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Insomnia and its risk factors in patients with type 2 diabetes: A cross-sectional study

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ABSTRACT

Aims: Insomnia is notably prevalent among individuals with type 2 diabetes and adversely affects both glycemic control and overall quality-of-life. The objective of this study was to evaluate the possible risk factors for insomnia in patients diagnosed with type 2 diabetes and co-morbid insomnia.
Methods: This is a baseline study analyzing cross-sectional data at baseline timepoint collected in a randomized controlled trial study. A total of 227 participants with type 2 diabetes and insomnia were recruited. The diagnosis of insomnia was based on Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition and the total score of Insomnia Severity Index. Multiple linear regression model was used to analyze the possible biomedical and mental health risk factors for insomnia severity, total sleep time, sleep efficiency and sleep onset latency.
Results: Factors significantly associated with insomnia severity included fasting blood glucose and depression. Blood magnesium level was related to total sleep time. Sleep efficiency was associated with blood phosphorus. Factors related to sleep onset latency were depression and fatigue.
Conclusion: Factors related to high insomnia severity and poor sleep quality in type 2 diabetes patients with insomnia included fasting blood glucose, blood magnesium, blood phosphorus, depression and fatigue.

1. Introduction

Diabetes mellitus encompasses a spectrum of metabolic disorders characterized by persistent hyperglycaemia [1]. The number of individuals with diabetes across the world has been reported to be 529 million in 2021, and the number has been projected to rise to over 1.31 billion by 2050 [2]. Among the various forms of diabetes, type 2 diabetes is the most prevalent, accounting for over 95 % of all diabetes [2–4]. The elevated mortality and disability rates associated with type 2 diabetes and its complications impose substantial financial burdens on individuals, families and society at large [5]. Type 2 diabetes is a chronic condition that leads to numerous complications, including obesity and cardiovascular diseases [6]. Furthermore, the prolonged presence of type 2 diabetes is linked to adverse mental health outcomes, contributing to the development of conditions such as insomnia, depression and anxiety [7].

Insomnia is a prevalent mental health issue that significantly affects the quality, timing, and duration of sleep, leading to impaired daytime functioning and increased mental distress [8]. Globally, insomnia affects up to 30 % of the population [9]. Research indicates that approximately

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37–50 % of individuals with type 2 diabetes experience sleep disturbances, with the prevalence of insomnia in this group exceeding 30 %, a rate substantially higher than that observed in the general population [10,11]. Moreover, poor blood glucose management in individuals with type 2 diabetes is associated with the onset of insomnia or comorbid insomnia symptoms [12]. For example, insulin or other antidiabetic medications can cause hypoglycaemia during the night, which can lead to irregular sleep patterns such as early wake ups [13]. High blood glucose levels can also impact the sleep by increasing the number of nocturnal urination, and it is common for type 2 diabetes patients to experience thirst, coughs, snores and bad dreams during the night, which make them harder to fall asleep at night and therefore reduce overall sleep quality [12,14,15]. In patients with type 2 diabetes, complications such as neuropathy and pain caused by diabetic foot can also cause early awakenings and fragmented sleep [15,16]. Additionally, mental health problems such as depression and anxiety is very common in patients with type 2 diabetes. The management of type 2 diabetes is stressful, and a chronic presence of diabetes and its complications leads to negative emotions and depressive thoughts, which make symptoms of depression and anxiety worse [17–19].

Trace elements such as potassium, sodium, chlorine, calcium, magnesium and phosphorus are important factors for sleep and glycemic control. Previous study has found that an increased dietary intake of sodium is associated with more nocturnal urination, which is commonly reported in type 2 diabetes patients and could possibly lead to poor sleep quality and short sleep duration [20]. Recent studies have also reported that potassium and magnesium supplementation decreases insomnia severity and prolongs sleep duration in diabetic patients by promoting the production of sleep hormones such as cortisol and melatonin [21,22]. In addition, the association between chlorine and sleep quality has not been reported, but the exposure to organochlorine pesticides is associated to an increased risk of type 2 diabetes [23]. Moreover, studies have mentioned that calcium participates in astroglial activities for the control of sleep-wake cycle, and lower level of serum calcium is associated with sleep disruption [24,25]. Previous studies have also found that less phosphorus intake was correlated with higher blood glucose and higher risk for short sleep [26,27].

