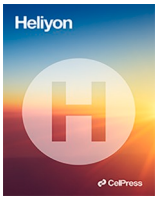
Heliyon 10 (2024) e26137

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Effect of fear of hypoglycaemia on sleep quality of patients with type 2 mellitus diabetes: The mediating role of alexithymia

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ARTICLE INFO

Keywords:
Fear of hypoglycaemia
Sleep quality
Alexithymia
Diabetes

ABSTRACT

Background: Patients with type 2 diabetes mellitus (T2DM) commonly experience poor sleep quality. This study aimed to investigate whether alexithymia mediates the association between fear of hypoglycaemia (FoH) and sleep quality in patients with T2DM.

Methods: From September 2021 to November 2021, a cross-sectional survey was conducted on 407 patients with T2DM in China. Data collection was made possible through the administration of the Chinese Version of the Worry Scale, Toronto Alexithymia Scale and Chinese version of the Pittsburgh Sleep Quality Index (CPSQI). Multiple linear regression analyses were also performed.

Results: A total of 65.6% of the participants were male, and 75.7% were aged 18–40 years. FoH showed a moderate and positive correlation with CPSQI scores ($r = 0.308$, $p < 0.001$). Alexithymia was weakly and positively correlated with CPSQI scores ($r = 0.185$, $p < 0.001$). Meanwhile, FoH exhibited a moderate and positive correlation with alexithymia ($r = 0.422$, $p < 0.001$), and difficulty in identifying ($r = 0.414$, $p < 0.001$) and describing feelings ($r = 0.416$, $p < 0.001$) and a weak and positive correlation with externally oriented thinking ($r = 0.221$, $p < 0.001$). The total effect ($\beta = 0.408$, $p < 0.001$) of FoH on CPSQI comprised not only the direct ($\beta = 0.293$, 95% confidence interval: 0.174–0.411, $p < 0.001$) but also the indirect effect ($\beta = 0.115$, $p < 0.001$) of alexithymia.

Conclusions: Alexithymia can mediate the association between FoH and sleep quality. Clinicians should recognize the potential effect of alexithymia and incorporate it in intervention planning and care. Addressing the affective disturbances arising from FoH can enhance emotional expression and sleep quality among T2DM patients.

Abbreviations: DM, diabetes mellitus; T2DM, type 2 diabetes mellitus; T1DM, type 1 diabetes mellitus; FoH, fear of hypoglycaemia; CPSQI, Chinese version of the Pittsburgh Sleep Quality Index; CWS, Chinese Version of the Worry Scale; TAS, Toronto Alexithymia Scale.

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https://doi.org/10.1016/j.heliyon.2024.e26137
Received 5 July 2023; Received in revised form 3 February 2024; Accepted 8 February 2024
Available online 9 February 2024

1. Introduction

The continued global spread of diabetes has resulted in a massive public health challenge. The global prevalence of diabetes has reached 529 million in 2021, and projections indicate that it will surpass 1.31 billion by 2050 [1]. In addition, Chinese diabetic patients constitute one-quarter of the total diabetic patient population worldwide [2]. Adults with type 2 diabetes mellitus (T2DM) commonly experience multiple sleep problems, including insomnia, sleep fragmentation, and obstructive sleep apnoea [3]. A total of 81% of patients with T2DM suffer from poor sleep quality [4]. The coronavirus disease (COVID-19) is the deadliest pandemic since the Spanish flu of 1918. In general, the COVID-19 pandemic has affected people's lives in various ways, including their sleep quality [5]. In this context, the status of sleep quality in patients with diabetes is unknown.

Hypoglycaemia is increasingly being recognised as an important and potentially preventable cause of morbidity, mortality and impaired quality of life [6]. Compared with patients with T2DM, patients with T1DM are more likely to experience hypoglycaemic episodes but have a lower heterogenous risk of developing hypoglycaemia [7]. A multicountry study revealed that 95.3% of T2DM patients reported hypoglycaemic events, with an estimated average of 2.37 hypoglycaemic events per patient per month [8]. Patients who have experienced hypoglycaemic events may develop a fear of such condition in the future [9]. In other words, the discomfort caused by hypoglycaemia causes a patient to fear hypoglycaemia. Fear of hypoglycaemic (FoH) is characterised by anxiety over glucose levels reaching extremely low levels and may result in avoidance behaviour [10]. The degree of FoH effects may range from uncomfortable symptoms to social shame to severe physical harm and death [11]. People with T2DM, including those who do not use insulin, commonly exhibit FoH and elevated concerns regarding hypoglycaemia and the avoidance behaviour associated with FoH [12, 13]. Approximately 27.7% of patients with T2DM who are undergoing insulin therapy and taking oral hypoglycaemic drugs experience FoH [14]. FoH can considerably negatively impact sleep quality [15,16]. These sleep disturbances can result in reduced interest in disease management, poor glycaemic control, and long-term complications, which ultimately negatively affect blood glucose stability [17]. In additiona, fluctuations in blood glucose levels aggravate FoH [18].

