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# Does sleep duration, napping, and social jetlag predict hemoglobin A1c among college students with type 1 diabetes mellitus?

**Jennifer Saylor**[a,*], **Xiaopeng Ji**[a], **Christina J. Calamaro**[b], **Adam Davey**[c]

[a]University of Delaware, Tower at STAR, 5th Floor, 100 Discovery Blvd, Newark, DE 19713, USA

[b]Children's Healthcare of Atlanta, 1649 Tullie Circle, Atlanta, GA 30329, US

[c]University of Delaware, Carpenter Sports Building, 26 North College Avenue, Newark, DE 19713, USA

## Abstract

**Aims:** The first aim examined the relationship between sleep behaviors (duration, napping, and social jetlag) and hemoglobin A1c (HbA1c) among emerging young adults (EYAs) with T1DM between 18 and 25 years old, who are living on a college campus. The second aim characterized the gender differences in glucose management, sleep behaviors, caffeine intake, and nighttime technology.

**Methods:** A cross-sectional study of eligible participants used a convenience sample of eli-gible participants. Using Research Electronic Data Capture (REDCap), participants com-pleted surveys about diabetes management, caffeine intake, nighttime technology use, and sleep-related behaviors. Data were analyzed using correlation and multiple linear regression to predict HbA1c from sleep behaviors, adjusting for covariates.

**Results:** Participants (N = 76) average years with T1DM was 10.25 ± 5.70. Compared to females, males had a longer sleep duration lower HbA1c levels. HbA1c levels were nega-tively correlated with weekday sleep ($r = 0.24$, $p = 0.03$) and positively correlated with nap-ping ($r = 0.34$, $p = 0.003$). After adjusting for covariates, participants who napped had a higher HbA1c level ($b = 0.74$, $p = 0.03$) compared with non-nappers.

**Conclusions:** Higher HbA1c levels were found among EYAs with T1DM in college who were nappers and had a longer sleep duration. Modifying sleep behaviors may be an appropriate target to improve glycemic control.

### Keywords

Sleep; Type 1 diabetes mellitus; Young adults; College; Emerging young adults; Glycemic control

[*]Corresponding author. jsaylor@udel.edu (J. Saylor).

Declarations of interest for all authors

The authors declared that there is no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.01.007.

## 1. Introduction

Despite scientific advancements in T1DM management over the past two decades, emerging young adults (EYAs), between 18 and 25 years old, remain one of the age groups with the highest hemoglobin (HbA1c) levels [1,2]. Only 14% of EYAs are able to achieve recommended glycemic targets (HbA1c < 7.0%) [1]. Many EYAs are transitioning from the daily routine of high school to college with a new found freedoms and independent living [3]. This transition is filled with possi-ble lifestyle changes including nutrition, physical activity, sleep, caffeine intake, and technology use [4]. Furthermore, the prevalence of insufficient glycemic control is highest among 19-year-olds with a mean HbA1c level of 9.2% [1], which is also the common age of college transition. It is well known that poor glycemic control is associated with negative health outcomes such as diabetes ketoacidosis and hastened cardiovascular disease; thus warranting a need to identify modifiable lifestyle factors to improve glycemic control among this high-risk group.

There is a growing body of literature focused on the rela-tionship between unhealthy sleep behaviors and neurocogni-tive function [5], elevated HbA1c levels [6], insulin sensitivity [7], insulin resistance [8–10], cardiovascular disease, and all-cause mortality [11]. The American Academy of Sleep Medi-cine recommends at least 7 h of sleep each night for optimal health among EYAs [12]. Yet, among college students, 70% report insufficient sleep and 50% report daytime sleepiness [13]. While there is little evidence of sleep duration and gen-der differences among college students with T1DM, research-ers found no gender differences and sleep duration among adults with type 2 diabetes (T2DM) [14]. Unhealthy sleep behaviors (duration, napping, and social jetlag) among ado-lescents may worsen for EYAs in college with erratic daily schedules and changes in lifestyle. Social jetlag, also referred to as “circadian misalignment”, is defined as a as a mismatch between the sleep–wake schedule and internal circadian tim-ing. The difference between weekday and weekend sleep– wake timing often serves as a proxy for the degree of social jetlag [15]. Among adolescents with T1DM, they had shorter sleep duration and diminished sleep quality than their peers without T1DM [16,17]. Conversely, healthy sleep behaviors reduced the risk of hyperglycemia among adolescents with T1DM [16]. Variations in sleep duration and sleep timing, may lead to increased insulin resistance in adults with T1DM [8–10]. A meta-analysis of sleep and T1DM revealed a decrease in sleep duration resulted in suboptimal glycemic control among adults with T1DM [6]. Among late adolescents, Jaser and Elis found that males who self-reported better sleep quality had a lower HbA1c, but no difference found among females [10]. With shorter nighttime sleep durations and dis-turbances, individuals may counteract by daytime napping [18]. This alters the circadian rhythm leading to changes in reduced insulin secretion [19] and insulin resistance [20]. Meta-analyses have shown that daytime napping increases risk of T2DM and metabolic syndrome [21,22]. Social jetlag, the discrepancy in hours slept between week and weekend days, increased HbA1c level among adults with T1DM [23] and social jetlag >30 min compared to those with <30 min also increased HbA1c level among adults with T2DM [24]. As sleep research focuses on adolescents and adults, the EYAs in college with T1DM are a vulnerable population and understudied.

