SPECIAL REPORT

Diabetes Management

Sleep parameters and diabetes-related considerations for children and adolescents with Type 1 diabetes

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Practice points

- Research is increasingly identifying sleep as an important variable to consider when working with children and adolescents with Type 1 diabetes (T1D).
- An emerging research literature highlights the importance of sleep in maintaining adequate glycemic control among children/adolescents with T1D, and therefore sleep is important for pediatric endocrinologists to evaluate and consider as a treatment target.
- Sleep appears to be crucial for functional outcomes such as academic performance and psychological functioning (e.g., internalizing/externalizing symptoms). Addressing sleep difficulties may lessen issues in these important outcome areas.
- Assessment of sleep should be incorporated into standard diabetes care and should include assessment of sleep habits, including typical weekday and weekend bedtimes and wake times, sleep-onset latency, symptoms of sleep-disordered breathing (e.g., snoring), the number and duration of night-time awakenings, sleep/wake transitions and excessive daytime sleepiness.

Potential alterations in sleep stages and disruptions during the night place children and adolescents with Type 1 diabetes (T1D) at risk for negative sequelae related to short sleep duration or suboptimal sleep. In this special report, research establishing the importance of sleep variables in diabetes care, including for improved adherence and glycemic control, is described. Also, emerging research is presented supporting the impact of sleep on academic performance, internalizing and externalizing symptoms, and parental functioning in children with adolescents with T1D. Given the various ways in which sleep relates to functional outcomes in children and adolescents with T1D, assessment suggestions for pediatric endocrinologists are discussed. Recommendations are also provided for intervention.

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Suboptimal sleep habits, sleep disorders and insufficient or irregular sleep are associated with impaired social, emotional, behavioral and academic outcomes during childhood and adolescence [1–3]. According to the National Sleep Foundation recommendations, healthy preschool-aged children should receive 10–13 h of sleep per night, school-aged children should receive 9–11 h of sleep, and adolescents should receive 8–10 h of sleep [4]. Despite these recommendations, sleep need functions similarly to a growth curve, and some children need more and some less at the same ages [5]. With this in mind, the majority of children and adolescents do not receive recommended amounts of sleep. In a national survey, 22% of preschoolers and 52% of school-age children received less than 10 h of sleep per night [6]. In adolescents, 45% received less than 8 h of sleep on school nights [7]. Information regarding sleep architecture and important facts regarding diagnosing and treating behavioral sleep problems in pediatric patients is readily available, including details such as the normative nature of nocturnal arousals, duration of sleep cycles (every 50–110 min depending on age) and factors affecting sleepiness (such as sleep duration and timing of awakening) [8,9].

The potential negative impact of sleep disturbances for children and adolescents [10,11] with Type 1 diabetes (T1D) may be even more pronounced than the impact on children and adolescents without T1D given the unique needs and effects of sleep for individuals with T1D. The current article reviews the current state of the literature regarding sleep disturbance in children and adolescents with T1D, considers evidence for disease- and psychosocial-related correlates of sleep difficulties and provides recommendations for interventions to improve sleep for children and adolescents with T1D.

Sleep disturbance in children & adolescents with T1D

A number of studies comparing youth with T1D to physically healthy controls have indicated the potential for greater difficulties with sleep initiation and maintenance, sleep-wake transitions and excessive daytime sleepiness [10,12–14]. Caruso and colleagues evaluated sleep in a sample of 49 participants with T1D and 36 physically healthy peers between the age of 6 and 16 years old [10]. Parents in the T1D group indicated that their children had higher levels of total sleep disturbance ($p < 0.001$), problems with sleep-wake transition (e.g., restless legs syndrome, bruxism; $p < 0.005$) and excessive somnolence ($p < 0.001$) compared with controls [10]. Despite the small sample, differences were statistically significant with medium to large effect sizes [10]. Also, in a small sample of children with T1D compared with controls, polysomnography suggested that the children with T1D had more nighttime awakenings than did controls ($p = 0.002$), but no data were presented on sleep efficiency to compare the two groups [14]. A larger study assessing quality of life found significant differences on sleep/rest fatigue between children ages 5–18 years with T1D and physically healthy controls ages 10–17 years, with a small effect size for child report and large effect size for parent report [13]. In a longitudinal study of high school students (117 with T1D, 122 controls) that followed participants 1 year after graduation, sleep disturbance increased for males with T1D compared with females with T1D and to controls [12].

