An Examination of Sleep Pattern Characteristics and Healthy Eating Index Scores Among Students in a Circadian Biology Class

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Abstract

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Introduction

Sleep restriction and circadian misalignment are associated with increased risk of chronic disease, as is poor dietary quality. College students are at risk for developing restricted, irregular sleep and poor dietary habits. This study sought to determine whether sleep duration, social jetlag, and chronotype are associated with dietary quality in third- and fourth-year college students as measured by the Healthy Eating Index-2015 (HEI-2015).

Methods

67 student participants collected sleep data on themselves using both an actigraphy watch and sleep diary to measure sleep duration and social jetlag. The Morningness-Eveningness Questionnaire was used to determine chronotype and two dietary recalls administered through the Automated Self-Administered 24-hour dietary assessment tool were used to calculate HEI-2015 scores. Five participants were excluded due to missing data. Linear regression was used to

analyze the data from the remaining 62 participants to test for associations between sleep and circadian factors and HEI-2015 scores, adjusting for sex.

Results

Average sleep duration was 7.2 ± 0.9 hours on the weekdays and 8.0 ± 1.3 hours on weekend days, with an average social jetlag of 1.0 ± 1.0 hours. The average MEQ score was 46.7 ± 9.1 with the most common chronotype being neither morningness nor eveningness (MEQ score 42-58). Average HEI-2015 score was 54.1 ± 15.3 out of 100. No significant associations were detected between sleep and circadian factors and dietary quality, though chronotype neared significance for an association with HEI-2015 overall score ($p=0.11$).

Discussion and conclusion

Overall, sleep duration on weekdays and weekend days, social jetlag, and chronotype were not significantly associated with overall dietary quality as measured by the HEI-2015 in this study. Near-significant results suggest a potential positive association of MEQ score and dietary quality, but the impact of this relationship would be marginal and MEQ is intended to identify an individual's chronotype rather than measure morningness. Dietary quality was similar to other sampled college populations, but the use of circadian biology students as a sample population may have biased the study against detecting associations given the topic matter and potentially longer sleep duration observed in this sample compared to others. Future studies should use larger sample sizes and continue to investigate potential relationships given the inconclusive nature of the current body of literature.

Introduction

Nearly half of all Americans have at least one chronic disease, conditions that account for approximately 7 out of 10 deaths, 75% of healthcare expenditures, and over $1 trillion in economic losses each year.[1] A problem of such scale requires multiple strategies to develop solutions. Primary prevention of chronic disease seeks to reduce incidence of the various conditions. The Centers for Disease Control and Prevention (CDC) has summarized numerous factors that influence the risk of chronic disease, including modifiable lifestyle factors such as tobacco use, poor dietary quality, sedentary patterns of activity, excess alcohol consumption, and inadequate sleep.[2] By identifying relationships among modifiable lifestyle risk factors, interventions can be developed to target multiple risk factors at once as opposed to multiple interventions targeting only single individual modifiable risk factors one at a time. Attempts to evaluate the relationship between sleep and diet remains inconclusive, with mixed findings in the literature.[3–18] It is thus of interest to investigate this potential relationship in order to inform strategic development of future interventions targeting relationships among modifiable lifestyle risk factors in order to improve health outcomes.

Poor dietary quality has long been established as a contributor to increased risk for chronic diseases, with demonstrated associations with increased mortality from all causes, cardiovascular disease, and cancer. Improving dietary quality has been shown to reduce risk of major chronic diseases.[19–24] Studies have described sleep disruption and circadian misalignment as impacting everything from immune function[25] and insulin sensitivity[26–28] to DNA repair,[29] various cancers, and subsequent complications,[30–36] representing potential mechanisms for development of chronic disease. Night shift work, particularly among nurses, is one commonly studied source of misalignment that has been implicated in higher rates of chronic disease,[32,37–39] with supporting evidence for pathophysiology in underlying biology.[25,40–42,28,43]

Interventions can improve efficiency by targeting groups at risk for modifiable risk factors such as poor dietary quality and inadequate sleep. Interventions should also consider life stage, as those earlier in life provide an expanded window for impact as opposed to those occurring in later years. College students comprise a population that is both young (80% are 24 years old or younger)[44] and at risk of inadequate dietary and sleep habits. Given the contributions to chronic disease risk by these modifiable lifestyle risk factors, their existing patterns among undergraduate college students is concerning. According to the American College Health Association's National College Health Assessment Spring 2018 report,[44] approximately 43% of college students report getting enough sleep to feel rested the next morning two or fewer days out of each week. Less than 30% of students get at least 8 hours of sleep and 35% report staying up until 3 am at least once per week.[45] In addition to the poor sleep hygiene noted among many college students, dietary habits of this population are suboptimal. Less than 5% of all college students consume the recommended 5 servings of fruits and vegetables per day, with 70% of college students consuming 2 or fewer servings of fruits and vegetables.[44] Cheap convenience foods are typically highly processed, high energy, low nutrient items, and convenience and price frequently influence the dietary choices of college students.[46] Further, food insecurity is a major issue for many college students, affecting an estimated 40% of students in some way,[47] and such insecurity introduces barriers to achieving dietary adequacy and reduces the ability to engage in healthful dietary practices.[48] Understanding how sleep and circadian factors are associated with dietary quality in college students could inform interventions to improve lifestyle factors and health for the incoming generation of workplace professionals, reducing healthcare costs and contributing to efforts to prevent development of chronic disease.