There is an emerging evidence demonstrating that decreased sleep in combination with increased caffeine intake to battle daytime sleepiness results in unhealthy food choices [10,25] and poor glucose control [26]. In the United States, 92% of college students self-reported that they consumed caffeinated beverages over the past year [27], which is above the national average for adults' caffeine usage [28]. Among adolescents, increased caffeine intake and late-night technology use resulted in altered sleep [29,30]. In Sweden, Mazzer and colleagues found a bi-directional relationship between self-reported technology use and a shortened sleep duration among high school students [31]. While college stu-dents may use technology to offset difficulty sleeping, stu-dents also consume caffeinated energy drinks to stay awake [32] and engage in less physical activity [30]. This may further complicate the management of T1DM as energy drink con-sumption leads to an increased carbohydrate load and requires adjustment of insulin regimen [33]. There is a research gap examining sleep, caffeine intake, and nighttime technology use simultaneously among EYAs with T1DM living on college campus.

The main purpose of this study was to examine the relation-ship between sleep behaviors (duration, napping, and social jetlag) and HbA1c among EYAs (18–25 years old) with T1DM, who are living on a college campus. We propose unhealthy sleep behaviors will be associated with an increase in HbA1c. We will also characterize the gender differences in glucose management, sleep behaviors, caffeine intake, and nighttime technology use among EYAs living on a college campus. Under-standing sleep behaviors (duration, napping, and social jetlag) and their relationship with glycemic control among EYAs with T1DM in college has the potential to inform the research, aca-demics, and clinical communities. Also, we may have the potential to develop interventions focused on improving mod-ifiable lifestyle factors to improve glycemic control.

## 2. Subjects, materials and methods

### 2.1. Participants and procedures

This cross-sectional study used convenience sampling and enrolled eligible participants through snowballing strategy, Facebook posts, and the College Diabetes Network (CDN) newsletter. Between February 2017 and April 2017, research-ers conducted an electronic survey about sociodemographic information, diabetes management, caffeine intake, night-time technology use, and sleep-related behaviors via Research Electronic Data Capture (REDCap) [34]. Participants who met the following criteria were enrolled: (a) 18–25 years old; (b) T1DM diagnosis at least 1 year; (c) currently living on a college/university campus; (d) enrolled in college courses; (e) internet access. Once eligibility was determined and informed consent was signed, researchers sent participants the survey link via REDCap. Participants received a remuner-ation of a $10 electronic gift card after completing the sur-vey. We obtained the Institutional Review Board (IRB) approval from our University before study initiation.

### 2.2. Measures

Participants self-reported their last HbA1c level from their healthcare provider's office to indicate the extent of diabetes management. According to the American Diabetes Associa-

tion, undesirable glycemic control for the EYA age group is defined as HbA1c level 7% [35].

**2.2.1. Adolescent Sleep, Caffeine Intake, and Technology Use—**Participants completed the Adolescent Sleep, Caffeine Intake, and Technology Use (ASCT) questionnaire. The ASCT is a 36item, 3concept instrument that takes approximately 10– 15 min to complete and assesses caffeine intake, nighttime media-related technology use, and sleep behaviors [36]. Orig-inal content and face validity were established by using 5 sleep experts to judge the relevancy of each item to the intent of the questionnaire [29]. The ACST was originally designed for adolescents, thus the primary author, with permission, modified the ACST for EYAs. The sleep behaviors include weekday and weekend sleep schedules (bedtime and wake time), sleep duration, napping on weekdays and weekends, and the number of nights having difficult to fall asleep per week. For the technology concept, participants were asked the report the average amount of time they use technological devices (I-pad, TV, computer, etc.) after 9 pm. For caffeine intake, the ACST instrument included pictures of various sizes of caffeinated beverages including tea, coffee, sodas, and energy drinks, candy and bars.

Napping behavior was recoded into a dummy variable rep-resenting nappers who took at least one nap on weekdays or weekends and non-nappers. Researchers calculated social jetlag from the absolute difference between the midpoint of habitual bedtime and wake-time on school nights and that on weekend nights [15]. Participants also self-reported their average daily caffeinated products that included the ounces consumed and the count each. From this data, researchers calculated daily total caffeine intake. Technology use was a self-report of the total in number of hours/minutes among all technology in an average day after 9 pm. This was then transformed into a technology index and a higher index indi-cates more technology use. Detailed procedures for caffeine calculation and technology index have been described else-where [29].