Despite the aforementioned biomedical and mental health factors, the association between certain key factors related to insomnia in patients with type 2 diabetes remains inadequately understood. Previous studies have reported the association between the dietary intake of trace elements and sleep quality in general population, but the exact correlations between serum levels of trace elements and sleep quality in patients with type 2 diabetes and co-morbid insomnia remains unknown. The association between mental health factors and sleep quality in patients with type 2 diabetes and co-morbid insomnia is also not clearly explained. To address these research gaps, this study aims to evaluate the relationships between various factors and insomnia severity, total sleep time, sleep efficiency, and sleep onset latency in patients with type 2 diabetes who experience insomnia. Specifically, the factors under investigation include biomedical factors such as blood glucose and trace elements, as well as mental health factors such as depression, anxiety and fatigue. As a baseline study conducted during a randomized controlled trial study, this study assessed the relationship between sleep and health outcomes in the cohort recruited for the randomized controlled trial study, and the factors significantly associated with sleep quality identified in this study was emphasized in the intervention plan which was delivered to the same cohort of patients in the randomized controlled trial.

2. Methods

2.1. Study design

This study is a baseline study analyzing cross-sectional data collected at baseline time point during a randomized controlled trial study. Cross-sectional data was collected as part of a randomized controlled trial study registered at Australian New Zealand Clinical Trials Registry (ANZCTR, trial ID: ACTRN12623000488606). The study protocol was approved by Griffith University Human Research Ethics Committee (GUHREC) (Reference Number: 2023/325) and the ethics committee at The First Affiliated Hospital of Ningbo University (Approval Number: 2023 045A). This study was conducted following the ethical principals in the Declaration of Helsinki [28].

2.2. Study population

Patients aged over 18 with both type 2 diabetes and insomnia were recruited from Department of Endocrinology and Metabolism at The First Affiliated Hospital of Ningbo University, Ningbo, Zhejiang, China. The diagnosis of type 2 diabetes was based on the Standards of Medical Care in Diabetes published by American Diabetes Association in 2019 [29]. The diagnostic criteria include: (1) Fasting plasma glucose $\geq$7.0 mmol/l (fasting time >8 h); (2) Two-hour postprandial blood glucose $\geq$11.1 mmol/l; (3) Random plasma glucose $\geq$11.1 mmol/L in patients with classic symptoms of hyperglycaemia or hyperglycemic crisis; (4) Glycated Haemoglobin A1c (HbA1c) $\geq$6.5 %. Insomnia was diagnosed based on The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) [8] and further screened using the Insomnia Severity Index questionnaire [30]. Patients reporting sleep difficulties at least three nights a week for at least three months causing distress or problems with daily functioning and a total Insomnia Severity Index score $\geq$10 points were included in this study. In addition, based on the face-to-face interview and the investigation of the online medical records at the hospital, patients with severe physical diseases, severe mental health problem or sleep disorders other than insomnia were excluded from this study. Patients who were pregnant were also excluded from the study. All participants included in this study were provided with the informed consent form, and the forms were signed by the participants upon fully understanding of the contents.

2.3. Outcome measurements

2.3.1. Sleep outcomes

Insomnia severity was measured by Insomnia Severity Index in this study. Insomnia Severity Index is a self-reported questionnaire assessing the severity of insomnia developed by Morin [30]. The questionnaire contains seven questions using five-point Likert scale [31]. The range of the final score for Insomnia Severity Index is 0–28, and a higher score indicates a more severe insomnia condition. Insomnia severity is divided into four groups based on the final Insomnia Severity Index score: absence of insomnia (score 0 to 7), sub-threshold insomnia (score 8 to 14), moderate insomnia (score 15 to 21) and severe insomnia (score 22 to 28) [30].

Sleep diaries were also used to measure the sleep characteristics of the patients. Outcomes obtained from sleep diaries included total sleep time (minutes), sleep efficiency (%) and sleep onset latency (minutes). Total sleep time described the total time a patient spent asleep in a sleep cycle. A total sleep time less than 6 h was considered as short sleep [32]. Sleep efficiency was calculated by total sleep time divided by the total amount of time spent in bed. A normal sleep efficiency was considered to be greater than 85 % [32]. Sleep onset latency referred to the time spent from turning the light off to completely falling asleep, and a normal sleep onset latency for an adult should be less than 30 min [32,33].

