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Sleep in Type 1 Diabetes: Implications for Glycemic Control and Diabetes Management

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Abstract

Purpose of Review—To highlight recent findings from studies of sleep in type 1 diabetes (T1D), with a focus on the role of sleep in self-management, the cognitive and psychosocial outcomes related to sleep disturbances, and factors associated with sleep disturbances specific to T1D.

Recent Findings—People with T1D experience higher rates of sleep disturbances than people without diabetes, and these disturbances have negative implications for glycemic control and diabetes management, as well as psychosocial and cognitive outcomes. Inconsistent sleep timing (bedtime and wake time) has emerged as a potential target for interventions, as inconsistent sleep has been linked with poorer glycemic control and adherence to treatment. Sleep-promoting interventions and new diabetes technology have the potential to improve sleep in people with T1D.

Summary—Sleep is increasingly considered a critical factor in diabetes management, but more multi-method and longitudinal research is needed. We emphasize the importance of sufficient and consistent sleep for people with T1D, and the need for providers to routinely assess sleep among patients with T1D.

Keywords

type 1 diabetes mellitus; sleep; self-management; adherence; glycemic control; diabetes technology

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Compliance with Ethical Standards

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

Conflict of Interest

Katia M. Perez, Emily R. Hamburger, Morgan Lyttle, Rodayne Williams, Erin Bergner, Sachini Kahanda, Erin Cobry, and Sarah S. Jaser declare that they have no conflict of interest.

Introduction

Sleep has received increasing attention in relation to diabetes, and for the first time, the 2017 American Diabetes Association's Standards of Medical Care in Diabetes identified sleep as an important consideration for clinicians, recommending "the assessment of sleep pattern and duration as part of the comprehensive medical evaluation based on emerging evidence suggesting a relationship between sleep quality and glycemic control." [1]. The most recent recommendations for sleep from the American Academy of Sleep Medicine, based on available evidence of the impact of sleep duration on health outcomes, indicate that school-age children (ages 6–12) should obtain 9–12 hours of sleep, adolescents (ages 13–18) should obtain 8–10 hours of sleep [2], and adults should obtain 7 or more hours of sleep [3]. The majority of people do not meet these recommendations, however, and insufficient sleep has been identified as a public health problem by the Institute of Medicine [4]. Further, insufficient sleep is an international problem, with fewer than 50% of adults from all countries surveyed reporting getting less sleep than needed on workdays [5].

While obtaining sufficient and good quality sleep is important for all individuals, there are additional implications for people with diabetes, evidenced by the rise in sleep-related research in this population. However, the majority of studies have been conducted in people with type 2 diabetes [6], and fewer researchers have focused on sleep in people with type 1 diabetes (T1D). Of these, the predominant focus has centered on describing the associations between sleep duration and quality with glycemic control. For example, in a meta-analysis of 22 studies of sleep in people of all ages with T1D, Reutrakul and colleagues found that children and adolescents with T1D obtained significantly less sleep than youth without diabetes, with a mean difference of 26 minutes, but found no significant association between sleep duration and glycemic control in children and adolescents [7]. These findings must be interpreted with caution, however, given that only 3 small studies of children and adolescents were included (n=70 with T1D). In this meta-analytic review, adults with T1D reported poorer sleep quality than adults without T1D, but unlike pediatric T1D patients, there was not a significant difference in sleep duration between adults with and without T1D. Further, both poorer sleep quality and shorter self-reported sleep duration (less than 6 hours/night) were related to poorer glycemic control, with a mean difference in hemoglobin A1c (HbA1c) of 0.19% and 0.24%, respectively. On the other hand, excessive sleeping has also been linked to hyperglycemia in adolescents with T1D [8]. Taken together, these findings suggest that obtaining sleep outside the recommended range (whether too little or too much) may have a negative impact on glycemic control.

