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ORIGINAL ARTICLE

The comparison of sleep disorders between type-1 diabetic and non-diabetic children and adolescents

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Abstract

Background Type 1 diabetes mellitus (T1DM) is one of the most encountered chronic diseases in children and adolescents. Sleep as an essential part of life cycles follows a complicated biological pattern.

Objective This study aimed to investigate and compare the sleep disorders between T1DM and non-diabetic children and adolescents.

Methods This is a cross-sectional study that was conducted in a pediatric endocrinology clinic in Qazvin City during 2018–2019. The participated samples in T1DM and non-diabetic groups were 47 and 44 samples, respectively. The Children Sleep Health Questionnaire (CSHQ) was completed by the parents. Data were analyzed using SPSS software package version 22.

Results The findings showed that the subscales of CSHQ including bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night waking, parasomnia, and total sleep disorder score of the diabetic patients were significantly higher than that of the control group ($p < 0.05$). The total score of CSHQ in the T1DM children group was higher than that the non-diabetic group, and this observed difference between scores was statistically significant (49.80 vs. 43.77, $p < 0.05$). The odds of the sleep complications in diabetic group (T1DM) are higher more than three times of the non-diabetic group controlling the confounding effects of the factors including age, sex, and BMI (OR = 3.16, 95% CI: 1.05–9.52).

Conclusion According to the findings of our study, impaired sleep conditions in the T1DM children group were approximately three times the observed ones in the non-diabetic children group. According to our findings, routine evaluation of sleep disorders in diabetic children and adolescents is recommended.

Keywords Sleep disorder · Type-1 diabetes · Children · Adolescents · Family tensions

Introduction

Sleep is among the most important parts of life cycles in the daytime (night and day) and one of the fundamental human needs, which follows a complicated biological rhythm. In most cases, sleep cycle disruption indicates early signs of various diseases. Flawless sleep has a crucial role in physical and mental health during childhood. Sleep disorder is the fifth leading cause of referring to pediatric clinics among the children and adolescents below 18 years old [1].

Approximately 20–30% of the general population are diagnosed with a sleep disorder, with a wide range of sleep disturbances [2], including sleep-resistance or onset insomnia, night-time (nocturnal) wakening, and insufficient sleep [3]. Some of the sleep disorder complications consist of obstructive sleep apnea (OSA), restless legs syndrome (RLS), periodic limb movement disorder

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(PLMD), narcolepsy, and behavior-based sleep disorders (e.g., childhood behavioral insomnia) [4].

However, sleep studies in youth with T1D report poorer sleep quality and greater glucose control with better sleep quality [5]. In a study of adolescents and young adults with type 2 diabetes, Gabbs et al. reported that poor sleep was associated with stress, distress, and poor blood sugar management. Regression analysis showed that poor sleep was associated with higher glycosylated hemoglobin [6]. Also, there is evidence showing that type 2 diabetes mellitus (T2DM) is associated with higher incidence of sleep disorder [7, 8]. On the other hand, researches have shown that sleep-related problems are more common in children with T1DM and are associated with poor metabolic control [9–13]. For patients with type 1 diabetes mellitus (T1DM), sleep disturbances can also be triggered by nocturnal awakening due to hypo/hyperglycemia and parental care at night [14].

Diabetes mellitus (DM) is a metabolic disease that is characterized by the presence of hyperglycemia due to impairment of insulin secretion, insulin action, or both. There are two major types of the disease: type 1 and type 2 diabetes [15, 16].

The prevalence of T1DM among children is currently increasing all over the world and still the main cause of which is still unknown. In the United States, 1 out of every 400 children and adolescents has diabetes. In Iran, diabetes is at the top of non-communicable diseases, so the annual incidence rate of T1DM has been estimated 3.7 cases per 100,000 individuals [15]. If not controlled sufficiently, this disease can cause complications such as heart attack, blindness, hypertension, neurological disorders, and kidney failure.

In addition, children [9] and young adults [17], with T1DM, subjectively report poor-quality sleep than in those without. Based on polysomnography (PSG), data has been reported that children with T1DM spend more time in stage 2 (light sleep) and less time in stage 3 (slow-wave sleep) compared to healthy control subjects [11]. Adults with T1DM also showed more stage 2 sleep and had significantly later sleep onset and offset (both by ~ 30 min) compared to healthy control subjects [18].

