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Research Article

Correlation between Blood Glucose Level and Short-Term Memory Score among 4th and 5th Grades of Primary School Children in Bogor, Indonesia

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ABSTRACT

The study aimed to analyze the correlation between Blood Glucose levels (BG) and Short-Term Memory scores (STM) among primary school children in Bogor, as controlled by Socioeconomic Status (SES), BMI-for-age (BAZ), Hemoglobin (Hb), folate, and vitamin B12 levels. It was a cross-sectional study applied for 915 students of the 4th–5th grades from 16 primary schools in the suburban area of the Cijeruk district. Morning blood samples were drawn from venous puncture of the inner arm. The specimens were then transported to laboratories to analyze the BG (hexokinase methods), Hb (non-cyanide Hb), as well as folate, and vitamin B12 using Liquid Chromatography and Mass Spectrometry. The STM was obtained through an object recall test performed by trained psychologists. The actual body weight and height were measured to determine BAZ. The characteristics of subjects and their SES were collected through interviews and structured questionnaires. Mann-Whitney and Chi-square tests were performed to compare differences between variables that were grouped by genders. Correlations between predictors and predicted variables were analyzed using simple logistic regression for the bivariates analysis and a binary logistic regression test for the multivariate analysis. There were significant differences in BAZ, BG, and STM between boys and girls ($p<0.05$). Most of the subject's BAZ was normal (85.2%). About 50.9% of subjects had normal Hb, 99.8% had folate deficiency, 47.8% had normal vitamin B12 level, and 54.9% had good STM score. There was no significant correlation between BAZ, Hb, folate, and vitamin B12 level with STM ($p\geq0.05$), respectively. There was a significant positive correlation between BG and STM ($p<0.05$; OR=1.583; 95% CI:1.067−2.348) after being controlled by BAZ, subject's characteristic, and SES. In conclusion, optimum blood glucose level improved the STM in primary school children. Therefore, provision of balanced diet, more especially breakfast, for school children is highly important.

INTRODUCTION

Nutrition affects both the development and health of brain structure and function. It provides proper components to create and maintain brain function that is critical for improved cognition and academic performance (Burkhalter & Hillman 2011). Investigation on nutrition related to cognitive performance is a challenge where cognitive performance may result from many factors (not only nutrition) such as demographics and socioeconomics (Lipina & Sigretin 2015), as well as genetics (Robinson *et al.* 2015) that make the effects difficult to determine. Regardless, understanding the role of nutrition is important as nutrition is one of the modifiable factors that can optimize cognitive performance.

Glucose is a macronutrient that is perhaps the most thoroughly studied in terms of its effects on cognitive function (Sünram-Lea & Owen 2017). Glucose is the primary fuel to produce energy for the brain (Nimgampalle *et al.* 2021). Acute changes in glucose supply have been found to affect cognitive function and a review study found that glucose affected cognitive performance, specifically in the memory domains (Smith *et al.* 2011).

Glucose metabolic rate of the brain is different and varies across the life span. Initially, the rising glucose consumption rates occur from newborns until they reach about four years old. Large amounts of glucose are also required between four to ten years old because an intense learning process occurs during this period, where children learn a lot related to basic cognitive concepts, such as reading, writing, and arithmetic (Sunehag & Haymond 2004). Oxygen is required for aerobic metabolism to utilize the brain energy and hemoglobin plays an essential role as the carrier of oxygen transferring (Kustiyah *et al.* 2005). On the other hand, folate and vitamin B12 are commonly mentioned as critical for the brain's optimal development and neurological function throughout the lifecycle (Van De Rest *et al.* 2012).

Socioeconomic Status (SES) is another factor that is strongly found to influence cognitive performance (such as memory), especially in children (Lipina & Sigretin 2015).