Less is known about the relationship between sleep and outcomes in T1D aside from glycemic control, or how psychosocial and behavioral aspects of diabetes care impact sleep. In the current review, we focus on the recent literature that describes sleep patterns and psychosocial and behavioral aspects related to sleep in T1D. Specifically, we will review recent studies that have examined sleep disturbances in people with T1D, the role of sleep in self-management or adherence behaviors, the cognitive and psychosocial outcomes related to sleep disturbances in people with T1D, and factors associated with sleep disturbances specific to people with T1D, including fear of hypoglycemia and nocturnal caregiving. In addition, we highlight recent developments in technology that have potential implications for sleep (e.g., hybrid closed loop devices), as well as sleep-promoting recommendations and interventions that may be useful for people with T1D.

Sleep Patterns and Disturbances in T1D

Sleep Disturbances in T1D

People with T1D encounter unique barriers to sufficient sleep, including but not limited to insufficient sleep duration, and these disturbances may have a negative impact on daytime functioning. In one study of adolescents with T1D, parents revealed that 15% of their children had trouble sleeping, 22% were overtired during the day, 29% believed they slept more than children without T1D, and 18% believed they slept less than children without T1D [8]. Similarly, compared to a control group of healthy children, parents have reported that children with T1D had more sleep problems, including more issues surrounding sleep initiation and maintenance, the sleep-wake transition, and daytime sleepiness [•9].

Diabetes-related sleep disturbances have been reported in adults with T1D as well, with studies generally reporting many of the same (and some novel) sleep disturbances as those experienced in pediatric T1D patients. Rates of obstructive sleep apnea are higher among individuals with T1D as compared to those without T1D, even those with normal weight, and may be related to glycemic control [10]. In a study observing 222 adults with long-standing T1D, 23% of the participants were at high risk for obstructive sleep apnea, and 13% exhibited excessive daytime sleepiness [10]. In this sample, 50% of women and 30% of men reported poor sleep quality, and 26% of the participants reported bad dreams. Interestingly, participants considered to be in poor glycemic control were found to be twice as likely to report trouble sleeping due to bad dreams, suggesting that poor glycemic control may negatively impact the quality of REM sleep [10]. Similarly, trouble sleeping, such as difficulty with sleep initiation and night awakenings, was related to glycemic control in both children and adults with T1D [8, 11]. Given that many of these studies were cross-sectional, it is difficult to determine whether poor glycemic control led to sleep disturbances or vice versa; it is likely that the relationship is bidirectional [12].

Sleep Variability in Relation to Diabetes Outcomes

One aspect of sleep that has been found to affect diabetes management in teens and adults is sleep variability, or the day-to-day changes in sleep timing and duration. Staying up late on weekend nights and getting up early on weekday mornings can result in a shift in one's circadian sleep cycle referred to as "social jetlag" [13]. Shifting between a weekday and a weekend schedule perpetuates social jetlag, and this variability in sleep timing can have significant consequences for individuals with T1D. One study of adults with T1D used wrist actigraphy to capture data on sleep duration, latency, fragmentation, and efficiency, which was used to calculate social jetlag, or the difference in total sleep time between nights [14]. Social jetlag at the beginning of the work week led to an increasing sleep debt, for which patients compensated on weekend nights by oversleeping. This shift in chronotype and the resulting social jetlag were found to be independently linked to higher HbA1c [14]. People with T1D may be even more likely to suffer from social jetlag; one study found that during the weekends, adolescents with T1D demonstrated sleep extension more than twice the length of their peers without T1D [15].

Delaying weekend bedtimes and oversleeping on weekend mornings has been associated with poor academic performance, mood problems, and obesity in adolescents in the general population [16], and variability in sleep timing has implications for diabetes management. In a recent study of adolescents with T1D, inconsistent sleep patterns, measured with actigraphy, were associated with poorer glycemic control (higher HbA1c and average blood glucose (BG) levels) and diabetes management (less frequent BG monitoring) [17]. Sleep variability has also been linked to decreased insulin sensitivity in adults with T1D. For example, differences in sleep duration and higher variability in sleep timing were significantly associated with poorer glycemic control (HbA1c) and insulin resistance in adults with T1D [•18]. Specifically, adults displaying frequent swings between insufficient sleep and sleep compensation had higher insulin requirements than those with lower sleep variability, highlighting the importance of sleep regularity in the management of diabetes, though behavioral substrates that may impact both sleep patterns and diabetes care, such as executive function, were not assessed [•18]. A separate study of sleep patterns in adolescents with T1D using questionnaire data revealed that the mean variability in weekday/weekend sleep timing was 2.5 hours, and this variability was significantly associated with increased insulin requirements, regardless of adherence to treatment [19]. These findings support that sleep variability has negative effects on glycemic control in both adults and adolescents with T1D. It may be that, for people with T1D, consistent sleep timing is more important for diabetes management than simply obtaining sufficient sleep.