**2.2.2. Covariates—**Participants self-reported sociodemographic information such as age, gender and race/ethnicity. We also considered the method of insulin administration (injection or pump), the number of years with diagnosed T1DM as covariates in this study.

## 2.3. Statistical analyses

Descriptive statistics were used to characterize glucose man-agement, sleep behaviors, caffeine intake, and nighttime technology, and all covariates. At the bivariate level, gender differences in age, years with T1DM, sleep duration (weekday and weekend), social jetlag, caffeine intake, and nighttime technology use index and were compared using t-tests. Chi-squared tests were performed to compare race/ethnicity, insulin administration, and napping behavior between gen-der groups. Pearson or Spearman correlation coefficients were used to evaluate associations between sleep variables and HbA1c. Multiple linear regression was used to estimate the predictive effects of sleep behaviors on HbA1c adjusting for age, gender, race, nighttime technology use, caffeine intake, insulin administration and years with T1DM. Sleep variables entered the regression model simultaneously because collinearity

was not problematic (all VIF < 1.49). All analyses were conducted using STATA 14.0 using a = 0.05.

## 3. Results

### 3.1. Sample characteristics and gender differences

Of the 84 respondents who completed the study, 8 were excluded because of reporting a HbA1c level more than six months before completing the survey. The final data set was comprised of 76 EYAs; 24.32% of the participants were women (n = 18). Mean participant age was 20.41 ± 1.64 years. Partici-pants were diagnosed with T1DM for 10.25 ± 5.70 years on average, with a majority using an insulin pump (n = 69, 90.79%)). In terms of sleep behaviors, participants slept 7.82 ± 1.30 h per night on weekdays and 8.36 ± 1.21 h on weekends. A total of 49 (64.47%) respondents self-reported napping at least once on either weekdays or weekends. Most of the par-ticipants had a later sleep phase during weekends, and the absolute difference in midpoints of nighttime sleep between weekdays and weekends was 1.62 ± 0.87 h.

Table 1 presents sample characteristics by gender. There were significant overall differences ($p < 0.01$) between women and men with respect to age, insulin administration and HbA1C values ($t = 8.03$, $p = 0.01$). Specifically, men were signif-icantly older ($t = 4.60$, $p = 0.03$) and reported lower HbA1C than females in our sample, and the prevalence of insulin pump usage was higher among women ($v^2(1) = 7.37$, $p = 0.01$).

### 3.2. Sleep behaviors, caffeine intake, and nighttime technology use and HbA1c associations

Table 2 presents the pairwise correlations among sleep dura-tion, social jetlag, napping, and HbA1c. While sleep duration on weekdays showed a moderate positive correction with sleep duration on weekends ($r = 0.33$, $p = 0.003$), napping behavior was significantly correlated with social jetlag($r = 2.28$, $p = 0.01$) and technology use index ($r = 0.23$, $p = 0.04$). Other pairwise correlations among sleep behaviors were not significant. In terms of HbA1c values, there was a negative correlation with sleep duration on weekdays ($r = 0.24$, $p = 0.03$) and a positive correlation with napping on either weekdays or weekends ($r = 0.31$, $p = 0.003$).

As shown in the adjusted model (Table 3), the relationship of sleep duration on weekdays and napping behaviors with HbA1c values remain significant after controlling for covari-ates. Specifically, there was a trend towards increasing HbA1c with decreasing sleep duration on weekdays ($b = 0.25$, $p = 0.04$). Compared with non-nappers, participants who self-reported napping behaviors also had higher HbA1c val-ues ($b = 0.74$, $p = 0.03$). In contrast, weekend sleep duration and social jetlag was not a significant predictor of HbA1c. Daily caffeine intake and nighttime technology use were not significantly associated with HbA1c.

## 4. Discussion/conclusion

This study examined the relationships between sleep behav-iors (duration, napping, and social jetlag) and, caffeine intake, and nighttime technology use among EYAs with T1DM in

col-lege and its effect on HbA1c. In this sample of college stu-dents with T1DM, more females managed their diabetes using an insulin pump and had a statistically higher HbA1c level compared to their male counterparts. No statistically significant gender differences were found in sleep-related behaviors or nighttime technology use. However, college males had longer sleep duration (weekdays and weekends) and increased napping behaviors and social jetlag, but used less technology compared to college females. In this sample, we found that college students with T1DM self-reported lower HbA1c levels when they had longer weekday sleep duration. In addition, those who self-reported napping behaviors during the week or weekend had higher HbA1c levels compared to non-nappers. After controlling for demographic variables and factors altering sleep behaviors such a caffeine and nighttime technology use, we found that EYAs who self-reported a longer sleep duration on weekdays had lower HbA1c levels. Although this study focused on a unique popu-lation of EYAs living on college campus, other studies found similar results in the adolescent and adult population with T1DM with suboptimal glucose control and increased HbA1c with decreased sleep duration [6,37].