2.3.2. Biomedical outcomes

Biomedical outcomes collected in this study included blood glucose related outcomes and trace elements. Blood glucose related outcomes included fasting blood glucose (mmol/L) and Glycated haemoglobin A1c (HbA1c, %). Trace elements included Potassium (mmol/L), Sodium (mmol/L), Chlorine (mmol/L), Calcium (mmol/L), Magnesium (mmol/L) and Phosphorus (mmol/L). The reference range for serum Potassium,

Sodium, Chlorine, Calcium, Magnesium and Phosphorus was 3.60–5.20 mmol/L, 136–146 mmol/L, 99–110 mmol/L, 2.1–2.6 mmol/L, 0.66–1.07 mmol/L and 0.81–1.45 mmol/L, respectively [34,35].

2.3.3. Mental health outcomes

Mental health outcomes included depression, anxiety and fatigue. Depression was measured by Hamilton Depression Rating Scale (HAM-D) [36]. HAM-D contains 17 items, with total score ranges from 0 to 52 points. A total score <10 points indicates no depression, 10–13 indicates mild depression, 14–17 indicates mild to moderate depression, and >17 indicates moderate to severe depression [36]. Anxiety was measured by Hamilton Anxiety Rating Scale (HAM-A) [37]. HAM-A contains 14 items. The score ranges are: mild anxiety = 8–14; moderate anxiety = 15–23; severe anxiety ≥24 (scores ≤7 were considered to be no or minimal anxiety) [38]. Fatigue was measured by Multidimensional Fatigue Inventory (MFI) [39]. MFI is a 20-item self-report questionnaire. All items are rated on a 5-point Likert score, and a greater total score indicates greater level of fatigue.

2.3.4. Demographic factors

Demographic factors collected in this study included age (years), gender (male or female), marital status (not married or married), education (primary school or below, secondary school, high school, TAFE/junior college, undergraduate or above), monthly income (no income, ¥0–9999, ¥10000–19999, ¥20000 or above), employment status (employed or not employed/retired), family size (1–2, 3, 4 or above) and religious belief (no religious belief or have religious belief).

2.4. Data collection

Cross-sectional data were collected immediately after enrolment at The First Affiliated Hospital of Ningbo University. Biomedical examinations were performed during the patients' regular physical examination every three months. Blood samples were collected during the physical examination and the tests were performed in automated clinical chemistry analyzers and electrochemical analyzers at the clinical laboratory at the hospital. Test results were uploaded to the hospital's online systems as part of the medical records and recorded by researchers. All sleep factors, mental health factors and demographic factors were collected through a face-to-face interview between the patient and researcher using a self-developed questionnaire.

2.5. Data analysis

This is a baseline study and only cross-sectional data collected at baseline time point were analyzed. Descriptive analyses were performed for all variables. The results of descriptive analyses were displayed as means and standard deviations (SD) for continuous variables, and numbers and percentages of each category for categorical variables.

The distribution of the variables were checked using Skewness and Kurtosis measurements [40]. Only variables which were normally distributed were included in the next step of data analysis. Multicollinearity among the independent variables were also assessed to make sure that the independent variables were not highly correlated with each other.

The relationship between biomedical factors, mental health factors and demographic factors and each of the sleep factors (Insomnia Severity Index, total sleep time, sleep efficiency and sleep onset latency) were analyzed in an independent multiple linear regression model. Dummy variables were created for all categorical variables. Unstandardized regression coefficient (B) with 95 % confidence interval (CI), standardized regression coefficient (β), t value and *p* value were displayed for every single independent variable. F-ratios, *p* values and R square (R^2) values and were also displayed to summarize the overall significance of the multiple linear regression models. F-ratio showed if independent variables statistically significantly predict the dependent variable. R^2 value, also called the coefficient of determination, referred to the percentage of variance in the dependent variable that can be explained by the independent variables.

All data analysis were completed using IBM SPSS Statistics 29.0 software. The level of significance was set at *p* less than 0.05.

3. Results

3.1. Participant characteristics

The descriptive characteristics of the participants were displayed in Table 1. A total of 227 participants were included in this study, with an average of 56.99 years (SD = 10.31) and 58.6 % (133 out of 227) female. Most of the participants were married (n = 213, 93.8 %), and the education level of over half of the participants (52.9 %) were year 9 or below. The overall income level of the participants was relatively low, with 75.8 % earning less than 10000 Chinese Yuan every month. The percentage of unemployed or retired participants (52.9 %) was slightly higher than employed participants (47.1 %). The majority of the participants have a small family size less than 3 people (76.2 %), with no religious belief (70.9 %). Participants reported high Insomnia Severity

Table 1
Descriptive characteristics for all participants.

