Sleep Medicine 115 (2024) 55–60

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

# Sleep disturbances in children and adolescents with type 1 diabetes mellitus: Prevalence, and relationship with diabetes management

Zeynep Donbaloğlu [a], Ebru Barsal Çetiner [a], Aynur İnan Yüksel [b], Berna Singin [a], Bilge Aydın Behram [a], Aynur Bedel [a], Mesut Parlak [a], Hale Tuhan [a,*]

[a] Department of Pediatric Endocrinology, Akdeniz University Hospital, Antalya, Turkey
[b] Department of Pediatrics, Akdeniz University Hospital, Antalya, Turkey

A B S T R A C T

*Objective:* A decline in sleep quality and regularity has been reported in patients with type 1 diabetes mellitus (T1D) in many studies. However, research on medical-based sleep disorders in patients with T1D is limited. Diagnosing sleep disorders is crucial, as it negatively impacts academic performance, cardiovascular health, and cognitive functions among children as well as essential skills for effective diabetes management. Our objective was to assess sleep disturbances in patients diagnosed with T1D and explore whether these patients experience significantly more sleep disturbances compared to their healthy peers.

*Methods:* This study, designed as a cross-sectional case-control investigation, involved a cohort of 250 participants (144 T1D, 106 control cases) aged 6–15 years. The Sleep Disturbance Scale for Children (SDCS) scores of the T1D group were compared with those of the control group. Furthermore, the study explored the correlation between clinical/biochemical parameters and SDCS scores within the T1D group.

*Results:* The mean age of individuals in the T1D group was 10.27 ± 3.25 years, while the control group had a comparable mean age of 10.48 ± 3.5 years (P = 0.303). Within the T1D group, the median duration of diabetes was 5 (1-15) years, and the median glycosylated hemoglobin $A1_c$ ($HbA1_c$) level for the past one year was 8.4 %. Although there was no significant difference in total SDSC scores between the T1D and control groups, both groups exhibited average scores that remained close to the threshold indicative of sleep disturbances (>39). Notably, individuals with total SDSC scores surpassing 39 were identified at rates of 48.6 % in the T1D group and 47.6 % in the control group, respectively. Furthermore, disorders of arousal nightmares (DA) were more prevalent in T1D patients compared to their healthy peers (P = 0.049). Additionally, $HbA1_c$ showed a positive correlation with scores for disorders of excessive somnolence (DOES) and total scores (P < 0.001, R = 0.368; P = 0.003, R = 0.243).

*Conclusion:* Our study found that the prevalence of sleep disturbances among children and adolescents with T1D was not significantly higher than that observed in their healthy peers. Nevertheless, it is crucial to note that a notable portion, 48.6 % of T1D cases and 47.6 % of healthy cases, displayed sleep disturbances based on SDSC scores. To optimize diabetes management and proactively address potential challenges, incorporating routine screening for sleep disturbances in the monitoring of T1D patients can yield valuable benefits.

## 1. Introduction

Diabetes mellitus (DM) refers to a cluster of metabolic disorders marked by a persistent elevation in blood glucose levels due to deficiencies in insulin secretion, insulin function, or a combination of both. Type 1 DM (T1D) is a chronic autoimmune condition characterized by the targeted destruction of insulin-producing pancreatic β cells. It stands out as the predominant form of diabetes in childhood [1,2].

Sleep is universally recognized as a fundamental physiological necessity, encompassing roughly one-third of human life and playing a crucial role in maintaining overall health [3]. Beyond its impact on productivity, sleep profoundly influences cognitive functions like memory and concentration, contributing to both physical and psychological restoration [4,5]. Epidemiological investigations revealed that 50 % of children grapple with sleep-related challenges [6–8], with approximately 4 % experiencing clinically significant sleep disorders [9]. These disorders can stem from medical sources, such as obstructive sleep apnea, restless legs syndrome, periodic limb movement disorder, narcolepsy, or behavioral factors, like childhood behavioral insomnia. Common complaints include difficulty initiating sleep, nocturnal awakenings, snoring, excessive daytime sleepiness, and compromised daytime functioning. Recognizing these complaints as potential symptoms of treatable sleep disorders underscores the importance of addressing sleep-related issues for overall well-being.