Alterations in sleep patterns may change during their col-lege campus living due to erratic schedules and new found independence [3,4,38]. According to the Centers for Disease Control and Prevention (CDC), in the Unites States, 32% of EYA's (18–24 years old) sleep less than 7 h per night and among all adults there is a higher prevalence of shorter sleep duration among non-Caucasians [39]. Our study revealed that college males had a longer weekend sleep duration compared to females. In contrast to our findings, researchers found no gender differences among adolescents and young adults (13–20 years old) with T1DM [10]. Compared to the CDC national data, participants in this study had a longer sleep duration. Furthermore, our sample's average HbA1c (7.43 ± 1.30; 58) was only slightly above recommended American Diabetes Association 2018 guidelines [35], but lower than other HbA1c levels reported in the literature (8.4 ± 1.7; 69) [2]. These findings are likely due to the sampling design method of recruitment via the CDN. The College Diabetes Network is a non-profit organization that focuses on provid-ing college students with peer support with local chapters on campus. Previous research has shown that CDN members may be more involved in their own diabetes management, particularly if they have a peer-led CDN chapter on their respective college campus [38].

Sleep research is growing as some studies have found that sleep behaviors impact one's physical and mental health. Sleep disturbance rates are much higher among those with T1DM, compared to those without T1DM [40]. Unhealthy sleep behaviors among individuals with T1DM are associated with insulin resistance [8,9], insulin sensitivity [7], and undesired glycemic control [6,17]. Specifically, decreased sleep duration among the adolescent and adult population with T1DM was associated with suboptimal glucose control and increased HbA1c [6,37]. Our results are consistent among EYAs with T1DM in college who self-reported a longer sleep duration on weekdays had lower HbA1c levels. While prior research illustrates conflicting results of sleep behaviors and gender differences [10,14,41,42]. A study of college students in medi-cal school found males to have a poor sleep and use smart-phone apps more than females [41]. Results from the National Longitudinal Study of Adolescent to Adult Health (Add Health) indicated that longer sleep duration had higher levels of C-reactive protein in males [42]. Our results found no

statistical gender differences among college students with T1DM, however, males self-reported longer sleep duration (weekdays and weekends) and increased napping and social jetlag. Also, social jetlag was associated with an increase in HbA1c among adults with T1DM [43] and T2DM [24]. On the other hand, our results found no relationship between HbA1c levels and weekend sleep duration and social jetlag among college students with T1DM. The discrepancies between our finding and previous studies [24,43] could be due to our small sample size and lack of statistical power. Thus, more research with a larger sample size is warranted.

Napping has been considered as a compensation for night-time sleep deficiencies or a risk factor for poor nocturnal sleep [18,44]. Our findings consistently suggested that nap-ping behavior was associated with a decreasing amount of weekday and weekend sleep at night, although the correla-tions showed a lack of statistical significance. While prior research generally indicated the neurocognitive benefits of napping behaviors [45], napping may exert a negative impact on metabolic health [5]. We found that college students with T1DM who reported napping on weekday/weekend had sig-nificantly higher HbA1c values. Evidence is sparse regarding napping and glycemic control among individuals with T1DM. However, our findings are in line with recent meta-analyses that showed an increased risk for prevalent and/or incident T2DM or metabolic syndrome among daytime nap-pers compared with non-nappers [21,22]. The mechanism underlying the relationship between napping and glucose metabolism is not well understood. Napping may lead to dis-rupted circadian rhythms, thus altering glucose tolerance and reducing insulin secretion [19]. Daytime napping has also been linked to elevated evening cortisol levels [46], which may further result in insulin resistance [20]. Our findings rep-resent the initial step to understanding the role of napping, independent of nighttime sleep duration, in glycemic control among EYAs with T1DM.

In a longitudinal national study, young adults (19–30 years old) had an average caffeine intake of 122.1 mg/day with the highest 90th percentile having a 285.9 mg/day intake [28]. Our results were similar to the highest 90th percentile of young adult, college students with T1DM who consumed a caffeine average of 265 mg/day. In our sample, we did not find a relationship between HbA1c levels and caffeine intake. The research is inconsistent in the relationship between HbA1c levels and caffeine consumption. Dewar and Heuberger con-ducted a meta-analysis including those with T1DM and T2DM and found 5 of the 7 studies suggested that caffeine increases glucose levels among adults, however 2 other stud-ies found no difference in glucose levels [47]. Students who consume caffeine to stay awake have been found to have an increase in nighttime technology use, leading to further sleep deprivation [31]. College students who with a shorter sleep duration less than 6 h were found to have increased technol-ogy use as compared to students with a longer sleep duration greater than 9 h [30] and smartphone addiction was also asso-ciated with poor sleep quality, anxiety, and depression [41]. Similarly, our study found that college students with T1DM who napped more had an increase use of nighttime technology.