Variable	N (%)
Gender	
Female	133(58.6)
Male	94(41.4)
Marital status	
Not married	14(6.2)
Married	213(93.8)
Education	
Primary school (year 1–6) or below	43(18.9)
Secondary school (year 7–9)	77(33.9)
High School (year 9–12)	44(19.4)
TAFE/Junior college	38(16.7)
Undergraduate or above	25(11.0)
Monthly income	
No income	25(11.0)
¥0-9999	147(64.8)
¥10000-19999	30(13.2)
>¥20000	25(11.0)
Employment status	
Unemployed/retired	120 (52.9)
Employed	107 (47.1)
Family size	
2 or below	112(49.3)
3	61(26.9)
4 or above	54(23.8)
Religious belief	
No religious belief	161(70.9)
Have religious belief	66(29.1)
Variable	**Mean (SD)**
Age	56.99 (10.31)
Sleep related outcomes	
Insomnia Severity Index	14.61 (3.48)
Total sleep time	287.51 (56.96)
Sleep efficiency	70.32 (6.46)
Sleep onset latency	55.58 (49.07)
Blood glucose	
Fasting blood glucose	7.42 (2.46)
HbA1c	7.33 (1.47)
Trace elements	
Potassium	4.02 (0.31)
Sodium	139.67 (1.91)
Chlorine	104.34 (2.28)
Calcium	2.34 (0.98)
Magnesium	0.84 (0.76)
Phosphorus	1.18 (0.16)
Hamilton Depression Rating Scale	4.70 (2.67)
Hamilton Anxiety Rating Scale	3.12 (2.54)
Multidimensional Fatigue Index	56.95 (10.95)

Table 2
Multiple linear regression results for insomnia severity and total sleep time.

Variables[a]	Insomnia Severity Index[a]						Total sleep time[b]					
	B	95 %CI	β	t	*p*	R^2	B	95 %CI	β	t	*p*	R^2
Blood glucose												
Fasting blood glucose	0.306	(0.064, 0.547)	0.215	2.497	**0.013**	**0.247**	−0.250	(-4.382, 3.883)	−0.011	−0.119	0.905	
HbA1c	0.146	(-0.238, 0.529)	0.061	0.748	0.455		1.903	(-4.663, 8.468)	0.049	0.571	0.568	**0.179**
Trace elements												
Potassium	0.490	(-1.199, 2.179)	0.039	0.572	0.568		−20.473	(-49.377, 8.430)	−0.100	−1.397	0.164	
Sodium	−0.113	(-0.421, 0.196)	−0.056	−0.722	0.471		−0.657	(-5.936, 4.621)	−0.020	−0.246	0.806	
Chlorine	−0.107	(-0.387, 0.174)	−0.063	−0.749	0.455		1.323	(-3.479, 6.124)	0.047	0.543	0.588	
Calcium	2.880	(-3.081, 8.841)	0.070	0.953	0.342		51.375	(-50.625, 153.376)	0.077	0.993	0.322	
Magnesium	6.969	(-1.418, 15.356)	0.107	1.638	0.103		−174.333	(-317.849, −30.816)	−0.163	−2.395	**0.018**	
Phosphorus	−4.177	(-8.430, 0.075)	−0.132	−1.937	0.054		43.576	(-29.194, 116.346)	0.084	1.181	0.239	
Depression	0.433	(0.172, 0.694)	0.332	3.269	**0.001**		−0.213	(-4.680, 4.254)	−0.010	−0.094	0.925	
Anxiety	0.037	(-0.215, 0.289)	0.027	0.288	0.774		1.693	(-2.621, 6.006)	0.075	0.774	0.440	
Fatigue	−0.007	(-0.051, 0.037)	−0.022	−0.308	0.758		0.106	(-0.644, 0.855)	0.020	0.277	0.782	
Age	−0.002	(-0.049, 0.045)	−0.005	−0.078	0.938		0.379	(-0.421, 1.180)	0.069	0.935	0.351	
Gender												
Female	0.825						−11.607					
Male	Ref.	(-0.133, 1.784)	0.117	1.698	0.091		Ref.	(-28.009, 4.796)	−0.101	−1.395	0.164	
Marital status												
Not Married	Ref.						Ref.					
Married	−0.680	(-2.509, 1.149)	−0.047	−0.733	0.465		−38.862	(-70.163, −7.561)	−0.164	−2.448	**0.015**	
Education												
Primary school or below	0.456						−11.589					
Secondary school	Ref.	(-0.807, 1.718)	0.051	0.712	0.477		Ref.	(-33.188, 10.010)	−0.080	−1.058	0.291	
High School	0.203	(-1.101, 1.506)	0.023	0.307	0.759		−10.616	(-32.919, 11.686)	−0.074	−0.939	0.349	
TAFE/Junior college	0.550	(-0.813, 1.914)	0.059	0.795	0.427		0.662	(-22.672, 23.995)	0.004	0.056	0.955	
Undergraduate or above	1.230	(-0.419, 2.879)	0.111	1.471	0.143		17.900	(-10.313, 46.113)	0.099	1.251	0.212	
Monthly income												
No income	−0.368						−17.966					
¥0-9999	Ref.	(-1.933, 1.196)	−0.033	−0.464	0.643		Ref.	(-44.738, 8.807)	−0.099	−1.323	0.187	
¥10000-19999	−0.804	(-2.229, 0.620)	−0.079	−1.113	0.267		8.638	(-15.736, 33.012)	0.051	0.699	0.485	
¥20000 or above	0.330	(-1.185, 1.845)	0.030	0.430	0.668		−11.753	(-37.678, 14.172)	−0.065	−0.894	0.372	
Employment status												
Unemployed/retired	Ref.						Ref.					
Employed	0.677	(-0.282, 1.636)	0.097	1.392	0.165		−13.271	(-29.683, 3.141)	−0.117	−1.594	0.112	
Family size												
1-2	Ref.						Ref.					
3	−0.806	(-1.922, 0.309)	−0.103	−1.426	0.156		9.017	(-10.068, 28.101)	0.070	0.932	0.353	
4 or above	0.267	(-0.880, 1.415)	0.033	0.459	0.646		14.424	(-5.212, 34.061)	0.108	1.448	0.149	
Religious belief												
No religious belief	Ref.						Ref.					
Have religious belief	−0.336	(-1.322, 0.651)	−0.044	−0.671	0.503		17.284	(0.406, 34.161)	0.138	2.019	**0.045**	