Previous study by Kustiyah *et al.* (2005) found that blood glucose levels are positively associated with STM in elementary school children. However, this study has not discussed the relationship between blood glucose levels and STM when analyzed simultaneously with other factors (such as hemoglobin, folate, and vitamin B12 levels, nutritional status, ages, genders, and SES) often associated with children's memory outcomes. It is crucial to analyze them simultaneously as covariates, given that memory performance is the result of interaction between various factors.

Understanding the role of nutrition-related cognition (in memory domains) in primary school children is essential. Based on Piaget's third stage of cognitive development in children 7−12 years old, a growth spurt occurs in the brain, especially in the frontal lobes that are responsible for cognitive function, with the growth peaks at about 8−10 years old (Ibda 2015; Shaffer & Kipp 2013). The optimum cognitive development in this period will affect their quality of life in the future, including achievements in career, their health, and also mortality risk. Therefore, the purpose of this study was to analyze the correlation between blood glucose level and STM score in primary school children in Bogor as adjusted by hemoglobin, folate, and vitamin B12 levels, nutritional status, ages, genders, parental educational levels, and family income.

METHODS

Design, location, and time

Our study was observational research with a cross-sectional study design, located in the suburban district of Cijeruk, Bogor in 16 public elementary schools. Where previous studies focused on urban or rural areas (as Cijeruk is a sub-urban area), no similar research has been conducted in the area before. The data collection was carried out from October to December 2019.

Sampling

A total of 915 healthy children (boys and girls) from fourth and fifth grade (ranging in age eight to 13 years) were enrolled in our study based on the inclusion criteria and ability to pass the writing and reading test. The inclusion criteria for the subject were based on several cognitive screening test including logical thinking, ability to engage in more complex cognitive tasks (Piaget's theory), and having good reading and writing ability. In addition, they should also be able to communicate well with teachers, parents, and researchers. Only students who passed the screening test and other criterias set by the researcher were recruited, thus the sampling method was purposive. Those who agreed to participate signed the informed consent and assent were examined for their blood profiles and were included in all the data collection. On the other hand, the exclusion criteria were last year's students (6^{th} grade; because of their final exams preparation) and the third or lower grade (had limited ability to read, write, and communicate well). Transfer students (within the previous six months) suffering from a severe illness, physically or mentally disabled, and girls who have menstruated were also excluded from our study.

Slovin's formula for population determined the total subject of the study. The population (N) was 9,241 of the public primary school students in the Cijeruk district (BPS-Statisticts of Bogor Regency 2019), and the margin of error used was 5%.

Data collection

The study was approved by The Ethics Commission of IPB University, with record number242/IT3.KEPMSM-IPB/SK/2019. Morning blood samples were drawn in venous puncture of the inner arm, done by trained physicians. Subjects were only allowed to drink plain water (fasting from foods) from the night before bed until the blood draw. The specimens were then transported to certified laboratories at *Prodia Lab* of Bogor (to analyze blood glucose and hemoglobin) and Labkesda of Bogor (folate and vitamin B12 analysis). In vitro blood samples were analyzed using hexokinase methods (blood glucose assay), non-cyanide hemoglobin (hemoglobin), and Liquid Chromatography, and Mass Spectrometry (folate and vitamin B12).

Anthropometric data includes actual body weight and height were measured using weight scales and microtoise (minimum reading scale of 0.1 cm), respectively. Then, the Body Mass Index (BMI) for age was determined. An object recall test was used to obtain the scores of Short-Term Memory (STM), done by trained psychologists. The use of the object recall test refers to the previous studies conducted by Kustiyah *et al.* (2005) and Lubis *et al.* (2008), where this method is relatively simple and comparatively inexpensive. A set of pictures was shown to the subjects, and they had to memorize them in 60 seconds. Then they were asked to list as many pictures as they could remember. The score was calculated based on the number of correct answers. The characteristic of subjects and the SES of the family were collected through interviews and structured questionnaires.