Using an electronic survey was economical and fostered national representation. Predominately Caucasian males with T1DM in college completed the study survey. Self-reported HbA1c levels may be associated with recall bias or response bias. This study used a

cross-sectional design with a small sample, so we cannot make causal inferences. Furthermore, the CDN assisted with enrolling participants, which may account for a slightly lower HbA1c than usually found among this age group. Thus, caution when generalizing results to all EYAs with T1DM in college. We did not assess if the partici-pant has other sleep conditions such as obstructive sleep apnea or take medications that may impact sleep behaviors. As with all anonymous survey data collection, the participant is an unidentified and may not have the medical condition being studied such as T1DM.

### 4.1. Summary and recommendations

In summary, researchers found an inverse relationship between sleep duration and HbA1c among EYAs with T1DM in college. Napping on weekdays or weekends worsened HbA1c levels in this college sample. Compared to females, males with T1DM in college had a longer sleep duration. These results indicate that modifying sleep behaviors may improve glycemic control. Maintaining healthy sleep patterns may be difficult when living on a college campus, but impor-tant for diabetes management among those with T1DM. Healthcare providers should incorporate sleep behaviors and their impact on diabetes management at clinical visits and educational sessions. In addition, healthcare providers should understand that EYAs with T1DM in college are extre-mely vulnerable as they have the highest HbA1c levels and are managing their diabetes in the complexity of college living.

More sleep research is needed with exact measurements for sleep such as actigraphy in conjunction with other sleep surveys. Researchers should take into consideration the amount of support available at a university or college for EYAs with T1DM in college such as a peer-led university-based chapter of CDN. Research focusing on sleep interventions that would promote healthy sleep behaviors may improve diabetes management and further prevent the sequela related to poor glucose control.

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## REFERENCES

[1]. Miller KM, Foster NC, Beck RW, Bergensta RM, DuBose SN, DiMeglio LA, et al. Current state of type 1 diabetes treatment in the U.S.: updated data from the t1d exchange clinic registry. Diabetes Care 2015;38:971–8. 10.2337/dc15-0078. [PubMed: 25998289]

[2]. McCarthy MM, Grey M. Type 1 diabetes self-management from emerging adulthood through older adulthood. Diabetes Care 2018;41 1608 LP-1614. [PubMed: 29802144]

[3]. Dowdell EB, Clayton BQ. Interrupted sleep: college students sleeping with technology. J Am Coll Heal 2018:1–7. 10.1080/07448481.2018.1499655.

[4]. Saylor J, Calamaro C. Transitioning young adults with type 1 diabetes to campus life. J Nurse Pract 2016;12 10.1016/j.nurpra.2015.09.010.

[5]. Ji X, Li J, Liu J. The relationship between midday napping and neurocognitive function in early adolescents. Behav Sleep Med 2018;00:1–15. 10.1080/15402002.2018.1425868.

[6]. Reutrakul S, Thakkinstian A, Anothaisintawee T, Chontong S, Borel AL, Perfect MM, et al. Sleep characteristics in type 1 diabetes and associations with glycemic control: systematic review and meta-analysis. Sleep Med 2016:23:2.6–45. 10.1016/j.sleep.2016.03.019.

[7]. Feupe SF, Frias PF, Mednick SC, McDevitt EA, Heintzman ND. Nocturnal continuous glucose and sleep stage data in adults with type 1 diabetes in real-world conditions. J Diabetes Sci Technol 2013;7:1337–45. 10.1177/193229681300700525. [PubMed: 24124962]

[8]. Hazen RA, Fehr KK, Fidler A, Cousino MK, MacLeish SA, Gubitosi-Klug R. Sleep disruption in adolescents with Type 1 diabetes mellitus: relationships with adherence and diabetes control. Diabetes Manage 2015:5:257–65. 10.2217/dmt.15.18.

[9]. Chontong S, Saetung S, Reutrakul S. Higher sleep variability is associated with poorer glycaemic control in patients with type 1 diabetes. J Sleep Res 2016:25:438–44. 10.1111/jsr.12393. [PubMed: 26912272]

[10]. Jaser SS, Ellis D. Sleep in adolescents and young adults with type 1 diabetes: associations with diabetes management and glycemic control. Heal Psychol Behav Med 2016;4:49–55. 10.1080/21642850.2015.1135293.