[a]: N = 227, $F(19, 207) = 3.168$, $p < 0.001$; [b]: N = 227, $F(19, 207) = 1.997$, $p = 0.010$. CI: confidence interval; Ref.: Reference.
[a] : All variables were normally distributed, and no multicollinearity was found among independent variables.

Index score (14.61 ± 3.48), short total sleep time (287.51 ± 56.96), low sleep efficiency (70.32 ± 6.46) and long sleep onset latency (55.58 ± 49.07). The average fasting glucose was 7.42 mmol/L (SD = 2.46), and the mean HbA1c was 7.33 % (SD = 1.47). Normal levels of blood Potassium (4.02 ± 0.31), Sodium (139.67 ± 1.91), Chlorine (104.34 ± 2.28), Calcium (2.34 ± 0.98), Magnesium (0.84 ± 0.76) and Phosphorus (1.18 ± 0.16) were also observed. Overall, the participants showed low depression levels (4.70 ± 2.67), low anxiety levels (3.12 ± 2.54), and relatively high fatigue levels (56.95 ± 10.95) (see Table 2).

3.2. Risk factors for insomnia severity and total sleep time

All independent variables were included in the multiple linear regression analysis because all variables were normally distributed, and no multicollinearity was found among the independent variables. The results of the multiple linear regression models for Insomnia Severity Index scores and total sleep time were displayed in Table 2. Overall, the independent variables statistically significantly predict Insomnia Severity Index scores ($F(19, 207) = 3.168$, $p < 0.001$, $R^2 = 0.247$) and total sleep time ($F(19, 207) = 1.997$, $p = 0.010$, $R^2 = 0.179$). Variables showed significant relationship with increased Insomnia Severity Index score were increased fasting blood glucose (B = 0.306, 95 % CI [0.064, 0.547], $p = 0.013$) and elevated depression level (B = 0.433, 95 % CI [0.172, 0.694], $p = 0.001$). No demographic factors identified affecting insomnia severity.

Increased total sleep time was significantly associated with decreased blood magnesium (B = −174.333, 95 % CI [−317.849, −30.816], $p = 0.018$). Possible demographic factors influencing total sleep time included marital status and religious belief. Patients who were married had shorter total sleep time compared with patients who were not married (B = −38.862, 95 % CI [−70.163, −7.561], $p = 0.015$). Moreover, total sleep time was longer in patients who had religious belief compared with patients who did not have religious belief (B = 17.284, 95 % CI [0.406, 34.161], $p = 0.045$).