Various sleep disturbances are reported in sleep logs such as sleep onset latency, sleep offset, and efficiency [19]. Sleep latency is perhaps one of the most important parameters in a sleep study. Sleep onset latency, as measured by PSG, is the amount of time passed until turning off the light and going to sleep. The average sleep latency is over 20 min [20]. Sleep offset refers to the time when a person wakes up in the morning. The percentage of time an adolescent spends asleep between the start and the end of sleep is referred to as sleep efficiency [21].

There is strong evidence to suggest the differences in neuroendocrine correlates of sleep; levels of growth hormone and epinephrine were elevated overall the night, and levels of adrenocortotropic hormone were found higher during the first 4 h of the night in adults with T1DM [18].

It is apparent that there are significant differences in pattern of sleep stages across a night of children with and without T1DM. Inadequate sleep can damage cognitive functions that are necessary for the effective control of diabetes [22]. On the other hand, poor diabetic control can also affect sleep [23].

Therefore, this study aimed to investigate the features and characteristics of sleep disorders among children and young adults with and without T1DM in Qazvin Province, Iran.

Methods and Materials

This is a cross-sectional study that was conducted in a pediatric endocrinology clinic in Qazvin City during 2018–2019. The diabetic children group included 47 children and adolescents with T1DM aged 2–18 years old who had been referred to Qazvin Endocrinology Clinic for a 1-year period. The needed sample size was calculated using the formula comparing two means in independent groups. The sample size formula and parameters are presented as followed. The values of parameters were extracted from the study by Caruso NC et al. [9] that are presented as follows:

$$\alpha = 0.05, 1-\alpha = 0.95, \beta = 0.2, 1-\beta = 0.8, \mu 1 = 50.9, \mu 2 = 61.3, \delta = 16.3$$

$$N = (2\sigma)^2 [Z1 - \frac{\alpha}{2} + Z1 - \beta]^{\frac{2}{\delta^2}}$$

The minimum required sample size in this study was determined as 41 patients in each study groups.

These individuals were diagnosed with T1DM and were included by a pediatric endocrinologist if they had one of the following criteria: fasting blood sugar level equal to or above 126 mg/dl in two separate tests, random blood sugar level equal to or above 200 mg/dl associated with symptoms that prove diabetes, and hemoglobin A1c level of 6.5 or higher, proved in two stages. Autoantibodies against insulin, anti-islet cells, and anti-GAD were checked for all patients. C-peptide levels were also measured to confirm the diagnosis of type 1 diabetes for all patients. The non-diabetic children group consisted of 43 healthy children aged 2–18 years old.

Individuals with diabetes who had some other comorbidity such as heart failure, chronic obstructive pulmonary disease (COPD), and asthma which might interfere with appropriate sleep, were excluded from the study.

In this study, once the demographic information, such as age and gender, and the HbA1C results were recorded in the draft, the Children's Sleep Health Questionnaire (CSHQ) was completed by the parents. This questionnaire was designed and built by Owens and Espirito et al. for school-aged children [24]. It consists of 45 items aiming to assess the children's sleep quality and habits. The CSHQ is one of the most frequently used questionnaires and has been validated for evaluating sleep and computing Sleep Scores (SS) among children [24]. The CSHQ evaluates the previous seven nights of a child's sleep, considering eight subscales that comprise the most frequently reported sleep complaints in children, such as bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night waking, parasomnias, sleep-disordered breathing, and daytime sleepiness. In CHSQ, the studied samples were divided into two groups based on a self-report SS of ≥ 41 points or < 41 points. The sleep score cutoff of ≥ 41 indicates a worse sleep condition [24]. The validity of this instrument was evaluated using the content validity evaluation method, and its reliability was determined by Shoghi via performing the re-test method on 10 children aged 6 to 11 years old ($r = 0.97$) [25].