T2DM leads to microvascular and macrovascular complications and can cause psychological distress [19]. Alexithymia refers to the difficulty in recognizing and describing emotions, limited imaginative processes and an externally oriented cognitive style [20]. Compared with healthy individuals, patients with diabetes have a higher prevalence of alexithymia [21]; in addition, approximately 63.9% of people with diabetes experience this symptom [22]. Alexithymia is related to sleep quality, and this relationship is independent of depression or anxiety [19]. Patients with alexithymia have reported more daytime dysfunction and a negative impact on their sleep quality based on their own subjective assessments [20,23]. To the best of our knowledge, the relationship between alexithymia and sleep quality has not been studied in patients with T2DM.

Hypoglycaemic episodes not only exert negative effects on the body but also cause psychological stress in patients with T2DM [24, 25]. FoH may have negative effects on psychosocial functioning [16]. A notably positive correlation was found between alexithymia and blood sugar levels of patients with T2DM [21]. However, to the best of our knowledge, no study has confirmed the association between alexithymia and FoH in patients with T2DM. Addressing issues, such as alexithymia and FoH, may be crucial to improving sleep quality among patients with T2DM.

Our study aimed to explore the possible relationship among FoH, alexithymia and sleep quality in diabetic patients during the COVID-19 epidemic.

Based on the results of the above analysis, we constructed the following research hypotheses:

Hypotheses 1. FoH and alexithymia are correlated with sleep quality.

Hypotheses 2. Alexithymia mediates the relationship between FoH and sleep quality (see Fig. 1).

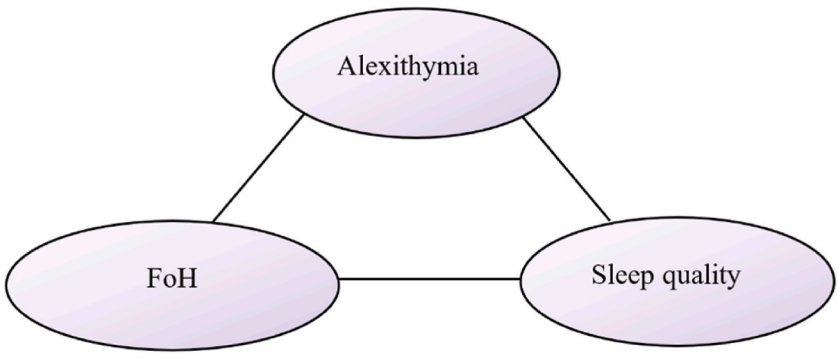

Fig. 1. Mediation effect hypothesis mode.
* FoH = fear of hypoglycaemia.

2. Materials and methods

2.1. Study design and participants

To enhance data collection and ensure its integrity, we conducted face-to-face interviews between September 2021 and November 2021. Interviews were conducted via convenience sampling at two elderly care service centres and two tertiary hospitals in Shiyan City, Hubei Province, China. The survey involved participants who met the inclusion criteria, including age ≥18 years and diagnosis of T2DM. However, individuals with diagnoses of dementia, neurodegenerative disorders, or neurological diseases were excluded. Prior to the survey, the survey's objectives and questionnaire instructions were comprehensively explained to the participants, in the presence of hospital administrators. The participants were informed that the data collected in the survey would be utilised solely for research purposes. In addition, they were guided to respond to survey questions sequentially, and their responses were recorded by trained professionals. Out of the 430 patients invited to participate, 23 were excluded from the analysis due to their incomplete survey responses, As a result, 407 patients were included in the final analysis. The study received ethical approval from the Ethics Committee of Hubei University of Medicine (2022-RE-012), and all participants provided informed consents prior to their participation.