Data analysis

Data analysis involved calculating and describing the prevalence of blood glucose, hemoglobin, folate, vitamin B12, BMI for age, STM scores, subject's characteristic, and SES. The serum concentrations were presented in mg/dL for blood glucose, g/dL for hemoglobin, ng/mL for folate, and pg/mL for vitamin B12. Blood glucose levels ranged from 70−110 mg/dL was considered normal, less than 70 mg/dL was low, and higher than 110 mg/dL was high (American Diabetes Association 2015). The cut-off point of normal Hb level was >11.4 g/dL, Hb levels ranged from 11−11.4 g/dL was determined as mild anemia, 8−10.9 g/dL as moderate anemia, and <8.0 g/dL was considered as severe anemia (WHO 2011). Folate serum was categorized as normal (≥5.0 ng/mL), possible deficiency (2.5−4.9 ng/mL), and deficiency (<2.5 ng/mL). Vitamin B12 serum was categorized as normal (≥200 pg/mL) and the deficiency (<200 pg/mL) (Bozkaya *et al.* 2017). Furthermore, the subject's STM was classified as "good" if the score was more than the median value and vice versa. Mann-Whitney and Chi-square tests were performed to compare differences between boys and girls for each variable.

In this study, BAZ Hb level, folate, vitamin B12 serum, and SES was classified as the covariates. We performed simple logistic regression test to analyse the correlation between blood glucose and the covariates to STM score in bivariate (crude analysis).

A binary logistic regression test was run to evaluate the simultaneous correlation between variables with a p<0.250 (Hosmer *et al.* 2013) in bivariate analysis to the STM score. If the p-value of the output was less than 0.05 (p<0.05) is considered significantly correlated. The confounding test was carried out by measuring the association both before and after adjusting for a potential confounder variable. If the difference between the association is more than the equivalent 10%, then the confounder was present, and vice versa (LaMorte & Sullivan 2021). No confounder found in our study (analytical data not presented in this manuscript).

RESULTS AND DISCUSSION

Subject's characteristics and socioeconomic status

Data on subjects' characteristics and SES from 915 students grouped by genders are presented in Table 1. There were significant differences between boys and girls both in age and pocket money (p<0.05) but there was no difference in joining tutoring class (p≥0.05).

Table 1 also shows that most of the subjects had low parental educational levels (did not graduate from Senior high school), both in father (81.5%) and mother (89.3%). Furthermore, the family income of most subjects (58.3%) was also low (<IDR1,500,000 per month).

Nutritional status, blood biomarkers, and short-term memory scores of subjects

Table 2 shows that there was a significant difference in BMI between boys and girls (p<0.05), which girls had a higher score of BMI. Most subjects had normal blood glucose levels (89.9%), where boys showed a higher mean

Table 1. Mean and disitribution of subjects' characteristics based on genders

Variables	Boys (n=446)		Girls (n=469)		Total (n=915)		*p*
	n	%	n	%	n	%	
Subject's age (years old)							
Mean±SD	10.72±0.84		10.50±0.77		10.60±0.81		0.000[b*]
Median (min−max)	10.80 (8.6−13.1)		10.45 (8.4−13.3)		10.58 (8.4−13.3)		
Taking after-school tutoring programs							
Yes	81	18.2	89	19.0	170	18.7	0.751[a]
No	365	81.8	380	81.0	745	81.3	
Pocket money (IDR/day)							
Mean±SD	6,130±3,560		6,747±3,534		6,447±3,558		0.001[b*]
Median (min−max)	5,000 (0−30,000)		5,000 (0−25,000)		5,000 (0−30,000)		
Father's age (years old)							
Mean±SD	42.82±7.80		42.21±8.05		42.51±7.93		0.151[b]
Median (min−max)	42 (29−75)		40 (25−72)		41 (25−75)		
Mother's age (years old)							
Mean±SD	37.33 ±6.82		36.25 ±6.58		36.77±6.71		0.019[b*]
Median (min−max)	37 (25−62)		35 (22−55)		36 (22−62)		
Father's educational level							
No formal education	63	14.1	79	16.8	142	15.5	0.294[a]
Elementary school	221	49.6	209	44.6	430	47.0	
Junior high school	89	19.9	85	18.1	174	19.0	
Senior high school & college	73	16.4	96	20.5	169	18.5	
Mother's educational level							
No formal education	77	17.3	89	19.0	166	18.1	0.927[a]
Elementary school	229	51.4	243	51.8	472	51.6	
Junior high school	89	19.9	90	19.2	179	19.6	
Senior high school & college	51	11.4	47	10.0	98	10.7	
Family income (IDR/month)							
<1,500,000	272	61.0	261	55.7	533	58.3	0.066[a]
1,500,000−2,500,000	101	22.7	128	27.2	229	25.0	
2,500,000−3,500,000	50	11.2	40	8.5	90	9.8	
>3,500,000	23	5.1	40	8.6	63	6.9	

