Examining the relationship between frequency of sleep hygiene behaviors and MUSE-S sleep score

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Mental ill-health is a rising problem, specifically among university students. It has been shown that quality sleep and good sleep hygiene practices can act as protective factors against mental ill-health, while poor sleep quality and poor sleep hygiene practices can act as risk factors for mental ill-health. However, there is not much established research on the relationship between the variables, especially utilizing objective, non-self-report measures of sleep quality. This study aims to explore that relationship in a sample of college students at a public education institution in New York enrolled in high-stress research programs. The primary research question this study aims to address is: What is the relationship between frequency of sleep hygiene behaviors and MUSE-S sleep score? Participants completed a pre-assessment survey, using a 12-item version of the 19-item Sleep Hygiene Questionnaire (Gellis & Lichstein, 2009). They then wore a MUSE-S sleep headband for 7 nights, using a daily survey to self-report their sleep score as a measure of sleep quality. They then completed the post-assessment to examine self-reported sleep hygiene over the participation period. Across six correlations, associations between sleep hygiene behaviors and sleep quality were weak (r = –.39 to .04) and nonsignificant (p = .054 to .997, contrasting the theory driving the study. The small sample size of this study and the limited scope of students in a specific program at a specific university limit the generalizability of these results and indicate areas for improvement in future studies that may lead to different results.

Table of contents

1 Introduction

In recent years, rates of psychopathology have been rising among university students, with an average of 33.6% and 39.0% of students experiencing depressive and anxious symptoms, respectively (Li et al., 2022), including a notable rise in mental distress, which stands as one of the most pressing health challenges of the 21st century in the U.S. among both youth and adults (Choudhry et al., 2016). Mental distress also leads to a wide range of harm for both individuals who are suffering and

to the community at large, including emotional harm as well as somatic symptoms such as insomnia, headaches, and lack of energy (Belay et al., 2021).

Adequate sleep has been linked to greater emotional regulation, cognitive performance, and life satisfaction (Palmer & Alfano, 2017), highlighting the importance of sleep in our everyday lives, especially concerning mental health. Additionally, prior research has shown that higher levels of quality sleep are associated with improvements in emotional well-being among young adults (Bodziony & Stetson, 2024). However, much of the existing literature relies primarily on self-reported measures, which may be limited by recall bias and subjective reporting, highlighting the need for novel research to incorporate objective biological measures to more accurately capture sleep behaviors and their influence on mental health outcomes. Further research also must consider specific social locations, such as minoritized status and socioeconomic status, among others, that may cause certain groups and individuals to be more at risk for experiencing mental distress and mental ill-health (CDC, 2025). Early health behaviors often have an impact on long-term outcomes, so it is crucial to encourage consistent sleep during adolescence and young adulthood to lead to improvements in long-term mental health outcomes.

1.1 Knowns and Unknowns

Due to the pervasiveness of mental distress — a subjective sense of discomfort, mental anguish, perceived lack of control, anxiety, or stress (CDC, 2025) — it is essential to address health behaviors such as sleep not only to reduce symptoms of distress but also to actively support well-being — defined as positive mood, life satisfaction, engagement, and meaning (Seligman, 2002). Research has shown that sleep quality and duration are significant predictors of mental health outcomes, and poor sleep hygiene is associated with increased mental distress (Dinis, 2018). Therefore, high-quality sleep may serve as a protective factor for college students with low mental well-being, while poor-quality sleep would serve as a risk factor. An ecological model is essential for understanding healthy adolescent development, as it emphasizes the importance of considering cultural and environmental contexts and recognizes that healthy development is shaped by a dynamic interaction of risk and protective factors (Kia-Keating et al., 2011).