[11]. Yamada T, Hara K, Shojima N, Yamauchi T, Kadowaki T. Daytime napping and the risk of cardiovascular disease and all-cause mortality: a prospective study and dose-response meta-analysis. Sleep 2015;38:1945–53. [PubMed: 26158892]

[12]. Watson N, Badr M, Belenky G, Al E. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. J Clin Sleep Med 2015;11:591–2. [PubMed: 25979105]

[13]. Hershner SD, Chervin RD. Causes and consequences of sleepiness among college students. Nat Sci Sleep 2014;6:73–84. 10.2147/NSS.S62907. [PubMed: 25018659]

[14]. Chasens ER, Morris JL, Strollo PJ, Sereika SM, Burke LE, Korytkowski M. Gender differences in the response to impaired sleep in adults with diabetes. Behav Sleep Med 2016;14:457–66. 10.1080/_15402002.2015.1017100. [PubMed: 26406786]

[15]. Wittmann M, Dinich J, Merrow M, Roenneberg T. Social jetlag: misalignment of biological and social time. Chronobiol Int 2006:23:497–509. 10.1080/07420520500545979. [PubMed: 16687322]

[16]. Turner SL, Queen TL, Butner J, Wiebe D, Berg CA. Variations in daily sleep quality and type 1 diabetes management in late adolescents. J Pediatr Psychol 2016:41:661–9. 10.1093/jpepsy/jsw010. [PubMed: 26994852]

[17]. Perfect MM, Patel PG, Scott RE, Wheeler MD, Patel C, Griffin K, et al. Sleep, glucose, and daytime functioning in youth with type 1 diabetes. Sleep 2012:35:81–8. 10.5665/sleep.1590. [PubMed: 22215921]

[18]. Jakubowski KP, Hall MH, Lee L, Matthews KA. Temporal relationships between napping and nocturnal sleep in healthy adolescents. Behav Sleep Med 2017:15:257–69. 10.1080/15402002.2015.1126595. [PubMed: 27078714]

[19]. Marcheva B, Ramsey KM, Buhr ED, Kobayashi Y, Su H, Ko CH, et al. Disruption of the clock components CLOCK and BMAL1 leads to hypoinsulinaemia and diabetes. Nature 2010:466:627–31. 10.1038/nature09253. [PubMed: 20562852]

[20]. Joseph JJ, Wang X, Spanakis E, Seeman T, Wand G, Needham B, et al. Diurnal salivary cortisol, glycemia and insulin resistance: the multi-ethnic study of atherosclerosis. Psychoneuroendocrinology 2015:62:327–35. 10.1016/j.psyneuen.2015.08.021. [PubMed: 26356041]

[21]. Yamada T, Shojima N, Yamauchi T, Kadowaki T. J-curve relation between daytime nap duration and type 2 diabetes or metabolic syndrome: a doseresponse meta-analysis. Sci Rep 2016:6 10.1038/srep38075. [PubMed: 28442741]

[22]. Chen GC, Liu MM, Chen LH, Xu JY, Hidayat K, Li FR, et al. Daytime napping and risk of type 2 diabetes: a meta-analysis of prospective studies. Sleep Breath 2018:22:815–24. 10.1007/s11325-017-1528-z. [PubMed: 28612266]

[23]. Larcher S, Gauchez A-S, Lablanche S, Pepin J-L, Benhamamou P-Y, Borel A-L. Impact of sleep behavior on glycemic control in type 1 diabetes: the role of social jetlag. Eur J Endocrinol 2016:175:411–9. 10.1530/EJE-16-0188. [PubMed: 27530460]

[24]. Reutrakul S, Hood MM, Crowley SJ, Morgan MK, Teodori M, Knutson KL, et al. Chronotype is independently associated with glycemic control in type 2 diabetes. Diabetes Care 2013:36:;2523:LP-2529. [PubMed: 23637357]

[25]. Westerlund L, Ray C, Roos E. Associations between sleeping habits and food consumption patterns among 1011-year-old children in Finland. Br J Nutr 2009:102:1531–7. 10.1017/S0007114509990730. [PubMed: 19664303]

[26]. Tran NL, Barraj LM, Bi X, Jack MM. Trends and patterns of caffeine consumption among US teenagers and young adults, NHANES 2003–2012. Food Chem Toxicol 2016;94:227–42. https://doi.org/10.10167j.fct.2016.06.007. [PubMed: 27288929]

[27]. Mahoney CR, Giles GE, Marriott BP, Judelson DA, Glickman EL, Geiselman PJ, et al. Intake of caffeine from all sources and reasons for use by college students. Clin Nutr 2018:1–8. 10.1016/jxlnu.2018.04.004.

