April – June, 2025
Original Article
DOI: http://dx.doi.org/10.30867/action.v10i2.2172
| Pages: 245 – 253 |
AcTion:
Aceh Nutrition Journal
p-issn 2527-3310; e-issn 2548-5741

Glucose levels, diabetes duration, vitamin intake and their association with cognitive function in patients with type 2 diabetes mellitus

Kadar glukosa, durasi diabetes, asupan vitamin dan hubungannya dengan fungsi kognitif pasien diabetes mellitus tipe 2

Khairizka Citra Palupi[1*], Siti Irma Durotunisa[2], Rachmanida Nuzrina[3], Yulia Wahyuni[4], Harna[5]

[1] Department of Nutrition Science, Faculty of Health Science, Esa Unggul University, West Jakarta, Indonesia.
E-mail: khairizka.citra@esaunggul.ac.id
[2] Department of Nutrition Science, Faculty of Health Science, Esa Unggul University, West Jakarta, Indonesia.
E-mail: durotunisairma@gmail.com
[3] Dietetic Profession Education, Esa Unggul University, West Jakarta, Indonesia.
E-mail: rachmanida.nuzrina@esaunggul.ac.id
[4] Department of Nutrition Science, Faculty of Health Science, Esa Unggul University, West Jakarta, Indonesia.
E-mail: yulia.wahyuni@esaunggul.ac.id
[5] Department of Nutrition Science, Faculty of Health Science, Esa Unggul University, West Jakarta, Indonesia.
E-mail: harna@esaunggul.ac.id

***Correspondence Author:**
Department of Nutrition Science, Faculty of Health Science, Esa Unggul University, West Jakarta, Indonesia.
E-mail: khairizka.citra@esaunggul.ac.id

Article History:
Received: September 20, 2024; Revised: November 01, 2024; Accepted: February 17, 2025; Published: June 10, 2025.

Publisher:
Politeknik Kesehatan Aceh
Kementerian Kesehatan RI

Abstract

Type 2 Diabetes Mellitus may also contribute to cognitive decline. Risk factors for cognitive decline in patients with type 2 DM include demographic characteristics, clinical conditions, and nutritional intake. However, there is controversy regarding whether micronutrient intake affects cognitive function among type 2 DM. Thus, we aimed to investigate the determinants of cognitive function in patients with type 2 diabetes mellitus. A cross-sectional design was used in this study. This research was conducted in Marzoeki Mahdi Hospital, Bogor, West Java, from May to June 2023 among 98 respondents. Data on blood glucose levels (HbA1c) were obtained from medical records over the last three months. Nutritional intake was assessed using the SQ-FFQ and cognitive function was assessed using the MoCA-Ina. A significant relationship was found between blood glucose levels, age, illness duration, and cognitive function (r=-0,212, p=0,036; r=-0,736, p=0,0001; r=-0,573, p=0,0001). However, there was no significant relationship between vitamin B12 or C intake and global cognitive function (r=-0,005; p=0,959, r=0,126; p=0,217). There was a relationship between vitamin C and aspects of cognitive function, namely, abstraction (r=0,350, p=0,0001). In conclusion, there is a relationship between blood glucose levels, age, and duration of DM and cognitive function. Vitamin C consumption is associated with abstraction ability.

Keywords: Blood glucose levels, cognitive function, duration of DM, type 2 DM, vitamin

Abstrak

Diabetes melitus tipe 2 memicu penurunan fungsi kognitif. Faktor risiko penurunan fungsi kognitif pada pasien dengan diabetes melitus tipe 2 meliputi karakteristik demografi, kondisi klinis, dan asupan gizi. Namun, masih ada kontroversi pada penelitian apakah zat gizi mikro mempengaruhi fungsi kognitif diantara pasien DM tipe 2. Oleh karena itu, kami bertujuan menginvestigasi faktor determinan fungsi kognitif pada pasien diabetes tipe 2. Kami menggunakan desain cross-sectional untuk penelitian ini. Penelitian dilakukan di RS Marzoeki Mahdi, Jawa Barat dari Mei-Juni 2023 pada 98 responden. Data kadar glukosa darah (HbA1c) diperoleh dari data rekam medis selama 3 bulan terakhir. Pengukuran asupan makan menggunakan SQ-FFQ dan fungsi kognitif dikaji dengan MoCA-Ina. Hasil, menunjukkan ada hubungan antara kadar glukosa darah (r=-0,212; p=0,036), usia (r=-0,736; p=0,0001), dan lama menderita DM (r=-0,573; p=0,0001) dengan fungsi kognitif . Namun, tidak ada hubungan yang bermakna antara asupan vitamin B12 (r=-0,005; p=0,959) dan vitamin C (r=0,126; p=0,217) secara umum dengan fungsi kognitif global. Ada hubungan antara vitamin C dengan aspek fungsi kognitif yaitu abstraksi (r=0,350;p=0,0001). Kesimpulan, terdapat hubungan antara kadar glukosa darah, usia, dan durasi DM terhadap fungsi kognitif. Konsumsi vitamin C berhubungan dengan kemampuan abstraksi.