Other studies have identified no sleep parameter differences between youth with T1D and controls. In a sample of young children with T1D, parent report of rates of behavioral insomnia and bedtime resistance were found to be generally comparable to rates of these difficulties in the general population [15]. Additionally, in a sample of older children and adolescents compared with matched controls, there were no significant differences between the groups on self-report of symptoms of insomnia and hypersomnia [16]. Research to date has not compared sleep duration in youth with T1D to physically healthy controls. One study characterized sleep within a combined sample of youth with T1D and their family members; 52% of children (ages 5–11 years) and 64% of adolescents (ages 12–19 years) received less than the recommended hours of sleep at night [17]. Relative to national survey data, these rates are generally similar [6,7].

Findings are inconclusive regarding symptoms of sleep-disordered breathing comparing children and adolescents with T1D with physically healthy controls. Although there is some evidence from two studies employing polysomography that children and adolescents with T1D are more likely than age-matched controls to have a higher apnea index ($p = 0.029$ [16], $p = 0.006$ [18]), the clinical significance of these group differences is unclear. However, Caruso and colleagues did not find significant differences between children

and adolescents with T1D and their physically healthy peers on a parent-report subscale of sleep-disordered breathing [10].

Sleep disturbance & glycemic control

Glycemic control may be related to some elements of sleep patterns and sleep structure in children and adolescents with T1D [11,16,18–19]. In a sample of adolescents with T1D, reductions in slow wave sleep (i.e., stage 3 or deep sleep) and a greater proportion of stage 2 sleep were related to worse glycemic control (i.e., HbA1c, $p = 0.003$, $p < 0.001$, respectively), but overall sleep time and sleep efficiency were unrelated to HbA1c [16]. Additionally, children ages 5–11 years old with poor glycemic control had a higher frequency of central apnea events than children with T1D who had good glycemic control ($p < 0.01$) [18]. Self-report of difficulties with sleep initiation ($p < 0.05$) [19] and parent report of their children sleeping too much ($r = 0.24$, $p < 0.05$) [11] were also associated with worse glycemic control. However, Caruso and colleagues [10] did not find a statistically significant relationship between a composite measure of parent-reported child sleep difficulties and HbA1c for children and adolescents ages 6–16 years. Taken together, the results suggest that it is important to consider different aspects of sleep when examining how sleep disturbance may relate to glycemic control. It should be acknowledged that the directionality of relationships between sleep disturbance and glycemic control has not yet been established.

One way in which hyperglycemia may impact sleep is via awakenings due to polyuria. Another possibility is that disruption in sleep may impact insulin sensitivity. Research in adults with T1D supports a relationship between sleep restriction and insulin resistance [20]. As Barone and Menna-Barreto [21] propose, it may be the relationship between hypergylcemia and the body's stress response (i.e., increased hypothalamic–pituitary–adrenal [HPA] axis activity) that leads to disruption in sleep. Disruptions in sleep may then impact daytime functioning and thereby influence decision making (i.e., adherence) regarding diabetes care, which further impacts glycemic control [21]. Research in children and adolescents with T1D is needed to examine how objective measures of sleep (e.g., actigraphy) relate to glucose levels and stress hormone levels.

Adherence to self-care tasks (e.g., blood glucose monitoring, insulin administration, carbohydrate counting) may be another mechanism through which sleep may impact glycemic control. Only one study to our knowledge has examined the relationship between sleep and adherence in youth with T1D. In a sample of adolescents in poor glycemic control, parental report of sleep difficulties/altered total sleep time was related to lower report of adherence ($r = -0.34$; $p < 0.001$ [11]), as assessed by adolescent report on the Self Care Inventory [22] and reduced frequency of blood glucose monitoring based on meter download ($r = -0.30$; $p < 0.05$) [11]. Additional research that includes adolescent report of sleep disturbance over time is needed to examine the directionality of relationships between sleep disturbance and adherence. Sleep quality may also impact executive functioning [10], family conflict or other psychosocial variables that are known correlates of adherence in children and adolescents with T1D.

Sleep disturbance & nocturnal hypoglycemia

Occurrences of nocturnal hypoglycemia are common in children with T1D and may also disrupt consolidated sleep at night or cause a significant risk to children's health. Individuals with T1D may be less likely than individuals without T1D to spontaneously awaken during episodes of hypoglycemia [14,23–24], which could result in fatal consequences. Research suggests that nocturnal hypoglycemia is associated with impairments in counterregulatory hormone release, which may explain reduced arousals during sleep [24–26]. In children, nocturnal hypoglycemia may be asymptomatic [27], and the risk for severe episodes of hypoglycemia is greater than in adults [28,29]. Therefore, children are particularly vulnerable to these negative effects. Although sample sizes have been small, the available research on nocturnal hypoglycemia in children and adolescents indicates that episodes of nocturnal hypoglycemia are typically not associated with arousals from sleep [27,30–31]. In fact, Pillar and colleagues [31] reported that greater slow wave sleep and increased sleep efficiency were more common for children experiencing nocturnal hypoglycemia. One small study of seven adolescents with T1D examined awakenings during hypoglycemia and during an auditory stimulus [32]. None of the adolescents woke during episodes of hypoglycemia induced during slow wave sleep, but awakenings did not differ for auditory stimuli during hypoglycemia versus euglycemia [32]. These results suggest that

