Determinants of Magnesium Intake, Zinc Intake and Body Mass Index (BMI) with Fasting Blood Glucose Levels in the Elderly in Klaten Regency

Aruni Aruan[1], Anik Lestari[2], Eti Poncorini Pamungkasari[3]
[1,2,3]Sebelas Maret University, Surakarta, Indonesia
Email: aruniaruan.abz@gmail.com

Abstract

The International Diabetes Federation (IDF) estimates that the number of diabetics in Indonesia will reach 28.57 million (2045) from 19.47 million (2021). One of the populations that is susceptible to diabetes is the elderly due to decreased organ function. This is a challenge due to the increasing global and Indonesian elderly populations. This study used a cross-sectional design. The subjects of this study were the elderly (≥ 60 years), as many as 158 people with inclusion criteria. Sampling using multistage random sampling technique. Characteristic data obtained from interviews. BMI was obtained from anthropometric measurements (height and weight). Intake of magnesium and zinc was obtained from 2 times food recal 24 hour and SQ FFQ. Fasting blood sugar data obtained from fasting blood sugar examination. Statistical analysis using multiple linear regression. The results showed that the three variables (Magnesium intake, zinc intake, BMI) could have an effect on fasting blood sugar by 7.2%. The model that occurs is GDP = 150.4 + (1.708*BMI) + (-4.16*Intake of Magnesium) + (-0.063*Intake of Zinc). From this model it can be suggested that the elderly consume foods rich in magnesium and zinc and control BMI to avoid increasing fasting blood sugar levels.

Keywords: *Body Mass Index*, *Magnesium Intake*, *Zink Intake*, *Fasting Blood Glucose*, *Elderly.*

– – – – – – – – – – ◆ – – – – – – – – – –

A. INTRODUCTION

The elderly population in the world is increasing every year. Based on data from the World Health Organization shows, elderly population reached 901 million people in 2015 or 12% of the total world population (United Nations, 2015). Population elderly in the world is predicted to 2,1 billion (22%) in 2050 (WHO, 2021a). The Central Bureau of Statistics (BPS) in 2018 also states that the prevalence of the elderly in Indonesia has doubled in the last 50 years (1971-2012). In 2018, the prevalence of the elderly around 24,49 million people (9,27%) and is predicted to increase to 20% in 2045 (BPS, 2018).

The increase in the number of elderly people is inseparable from government programs, especially in the fields of health, housing, and sanitation. However, as the elderly population increases, this age group becomes more susceptible to degenerative diseases due to decreased organ function and one of the degenerative diseases that attack the elderly is diabetes. Diabetes is a chronic metabolic disease characterized by elevated levels of blood glucose, which causes serious damage to the heart, blood vessels, eyes, kidneys, and nerves (WHO, 2021b). Type 2 diabetes or non-

insulin-dependent diabetes mellitus (NIDDM) is most commonly affects by adults to the elderly which is caused by insulin resistance and failure of pancreatic cells to produce insulin (Soelistijo, 2021).

WHO declares diabetes to be one of the four main non-communicable diseases that cause death in the world. In 2019, diabetes was the direct cause of 1,5 million deaths and 48% of all diabetes deaths occurred before the age of 70 year(WHO, 2021c).

The results of Basic Health Research in 2018 show that the prevalence of diabetes according to a doctor's diagnosis for ages 15 years in Indonesia is 2%. The prevalence of diabetes has increased compared to 2013 which was 1,5%. Based on the consensus of the Indonesian Endocrinology Association (PERKENI) stated there was an increase in the prevalence of Diabetes Mellitus (DM) from 6,9% in 2013 to 8,9% in 2018 with the highest prevalence of DM in the age range of 55-64 years (6,3%), 65-74 years (6%), and >75 (7,5%) (Riskesdas, 2018). The International Diabetes Federation (IDF) revealed that the prevalence of diabetes in the world increases with the age of the population. Another prediction suggests that the number of diagnosed cases of diabetes at the age of 65 will increase 4,5-fold between 2005 and 2050 (Halter, 2012).