[28]. Fulgoni VL, Keast DR, Lieberman HR. Trends in intake and sources of caffeine in the diets of US adults: 2001–2010. Am J Clin Nutr 2015;101:1081–7. 10.3945/ajcn.113.080077. [PubMed: 25832334]

[29]. Calamaro CJ, Mason TBA, Ratcliffe SJ. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. Pediatrics 2009;123 e1005 LP-e1010. [PubMed: 19482732]

[30]. Melton BF, Bigham LE, Bland HW, Bird M, Fairman C. Health-related behaviors and technology usage among college students. Am J Health Behav 2014;38:510–8. 10.5993/A.THB.38.4.4. [PubMed: 24636113]

[31]. Mazzer K, Bauducco S, Linton SJ, Boersma K. Longitudinal associations between time spent using technology and sleep duration among adolescents. J Adolesc 2018;66:112–9. 10.1016/J.AD0LESCENCE.2018.05.004. [PubMed: 29842997]

[32]. Cabezas-Bou E, De Leon-Arbucias J, Matos-Vergara N, A lvarez-Bagnarol Y, Ortega-Guzman J, Narvaez-Perez K, et al. A survey of energy drink consumption patterns among college students at a mostly Hispanic University. J Caffeine Res 2016;6:154–62. 10.1089/jcr.2016.0011. [PubMed: 28078169]

[33]. Olateju T, Begley J, Green DJ, Kerr D. Physiological and glycemic responses following acute ingestion of a popular functional drink in patients with type 1 diabetes. Can J Diabetes 2015;39:78–82. 10.1016/j.jcjd.2014.07.220. [PubMed: 25444682]

[34]. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) - a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42:377–81. [PubMed: 18929686]

[35]. Care D, Suppl SS. 4. Lifestyle management: standards of medical care in diabetes 2018. 2018;41:38–50. 10.2337/dc18-S004.

[36]. Calamaro CJ, Saylor J, Hanna KM. Health care experience of young adults diagnosed with type 1 diabetes. J Nurse Pract 2018 10.1016/j.nurpra.2018.02.002.

[37]. Borel A-L, Pepin J-L, Nasse L, Baguet J-P, Netter S, Benhamamou P-Y. Short sleep duration measured by wrist actimetry is associated with deteriorated glycemic control in type 1 diabetes. Diabetes Care 2013;36:2902–8. 10.2337/dc12-2038. [PubMed: 23715755]

[38]. Saylor J, Lee S, Ness M, Ambrosino J, Ike E, Ziegler ML, et al. Positive health benefits of peer support and connections for college students with type 1 diabetes. Diabetes Educ 2018;44:340–7. 10.1177/0145721718765947. [PubMed: 29949457]

[39]. Centers for Disease Control and Prevention. Short sleep duration among US adults; 2017 https://www.cdc.gov/sleep/datastatistics.html [accessed November 2, 2018].

[40]. Perez KM, Hamburger ER, Lyttle M, Williams R, Bergner E, Kahanda S, et al. Sleep in type 1 diabetes: implications for glycemic control and diabetes management. Curr Diab Rep 2018;18 10.1007/s11892-018-0974-8. [PubMed: 29497863]

[41]. Chen B, Liu F, Ding S, Ying X, Wang L, Wen Y. Gender differences in factors associated with smartphone addiction: a cross-sectional study among medical college students. BMC Psychiatry 2017;17:1–9. 10.1186/s12888-017-1503-z. [PubMed: 28049496]

[42]. Bakour C, Schwartz S, O'Rourke K, Wang W, Sappenfield W, Couluris M, et al. Sleep duration trajectories and systemic inflammation in young adults: results from the national longitudinal study of adolescent to adult health (add health). Sleep 2017;40:1–9. 10.1093/sleep/zsx156.

[43]. Rusu A, Ciobanu D, Bala C, Cerghizan A, Roman G. Social jetlag, sleep-related parameters, and glycemic control in adults with type 1 diabetes: results of a cross-sectional study. J Diabetes 2018 10.1111/1753-0407.12867.

[44]. Owens JF, Buysse DJ, Hall M, Ph D, Kamarck TW, Lee L, et al. Mid-life adults; n.d.

[45]. Lau EYY, Wong ML, Lau KNT, Hui FWY, Tseng CH. Rapid-eye-movement-sleep (REM) associated enhancement of working memory performance after a daytime nap. PLoS One 2015;10:1–16. 10.1371/journal.pone.0125752.

[46]. Woods DL, Kim H, Yefimova M. To nap or not to nap: excessive daytime napping is associated with elevated evening cortisol in nursing home residents with dementia. Biol Res Nurs 2013;15:185–90. 10.1177/1099800411420861. [PubMed: 21998447]

[47]. Dewar L, Heuberger R. The effect of acute caffeine intake on insulin sensitivity and glycemic control in people with diabetes. Diabetes Metab Syndr Clin Res Rev 2017;11:S631–5. 10.1016/j.dsx.2017.04.017.

