n=18)		Sufficient (n=112)	Deficient / Insufficient (n=45)		Sufficient (n=103)	Deficient (n=25)	
WPPSI-IV categories	**Abilities measured [13]**	**Mean ± SE**	**Mean ± SE**	**Sig.**	**Mean ± SE**	**Mean ± SE**	**Sig.**	**Mean ± SE**	**Mean ± SE**	**Sig.**
1. Full scale IQ (FSIQ) score										
	Overall intellectual ability	87.3 ±0.9	92.0 ±2.7	.116	86.1 ±1.0	91.6 ±1.6	.006*	87.7 ±1.0	89.9 ±2.8	.466
2. Individual subtests										
Verbal Comprehension Index (VCI)	Acquired knowledge, verbal reasoning and comprehension skills, and ability to pay attention to verbal stimuli as presented	12.2 ±0.4	13.5 ±1.1	.292	11.6 ±0.5	13.8 ±0.8	.023*	11.9 ±0.5	13.4 ±1.1	.235
Visual Spatial Index (VSI)	Ability to attend to visual details, organize visual information, understand part-whole relationships, & simultaneously integrate visual & motor functions	8.9 ±0.3	8.8 ±0.7	.918	8.5 ±0.3	9.9 ±0.4	.009*	9.2 ±0.3	8.2 ±0.6	.152
Fluid Reasoning Index (FRI)	Fluid & inductive reasoning skills, broad visual intelligence, simultaneous processing, conceptual thinking, & individual classification abilities	8.6 ±0.2	9.4 ±0.6	.183	8.5 ±0.2	8.9 ±0.4	.356	8.5 ±0.3	8.7 ±0.5	.750
Working Memory Index (WMI)	Visual working memory, visual-spatial working memory & ability to resist proactive interference when using attention, concentration, mental control & reasoning skills. Essential for other higher-order cognitive processes	9.0 ±0.2	9.5 ±0.6	.405	8.9 ±0.2	9.4 ±0.4	.295	9.1 ±0.2	9.8 ±0.6	.308
Processing Speed Index (PSI)	Ability to quickly & correctly complete scanning & sequencing questions & discriminate among simple visual information as presented	20.5 ±0.4	23.7 ±1.2	.022*	20.4 ±0.4	21.9 ±0.6	.048*	20.6 ±0.4	22.5 ±1.1	.118

*Significant at 0.05 level.

Table 6: Factors that contributed to the variance in children's FSIQ score.

Independent variables	B	Std. Error	Standardized Beta	t	Sig.
Serum vitamin D (mcg/L)	.006	.101	.005	.056	.955
Plasma riboflavin (mcg/L)	.010	.059	.017	.174	.862
Hemoglobin (g/dL)	-.081	.110	-.071	-.738	.462
Serum vitamin C (mg/L)	-.197	.158	-.121	-1.247	.215
C-reactive protein (+ or -)	3.100	3.312	.088	.936	.352
BMI-for-age z-score	-.275	.730	-.037	-.377	.707
Height-for-age z-score	.267	.829	.032	.322	.748
Mother's educational attainment	2.913	1.361	.208	2.140	.035*
Sex	2.597	2.270	.114	1.144	.255
Age in years	1.761	1.323	.131	1.331	.168
(Constant)	81.34	16.54		4.919	.000

*Significant at 0.05 level.

Table 7: Final model fit after backward elimination procedure.

Independent variable	B	Std. Error	Standardized Beta	t	Sig.
(Constant)	83.466	2.101			
Mother's education	2.966	1.288	.212	2.303	.023

Discussion

The present study showed that the present sample of kindergarten and first grade schoolchildren, in general, possessed average and below average levels of overall intellectual ability based on their FSIQ scores. Ironically, children with vitamin D deficiency had significantly higher mean FSIQ scores than those with sufficient vitamin D. In the individual subtests, children with vitamin D deficiency scored significantly higher in Verbal Comprehension Index and Visual Spatial Index tests. While children with no inflammation and adequate vitamin D status performed significantly faster in the Processing Speed test.