New DM cases, especially in Juwiring District, Klaten increased from 355 cases (2017) to 544 cases (56.06%) in 2018 (Klaten District Health Office, 2018). The elderly are more susceptible to diabetes because the aging process interferes with insulin secretion from cells in response to endogenous incretion which is associated with decreased insulin sensitivity, thereby triggering cell damage by inducing mitochondrial dysfunction (Chia, Egan and Ferrucci, 2018). In the elderly, abnormalities of insulin sensitivity and insulin secretion gradually lead to impaired glucose tolerance and consequently to clinically manifest diabetes. The aging process in the elderly also causes systemic chronic inflammation, oxidative stress, DNA damage, decreased mitochondrial function, cellular aging, and tissue dysfunction, resulting in metabolic disorders. Postprandial hyperglycaemia is a hallmark of type 2 diabetes in the elderly[10)]. Research conducted in the elderly community in Thailand also shows that there is a significant positive relationship between elderly age and blood sugar levels (Suksatan, Prabsangob and Choompunuch, 2021).

Elderly people who have long-term uncontrolled blood sugar are at risk for limb weakening, disability, illness, and mortality (Yoon and Kim, 2019). In Korea, researchers discovered that the prevalence of geriatric syndromes such as polypharmacy, falls, urinary incontinence, cognitive and functional impairment was significantly higher in the elderly with diabetes than in the elderly without diabetes (Moon *et al*., 2019).

Therefore, it is necessary to check blood sugar levels for early detection of diabetes in the elderly. Other factors that cause diabetes are physical activity, nutritional status, and intake of nutrients (Digestive, 2021).

BMI is the standard used to determine the nutritional status of adults. While nutritional status is a condition caused by a balance between nutrient intake from food and the body's nutritional needs. A person's nutritional status is determined by his nutritional intake and needs (Holil, 2016). According to research conducted in India,

the prevalence of diabetes increases with increasing BMI values, as evidenced by the prevalence of diabetes only 2.4% (BMI <17-18.4), 5% (BMI 18.5-25), 7.5% (BMI 25.1-27)), and 30.4% (BMI > 27) (Medhi et al.., 2021). Multivariate analysis also revealed that obesity was associated with an 8.3-fold increased risk of developing diabetes when compared with people of normal weight. Obesity and overweight are often associated with increased distribution of abdominal and intra-abdominal fat, as well as increased intrahepatic and intramuscular triglyceride levels. This fat distribution is a major risk factor for prediabetes and type 2 diabetes because it causes insulin resistance and pancreatic cell dysfunction (Klein *et al.*, 2022)

Magnesium is an important mineral source that can be found in various food sources such as whole grains, green leafy vegetables, coffee, and nuts. Magnesium is an important cofactor in > 300 enzymatic reactions, including those related to energy metabolism (Hruby *et al.*, 2013). The results of a meta-analysis showed that a diet high in magnesium was associated with a reduced risk of type 2 diabetes and in intervention studies, showed that magnesium intake could improve blood glucose levels and insulin metabolism in healthy adults, people with insulin resistance and type 2 diabetes (Pelczyńska, Moszak and Bogdański, 2022).

In diabetics, adequate intake of magnesium allows glucose and insulin metabolism to occur through insulin receptor tyrosine kinase activity, which depends on the binding of two Mg^{2+} (Piuri *et al.*, 2021). Magnesium also regulates the translocation of glucose into cells, thereby helping in controlling extracellular glucose levels. Diabetes, it will cause reduced insulin receptor activation, resulting in insulin resistance (Barbagallo and Dominguez, 2015). A study conducted by (Zhao *et al.*, 2020) stated that a lower than average magnesium intake had a 22% risk of developing type 2 diabetes compared to a higher magnesium intake

Zinc is an important micronutrient to help the immune system and can reduce the risk of certain diseases, especially the management of diabetes mellitus (Tamura, 2021). Meta-analysis studies show that zinc has an important role in carbohydrate metabolism to prevent type 2 diabetes. In the metabolic system, zinc is involved in the synthesis, storage, crystallization, and secretion, as well as the translocation of insulin into cells. In addition, zinc also plays a role in suppressing pro inflammatory cytokines, such as interleukin-1β and nuclear factor kβ, to prevent pancreatic beta cell damage so that insulin production is maintained (Zhang *et al.*, 2018).

Meta-analysis research conducted by (Fernández-Cao *et al.*, 2019) showed that subjects who consumed adequate zinc intake could reduce the risk of diabetes by 13% and up to 41% in rural residents. Based on this, this study aims to see the relationship between magnesium and zinc intake with fasting blood sugar levels in the elderly.