Kata Kunci: DM tipe 2, fungsi kognitif, kadar glukosa darah, lama menderita DM, vitamin

Introduction

The International Diabetes Federation (IDF) estimated that at least 483 million individuals aged 20-79 years globally were affected by diabetes mellitus in 2019. Indonesia ranks seventh among these countries, with a prevalence rate of 10,7% (Kemenkes RI, 2020). The prevalence of type 2 Diabetes Mellitus in Bogor City was 12,273 individuals in 2019, increasing to 19,694 by 2020 (Dinkes Jabar, 2022). Type 2 diabetes mellitus is the most prevalent form of diabetes (Salim & Hasibuan, 2016) and represents a substantial disease burden in terms of morbidity, mortality, and disability (Molina-Sotomayor et al., 2020). Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from abnormalities in insulin secretion, insulin function, or both (Bhatt et al., 2016). Type 2 Diabetes Mellitus may increase the risk of cognitive decline and dementia (Nurhayati et al. 2022; Nuraisyah 2018). The risk of developing cognitive impairment is 1.5 times higher and eight times more prevalent in patients with type 2 diabetes mellitus than in individuals without diabetes (Saedi et al., 2016). Cognitive disorders found in patients with type 2 DM are generally characterized by a decrease in memory, concentration, and learning processes, short-term memory ability, speaking fluency, decreased psychomotor speed, and reduced frontal lobe/executive function (Hye-geum, 2019; Munshi, 2017).

HbA1c is a strong predictive marker of cognitive decline in patients with type 2 diabetes mellitus. Prolonged hyperglycemia, neuroinflammation, and vascular disorders contribute to the development of complications characterized by impaired cognitive function in patients with diabetes mellitus (Meloh et al., 2015; Salim & Hasibuan, 2016). These complications may disrupt various systems, particularly the central nervous system, which is involved in cognitive function (Meloh et al., 2015). High serum HbA1c levels can lead to a 10% faster decline in cognitive function compared to normal HbA1c levels (Doroodgar et al., 2019).

Cognitive impairment in patients with type 2 diabetes mellitus is influenced by various factors, including demographic characteristics (age, sex, and education level), clinical characteristics, and accompanying vascular risk factors (Xia et al., 2019; Xia et al., 2020). Studies have demonstrated that lifestyle factors, including nutritional status, dietary patterns, and specific micronutrients and food components, are associated with cognitive function (Ogawa, 2014).

Age is a non-modifiable risk factor for type 2 diabetes. In patients with DM aged 35–64 years, high HbA1c levels were associated with low cognitive function (Chentli et al., 2015). In addition, the duration of DM and glycemic control are important factors in the pathogenesis of decreased cognitive function in patients with type 2 DM (Meloh et al., 2015). Prolonged DM is related to chronic hyperglycemia, which may change the function and structure of the microvasculature in the central nervous system and influence the development of atherosclerosis in the blood vessels that supply blood to the hippocampus, which can cause a decline in cognitive function (Salim & Hasibuan, 2016).

Several vitamins that affect cognitive function have been identified. However, the relationship between vitamin B12 levels and cognitive decline remains controversial. Several studies have shown that elevated homocysteine levels may be an independent risk factor of impaired cognitive function (Kim et al. 2014). Studies have shown that a faster cognitive decline is associated with lower serum vitamin B12 levels. However, a longitudinal aging study by Amsterdam et al. found no association between vitamin B12 levels and cognitive decline (Kommer et al. 2017). In addition to vitamin B12, vitamin C has also been identified as an antioxidant that protects against oxidative stress and cognitive impairment. Participants with a lower intake of vitamin C experienced cognitive impairment compared to those with adequate intake of vitamin C (Rahmawati et al., 2012). However, there is limited evidence of nutritional factors affecting cognitive function among patients with type 2 DM in Indonesia.

Currently, public attention and knowledge regarding impaired cognitive function, which is influenced by prolonged hyperglycemia and lifestyle factors such as micronutrient intake, are still lacking in Indonesia. Therefore, this study aimed to analyze the relationship between blood glucose levels, intake of vitamin B12, and vitamin C, and cognitive function in patients with type 2 diabetes mellitus at Hospital Dr. H. Marzoeki Mahdi. Hypothesis that micronutrient intake affects cognitive function in patients with type 2 diabetes.