[a]Chi-square test; [b] Mann Whitney test; IDR: Indonesian Rupiah; SD: Standard Deviation; Min: Minimum; Max: Maximum

blood glucose concentration than girls (p<0.05). About 50.9% of subjects had a normal level of hemoglobin, while 40.1% were anemic. The study found that the prevalence of anemia among boys was higher than girls, where 52.2% of boys and 46.1% of girls were anemic. Nevertheless, there was no difference in mean hemoglobin levels between boys and girls.

Regarding serum folate, this study found that almost all subjects were folate-deficient (99.8% from total subjects), and about 55.2% of total subjects were deficient in vitamin B12. The statistical analysis also did not find the difference in folate and vitamin B12 serums between boys and girls, respectively. The deficiency of folate and Vit B12 was much more common in many countries because of many factors, but insufficient dietary intake was assumed to be the primary reason (Khan & Jialal 2021). The Object recall task assessment was used to measure STM

Tabel 2. Body mass index, blood biomarkers, and short-term memory scores of subjects

Variables	Boys (n=446)		Girls (n=469)		Total (n=915)		*p*
	n	%	n	%	n	%	
Body mass index (kg/m²)							
Mean±SD	16.56±2.85		17.05±3.17		16.81±3.02		0.007[a*]
Median (min−max)	15.98 (12.2−33.5)		16.29 (12.13−34.3)		16.09 (12.1−34.3)		
Body mass index for age							
Severe thinness	1	0.2	0	0.0	1	0.1	0.111[b]
Thinness	14	3.1	7	1.5	21	2.3	
Normal	381	85.4	399	85.1	780	85.2	
Overweight	22	4.9	30	6.4	52	5.7	
Obese	28	6.3	33	7.0	61	6.7	
Blood glucose (mg/dL)							
Mean±SD	11.57±0.99		11.65±0.93		11.61±0.96		0.595[a]
Median (min−max)	11.6 (7.2−15.1)		11.6 (8.4−14.6)		11.6 (7.2−15.1)		
Low (<70)	37	8.3	51	10.9	88	9.6	
Normal (70−110)	406	91	417	88.9	823	89.9	
High (>110)	3	0.7	1	0.2	4	0.4	
Serum hemoglobin (g/dL)							
Mean±SD	11.57±0.99		11.65±0.93		11.61±0.96		0.595[a]
Median (min−max)	11.6 (7.2−15.1)		11.6 (8.4−14.6)		11.6 (7.2−15.1)		
Severe anemia (<8.0)	2	0.4	0	0.0	2	0.2	
Moderate (8.0−10.9)	90	20.2	97	20.7	187	20.4	
Mild (11−11.4)	141	31.6	119	25.4	260	28.4	
Normal (>11.4)	213	47.8	253	53.9	466	50.9	
Serum folate (ng/mL)							
Mean±SD	0.45±0.40		0.45±0.35		0.45±0.37		0.595[a]
Median (min−max)	0.33 (0.01−3.49)		0.35 (0.01−2.15)		0.34 (0.01−3.49)		
Deficiency (<2.5)	444	99.6	469	100	913	99.8	
Possible deficiency (2.6−5.0)	2	0.4	0.0	0.0	2	0.2	
Normal (≥5.0)	0	0.0	0	0.0	0	0.0	
Serum vitamin B12 (pg/mL)							
Mean±SD	236.18±181.72		249.08±220.11		242.79±202.30		0.511[a]
Median (min−max)	200 (80−3,220)		200 (80−3,440)		200 (80−3,440)		
Deficiency (<200)	236	52.9	242	51.6	478	52.2	
Normal (≥200)	210	47.1	227	48.4	437	47.8	
Short-term memory score							
Mean±SD	54.83±21.17		61.63±19.83		58.32±20.76		0.000 a[*]
Median (min−max)	53 (7−100)		60 (7−100)		60 (7−100)		
Low	234	52.5	179	38.2	413	45.1	
Good	212	47.5	290	31.7	502	54.9	