B. METHOD

1. Design

This study is a cross-sectional analytic observational study. The research was carried out in December 2019 in Klaten. The entire elderly population in the elderly Integrated Healthcare Centre area, Juwiring District, Klaten.

2. Participants and Setting

The target population of this study were all elderly people aged 60 years who were recorded in the Juwiring Health Center, Juwiring District, Klaten. The characteristic inclusion for sample in this study were ≥ 60 years old, had good memory skills and could stand up straight to take anthropometric measurements. The exclusion criteria in this study were that the subject was unable to carry out daily activities, had a disability, and was seriously ill at the time of data collection. The number of elderly who met the criteria in this study were 158 people.

3. Sampling

The research subjects were taken by multistage random sampling of 120 subjects and included 20% lost follow consideration and the elderly who met inclusion and exclusion criteria in this study were 158 people.

4. Instrument & Data Collection

The primary data collected were sample characteristics (gender, age, and education), magnesium intake, zinc intake and fasting blood sugar. Characteristic data were obtained through interviews and the results were recorded in a questionnaire. Gender data are male and female. Age data are 60-64 years, 65-80 years, and > 80 years based on the elderly RDA group. The latest education data is not attending school, elementary school, junior high school, high school, and bachelors. Data on the nutritional status of the subject that has been obtained from measurements of height and weight then the body mass index is calculated.

Data on intake of magnesium and zinc used a food recall 24-hour questionnaire for two non-consecutive days and a semi-quantitative food frequency questionnaire (SQ-FFQ), then calculated to obtain the average daily intake.

Fasting blood sugar (capillary plasma) data was obtained from blood sugar examination using the Easy Touch GCU Multi-Function Monitoring System Model ET-301. Before taking blood samples, subjects were conditioned to fast for 8 hours. The fasting blood sugar sample was taken by the midwife and the results of the fasting blood sugar examination were recorded on the questionnaire.

The secondary data collected were the number of elderly population and the characteristics of the research area obtained from the community Health centres (puskesmas) and the elderly Integrated Healthcare Centre (posyandu) in the Juwiring District, Klaten.

5. Analysis

Characteristic data measurement results are displayed in percentage form. Data on BMI, magnesium intake, zinc intake, and fasting blood sugar are presented based on the min, max, mean and SD values. The determinant between the dependent and independent variables was carried out by testing the multiple linear regression.

C. RESULT AND DISCUSSION

1. Descriptive Statistics Test

Table 1. Frequency Distribution Based on Subject Characteristics Data

Variables	n = 158	%
Age		
50-64	49	31,0
65-80	100	63,3
> 80	9	5,7
Gender		
Man	26	16,5
Woman	132	83,5
Education		
Not attending school	50	31.6
Elementary School	69	43,7
Junior High School	23	14,6
High School	14	8,9
Bachelor	2	1.3

Based on table 1 shows that most respondents were aged 65-80 years (63,3%). This study also showed that most of the subjects were female (83,5%) and the last level of education of the respondents was mostly elementary school (43,7%).

Table 2. Frequency Distribution Based on BMI, Average Magnesium Intake, Zinc Intake, and Fasting Blood Sugar

Variables	Min	Max	$\bar{x}$	SD
BMI (kg/m^2)	11.5	30.5	22.49	3.88
Magnesium intake (mg)	176,6	834,3	429,82	175,56
Zink intake (mg)	4,9	15,7	9,33	2,53
Fast glucose (mg/dl)	45,0	576,0	122,98	74,11

Based on Table 2, it can be shown that an average BMI of 22,49 ± 3.88, which is included in the category of normal nutritional status. The elderly has a BMI range from 11,5 (extremely thin) to 30,5 (obesity), with 30,5 being the highest and 11,5 being the lowest.

The average daily intake of magnesium of subjects at 429,82 ± 175,56 mg. The average magnesium intake of subjects in this study was higher than Indonesia's recommended Dietary Allowance (RDA) for the elderly, which was 320 to 360 mg. The average daily intake of zinc consumed by the subjects was 9,33 ± 2,53 mg. The average daily intake is lower than RDA for the elderly is 25-30 mg.

Fasting blood sugar is carried out after the subject is in a state of fasting for 8 hours. Fasting blood sugar results are classified into not diabetic (< 99 mg/dl), unindicated diabetes (90-99 mg / dl), and diabetes (≥100 mg/dl) (PERKENI, 2015). This study showed an average FBS of 122,98 ± 74,11 mg /dl. Thus, it can be concluded that the average fasting blood sugar of the subject belongs to the category of prediabetes.