2.2. Sample size

The sample size was calculated using the following formula: $N = Z_{\alpha}^2 P (1 - P)/d^2$, where N = the number of samples, P = the estimated overall prevalence rate of poor sleep quality, d = the admissible error, Z_{α} = the statistic representing a certain confidence level. In this study, the prevalence of poor sleep quality among patients with T2DM was set at 81%, following a previous research [4]. Thus, the sample size was at least 91 ($d = 0.1P$, $\alpha = 0.05$ and $Z_{\alpha} = 1.96$), and it was expanded by 15% to account for invalid responses and missing data. The final sample size was at least 104 cases. A total of 430 patients participated in our study, and the valid questionnaire included 407 cases.

2.3. Measurements

2.3.1. Sociodemographic and disease characteristics

A questionnaire was used to collect detailed information, including age (years), gender (female or male), residence, living arrangement, educational level, employment, marital status, family history of the T2DM, complications, insulin therapy, diabetes mellitus (DM) control status, social support and level of knowledge about FoH. Two age groups were established (18–40 and 41–85 years). Living arrangement was divided into two clusters (living alone/living with others), and marital status was split into three categories (unmarried, married and divorced/widow/widower). Social support was measured using the question 'Could you feel the support and help of others when you suffered from diabetes?' This demographic was divided into three categories (low/moderate/high). The height and weight of the participants were measured while they were wearing light clothing. Based on these measurements, body mass index was further categorised using the cut-points established by the National Health and Family Planning Commission of China as follows: underweight (<18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), overweight (24.0–27.9 kg/m^2) or obesity (≥28.0 kg/m^2) [26].

2.3.2. Chinese Version of the Worry Scale (CWS-10)

The CWS-10 assesses the concern of people with diabetes regarding hypoglycaemia in the previous six months [27]. The scale has 10 items, a five-point Likert scale, with values ranging from '0 = never' to '4 = always', is used in scoring. The score range is 0–40, with a high score indicating severe FoH. In our research, the CWS-10 showed a high content validity [28], with Cronbach's alpha coefficient of 0.918. CWS-10 is a unidimensional variable with 10 entries, and thus, a factorial balance method was used to categorise FoH into five-item groups and construct a hypothesis model [29].

2.3.3. Toronto Alexithymia Scale (TAS-20)

TAS-20 is a self-reported questionnaire and consists of 20 items with three distinct components (difficulty in identifying feelings, difficulty in describing feelings and externally oriented thinking cognitive style) [30]. The respondents answer each item using a five-point Likert scale to indicate the extent of their agreement with a set of proposed claims. The scale ranges from 1 (strongly disagree) to 5 (strongly agree), and the total score ranges from 20 to 100, with higher total scores indicating a pronounced alexithymia. The scale in this study had a Cronbach's alpha coefficient of 0.827.

2.3.4. Chinese Pittsburgh Sleep quality index (CPSQI)

The CPSQI, which comprises 7 dimensions and 19 items, is used to evaluate sleep quality [31]. Each CPSQI item must be answered on a four-point scale (between 0 and 3), with scores ranging from 'never' to 'three times or more a week'. The sum of the participants' subjective ratings on sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleeping medication and daytime dysfunction (four-point scale from 'very good' to 'very bad'). The CPSQI scale ranges from 0 to 21, with high scores indicating poor sleep. Respondents with CPSQI scores of >7 are recognised as poor sleepers [29], as has been recommended in Chinese clinical practice and research. In this study, the Cronbach's alpha coefficient for this scale was 0.845.

2.5. Quality control

Investigators were trained before the survey. A presurvey was also conducted among the target subjects to ensure their comprehension of the survey. Questionnaire items with identical answers or a large number of missing answers were excluded from the analysis. After the investigation, the researcher carried out logical verification of the questionnaire to ensure data accuracy.

Table 1
Characteristics of study participants and comparisons of their sleep quality.