**Table 1 –**

Sample characteristics of EYAs[a] with T1DM[b] in college by gender groups (n = 76).

| | Total | Women | Men | $v^2/t$[c] |
|---|---|---|---|---|
| Age | 20.41 ± 1.64 | 20.13 ± 1.49 | 21.00 ± 1.50 | 4.69 * |
| Race | | | | 1.76 |
| Non-white | 5 6.76%) | 0(0%) | 5(9.09%) | |
| White | 69(93.24%) | 18(100%) | 50(90.91%) | |
| Insulin administration | | | | 7.37 ** |
| Injection | 20(26.32%) | 10(17.86%) | 9(50.00%) | |
| Pump | 56(73.68%) | 46(82.14%) | 9(50.00%) | |
| Years of T1DM | 10.25 ± 5.70 | 10.41 ± 5.40 | 9.83 ± 6.40 | 0.14 |
| Sleep Duration: (hours) | | | | |
| Weekday | 7.82 ± 1.30 | 7.71 ± 1.11 | 8.00 ± 1.75 | 0.67 |
| Weekend | 8.36 ± 1.21 | 8.32 ± 1.11 | 8.39 ± 1.54 | 0.04 |
| Social Jetlag (hours) | 1.62 ± 0.87 | 1.66 ± 0.90 | 1.72 ± 0.75 | 0.07 |
| Napping | | | | 2.31 |
| Non-napper | 26(35.14%) | 9(50%) | 17(30.36%) | |
| Napper | 48(64.86%) | 9(50%) | 39(69.64%) | |
| Caffeine Intake (mg) | 265.28 ± 202.095 | 344.15 ± 259.87 | 238.49 ± 173.26 | 3.82 |
| Technology Use Index | 0.88 ± 0.48 | 0.93 ± 0.48 | 0.69 ± 0.45 | 3.65 |
| HbA1C (%; mmol/mol) | 7.43 ± 1.30; 58 | 7.68 ± 1.20; 60 | 6.74 ± 1.30; 50 | 8.03 ** |

Note. Data were provided as n (%) or mean ± standard deviation.

[a] EYAs: emerging young adults.

[b] T1DM: Type 1 diabetes mellitus.

[c] $v^2$ test was used for categorical variables and t-test was used for continuous variables.

* $p < 0.05$.

** $p < 0.01$.

**Table 2 –**

Correlation coefficients between HbA1c and sleep variables among EYAs[a] with T1DM[b] in college (n = 76).

| | HbA1c | Weekday sleep duration | Weekend sleep duration | Social jetlag | Nap | Caffeine intake |
|---|---|---|---|---|---|---|
| Weekday sleep duration | 0.24* | ** | | | | |
| Weekend sleep duration | 0.02 | 0.33 | | | | |
| Social jetlag[c] | 0.02** | 0.05 | 0.001 | | | |
| Nap | 0.31 | 0.21 | 0.12 | 0.28** | | |
| Caffeine intake | 0.04 | 0.04 | 0.15 | 0.001 | 0.19* | |
| Technology use index | 0.23 | 0.18 | 0.08 | 0.03 | 0.23 | 0.07 |

[a] EYAs: emerging young adults.

[b] T1DM: Type 1 diabetes mellitus.

[c] Data provided were Pearson correlation coefficients, except the correlation of napping with other variables (Spearman correlation)

* $p < 0.05$.

** $p < 0.01$.

**Table 3 –**

Adjusted linear regression model for Hemoglobin A1c among EYAs[a] with T1DM[b] in college (n = 70[c]).

| Variables | b (se) | P | 95% CI |
|---|---|---|---|
| Age *d* | 0.28 (0.11) | 0.02* | (0.50, 0.05) |
| Race*e* | 0.16 (0.59) | 0.79 | (1.02, 1.33) |
| Gender | 0.76 (0.37) | 0.047 | (0.01, 1.50) |
| Insulin Administration | 0.29 (0.36) | 0.42 | (1.01, 0.43) |
| Years of T1DM | 0.02 (0.03) | 0.61* | (0.04, 0.07) |
| Weekday sleep Duration | 0.25 (0.12) | 0.04 | (0.49, 0.01) |
| Weekend Sleep Duration | 0.14 (0.13) | 0.28 | (0.12, 0.41) |
| Social*f* Jetlag | 0.17 (0.18) | 0.35* | (0.52, 0.19) |
| Nap | 0.74 (0.33) | 0.03 | (0.09, 1.40) |
| Caffeine Intake | 0.001 (0.001) | 0.10 | (0.001, 0.003) |
| Technology Use Index | 0.001 (0.04) | 0.95 | (0.08, 0.08) |

[a] EYAs: emerging young adults.

[b] T1DM: Type 1 diabetes mellitus.

[c] Only participants with complete data on predictors and all covariates were included in the regression model.

[d] Race: the reference group is non-white.

[e] Gender: the reference group is female.

[f] Nap: the reference group is non-napper; se = standard deviation.

* $p < 0.05$.