This study sought to test the hypothesis that shorter sleep duration, higher social jetlag, and evening chronotype would be associated with lower dietary quality by determining how these sleep and circadian factors are related to dietary quality as measured by the Healthy Eating Index-2015 (HEI-2015) in a population of college undergraduate students. Prior studies that have examined sleep and circadian measures in relation to dietary quality have used previous and alternative iterations of the HEI[3–8] or different measures entirely.[9,37,10,49,50,11,51,12–14] This study would be, to our knowledge, the first of its kind to examine potential relationships of sleep duration, social jetlag, and chronotype with dietary quality as measured by the updated HEI-2015 in college undergraduates.

Literature Review

Sleep and circadian variables

Circadian rhythms are 24-hour oscillating patterns of biological processes that are endogenously generated and influenced by environmental entrainment. The sleep-wake cycle is one such example. An individual's sleep duration is influenced by both genetic and external factors as well as an individualized propensity for timing of the occurrence of a sleep event that may or may not align with external cues, such as the period of daylight, routines, social activities, artificial light, alarms, and other stimuli.[52] This propensity, or chronotype, is often described as a spectrum of morningness to eveningness and is variably age-dependent throughout the lifecycle.[53] The current gold standard for assessing chronotype is the Horne-Östberg Morningness-Eveningness Questionnaire (MEQ)[54] and the tool is well-suited for assessing college student populations, as it was developed in this manner.[55] While the observed expression of one's chronotype may be due to social factors,[56] it can provide context about whether an individual's daily schedule, responsibilities, and subsequent sleep pattern to accommodate these is aligned with inherent preferences for their sleep-wake cycle. Social jetlag occurs when an individual's committed obligations and responsibilities of a workday (weekday) are not aligned with the inherent free-living sleep pattern preferences on a free (weekend) day.[57] Measured as the difference in the midpoints of sleep events that occur on a weekday day relative to those occurring on a weekend day, social jetlag impacts the way the body interacts with societally-defined time in a way that mimics the jetlag incurred travelling across time zones.[52] While the misalignment resulting from actual jetlag is temporary, that produced by such weekly circadian misalignment approximates chronic~~, low-level~~ shift work.[52]

Assessing dietary quality

The Healthy Eating Index (HEI) is a measure of diet quality, assessing alignment of dietary intake with federal dietary guidelines.[58] The Dietary Guidelines for Americans (DGA) are produced by the U.S. Department of Agriculture (USDA) and updated every five years, with the most current iteration being the DGA 2015-2020. The HEI is subsequently updated to permit assessment of dietary intake through the lens of the most recent guidelines. The most recent version is the HEI-2015, comprised of 13 categories of dietary intake which each receive a score (0-5 or 0-10, depending on category) based on alignment with DGA recommendations. The category subscores are summed to produce the overall HEI-2015 score, with a maximum possible score of 100 indicating excellent alignment of dietary intake with guidelines. All but three component categories standardize the intake of a food group or nutrient per 1000 calories. Two subscores are based on percentage of total calorie intake (that from saturated fat and from added sugars) while the final category score (fatty acids) is based on a ratio of total unsaturated fatty acid intake to saturated fatty acid intake.

Sleep and circadian variables and dietary quality

Research on the relationship between sleep and dietary quality in college students is minimal. One similar investigation by Highaghatdoost and colleagues in Iranian female medical students age 18-28 years measured dietary quality by several indices (including a previous iteration of the HEI, the original method developed by Kennedy and colleagues in 1995[58]) and found a positive relationship between sleep duration and dietary quality.[4] Participants that reported sleeping more than 8 hours per night scored higher on indices of dietary quality and variety compared to those who reported fewer than 6 hours nightly, with higher consumption of fruits, whole grains, and legumes among long sleepers. Long sleep (defined as greater than 8 hours) was also associated with lower calorie intake, lower likelihoods of overweight, obesity, and abdominal adiposity, and lower values for BMI, waist circumference, and diastolic blood pressure compared to the short level of sleep (defined as less than 6 hours). In a study examining weight gain during the first semester of college,[12] Ludy and colleagues demonstrated that students who maintained weight over the course of the semester also displayed significantly increased duration of sleep (by 18 minutes) and improved dietary quality scores across the same time period. Those who gained the most weight (approximately +4 kg) exhibited significantly reduced sleep duration (by 24 minutes) and marginally improved dietary scores. Interestingly, “modest gainers” (approximately +2 kg weight gain over the course of the semester) showed improved dietary scores but no change in sleep duration. There were no differences across groups for either sleep duration or dietary quality at baseline. This suggests a potential protective association of longer sleep against weight gain in the initial college living environment and that the effect could potentially be mediated by dietary quality. In a study of first-year Indian medical school students,[59] Gangwar and colleagues concluded that low vegetable intake was associated with poor sleep quality among definite evening and intermediate chronotypes (assessed by MEQ), though this was determined by asking participants if they followed a vegetarian or non-vegetarian dietary pattern and did not assess dietary intake. Other modifiable lifestyle factors, including tobacco and alcohol use, were also noted to have associations with evening chronotype.