Methods

This was a quantitative, cross-sectional study. This research was conducted from May to June 2023 at Hospital Dr. H. Marzoeki Mahdi Bogor. The sampling technique used non-probability sampling with a purposive sampling method, which is widely used in clinical settings. The total sample size in this study was 98. The inclusion criteria were patients with type 2 DM, aged 40-60 years, having undergone an HbA1c examination within the last 3 months of data collection, able to communicate well, and willing to be a respondent. The exclusion criteria were patients with visual and hearing impairments, inability to read and write, patients suffering from type 2 DM with comorbidities such as Parkinson's disease, personal history of stroke, head trauma, brain tumors, HIV/AIDS, epilepsy, depression, or other mental illnesses. This study was approved by the Research Ethics Committee of Esa Unggul University (number: 0923-05.043/DPKE-KEP/FINAL-EA/UEU/IV/2023).

Data collection included general characteristics (age, sex, education, illness duration, and comorbidities), blood glucose level (HbA1c), dietary intake, and cognitive function. Sample identity data were obtained by filling out a questionnaire and conducting interviews with the respondents. Data on blood glucose levels (HbA1c) were obtained by collecting data from the medical records of respondents who underwent examinations for a maximum of 3 months from data collection. Data on dietary quality and quantity were obtained through interviews using the SQ-FFQ form (Semi Quantitative Food Frequency Questioner) with a kappa value of 0,21 (Syauqy et al., 2021). Cognitive function data were obtained using the MoCA-Ina questionnaire (Montreal Cognitive Assessment, version Indonesia*)*, with a sensitivity value of 90% and specificity of 87%. MoCa-Ina assesses domains of cognitive function, such as executive function, visuospatial function, language, delayed recall, attention, memory, abstraction, and orientation (Husein et al., 2010). The MoCA-Ina questionnaire has been widely used for patients with type 2 Diabetes in Indonesia (Putra et al., 2019).

Data analysis included both univariate and bivariate analyses. Univariate analysis was performed to obtain an overview of the distribution of each independent and dependent variable to produce a frequency distribution table. Bivariate analysis was performed to analyze the relationship (blood glucose levels, vitamin B12 intake, vitamin C intake) and cognitive function in patients with type 2 diabetes mellitus at H. Marzoeki Mahdi Hospital Bogor. All variables in the bivariate analysis used a ratio measuring scale. Data analysis was performed using Spearman's correlation test after testing the data for normality with 95% confidence intervals.

Result and Discussion

Respondent characteristics

In this study, 98 patients with type 2 DM underwent outpatient treatment at our hospital. H. Marzoeki Mahdi who met the inclusion and exclusion criteria was included in the research as a research subject. Based on the results of the analysis, it can be seen that the age of Type 2 DM patients is dominated by aged 56-60 years with as many as 48 people (49,0%), and there were more female respondents than men (62 people, 63,3%); the education level of the respondents was the highest, namely elementary school, 41 people (41,8%), respondents with an average illness of 6-10 years, 39 people (39,8%), and the respondents with the most comorbidities, namely hypertension, were 33 people (33,7%), as shown in Table 1.

Table 1. Characteristics of respondents

Characteristics	n	%
Age		
40-45	8	8,2
46-55	42	42,9
56-60	48	49,0
Gender		
Man	36	36,7
Women	62	63,3
Education		
Elementary School	41	41,8
Junior High School	8	8,2
Senior High School	38	38,8
College	11	11,2
Duration of DM (year)		
1-5	37	37,8
6-10	39	39,8
11-15	22	22,4
Concomitant Disease		
There isn't any	50	51,0
Hypertension	33	33,7
Dyslipidemia	3	3,1
CHF (Congestive Heart Failure)	6	6,1
CKD (Chronic Kidney Disease)	2	2,0
CAD (Coronary Artery Disease)	4	4,1

Table 2 shows that the average cognitive function score is 21,72 in the age range of 40-60 years, where the minimum value is 14 and the maximum value is 28. From the research results, it is also known that 82,7 percent of the respondents with impaired cognitive function had a score <26. The average length of time respondents suffered from DM was 7,37 ± 3,63 with a minimum value of 1 and a maximum value of 15. The average blood glucose level (HbA1c) for type 2 DM patient was 9,02 ± 2,35, where the minimum value for Hba1c levels was 5,2% and the maximum value was 15%. The average intake of Vitamin B12 was 1,68 mcg where the minimum intake value is 0,2 mcg and maximum value were 9,9 mcg. The average value of Vitamin C intake is 27,25 mg where the minimum intake value is 3,7 mg and the maximum value is 147,8 mg. Based on the research, the majority of respondents' blood glucose levels were uncontrolled (HbA1c ≥6,5%), as much as 86,7 percent. Most respondents' vitamin B12 intake was deficient (92,9%). Most of the respondents' vitamin C intake was deficient (93,9%)

Table 2. Blood glucose levels, age, duration of DM, vitamin B12 and C intake, and cognitive function

Variable	Min-Max	Mean±SD
Blood Glucose Level (HbaIc) (%)	5,2-15	9,02±2,35
Age	40-60	54,12±5,93
Duration of DM (year)	1-15	7,37±3,63
Vitamin B12 (mcg)	0,2-9,9	1,68±1,64
Vitamin C (mg)	3,7-147,8	27,25±27,68
Cognitive Function	14-28	21,72±3,47