While we know the importance of both sleep quality and sleep hygiene as risk and protective factors for mental health outcomes, we do not know how these two separate assessments of sleep relate. The relationship between sleep hygiene behaviors and sleep quality continues to be an area of significant inquiry within sleep research. Studies have found that the frequency of engaging in healthy sleep hygiene behaviors also leads to increases in indicators of quality sleep, such as scores of 5 or higher on the Pittsburgh Sleep Quality Index (PSQI) (Tsai et al., 2016). Further, a positive relationship has been established between frequency of poor sleep hygiene practices and frequency of insomnia symptoms (Lukowski and Tsukerman, 2021), indicating an association between sleep quality and sleep hygiene behaviors. However, there is a lack of research connecting sleep hygiene behaviors to the MUSE-S sleep score as an objective measure of sleep quality, specifically.

1.2 Research Aims

The primary gap is a methodological gap due to the limited number of studies examining the biological data of participants' sleep throughout the night. Though self-reported data is a relatively effective way of assessing quality of sleep, it can be subjective, whereas physiological data captured

through the MUSE-S headband, such as brainwaves and sleep score, provide objective indicators aligned with different units of analysis, as emphasized by the National Institute of Mental Health's (NIMH) Research Domain Criteria (RDoC) framework (Michelini et. al., 2021). Additionally, there is a lack of existing research regarding sleep hygiene behaviors, specifically, and their relationship to sleep quality, especially objective measures of sleep quality. Thus, this study takes an exploratory approach, aiming to: 1) utilize objective measures of sleep quality, 2) examine sleep hygiene behaviors of participants, and 3) assess the associations between objective sleep quality measures and self-reported sleep hygiene behaviors, with the hypothesis that as the frequency of poor sleep hygiene behaviors increases, the MUSE-S sleep score will decrease. The primary research question this study aims to address is: What is the relationship between **frequency of sleep hygiene behaviors** and **MUSE-S sleep score?**

2 Methods

2.1 Participants and Sampling

The study was approved by the Institutional Review Board of a public higher education institution in New York. Research was conducted ethically to protect the rights, welfare, confidentiality, and privacy of participants. Also, participants were informed of the project and provided their consent before beginning the survey. Participants were eligible to participate if they were at least 18 years of age and were students at Binghamton University participating in a high-stress academic program, such as the First-Year Research Immersion (FRI) program or the Summer Research Immersion (SRI) program. Individuals were recruited either in person or virtually; they were shown either an informational presentation or an informational video, respectively, explaining the study and its purposes. They were informed of the requirements of participation, as well as the potential benefits and harms associated with participating. Potential participants were then given access to a Google form to provide consent and express interest if they still wished to participate in the study.

Data were collected via survey using Qualtrics. Participants completed a day-one pre-assessment survey, taking approximately 15 minutes, in which they filled out information on their sleep hygiene behaviors in the past week. They then wore a MUSE-S headband during sleep for seven days, using a daily Qualtrics survey to transfer their data from the MUSE app as collected by the headband. Finally, at the end of their seven-day participation, participants completed a day-seven Qualtrics survey — similar to the day-one survey — with how often they participated in each of a number of sleep hygiene behaviors in the past week, during their seven-day participation period.

2.2 Measures

Sleep hygiene, broadly referred to as "a set of behaviors that influence the quality of one's sleep", was measured via self-report using the 19-item Sleep Hygiene Questionnaire (Gellis & Lichstein, 2009). The measure, as used in our study, captures 4 items of activating or arousing activities near bedtime (e.g., "Worried, planned, or thought about important matters at bedtime"); 4 items of use of the bed for activities other than sleep (e.g., "Read in bed"); and 4 items of environmental characteristics (e.g., "Slept in a room with an uncomfortable nighttime temperature") for a total of 12 items in which respondents indicate the number of days in the past week they have engaged in each item's activity. Each item for sleep hygiene was averaged to produce a composite score.

(Specifically, the score for each item was added and then divided by the number of items for the measure.)

Additionally, sleep data was collected using the MUSE-S headband. This piece of technology monitors participants' sleep stages, time spent in each sleep stage, how quickly they fall asleep, time asleep, how frequently they wake up in the night, slow wave intensity, restoration points, sleep position, stillness, heart rate, and, most importantly for this specific report, overall sleep score. For the purposes of this study, the overall sleep score as measured by the MUSE-S represents a biological measure of sleep quality.

