Sleep in adolescents and young adults with type 1 diabetes: associations with diabetes management and glycemic control

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Abstract

Objective: To describe sleep in adolescents and young adults with type 1 diabetes (T1D) and explore the association between sleep disturbances, diabetes management and glycemic control.

Methods: Adolescents with T1D (n = 159, mean age = 16.4, 43% female, 69% white, mean hemoglobin A1c = 9.3%) completed the Pittsburgh Sleep Quality Index to assess sleep quantity and quality and sleep disturbances. Frequency of blood glucose monitoring (meter downloads) was used as a measure of diabetes management. Results: Average sleep duration was 7.4 hours, below the recommended duration for this age. Adolescents using insulin pumps reported fewer sleep disturbances and longer sleep duration than those on injections, and older adolescents reported less sleep than younger adolescents. Poorer sleep duration was related to poorer diabetes management, and better self-reported sleep quality was associated with better glycemic control for males but not for females. Conclusions: Assessing for and treating sleep disturbances in adolescents may improve diabetes management.

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Keywords

Sleep; adolescents; type 1 diabetes; self-management

Introduction

Type 1 diabetes (T1D) is one of the most common chronic health conditions in youth, with over 18,000 new cases diagnosed each year, and the prevalence is increasing (Hamman et al., 2014). The recommended treatment regimen is complex and demanding, including frequent blood glucose monitoring, insulin administration (via injections or pump), careful tracking of diet and activity levels, and frequent insulin adjustments (American Diabetes, 2015). Adherence to this regimen is linked with better glycemic control and reduces the risk for acute and long-term medical complications (Hood, Peterson, Rohan, & Drotar, 2010). However, adolescents and young adults T1D are at increased risk for deteriorating glycemic control and problems with adherence, with only 16% of adolescents (age 13–17) and 25% of young adults (age 18–25) meeting targets for glycemic control (Miller et al., 2015). Insufficient sleep and sleep disturbances may increase risk for these adverse outcomes.
Sleep disturbances have recently gained attention as a potential risk factor for individuals with diabetes (Koren, O’Sullivan, & Mokhlesi, 2015), yet the associations between sleep and diabetes outcomes have not been well studied in adolescents and young adults with T1D. The recommended amount of sleep is 8–10 hours for adolescents (National Sleep Foundation, 2015), but the majority of adolescents obtain insufficient sleep (defined as < 8 hours/night) (Eaton et al., 2010). In laboratory studies with adults with T1D, reduced sleep duration and sleep disturbances have been shown to increase evening cortisol and growth hormone levels (hormones counter-regulatory to insulin), as well as to increase insulin resistance (Donga et al., 2010; Jauch-Chara, Schmid, Hallschmid, Born, & Schultes, 2008). However, the relationship between sleep quantity or quality with glycemic control in adolescents with T1D is largely unstudied. In one of the only studies to measure sleep in adolescents with T1D, Perfect et al. (2012) found that adolescents with T1D spend less time in slow wave sleep than matched controls, which was associated with worse glycemic control. However, this study did not examine sleep in relation to diabetes management. Further, demographic factors (e.g. race/ethnicity, gender) may be important to consider, as minority youth have greater prevalence of insufficient sleep (Stamatakis, Kaplan, & Roberts, 2008) and gender-related differences have emerged for other health risks related to short sleep duration (Knutson, 2005; Peach, Gaultney, & Reeve, 2015).

In addition to its direct effects on glycemic control, poor sleep may affect glycemic control indirectly through poor diabetes management. Reduced sleep duration has been found to affect food choices, such as consumption of energy-dense foods (Westerlund, Ray, & Roos, 2009). In addition, sleep restriction in children has been shown to lead to impairments in measures of mental flexibility, verbal fluency and abstract thinking (Ran dazzzo, Muehlbach, Schweitzer, & Walsh, 1998) and in working memory (Steenari et al., 2003), all critical factors in good diabetes management. Poor sleep is a potentially modifiable risk factor in adolescents, yet the relationship between sleep, diabetes management and health outcomes has been largely overlooked in the literature on pediatric T1D. Therefore, the aim of this secondary analysis was to examine sleep in relation to glycemic control and diabetes management in the high-risk sample of adolescents and young adults with T1D. We hypothesized that poorer quality sleep would be associated with worse glycemic control and poorer diabetes management (less frequent blood glucose monitoring). In addition, we explored whether demographic (i.e. race/ethnicity, gender) and clinical (i.e. treatment type, duration of diabetes) factors were correlated with sleep disturbances.