3.3. Risk factors for sleep efficiency and sleep onset latency

The results of the multiple linear regression models for sleep efficiency and sleep onset latency were displayed in Table 3. The independent variables did not statistically significantly predict sleep efficiency ($F(19, 207) = 0.848$, $p = 0.648$, $R^2 = 0.090$), but these variables statistically significantly predicted sleep onset latency ($F(19, 207)$

Table 3
Multiple linear regression results for sleep efficiency and sleep onset latency.

Variables[a]	Sleep efficiency[c]						Sleep onset latency[d]					
	B	95 %CI	β	t	*p*	R^2	B	95 %CI	β	t	*p*	R^2
Blood glucose	−0.088	(-0.581, 0.406)	−0.033	−0.350	0.727	**0.090**	−0.957	(-4.390, 2.475)	−0.048	−0.550	0.583	**0.237**
Fasting blood glucose	−0.091	(-0.875, 0.694)	−0.021	−0.228	0.820		−1.329	(-6.782, 4.125)	−0.040	−0.480	0.631	
HbA1c												
Trace elements	−0.024	(-3.477, 3.429)	−0.001	−0.014	0.989		−10.119	(-34.127, 13.890)	−0.057	−0.831	0.407	
Potassium	−0.027	(-0.658, 0.604)	−0.007	−0.085	0.933		−2.008	(-6.393, 2.376)	−0.070	−0.903	0.367	
Sodium	0.198	(-0.375, 0.772)	0.063	0.682	0.496		1.288	(-2.700, 5.277)	0.054	0.637	0.525	
Chlorine	2.966	(-9.220, 15.152)	0.039	0.480	0.632		−51.355	(-136.082,	−0.089	−1.195	0.233	
Calcium	1.787	(-15.359,	0.015	0.206	0.837		75.640	33.371)	0.082	1.251	0.212	
Magnesium	11.350	18.934)	0.193	2.574	**0.011**		−18.206	(-43.572,	−0.041	−0.594	0.553	
Phosphorus		(2.656, 20.044)						194.852)				
								(-78.652, 42.241)				
Depression	0.062	(-0.472, 0.596)	0.026	0.229	0.819		5.104	(1.394, 8.815)	0.278	2.712	**0.007**	
Anxiety	−0.221	(-0.737, 0.294)	−0.087	−0.846	0.398		0.525	(-3.057, 4.108)	0.027	0.289	0.773	
Fatigue	−0.042	(-0.132, 0.047)	−0.072	−0.933	0.352		0.625	(0.003, 1.248)	0.140	1.980	**0.049**	
Age	−0.006	(-0.101, 0.090)	−0.009	−0.118	0.906		0.125	(-0.540, 0.789)	0.026	0.370	0.712	
Gender	−1.914	(-3.874, 0.045)	−0.146	−1.926	0.056		−2.136	(-15.761, 11.490)	−0.021	−0.309	0.758	
Female	Ref.						Ref.					
Male												
Marital status	Ref.	(-1.504, 5.975)	0.083	1.179	0.240		Ref.	(-49.584, 2.416)	−0.116	−1.789	0.075	
Not Married	2.236						−23.584					
Married												
Education	−0.914	(-3.495, 1.666)	−0.056	−0.699	0.486		0.699	(-17.242, 18.640)	0.006	0.077	0.939	
Primary school or below	Ref.	(-3.328, 2.001)	−0.041	−0.491	0.624		Ref.	(-22.888, 14.164)	−0.035	−0.464	0.643	
Secondary school	−0.663	(-4.436, 1.140)	−0.095	−1.166	0.245		−4.362	(-17.371, 21.393)	0.015	0.205	0.838	
High School	−1.648	(-3.287, 3.455)	0.004	0.049	0.961		2.011	(-33.300, 13.570)	−0.063	−0.830	0.407	
TAFE/Junior college	0.084						−9.865					
Undergraduate or above												
Monthly income	−0.589	(-3.787, 2.610)	−0.029	−0.363	0.717		12.864	(-9.375, 35.102)	0.082	1.141	0.255	
No income	Ref.	(-3.220, 2.604)	−0.016	−0.208	0.835		Ref.	(-32.188, 8.304)	−0.083	−1.163	0.246	
¥0-9999	−0.308	(-4.654, 1.541)	−0.076	−0.991	0.323		−11.942	(-34.310, 8.758)	−0.082	−1.170	0.243	
¥10000-19999	−1.556						−12.776					
¥20000 or above												
Employment status	Ref.	(-3.215, 0.707)	−0.097	−1.261	0.209		Ref.	(-32.775, −5.510)	−0.195	−2.769	**0.006**	
Unemployed/retired	−1.254						−19.142					
Employed												
Family size	Ref.	(-1.314, 3.246)	0.066	0.836	0.404		Ref.	(-23.248, 8.457)	−0.067	−0.920	0.359	
1–2	0.966	(-3.153, 1.539)	−0.053	−0.678	0.498		−7.396	(-15.580, 17.043)	0.006	0.088	0.930	
3	−0.807						0.731					
4 or above												
Religious belief	Ref.	(-1.742, 2.291)	0.019	0.268	0.789		Ref.	(-24.035, 4.004)	−0.093	−1.409	0.160	
No religious belief	0.274						−10.016					
Have religious belief												

