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Sleep and depressive symptoms in adolescents with type 1 diabetes not meeting glycemic targets

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Abstract

Aims: Adolescents with type 1 diabetes (T1D) are at risk for problems with self-management and suboptimal glycemic control, and depressive symptoms and sleep disturbances predict poorer diabetes outcomes. Despite evidence for associations between adolescent depressive symptoms and sleep in the general population, few studies have investigated this link in the vulnerable group of adolescents with T1D not meeting glycemic targets. The current study sought to assess both depressive symptoms and sleep in relation to diabetes indicators in adolescents with T1D.

Methods: 120 adolescents (ages 13–17 years) with above target glycemic control completed measures of depressive symptoms, sleep duration and quality, and self-management; parents also reported on adolescents' diabetes management. Clinical data (i.e., HbA1c) were extracted from medical records.

Results: In our sample, 40% of adolescents reported at least mild depressive symptoms, and 26% reported clinically significant sleep disturbances. Adolescents with sleep disturbances were more likely to report at least mild symptoms of depression, and both depressive symptoms and sleep quality were associated with poorer diabetes management. No significant differences emerged regarding HbA1c or frequency of blood glucose monitoring.

Conclusions: The current findings highlight the importance of clinical assessment of both depressive symptoms and sleep in the vulnerable group of adolescents with T1D.

Keywords

Type 1 diabetes; Adolescents; Sleep; Depression; Adherence; Self-management

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Declaration of Competing Interest

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1. Introduction

Many adolescents with type 1 diabetes (T1D) experience problems with diabetes management, and only a minority of adolescents (17%) meet glycemic targets [1]. Given that the glycemic target for youth has recently been decreased (HbA1c < 7%/53 mmol/mol) [2], the percentage of adolescents meeting this lower glycemic target may be even smaller than the 17% reported in 2018. By keeping blood glucose levels as close to normal as possible, adolescents can prevent acute and long-term complications [3]. Hence, in research as well as in clinical interventions, it is important to focus on vulnerable adolescents not achieving glycemic targets.

Additionally, youth with T1D experience higher levels of depressive symptoms than their peers without diabetes, with up to 30% pooled prevalence reported in a recent *meta*-analysis, compared to 13% in the general adolescent population [4,5]. Recent studies support that sleep quality and duration are also important factors influencing diabetes outcomes in adolescents [6]. While adolescent sleep has been associated with increased depressive symptoms in the general population [7], research in adolescents with T1D investigating the role of both sleep and depressive symptoms is scarce [8].

Three large epidemiological studies indicate that adolescents with T1D experience elevated levels of depression; rates of depression ranged from 13% of youth aged 10–17 years reporting clinically significant symptoms [9], 20% of youth aged 10–21 years (13% mild and 7% moderate to severe symptoms) [10], to 52% of an Australian sample of youth aged 13–19 years (31% mild symptoms, 21% moderate-severe) [11]. Depressive symptoms in adolescents with T1D have been related to greater problems with diabetes management, including behaviors such as blood glucose monitoring (BGM) [12], as well as decreases in adolescent diabetes self-management over time [13]. Depressive symptoms may influence glycemic outcomes indirectly; a series of studies by Hood and colleagues [14,15] indicated that the relationship between depressive symptoms and glycemic control may be mediated by diabetes management (e.g., BGM).

More recently, researchers have begun to examine sleep duration and quality as risk or protective factors for diabetes outcomes in adolescents with T1D. A recent *meta*-analysis indicated that children and adolescents with T1D obtain significantly less sleep than their peers without diabetes (mean difference 26 min) [16]. In addition to barriers to obtaining sufficient sleep typical among adolescents (e.g., early school start times, electronics use), people with T1D also experience diabetes-related sleep disturbances, such as waking at night to treat hypoglycemic episodes and to respond to device alarms [17]. Emerging evidence indicates that sleep disturbances are linked with diabetes outcomes, including self-management and glycemic control [16], but findings are inconsistent across sleep quality and sleep duration. For example, lower sleep quality, but not duration, was significantly associated with higher HbA1c in a study of adolescents with T1D (age 12–21) [18]. Longer sleep duration has been associated with increased self-management behaviors in adolescents with T1D, such that a 15-minute increase in sleep duration was associated with an additional blood glucose check per day, and a 20-minute increase was associated with an additional insulin bolus [19]. Finally, in a study of adolescents and young adults, longer sleep duration

was related to more frequent BGM in males (but not females), and better sleep quality was related to better glycemic control [20].