2. **Multi variant Analysis**

Table 3. BMI percentage, magnesium intake, zinc intake to FBS

Independent Variable	R Square
BMI, magnesium intake, zinc intake	0.072

The R Square value is 0.072, meaning that BMI, magnesium intake, zinc intake can explain FSB of 7.2% while the rest is explained by other variables (Table 3).

Table 4. Multiple linear regression models

Independent Variable	B	VIF
Constant	150.424	
BMI	1.708	1.196
magnesium intake	-0.063	3.064
zinc intake	-4.166	2.757

Table 4 shows Multiple linear regression models is FBS = 150,424 + (1,708*BMI) + (-0.063*magnesium intake) + (-4.166*zinc intake)

The majority of the subjects in this study (63,3%) were between the ages of 65 and 80. The elderly are the subjects of this study because they are more vulnerable to a decrease in the body's metabolic system, particularly a decrease in the function of pancreatic beta cells in producing insulin, increasing the risk of developing type 2 diabetes mellitus, which is characterized by an increase in fasting blood sugar (FBS)(Mordarska and Zawada, 2017).

The average FBS in the subjects of this study was 122,98 ± 74,11mg / dl which was included in DM category. According to Erika, et al (2018) the elderly must maintain a FBS between 90 to 140 mg/dl and still pay attention to other comorbid diseases (Leung, Wongrakpanich and Munshi, 2018).

The condition of impaired fasting blood sugar (IFBS) in Indonesia is most commonly found in the male sex, but the incidence of DM is most commonly found in the female sex. Women tend to have more risk factors for developing diabetes because there is a gestational risk of diabetes during pregnancy (Fitriani, Murbawani and Nissa, 2018).

Based on the results of multiple linear regression analysis, it was shown that there was a positive relationship between BMI (describing nutritional status) and fasting blood sugar levels in the elderly in this study. This is in accordance with research conducted by (JC Okafor, 2020) which found a significant relationship between blood glucose and nutritional status.

In this study, magnesium intake and zinc intake had a negative relationship with FBS. This is consistent with Lima et al. (2018) meta-analysis study, which found a relationship between magnesium intake and blood sugar profile levels (Brandão-Lima *et al.*, 2018).

Magnesium is an enzyme cofactor involved in glucose metabolism. Magnesium binds ATP molecules, forming mg-ATP complexes that participate in phosphate transfer reactions (Fiorentini *et al.*, 2021). As a result, magnesium aids in the auto

phosphorylation of insulin receptor subunits, as well as the proliferation and maintenance of pancreatic cells(Brandão-Lima *et al.*, 2018).

This study also discovered a link between zinc consumption and fasting blood sugar levels. The analysis showed a negative relationship, implying that the higher the zinc intake, the lower the fasting blood sugar value. This is consistent with research by (Zhang *et al.*, 2018), who discovered a link between low serum zinc levels in the blood and diabetic complications such as diabetic retinopathy, diabetic nephropathy, diabetic neuropathy, and diabetic macro angiopathy.

A meta-analysis conducted by Cao, et al (2019) stated that zinc intake from moderate to higher than RDA can reduce the risk of type 2 diabetes by 13% and can reduce the risk of type 2 diabetes by up to 41% in residents in rural area (Fernández-Cao *et al.*, 2019)

Zinc has a role in insulin homeostasis and inflammatory responses in people with type 2 diabetes. Zinc can affect insulin sensitivity and resistance by activating some insulin secretion cells from pancreatic cells, in addition to that, it also contributes to insulin transport. Zinc-deficient body cells have been shown to have fewer insulin granules and are more susceptible to oxidative stress (Cruz, 2015).

D. CONCLUSION

According to the findings of this study, BMI, intake of magnesium and zinc have a relationship with fasting blood sugar (FBS) in the elderly. The positive relationship is shown by BMI, while the negative relationship is magnesium intake and zinc intake. Therefore, the elderly is advised to consume foods high in magnesium and zinc, and monitor BMI to maintain fasting blood sugar levels within normal limits. It is recommended that the elderly who have fasting blood sugar levels higher than normal (> 100 mg/dl) carry out routine blood sugar checks and consult a nutritionist to regulate eating patterns (type, amount, and schedule).