Characteristics	N (%)	CPSQI (x ± s)	P [a]	Good sleep quality (n = 198)	Poor sleep quality (n = 209)	P [b]
Gender			0.013			0.023
Male	267 (65.6)	7.76 ± 3.72		119 (60.1)	148 (70.8)	
Female	140 (34.4)	6.78 ± 3.95		79 (39.9)	61 (29.2)	
Age category (years)			0.854			0.970
18–40	308 (75.7)	7.44 ± 3.81		150 (75.8)	158 (75.6)	
41–85	99 (24.3)	7.36 ± 3.87		48 (24.2)	51 (24.4)	
BMI (kg/m^2)			0.240			0.262
Underweight	119 (29.2)	6.95 ± 4.10		63 (32.0)	56 (26.8)	
Normal	189 (46.4)	7.54 ± 3.70		90 (45.7)	99 (47.4)	
Overweight	47 (11.5)	7.32 ± 4.12		25 (12.7)	22 (10.5)	
Obesity	51 (12.5)	8.22 ± 3.28		19 (9.6)	32 (15.3)	
Residence			0.001			<0.001
Rural	180 (44.2)	8.10 ± 3.74		70 (35.4)	110 (52.6)	
Urban	227 (55.8)	6.89 ± 3.81		128 (64.6)	99 (47.4)	
Living arrangement			0.036			0.075
Living alone	111 (27.3)	8.07 ± 3.96		46 (23.2)	65 (31.1)	
Living with others	296 (62.7)	7.18 ± 3.75		152 (76.8)	144 (68.9)	
Educational level			0.131			0.058
Elementary school or under	10 (2.5)	8.20 ± 2.66		3 (1.5)	7 (3.3)	
Junior Middle school	98 (24.1)	7.84 ± 3.80		15 (7.6)	31 (14.8)	
Senior Middle school	104 (25.6)	7.51 ± 3.79		47 (23.7)	51 (24.4)	
Junior Middle school	46 (11.3)	8.24 ± 3.64		48 (24.2)	56 (26.8)	
College or University	134 (32.9)	6.88 ± 3.92		77 (38.9)	57 (27.3)	
Postgraduate	15 (3.6)	6.00 ± 4.05		8 (4.0)	7 (3.3)	
Employment			<0.001			<0.001
Employed	289 (71.0)	6.84 ± 3.70		160 (80.8)	129 (61.7)	
Retired	54 (13.3)	8.46 ± 3.85		19 (9.6)	35 (16.7)	
Unemployed	44 (10.8)	9.82 ± 3.72		9 (4.5)	35 (16.7)	
Others	20 (4.9)	7.85 ± 3.20		10 (5.1)	10 (4.8)	
Marital status			<0.001			0.002
Unmarried	163 (40.0)	7.35 ± 3.68		81 (40.9)	82 (39.2)	
Married	221 (54.3)	7.15 ± 3.87		114 (57.6)	107 (51.2)	
Divorced/Widow/Widower	23 (5.7)	10.57 ± 3.01		3 (1.5)	20 (9.6)	
Family history of the T2DM			0.300			0.078
Yes	246 (60.4)	7.59 ± 3.57		111 (56.1)	135 (64.6)	
No	161 (39.6)	7.17 ± 4.18		87 (43.9)	74 (35.4)	
Complications			<0.001			<0.001
0	217 (53.3)	6.60 ± 3.79		124 (62.6)	93 (44.5)	
1	150 (36.9)	8.09 ± 3.56		61 (30.8)	89 (42.6)	
> 1	40 (9.8)	9.40 ± 3.89		13 (6.6)	27 (12.9)	
Insulin therapy			0.184			0.461
Yes	250 (61.4)	7.63 ± 3.72		118 (59.6)	132 (63.2)	
No	157 (38.6)	7.10 ± 3.98		80 (40.4)	77 (36.8)	
T2DM control status			0.005			0.005
Poor	39 (9.6)	8.72 ± 3.83		12 (6.1)	27 (12.9)	
Fair	184 (45.2)	7.77 ± 3.54		82 (41.4)	102 (48.8)	
Good	184 (45.2)	6.81 ± 4.01		104 (52.5)	80 (38.3)	
Social Support			0.004			0.057
Low	85 (20.9)	7.27 ± 3.68		43 (21.7)	42 (20.1)	
Moderate	136 (33.4)	8.29 ± 3.96		55 (27.8)	81 (38.8)	
High	186 (45.7)	6.87 ± 3.69		100 (50.5)	86 (41.1)	
Level of knowledge about FoH			<0.001			0.012
Few	37 (9.1)	8.22 ± 4.08		15 (7.6)	22 (10.5)	
A Few	123 (30.2)	8.33 ± 3.82		50 (25.3)	73 (34.9)	
Some	150 (36.9)	7.39 ± 3.48		73 (36.9)	77 (36.8)	
Many	97 (23.8)	6.03 ± 3.48		60 (30.3)	37 (17.7)	

*DM = diabetes mellitus, FoH = fear of hypoglycaemia, CPSQI = Chinese Pittsburgh Sleep Quality Index.
[a] t/F test.
[b] Chi-square test.