Relationship between Blood Glucose Levels, Vitamin B12 and Vitamin C Intake with Cognitive Function

The results in Table 3 show that there is a significant negative relationship between blood glucose levels and cognitive function (r=-0,212; p=0,036), blood glucose levels and age (r=-0,736; p=0,0001), blood glucose levels, and length of DM (r=-0,573; 0,0001). From these results, it is clear that the relationships between the variables are negatively correlated. There was no significant relationship between vitamin B12 intake and cognitive function (p>0,05), with a correlation value of -0,005. There was no significant relationship between vitamin C intake and cognitive function (P >0,05), with a correlation coefficient of 0,126.

Table 3. Relationship between blood glucose levels, age, duration of DM, vitamin B12 and vitamin C intake with cognitive function

Variable	Cognitive Function	
	Correlation (r)	p-value
Blood Glucose Level (Hba1c)	-0,212	0,036*
Age	-0,736	0,0001*
Duration of DM	-0,573	0,0001*
Vitamin B12 Intake	-0,005	0,959
Vitamin C Intake	0,126	0,217

Relationship between Blood Glucose Levels, Age, Duration of DM, Vitamin B12 and Vitamin C Intake with Aspects of Cognitive function

Table 4 shows how the variables relate to the aspects of cognitive function, namely visuospatial/executive function, naming, attention, language, abstraction, memory, and orientation. Blood glucose levels were associated with decreased memory function. Elevated HbA1C levels are significantly and inversely correlated with cognitive function. Age had a significant relationship with a decline in all cognitive functions. The duration of type 2 DM is significantly related to negative correlations with executive function, naming, attention, memory, and orientation. Vitamin C was associated with a decrease in abstraction function, whereas Vitamin B12 did not have a significant relationship with a decrease in cognitive function.

HbA1c is used as the most appropriate benchmark in diabetes management to determine whether a person can control their blood sugar because it can assess the effectiveness of therapy by monitoring long-term blood glucose regulation within 4 weeks to 3 months and is used as a gold standard in measuring glycemic levels related to brain volume and cognitive performance (Ravona-Springer et al., 2014).

The results of the research showed that there is a significant relationship between blood glucose levels (HbA1c) and cognitive function, and that the relationship between variables is negatively correlated, which means that the higher the blood glucose level, the lower the cognitive function. This is also in line with research conducted by Kawamura (2014), which states that there is a correlation between blood sugar control and decreased cognitive function and that worsening glucose control can cause worsening cognitive function in respondents (Kawamura et al., 2014). Impaired cognitive function in patients with diabetes mellitus is influenced by chronic hyperglycemia and fluctuating blood sugar levels. The results of the study showed that uncontrolled blood sugar levels significantly increased the risk of impaired cognitive function 3,69 times compared to middle-aged adult type 2 DM sufferers. and controlled blood sugar levels (Nugroho et al. 2016).

Table 4, Relationship between blood glucose levels, age, duration of DM, vitamin B12 and vitamin C intake with aspect of cognitive function

		HbA1C	Age	Duration of DM	Vitamin C	Vitamin B12
Visuospatial	r	-0,078	-0,472	-0,393	-0,003	-0,125
/Executive	p-value	0,443	0,0001*	0,0001*	0,979	0,221
Naming	r	0,001	-0,389	-0,266	0,033	0,060
	p-value	0,994	0,0001*	0,008*	0,750	0,559
Attention	r	-0,076	-0,385	-0,373	0,131	-0,047
	p-value	0,458	0,0001*	0,0001*	0,199	0,643
Language	r	0,065	-0,221	-0,093	0,023	-0,115
	p-value	0,525	0,029*	0,363	0,821	0,259
Abstraction	r	-0,024	-0,304	-0,173	0,350	0,097
	p-value	0,818	0,002	0,089	0,0001*	0,340
Memory	r	-0,193	-0,793	-0,594	0,084	0,007
	p-value	0,050*	0,0001*	0,0001*	0,409	0,946
Orientation	r	-0,153	-0,440	-0,376	0,016	0,063
	p-value	0,133	0,0001*	0,0001*	0,876	0,535

Glycemic control appears to play a role in determining the degree of cognitive dysfunction in patients with type 2 diabetes, although this has not been uniformly recognized (Kim, 2019). Hyperglycemia and insulin resistance can result in chronic complications in patients with type 2 DM with long-term treatment, namely macrovascular, microvascular, and neuropathy complications that can cause changes and disorders in various systems, including the central nervous system, which are related to cognitive function (Meloh et al., 2015).