ACKNOWLEDGMENTS

The researchers would like to thank my thesis supervisors, the head of the Juwiring sub-district health center, the midwife of the sub-district health center, the cadres of the elderly Integrated Healthcare Center (posyandu), and the respondents and their families.

REFERENCES

1. Badan Pusat Statistik (BPS) (2018) *Statistik Lansia 2018*.
2. Barbagallo, M. and Dominguez, L. J. (2015) 'Magnesium and type 2 diabetes.', *World journal of diabetes*, 6(10), pp. 1152–1157. doi: 10.4239/wjd.v6.i10.1152.
3. Brandão-Lima, P. N. *et al.* (2018) 'Intakes of Zinc, Potassium, Calcium, and Magnesium of individuals with type 2 diabetes mellitus and the relationship with glycemic control', *Nutrients*, 10(12), pp. 1–12. doi: 10.3390/nu10121948.
4. Chia, C. W., Egan, J. M. and Ferrucci, L. (2018) 'Age-Related Changes in Glucose Metabolism, Hyperglycemia, and Cardiovascular Risk.', *Circulation research*,

123(7), pp. 886–904. doi: 10.1161/CIRCRESAHA.118.312806.
5. Cruz, K. J. C. (2015) 'Antioxidant role of zinc in diabetes mellitus', *World Journal of Diabetes*, 6(2), p. 333. doi: 10.4239/wjd.v6.i2.333.
6. Digestive, N. I. of D. and K. D. (2021) *Symptoms & Causes of Diabetes*. Available at: https://www.niddk.nih.gov/health-information/diabetes/overview/symptoms-causes (Accessed: 19 July 2022).
7. Dinas Kesehatan Kabupaten Klaten (2018) 'Profil Kesehatan Kabupaten Klaten Tahun 2018'. Dinas Kesehatan Kabupaten Klaten. Available at: https://dinkes.klaten.go.id/.
8. Fernández-Cao, J. C. *et al.* (2019) 'Zinc intake and status and risk of type 2 diabetes mellitus: A systematic review and meta-analysis', *Nutrients*, 11(5), pp. 1–26. doi: 10.3390/nu11051027.
9. Fiorentini, D. *et al.* (2021) 'Magnesium: Biochemistry, Nutrition, Detection, and Social Impact of Diseases Linked to Its Deficiency.', *Nutrients*. Switzerland, 13(4). doi: 10.3390/nu13041136.
10. Fitriani, L. I., Murbawani, E. A. and Nissa, C. (2018) 'Hubungan Asupan Vitamin C, Vitamin E Dan B-Karoten Dengan Kadar Gula Darah Puasa Pada Wanita Usia 35-50 Tahun', *Journal of Nutrition College*, 7(2), p. 84. doi: 10.14710/jnc.v7i2.20827.
11. Ha, N. T., Phuong, N. T. and Ha, L. T. T. (2019) 'How dietary intake of type 2 diabetes mellitus outpatients affects their fasting blood glucose levels?', *AIMS Public Health*, 6(4), pp. 424–436. doi: 10.3934/publichealth.2019.4.424.
12. Halter, J. B. (2012) 'Diabetes Mellitus in an Aging Population: The Challenge Ahead', *The Journals of Gerontology: Series A*, 67(12), pp. 1297–1299. doi: 10.1093/gerona/gls201.
13. Holil, M. P. (2016) *Penilaian Status Gizi*. EGC.
14. Hruby, A. *et al.* (2013) 'Higher magnesium intake is associated with lower fasting glucose and insulin, with no evidence of interaction with select genetic loci, in a meta-analysis of 15 CHARGE consortium studies1-4', *Journal of Nutrition*, 143(3), pp. 345–353. doi: 10.3945/jn.112.172049.
15. JC Okafor, A. A. (2020) 'Nutritional status and blood glucose level of elderly residing in ilaro, Ogun state, Nigeria', *IOSR J Environ Sci Toxicol Food Technol*, 14(2), pp. 14–21. doi: 10.9790/2402-1402011421.
16. Kang, H. M. and Kim, D. (2012) 'Total Energy Intake May Be More Associated with Glycemic Control Compared to Each Proportion of Macronutrients in the Korean Diabetic Population', pp. 300–306.
17. Kemenkes RI (2019) 'Peraturan Menteri Kesehatan Republik Indonesia Nomor 28 Tahun 2019 Tentang Angka Kecukupan Gizi'. PB.PERKENI. Available at: www.ginasthma.org.
18. Klein, S. *et al.* (2022) 'Why does obesity cause diabetes?', *Cell Metabolism*, 34(1), pp. 11–20. doi: 10.1016/j.cmet.2021.12.012.
19. Leung, E., Wongrakpanich, S. and Munshi, M. N. (2018) 'Diabetes Management in the Elderly.', *Diabetes spectrum : a publication of the American Diabetes Association*, 31(3), pp. 245–253. doi: 10.2337/ds18-0033.