2.6. Statistical analysis

SPSS version 22.0 (IBM Corp., Armonk, NY, USA) was used in descriptive and inferential statistical analyses. Independent sample *t*-test and one-way analysis of variance were used to compare the mean ± standard deviation of each group. Spearman correlation analysis was used to examine the correlation among FoH, alexithymia and sleep quality in patients with T2DM. Multiple linear regression was applied to explore the effect of FoH and alexithymia on sleep quality.

Structural equation modelling (SEM) is used to construct, estimate and test models of causal relationships [32]. The relationship between variables can be displayed intuitively through the path diagram. SEM is not only suitable for studying observable variables but also for hidden ones that cannot be directly observed. This method has been widely used in the fields of medicine, psychology and sociology [33,34]. With the use of AMOS software (version 22), SEM was used to assess the exploration of the effects of FoH on sleep quality based on sleep quality as the mediating variable. A good model fit was concluded when $\chi^2/df < 3.00$, standardised root means square residual (SRMR) < 0.08, goodness-of-fit index (GFI) > 0.90, normed fit index (NFI) > 0.90, incremental fit index (IFI) > 0.90, Tucker–Lewis index (TLI) > 0.90, comparative fit index (CFI) > 0.90 and root mean square error of approximation (RMSEA) < 0.08. To evaluate the mediating effect of hypoglycaemia on the relationship between FoH and sleep quality, we adopted Baron and Kenny's regression approach [35]. The statistical significance level was set at $\alpha = 0.05$.

3. Results

3.1. Basic characteristics of participants

Table 1 shows the characteristics of the study participants. Most participants were male 65.6% (n = 267), had mean CPSQI scores of 7.76 ± 3.72, which indicated poor sleep quality, and aged 18–76 years. Approximately 75.7% were 18–40 years old, 54.3% were married, and 97.5% completed junior middle school or higher. Sleep quality varied significantly depending on the gender, residence, living arrangement, employment, marriage status, complication, DM control status, social support level and level of knowledge about FoH ($p < 0.05$). Among 407 participants, a 209 (51.4%) out had poor sleep quality (CPSQI ≥7).

3.2. Correlation analysis among alexithymia, FoH and CPSQI in T2DM patients

Table 2 presents the correlations between alexithymia, FoH and CPSQI in T2DM patients. The CPSQI scores displayed a weak and positive correlation with TAS total scores ($r = 0.185$, $p < 0.001$) and difficult in identifying feelings ($r = 0.136$, $p < 0.05$). A moderate and positive correlation existed between difficulty in describing feelings and externally oriented thinking ($r = 0.559$, $p < 0.001$). FoH showed a moderate and positive correlation with difficulty in identifying feelings ($r = 0.414$, $p < 0.001$), difficulty in describing feelings ($r = 0.416$, $p < 0.001$), and CPSQI scores ($r = 0.308$, $p < 0.001$) but a weak and positive correlation with externally oriented thinking ($r = 0.221$, $p < 0.001$). Furthermore, alexithymia and FoH showed a moderate and positive correlation ($r = 0.422$, $p < 0.001$). These findings provide initial evidence for the research hypotheses.

3.3. Moderating analysis of alexithymia in the association between FoH and sleep quality

We initially examined the effect of FoH on sleep quality. Model 1 in Table 3, reveals FoH was positively related to CPSQI ($\beta = 0.138$, $p < 0.05$), after controlling for the effects of gender, place of residence, living arrangements, marriage status, employment, complications, DM control status, social support and level of knowledge regarding FoH. Next, we examined the effect of alexithymia on sleep quality. Model 2 in Table 3 indicates alexithymia was positively related to CPSQI ($\beta = 0.170$, $p < 0.001$). Then, we tested the effect of FoH and alexithymia on sleep quality. Model 3 in Table 3 unveils that alexithymia was positively related to CPSQI ($\beta = 0.139$, $p < 0.05$) and the lack of significant effect FoH on the latter ($\beta = 0.081$, $p > 0.05$). Furthermore, we explored the effect of FoH on alexithymia. Model 4 in Table 3 shows that FoH was positively related to alexithymia ($\beta = 0.410$, $p < 0.001$).