Based on the results of the analysis, the memory domain is known to decrease or impair cognitive function. From these results, it is known that the relationship between variables is negatively correlated, which means that the higher the blood glucose level, the more impaired the cognitive function domain, namely memory. It is necessary to control blood glucose levels (HbA1C) to maintain cognitive function and increase the quality of life. The mechanism through which insulin influences memory may involve several pathways. The first is the role of insulin in the energy metabolism in the brain. Insulin is thought to increase the translocation of GLUT4 (a glucose transporter) in the brain. Beta-cell dysfunction in diabetes can interfere with insulin secretion, reduce insulin levels in the brain, and affect this mechanism, causing glucose dysregulation. In addition, impaired insulin signaling in diabetes may also affect this process, leading to impaired glucose metabolism, which can affect neuronal development, learning, and memory (Cerasuolo et al., 2017). Uncontrolled blood glucose levels can cause toxic effects on the brain (Okaniawan & Agustini, 2021). The presence of oxidative stress and accumulation of advanced glycation end products (AGEs) have the potential to damage brain tissue in the hippocampus. The hippocampus, in the cognitive domain, is involved in the formation of long-term memory and learning processes, such as concentration, calculation ability, remembering new things in the long term, and remembering in the short term (Voss et al., 2018).

The results of the analysis showed that the average age of the respondents was 54 years and was dominated by middle-aged to elderly adults. The results of the correlation tests between age and cognitive function showed that age had a significant relationship with a decline in all cognitive functions. The average duration of suffering is seven years, with a range of 1-15 years, which shows that long suffering from DM has a significant relationship with a decrease in executive function, naming, attention, memory, and orientation. In executive/visuospatial function, it is known that as a person gets older, a or person's executive function will decrease so that it will be more difficult to solve problems, create new things, and tend to follow or repeat previously known methods.

In the language domain, naming, sentence repetition, and fluency were assessed. In terms of naming parameters, namely, the ability to refer to objects, in this case animals, from the results of univariate analysis, it is known that the average respondent cannot answer the questionnaire questions well, indicating the respondent's cognitive ability to process what is seen by providing a response in the form of being able to say the name of the object. that's not good. The respondents experienced difficulties in terms of fluency because their ability to process quickly had decreased. In general, the pre-elderly group has a weak function in understanding and repeating words spoken by other people but is still good at naming certain objects (Byczewska & Konieczny, 2020).

In the attention function, it is difficult to quickly digest information. This is in line with research by Huntley et al. (2018) that, with increasing age, attentional abilities will decrease in digesting information quickly, directing focus on certain information, and tending to avoid and divert irrelevant information (Huntley et al., 2018). In the abstraction domain, respondents' cognitive abilities in the abstraction domain, namely the ability to state the similarities of an object, is not good. The most important factors in abstraction ability are information processing speed, inhibitory control, and working memory.

The results showed that the respondents experienced a decline in the memory domain. Memory decline associated with aging is episodic. The Assocoative Deficit Hypothesis (ADH) argues that episodic memory deficits are caused by a decrease in the ability to bind different components of an episode during memory encoding, and in the ability to access these memories (Huntley, 2018). Low memory scores indicate decreased ability to recall certain information after a period of rest or distraction from that information.

In the orientation domain, it focuses on the abilities that make it possible to be aware of oneself and the context in which one finds oneself at a certain moment; in this case, it is time oriented. In this study, the average respondent's ability in the orientation domain was not fully oriented toward manifesting themselves personally (self-identity), temporally (time), or spatially (space, place).

The results of the correlation test using the Spearman test carried out in this study on the variable vitamin B12 intake and cognitive function, presented in Table 3, show that there was no significant relationship between vitamin B12 intake and cognitive function. The results of this study are not in line with those of previous studies that stated that vitamin B12 was positively correlated (Setyowati et al., 2019). The low intake of vitamin B12 in this study may have been caused by a lack of vitamin B12 intake from the respondents' daily food, such as consuming animal protein, which is a source of vitamin B12, and consuming more vegetable protein as the main side dish. This is in line with research by Setyowati (2019), who examined vitamin B12 intake in the elderly, stating that most elderly people do not have sufficient vitamin B12 intake because of the low intake of animal protein; they consume more vegetable protein in their daily menus, such as tofu and tempeh.

The relationship between vitamin B12 and neurogenesis is well established. Vitamin B12 (cobalamin) is an important vitamin required for DNA synthesis and the maintenance of nerve myelin integrity. In theory, vitamin B12, together with other vitamins (folate and B6), plays a role in converting folate into the active form and in the normal metabolic function of all cells, especially cells of the gastrointestinal tract, bone marrow, and nervous tissue. Vitamin B12 deficiency is a risk factor for diabetic complications related to hyperhomocysteinemia. Conversion of homocysteine to methionine is controlled by vitamin B12 and folic acid during the remethylation cycle. Vitamin B12 protects arteries from damage due to the influence of homocysteine by converting it into cysteine, which is ultimately excreted in urine. Vitamin B12 itself has very sensitive properties and is easily damaged when exposed to physical or chemical conditions, including the presentation of food and the use of preservatives, which results in low levels of vitamin B12. In addition, not all human bodies can activate vitamin B12 even if the intake is sufficient, which can cause an increase in homocysteine levels (Stover, 2016). For example, in elderly people, lack of vitamin B12 intake often occurs due to decreased appetite, lack of vitamin B12 intake because in elderly people the function of the taste buds usually decreases, intestinal malabsorption occurs and the inability to release vitamin B12 from food protein (Salsabila, 2020).