In many studies, a decline in sleep quality and regularity has been reported in patients with diabetes, similar to other chronic illnesses [10,11]. Most of these studies, predominantly involving the adult population, have focused on evaluating sleep quality, specifically by

* Corresponding author. Department of Pediatric Endocrinology, Akdeniz University Faculty of Medicine Hospital, Pinarbasi, 07070, Antalya, Turkey.
*E-mail address:* haletuhan@akdeniz.edu.tr (H. Tuhan).

https://doi.org/10.1016/j.sleep.2024.01.031
Received 16 November 2023; Received in revised form 29 January 2024; Accepted 30 January 2024
Available online 1 February 2024
1389-9457/© 2024 Elsevier B.V. All rights reserved.

investigating cases of Type 2 DM (T2D) due to the adverse effects of obesity and its associated comorbidities on sleep quality [11]. In the context of T1D, recent findings across both pediatric and adult populations indicate a dynamic and reciprocal relationship between sleep and T1D [12,13]. Physiological and behavioral aspects of T1D and its management can contribute to poor sleep quality [13–15], reduced sleep duration [13,16], and alterations in sleep architecture [13,17]. Conversely, sleep problems and disruptions can also impact insulin sensitivity and glucose regulation [18,19]. In a comprehensive study utilizing 7-day actigraphy and single-night home-based polysomnography (PSG) recordings to assess sleep patterns, notable differences were identified between individuals with T1D and the control group. The findings revealed that T1D cases exhibited significantly delayed sleep onset and offset compared to the control group. Furthermore, within the T1D patient group, those with suboptimal glycemic control ($HbA1_c \geq 7.5$ % [≥58 mmol/mol]) displayed a distinct pattern, experiencing significantly shorter total sleep time based on actigraphy-derived measurements [20]. A study also highlighted that adolescents at high risk of T1D encounter sleep difficulties, primarily attributable to delayed bedtime, resulting in a cumulative sleep deficit. Interestingly, despite the absence of objective disparities, these individuals perceive their sleep quality to be worse compared to their non-diabetic peers [21].

Besides these topics, research on medical-based sleep disorders in individuals with T1D, especially among children and adolescents remains limited. Additionally, the researchers indicate that sleep disturbances in children are often insufficiently screened, not adequately reported by parents, and consequently underdiagnosed [22,23]. Diagnosing sleep disorders is crucial, as it negatively impacts academic performance, cardiovascular health, and cognitive functions among children as well as essential skills for effective diabetes management [23].

In our study, our first objective was to assess sleep disturbances in patients diagnosed with T1D and explore whether these patients experience significantly more sleep disturbances compared to their healthy peers. Secondly, we aimed to examine the correlations of sleep disturbance scores with glycemic control and clinical/laboratory findings within the T1D group.

## 2. Materials and methods

### 2.1. Study design

This study, designed as a cross-sectional, single-center, case-control investigation, involved a cohort of 250 participants aged 6–15 years. Among these, 144 were allocated to the T1D group, comprising individuals diagnosed with T1D and undergoing follow-up at the pediatric endocrinology clinic of Akdeniz University Hospital, Antalya, Turkey. The control group consisted of 106 healthy volunteers carefully matched with T1D patients for age, gender, and sharing a similar sociodemographic profile. They were recruited through primary, secondary, and high school students residing in the city center, and individuals willing to participate in this study were invited to our hospital accompanied by their parents. Anthropometric measurements were taken. A comprehensive review of the control group participants' prior clinical assessments, health records, and prescriptions was conducted using the national "e-nabiz" data system, supported by the Turkish Ministry of Health. Exclusions from the control group encompassed individuals with chronic diseases or those utilizing medications. For the T1D group, additional exclusion criteria included patients diagnosed with types of diabetes other than T1D and those with a T1D diagnosis of less than one year. Participants in either group using medications known to influence sleep disturbances, such as antidepressants, melatonin, or stimulant drugs, were also excluded from the study. The Sleep Disturbance Scale for Children (SDCS) scores of the T1D group were compared with those of the control group. Furthermore, the study explored the correlation between clinical/biochemical parameters and SDCS scores within the T1D group.

### 2.2. Diagnosis of T1D and clinical/laboratory investigations

We determined the diagnosis of patients with T1D according to the International Society for Pediatric and Adolescent Diabetes (ISPAD) 2018 guideline [24]. Data on sociodemographic characteristics (e.g. age, parent's education, family income, number of people living at home) were collected using a questionnaire. The frequency of daily blood glucose checks, insulin regimen (pen or pump), using continuous glucose monitoring (CGM) or not, total insulin dosage (u/kg/day), and diabetic ketoacidosis (DKA) history in the last 6 months, were also recorded. Body weight was measured using an electronic scale. Height was measured with a wall-mounted stadiometer in both the upright standing position and during deep inspiration. Body Mass Index (BMI) was calculated by dividing weight by the square of height ($kg/m^2$). Standard deviation scores (SDS) for height, weight, and BMI were determined based on reference values for Turkish children [25].