Impact of Sleep on Diabetes Care

Adherence and Diabetes Management

The reported changes in sleep patterns and architecture have implications for self-management and adherence behaviors, and this has been demonstrated in pediatric T1D populations. Hazen and colleagues found that, in addition to poorer glycemic control and higher average BG levels, parent report of sleeping more than other children was associated with less frequent BG checks, and lower self-reported adherence [8]. The act of sleeping too much may preclude engagement in some adherence behaviors, as children may be asleep at times that they are required to check BG or administer insulin. In contrast, McDonough et al. found that for adolescents using insulin pumps, an increase in sleep duration of as little as 15 to 20 minutes resulted in an additional BG check or insulin administration the following day [•20]. Similarly, Jaser and Ellis found BG monitoring was positively associated with sleep duration in adolescents [21]. When analyzed by gender, they found that for males, better diabetes management (BG monitoring) was related to longer sleep duration [21].

Sleep quality is also important to consider in relation to diabetes management. For example, Turner et al. observed that perceptions of poorer sleep quality increased the incidence of self-regulatory failures and led to an increased risk of hyperglycemia [22]. These data came from the 14-day diaries of older adolescents with T1D, who recorded information regarding sleep, BG levels, and self-care behaviors, including self-regulatory failures of cognitive, emotional, and behavioral processes related to BG checking. Notably, reporting better sleep quality than one's usual (even among teens with generally good quality sleep on average) was linked with fewer reported self-regulatory failures in diabetes management [22]. These findings suggest that for children and adolescents with T1D, adequate and good quality sleep contribute to maintaining optimal glycemic control, and this may be explained by the impact sleep exerts on behaviors that drive adherence to diabetes management regimens. Parents' sleep quality may also be important to consider, as poor parental sleep quality has been associated with lower self-efficacy for diabetes management [23]. Sleep disturbances in parents of young children with T1D, which are common, may negatively impact their ability to manage their children's diabetes. More data are needed to determine if these relationships between sleep disturbances and self-management behaviors exist for adults with T1D as well.

Psychosocial, Neurocognitive and Academic Correlates of Sleep Disturbances

Along with impacting adherence, sleep disturbances have been linked to a variety of psychosocial outcomes. In a study of adolescents with poorly controlled T1D, trouble sleeping, overtiredness, and sleeping more than other children were linked with higher levels of depressive symptoms [8]. Similarly, in a study reporting that children with T1D had a higher incidence of problem behaviors, problems sleeping, and reduced executive functioning, sleep difficulties were found to mediate the effects of diabetes on externalizing behavior, internalizing behavior, and metacognition [•9]. Given that the pre-frontal cortex and limbic system perform functions that are particularly sensitive to sleep disruption, sleep disturbances may result in neurocognitive and behavioral difficulties [•9]. These same regions are also highly dense in insulin receptors and are thought to be susceptible to irregular BG levels. Therefore, it is possible that people with T1D may be at an increased risk of neurocognitive and behavioral problems due to sleep disturbances.

Sleep also plays a significant role in academic outcomes for youth with TD, including school absences, standardized test scores, and grade point average [24]. For youth with T1D, it is possible that insufficient sleep exacerbates problems with diabetes management, leading to more illness-related school absences. In one study, shorter sleep duration on school nights was related to greater number of school absences, and the number of school absences was significantly associated with greater perceived disease impact (a scale that includes items relating to poorer health, effect of diabetes on relationships and activities, and the demands of self-management). Similar to findings that variable sleep timing contributes to diabetes outcomes [17], Perfect and colleagues also found that greater delay in weekend bedtimes reported by adolescents with T1D was associated with lower grade point average, as well as lower scores on standardized reading, writing, and mathematics assessments [24].