The broader literature examining associations between sleep duration and dietary quality is not strongly conclusive, potentially due to heterogeneity of study designs and methodology. Children and adolescents are frequently studied populations for such inquiries,[60–66] and it should be noted that these populations differ significantly from adults. Sleep requirements are higher in children and adolescents than adults[67] and average chronotype shifts from morningness in children to eveningness in adolescents before gradually shifting towards morningness once more in later years.[53] Some studies have found no impact of sleep duration on dietary quality[5,9,15] or mixed associations,[11,13] while others have linked longer or optimal sleep event durations to higher dietary quality.[10,13,14,16] However, both inadequate and excessive sleep could be associated with poorer quality dietary patterns.[8,17] Stern, et al found sleep durations of ≤6 hours and ≥8 hours both had lower dietary quality than the reference group of 7 hours[7] while other studies suggest that the lowest and highest tertiles levels of sleep are related to increased dietary quality.[11,13,63]

The literature exploring associations between chronotype or social jetlag and dietary quality is sparse. In animal models, social jetlag and a diet approximating low quality cafeteria fare each separately resulted in murine metabolic disturbances without weight gain, but when combined the conditions resulted in overconsumption of the cafeteria diet, weight gain, and promotion of criteria for metabolic syndrome.[68] In a study of outpatients with obesity-related chronic diseases, social jetlag of greater than one hour was associated with higher intakes of calories, protein, total and saturated fat, and cholesterol, as well as meats, eggs, and sweets compared to those with social jetlag of less than one hour.[18] In pregnant women in the first gestational trimester, morningness was associated with higher scores for total grains, but lower scores for total fruit.[3]

Materials and Methods

A cross-sectional study design was used to test the hypothesis that college students who slept less, had greater social jetlag, and had lower MEQ scores (evening chronotype) would have lower HEI-2015 scores. Participants were 67 third- and fourth-year undergraduate students enrolled in a 400-level Biology of Circadian Rhythms class at the University of Washington during spring 2018 (approximate dates of data collection were April 9th through May 7th). Data were collected in two-week waves (roughly half the students per wave) due to limited equipment availability. Students collected data on themselves for a class laboratory exercise and performed basic analyses with subsequent group discussions. At the conclusion of the quarter, participants were provided the opportunity to volunteer their data for research use. The instructor was dismissed from the end of the lab exercise class session and the teaching assistant discussed data sign over and obtained written informed consent from those agreeing to provide their data. Participants were explicitly informed that their consent would have no effect on their grades and that they could revoke consent at any time. All 67 participants volunteered their sleep lab data for research purposes. Use of data from consenting students received IRB approval from the University of Washington Institutional Review Office.

Sleep lab data collection and initial processing

Sleep data collection and cleaning procedures have been previously described.[69] Briefly, data collection occurred during the spring quarter of 2018, several weeks after the daylight savings time switchover, eliminating the potential confounding effects of the change on sleep events. Participants were provided with activity monitors (Actiwatch Spectrum Plus) to be worn on the non-dominant wrist that collected data in 15-second epochs. A button on the watch was pressed whenever participants went to sleep and awoke, marking the sleep event to later assist in interpretation of actograms. Sleep intervals and actograms were generated using Phillips Actiware v6. During the 2-week period, participants also accessed a diary through an online portal each day in which they logged details about the previous night's sleep and events of the previous day, including information about the sleep event, removal of the watch, and free text notes. The diary and watch sources of data were compared and clearly incorrect actograms (e.g. a software call for sleep onset resulting in a sleep event defined as occurring during an activity bout) and sleep event differences greater than one hour were adjusted, with the watch being considered the more accurate source of data unless the sleep diary and watch button event marker were in agreement. Sleep data returned include average sleep duration for a school or workday (henceforth referred to as a weekday) and a free day (henceforth referred to as a weekend day), average time for sleep onset and offset for weekdays and weekend days, average midpoint of the sleep event for each, and social jetlag as the difference between the two midpoints. Sleep efficiency (the percentage of time in bed spent sleeping rather than lying awake) was also calculated from the actigraphy data collected, but the process of data cleaning adjusted the sleep onset or offset times for some sleep events. While average values for sleep onset, offset, duration, and midpoints were subsequently updated, efficiency was not, precluding its use as a variable.

Chronotype, daytime sleepiness, and mood were also assessed via questionnaires that were accessed through the same portal as the sleep diary. These questionnaires were completed a single time and included the Morningness-Eveningness Questionnaire[55] (MEQ) and the Munich Chronotype Questionnaire[70] (MCTQ) for assessing chronotype, the Epworth Sleepiness Scale (ESS) for daytime sleepiness,[71] and the Beck Depression Inventory II (BDI-II) for mood.[72] Participants scoring higher than 20 (minimum threshold for moderate depression) on the BDI-II were privately contacted by the instructor via email to be reminded about access to mental health services. See Table 1 for a summary of data collected and tools used and Figure 1 for a summary of the 2-week lab exercise data collection process.