2.3 Data Analysis Plan

Data were analyzed using R to calculate descriptive statistical measures — including means, medians, standard deviations, and ranges — and to visualize relationships among sleep hygiene items and composite sleep scores across the study period. Data from the pre- and post-assessment surveys, as well as the daily surveys, were imported into Posit Cloud, cleaned, and merged using participant identifiers such as survey password. Variable names were tidied, numeric vectors were ensured, and relevant items were recoded as needed.

Composite scores were calculated for three sleep hygiene items of particular interest for this analysis, including "Worried, planned, or thought about important matters at bedtime" (Gellis & Lichstein, 2009), or Bedtime Worrying (SH_11), "Lounged around in bed" (Gellis & Lichstein, 2009) or Bed Lounging (SH_14), and "Slept in a room that was too bright" (Gellis & Lichstein, 2009) or Bright Bedtime Environment (SH_19). These items were selected as representations of each of the three subcategories of sleep hygiene items collected in this study — items of activating or arousing activities near bedtime, items involving the use of the bed for activities other than sleep, and items assessing environmental characteristics, respectively. Composite scores were created for each of these items at both pre- and post-assessment, and a composite measure of sleep score was also created for overall sleep quality. Cronbach's alpha was computed for each composite to assess internal consistency and confirm that averaging items provided meaningful scores. Normality of composite scores was evaluated via histograms, and participants with incomplete responses or missing consent were excluded.

Bivariate associations between sleep hygiene items and composite sleep scores were examined using Pearson correlations, with scatterplots and regressions lines indicating 95% confidence intervals used to visualize trends. A Violin plot with overlaid boxplots was generated to compare distributions of these sleep hygiene scores across the two different time points measured. Exploratory analyses examined changes in sleep hygiene behaviors and their relation to overall sleep quality. All data cleaning, variable transformation, reliability assessments, and visualizations were conducted in using tidyverse and supporting packages, ensuring full reproducibility of the workflow.

2.4 Load

```
library(tidyverse)
```

```
-- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
v dplyr     1.1.4     v readr     2.1.5
v forcats   1.0.1     v stringr   1.5.2
v ggplot2   4.0.0     v tibble    3.3.0
v lubridate 1.9.4     v tidyr     1.3.1
v purrr     1.1.0
-- Conflicts ------------------------------------------ tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become
```

```
library(psych)
```

```
Attaching package: 'psych'

The following objects are masked from 'package:ggplot2':

    %+%, alpha
```

```
library(knitr)
library(tibble)
library(dplyr)
library(tidyr)
library(scales)     # for number formatting like comma()
```

```
Attaching package: 'scales'

The following objects are masked from 'package:psych':

    alpha, rescale

The following object is masked from 'package:purrr':

    discard

The following object is masked from 'package:readr':

    col_factor
```

```
library(english)    # to convert numbers to words
```

```
Attaching package: 'english'
```

```
The following object is masked from 'package:scales':

    ordinal
```

```
library(stringr)    # for text functions like str_c()

#source: Importing Data Once (Hei & McCarty, 2025): https://shanemccarty.github.io/FRIplaybook/
```

2.5 Import Data

2.5.1 Day 1 & 7

```
library(readxl)
# Import Excel file
day17data <- read_excel(
    "day17_clean.xlsx",
    col_names = TRUE)

day17data[day17data == -99] <- NA
day17data[day17data == -50] <- NA

#source: Importing Data Once (Hei & McCarty, 2025): https://shanemccarty.github.io/FRIplaybook/
#explanation: all -99 and -50 data will be treated as missing data
```