#### 2.2.1. Sleep disturbance evaluation

Sleep Disturbance Scale for Children was used to evaluate sleep disturbances of T1D and control cases. SDSC is a tool developed by Bruni et al. [26] in 1996 to assess a child's sleep behaviors and disturbances over the preceding 6 months. This instrument is internally consistent, reliable, and valid within the 6–15 age population. Designed on a five-point Likert scale, the questionnaire can differentiate between six groups of sleep disorders most commonly observed among children and adolescents: 1) disorders of initiating and maintaining sleep (DIMS), 2) sleep-disordered breathing (SDB), 3) disorders of arousal nightmares (DA), 4) sleep-wake transition disorders (SWTD), 5) disorders of excessive somnolence (DOES), 6) sleep hyperhidrosis (SHY). The total score of the scale is calculated by summing the scores of the six sub-dimensions of sleep disturbance, with higher scores indicating a greater occurrence of sleep disorders. The researchers have suggested a cutoff score of 39, noting that in their assessments, this score corresponds to the third quartile of the control group, with a sensitivity of 0.89 and specificity of 0.74 [26]. SDSC is a scale based on parental notification, and literate parents completed this survey, taking into account their children's sleep patterns over the last 6 months. SDSC was validated in clinical samples and it was found to be a reliable scale that could screen sleep disturbance in school-age Turkish children by Akçay et al. [27].

### 2.3. Statistical analysis

We conducted the statistical analysis using The Statistical Package for the Social Sciences (SPSS for Windows, Version 23.0, Chicago, IL, USA). Continuous measurements were reported as either median [Interquartile range (IQR)] or mean ± standard deviation (SD), while categorical data were presented as counts and percentages. For the comparison of categorical variables, we employed Pearson's chi-square and Fisher's exact tests. To assess normality, the Shapiro-Wilk test was used, and distribution was also checked when comparing continuous measurements. Normally distributed parameters were compared using the *t*-Test, while non-normally distributed parameters were compared using the Mann-Whitney *U* test. The Pearson correlation test was utilized to explore relationships among normally distributed variables, and the Spearman correlation was employed for variables that did not adhere to a normal distribution. A p-value less than 0.05 was considered indicative of statistical significance.

### 2.4. Ethics

This study received approval from the Akdeniz University Ethics Committee (approval number: 70904504/136). Before commencement,

informed consent was obtained from their parents. The research adhered to the principles outlined in the Declaration of Helsinki and followed the Ethical Guidelines for Medical and Health Research Involving Human Subjects.

## 3. Results

In total, 144 T1D patients and 106 control cases completed the required questionnaires and were included in the study. The mean age of the cases in the T1D group was 10.27 ± 3.25 years and the control group was similarly 10.48 ± 3.5 years (P = 0.303). Gender rates and anthropometric measures were also similar in the two groups (Table 1). No statistically significant differences were observed in terms of BMI between the groups. Likewise, the obesity rate in the T1D group was 3.4 % (5 out of 144), while in the control group, it was 3.7 % (4 out of 106).

In the T1D group, the median duration of diabetes was 5 (1 - 15) years. The rate of those who had a DKA attack in the last 6 months was 11.8 %. 34 % of the cases were using insulin pumps and 68.8 % were using CGM. The median $HBA1_c$ level of the patients for the last year was 8.4 % (Table 2).

Sleep disturbance scale for children scores of T1D patients and controls were given in Table 3. There was no significant difference between the T1D group and the control group in the SDSC scores and subscales of the SDSC except DA. It was found that DA is more prevalent in T1D patients when compared to healthy peers (P = 0.049). Nevertheless, in both groups, the average score remained close to the threshold for defining sleep disturbances (total score >39). According to this cut-off value, the findings revealed a 48.6 % incidence of sleep disturbance in the T1D group and a comparable rate of 47.6 % in the control group (P = 0.979).

Correlational analyses of SDSC scores with clinical and laboratory findings of T1D patients were given in Table 4. $Hba1_c$ was positively correlated with the DOES scores and total scores (P < 0.001, R = 0.368; P = 0.003, R = 0.243). The SHY score was negatively correlated with the duration of diabetes (P = 0.013, R = −0.214).

Subgroup analyses of T1D patients were also examined according to the usage of insulin pump or CGM. SDSC scores of cases using and not using CGM were found to be similar, just as in cases using and not using insulin pump.

## 4. Discussion

Sleep disturbances have been consistently observed as a common occurrence in individuals with T1D throughout their lifespan, starting as early as childhood [28]. In addition to qualitative research exploring data associated with T1D; studies examining medical-based sleep issues in individuals with T1D are limited. Evaluating sleep disturbances in individuals with T1D is essential because of the potential influence of sleep disorders on diabetes management. Moreover, considering T1D as a lifelong chronic condition, extended exposure to sleep disturbances may contribute to an increased risk of exacerbating complications related to diabetes [14,28–30]. In our study, although we did not observe a significant difference in the total SDSC scores between the two groups when comparing patients with T1D to their healthy peers, the responses from parents on the questionnaire concerning patients with T1D indicated that 48.6 % of them met the clinical cutoff of sleep disturbances. In a sample of preschoolers, 9 out of 10 children with T1D exceeded the clinical cutoff value on a parent-reported sleep diary of sleep disturbance [31]. In the school-age population, 67 % of children with T1D surpassed the score cutoff on a parent-reported measure evaluating sleep disturbances through the Child Sleep Habits Questionnaire and Pittsburgh Sleep Quality Index (PSQI) [15], with a noted prevalence of 60 % in adolescents through School Sleep Habits Survey [32]. In a cross-sectional study involving T1D and healthy controls matched for age range, subjective sleep characteristics were evaluated using the SDSC scale and the study revealed no significant difference in the mean SDSC score between children with diabetes and controls, with total scores of 39.58 ± 8.74 and 39.6 ± 8.68, respectively. These findings align closely with the results obtained in our study [33]. Moreover, they also highlighted that the mean score in both groups was on the borderline for categorizing sleep disturbances [33].