The participants categorized in the questionnaire included the following: (1) resistance against sleep, (2) delayed onset of sleep, (3) sleep duration, (4) sleep anxiety, (5) night (nocturnal awakening), (6) parasomnia (pseudo-sleep), (7) breathing-related sleep disorders (sleep-related breathing disorders), and (8) daily drowsiness. The CSHQ's score range was between 33 and 99, as higher scores indicated more sleep disorders. A score of 41 or higher was clinically significant and a score of less than 33 indicated a flawless sleep. The questionnaire was scored based on a five-degree (five-grade) Likert scale and included 45 questions. Some of the questions had merely diagnostic and therapeutic values and were not research-oriented questions. Thus, only 33 questions were selected for scoring. Every answer had a value ranging between 1 and 3 (from rarely to usual), except for items 26, 11, 10, 3, 2, and 1, which were scored inversely. The score range was from 33 to 99, and the score of each subscale was obtained from the sum of the scores of the mentioned questions.

In order to assess the mean of T1DM disease duration with hyperglycemia control status in T1DM group, we defined the hyperglycemia control status according to American Diabetes Association for non-pregnant adults. Therefore, there were three divided groups including HbA1C $< 7\%$ as good control, 7–8% as inadequate control, and greater than 8% as poor control [26].

Data were analyzed using SPSS software package version 22. The mean and standard deviation were used to report descriptive of quantitative data, and frequency and percentage were used for qualitative data. Normality of quantitative variables were assessed using the Kolmogorov–Smirnov test. In all analyses, a p-value less than 0.05 was considered statistical significant level.

Table 1 The comparison of studied variables between two study groups

Variable	Type-1 diabetes group	Non-diabetic group	p-value
Age Mean (±)	11.26 ± 4.12	10.73 ± 4.14	ns*
BMI Mean (±)	20.47 ± 3.67	21.66 ± 12.86	ns
Sex Freq.(%)			ns
Female	23 (48.90)	24 (54.5)	
Male	24 (51.10)	20 (45.5)	

ns non-significant

Table 2 The mean and diversions of subscales of CSHQ in total study samples

Subscales of CSHQ	Min	Max	Mean	Std. deviation
Bedtime resistance	6.00	16.00	8.81	2.45
Sleep onset delay	1.00	3.00	1.31	0.64
Sleep duration	3.00	7.00	3.69	1.09
Sleep anxiety	4.00	12.00	5.93	2.35
Night waking	3.00	9.00	4.23	1.46
Parasomnias	7.00	14.00	8.09	1.61
Sleep disordered breathing	3.00	6.00	3.28	0.63
Daytime sleepiness	8.00	19.00	11.53	2.88
Total Score	35.00	71.00	46.89	8.31

Results

The results of this study show a mean age of 10.73 ± 4.14 years old among the non-diabetic children group and 11.26 ± 4.12 years old among the T1DM children group. The diabetic children group included 23 girls (48.9%) and 24 boys (51.1%), and the non-diabetic children group consisted of 24 girls (54.5%) and 20 boys (45.5%). There was no statistically significant difference between the T1DM and non-diabetic children groups in terms of age ($p > 0.05$) (Table 1).

The mean and diversions of subscales of CSHQ in total study samples are presented in Table 2. According to the results, the CSHQ score for studied samples was > 41 points, which is considered as the worst sleep condition. The mean and standard deviations of subscales of CSHQ among two study groups are presented in Table 3. Also, the comparison of the mean of duration of T1DM disease with Glycemic control status in T1DM group are presented in Table 4.

Table 3 The mean and standard deviations of subscales of CSHQ among two study groups

Subscales of CSHQ	Type-1 diabetes group Mean (±)	Non-diabetic group Mean (±)	Mean difference	*p* value
Bedtime resistance	9.36 ± 2.59	8.22 ± 2.17	1.14	0.02
Sleep onset delay	1.46 ± 0.77	1.13 ± 0.41	0.33	0.01
Sleep duration	7.00 ± 1.26	8.36 ± 0.74	0.64	0.004
Sleep anxiety	6.53 ± 2.56	5.29 ± 1.93	1.24	0.01
Night waking	4.72 ± 1.66	3.70 ± 0.97	1.02	0.001
Parasomnia	8.55 ± 1.96	7.61 ± 0.92	0.94	0.004
Sleep disordered breathing	3.29 ± 0.64	3.27 ± 0.63	0.02	ns*
Daytime sleepiness	11.89 ± 3.23	11.14 ± 2.44	0.75	ns
Total Score	49.80 ± 8.87	43.77 ± 6.41	6.03	0.001