2.5.2 Daily

```
library(readxl)
# Import Excel file
dailydata <- read_excel(
    "10.20.2025.dailydata.team2.clean.xlsx",
    col_names = TRUE)
```

```
New names:
* `HEARTRATE` -> `HEARTRATE...39`
* `HEARTRATE` -> `HEARTRATE...43`
```

```
dailydata[dailydata == -99] <- NA
dailydata[dailydata == -50] <- NA

#source: Importing Data Once (Hei & McCarty, 2025): https://shanemccarty.github.io/FRIplaybook/
#explanation: all -99 and -50 data will be treated as missing data
```

2.5.3 Convert Long to Wide for Day 1 & 7 Surveys

```
library(tidyr)

## Convert to wide format
wide_17data <- day17data %>%
  pivot_wider(
    id_cols = PASSWORD,
    names_from = SURVEYDAY,
    values_from = c(`SH _8`, `SH_9`, `SH_10`, `SH _11`, `SH _12`, `SH _13`, `SH _14`, `SH _15`
    names_glue = "{.value}_T{SURVEYDAY}"
  )
#source: Tidying your Data (McCarty et. al., 2025): https://shanemccarty.github.io/FRIplaybook/
#explanation: Convert long format data to wide format to allow for within-person analyses with
```

2.5.4 Convert Long to Wide for Daily Survey

```
library(tidyr)

## Convert to wide format
wide_dailydata <- dailydata %>%
  pivot_wider(
    id_cols = PASSWORD,
    names_from = DAY,
    values_from = c(SLEEPSCORE),
    names_glue = "{.value}_T{DAY}"
  )
#source: Tidying your Data (McCarty et. al., 2025): https://shanemccarty.github.io/FRIplaybook/
#explanation: Convert long format data to wide format to allow for within-person analyses with
```

2.5.5 Import Clean Daily Data

```
library(readxl)
# Import Excel file
wide_dailydata_clean <- read_excel(
    "daily_survey_clean.xlsx",
    col_names = TRUE)

#source: Importing Data Once (Hei & McCarty, 2025): https://shanemccarty.github.io/FRIplaybook/
#explanation: Manually entered wide daily data into an excel file that was then imported, due t
```

2.5.6 Join Data Sets

```
library(readxl)
library(dplyr)

#| label: join-datasets

#source: https://dplyr.tidyverse.org/reference/mutate-joins.html

#day17data ## primary - Day 1/7
#wide_dailydata_clean ## secondary - daily


# Select only the variables you need from secondary dataset, then join
combined <- wide_17data %>%
  left_join(
    wide_dailydata_clean %>% select("PASSWORD", "SLEEPSCORE_T1", "SLEEPSCORE_T2", "SLEEPSCORE_T
    by = "PASSWORD"
  )

#explanation: This code joins together the necessary sleep score data taken from the daily surv
```

2.6 Tidy

2.6.1 Remove Spaces from Variable Names in Day 1/7 Survey

```
names(wide_17data) <- gsub(" ", "", names(wide_17data))

#source: Wickham, Hadley & Grolemund, Garrett. R for Data Science (2e) - Chapter 12: "Tibbles.'
#explanation: Some of the variables had spaces in the names which was messing up data analysis
```

2.6.2 Change to Numeric Vectors

```
combined <- combined %>%
  mutate(across(where(is.list), ~ sapply(., function(x) if (is.null(x)) NA else x[1])))

#source: https://dcl-prog.stanford.edu/list-columns.html
#explanation: Columns were consisiting of lists and not numeric vectors, so this was run to cor
```

2.6.3 Remove Spaces from Variable Names in Combined Data Set

```
names(combined) <- gsub(" ", "", names(combined))

#source: Wickham, Hadley & Grolemund, Garrett. R for Data Science (2e) - Chapter 12: "Tibbles.
#explanation: Some of the variables had spaces in the names which was messing up data analysis
```