The results of the Spearman correlation test carried out on the variable vitamin C intake and cognitive function, which are presented in Table 3, show that there was no significant relationship between vitamin C intake and cognitive function. This finding is in line with research by Sinambela (2018), who found no significant relationship between vitamin C intake and cognitive function (Sinambela, 2018). Vitamin C is an important redox homeostatic factor in the central nervous system, and one study linked inadequate dietary intake of Vitamin C with negative effects on cognitive performance (Hansen et al., 2014). The low intake of vitamin C among respondents in this study was due to changes in their consumption patterns and a lack of food intake containing vitamin C from foods such as vegetables and fruits. In a study by Gray *et al.* (2008), 2,969 participants (≥65 years) were followed for an average of 5,5 years and there was no significant effect of Vitamin C, Vitamin E, or multivitamins, which was associated with a reduced incidence of cognitive impairment or dementia.

Vitamin C is an important antioxidant in the brain and has been reported to have many functions, including scavenging reactive oxygen species, neuromodulation, and angiogenesis. Antioxidants improve the immune system and reduce free radicals caused by hyperglycemia. Antioxidants, which are sources of vitamin C, are found in fresh fruits and vegetables (Wulansari 2020). Accumulation of damaged membrane lipids and DNA by free radicals and reactive oxygen species disrupts cell function and nerve death. Antioxidants such as vitamin C are one of the body's natural defense mechanisms against oxidative stress.

Cognitive decline among patients with type 2 diabetes is multifactorial and can be caused by several factors such as demographic characteristics (age, sex, and level of education), clinical characteristics (length of illness, glycemic control, and treatment), and other factors. Other vascular risk factors such as comorbidities (hypertension, dyslipidemia, central obesity, smoking, and coronary heart disease); therefore, to evaluate the causes of cognitive decline, a multifactorial assessment must be performed.

A limitation of this study is that we did not examine other factors that may influence cognitive function, such as income level, food expenditure, and social environment. Micronutrient assessments of vitamins C and B were obtained from food sources in the food frequency questionnaire.

Conclusion

In this study, we concluded that there is a relationship between blood glucose levels and cognitive function in patients with type 2 DM. Marzoeki Mahdi Bogor Hospital. This shows that glucose levels that are not well controlled may reduce cognitive function; therefore, appropriate therapy and preventive measures are needed, such as early education or counseling among patients with type 2 DM, so that a worse decline in cognitive function, such as dementia, can be suppressed and patients' quality of life improves.

Acknowledgments

Thank you to Dr. H. Marzoeki Mahdi Bogor Hospital and outpatients with type 2 DM who were willing to become respondents so that the research could be carried out well. This manuscript has been included in the Scientific Article Writing Training (SAWT) Batch IX, GREAT 4.1e Work Program, Undergraduate Nutrition Study Program, Faculty of Health Sciences, Esa Unggul University.

References

Bhatt, H., Saklani, S., & Upadhayay, K. (2016). Anti-oxidant and anti-diabetic activities of ethanolic extract of Primula Denticulata Flowers. *Indonesian Journal of Pharmacy*, *27*(2), 74–79. https://doi.org/10.14499/indonesianjpharm27iss2pp74

Cerasuolo, J. O., Cipriano, L. E., Sposato, L. A., & Kapral, M. K. (2017). Population-based stroke and dementia incidence trends: age and sex variations. *Alzheimer's & Dementia*, *13*(10), 1081–1088.

Chentli, Farida, Said, A., & Souad, M. (2015). Diabetes mellitus in elderly. *Indian Journal of Endocrinology and Metabolism*, *19*(6), 744–752.

Dinkes Jabar. (2022). Jumlah Penderita Diabetes Melitus Berdasarkan Kabupaten/Kota di Jawa Barat. OPENDATA JABAR. https://opendata.jabarprov.go.id/id/dataset/jumlah-penderita-diabetes-melitus-berdasarkan-kabupatenkota-di-jawa-barat

Doroodgar, M., Doroodgar, M., & Tofangchiha, S. (2019). Evaluation of relation between hba1c level with cognitive disorders and depression in type 2 diabetes mellitus patients. *Open Access Macedonian Journal Of Medical Sciences*, *7*(15), 2462–2466. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6814457/#

Hansen, S. N., Tveden-Nyborg, P., & Lykkesfeldt, J. (2014). Does vitamin C deficiency affect cognitive development and function? *Nutrients*, *6*(9), 3818–3846. https://doi.org/10.3390/nu6093818

Huntley, J., Corbett, A., Wesnes, K., Brooker, H., Stenton, R., & Hampshire, A. (2018). Online assessment of risk factors for dementia and cognitive function in healthy adults. *Int J Geriatr Psychiatry.*, *2*(33), 86–93.