Studies have shown inconsistent findings with respect to the role of vitamin D in children's cognitive function. One study [14] showed that cognitive function improved by a mean difference of 1.22 intelligence quotient (IQ) points with increased 25(OH) D concentration, while others [15,16] showed no association. In the present study, faster Processing Speed (but not overall IQ) was associated with both sufficient serum vitamin D and the absence of inflammation. Studies have shown a relationship between chronic systemic inflammation and poor cognition in children [17]. Inflammation can be due to gut dysbiosis that triggers chronic intestinal inflammation, contributing to the development of chronic intestinal diseases [17]. Poor diet, contaminated water, and poor hygiene can cause enteric infections that shift the composition of the gut microbiota towards pathogenic species. These conditions are characteristic of an urban poor setting, which comprised the present sample's home environment. Gut dysbiosis is linked to brain pathologies including neurodegenerative, neurodevelopmental, and psychiatric disorders, known as the microbiota-gut-brain axis [17,18]. Studies showed that the brain is affected by persistent peripheral inflammation, causing activation of microglia and perivascular macrophages leading to a state of neuroinflammation [19]. Vitamin D was shown to protect against sepsis-induced brain injury in a mouse model by inhibiting histone-induced pyroptosis (a form of programmed cell death due to inflammation) and ferroptosis (a form of programmed cell death dependent on iron and characterized by accumulation of lipid peroxides due to impaired antioxidant defense mechanisms) [19]. Septic mice treated with calcitriol (the active form of vitamin D) showed greater cognitive function compared with untreated mice [19].

The presence of viral infections can also cause neuroinflammation [20]. An earlier study on the same sample [6] found that more than 88 percent of children had previous Epstein-Barr virus (EBV) infection. Viruses can traverse the blood-brain barrier and stimulate the release of inflammatory cytokines, resulting in brain endothelium dysfunction [20]. There is evidence that endogenous retroviruses are involved in the pathogenesis of inflammatory neurodegenerative diseases such as multiple sclerosis as well as mental disorders [20]. These mechanisms may explain why in this study, children without inflammation and with adequate vitamin D status showed significantly improved processing speed.

Multiple linear regression revealed that higher maternal education, rather than absence of inflammation or improved micronutrient status, predicted higher FSIQ score. This finding suggests that, in the current local setting, better-educated mothers (indicating improved intellectual ability) exerted an important influence on children's cognitive abilities regardless of the child's nutritional state. Previous studies confirmed the significant association of mother's education with children's cognitive function [21-23]. A cohort study on Spanish children aged 5 to 6 years found that at lower socioeconomic levels, maternal characteristics (i.e., maternal education, age, intelligence) significantly explained the variance in child cognitive scores compared with paternal characteristics, with maternal education being the strongest determinant [21]. Another cohort study on Dutch children showed a significant positive association between parental education and child intelligence at age 12 [22]. The authors found that higher educated parents were more likely to provide family routines that included tasks related to education and cognition [22], resulting in improved intellectual development of their children. Mothers with higher education also tend to have higher intelligence scores. A study in China showed that mothers with higher IQ had a significantly higher educational level and had children with better motor development [24]. The strong association between parental education and child intelligence reflects the interaction of both environmental and genetic factors in shaping children's cognitive abilities.

Limitations of the study

The study is limited by its small sample size, cross-sectional design, and limited use of social and environmental variables that will allow greater insight into children's cognitive development. In spite of this, it is the only study that has assessed the intellectual ability of children post-pandemic and examined the role of nutrition in cognitive function. The Philippines consistently performs poorly in PISA (Programme for International Student Assessment) tests, the global assessment of student skills in mathematics, reading, and science [25]. The tests explore how well students can solve complex problems, think critically, and communicate effectively. The present study should help policy makers develop more effective interventions to make Filipino children globally competitive.

Conclusion

The study showed that the present sample of low-income schoolchildren enrolled in public schools have low intellectual ability, reducing their capacity to overcome future challenges and achieve future success. Sufficient vitamin D status and the absence of inflammation were associated with faster Processing Speed but not overall IQ. Mother's educational attainment contributed significantly to the variance in children's overall IQ scores, with increasing maternal education predicting higher scores. While good nutrition is important to improve children's intellectual ability, it is also necessary to equip mothers with sufficient physical and mental skills to raise intelligent children. The Philippine government should intensify its efforts to improve the health and education of women and girls if it wishes to increase the quality of the country's human resources and overcome poverty.

Author declarations

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Conflict of interest: B.C. is an employee Nestle Philippines Inc. The rest of the authors (M.S.A., F.DL.R., W.S.) declare no conflict of interest. The study is part of a larger project that includes assessment of diet, physical fitness, and immune function of Filipino schoolchildren. The funding sponsor played no role in the study's conception, execution, interpretation, or writing.

Data availability statement: Data supporting these findings are available upon request.

Informed consent statement: Informed consent was obtained from parents/legal guardians of all participants taking part in the study.

Institutional review board statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of [REGION II TRAUMA AND MEDICAL CENTER, REPUBLIC OF THE PHILIPPINES] (R2TMC-IRB Protocol No. 2022:102 dated July 28, 2022).

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