*Non-significant

Table 4 Comparison of the mean of duration of T1DM disease with Glycemic control status in T1DM group

Glycemic control status	Mean (S.D.)	*F*	*p* value
Good control (< 7%)	3.13 (2.20)	1.67	0.1
Inadequate control (7–8%)	4.41 (1.62)		
Poor control (> 8%)	4.74 (2.31)		

Table 5 The comparison of frequency and percent of worse sleep condition between two study groups using a sleep score cutoff of ≥ 41

Sleep condition	Type-1 diabetes group Freq. (%)	Non-diabetic group Freq. (%)	*p* value
Non-sleep disorder (score cutoff of < 41)	10 (21.3)	16 (36.4)	0.04
Worse sleep condition (score cutoff of ≥ 41)	37 (78.7)	28 (43.1)	

The obtained results indicated a significant difference between the two T1DM and non-diabetic children groups in terms of total CSHQ score (p-value < 0.05). Moreover, the comparison of the means between two groups regarding subscales of CSHQ showed that the scores in all subscales were higher in the T1DM group rather than the non-diabetic children group. The observed mean differences were statistically significant ($p < 0.05$), except for the subscales of "Sleep-disordered breathing" and "Daytime sleepiness". The highest and lowest mean differences were seen in the "Sleep anxiety" and "Sleep-disordered breathing" subscales, respectively (the highest and lowest mean differences values; 1.24, $p < 0.05$, and 0.02 $p > 0.05$ respectively). The total score of CSHQ in the T1DM children group was higher than the non-diabetic group, and this observed difference score was statistically significant (49.80 vs. 43.77, $p < 0.05$).

The results of the comparison of the T1DM duration and hypoglycemia control showed no statistically significant difference in the mean of duration of T1DM in three groups of good control, inadequate control, and poor control (Tables 3 and 4). As shown in Table 5, the worst sleep condition (SS of ≥ 41 points) in the T1DM children group was approximately twice that in the non-diabetic children group, and this was statistically significant (78.7% vs. 43.1%, $p < 0.05$).

As shown in Table 6, the odds of worst sleep condition in diabetic group is more than three times higher than non-diabetic group controlling the confounding factors including age, sex, and BMI (OR = 3.16, 95% CI: 1.05–9.52). Moreover, the results showed that the OR for the variable of age is 0.72 (OR = 0.72, 95% CI: 0.60–0.86). It means that the odds of worst condition decrease by 0.28 per 1 year increase in age.

Discussion

The aim of the present study was to compare the sleep disorders between children and adolescents with or without T1DM. The findings of this study showed the subscales of CSHQ including bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night waking, parasomnias, and total sleep disorder score of the diabetic patients were significantly higher in comparison to the control group ($p < 0.05$). The mean score of subscales of sleep-disordered breathing and daytime sleepiness was higher in T1DM, but the observed differences were not statistically significant ($p > 0.05$). The results of the current study showed that worse sleep conditions (SS of ≥ 41 points) in the T1DM group were three times more than the non-diabetic group, which was statistically significant (78.7% vs. 43.1%, $p < 0.05$).

Consistent with this study, Farabi et al. reported that adults and children with T1DM had poorer sleep quality than those without diabetes. They presented alterations in sleep quality can be the cause of both behavioral and physiological aspects of this disease and its management [27].

Table 6 The results of regression logistic about the relationship of type 1 diabetes and worse sleep condition

Variables	β	S.E	Odds ratio (OR)	95% C.I. for OR	p value
Sex (female)	0.6	0.54	1.82	0.62–5.29	0.2
Age	−0.32	0.09	0.72	0.60–0.86	0.001
Group (T1DM)	1.15	0.56	3.16	1.05–9.52	0.04
BMI	−0.006	0.02	0.99	0.94–1.04	0.8
Constant	4.08	1.18	-	-	-

In addition, Bahadur et al. in 2021 evaluated 75 children with T1DM and 49 children without T1DM. CSHQ results showed that 65.3% of all children in both groups had sleep disorders. Children with T1DM had significantly higher sleep problems compared to controls ($p=0.024$, $p=0.008$, respectively) [28].