In the general population, adolescent sleep is strongly associated with mood; sleep deprivation studies demonstrate that sleep loss causes increased depressive symptoms, particularly among females [7]. Further, a *meta*-analytic study found that adolescents who were diagnosed with depression reported significantly more sleep disturbances and poorer sleep quality than those without depression [21]. Researchers have proposed a recursive cycle of daytime factors such as stress and symptoms of depression influencing daytime diabetes management and blood glucose levels, which in turn influence sleep duration and quality, but this has not yet been tested [8]. In sum, while the literature supports a pathway between depressive symptoms and diabetes management in adolescents, emerging evidence suggests that sleep may also be important to consider in relation to depressive symptoms and diabetes management.

To our knowledge, few studies have examined sleep in relation to depressive symptoms in adolescents with T1D, and even fewer studies focused on the vulnerable population of adolescents with above target glycemic control. To address this gap, we examined depressive symptoms and sleep quality in a sample of youth not meeting targets for glycemic control. We hypothesized that higher levels of depressive symptoms and poorer sleep quality would be related to lower levels of diabetes management and poorer glycemic control. Further, we explored whether sleep duration or sleep quality would account for the associations between depressive symptoms and diabetes indicators.

2. Methods

2.1. Participants

The current study was a secondary analysis of baseline data collected for a randomized controlled trial (NCT02746627). We enrolled 120 adolescent-caregiver dyads from an outpatient pediatric diabetes clinic. Adolescents were age 13–17, diagnosed with T1D ≥ 6 months, and had a HbA1c level between 8 and 12% (64–108 mmol/mol). This HbA1c level was selected to target adolescents who were not meeting glycemic targets but who were not at HbA1c levels so high that a low-intensity intervention would be unlikely to have an effect. Participants consented/assented to participate in a positive psychology intervention that consisted of 8 weeks of phone calls or text messages and follow-up data collection at 3 months and 6 months. Sixty five percent of eligible adolescents participated in the study. No differences in HbA1c, age, sex, or race/ethnicity emerged between those who did and did not enroll. The University Institutional Review Board approved the protocol prior to implementation of the study procedures.

2.2. Measures

Participants completed measures at the baseline study visit, corresponding with their regularly scheduled diabetes clinic visit. Surveys were administered on iPads and data were directly entered into REDCap, a secure data management system.

Depressive Symptoms.—Adolescents completed the Patient Health Questionnaire-9 [PHQ, 22], a clinical screening tool to assess the 9 symptoms of major depressive disorder (i.e., sadness, anhedonia, fatigue, concentration, appetite, sleep, guilt/worthlessness, and suicidality). Scores range from 0 to 27, and in adolescents, scores of 0–4 are considered minimal, 5–10 indicate mild depression, 11–14 indicate moderate depression, 15–19 indicate moderately severe depression, and 20 or higher indicate severe depression [23]. Among adolescents in the general population, a PHQ-9 score of ≥ 11 demonstrated sensitivity of 89.5% and specificity of 77.5% for detecting major depressive disorder [23]. In the current study, if adolescents endorsed the item indicating suicidal ideation, they were immediately assessed for safety and referred to treatment as needed, following a self-harm protocol devised for the study. In the current sample, Cronbach's alpha was 0.77.