Recall collection methods and HEI score generation

Participants were asked to complete two 24-hour dietary recalls (one per week) collected on different weekdays approximately one week apart (for example, a Wednesday one week and a Thursday the following week). Recalls were administered using the National Institutes of Health (NIH) Automated Self-Administered 24-Hour Recall tool (ASA24; 2016 version). Participants were provided instruction on how to navigate and use the recall system at the same time they received their actigraphy watches and instructions for use. Output data included estimated daily intake of calories, macronutrients, micronutrients, and food groups. Data from the two recalls were averaged for each participant. When a participant completed only one of the two recalls (n = 8), the single recall was taken to represent that participant's weekday intake. HEI-2015 scores were calculated according to the US Department of Agriculture Food and Nutrition Service criteria using each participant's average recall data.[73] Component subscores for each of the 13 HEI-2015 scoring categories were calculated by generating a linear equation for each category such that the minimum and maximum scored levels of intake resulted in the respective minimum or maximum score with the aid of an online graphing calculator (Desmos). Generated component subscores were adjusted to meet the minimum or maximum score allowed and adjusted scores were summed to produce an HEI-2015 score for each participant.

Analysis – Normality and simple comparisons

Data analysis was performed using STATA/IC 16.0 and RStudio in collaboration with University of Washington Statistical Consulting Services. Following exclusion of participants with missing data (*n*=5) the sleep and circadian factors investigated were examined for multicollinearity.

Variance inflation factor (VIF) of all sleep and circadian factors was <5 (maximum VIF = 1.55), indicating multicollinearity among independent variables was not a concern. Sleep, circadian, and dietary quality variables were grouped by sex and assessed for normality using Shapiro-Wilk tests with significance set at p=0.05. Group differences by sex for normally distributed variables were assessed using Student's t test (two-tailed, significance at p=0.05). The group differences between other variables were assessed using Mann-Whitney U tests of median values (two-tailed, significance at p=0.05).

Analysis – Relationships among variables

Linear regression using each sleep or circadian factor as a predictor of HEI-2015 was first performed to produce crude models, which were then adjusted for sex. Log transformation of predictive variables lacking a normal distribution were attempted, but this did not improve normality of the distributions and so the analysis was performed with these variables in their natural state. Additional adjustments for age, race, and ethnicity were not made due to the small sample size. The small sample size also precluded further categorization of variables and subgroup analysis, such as short, normal, and long duration sleepers, tertiles of social jetlag, or chronotype category according to MEQ score.

Results

67 participants signed informed consent forms and volunteered their data for research use following the conclusion of the laboratory and class. 5 participants were missing sleep or sex data and were excluded from the analysis. Tests for normality of characteristics by sex indicated

non-normal distributions for social jetlag (p = 0.040 females; p = 0.042 males), age (p < 0.001 females; p = 0.048 males), BDI-II score (p = 0.017 females; p = 0.009 males), and chronotype for females (p = 0.0.048). Mann-Whitney U tests of these variables showed a significant difference between sex groups for age only (U = 612.5, p = 0.009). Student's t tests of the other normally distributed variables indicated a significant difference between groups for weekend sleep duration only (t(60) = 3.446, p = 0.001). Summaries of tests for normality and simple comparisons can be found in the supplementary tables in Appendix A.

The age of participants ranged from 17 to 27 years old (average age 21.4 ± 1.7 years); two participants (3.2%) did not report age. Participants were 54.8% female (n = 34) and 54.8% white or Caucasian (n = 34), 21.0% Asian or Asian Indian (n = 13), and 6.5% Hispanic (n = 4). 17.7% of participants (n = 11) did not report race or ethnicity. Average weekday sleep duration was 7.2 ± 0.9 hours, with 19.4% of participants (n = 12) getting an average of at least 8 hours of sleep on weekdays. Average weekend day sleep duration was 8.0 ± 1.3 hours and 43.5% of participants (n = 27) were able to get an average of 8 or more hours of sleep on weekends. The average social jetlag in this sample was 1.0 ± 1.0 hours of delayed sleep midpoint on the weekends and the average MEQ score was 46.7 ± 9.1. 35 participants (56.5%) scored as neither MEQ type, while 18 participants (29.0%) scored as at least moderate eveningness and 9 participants (14.5%) scored as moderate morningness. All but three participants reported normal or mild daytime sleepiness (ESS score 0-14; n = 59; 95.1%) with an average score of 7.3 ± 6.4. The average BDI-II score was 10.3 ± 8.4, with 85.4% of participants scoring for either minimal (BDI-II score 0-13) or mild (BDI-II score 14-19) depression. One participant did not complete either the ESS or BDI-II. 88.1% of participants (*n* = 59) completed both ASA24 recalls, while 11.9% (*n* = 8) completed a single recall. Average HEI-2015 score (out of a possible 100) was 54.1 ± 15.3. A summary of participant characteristics can be found in Table 2.

No significant associations between sleep and circadian variables and dietary quality were detected, though a positive relationship between MEQ score and HEI-2015 did emerge ($\beta = 0.34$, $p = 0.011$). Adjusting for sex slightly impacted the regression coefficient but not the level of significance (from $\beta = 0.35$, $p = 0.011$). See Table 3 for crude and adjusted linear regression results for all tested variables.