nocturnal hypoglycemia may not impact arousal thresholds for auditory stimuli despite reduced arousals during hypoglycemia. Even in less severe situations, episodes of nocturnal hypoglycemia may impact functioning for individuals with T1D because nocturnal hypoglycemia may result in decreased sleep quality or disrupted sleep if the child awakens. The rate of the variation in blood glucose level may be important to consider in addition to the extent of the change in glucose level, because there is some evidence that rapid declines in glucose levels are more likely to be associated with awakenings than gradual declines [31].

Sleep disturbance & psychological functioning

Elevations in psychological distress, such as depression and anxiety, are associated with difficulties with adherence and glycemic control [33,34]. In addition, sleep disturbance is associated with increased emotional distress [1]. Thus, it is important to consider how sleep may relate to psychological functioning in children and adolescents with T1D. In a sample of youth ages 10–16 years of age [16], daytime sleepiness, behavioral sleep problems and increased time spent in stage 2 of sleep were correlated with reduced quality of life and increased depressive symptoms. Increases in depressive symptoms in children have also been found the day after experiencing nocturnal hypoglycemic episodes [27]. Additionally, higher parent report of sleep disturbance has been associated with reduced executive functioning in children and adolescents with T1D [10]. Executive functioning has been shown to be associated with adherence to diabetes care in children and adolescents with T1D [35].

Although research has supported the increased risk for behavioral and emotional difficulties among adolescents with T1D, the role of sleep problems as a contributor to psychosocial functioning has not been examined until recently [10]. Caruso and colleagues [10] examined sleep problems as a mediator of the relationship between the presence of T1D and increased behavioral/emotional problems. The results supported parent-reported sleep quality as a mediator of the relationships between the presence of T1D and both increased externalizing and internalizing symptoms. These results are important, as they suggest that early identification and treatment of sleep difficulties may serve to reduce risk for impaired psychological functioning [10]. Furthermore, given that reduced psychological functioning is associated with worse glycemic control, it will be important for future studies to examine the potential interplay between sleep difficulties, psychological functioning and glycemic control.

Sleep disturbance & academic functioning

Academic difficulties (e.g., reading difficulties) have been identified at a slightly higher rate in children and adolescents with T1D [36], which highlights the importance of identifying potential contributors to this increased risk. Research by Perfect and colleagues has supported the association between sleep disturbance and academic performance among children and adolescents with T1D [16,37]. Specifically, sleepiness and reduced time in stage 2 sleep were associated with lower grades in school for children and adolescents [16]. In addition, delaying bedtime during the school week was associated with lower test scores and lower grade point averages for adolescents [37]. Shorter weekday sleep duration was also associated with more school absences and poorer writing performance [37]. Additionally, the findings related to impairments in executive functioning associated with reduced sleep quality [10] have implications for academic performance. It should be noted that there could be a third variable, such as parental monitoring, that may be impacting both sleep habits and academic performance. Nonetheless, taken together with results of studies suggesting an increased risk for school problems among a subset of youth with T1D [36,38], these results highlight the value of evaluating child and adolescent patients with T1D for adequate sleep as well as referring any of those with possible problems for treatment to facilitate behavioral/medical interventions to address sleep difficulties and prevent poor or deteriorating academic performance.

Sleep disturbance & parental/family functioning

It is important to consider the impact of nocturnal blood glucose monitoring and child sleep difficulties on parents of children with T1D. This is particularly relevant for parents of younger children with T1D, since they are more likely to be involved in daily management and also are more likely to experience stress related to diabetes management [39]. Emerging research suggests that the majority of parents of young children

engage in nocturnal blood glucose monitoring [15,40], and this has been found to be more common among parents of children on intensive insulin regimens and with a longer duration of T1D [15,40]. There is also evidence that parents of young children with T1D are likely to receive less than the recommended hours of sleep/night and report greater sleep problems than expected based on national norms for adults [41]. Additionally, higher levels of bedtime resistance and behavioral insomnia in children ages 2 to 5 years old with T1D have been found to be associated with higher levels of difficulties with parenting stress and anxiety [15]. Parental stress and state anxiety may also be related to worry about nocturnal hypoglycemia and nocturnal blood glucose monitoring [15]. These data highlight the importance of assessing parental sleep, anxiety and frequency of nocturnal blood glucose monitoring in parents of children with T1D. Increasing parental sleep quality may have implications for enhancing parent and child psychological functioning as well as the child's glycemic control.