In a sleep study using polysomnography in youth with T1D ages 10–16, researchers found that that the proportion of time spent in stage N2 (a lighter stage of sleep) was significantly related to a variety of psychosocial and academic variables, including parent reports of both emotional and behavioral problems, as well as decreased diabetes quality of life, lower grades, worse performance on a standardized math examination, sleep-wake behavior problems, depressed mood, and daytime sleepiness [25]. Daytime sleepiness itself was significantly associated with lower grades, decreased diabetes quality of life, increased diabetes-related worries, and depressed mood [25]. More research is needed to determine the impact of sleep disturbances on psychosocial and cognitive functioning in adults with T1D.

Impact of Type 1 Diabetes on Sleep

Fear of Hypoglycemia

Fear of hypoglycemia is common among patients with diabetes and their caregivers [26], and several studies have examined the frequency of nocturnal hypoglycemia in patients with T1D in relation to fear of hypoglycemia. In one observational study, children with and without T1D underwent polysomnographic recordings in order to evaluate the interaction between nocturnal hypoglycemia and sleep [27]. Five of the children (33%) with T1D had profound nocturnal hypoglycemia. Brief arousals from sleep occurred less in those with hypoglycemia but more in the children with T1D compared to the controls [27]. Another study with 20 adolescent patients with diabetes revealed that 30% of them experienced hypoglycemia at some point during the night, and this was not predicted by their last BG check before going to sleep [28]. Similarly, in a study of adult patients with T1D, 20% experienced at least 10 nighttime non-severe hypoglycemic episodes in the past three months [29]. In this same study, 21% of participants reported having a difficult time returning to sleep, and 26% of participants reported that the non-severe hypoglycemia event had an impact on their emotional state the next day [29]. These studies highlight the frequency of nocturnal hypoglycemic events in both pediatric and adult T1D populations as well as the impact hypoglycemia has on sleep. Findings from these studies with adolescents and adults indicate that nocturnal hypoglycemic episodes are fairly common, and the fear of hypoglycemia is not unfounded.

Nocturnal Caregiving

Studies consistently demonstrate that parents of children with T1D experience poor sleep quality [23, 30–32]. Parents of young children with T1D reported, on average, just over 6 hours of sleep per night [23, 30, 32], which is considerably less than the recommended 7–9 hours. In addition to obtaining insufficient sleep, parents of children with T1D also report poor sleep quality; Herbert et al. found that approximately one-third of parents indicated that their overall sleep quality was “fairly bad” or “very bad” [23]. Similarly, a recent study of 515 parents of children ages 2–12 years old in the T1D Exchange Clinic Registry found that poorer child sleep quality was significantly associated with poorer parental sleep quality and well-being, and greater fear of hypoglycemia [•32].

Parents who worry about hypoglycemia are likely to experience poorer sleep quality because they perform nighttime diabetes management, and/or they cannot sleep due to worry about nocturnal hypoglycemia, [23, 30]. In a study of parents of young children (≤ 6 years old) with T1D, greater fear of hypoglycemia was significantly and positively associated with the number of nighttime BG checks parents reported in a week [23]. Similarly, all of the parents in Jaser et al.’s study of young children with T1D (ages 3–5) reported doing nighttime BG checks, and glucometer downloads revealed 1.7 BG checks per night, even though none of the overnight readings indicated low BG levels [30]. These findings suggest that parents may be performing more overnight BG checks than necessary, which has the potential to disturb both parent and child sleep.