Discussion

This study investigated the association of the above sleep and circadian variables with HEI-2015 scores in undergraduate college students enrolled in a circadian biology class. Other studies examining prospective relationships between sleep duration, social jetlag, or chronotype and dietary quality have utilized earlier or alternative iterations of the HEI[3–8] or entirely differed metrics altogether.[9–11,13,14,37,49–51,66] To our knowledge, this is the first study of its kind to utilize the most up-to-date version of the HEI corresponding to the 2015-2020 DGA. The findings of this study did not confirm the hypothesis that shorter sleep duration, higher social jetlag, and evening chronotype would be associated with lower HEI-2015 scores. No sleep or circadian factors assessed were significantly associated with dietary quality, contradicting the findings of Highaghatdoost and Judy but confirming similar findings of studies in non-college populations.[5,15] However, one of these studies utilizing self-reported sleep duration[5] was followed up by the lead author. Using actigraphy measures of sleep in the follow up study, a positive association of sleep duration and dietary quality was observed, though the impact was quite small (a 0.30-point increase in HEI-2010 score per standard deviation, or 1.05-hour, increase in sleep duration, p = 0.02).[6] Though chronotype was the independent variable rather than sleep duration, a similarly marginal association was observed in our study, suggesting that sleep and circadian factors may have weak relationships with dietary quality. The positive relationship between scores for MEQ and HEI-2015 approached significance and was suggestive of a very slight increase (approximately a third of a point on a 100-point scale) in overall dietary quality score for every unit of MEQ score increase. In addition to the rather insubstantial impact of this potential relationship, the characteristics of the relationship should be interpreted with caution, as dietary quality was analyzed by MEQ score as a continuous variable rather than by chronotype category. On the MEQ scale, a score of 42-58 is categorized as neither morning nor evening type and thus while a unit of MEQ score increase is a unit closer to morningness, it should not be interpreted as indicating "higher morningness." Such considerations prevent comparison with the findings of Gangwar, et al, which were not based on a robust assessment of dietary quality in the first place.

Overall, this sample had lower average HEI scores than the national average for adults 18-64 years old (HEI-2015 54.1 ± 15.3 compared to 58.3, no reported SD,[74] respectively). The results herein (average HEI-2015 scores 52.8 ± 16.3 for females; 55.6 ± 14.1 for males) are more similar to studies of college students specifically (average HEI-2010 scores 56.1 ± 16.1 for females, 53.2 ± 15.0 for males).[75]

The National Sleep Foundation (NSF) updated recommendations for age-specific appropriate sleep durations in 2015, recommending 7-9 hours of sleep per night for younger adults age 18-25.[67] By average sleep duration, 53.2% of participants (n = 33) in this study achieved recommendations on weekdays, increasing to 66.1% of participants (n = 41) on weekend days. This sample also appeared to have better sleep patterns than that assessed by Lund and colleagues, who reported figures for overall sleep duration only rather than by weekday and weekend.[45] Lund, et al found only 29.4% of total participants to achieve 8 or more hours of sleep on average, which is slightly more than this study's weighted average of 26.3% (19.4% of participants, n = 12 on weekdays; 43.5% of participants, n = 27 on weekend days). The Lund study found that 25% of participants got less than 6.5 hours of overall sleep, which is similar to the present values for average length of sleep on weekdays (25.8%; n = 16), but not weekend days (9.7%; n = 6), in this sample (overall 21.2% weighted average). However, the overall average in Lund and colleague's study was 7.0 ± 1.2 hours compared to the weekday average of 7.2 ± 1.0 hours and weekend day average of 8.0 ± 1.3 hours (weighted average 7.4 hours).

It has not been determined whether or not these observed differences between study samples are meaningful, but they speak to a potential issue with the design of the present study. Dietary quality scores of the sample in this study appear to be similar to those of other college students, yet adequate sleep duration was achieved by a majority of the present sample across all days, and average sleep duration was longer on average than that assessed in a large cohort by Lund and colleagues. Considering that this small sample was comprised entirely of students in a circadian biology class, participants may have prioritized improved sleep habits more than peers studying other subjects. Use of this sample may have biased against the detection of a relationship between sleep duration or social jetlag and dietary quality.

This study has several strengths, namely tools utilized to collect data, including wrist actigraphy for sleep, MEQ for chronotype, and HEI-2015 for dietary quality. The two-week window for data collection permits a broad sampling of sleep events, and two dietary recalls provide more information than a single recall. However, this study also has multiple limitations that should be given consideration. College undergraduates are not generalizable to the general population. Further, given that this sample is comprised entirely of students enrolled in a 400-level course on circadian biology in which relationships between sleep, circadian alignment, and health were discussed, there is the possibility that this particular sample of undergraduate students is non-generalizable to undergraduate students overall as students may be influenced to conscientiously alter or monitor their sleep patterns based on information received in class. Since data collection occurs as part of a required student lab exercise, no participants are excluded for potential confounding factors, nor are data on such factors collected. Such factors may include but are not limited to type of work,[76] sleep disorders,[77] measurements of screen time and late-night blue light exposure,[78] use of prescription medications, recreational substances, or both that may interfere with sleep events,[79] and exertion level of exercise.[80] The small sample size of this study prevented categorization of independent variables, and sex was the only demographic variable adjusted for. The data cleaning process that corrected for misinterpretations by the actigraphy software did not subsequently correct the efficiency of the sleep event and prevented the use of this as an additional independent variable. The lack of a normal distribution for some predictive variables may have violated the assumptions of the regression modeling. The ASA24 has several inherent limitations with its use as a dietary recall instrument for both participants and researchers. Multiple aspects of the ASA24-2016 make it challenging to use, particularly the search function when attempting to locate food items or build a recipe. The database of foods heavily favors Western dietary items, which may make it challenging for students with non-Western dietary inclinations to accurately describe their intake. The use of two separate weekday recalls approximating dietary intake excludes dietary choices and behaviors on weekends, preventing specific comparison of weekday and weekend associations among sleep variables and dietary quality.