Studies investigating the relationship between T1D and sleep delve into various aspects beyond sleep disturbances, including sleep quality, sleep duration, and sleep architecture through sleep cycles. In a study assessing sleep timing and quality using the PSQI, adolescents with T1D reported later bedtimes (an increase of 36 min, p < 0.05) and shorter sleep duration (a decrease of 53 min, p < 0.05) compared to the control group. Additionally, they were more likely to rate subjective sleep duration, efficiency, and quality as 'poor.' However, objectively measured sleep patterns, determined through a 7-day actigraphy, were found to be similar between the two groups [21]. In a meta-analysis conducted by Reutrakul et al. [13], it was similarly observed that children with T1D experienced shorter sleep durations compared to the

**Table 1**
Descriptive findings of the participants.

| *Variable* | T1D N = 144 | Controls N = 106 | *P value* |
|---|---|---|---|
| Age | 10.27 ± 3.25 | 10.48 ± 3.5 | 0.303 |
| Gender (F/M) | 72/72 | 48/58 | 0.461 |
| Weight SDS | 0.24 (−0.43 / 0.97) | −0.01 (−0.80 / 0.77) | 0.229 |
| Height SDS | 0.28 (−0.47 / 0.87) | 0.27 (−0.52 / 1.01) | 0.879 |
| BMI SDS | 0.25 (−0.52 / 0.88) | −0.17 (−0.82 / 0.70) | 0.064 |

Data are expressed as mean ± SD or median ($25^{th}$ - $75^{th}$ percentiles) or as number (percent).
T1D: type 1 diabetes mellitus; SDS: standard deviation score; F: female; M: male; BMI: body mass index.

**Table 2**
Clinical and laboratory findings of type 1 diabetes mellitus patients.

| *Variable* | N = 144 |
|---|---|
| Age at diagnosis (year) | 7.5 (4 – 10) |
| Diabetes duration (year) | 5 (1 – 6) |
| DKA + | 17 (11.8 %) |
| DKA - | 127 (88.2 %) |
| Insulin regimen | |
| Pen | 95 (66 %) |
| Pump | 49 (34 %) |
| Insulin dosage (u/kg/day) | 0.71 (0.56 – 0.97) |
| Daily glucose check[a] | 7 (5 – 9) |
| CGM usage | 45 (31.2 %) |
| $HbA1_c$ (%, mmol/mol) | 8.4 % (7.5 – 10.2), 58.8 (52.5 – 71.4) |

Data are expressed as median ($25^{th}$ - $75^{th}$ percentiles) or as number (percent).
T1D: type 1 diabetes mellitus; DKA: diabetic ketoacidosis; CGM: continuous glucose monitoring; $HbA1_c$: glycolisated hemoglobin $A1_c$.
[a] Only in CGM(−) cases (n = 99).

**Table 3**
Sleep disturbance scale for children scores of participants.

| *SDSC subgroups* | T1D N = 144 | Controls N = 106 | *P value* |
|---|---|---|---|
| DIMS | 13 (11 – 16) | 13.5 (12 – 16) | 0.075 |
| SDB | 3 (3 – 4) | 4 (3 – 4.5) | 0.211 |
| DA | 5 (3 – 6) | 4 (3 – 5) | 0.049 |
| SWTD | 6 (5 – 8) | 6 (4 – 8) | 0.322 |
| DOES | 8 (7 – 11) | 8 (6 – 10) | 0.089 |
| SHY | 3 (2 – 4.5) | 3 (2 – 4) | 0.244 |
| Total score | 39 (33.5 – 46) | 39 (35 – 46) | 0.722 |

Data are expressed as median ($25^{th}$ - $75^{th}$ percentiles).
T1D: type 1 diabetes mellitus; SDSC: sleep disturbance scale for children; DIMS: disorders of initiating and maintaining sleep; SDB: sleep-disordered breathing; DA: disorders of arousal nightmares; SWTD: sleep-wake transition disorders; DOES: disorders of excessive somnolence; SHY: sleep hyperhidrosis.