Fig. 2 shows the structural relationship of standardisation coefficients. Table 4 presents the fit indices of the model, which revealed an acceptable data fit, with $\chi^2/df = 3.063$, SRMR = 0.064, GFI = 0.918, NFI = 0.903, IFI = 0.933, TLI = 0.918, CFI = 0.931 and RMSEA = 0.071. Fig. 2 and Table 4 indicate the positive effect of FoH on CPSQI, which was mediated by alexithymia. Table 4 demonstrates that the total effect ($\beta = 0.408$, $p < 0.001$) of FoH on CPSQI comprised not only the direct ($\beta = 0.293$, 95% confidence

Table 2
Correlations among FoH, alexithymia and CPSQI in patients with T2DM.

	Variables	TAS total scores	DIF	DDF	EOT	CWS scores	CPSQI scores
1	TAS total scores	1					
2	DIF	.407***	1				
3	DDF	.712***	.633***	1			
4	EOT	.788***	.559***	.633***	1		
5	CWS scores	.422***	.414***	.416***	.221***	1	
6	CPSQI scores	.185***	.136**	−.005	−.026	.308***	1

* TAS = Toronto Alexithymia Scale, CWS = Chinese Version of the Worry Scale, DIF = difficult identifying feelings, DDF = difficult describing feelings, EOT = externally oriented-thinking, CPSQI = Chinese Pittsburgh Sleep Quality Index, **$p < 0.05$, ***$p < 0.001$.

Table 3
Results of mediating effect test.

Variables	Sleep quality									Alexithymia		
	Model 1			Model 2			Model 3			Model 4		
	β	t	p	β	t	p	β	t	p	β	t	p
FoH	0.138	2.845	0.005				0.081	1.546	0.123	0.410	8.470	<0.001
Alexithymia				0.170	3.665	<0.001	0.139	2.763	0.006			
F	6.444			6.838			6.614			6.674		
p	$p < 0.001$			$p < 0.001$			$p < 0.001$			$p < 0.001$		
R^2	0.220			0.230			0.235			0.226		
ΔR^2	0.186			0.196			0.199			0.192		

* The reported results are standardised coefficients (FoH = fear of hypoglycaemia). The models were adjusted for gender, place of residence, living arrangements, marriage status, employment, complications, DM control status, social support and level of knowledge about FoH. Model 1: multiple linear regression analysis of the relationship between FoH and sleep quality; Model 2: multiple linear regression analysis of the relationship between alexithymia and sleep quality; Model 3: multiple linear regression analysis of the relationship among FoH, alexithymia and sleep quality; Model 4: multiple linear regression analysis of the relationship between FoH and alexithymia.