Conclusion

In this sample of 62 third- and fourth-year undergraduate college students, sleep duration on weekdays and weekend days, social jetlag, and chronotype were not significantly associated with dietary quality. A near significant association of chronotype and dietary quality was observed but given that the MEQ does not measure morningness and that the impact of the association would be quite marginal, further research should utilize larger sample sizes to evaluate this potential relationship according to chronotype category. With the lack of consistency and the heterogenous nature of investigations into sleep and dietary associations in the present literature, continued investigations into such relationships would inform the development of interventions targeting both of these modifiable lifestyle risk factors for chronic disease prevention.

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Tables and Figures

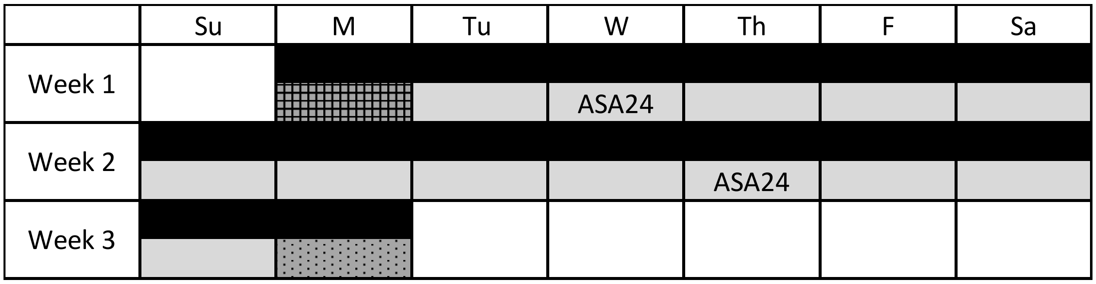

Figure 1. Summary of 2-week data collection period for an undergraduate circadian biology class laboratory exercise. Watches were provided to participants at orientation (grey with hash pattern) along with instructions for use and instructions for the ASA24 dietary recalls. Actigraphy watches were worn (black) throughout study period with the exception of water exposure and high impact activities; sleep diaries were also completed during these days. Dietary recall sessions (light gray; ASA24) were assigned on non-consecutive weekdays, two days per participant. Watches were returned two weeks after orientation, marking the end of the data collection period (gray with stippled pattern). One-time questionnaires (Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ) and the Munich Chronotype Questionnaire (MCTQ) for chronotype; Epworth Sleepiness Scale (ESS) for daytime sleepiness; Beck depression Inventory II (BDI-II) for mood) were assigned at orientation and completed at any time during the data collection period. A discussion of informed consent and volunteering of participant data for research use occurred on the last day of class following lab completion (not shown; occurred several weeks after data collection).

Table 1

A summary of tools utilized and types of data collected

Tool	Period of use	Data returned
Actigraphy watch	Daily (constant)	Sleep onset,* sleep offset,* sleep duration,* sleep efficiency,* midpoint of sleep,* social jetlag**
Sleep diary	Daily (single use)	Daily activity details to inform actigraphy interpretation, including sleep onset and offset, watch removal, and free text notes; eating event timing details***
Questionnaires	One-time	
MEQ[a]		Morningness-eveningness (chronotype)
MCTQ[b]		Chronotype
ESS[c]		Daytime sleepiness
BDI-II[d]		Mood (depression)
Demographics		Sex, age, ethnicity, race, college generation status
ASA24[e]	Twice (1x/week)	Dietary intake

* Both workday (weekday) and free day (weekend day)

** Difference between workday and free day midpoints of sleep

*** Coding malfunction of online diary prevented use of this data

a Morningness-Eveningness Questionnaire

b Munich Chronotype Questionnaire

c Epworth Sleepiness Scale

d Beck Depression Inventory II

e NIH Automated, Self-Administered 24-Hour dietary recall tool

Table 2

Characteristics of study all participants, *n* = 62

Sex (n (%))	
Female	34 (54.8)
Male	28 (45.2)
Age (years; n (%))	
<18	1 (1.6)
18-21	39 (62.9)
22-25	18 (29.0)
26+	2 (3.2)
Not indicated	2 (3.2)
Age (years; mean ± SD)	
All	21.4 ± 1.7
Females	**21.9 ± 1.7**
Males	**20.7 ± 1.3**
Race/Ethnicity (n (%))	
Asian or Asian Indian	13 (21.0)
Hispanic	4 (6.5)
White or Caucasian	34 (54.8)
Not indicated	11 (17.7)
College generation status (n (%))	
First generation college	
Yes	2 (3.2)
No	41 (66.1)
Not indicated	19 (30.6)
First generation graduating	
Yes	9 (14.5)
No	34 (54.8)
Not indicated	19 (30.6)
Weekday sleep duration[a] (n (%))	
Short (<7 hrs)	29 (46.8)
Normal (7-9 hrs)	32 (51.6)
Long (>9 hrs)	1 (1.6)
Weekday sleep duration (hours, mean ± SD)	
All	7.2 ± 0.9
Females	7.2 ± 1.0
Males	7.2 ± 0.9
Weekend day sleep duration[a] (n (%))	
Short (<7 hrs)	11 (17.7)
Normal (7-9 hrs)	38 (61.3)
Long (>9 hrs)	13 (21.0)
Weekend day sleep duration (hours, mean ± SD)	
All	8.0 ± 1.3
Females	**8.5 ± 1.3**
Males	**7.4 ± 1.1**
Social jetlag[b] (n (%))	
Wakes earlier on weekend days	8 (12.9)
Sleeps in 0-1 hrs on weekend days	22 (35.5)
Sleeps in >1-2 hrs on weekend days	25 (40.3)
Sleeps in >2-3 hrs on weekend days	5 (8.1)
Sleeps in >3 hrs on weekend days	2 (3.2)
Social jetlag[b] (hours, mean ± SD)	
All	1.0 ± 1.0
Females	1.1 ± 1.1
Males	1.0 ± 0.9