Sleep Duration and Quality.—Adolescents completed the Pittsburgh Sleep Quality Index [PSQI, 24], a self-report measure of sleep duration and quality. The PSQI consists of 17 items (e.g., "*In the past month, how long has it taken you (in minutes) to fall asleep each night?*). A global score is calculated indicating overall sleep quality, with higher scores indicating poorer sleep quality. Scores of 5 or higher are considered clinically significant. In addition, we used the self-reported sleep duration item in analyses.

Self-Management.—Both adolescents and their parents completed the Self Care Inventory [SCI, 25] to assess diabetes selfmanagement. The SCI consists of 14 items (e.g., "*In the past month, how often have you followed recommendations for glucose testing?*") and a mean score is calculated to indicate how well the adolescent is managing diabetes. Scores range from 1 (*not at all*) to 5 (*always*). In the current sample, Cronbach's alpha was 0.73 for adolescent-reports, and 0.75 for parent- proxy-reporters. In addition, we obtained glucometer data as an objective measure of adolescents' BGM (average checks per day over the previous 30 days). Blood glucose data were obtained on the same day as surveys were completed.

Glycemic Control.—Point-of-care HbA1c was obtained during regularly scheduled outpatient diabetes clinic visits, the same day that the surveys were completed. HbA1c values were extracted from participants' medical records, with consent. Currently, the recommended target for adolescents with T1D is < 7.0% (53 mmol/mol), and at the time of the study, the target was < 8% (64 mmol/mol).

2.3. Data analyses

First, we conducted descriptive analyses to assess depressive symptoms and sleep quality in participating adolescents, and we calculated bivariate correlations to examine associations between depressive symptoms, sleep and diabetes indicators. Non-parametric tests (Mann-Whitney U tests) were used to assess group differences in diabetes indicators among adolescents who reported no/minimal depressive symptoms vs. those reporting at least mild depressive symptoms (PHQ-9 score 0–4 vs. score ≥ 5). Similarly, we compared group differences in diabetes indicators among adolescents who did and did not report poor sleep quality (PSQI score ≥ 5). Finally, we conducted multivariable regression analyses to explore whether depressive symptoms and sleep quality were predictors of diabetes management. In

the first step of the model, we included adolescent sex, age, and diabetes duration. The second step of the model included self-reported depressive symptoms (PHQ-9), and the third step of the model included adolescents' self-reported sleep quality (PSQI). Both adolescent self-reported and parent-proxy-reported measures of self-management were assessed as outcomes, resulting in two sets of multivariable analyses.

3. Results

3.1. Descriptive Analyses.

In the current sample, 52.5% of adolescents were female, 87.5% identified as White, non-Hispanic, 50.8% were using an insulin pump, and none of the adolescents were using continuous glucose monitors (Table 1). Mean HbA1c was 9.2% (77 mmol/mol). A total of 40% of adolescents reported at least some depressive symptoms (34% mild, 6% moderate/severe), and the remaining 60% of adolescents reported no/minimal depressive symptoms. Further, 26% of adolescents reported clinically significant sleep disturbances. Adolescents with clinically significant sleep disturbances were more likely to report at least mild symptoms of depression ($\chi^2 = 10.1$, $p < .001$); 65% of adolescents with poor sleep quality reported elevated depressive symptoms vs. 32% of those with good sleep quality.

No significant differences in depressive symptoms emerged related to adolescent sex, race/ethnicity, or income level. Age was significantly associated with depressive symptoms, with older adolescents reporting higher levels of depressive symptoms ($r = 0.26$). In terms of sleep quality, there were no significant differences related to age, sex, race/ethnicity, or income level. Sleep duration was also related to age ($r = -0.22$), with older adolescents reporting fewer hours of sleep/night. Sleep duration was not significantly associated with sex, race/ethnicity, or income level.

Regarding diabetes-related factors, we found that disease duration was not significantly associated with adolescents' depressive symptoms, sleep quality, or sleep duration. Further, there were no significant differences between those using insulin pumps vs. injections in depressive symptoms, sleep quality, or sleep duration.