Husein, N., Lumempouw, S. F., Ramli, Y., & Herqutanto. (2010). Uji Validitas dan Reliabilitas Montreal Cognitive Assessment versi Indonesia (MoCA-Ina) untuk Skrinning Gangguan Fungsi Kognitif. *Neurona*, *4*(27), 15–21.

Hye-geum, K. (2019). Cognitive dysfunctions in individuals with diabetes mellitus. *Yeungnam University Journal of Medicine*, *36*(3), 183–191. https://doi.org/10.12701/yujm.2019.00255

Karolina Byczewska, & Konieczny. (2020). *Relation between cognitive and behavioral aspects of dysexecutive functioning in normal aging*. 334–344. https://doi.org/10.1080/23279095.2018.1550409

Kawamura, T., Umemura, T., & Umegaki, H. (2014). Effect of renal impair- ment on cognitive function during a 3-year follow-up in elderly patients with type 2 diabetes: association with microinflammation. *J Diabetes Investig. Epub*.

Kemenkes RI. (2020). Infodatin tetap produktif, cegah, dan atasi Diabetes Melitus 2020. In *Pusat Data dan Informasi Kementerian Kesehatan RI* (pp. 1–10). https://pusdatin.kemkes.go.id/resources/download/pusdatin/infodatin/Infodatin-2020-Diabetes-Melitus.pdf

Kim, H., Kim, G., Jang, W., Kim, S. Y., Chang, N., Nilsson-Ehle, H., Kljakovic, M., Crisp, D., Christensen, H., Thomas, R., Thal, L., Taddei, K., Taddei, T., Trounson, B., Villemagne, V., Ward, V., Ames, D., Masters, C., & Bush, A. (2014). Association between intake of B vitamins and c. *Nutrition Journal 2014 13:1*, *81*(Suppl 2), 1155–1162. https://nutritionj.biomedcentral.com/articles/10.1186/1475-2891-13-118

Kim, H. G. (2019). Cognitive dysfunctions in individuals with diabetes mellitus. *Yeungnam University journal of medicine*, *36*(3), 183-191. https://doi.org/10.12701/yujm.2019.00255

Kommer, T. N. Van Den, Deeg, D. J. H., Flier, W. M. Van Der, & Comijs, H. C. (2017). OUP accepted manuscript. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *73*, 57–64. https://doi.org/10.1093/geronb/gbx151

Li, W., Sun, L., Li, G., & Xiao, S. (2019). Prevalence, influence factors and cognitive characteristics of mild cognitive impairment in type 2 diabetes mellitus. *Frontiers in Aging Neuroscience*, *10*(JUL), 1–7. https://doi.org/10.3389/fnagi.2019.00180

Meloh, M. L., Pandelaki, K., & Sugeng, C. (2015). Hubungan Kadar Gula Darah Tidak Terkontrol Dan Lama Menderita Diabetes Melitus Denganfungsi Kognitif Pada Subyek Diabetes Melitus Tipe 2. *E-CliniC*, *3*(1). https://doi.org/10.35790/ecl.3.1.2015.6837

Molina-Sotomayor, E., Onetti-Onetti, W., Castillo-Rodríguez, A., & González-Jurado, J. A. (2020). Changes in cognitive function and in the levels of glycosylated haemoglobin (HbA1c) in older women with type 2 diabetes mellitus subjected to a cardiorespiratory exercise programme. *Sustainability (Switzerland)*, *12*(12), 1–14. https://doi.org/10.3390/su12125038

Munshi, M. N. (2017). Cognitive dysfunction in older adults with diabetes: What a clinician needs to know. *Diabetes Care*, *40*(4), 461–467. https://doi.org/10.2337/dc16-1229

Nuraisyah, F. (2018). Faktor Risiko Diabetes Mellitus Tipe 2. *Jurnal Kebidanan Dan Keperawatan Aisyiyah*, *13*(2), 120–127. https://doi.org/10.31101/jkk.395

Nurhayati, P., Irham, A. M., Bagus, I. D., & Widya, K. (2022). Hba1c sebagai kandidat biomarker untuk prediksi progesivitas gangguan kognitif terkait diabetes melitus tipe 2. *Jurnal Kedokteran Unram*, *11*(1), 732–738.