Table 2 continued

Characteristics of study all participants, *n* = 62	
Chronotype (MEQ[c] score; n (%))	
Definite Evening (16-30)	1 (1.6)
Moderate Evening (31-41)	17 (27.4)
Neither (42-58)	35 (56.5)
Moderate Morning (59-69)	9 (14.5)
Definite Morning (70-86)	0 (0.0)
Chronotype (MEQ[c] score; mean ± SD)	
All	46.7 ± 9.1
Females	46.5 ± 9.3
Males	46.9 ± 9.0
Daytime sleepiness (ESS[d] score; n (%))	
Normal (0-10)	52 (83.8)
Mild (11-14)	7 (11.3)
Moderate (15-17)	1 (1.6)
Severe (18-24)	1 (1.6)
No response	1 (1.6)
Daytime sleepiness (ESS[d] score; mean ± SD)	
All	7.3 ± 6.4
Females	7.0 ± 4.0
Males	7.8 ± 3.3
Depression (BDI-II[e] score; n (%))	
Minimal (0-13)	42 (67.7)
Mild (14-19)	11 (17.7)
Moderate (20-28)	5 (8.1)
Severe (29-63)	3 (4.8)
No response	1 (1.6)
Depression (BDI-II[e] score; mean ± SD)	
All	10.3 ± 8.4
Females	10. 4 ± 8.6
Males	10.3 ± 8.2
Dietary quality (HEI-2015[f] score; mean ± SD)	
All	54.1 ± 15.3
Females	52.8 ± 16.3
Males	55.6 ± 14.1

Boldface indicates significant difference between group distributions at significance level $p < 0.05$. Median age values compared using Mann-Whitney U test, two tailed. Mean MEQ scores compared using student's t test, two tailed.

[a] Sleep durations categorized to assess alignment with National Sleep Foundation recommendations

[b] Difference in midpoint of sleep event on week day vs weekend day

[c] Horne-Ostberg Morningness-Eveningness Questionnaire

[d] Epworth Sleepiness Scale

[e] Beck Depression Inventory II

[f] Healthy Eating Index 2015; corresponds to alignment with 2015-2020 Dietary Guidelines for Americans

Table 3

Regression coefficients for associations of sleep and circadian variables with the HEI-2015[a]

	β (SE)	P-value
Weekday Sleep Duration	-0.94 (2.11)	0.66
Adjusted for sex	*-0.93 (2.12)*	*0.66*
Weekend Day Sleep Duration	-1.89 (1.47)	0.21
Adjusted for sex	*-1.72 (1.62)*	*0.29*
Social Jetlag	-0.38 (1.97)	0.85
Adjusted for sex	*-0.31 (1.98)*	*0.89*
Chronotype	0.35 (0.21)	0.11
Adjusted for sex	*0.34 (0.21)*	*0.11*

[a] Healthy Eating Index 2015; corresponds to alignment with 2015-2020 Dietary Guidelines for Americans

Appendix A: Supplementary tables

Supplementary Table S1

Characteristics of participants for primary sleep variables and expanded HEI scores, compared by sex (*n* = 62)

	Mean ± SD			Median	
	All	*Females*	*Males*	*Females*	*Males*
Weekday sleep duration (hours)	7.2 ± 0.9	**7.2 ± 1.0**	**7.2 ± 0.9**	6.9	7.3
Weekend sleep duration (hours)	8.0 ± 1.3	**8.5 ± 1.3**	**7.4 ± 1.1**	8.3	7.6
Social jetlag (hours)	1.0 ± 1.0	1.1 ± 1.1	1.0 ± 0.9	**1.1**	**0.9**
Chronotype (MEQ score, 16 - 86)	46.7 ± 9.1	46.5 ± 9.3	46.9 ± 9.0	**48.0**	**46.5**
HEI-2015 dietary score 0-100	54.1 ± 15.3	**52.8 ± 16.3**	**55.6 ± 14.1**	51.7	55.4
Total fruits (5)	2.2 ± 2.0	2.7 ± 2.0	1.7 ± 2.0	**2.3**	**0.5**
Whole fruits (5)	2.6 ± 2.2	3.2 ± 2.1	1.9 ± 2.2	**4.5**	**0.2**
Total vegetables (5)	3.5 ± 1.5	3.5 ± 1.5	3.4 ± 1.6	**3.4**	**3.8**
Greens and beans (5)	2.7 ± 2.3	3.0 ± 2.3	2.3 ± 2.3	**4.5**	**1.3**
Whole grains (10)	3.1 ± 3.3	3.2 ± 3.4	3.0 ± 3.1	**2.2**	**1.9**
Dairy (10)	5.8 ± 3.4	5.8 ± 3.5	5.7 ± 3.4	**6.5**	**5.5**
Total proteins (5)	4.5 ± 1.0	4.3 ± 1.3	4.8 ± 0.4	**5**	**5**
Seafood and plant proteins (5)	3.1 ± 2.1	2.9 ± 2.2	3.3 ± 2.0	**3.6**	**4.6**
Refined grains (10)	5.3 ± 3.5	5.1 ± 3.8	5.6 ± 3.2	**5.4**	**6.2**
Added sugars, % total kcals (10)	6.6 ± 3.8	5.0 ± 4.0	8.5 ± 2.4	**5.1**	**9.8**
Fatty acids unsaturated:saturated (10)	4.9 ± 3.8	5.1 ± 3.7	4.7 ± 3.9	**4.2**	**3.5**
Sodium (10)	4.1 ± 4.3	3.1 ± 4.0	5.3 ± 4.4	**0.3**	**6.7**
Saturated fats, % total kcals (10)	5.7 ± 3.2	5.8 ± 3.2	5.5 ± 3.2	**6.6**	**5.7**
Total calorie intake (kcal)	1914.1 ± 737.8	**1624.3 ± 432.6**	**2266.0 ± 875.7**	1678.3	2150.2