**Table 4**
Correlational analyses of sleep disturbance scale for children scores with clinical and laboratory findings of type 1 diabetes mellitus patients.

| *Variable* | DIMS | SDB | DA | SWTD | DOES | SHY | Total score |
|---|---|---|---|---|---|---|---|
| Age (year) | P = 0.240 | P = 0.088 | P = 0.787 | P = 0.837 | P = 0.127 | P = 0.720 | P = 0.389 |
| | R = 0.102 | R = 0.013 | R = −0.024 | R = −0.018 | R = 0.132 | R = −0.031 | R = 0.075 |
| Diabetes duration (year) | P = 0.752 | P = 0.083 | P = 0.309 | P = 0.155 | P = 0.694 | P = 0.013[a] | P = 0.952 |
| | R = −0.028 | R = 0.013 | R = 0.089 | R = 0.123 | R = 0.034 | R = −0.214 | R = 0.005 |
| $HbA1_c$ | P = 0.133 | P = 0.055 | P = 0.063 | P = 0.094 | P < 0.001[a] | P = 0.787 | P = 0.003[a] |
| | R = 0.126 | R = 0.161 | R = 0.156 | R = 0.140 | R = 0.368 | R = −0.023 | R = 0.243 |

HbA1c: glycolisated hemoglobin; DIMS: disorders of initiating and maintaining sleep; SDB: sleep-disordered breathing; DA: disorders of arousal nightmares; SWTD: sleep-wake transition disorders; DOES: disorders of excessive somnolence; SHY: sleep hyperhidrosis.
[a] Statistically significant correlation.

control group. Adolescents and young adults with T1D often disclose sleeping fewer hours than the recommended 8–10 hours per night, with a self-reported average of 7 hours of nightly sleep. On the subject of sleep architecture, specifically the structural arrangement of sleep types and stages, individuals with T1D exhibited a diminished proportion of slow-wave ('deep') sleep compared to matched controls without diabetes [17,34]. Qualitative investigations within these demographics have unveiled recurring themes concerning impediments to sleep, encompassing both general factors such as pre-bedtime electronic use, homework-related stress, and overall anxiety, as well as diabetes-specific challenges like the fear of hypoglycemia, fluctuations in glucose levels, and disruptions caused by CGM or pump alarms [35,36]. Current studies suggest that there is a dynamic and bidirectional relationship between sleep patterns and T1D [12,13]. Sleep restriction has been correlated with challenges in executive functioning, memory impairment, and behavioral dysregulation - all crucial skills for effective diabetes management [28,37,38]. Furthermore, sleep debt, irregular sleep patterns, and untreated SDB may influence glycemic control through increased cortisol levels and an imbalance in autonomic nervous system activity [3–5]. Additionally, recent research indicated that factors such as sleep efficiency, the time it takes to fall asleep, wakefulness after sleep onset, and bedtime are significant contributors to glycemic outcomes in children with T1D. These results imply that the quality of sleep, as opposed to the total sleep time, is closely linked to glycemic variability in this particular group of children [39].

In our study, a significant positive relationship was identified between the total SDSC score and $HbA1_c$ levels. Some studies propose that adolescents facing more significant sleep disturbances and experiencing lower sleep quality tend to exhibit poorer management of T1D and higher $HbA1_c$ levels [14,40,41]. Moreover, there is a potential risk for children and adolescents with T1D who undergo reduced sleep duration and an escalation in sleep disturbances, as they may be prone to higher $HbA1_c$ values [42]. Furthermore, a study has demonstrated that the cumulative impact of self-reported poor sleep is associated with elevated $HbA1_c$ levels, increased instances of severe hypoglycemia, and a higher frequency of episodes of DKA in young individuals [42].

The scores related to the DOES subscale, encompassing questions that evaluate difficulty in waking up, tiredness when waking up, sleep paralysis, daytime somnolence, sleep attacks, and bed-wetting were similar in patients with T1D and controls in our study. Conversely, we observed a positive correlation between DOES scores and $HbA1_c$ levels in cases with T1D. This condition may suggest that poorly managed diabetes may contribute to a potential hyperglycemic course, leading to bed-wetting, as well as disrupting nighttime sleep quality and resulting in problems such as feeling sleep-deprived during the day and waking up fatigued. On the other hand, similar to the observed negative correlation between diabetes duration and the SHY subgroup, the possibility exists that these correlations may result in random statistically significant outcomes due to the narrow range of scoring scales and the low correlation coefficients employed within these subgroups. Additionally, in the assessment of subgroup analyses, the scores related to the DA subscale, encompassing questions that evaluate sleepwalking, sleep terrors, and nightmares, were statistically higher in patients with T1D. Comprehensive studies are needed to assess whether these findings are indeed higher in individuals with T1D compared to their healthy peers, to determine the prevalence of arousal nightmares in T1D cases, and to investigate the potential relationship between T1D and these sleep disturbances.