[a]Mann Whitney test; [b]Chi-square test; SD: Standard Deviation; Min: Minimum; Max: Maximum

performance and found a significant difference between boys and girls, where girls had higher scores than boys (Table 2).

Correlation between variables to short-term memory

Table 3 shows that blood glucose level correlated significantly with STM score. In contrast, BMI for age had no association with STM score. This finding was in line with Ong *et al.* (2010) and Veldwijk *et al.* (2011). Furthermore, Haile *et al.* (2016) explained that BMI-for-age indicated the acute nutritional status, and it did not determine or impair the cognitive function.

The bivariate analysis showed that folate and vitamin B12 serum did not correlate with STM. Our result was inline with Kvestad *et al.* (2020) and Rauh-Pfeiffer *et al.* (2014). Furthermore, Van der Zwaluw *et al.* (2014) explained that vitamin levels could be linked to changes in the brain but not translated to psychological tests in healthy people.

Table 3 also shows that hemoglobin level had no relation with STM. Anemia was associated with lower cognitive function in specific domains, but not for memory (Schneider *et al.* 2015).

A binary logistic regression test was performed to determine the combination of factors that best predict STM scores in children. After being controlled by the covariates, blood glucose level was still found to be correlated with STM ($p<0.05$; OR=1.583; 95% CI:1.067−2.348) (Table 4). It can be interpreted that blood glucose within normal levels has the opportunity by 1.583 times to increase the STM score of the primary school children compared to those who abnormal's.

Kustiyah *et al.* (2005) found similar results with this study, where blood glucose level was positively correlated with STM in primary school children. The human brain is an organ that is much more energetically demanding than other organs, and glucose is the primary energy source for the brain. Several specific neurocognitive mechanisms thought potentially underlie the effects of glucose in the brain in its relation to memory outcomes. However, the most robust theory in terms of empirical evidence is the hypothesis that glucose improves memory via its effects on the synthesis of Acetylcholine (ACh). In addition, there is also a role for insulin, ATP, and extracellular glucose availability in the brain on memory (Smith *et al.* 2011).

Table 3. Output of bivariate analysis between variables and short-term memory score

Variables	Short-term memory (reference=1)		
	B	*p*	OR (95% CI)
BMI-for-age			
Normal (1) Abnormal (0)	0.247	0.186	1.280 (0.888−1.845)
Serum hemoglobin			
Normal (1) Abnormal (0)	0.012	0.927	1.012 (0.780−1.313)
Blood glucose level (mg/dL)			
Normal (1) Abnormal (0)	0.492	0.012*	1.635 (1.114−2.400)
Serum folate (ng/mL)			
>2.5 (1) ≤2.5 (0)	-0.196	0.890	0.822 (0.051−13.188)
Serum vitamin B12 (pg/mL)			
>200 (1) ≤200 (0)	0.093	0.485	1.097 (0.845−1.424)
Gender			
Boy (0) Girl (1)	0.581	0.000*	1.788 (1.374−2.327)
Subject's age (years old)			
>11 (1) ≤11 (0)	0.363	0.008*	1.438 (1.099−1.881)
Taking after-school tutoring programs			
Yes (1) No (0)	0.336	0.054	1.399 (0.994−1.969)
Pocket money (IDR/day)			
≥5,000 (1) <5,000 (0)	0.418	0.016*	1.519 (1.081−2.136)
Father's educational level			
High (1) Low (0)	0.397	0.024*	1.487 (1.055−2.096)
Mother's educational level			
High (1) Low (0)	0.389	0.078	1.476 (0.957−2.275)
Family income (IDR/month)			
≥1,500,000 (1) <1,500,000 (0)	0.318	0.019*	1.374 (1.053−1.792)