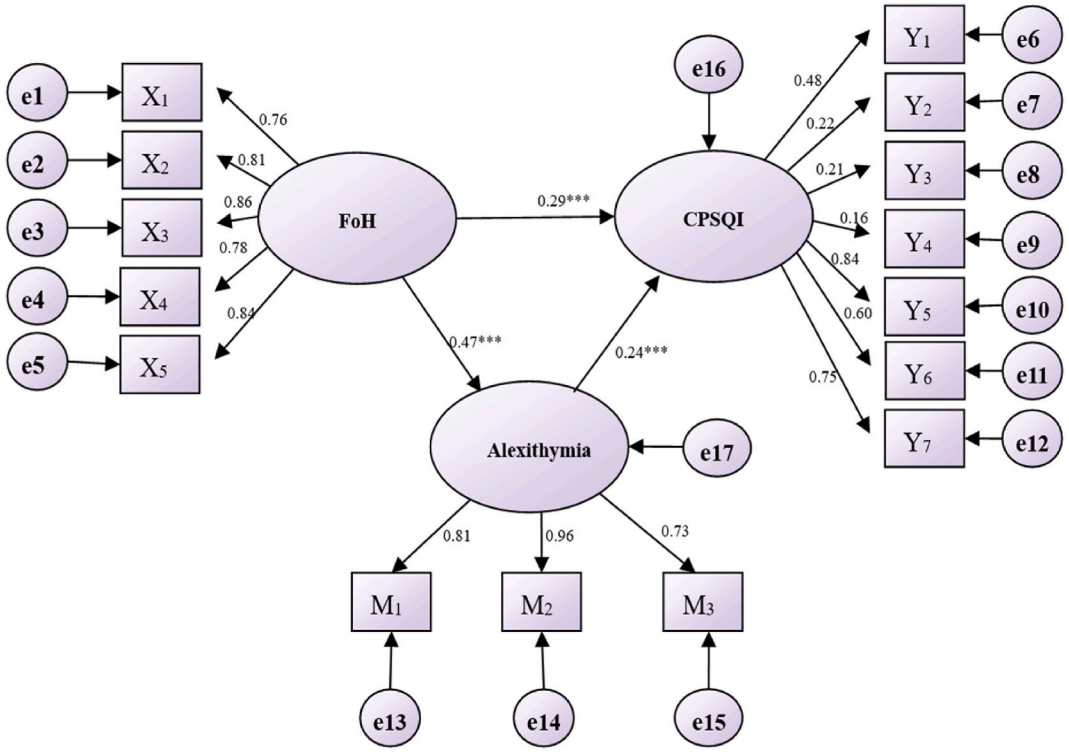

Fig. 2. Model of the mediating effect of alexithymia on FoH and sleep quality in patients with T2DM.
* The normalised path coefficients are shown in the figure. X_{1-5} represent the five dimensions of FoH, M_{1-3} denote the three dimensions of alexithymia and Y_{1-7} refer to the seven dimensions of CPSQI; $^{**}p < 0.05$, $^{***}p < 0.001$.

Table 4
Model and the mediation effect of alexithymia on sleep quality in patients with T2DM.

Path	Estimate	S.E.	C.R.	95%CI		*p*
				Boot LLCI	Boot ULCI	
FoH → Alexithymia	0.472	0.044	10.727	0.380	0.553	<0.001
Alexithymia → Sleep quality	0.243	0.062	3.919	0.118	0.365	<0.001
FoH → Sleep quality	0.293	0.061	4.803	0.174	0.411	<0.001

* The reported findings are standardised results, and the Bootstrap sample size was 5000; FoH = fear of hypoglycaemia; CPSQI = Chinese Pittsburgh Sleep Quality Index.

interval: 0.174–0.411, $p < 0.001$) but also the indirect effects ($\beta = 0.115$, $p < 0.001$) of alexithymia. Therefore, alexithymia partially mediated the relationship between FoH and sleep quality, with a 28.19% mediating effect.

4. Discussion

Despite substantial advancements in sleep management and treatment, most patients with T2DM continue to experience sleep issues [4,36]. Poor sleep quality is a persistent problem among people with T2DM, and it leads to adverse health outcomes, such as impaired cardiac autonomic function, complications, poor quality of life and increased mortality [3,37]. Therefore, target-related measures are required to manage sleep quality in patients with T2DM [38]. To the best of our knowledge, this study is the first to quantify the mediating effect of alexithymia on the relationship between FoH and sleep quality.

The results revealed a strong negative correlation between FoH and sleep quality after adjustments for numerous confounders. The findings of our study were consistent with those of the research conducted on an American adolescent population [39]. FoH places a major psychological burden on individuals with DM and can affect sleep quality [40]. The effects of FoH on sleep quality appear from several aspects: The difficulty in falling asleep experienced by patients with FoH is attributable to their apprehensiveness regarding the occurrence of hypoglycaemia at night and the steps they take to avoid it because nocturnal hypoglycaemia is twice as common as daytime episodes [41,42]. To prevent nocturnal hypoglycaemia, patients may purposefully increase their blood sugar levels before sleeping [43]. Patients with FoH may resort to an 'over-compensatory behaviour' to avoid the experiencing the unpleasant symptoms of previous hypoglycaemic episodes. This behaviour can entail discontinuing diabetes medications or overindulging to prevent hypoglycaemia. This coping strategy promotes the risk of losing sleep [44]. Moreover, concerns regarding hypoglycaemia may manifest as adrenergic neurogenic (anxiety/increased sleep arousal) and cholinergic neurogenic (sweating and paraesthesia) symptoms, which may lead to poor sleep quality [45]. Therefore, although the relationship between FoH and sleep quality in T1DM has been the main focus [40,42,46], speculation of the serious effect of FoH on the sleep quality of patients with T2DM is reasonable based on the above findings.

Our study showed the association of alexithymia with sleep quality. Our findings were consistent with those of previous studies conducted on other populations, which revealed the strong relationship between alexithymia and poor sleep quality using objective and subjective assessments of sleep quality [19,23,47]. People with alexithymia have atypical interoception–perception of 'one's internal bodily state' [48], and those with such perception under clinical observation may experience poor sleep quality [49]. Given the difficulty in identifying and describing their feelings, individuals with alexithymia exhibit an increased nocturnal arousal [50]. Poor awareness and ability to cope with emotions may increase the vulnerability of alexithymic individuals with T2DM to continuous stress, which can affect their sleep quality [51]. In addition, alexithymia is associated with decreased time in the deepest stage of sleep and increased time in the lightest stage [23]. The decrease in deep sleep may lead to a sense of nonrestoration or a feeling of mental and physical fatigue during the day [52,53]. These factors explain the poor sleep quality of individuals with great levels of alexithymia.