Evaluating conditions related to breathing problems, sleep apnea, and snoring in the SDB subscale, there was no difference between the patient and control groups in our study. In a prospective case-controlled study, the prevalence of SDB in individuals with T1D was reported to be 35 %, and this rate was stated to be comparable to the control group [17]. On the other hand, the data from the same study, support that even mild SDB contributes to elevated glucose levels and hyperglycemia in youth with T1D, as previously reported by Villa et al. [43]. Findings of three pediatric studies linked SDB with suboptimal glycemic control. Specifically, when compared to youth maintaining well-controlled diabetes, those with poor control exhibited increased respiratory challenges, including more frequent respiratory arousals, apneas, and central apneas [17,43,44]. A comprehensive nationwide study in France unveiled that 12.4 % of adult patients diagnosed with T1D exhibited mild-to-moderate sleep apnea, with an additional 3.4 % experiencing severe sleep apnea. Performing a multivariate analysis after adjusting for age, gender, BMI, and hypertension, as significant factors linked to sleep apnea, the presence of severe sleep apnea was notably associated with macrovascular complications, while mild-to-moderate sleep apnea showed a significant correlation with the presence of diabetic retinopathy [45]. Despite the lower prevalence of macrovascular and microvascular complications in the pediatric age group, attributed to the shorter duration of diabetes in comparison to adults, screening for SDB in the early stages can still be beneficial for patients in terms of effective diabetes management and long-term complication risk monitoring.

Finally, SDSC scores of cases using and not using CGM were found to be similar, just as in cases using and not using an insulin pump. Studies are also beginning to examine how diabetes management technology impacts children and adolescents' sleep behaviors and the results are controversial. For subjective reports of sleep quality and disturbances, children and young adults do not report challenges initiating and maintaining sleep due to their CGM usage or continuous subcutaneous insulin infusion [33,42]. Certainly, in a particular study, investigators discovered that adolescents utilizing an insulin pump reported experiencing fewer disruptions in sleep and longer durations of sleep compared to their counterparts who relied on injections [31]. On the other hand, although the utilization of CGM and insulin pumps considerably streamlines diabetes management in comparison to traditional fingerstick glucose measurements and insulin injections with a pen, parents report increased sleep disruptions attributed to device alarms [46,47]. In patients with T1D using a closed-loop insulin pump system, sleep disturbance research may yield different results by eliminating hypoglycemia fear and issues related to alarm systems. Subgroup analysis was not performed in our study as the number of cases using a closed-loop insulin pump system did not provide a sufficient sample size.

There are certain limitations in our study. Firstly, being a case-control study cannot establish a causal relationship between sleep disturbance disorders and T1D. Secondly, we chose to assess sleep

disturbances using a questionnaire, a subjective method relying on parents' observations. Confirmation of the findings through methods that provide objective results, such as PSG and actigraphy, would offer more reliable outcomes. Thirdly, CGM records and fingerstick glucose results were not taken into consideration, limiting our ability to investigate the impact of nocturnal glucose trends on sleep, including hyperglycemic and hypoglycemic events. Fourthly, it should be noted that the subgroup results of the SDSC questionnaire lack sufficient power to generalize the findings to the overall population, as mentioned earlier.

In conclusion, our study found that the prevalence of sleep disturbances among children and adolescents with T1D was not significantly higher than that observed in their healthy peers. Nevertheless, it is crucial to note that a notable portion, 48.6 % of T1D cases and 47.6 % of healthy cases, displayed sleep disturbances based on SDSC scores. To optimize diabetes management and proactively address potential challenges, incorporating routine screening for sleep disturbances in the monitoring of T1D patients can yield valuable benefits.

## Financial disclosure

This study received no financial support.

## CRediT authorship contribution statement

**Zeynep Donbaloğlu:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ebru Barsal Çetiner:** Resources, Project administration, Formal analysis, Data curation, Conceptualization. **Aynur İnan Yüksel:** Methodology, Investigation, Formal analysis, Data curation. **Berna Singin:** Methodology, Investigation, Formal analysis, Data curation. **Bilge Aydın Behram:** Methodology, Investigation, Formal analysis, Data curation. **Aynur Bedel:** Methodology, Investigation, Formal analysis, Data curation. **Mesut Parlak:** Visualization, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hale Tuhan:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare no conflicts of interest.

## Acknowledgement

The authors extend their gratitude to Duygu Akçay for providing Turkish validation of the SDSC and permission for its use in our study.