[c]: N = 227, $F(19, 207) = 0.848$, $p = 0.648$; [d]: N = 227, $F(19, 207) = 3.224$, $p < 0.001$. CI: confidence interval; Ref.: Reference.
[a] : All variables were normally distributed, and no multicollinearity was found among independent variables.

= 3.224, $p < 0.001$, $R^2 = 0.237$). Increased blood phosphorus level showed significant relationship with increased sleep efficiency (B = 11.350, 95 % CI [2.656, 20.044], $p = 0.011$). Increased depression level (B = 5.104, 95 % CI [1.394, 8.815], $p = 0.007$) and increased fatigue level (B = 0.625, 95 % CI [0.003, 1.248], $p = 0.049$) showed significant association with prolonged sleep onset latency. Possible demographic factor for sleep onset latency was employment status. People being employed showed shorter sleep onset latency compared with people who were not employed or retired (B = −19.142, 95 % CI [−32.775, −5.510], $p = 0.006$).

4. Discussion

Overall, the independent variables statistically significantly predicted Insomnia Severity Index, total sleep time and sleep onset latency, but not sleep efficiency. Possible factors affecting insomnia severity and sleep quality in patients with type 2 diabetes and co-morbid insomnia included fasting blood glucose, blood phosphorus, blood magnesium, depression and fatigue.

4.1. Biomedical risk factors for insomnia in patients with type 2 diabetes

It was found that increased fasting glucose level was associated with increased level of insomnia severity, which was consistent to the findings in previous studies [41]. As mentioned in previous studies, patients with poor management of blood glucose have a higher chance of developing complications and mental health problems, which may provide negative effect on sleep quality [42,43]. Decreased total sleep time was found to be significantly related to increased levels of serum magnesium within the normal range. Previous studies have reported that magnesium deficiency is associated with poor sleep quality and glycemic control, and dietary magnesium intake is beneficial for improving sleep quality, sleep duration and reducing blood glucose level [22,44]. However, based on the findings from this study, an increased level of serum magnesium within the normal range may also provide negative effect on total sleep time. A recent study have mentioned that increased serum magnesium level was significantly related to higher serum creatinine levels and lower estimated glomerular filtration rate, which both indicated an impaired renal function [45]. In this case, increased serum magnesium can be an indicator of early stage of renal disease complicated with type 2 diabetes, which may lead to more nocturnal urinations that impair the continuation of sleep [21,45]. Moreover, increased blood phosphorus level within the normal range was significantly associated with increased sleep efficiency. The relationship between blood phosphorus level and sleep has been reported in previous studies in patients with chronic kidney diseases [46], but no

studies reported the effect of blood phosphorus in type 2 diabetes patients. Previous studies showed higher intakes of dietary phosphorus were correlated with poorer sleep quality in patients with chronic kidney diseases [46,47], which is inconsistent to the findings in the present study. A possible explanation is that higher dietary intake level of phosphorus exerts greater pressure on kidney in patients with renal insufficiency, but the study population in the present study had relatively normal kidney function and blood phosphorus level, so the negative effect of high phosphorus intake was not significant. According to previous study, high serum phosphorus within the normal range can also be an important indicator of diabetic kidney disease which significantly affects sleep quality, and phosphorus excess has a significant impact on cardiovascular disease [48]. Therefore, it is important to maintain the serum phosphorus level within the normal range while monitoring the overall kidney function in patients with type 2 diabetes.