Recommendations for addressing sleep

It is important to be aware of a child/adolescent patient's sleep schedule in order to understand the timing and significance of self monitoring blood glucose values, but also to gain clinical insight into the effect sleep may have on adherence behaviors and concomitant glycemic control and variability. While beyond the scope of this article, detailed guidelines are available for the clinical assessment of pediatric sleep [8,9]. In brief, health care providers should routinely ask about their child/adolescent patients' sleep behaviors, including the typical time the child gets into bed and falls asleep on the weekdays and weekends, the existence of extended wake ups during the night and the typical wake up time on the weekdays and weekends [9]. Providers should also ask about symptoms of sleep-disordered breathing, such as snoring and symptoms of other sleep disorders including insomnia, restless legs syndrome and narcolepsy/hypersomnia. Many of these questions may be assessed via an intake form with follow-up questions asked face-to-face. In addition, there are several reliable and well-validated self- and parent-report measures available for assessing sleep in children and adolescents [42], including the Children's Sleep Habits Questionnaire [43] and the Sleep Disturbance Scale for Children [44]. These standardized measures could be incorporated into the previsit screening to guide additional sleep assessment and recommendations. It is important to assess sleep at each visit because sleep schedules might change drastically, especially over the summer.

Following a provider's thorough assessment of patient/parent sleep variables, providers working with children and adolescents with T1D have the opportunity to provide information to families about the importance of sleep for diabetes care and psychosocial outcomes. Parents should also be provided with education about recommended sleep duration for the child's age [4] and the importance of parental monitoring of consistent sleep schedules [45]. In addition, discussion of sleep hygiene [9], especially considering normal circadian rhythm fluctuations in adolescence, may lead to improvement in sleep habits. For children and adolescents who are struggling with daytime sleepiness or maintenance of a regular schedule, referrals to sleep specialists may be needed [46,47], including to physicians and PhD's who are board certified in sleep medicine and/or to psychologists certified in behavioral sleep medicine when these providers are available in your geographic region [48]. In the case of a child/adolescent who has snoring with daytime sleepiness (particularly those who may be overweight/obese and have a family history of obstructive sleep apnea [49]), referral for a formal sleep study is warranted [46]. When there are complaints of excessive daytime sleepiness despite getting adequate and regular sleep, consider an evaluation for hypothyroidism, celiac disease and Addison's disease [50]; if these are normal, consider referral to a sleep specialist for consultation regarding evaluation for narcolepsy/hypersomnia [48].

Changes to diabetes care to improve sleep may also be needed. In our practice, when families report hypoglycemia or hyperglycemia that is contributing to sleep disturbances, we recommend appropriate insulin changes and provide guidance about carbohydrates and exercise. If families are unnecessarily testing blood glucose multiple times per night due to fear of hypoglycemia, use of a continuous glucose monitor may be helpful [51,52]. However, it is also important to keep in mind that a continuous glucose monitor may contribute to frequent awakenings due to the alarms. Alarms must be set with careful thought for each individual patient, as too many false alarms are discouraging and disrupting [53].

Conclusion & future perspective

The research literature on sleep in children and adolescents with T1D is growing but is still quite limited in comparison to the number of studies that have examined other risk factors for poor glycemic control (e.g., family functioning and psychological risk factors). Furthermore, the underlying mechanisms responsible for relationships between sleep and glycemic control are not yet fully understood. Although the research on glycemic control and sleep is still evolving, the current literature highlights the importance of better understanding and addressing sleep in children and adolescents with T1D. The addition of multicenter studies that track sleep habits and sleep architecture over time as they relate to child and parent psychological functioning, adherence and glycemic control will improve our ability to best identify those who are most at risk. Future research with larger samples is needed to better understand if there are other individual or group levels factors (e.g. gender, race/ethnicity) that may increase risk for differences in sleep duration or regularity. Further research is also needed to examine symptoms of sleep-disordered breathing among children and adolescents with T1D compared with the general population. Additionally, research on sleep interventions tailored to children and adolescents with T1D will provide guidance to clinicians on evidence-based practices for improving sleep.

As sleep becomes increasingly recognized as an area for frequent assessment and intervention for children and adolescents with T1D, it is likely that recommendations for addressing sleep habits during routine diabetes care will become more standardized and referrals for medical and behavioral sleep medicine interventions will become more common. Integration of psychological services within routine diabetes appointments also offers an avenue for assessment and intervention when concerns about sleep arise. Finally, standard diabetes education at the time of diagnosis is likely to include education regarding sleep habits and sleep hygiene recommendations that take into account the daily demands of diabetes care.

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