## References

[1] Ozougwu JC, Obimba KC, Belonwu CD, Unakalamba CB. The pathogenesis and pathophysiology of type 1 and type 2 diabetes mellitus. J Physiol Pathophysiol 2013;4:46–57.
[2] Donbaloğlu Z, Tuhan H, Tural Kara T, Bedel A, Barsal Çetiner E, Singin B, et al. The Examination of the relationship between COVID-19 and New-onset type 1 diabetes mellitus in children. Turk Arch Pediatr 2022 Mar;57(2):222–7.
[3] Jiang F, Vandyke RD, Zhang J, Li F, Gozal D, Shen X. Effect of chronic sleep restriction on sleepiness and working memory in adolescents and young adults. J Clin Exp Neuropsychol 2011 Oct;33(8):892–900.
[4] Vriend JL, Davidson FD, Corkum PV, Rusak B, Chambers CT, McLaughlin EN. Manipulating sleep duration alters emotional functioning and cognitive performance in children. J Pediatr Psychol 2013;38(10):1058–69.
[5] Sadeh A, Gruber R, Raviv A. The effects of sleep restriction and extension on school-age children: what a difference an hour makes. Child Dev 2003;74(2):444–55.
[6] Owens JA, Spirito A, McGuinn M, Nobile C. Sleep habits and sleep disturbance in elementary school-aged children. J Dev Behav Pediatr 2000;21(1):27–36.
[7] Pagel JF, Forister N, Kwiatkowki C. Adolescent sleep disturbance and school performance: the confounding variable of socioeconomics. J Clin Sleep Med 2007;3(1):19–23.
[8] Liu X, Liu L, Owens JA, Kaplan DL. Sleep patterns and sleep problems among schoolchildren in the United States and China. Pediatrics 2005;115(Suppl.1):241–9.
[9] Meltzer LJ, Johnson C, Crosette J, Ramos M, Mindell JA. Prevalence of diagnosed sleep disor-ders in pediatric primary care practices. Pediatrics 2010;125(6):e1410–8.
[10] Ogilvie RP, Patel SR. The epidemiology of sleep and diabetes. Curr Diabetes Rep 2018;18:82.
[11] Laverty B, Puthezhath Jayanandan S, Smyth S. Understanding the relationship between sleep and quality of life in type 2 diabetes: a systematic review of the literature. J Health Psychol 2023 Jul;28(8):693–710.
[12] Farabi SS. Type 1 diabetes and sleep. Diabetes Spectr 2016;29(1):10–3.
[13] Reutrakul S, Thakkinstian A, Anothaisintawee T, et al. Sleep characteristics in type 1 diabetes and associations with glycemic control: systematic review and meta-analysis. Sleep Med 2016;23:26–45.
[14] Von Schnurbein J, Boettcher C, Brandt S, et al. Sleep and glycemic control in adolescents with type 1 diabetes. Pediatr Diabetes 2018;19(1):143–9.
[15] Jaser SS, Foster NC, Nelson BA, et al. Sleep in children with type 1 diabetes and their parents in the T1D Exchange. Sleep Med 2017;39:108–15.
[16] Borel AL, Pépin JL, Nasse L, Baguet JP, Netter S, Benhamou PY. Short sleep duration measured by wrist actimetry is associated with deteriorated glycemic control in type 1 diabetes. Diabetes Care 2013 Oct;36(10):2902–8.
[17] Perfect MM, Patel PG, Scott RE, Wheeler MD, Patel C, Griffin K, et al. Sleep, glucose, and daytime functioning in youth with type 1 diabetes. Sleep 2012;35:81–8.
[18] Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. Lancet 1999;354(9188):1435–9.
[19] Donga E, van Dijk M, van Dijk JG, et al. Partial sleep restriction decreases insulin sensitivity in type 1 diabetes. Diabetes Care 2010;33(7):1573–7.
[20] Macaulay GC, Galland BC, Boucher SE, Wiltshire EJ, Haszard JJ, Campbell AJ, et al. Impact of type 1 diabetes mellitus, glucose levels, and glycemic control on sleep in children and adolescents: a case-control study. Sleep 2020 Feb 13;43(2):zsz226.
[21] Rose S, Boucher SE, Galland BC, Wiltshire EJ, Stanley J, Smith C, et al. Impact of high-risk glycemic control on habitual sleep patterns and sleep quality among youth (13-20 years) with type 1 diabetes mellitus compared to controls without diabetes. Pediatr Diabetes 2021 Aug;22(5):823–31.
[22] Blunden S, Lushington K, Lorenzen B, Ooi T, Fung F, Kennedy D. Are sleep problems under-recognised in general practice? Arch Dis Child 2004;89(8):708–12.
[23] Chervin RD, Archbold KH, Panahi P, Pituch KJ. Sleep problems seldom addressed at two general pediatric clinics. Pediatrics 2001;107(6):1375–80.
[24] Wolfsdorf JI, Glaser N, Agus M, Fritsch M, Hanas R, Rewers A, et al. ISPAD clinical practice consensus guidelines 2018: diabetic ketoacidosis and the hyperglycemic hyperosmolar state. Pediatr Diabetes 2018;19(Suppl 27):155–77.
[25] Neyzi O, Bundak R, Gökçay G, Günöz H, Furman A, Darendeliler F, et al. Reference values for weight, height, head circumference, and Body mass index in Turkish children. J Clin Res Pediatr Endocrinol 2015;7(4):280–93.
[26] Bruni O, Ottaviano S, Guidetti V, Romoli M, Inno-cenzi M. The Sleep Disturbance Scale for Chil-dren (SDSC). Construction and validation of an instrument to evaluate sleep disturbances in childhood and adolescence. J Sleep Res 1996;5:251–61.
[27] Akçay D, Akçay BD, Bozkurt ÖH. Reliability and validity of Turkish sleep disturbance scale for children. Anatol J Psychiatry 2020;21:70–7.
[28] Perfect MM. Sleep-related disorders in patients with type 1 diabetes mellitus: current insights. Nat Sci Sleep 2020 Feb 11;12:101–23.
[29] Caruso NC, Radovanovic B, Kennedy JD, Couper J, Kohler M, Kavanagh PS, Martin AJ, Lushington K. Sleep, executive functioning and behaviour in children and adolescents with type 1 diabetes. Sleep Med 2014 Dec;15(12):1490–9.
[30] Turner SL, Queen TL, Butner J, Wiebe D, Berg CA. Variations in daily sleep quality and type 1 diabetes management in late adolescents. J Pediatr Psychol 2016 Jul;41(6):661–9.
[31] Jaser SS, Ellis D. Sleep in adolescents and young adults with type 1 diabetes: associations with diabetes management and glycemic control. Health Psychology and Behavioral Medicine 2016;4(1):49–55.
[32] Perfect MM. The relations of sleep and quality of life to school performance in youth with type 1 diabetes. J Appl Sch Psychol 2014;30(1):7–28.
[33] Adler A, Gavan MY, Tauman R, Phillip M, Shalitin S. Do children, adolescents, and young adults with type 1 diabetes have increased prevalence of sleep disorders? Pediatr Diabetes 2017 Sep;18(6):450–8.
[34] Nefs GM, Bazelmans E, Donga E, Tack CJ, de Galan BE. Sweet dreams or bitter nightmare: a narrative review of 25 years of research on the role of sleep in diabetes and the contributions of behavioural science. Diabet Med 2020 Mar;37(3):418–26.
[35] Bergner EM, Williams R, Hamburger ER, et al. Sleep in teens with type 1 diabetes perspectives from adolescents and their caregivers. Diabetes Educat 2018;44(6):541.
[36] Griggs S, Whittemore R, Redeker NS, Grey M. Facilitators and barriers of sleep in young adults with type 1 diabetes. Diabetes Educat 2020;46(3):242–51.
[37] Beebe DW, Rose D, Amin R. Attention, learning, and arousal of experimentally sleep-restricted adolescents in a simulated classroom. J Adolesc Health 2010;47(5):523–5.