Methods

Participants and procedure

The current study is a secondary analysis of baseline data from two intervention studies aimed at improving adherence conducted at separate pediatric diabetes clinics, with a combined sample of 159 adolescents and young adults with T1D. The first site (n = 68) was a university-affiliated clinic in an urban children’s hospital located in a large Midwestern city. Eligible participants at the first clinic were 16–20 years of age and diagnosed with T1D for at least six months. The second site was a university-affiliated diabetes center in a Southeastern city (n = 91), with a four-state catchment area. At the second clinic, eligible
participants were 13–17 years of age and diagnosed with T1D for at least 12 months. Participants at both sites had to be English speaking and without other known health problems or developmental delays. The research was approved by the respective hospital Institutional Review Boards. Participants provided informed consent and/or assent (depending on age) to participate and were paid for participation in the study. At the Midwestern site, 148 youth were approached, 50 (30%) refused, 31 (21%) expressed interest but were not enrolled before the study closed and 68 (46%) were consented and enrolled. At the Southeastern site, 175 adolescents were approached, 54 (31%) refused, 30 (17%) expressed interest in participating at a later date, and 91 (52%) were consented and enrolled.

The sample (mean age = 16.4 ± 2.1) was diverse with regard to gender (43% female) and ethnicity (4.4% Hispanic, 22% African American, 73% White, 5% Other). The majority of participants used injected insulin for insulin management (65.2%) with the minority (34.8%) on pump therapy. Mean hemoglobin A1c was 9.3% (SD = 1.6%).

**Measures**

The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989) was used to assess sleep parameters. The PSQI is a 19-item self-report measure that assesses sleep quantity (duration) and quality during the past month. The measure has been shown to be associated with objective measures of sleep such as polysomnography, and has been used in studies with adolescents (Megdal & Schernhammer, 2007). In order to assess the differential relation between diabetes outcomes and different aspects of sleep similar to what has been examined in adults with T1D (Koren et al., 2015), we focused on the following subscales for the present study: sleep duration (hours/night), sleep disturbance (sum of 9 items, e.g. feel too hot, have bad dreams) on a scale of 0 (not during the last month) to 3 (three or more times a week), and sleep quality (perceived overall quality of sleep).

Diabetes management was assessed via objective data (glucometer) of mean daily frequency of blood glucose testing over 30 days. While blood glucose testing is only one component of diabetes management, this is also the diabetes management behavior that has been most closely linked to glycemic control in youth with T1D (Hood et al., 2010). Mean frequency of daily blood glucose checks (over 30 days) was 2.7 (SD = 1.8).

Glycemic control was assessed with glycosylated hemoglobin (HbA1c), an objective measure of blood glucose values over the previous 8–12 weeks. At the Midwestern site, HbA1c was collected with home assay and sent to a laboratory, and at the Southeastern site, HbA1c was measured with a point-of-service clinical assay (DCA 2000, Bayer, Tarrytown NY). Other studies support the high agreement of HbA1c values obtained from the laboratory and DCA measurements (The Diabetes Research in Children Network Study Group, 2005), and there was not a significant difference in HbA1c values between sites. The goal for adolescents in this age range is ≤ 7.5% (American Diabetes, 2015).

**Results**

Prior to data analyses, frequency distributions were checked for normality assumptions and for univariate outliers. Outliers removed if they were > 3 SDs from the mean, resulting in the removal of 7 data points in total. Sleep duration ranged from 3 to 12 hours per night
(mean = 7.4 ± 1.5), with 20.2% of adolescents reporting “poor” or “very poor” sleep quality. Consistent with the general pediatric sleep literature, adolescents’ age was significantly related to sleep quality \((r = 0.17, P = 0.04)\), disturbances \((r = 0.62, P < 0.001)\) and duration \((r = -0.27, P = 0.001)\).