*Bivariate analysis, simple logistic regression test significantly at $p<0.05$; B: Constant-Coefficient; OR: Odds Ratio; CI: Confidence Interval; IDR: Indonesian Rupiah; BMI: Body Mass Index

Oral glucose consumption or acute stress/ emotional arousal will increase the concentration of glucose circulating in the periphery and then distribute to the central nervous system. Glucose increases the synthesis of ACh in the hippocampus, brain insulin secretion, intra-neural ATP levels (production of neurotransmitters), and the availability of extracellular glucose in the brain (to supply the glucose needs for the hippocampus); which in turn acts as a potential mediator of memory enhancement (Smith *et al.* 2011).

Based on the logistic regression test (Table 4), it shows that the value of the Odds Ratio (OR) for sex is higher (OR=1.896; reference value was one for girl) than the OR for blood glucose (1.583). Hence, it is assumed that girls' memory scores are better than the boys' even though boys' blood glucose levels are higher than the girls' (Table 2). In general, women had more significant amounts of estrogen in the dorsolateral prefrontal cortex and the hippocampus, to which these two brain regions are associated closely related to memory (Slotnick 2017). Asperholm *et al.* (2019) show that females in general, have a higher tendency in memory performance, especially in object recall memory (Spets & Slotnick 2019) compared to males. In line with the literature studies, girls' memory was better than boys', measured by remembering pictures or objects. Podila (2019) stated that girls are more motivated than boys to perform well during elementary school. It is also thought to be a contributing factor that causes girls to have better memory scores than boys.

In this study, the subject's ages varied from 8 years to 13 years. Table 4 also shows that the older subject's age, the better the STM score ($p<0.05$; OR=1.567; 95% CI:1.183−2.076). Brenhouse & Andersen (2011) state that cognitive function continues to develop with age, as reflected from the maturation process of the central nervous system. The process continues to occur over time, not only in childhood but also until humans reach adulthood.

As mentioned above in Table 4, factors that were positively associated with STM were blood glucose level, gender, and age ($p<0.05$). People with higher glucose metabolism (related to glucose facilitation effect) performed better on cognitive tasks than those who had low glucose level. Roalf *et al.* (2014) found that older children (late childhood) had a higher brain glucose metabolism than younger ones due to brain maturation. Gur & Gur (2017) also found that brain glucose metabolism was generally higher in girls than boys during this period. Specifically, girls had significantly higher glucose metabolism in the brain regions responsible for memory tasks (hippocampus). While in boys, it performed better in spatial and motoric tasks (Gur & Gur 2017).