4.2. Mental health risk factors for insomnia in patients with type 2 diabetes

The findings showed that increased depression level was significantly related to higher insomnia severity and longer sleep onset latency. This is consistent with previous research results [49]. As explained in previous studies, the relationship between insomnia and depression is bidirectional [49]. Patients with worse sleep quality have a greater chance of developing depressive thoughts, and the increased depressive thoughts with higher level of depression can further worsens the insomnia severity and sleep quality.

Additionally, increased level of fatigue was significantly associated with longer sleep onset latency. As the most common daytime complaint associated with insomnia, a higher level of fatigue usually reflects a worse sleep quality during the night [50]. A longer sleep onset latency suggested that the patients need more time to fall asleep, and more difficulty falling asleep is an important indicator of the increased insomnia severity, which leads to a higher level of fatigue during the day. Reducing fatigue during the day is very important for type 2 diabetes patients as it affects daytime functioning such as regular medication intake and physical exercise, which is vital for their glycemic control.

4.3. Possible demographic factors affecting sleep quality

The multiple linear regression model found that the total sleep time for patients who were married was shorter than patients who were not married. A possible explanation could be patients who are married are more likely to be disturbed by their partners sharing the same bed, such as snoring, talking, watching televisions and using smartphones in bed. The noise and light produced by their partners could be negative factors affecting their sleep quality. But giving that marital status was not significantly correlated with other sleep outcomes, it is hard to conclude that marital status has a definite impact on sleep. The results also showed that patients with religious belief was more likely to have longer total sleep time, which is similar to the results reported in another study [51]. Patients with religious belief has a greater chance to calm down and relax in bed, which increases their chance of falling asleep and overall sleep satisfaction. Similar to marital status mentioned above, religious belief did not show any significant associations with other sleep outcomes, so the impact of religious belief on overall sleep quality and insomnia severity is still limited. Moreover, although we found that marital status and religious belief might have an impact on sleep quality, these factors might be confounded by different socioeconomic and lifestyle factors such as wealth, dietary habit and daily exercise, which also have potential impact on sleep management. In addition, reduced sleep onset latency was observed in patients being employed. People being employed have heavier workload and pressure during the day. As more fatigue is accumulated during their work, they are more likely to fall asleep more quickly than people with smaller workload and less working stress.

4.4. Strength, limitations and implications

In this study, we assessed possible biomedical and mental health risk factors for insomnia in patients with type 2 diabetes and co-morbid insomnia. Fasting glucose and HbA1c levels were especially important in patients with type 2 diabetes compared with the general population. Few studies assessed the trace elements potassium, sodium, chlorine, calcium, magnesium and phosphorus in relation to insomnia severity, total sleep time, sleep efficiency and sleep onset latency in patients with type 2 diabetes.

The limitation of this study was that the overall sample size of the database was relatively small. Therefore, further studies with bigger sample size and more advanced statistic models are required to validate the findings from this study. In addition, due to the limited budget, polysomnography tests were not available for the participants to acquire a more accurate and objective monitoring of the sleep characteristics, sleep characteristics obtained from sleep diaries might be subjective and biased. Moreover, in this study, there is a number of potential confounding factors we did not mentioned, including medications, dietary habits, physical activity, substance intake and presence of chronic pain. These factors may also affect sleep quality, but the information was not completely collected during our data collection process, so they were not included in the data analysis.

When considering the management of sleep quality and glycemic control in patients with type 2 diabetes and comorbid insomnia, we recommend that the therapists take trace elements into consideration. The oral supplementary of trace elements is necessary when there is a deficiency, but the dose design need to be careful to maintain the levels of trace elements within the normal range. Also, the therapists need to monitor the trace element levels and kidney functions regularly to avoid the deterioration of diabetic kidney diseases. The management of depression conditions and daytime fatigue should be prioritized to improve the overall management of the disease.

5. Conclusion

In conclusion, high insomnia severity and poor sleep quality in type 2 diabetes patients are significantly related to elevated levels of fasting blood glucose, serum magnesium, serum phosphorus, depression and fatigue. It is recommended that therapists need to pay more attention to the dietary intake of magnesium and phosphorus, as well as the management of depression and daytime fatigue while managing sleep in type 2 diabetes patients.

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CRediT authorship contribution statement

Li Li: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation. **Dawei Xu:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Miao Xu:** Supervision, Methodology. **Yunxin Ji:** Supervision, Resources, Methodology. **Zhongze Lou:** Writing – review & editing, Supervision, Project administration, Methodology. **Jing Sun:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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