Boldface indicates measure of central tendency used for comparison of groups by sex. See Table S2 for summary of tests for normality and simple comparisons.

Supplementary Table S2

Summary of tests for normality in distribution of variable values, corresponding measures of central tendancy, and tests for differences by sex group.

Variable	Test of Normality (Shapiro-Wilk)			Central Tendency			Student's T-Test/Mann-Whitney U-Test		
	Sex	W	P-value	Sex	Measure	Value	Test	Statistic	P-value
Weekday Sleep Duration (hours)	F	0.95	0.16	F	Mean ± SD	7.2 ± 1.0	Student	0.019	0.99
	M	0.97	0.62	M		7.2 ± 0.9			
Weekend Day Sleep Duration (hours)	F	0.96	0.26	F	Mean ± SD	8.5 ± 1.3	Student	3.446	**< .01**
	M	0.96	0.42	M		7.4 ± 1.1			
Social Jetlag (hours)	F	0.93	**0.04**	F	Median	1.1	Mann-Whitney	524	0.50
	M	0.92	**0.04**	M		0.9			
Chronotype (MEQ score)	F	0.94	**0.05**	F	Median	48.0	Mann-Whitney	470.5	0.94
	M	0.97	0.48	M		46.5			
HEI-2015 Overall Score	F	0.97	0.56	F	Mean ± SD	52.8 ± 16.3	Student	-0.735	0.47
	M	0.98	0.93	M		55.6 ± 14.1			
Calories	F	0.97	0.56	F	Mean ± SD	1624.3 ± 432.6	Student	-3.757	**< .001**[a]
	M	0.96	0.28	M		2266.0 ± 875.7			
HEI-2015 Total Fruit Score	F	0.84	**< .001**	F	Median	2.3	Mann-Whitney	613.5	**0.05**
	M	0.78	**< .001**	M		0.5			
HEI-2015 Whole Fruit Score	F	0.77	**< .001**	F	Median	4.5	Mann-Whitney	641	**0.02**
	M	0.73	**< .001**	M		0.2			
HEI-2015 Total Vegetable Score	F	0.86	**< .001**	F	Median	3.4	Mann-Whitney	509.5	0.64
	M	0.89	**< .01**	M		3.8			
HEI-2015 Greens & Beans Score	F	0.73	**< .001**	F	Median	4.5	Mann-Whitney	549.5	0.28
	M	0.73	**< .001**	M		1.3			
HEI-2015 Whole Grains Score	F	0.84	**< .001**	F	Median	2.2	Mann-Whitney	476	>.999
	M	0.87	**< .01**	M		1.9			
HEI-2015 Dairy Score	F	0.89	**< .01**	F	Median	6.5	Mann-Whitney	486	0.89
	M	0.91	**0.02**	M		5.5			
HEI-2015 Total Protein Score	F	0.64	**< .001**	F	Median	5.0	Mann-Whitney	388	0.12
	M	0.49	**< .001**	M		5.0			
HEI-2015 Seafood & Plant Protein Score	F	0.77	**< .001**	F	Median	3.6	Mann-Whitney	444	0.64
	M	0.76	**< .001**	M		4.6			
HEI-2015 Refined Grains Score	F	0.88	**< .01**	F	Median	5.4	Mann-Whitney	441.5	0.63
	M	0.93	0.06	M		6.2			
HEI-2015 Added Sugars Score	F	0.86	**< .001**	F	Median	5.1	Mann-Whitney	230	**< .001**[a]
	M	0.70	**< .001**	M		9.8			
HEI-2015 Sodium Score	F	0.73	**< .001**	F	Median	4.2	Mann-Whitney	353.5	0.07
	M	0.79	**< .001**	M		3.5			
HEI-2015 Saturated Fat Score	F	0.92	**0.01**	F	Median	0.3	Mann-Whitney	511	0.63
	M	0.94	0.12	M		6.7			
HEI-2015 Fatty Acid Ratio Score	F	0.88	**< .01**	F	Median	6.6	Mann-Whitney	505	0.69
	M	0.86	**< .01**	M		5.7			

Boldface indicates significance at p=0.05.

[a] Levene's test is significant (p < .05), suggesting a violation of the equal variance assumption