[38] McNally K, Rohan J, Pendley JS, Delamater A, Drotar D. Executive functioning, treatment adherence, and glycemic control in children with type 1 diabetes. Diabetes Care 2010;33(6):1159–62.
[39] İpar N, Boran P, Barış HE, Us MC, Aygün B, Haliloğlu B, et al. Associations between sleep characteristics and glycemic variability in youth with type 1 diabetes. Sleep Med 2023 Sep;109:132–42.
[40] Monzon A, McDonough R, Meltzer LJ, Patton SR, Susana Patton CR. Sleep and type 1 diabetes in children and adolescents: proposed theoretical model and clinical implications. Pediatr Diabetes 2019;20(1):78–85.
[41] Hazen RA, Fehr KK, Fidler A, Cousino MK, MacLeish SA, Gubitosi-Klug R. Sleep disruption in adolescents with Type 1 diabetes mellitus: relationships with adherence and diabetes control. Diabetes Manag 2015;5(4):257.
[42] Meltzer LJ, Moore M. Sleep disruptions in parents of children and adolescents with chronic illnesses: prevalence, causes, and consequences. J Pediatr Psychol 2007;33 (3):279–91.
[43] Villa MP, Multari G, Montesano M, Pagani J, Cervoni M, Midulla F, Cerone E, Ronchetti R. Sleep apnoea in children with diabetes mellitus: effect of glycaemic control. Diabetologia 2000 Jun;43(6):696–702.
[44] Kostkova M, Durdik P, Ciljakova M, Vojtkova J, Sujanska A, Pozorciakova K, Snahnicanova Z, Jancinova M, Banovcin P. Short-term metabolic control and sleep in children and adolescents with type 1 diabetes mellitus. J Diabet Complicat 2018 Jun;32(6):580–5.
[45] Pépin JL, Bailly S, Texereau JB, Sonnet E, Picard S, Vergès B, et al. Prevalence of sleep apnoea in patients with type 1 diabetes and its association with comorbidities and diabetic complications: a French nationwide prospective study. Diabetes Obes Metabol 2023 Jun;25(6):1624–31.
[46] Barnard K, Crabtree V, Adolfsson P, et al. Impact of type 1 diabetes technology on family members/significant others of people with diabetes. J Diabetes Sci Technol 2016;10(4):824.
[47] Landau Z, Rachmiel M, Pinhas-Hamiel O, et al. Parental sleep quality and continuous glucose monitoring system use in children with type 1 diabetes. Acta Diabetol 2014;51(3):499–503.