There was a significant difference in sleep disturbance by race/ethnicity and by site; white, non-Hispanic adolescents reported significantly fewer sleep disturbances \((M = 9.2)\) than minority adolescents \((M = 14.0)\) \((t = -4.42, P < .001)\). No significant differences in sleep duration or quality related to race/ethnicity were found. Gender was unrelated to sleep duration, quality or disturbances. However, there was a significant difference in sleep duration and disturbance (but not sleep quality) related to type of insulin therapy; adolescents who used insulin pumps reported significantly fewer sleep disturbances \((M = 7.9)\) than those who used injections \((M = 12.0)\) \((t = -4.07, P < 0.001)\). A similar result was found for sleep duration; those on the pump slept longer \((M = 7.8)\) than those on injections \((M = 7.2)\) \((t = 2.51, P = 0.013)\). Finally, there was a significant difference by site for sleep quality \((t = -2.02, P = 0.046)\) and sleep duration \((t = 2.97, P = 0.003)\) with the Midwestern site reporting poorer sleep quality and shorter sleep duration than the Southeastern site. However, in multivariate models predicting the sleep variables, none of the demographic variables emerged as significant predictors.

Next, bivariate correlations were conducted to test for associations between sleep and diabetes management and glycemic control (HbA1c). As seen in Table 1, HbA1c was not significantly associated with sleep duration, disturbances or sleep quality. Sleep duration was significantly associated with blood glucose monitoring \((r = 0.18, P = 0.028)\), such that longer sleep duration was related to more frequent blood glucose monitoring. There was not a significant association between sleep disturbances or sleep quality and diabetes management.

Finally, separate analyses were conducted by gender. As seen in Table 2, when males and females were considered separately, a different picture emerged. A significant positive association was identified between sleep duration and frequency of blood glucose monitoring for males \((r = 0.27)\) but not females \((r = 0.14)\). Further, a negative significant association was found between sleep quality and glycemic control for males but not females, such that better self-reported sleep quality was related to better (lower)

Table 1. Descriptive statistics and correlations among adolescent sleep and diabetes variables.

|                          | 1     | 2     | 3     | 4     | 5     | 6     |
|--------------------------|-------|-------|-------|-------|-------|-------|
| (1) Adolescent age       | –     |       |       |       |       |       |
| M = 16.38 (2.11)         |       |       |       |       |       |       |
| (2) Sleep duration       | –0.27*** | –     |       |       |       |       |
| M = 7.35 (1.41)          |       |       |       |       |       |       |
| (3) Sleep quality        | 0.17*  | –0.47*** | –     |       |       |       |
| M = 2.03 (0.66)          |       |       |       |       |       |       |
| (4) Sleep disturbances   | 0.21*  | –0.17*  | 0.41*** | –     |       |       |
| M = 7.25 (4.62)          |       |       |       |       |       |       |
| (5) Blood glucose monitoring | –0.42*** | 0.18*  | –0.09  | –0.14 | –     |       |
| M = 2.63 (1.51)          |       |       |       |       |       |       |
| (6) HbA1c                | 0.12   | –0.00  | –0.13  | 0.09  | –0.37*** | –     |
| M = 9.32 (1.54)          |       |       |       |       |       |       |

Note: Blood glucose monitoring is average checks per day over the previous 30 days.

*P < .05.
**P < .01.
***P < .001.
HbA1c ($r = -0.29, P = -0.022$). There was not a significant relationship between sleep disturbances and diabetes outcomes for either gender.

**Discussion**

Adolescents and young adults with T1D from an ethnically and geographically diverse sample reported sleep duration (mean of 7.4 hours per night) that was below the recent recommendation of 8–10 hours for this age group (National Sleep Foundation), but similar to the general adolescent population (Eaton et al., 2010). For males, longer sleep duration was significantly associated with better diabetes management, and better sleep quality was associated with better glycemic control. Use of an insulin pump was also associated with better sleep quantity and quality for both males and females, which may be due to lower risk for hypoglycemia observed in pump users (Boland, Grey, Oesterle, Fredrickson, & Tamborlane, 1999). As these data are cross-sectional, additional studies are needed to better understand the mechanisms and direction of these effects, including information about sleep habits that might contribute to poor quality of sleep in adolescents with T1D (e.g. caffeine use, electronic media use) (Owens, 2014). The relationship between sleep and diabetes outcomes is also likely to be bidirectional. For instance, poor glycemic control increases the likelihood of nocturnal hypo- and hyperglycemia, which can disrupt sleep (Matyka, Crawford, Wiggs, Dunger, & Stores, 2000; Yeshayahu & Mahmud, 2010), creating a negative cycle between sleep disturbances and suboptimal glycemic control.