Diabetes Devices

With advances in diabetes technology and devices, there is potential for improved diabetes management, but the effects on sleep may be less positive. For example, an unintended consequence of the flexibility around mealtimes afforded by using insulin pumps [33] may be an increased rate of late-night snacking behaviors in adults, leading to shorter sleep duration. In one study of adults with T1D, the proportion of adults using insulin pumps who also engaged in late night snacking was somewhat high, with 38.5% reporting that they "sometimes" ate after 10 PM, and 7.4% reporting "often" eating after 10 PM [34]. However, late night snacks were not independently related to glycemic control. Moreover, despite many parents' hope that continuous glucose monitors (CGMs) would allay their fear of hypoglycemia, a study that used actigraphy to measure sleep found that the use of CGM did not improve parental sleep quality, and may even have negative effects on parental sleep continuity [31]. Additionally, in a large study of children ages 2–12, neither the use of insulin pumps nor use of CGM were not associated with child sleep quality (as measured by parent report) [•32]. Finally, a recent study found that parents and partners of people with T1D reported high levels of sleep disturbances related to diabetes technology (73% of caregivers and 59% of partners), many of these due to false alarms [35]. Taken together, these findings suggest that diabetes devices may be disturbing the sleep of people with T1D and their caregivers and partners.

Discussion

While recognition of the importance of sleep in T1D has grown in recent years, more longitudinal studies are needed, including experimental designs (i.e., sleep restriction/ promotion), to better understand the complex relationship between sleep, glycemic control, and other important diabetes-related outcomes. As the field moves forward, it will be important to carefully consider the challenges with measuring sleep and characterizing sleep disturbances with questionnaires. In a recent review, Spruyt and Gozal reported that few surveys used to characterize sleep parameters and problems in pediatric and young adult populations have been subjected to extensive psychometric evaluation and meet established criteria based on fundamental operational principles of instrument development [36]. Thus, a multi-method approach to gathering data, including the concurrent use of objective measures of sleep and glucose levels (e.g., actigraphy and continuous glucose monitoring/pump data) will be central to overcoming the limitations inherent to self-reported accounts of sleep habits/logs and adherence, and will allow us to better understand the dynamic relationship between sleep and T1D.

Sleep-Promoting Interventions

As our knowledge on the relationship between sleep and T1D continues to expand, efforts to translate findings into useful clinical tools for providers who care for patients with T1D will become increasingly important, and behavioral intervention trials are needed to inform practical guidelines.

To our knowledge, the only sleep-promoting intervention study conducted in the T1D population was a pilot study by Perfect et al [•37]. The intervention included 79 participants with T1D between the ages of 10 to 16 years who were randomized to a Sleep Extension group or Fixed Sleep Duration attention control group. For the participants in the Fixed Sleep Duration group, no change in bedtime was recommended. For those in the Sleep Extension group, individualized recommendations were developed for adolescents to increase time in bed by making changes to their sleep habits. The intervention consisted of an in-person visit with a trained member of the research team and a phone call to discuss compliance and address any difficulties they may have had with the prescribed sleep schedule. The authors were able to demonstrate feasibility in implementing a sleep extension intervention in this population and success in improving the total sleep time of participating adolescents by targeting bedtimes. Nearly 80% of participants in the sleep extension group obtained at least 15 minutes of additional sleep each intervention night, with a mean increase in total sleep time of 29 minutes as measured by actigraphy and 48 minutes as measured by sleep diaries [•37].

Additionally, sleep promotion intervention trials conducted in other populations have demonstrated the potential to improve the quantity and quality of sleep. For example, a sleep study conducted with 12–19 year olds who reported insufficient sleep (n=55, 85% female) found that moving bedtimes earlier, coupled with sleep hygiene advice delivered by phone, resulted in earlier sleep onset, more time in bed, and longer sleep duration [38]. On weekdays, average bedtime changed from 11:28 pm to 10:59 pm, mean time spent in bed increased by 30 minutes, and total sleep time increased by 13 minutes. On weekends, bedtime average changed from 1:26 am to 11:20 pm, time in bed increased by 42 minutes, and total sleep time increased by 17 minutes [38]. In addition, self-reported depressive, insomnia, and chronic sleep reduction symptoms improved [38].