FoH was also associated with patients' difficulties in expressing their emotions. Adults with T2DM often deal with their concerns through negative means, such as avoidance, and an overall sense of efficacy in the FoH [11]. This 'emotional self-efficacy' may be negatively associated with alexithymia [54]. In addition, excessively high levels of fear, which cause constant emotional stress, tension, restriction of freedom, and insecurity, may trigger or intensify alexithymia [18]. Patients with FoH experience difficulty expressing their emotions [49]. Thus, logically, FoH in patients with T2DM affects alexithymia, as drawn from the above study.

To the best of our knowledge, nontraditional risk factors, such as alexithymia, were excluded in the mediation studies despite their potential importance and possible contribution to the risk of T2DM-related sleep disturbances. Our results indicated that increased alexithymia partially mediates the relationship between high FoH and low sleep quality. Specifically, individuals with high FoH present a high degree of alexithymia, which may increase the risk of sleep disorders. The inherent characteristics of the mediation analysis technique can achieve an additional 28.19% relative risk reduction in sleep disorders. These predictive analytics models test the direct and indirect effects of FoH on sleep quality and may serve a hypothesis-generating function for future intervention research on the sleep quality of Chinese adults with T2DM. Given the relatively low mediating effect of alexithymia, we speculated that other factors, such as anxiety or depression, may also influence the relationship between FoH and sleep quality. Further research and exploration of these potential factors may contribute to a complete understanding of the complex relationship between FoH and sleep quality.

This study contributes to the exploration of mechanisms underlying the effects of FoH on the sleep quality of patients with T2DM and the mediating role of alexithymia in such a relationship. However, several limitations have arisen in the conduct of the study. Firstly, this work is a cross-sectional research, and thus, obtaining causal inferences was impossible. Future studies should adopt a longitudinal design to explore the process through which FoH influences sleep quality. Secondly, although we focused on the role of alexithymia in the relationship between FoH and sleep quality, other important mediating variables, such as self-efficacy or mental resilience, need to be explored. Thirdly, the sample was selected from two specialised senior service centres and two grade-III class A hospitals through convenience sampling rather than random sampling, which might have led to selection bias and inadequate sample representativeness. Random sampling method must be adopted in future reserach should to improve the reliability and generalisation of research results. In addition, the study did disregarded the frequency and severity of hypoglycaemia episodes and the usage of hypoglycaemic drugs in T2DM patients. Future studies need to consider such details. Despite these limitations, the results of this study will help us comprehend the intrinsic relationship between FoH and sleep quality to a certain extent and determine the possible causes and mechanisms of this relationship in the context of Chinese culture.

5. Conclusions

The findings of the present study are important in China's health context given the high burden imposed by poor sleep quality on patients with T2DM. Our study demonstrated the relationship between FoH and sleep quality, which is partially mediated by alexithymia. The findings of this study deepen our comprehension of underlying mechanisms linking FoH and sleep quality in T2DM patients. Clinicians should gain awareness of the potential effect of alexithymia and incorporate such knowledge in intervention planning and care. Addressing the affective disturbances arising from FoH can lead to enhanced emotional expression and sleep quality of patients. Moreover, early detection of abnormal blood sugar conditions through regular monitoring, optimization of treatments and appropriate adjustments at individual and hospital levels can foster better diet, work, rest, and social relationships for individuals with T2DM, which ultimately elevate the overall management and sleep quality.

Funding

This work was supported by the Advantages Discipline Group (Public Health) Project in Higher Education of Hubei Province (2021–2025) (Grant no. 2022PHXKQ2), the Faculty Development Grants from Hubei University of Medicine (Grant no. 2020QDJRW003) and the Natural Science Foundation of Hubei Provincial Department of Education (Grant no. D20222105).

Availability of data and materials

The data collected during this study will be available from the corresponding author upon reasonable request. Considering the ethical and confdentiality issue, it will be kept restricted.

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Hubei University of Medicine (2022-RE-012). All participants provided informed consent to participate.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Liuhong Tian: Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Ke Liu:** Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Li Li:** Writing – review & editing, Supervision. **Wenwen Wu:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Ningrui Zhang:** Formal analysis.

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.

Acknowledgements

The authors would like to thank all the participants for their assistance and contributions to the study.

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