The differences in the associations for males vs. females warrant replication in additional pediatric samples. Other studies in adolescent populations have found that sleep disturbances were linked with higher body mass index and increased hypertension in boys (Knutson, 2005; Peach et al., 2015), but not girls, yet the observational nature of these studies does not provide information on whether these differences are physiological or behavioral. The present study was limited by the use of self-report methodology, vs. more objective measure of sleep (e.g. actigraphy), but to our knowledge, this was the first study to examine sleep in relation to both glycemic control and diabetes management behaviors in adolescents and young adults with T1D. Further, a control group of adolescents and young adults without diabetes may help highlight which barriers to sleep are unique to diabetes. In addition, the different eligibility criteria at the two sites may have affected findings. Nevertheless, these findings suggest that sleep may be an important target for future interventions to improve diabetes.

### Table 2. Correlations among adolescent sleep and diabetes variables by gender.

|               | 1  | 2  | 3  | 4  | 5  | 6  |
|---------------|----|----|----|----|----|----|
| (1) Adolescent age | –  | –0.22 | 0.22 | 0.30* | –0.55*** | 0.15 |
| (2) Sleep duration | –0.30** | – | –0.48*** | –0.08 | 0.27* | 0.12 |
| (3) Sleep quality | 0.13 | –0.46*** | – | 0.23 | –0.13 | –0.29* |
| (4) Sleep disturbances | 0.13 | –0.26* | 0.56*** | – | –0.14 | 0.00 |
| (5) Blood glucose monitoring | –0.35*** | 0.14 | –0.07 | –0.15 | – | –0.32* |
| (6) HbA1c | 0.10 | –0.08 | –0.03 | 0.15 | –0.40*** | – |

Note: Bivariate correlations for males ($n = 65$) are presented above the diagonal, and bivariate correlations for females ($n = 87$) are presented below the diagonal. Blood glucose monitoring is average checks per day over the previous 30 days.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

HbA1c ($r = -0.29, P = -0.022$). There was not a significant relationship between sleep disturbances and diabetes outcomes for either gender.
In summary, the present study is the first to demonstrate a relationship between sleep and diabetes management in a diverse sample of adolescents and young adults with T1D. Sleep hygiene is not typically addressed in clinical visits for diabetes. Providers should consider assessing for inadequate sleep as a way to identify youth at risk for poor diabetes management and related difficulties with glycemic control.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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**References**

American Diabetes Association. (2015). Standards of medical care in diabetes – 2015. *Diabetes Care*, 38, S41–S48.

Boland, E. A., Grey, M., Oesterle, A., Fredrickson, L., & Tamborlane, W. V. (1999). Continuous subcutaneous insulin infusion: A new way to lower risk of severe hypoglycemia, improve metabolic control, and enhance coping in adolescents with type 1 diabetes. *Diabetes Care*, 22, 1779–1784.

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index (PSQI): A new instrument for psychiatric research and practice. *Psychiatry Research*, 28, 193–213.

Donga, E., Van Dijk, M., Van Dijk, J. G., Biermasz, N. R., Lammers, G.-J., Van Kralingen K. ... Romijn, J. A. (2010). Partial sleep restriction decreases insulin sensitivity in type 1 diabetes. *Diabetes Care*, 33, 1573–1577.

Eaton D. K., McKnight-Eily, L. R., Lowry, R., Perry, G. S., Presley-Cantrell, L., & Croft, J. B. (2010). Prevalence of insufficient, borderline, and optimal hours of sleep among high school students – United States, 2007. *Journal of Adolescent Health*, 46, 399–401.