In another intervention focused on improving sleep quality, participants between the ages of 10–19 years (n=33) with self-identified sleep problems completed the F.E.R.R.E.T. (Food, Emotions, Routine, Restrict, Environment and Timing) sleep hygiene program [39]. This pilot study consisted of an in-person session lasting approximately 90 minutes, in which participants were given individualized sleep education information, followed by phone calls every 2 weeks and a one-on-one session every 6 weeks to discuss progress. The investigators reported significant improvements in sleep hygiene and a reduction in daytime sleepiness and sedentary/light activity. Notably, scores on the Pittsburgh Sleep Quality Index, a measure of sleep quality, decreased from 7.47 to 4.47, from the clinically significant range to the acceptable range (score <5). However, no significant change in actigraphy data was observed [39].

Cognitive behavioral therapy for insomnia has been successful in improving sleep in adults, as well. A randomized trial of 86 adults demonstrated that 4 biweekly, individual sessions of cognitive behavioral therapy significantly improved insomnia symptoms in 58% of patients [40]. In addition, participants maintained improvements in total sleep time and sleep efficiency, measured with sleep diaries and actigraphy, 6 months after the intervention [40].

These intervention trials offer support that sleep-promoting interventions can successfully improve sleep duration and quality, but they were limited by small sample sizes. Future studies may build on the successful components of these interventions, and adapt them in ways that address diabetes-specific challenges, such as minimizing overnight BG monitoring or targeting fear of hypoglycemia.

Impact of Advances in Diabetes Technology on Sleep

Finally, as diabetes technology continues to evolve, it will be important to observe the direct impact new diabetes devices have on sleep, as well as the impact on other diabetes-related factors associated with sleep disturbances (e.g., fear of hypoglycemia). The most recent advancement in diabetes technology has been the development of an “artificial pancreas” or a closed-loop system. In this type of system, the insulin pump is in direct communication with a CGM, and adjustments in insulin are made based on the glucose values transmitted to the device. The systems currently available to the public outside of a research setting are referred to as “hybrid” systems, as they require human input, including entering calibration BG values and mealtime carbohydrate counts. Other fully automated systems are still in the research phase. Hybrid closed-loop systems have been studied in hospital and home settings for safety and efficacy and have been shown to reduce hypoglycemic events and maintain glucose levels within range more frequently compared to standard management, most notably during the nighttime hours [41–43]. Given that substantial fluctuations in glucose levels can also contribute to nighttime awakenings and decreased sleep duration [27], the closed-loop systems have the potential to reduce sleep disturbances in people with T1D beyond those solely due to hypoglycemic events.

The potential impact of closed loop systems on sleep in people with T1D and their caregivers and partners is also of particular interest. Ziegler et al. demonstrated that, as systems were used and trusted by families, parents reported decreased fear of hypoglycemia [44]. Thus, the use of closed loop systems may also function to decrease diabetes-related distress, resulting in fewer nocturnal caregiving behaviors. The combination of the positive physiologic effect on BG regulation, as well as the potential psychosocial benefits of reducing distress and fear, suggest that the closed-loop system will be a promising device for improving sleep in people with T1D and their caregivers.

Conclusions

In summary, the current literature suggests that sleep may influence diabetes-related behaviors (e.g., adherence) and sleep disturbances are linked with emotional, behavioral, and cognitive/academic problems in people with T1D. In turn, diabetes-related factors (e.g., fear of hypoglycemia) may impact the quantity and quality of sleep in people with T1D and, in the case of children, their caregivers. Future research should include multi-method assessments of sleep parameters and outcome variables, as well as longitudinal study designs, in order to improve our understanding on the extent and direction of these effects and allow us to design appropriate sleep-promoting interventions tailored to people with T1D. In line with recent recommendations [1], we encourage providers to routinely ask about sleep timing and symptoms of sleep disorders, educating patients and families about the importance of sleep for people with T1D, and/or making referrals to sleep specialists as needed. Maintaining a stable sleep schedule during weekend and weekend nights to avoid social jetlag could promote better glycemic control and have the potential to improve diabetes management.

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