Ogawa, S. (2014). Nutritional management of older adults with cognitive decline and dementia. *Geriatrics and Gerontology International*, *14*(SUPPL2), 17–22. https://doi.org/10.1111/ggi.12252

Okaniawan, P. E. P., & Agustini, N. N. M. (2021). Penurunan fungsi kognitif akibat diabetes melitus. *Ganesha Medicine*, *1*(1), 28. https://doi.org/10.23887/gm.v1i1.31708

Putra, M. R., Fithrie, A., & Fitri, F. I. (2019). The Correlation Between Severity of Diabetic Neuropatic with Cognitive Function Disorders in Patients DM. *International Journal of Research Science and Management*, *6*(7), 70-77.

Rahmawati, A., Pramantara, I. D. P., & Purba, M. (2012). Asupan zat gizi mikro dengan fungsi kognitif pada lanjut usia. *Jurnal Gizi Klinik Indonesia*, *8*(4), 195. https://doi.org/10.22146/ijcn.18218

Ravona-Springer, R., Heymann, A., Schmeidler, J., Moshier, E., Godbold, J., Sano, M., Leroith, D., Johnson, S., Preiss, R., Koifman, K., Hoffman, H., Silverman, J. M., & Schnaider Beeri, M. (2014). Trajectories in glycemic control over time are associated with cognitive performance in elderly subjects with type 2 diabetes. *PLoS ONE*, *9*(6). https://doi.org/10.1371/journal.pone.0097384

Saedi, E., Gheini, M. R., Faiz, F., & Arami, M. A. (2016). Diabetes mellitus and cognitive impairments. *7*(17), 412–422. https://doi.org/10.4239/wjd.v7.i17.412

Salim, I. O., & Hasibuan, P. J. (2016). Hubungan kadar glukosa darah sewaktu dan gangguan fungsi kognitif pada pasien diabetes melitus tipe 2 di puskesmas purnama pontianak. *Jurnal Cerebellum*, *2*(1), 385–401.

Salsabila, D. M. (2020). Defisiensi vitamin b12 dan gangguan neurologis. *Jurnal Medika Hutama*, *2*(1), 48–59. https://jurnalmedikahutama.com/index.php/JMH/article/download/71/37/

Setyowati, E., Iman Santosa, N., & Kridawati, A. (2019). Hubungan Asupan Vitamin B12 dan Asam Folat dengan Fungsi Kognitif Lansia. *Jurnal Endurance*, *4*(1), 184. https://doi.org/10.22216/jen.v4i1.2256

Sinambela, M. P. (2018). Hubungan asupan zat gizi (protein, vitamin a, asam folat, vitamin b12 dan vitamin c) dan fungsi kognitif pada lansia di panti werdha wisma mulia kowani jakarta barat tahun 2018. https://digilib.esaunggul.ac.id/hubungan-asupan-zat-gizi-protein-vitamin-a-asam-folat-vitamin-b12-dan-vitamin-c-dan-fungsi-kognitif-pada-lansia-di-panti-werdha-wisma-mulia-kowani-jakarta-barat-tahun-2018-10489.html

Stover , P. (2016). *Vitamin B12 and older adults. Curr Opin Clin Nutr Metab Care, 13*(1): 24-27

Syauqy, A., Afifah, D. N., Purwanti, R., Nissa, C., Fitranti, D. Y., & Chao, J. C. J. (2021). Reproducibility and validity of a food frequency questionnaire (Ffq) developed for middle-aged and older adults in semarang, Indonesia. *Nutrients*, *13*(11). https://doi.org/10.3390/nu13114163

Travica, N., Ried, K., Sali, A., Hudson, I., Scholey, A., & Pipingas, A. (2019). Plasma Vitamin C concentrations and cognitive function: A cross-sectional study. *Frontiers in Aging Neuroscience*, *11*(APR), 1–21. https://doi.org/10.3389/fnagi.2019.00072

Travica, N., Ried, K., Sali, A., Scholey, A., Hudson, I., & Pipingas, A. (2017). Vitamin c status and cognitive function: A systematic review. *Nutrients*, *9*(9), 1–21. https://doi.org/10.3390/nu9090960

Voss, J, Bridge, D, Cohen, N, Walker, J. (2018). A closer look at the hippocampus and memory. *Trends Cogn Sci*, *21*(8), 577–588.

Widie Nugroho, B. A., Oka Adnyana, I. M., & Purwa Samatra, D. P. G. (2016). Gula darah tidak terkontrol sebagai faktor risiko gangguan fungsi kognitif pada penderita diabetes melitus tipe 2 usia dewasa menengah. *Medicina*, *47*(1). https://doi.org/10.15562/medicina.v47i1.71

Wulansari, I. (2020). Hubungan asupan vitamin c dengan kadar glukosa darah pada pasien diabetes mellitus tipe ii di puskesmas tawangsari sukoharjo.

Xia, S.-S., Xia, W.-L., Huang, J.-J., Zou, H.-J., Tao, J., & Yang, Y. (2020). The factors contributing to cognitive dysfunction in type 2 diabetic patients. *Annals of Translational Medicine*, *8*(4), 104–104. https://doi.org/10.21037/atm.2019.12.113