The findings of other studies showed that self-reported average of sleep among young T1DM patients ranged below the recommended amount of sleep (7.4 to 8.6 h/night) [29, 30]. This sleep disorder may be related to the defective function of pancreatic β-cells in the population with T1 diabetes. Following the destruction of pancreatic beta cells and insulin deficiency in type 1 diabetic patients, blood glucose concentration increases, and this hyperglycemia leads to polydipsia, polyuria, and nocturnal enuresis, which leads to sleep disorders in diabetic patients. Persistent hyperglycemia may also lead to diabetic ketoacidosis (DKA) [31]. Moreover, derangements in night sleep due to symptoms of hypo- or hyperglycemia, frequent urination, and thirst negatively affect glycemic control via elevations in cortisol and an imbalance in parasympathetic and sympathetic activity [32].

Inadequate sleep time, especially in children and young people with diabetes, can negatively affect insulin sensitivity and worsen blood sugar control [22]. It is reported that sleep disorders during the night in adults would reduce insulin-stimulated glucose absorption by 14–21%, and chronic sleep deprivation might increase insulin resistance in the patients with T1DM. Insulin resistance is associated with an increased risk of micro- and macrovascular complications in T1DM [22, 33]. Therefore, if T1DM causes disorders in sleep patterns, it would also be able to cause abnormal regulation of blood glucose and result in forming negative chain reactions.

In the current study, the sleep duration in T1DM group was lower than control group. In some other studies [10, 11], sleep duration with polysomnography in population with diabetic was lower than healthy controls. Reutrakul et al. in a systematic review and meta-analysis demonstrated that patients with type 1 diabetes had poorer sleep quality, but there was no difference in sleep duration according to patients' self-reports [34].

In addition, we found that the mean of daytime sleepiness in the T1DM group (11.89 ± 3.23) was more compared to the control group (11.14 ± 2.44), but this difference was not significant. In contrast with our results, Adler et al. in a study in 2017 reported fewer patients with T1DM than healthy population had (age of 6–30) excessive daytime sleepiness [30]. It seems that the difference between the results of our study and the mentioned study is in the age range of the population under investigation.

We did not find any association between the duration of T1DM disease with glycemic control status. This can be because of the relatively small sample sizes in our study. Similar to our results, Frye et al. in 2019 reported that average sleep duration was directly related to patient average glycemic control but inversely related to average HbA1c, indicating that less sleep is associated with worse glycemic management and control [35]. Thus, based on the obtained results, it seems that diabetes care teams should provide adolescents with consultation and advice about the importance of sufficient sleep.

Strengths and limitations of the study

The more important strength of this study is that it addresses a relevant research question regarding the association between sleep disorders and type 1 diabetes mellitus in children and adolescents and fills a gap in the existing literature by examining sleep disorders in children and adolescents in the studied pediatric population with T1DM. In this study, we have used samples from a single pediatric endocrine clinic in Qazvin City, so this is considered a limitation of our study. While using these findings, their generalizability should be paid attention. Therefore, it is suggested that it is beneficial that more studies be conducted worldwide to collect the pieces of evidence required to meet the external validity and generalizability. Moreover, we were obliged to collect the data from parental reports due to the very young age of some participants (range of age: 4–17 years old). Parental reports via the CSHQ may lead to subjective biases, which is the other limitation of our study.

Conclusion

According to the findings of our study, worse sleep condition in the T1DM children group was approximately three times than non-diabetic control group. It is recommended to conduct

more studies in order to further clarify the role of sleep in the outcomes and consequences of diabetes control and to perform behavioral tests to increase and stabilize sleeping.

Data availability statement The datasets will be available from the corresponding author on reasonable request.

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Declarations

Ethical approval The present work was conducted after being approved by the Ethical Committee of Qazvin University of Medical Sciences (IR.QUMS.REC.1397.319).

Conflict of interest The authors declare no competing interests.

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