20. Medhi, G. K. *et al.* (2021) 'Prevalence of Diabetes and Its Relationship With Body Mass Index Among Elderly People in a Rural Area of Northeastern State of India.', *Cureus*, 13(1), p. e12747. doi: 10.7759/cureus.12747.
21. Moon, S. *et al.* (2019) 'Clinical Features of Geriatric Syndromes in Older Koreans with Diabetes Mellitus.', *Annals of geriatric medicine and research*. Korea (South), 23(4), pp. 176–182. doi: 10.4235/agmr.19.0041.
22. Mordarska, K. and Zawada, G. M. (2017) 'Diabetes in the elderly.', *Przeglad menopauzalny = Menopause review*, 16(2), pp. 38–43. doi: 10.5114/pm.2017.68589.
23. Nakrani, M. N., Wineland, R. H. and Anjum, F. (2022) 'Physiology, Glucose Metabolism.', in. Treasure Island (FL).
24. Pelczyńska, M., Moszak, M. and Bogdański, P. (2022) 'The Role of Magnesium in the Pathogenesis of Metabolic Disorders', *Nutrients* . doi: 10.3390/nu14091714.
25. Piuri, G. *et al.* (2021) 'Magnesium in Obesity, Metabolic Syndrome, and Type 2 Diabetes.', *Nutrients*, 13(2). doi: 10.3390/nu13020320.
26. Riskesdas, K. (2018) 'Hasil Utama Riset Kesehata Dasar (RISKESDAS)', *Journal of Physics A: Mathematical and Theoretical*, 44(8), pp. 1–200. doi: 10.1088/1751-8113/44/8/085201.
27. Soelistijo, S. A. (2021) *Pedoman Pengelolaan Diabetes Melitus Tipe 2 di Indonesia 2021*. PB.PERKENI.
28. Suksatan, W., Prabsangob, K. and Choompunuch, B. (2021) 'Association between Health Literacy, Self-care Behavior, and Blood Sugar Level among Older Patients with Type 2 Diabetes in Rural Thai Communities.', *Annals of geriatric medicine and research*. Korea (South), 25(4), pp. 318–323. doi: 10.4235/agmr.21.0117.
29. Tamura, Y. (2021) 'The Role of Zinc Homeostasis in the Prevention of Diabetes Mellitus and Cardiovascular Diseases.' *Journal of atherosclerosis and thrombosis*, 28(11), pp. 1109–1122. doi: 10.5551/jat.RV17057.
30. United Nations (2015) *World Population Ageing 2015*, *Demographic Research Monographs*. doi: 10.1007/978-3-642-12612-3_2.
31. WHO (2021a) *Ageing and health*. Available at: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health (Accessed: 21 July 2022).
32. WHO (2021b) *Diabetes*. Available at: https://www.who.int/health-topics/diabetes#tab=tab_1 (Accessed: 21 July 2022).
33. WHO (2021c) *WHO reveals leading causes of death and disability worldwide: 2000-2019*. Available at: https://www.who.int/news/item/09-12-2020-who-reveals-leading-causes-of-death-and-disability-worldwide-2000-2019 (Accessed: 21 July 2021).
34. Yoon, S.-J. and Kim, K.-I. (2019) 'Frailty and Disability in Diabetes.', *Annals of geriatric medicine and research*. Korea (South), 23(4), pp. 165–169. doi: 10.4235/agmr.19.0036.
35. Zhang, Y. *et al.* (2018) 'Association between serum magnesium and common complications of diabetes mellitus', *Technology and Health Care*, 26(S1), pp. S379–S387. doi: 10.3233/THC-174702.
36. Zhao, B. *et al.* (2020) 'Association of magnesium intake with type 2 diabetes and total stroke: an updated systematic review and meta-analysis', *BMJ Open*, 10(3), p.

e032240. doi: 10.1136/bmjopen-2019-032240.