3.2. Bivariate correlations

As seen in Table 2, bivariate correlations indicated that adolescents' self-reported depressive symptoms were significantly associated with poorer self-reported sleep quality ($r = 0.31$, $p < .001$) and shorter sleep duration ($r = -0.20$, $p = .028$). In addition, greater depressive symptoms were significantly related to lower levels of self-reported diabetes management ($r = -0.30$, $p < .001$), but the association with parent-reported diabetes management was not significant, nor was the association with BGM. Similarly, poorer sleep quality and shorter sleep duration were both significantly related to lower self-reported diabetes management ($r = -0.31$, 0.22, respectively) but not to parent-reported management or BGM. Depressive symptoms, sleep quality, and sleep duration were not significantly related to HbA1c.

3.3. Group differences

Comparison of participants who scored 0–4 on the PHQ-9 (no/minimal depression) with those scoring 5 or higher (at least mild depression), and participants who scored 0–4 on the PSQI (good sleep quality), and those scoring 5 or higher (poor sleep quality) revealed differences on several measures. Parents reported significantly lower diabetes management in adolescents who reported depressive symptoms than those without depressive symptoms (U = 1251.50, z = −2.56, $p = .011$). Likewise, parents reported significantly lower diabetes management in adolescents who reported poor sleep quality than those with good quality sleep (U = 1008.00, z = −2.16, $p = .031$). Similarly, adolescents reporting elevated depressive symptoms reported worse self-care than adolescents without depressive symptoms (U = 1114.00, z = −3.20, $p = .001$). Adolescents reporting poor sleep quality also reported worse self-care than those who reported good sleep quality (U = 868.00, z = −2.80, $p = .005$). However, there were no significant differences in HbA1c for depressive symptoms (U = 1438.00, z = −1.56, $p = .120$) or sleep quality (U = 1242.00, z = −0.74, $p = .461$). We also did not observe significant group differences in frequency of BGM related to depressive symptoms (U = 1525.00, z = −0.73, $p = .468$) or sleep quality (U = 1183.00, z = −0.84, $p = .401$).

3.4. Regression analyses

Finally, as seen in Table 3, the overall model predicting adolescent self-reported diabetes management was significant, explaining 17% of the variance in self-reported adolescent self-management ($F = 4.67$, $p = .001$). In Step 1, none of the demographic or clinical variables were significant. In Step 2, depressive symptoms emerged as a significant predictor ($\beta = -0.29$), explaining an additional 8% of the variance in diabetes management. In the final step of the model, sleep quality was a significant predictor ($\beta = -0.25$), explaining an additional 6% of the variance in self-reported diabetes management, after adjusting for depressive symptoms. The overall model predicting proxy parent-reported diabetes management (P-SCI) was not significant ($F = 1.89$, $p = 102$).

4. Discussion

To our knowledge, the current study was the first to assess both sleep and depressive symptoms in adolescents with T1D not meeting glycemic targets, and to investigate sleep in relation to depressive symptoms in youth with T1D. We found that a substantial percentage of youth in our sample reported at least mild depressive symptoms (40%) and poor sleep quality (26%). Interestingly, while the rates of sleep disturbances in our study were comparable to rates in other recent studies of adolescents with T1D [26], adolescents in the current study reported rates of mild depressive symptoms more than twice as high as what has been previously reported (34% in our sample vs. 13% in the SEARCH study) [9]. Our findings suggest that higher rates of depressive symptoms may be observed among youth who are not meeting glycemic targets. In light of these elevated rates among adolescents, understanding the interplay of depressive symptoms, sleep, and diabetes indicators is especially important.