Table 4. The final model of variables that predict the short-term memory score

Variables	Short-term memory (reference=1)		
	B	*p*	OR (95% CI)
BMI-for-age			
Normal (1) Abnormal (0)	0.229	0.234	1.258 (0.862−1.834)
Blood glucose level			
Normal (1) Abnormal (0)	0.459	0.022*	1.583 (1.067−2.348)
Gender			
Boy (0) Girl (1)	0.639	0.000*	1.896 (1.443−2.490)
Subject's age (years old)			
>11 (1) ≤11 (0)	0.449	0.002*	1.567 (1.183−2.076)
Taking after-school tutoring programs			
Yes (1) No (0)	0.238	0.187	1.268 (0.891−1.805)
Pocket money (IDR/day)			
≥5,000 (1) <5,000 (0)	0.344	0.055	1.411 (0.992−2.008)
Father's educational level			
High (1) Low (0)	0.252	0.221	1.287 (0.859−1.928)
Mother's educational level			
High (1) Low (0)	0.216	0.406	1.241 (0.746−2.063)
Family income (IDR/month)			
≥1,500,000 (1) <1,500,000 (0)	0.177	0.224	1.193 (0.898−1.586)

Multivariate analysis, binary regression logistic test significantly at $p<0.05$; B: constant-coefficient: OR: Odds Ratio; CI: Confidence Interval; BMI: Body Mass Index: IDR; Indonesian Rupiah

The result of regression analysis in SES are also shown in Table 4. The significant associations were found when SES, consisting of parental education, pocket money, and family income independently analyzed with STM (bivariate analysis shown in Table 3). Nevertheless, when they simultaneously analyzed with other variables (BMI-for ages, subject's ages, and genders) by logistic regression test, the result was found to be not significant.

Piccolo *et al.* (2016) pointed out that age moderates the effects of SES on cognitive performance (including memory domains). The impact of SES on cognitive performance is only prominent until the age of 9 years, while after that, the effect decreases. The influence of the environment and peers becomes more substantial than the socioeconomic influence of the family in the period of age. In addition, the thickness of the brain's cortex also increases and improves cognitive performance. The cortex is continuously developed until the adolescence period is started (Piccolo *et al.* 2016). Therefore, it can be assumed that age reduces the effect of family SES on the subject in this study (Table 4).

Although gender and age affect the subject's memory score, the blood glucose level is a factor that is modifiable in terms of achieving a more optimal memory performance. However, further studies are essential to be conducted regarding nutrition and gender on memory performance. Our study implies that optimal blood glucose levels are essential for elementary school children to optimize their memory performance during school. One way to keep the blood glucose level optimal is having healthy breakfast regularly before school. Various studies have shown a strong relationship between breakfast habits and blood glucose levels in school children (Tang *et al.* 2017). Some limitations deserve attention in future studies. Firstly, no measurement of stress level and motivation is carried out in this study to influence cognitive performance. In addition, the instrument of memory test measurement was only for remembering pictures that could not be enough to describe the STM of all subjects however it is universal enough for cross culture use. Besides the limitations, this study also had strengths where a large sample size was collected, a direct measurement for short-term memory with a universal tools conducted by trained professional was used, and many covariates were adjusted. We also presented the many nutritional biomarkers that may contribute to cognitive ability, which are still rarely found in Indonesian research related to STM among school children.

Further research is needed to deepen the study results and clarify the influence of nutritional factors that can affect the subject's memory ability.

Furthermore, the test instrument used to measure STM scores can be made more varied (not only by remembering pictures) to describe the memory abilities of school-age children in more detail.

CONCLUSION

Blood glucose levels were positively correlated to STM scores ($p<0.05$) with an odds ratio of 1.583 (95% CI:1.067−2.348) after being controlled by BMI-for age, subject's age, gender, tutoring after class, pocket money, parents' educational level, and family income among primary school children grade 4^{th} and 5^{th}. Students with normal blood glucose level have 1.583 times opportunity to have better short-term memory score compared to those who have low blood glucose level.

Suggestion for future research include utilizing a more robust design (Randomized control trial) as well as adding other variables such as the subject's motivation in learning and stress level. The authors also suggest parents to provide regular breakfast for their children to keep their blood glucose at a normal level when participating in school activities. In addition, parents are also expected to provide balanced and varied nutritious food every day so that the children's nutritional needs are met to maintain health and optimize their overall cognitive performance.

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DECLARATION OF CONFLICT OF INTERESTS

All authors have no conflict of interest in the research.

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