Hamman, R. F., Bell, R. A., Dabelea, D., D’Agostino, R. B., Dolan, L., Imperatore, G., ... Saydah, S. (2014). The SEARCH for diabetes in youth study: Rationale, findings, and future directions. *Diabetes Care*, 37, 3336–3344.

Hood, K. K., Peterson, C. M., Rohan, J. M., & Drotar, D. (2010). Association between adherence and glycemic control in pediatric type 1 diabetes: A meta-analysis. *Pediatrics*, 124, e1171–e1179.

Jauch-Chara, K., Schmid, S. M., Hallsworth, M., Born, J., & Schultes, B. (2008). Altered neuroendocrine sleep architecture in patients with type 1 diabetes. *Diabetes Care*, 31, 1183–1188.

Knutson, K. L. (2005). Sex differences in the association between sleep and body mass index in adolescents. *Journal of Pediatrics*, 147, 830–834.

Koren, D., O’Sullivan, K. L., & Mokhlesi B. (2015). Metabolic and glycemic sequelae of sleep disturbances in children and adults. *Current Diabetes Reports*, 15, 562–572.

Matyka, K., Crawford, C., Wiggs, L., Dunger, D. B., & Stores, G. (2000). Alterations in sleep physiology in young children with insulin-dependent diabetes mellitus: Relationship to nocturnal hypoglycemia. *Journal of Pediatrics*, 137, 233–238.

Megdal, S. P., & Schernhammer, E. S. (2007). Correlates for poor sleepers in a Los Angeles high school. *Sleep Medicine*, 9, 60–63.

Miller, K. M., Foster, N. C., Beck, R. W., Bergenstal, R. M., DuBose, S. N., DiMeglio, L. A., ... Tamborlane, W. V. (2015). Current state of type 1 diabetes treatment in the U.S.: Updated data from the T1D exchange clinic registry. *Diabetes Care*, 38, 971–978.
National Sleep Foundation (2015). *Children and sleep. Secondary children and sleep*. Retrieved from http://sleepfoundation.org/sleep-topics/children-and-sleep

Owens, J. (2014). Adolescent sleep working group committee on adolescence. *Insufficient Sleep in Adolescents and Young Adults: An Update on Causes and Consequences*. *Pediatrics*, 13, e921–e932.

Peach, H., Gaultney, J. F., & Reeve, C. L. (2015). Sleep characteristics, body mass index, and risk for hypertension in young adolescents. *Journal of Youth and Adolescence*, 44, 271–284.

Perfect, M. M., Patel, P. G., Scott, R. E., Wheeler, M. D., Patel, C., Griffin, K., ... Quan, S. F. (2012). Sleep, glucose, and functioning in youth with type 1 diabetes. *Sleep*, 35, 81–88.

Randazzo, A. C., Muehlbach, M. J., Schweitzer, P. K., & Walsh, J. K. (1998). Cognitive function following acute sleep restriction in children ages 10–14. *Sleep*, 21(8), 861–868.

Stamatakis, K. A., Kaplan, G. A., & Roberts, R. E. (2008). Short sleep duration across income, education, and race/ethnic groups: Population prevalence and growing disparities during 34 years of follow-up. *Annals of Epidemiology*, 17, 948–955.

Steenari, M. R., Vuontela, V., Paavonen, E. J., Carlson, S., Fjällberg, M., & Aronen, E. T. (2003). Working memory and sleep in 6- to 13-year-old schoolchildren. *Journal of the American Academy of Child Adolescent Psychiatry*, 42(1), 85–92.

The Diabetes Research in Children Network Study Group. (2005). Comparison of fingerstick hemoglobin A1c levels assayed by DCA 2000 with the DCCT/EDIC central laboratory assay: Results of a Diabetes Research in Children Network (DirecNet) study. *Pediatric Diabetes*, 6, 13–16.

Westerlund, L., Ray, C., & Roos E. (2009). Associations between sleeping habits and food consumption patterns in 10–11 year children from Finland. *British Journal of Nutrition*, 102, 1531–1537.

Yeshayahu, Y., & Mahmud, F. H. (2010). Altered sleep patterns in adolescents with type 1 diabetes: implications for insulin regimen. *Diabetes Care*, 33, e142.