Indeed, depressive symptoms were significantly related to both sleep quality and sleep duration in our sample, and youth who reported clinically significant sleep disturbances were significantly more likely to report at least mild symptoms of depression. In addition, adolescents who reported depressive symptoms or poor sleep quality had poorer diabetes management (based on both self- and parent-report) as compared to adolescents who reported minimal depressive symptoms or good sleep quality. However, neither self-reported depressive symptoms nor sleep quality were significantly associated with diabetes indicators, such as glycemic control or frequency of BGM. It may be that depressive symptoms are only associated with HbA1c when symptoms reach a more debilitating (moderate-severe) level [27]. Alternatively, as noted above, diabetes management may mediate the relationship between depression and glycemic control [14], and in our sample, we found evidence for the links between depressive symptoms and poorer self-care, as well as significant associations between diabetes management and glycemic control. A larger sample and longitudinal study design are needed, however, to fully test this mediational model.

While psychiatric comorbidities are a strong risk factor for poorer glycemic control [28], specific depressive symptomology may impact glycemic control as well. In a study of adults with T1D, somatic symptoms (e.g., fatigue, change in sleep, change in appetite) were found to be positively associated with worse glycemic control, whereas affective symptoms (e.g., depressed mood, worthlessness, guilt) were negatively associated with glycemic control [29]. Future studies are needed to assess whether specific symptoms (e.g., somatic vs. affective symptoms) are more strongly associated with diabetes outcomes in adolescents. Alternatively, studies could assess depressive symptoms and sleep at critical time points; for example, one study found that youth who experienced depressive symptoms within the first month after diagnosis were more likely to have a higher HbA1c at 6 months [30]. Thus, more research is needed to determine whether specific depressive symptoms and timing of depressive symptoms predict diabetes outcomes in adolescents.

Finally, our findings that sleep quality and duration were associated with diabetes self-management are in line with similar studies in adolescents with T1D [19,20]. Notably, adolescents' sleep quality was significantly associated with self-reported diabetes management, even after adjusting for depressive symptoms. However, the lack of associations between sleep quality or duration with glycemic control may be explained in part by the limited range of HbA1c in our sample. It is also important to note that the relationship between sleep disturbances and glycemic control is likely to be bidirectional [31], and adolescents with T1D experience diabetes-specific sleep disturbances [17]. Further, more objective measures of sleep (e.g., actigraphy devices to assess sleep characteristics) may be needed to identify meaningful differences in sleep duration and variability in sleep timing [32].

5. Limitations

The current study focused on individuals not meeting glycemic targets. As this cohort may be at higher risk for both depressive symptoms and sleep disturbances, our findings may not be representative of the general population of adolescents with T1D. Hence, replication of

findings in a larger sample of adolescents with a wider range of HbA1c levels may be warranted to generalize findings to adolescents both on and above glycemic target. Further, reliance on a self-report measure of sleep limited our ability to identify more detailed sleep characteristics, particularly related to sleep duration and timing [32]. Finally, our study was cross-sectional, which limited our ability to test directionality of effects. To clarify the complex directional pathways, future studies should utilize longitudinal designs and investigate recursive pathways [8]. For example, although sleep is hypothesized to be a precursor of depressive symptoms, which are linked to worse diabetes outcomes, sleep disturbance is also a key symptom of depression. Furthermore, although researchers tend to investigate glycemic control as an outcome, blood glucose levels have also been shown to negatively influence sleep [31].

5.1. Clinical implications

Findings from the current study support including screening measures of sleep disturbance in addition to screening for depressive symptoms in adolescents with T1D [2], especially as sleep quality is readily identifiable in clinical encounters through brief clinical assessment or by using cost-effective questionnaires [8]. Further, treating sleep disturbances (e.g., Cognitive Behavioral Therapy for Insomnia) has been shown to be effective in adults [33], and may prevent the onset of depression and subsequent problems with diabetes management in adolescents. Longitudinal and experimental studies are needed to confirm this hypothesis. Furthermore, screening should only be conducted when systems are in place to ensure accurate diagnosis, psychotherapy, and follow-up, which may not be available in all diabetes clinics. Advocacy is needed to support the needs of our highest-risk populations, including adolescents with T1D.

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Table 1 –

Demographics and Clinical Characteristics (n = 120).

Adolescent Clinical Variables			
	Range	**Mean (SD)**	**N (%)**
Duration of Diabetes (years)	1–16	5.8 (3.6)	–
HbA1c (%) (mmol/mol)	8.0–11.5	9.2 (0.9)	–
	64–102	77 (7.6)	
Daily BGM	0.21–9.30	3.29 (1.75)	–
PHQ-9	0–24	4.14 (4.02)	
Minimal (0–4)			72 (60.0)
Mild (5–10)			41 (34.2)
Moderate/Severe (≥11)			7 (5.8)
PSQI	2–16	4.73 (2.30)	
Sleep Quality (0–4)			88 (73.9)
Poor Sleep Quality (>5)			31 (26.1)
Adolescent Demographic Variables			
			N (%)
Age (years)	13–17	14.83 (1.44)	–
Sex			
Male	–	–	57 (47.5)
Female	–	–	63 (52.5)
Race/Ethnicity			
White, Non-Hispanic	–	–	105 (87.5)
Other	–	–	14 (11.7)
Unknown	–	–	1 (0.8)
Annual Family Income (USD)			
<39,000	–	–	32 (26.7)
40,000–79,000	–	–	45 (37.5)
>80,000	–	–	43 (35.8)
Treatment Type			
Insulin Pump	–	–	61 (50.8)

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Adolescent Clinical Variables

	Range	Mean (SD)	N (%)
Injection	–	–	59 (49.2)

Note. Daily BGM = Average daily blood glucose checks from meter download. PHQ-9 = Pediatric Health Questionnaire measures depressive symptoms. PSQI = Pittsburgh Sleep Quality Index

Table 2 –

Correlations between Depressive Symptoms, Sleep Quality, and Diabetes Indicators.

	1	2	3	4	5	6	7	8	9
1. Age	–								
2. Duration of Diabetes	0.18	–							
3. A1C	0.14	0.11	–						
4. PHQ-9	0.26**	−0.02	0.08	–					
5. PSQI	0.15	−0.09	0.12	0.31***	–				
6. Sleep Duration	−0.22*	0.03	−0.10	−0.20*	−0.67***	–			
7. Daily BGM	−0.27**	−0.20*	−0.26**	−0.04	0.04	0.03	–		
8. P-SCI	−0.09	−0.21*	−0.19*	−0.17	−0.09	0.06	0.16	–	
9. C-SCI	−0.10	−0.08	−0.39***	−0.30***	−0.31***	0.22*	0.25**	0.38***	–

Note. PHQ-9 = Pediatric Health Questionnaire; PSQI = Pittsburgh Sleep Quality Index Global Score; P-SCI = parent-reported Self Care Inventory; C-SCI = child-reported Self Care Inventory; Daily BGM = frequency of average daily blood glucose monitoring.

* $p < .05$.

** $p < .01$.

*** $p < .005$

Table 3 –

Adolescent Depressive Symptoms and Sleep Quality as Predictors of Diabetes Management.

	C-SCI				P-SCI			
Predictor	**R^2**	**ΔR^2**	***β***	**F**	**R^2**	**ΔR^2**	***β***	**F**
Step 1	0.04			1.44	0.02			1.84
Child Sex			−0.15				0.03	
Age			−0.13				−0.04	
Diabetes Duration			−0.05				−0.20 *	
Step 2	0.12	0.08 **		3.70 **	0.04	0.03		2.25
PHQ-9			−0.29 **				−0.17	
Step 3	0.17	0.06 **		4.67 ***	0.04	0.00		1.89
PSQI			−0.25 **				−0.07	

Note. C-SCI = Child Self-reported Self Care Inventory, P-SCI = Parent Proxy Report Self Care Inventory; PHQ-9 = Patient Health Questionnaire; PSQI = Pittsburgh Sleep Quality Index.

* $p < .05$.

** $p < .01$.

*** $p < .001$.