2.7 Transform

2.7.1 Assign Labels to Sleep Hygiene Items at Time 1 and Time 2

```
combined <- combined %>% filter(!is.na(SH_8_T1)) %>%
  mutate(
    SH_8_T1 == case_when(
      SH_8_T1 == 0 ~ "0 Days",
      SH_8_T1 == 1 ~ "1 Day",
      SH_8_T1 == 2 ~ "2 Days",
      SH_8_T1 == 3 ~ "3 Days",
      SH_8_T1 == 4 ~ "4 Days",
      SH_8_T1 == 5 ~ "5 Days",
      SH_8_T1 == 6 ~ "6 Days",
      SH_8_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_8_T2)) %>%
  mutate(
    SH_8_T2 == case_when(
      SH_8_T2 == 0 ~ "0 Days",
      SH_8_T2 == 1 ~ "1 Day",
      SH_8_T2 == 2 ~ "2 Days",
      SH_8_T2 == 3 ~ "3 Days",
      SH_8_T2 == 4 ~ "4 Days",
      SH_8_T2 == 5 ~ "5 Days",
      SH_8_T2 == 6 ~ "6 Days",
      SH_8_T2 == 7 ~ "7 Days"
    )

  )
```

```r
#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_9_T1)) %>%
  mutate(
    SH_9_T1 == case_when(
      SH_9_T1 == 0 ~ "0 Days",
      SH_9_T1 == 1 ~ "1 Day",
      SH_9_T1 == 2 ~ "2 Days",
      SH_9_T1 == 3 ~ "3 Days",
      SH_9_T1 == 4 ~ "4 Days",
      SH_9_T1 == 5 ~ "5 Days",
      SH_9_T1 == 6 ~ "6 Days",
      SH_9_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_9_T2)) %>%
  mutate(
    SH_9_T2 == case_when(
      SH_9_T2 == 0 ~ "0 Days",
      SH_9_T2 == 1 ~ "1 Day",
      SH_9_T2 == 2 ~ "2 Days",
      SH_9_T2 == 3 ~ "3 Days",
      SH_9_T2 == 4 ~ "4 Days",
      SH_9_T2 == 5 ~ "5 Days",
      SH_9_T2 == 6 ~ "6 Days",
      SH_9_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_10_T1)) %>%
  mutate(
    SH_10_T1 == case_when(
      SH_10_T1 == 0 ~ "0 Days",
      SH_10_T1 == 1 ~ "1 Day",
      SH_10_T1 == 2 ~ "2 Days",
      SH_10_T1 == 3 ~ "3 Days",
```

```
      SH_10_T1 == 4 ~ "4 Days",
      SH_10_T1 == 5 ~ "5 Days",
      SH_10_T1 == 6 ~ "6 Days",
      SH_10_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_10_T2)) %>%
  mutate(
    SH_10_T2 == case_when(
      SH_10_T2 == 0 ~ "0 Days",
      SH_10_T2 == 1 ~ "1 Day",
      SH_10_T2 == 2 ~ "2 Days",
      SH_10_T2 == 3 ~ "3 Days",
      SH_10_T2 == 4 ~ "4 Days",
      SH_10_T2 == 5 ~ "5 Days",
      SH_10_T2 == 6 ~ "6 Days",
      SH_10_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_11_T1)) %>%
  mutate(
    SH_11_T1 == case_when(
      SH_11_T1 == 0 ~ "0 Days",
      SH_11_T1 == 1 ~ "1 Day",
      SH_11_T1 == 2 ~ "2 Days",
      SH_11_T1 == 3 ~ "3 Days",
      SH_11_T1 == 4 ~ "4 Days",
      SH_11_T1 == 5 ~ "5 Days",
      SH_11_T1 == 6 ~ "6 Days",
      SH_11_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_11_T2)) %>%
  mutate(
    SH_11_T2 == case_when(
      SH_11_T2 == 0 ~ "0 Days",
      SH_11_T2 == 1 ~ "1 Day",
      SH_11_T2 == 2 ~ "2 Days",
      SH_11_T2 == 3 ~ "3 Days",
      SH_11_T2 == 4 ~ "4 Days",
      SH_11_T2 == 5 ~ "5 Days",
      SH_11_T2 == 6 ~ "6 Days",
      SH_11_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_12_T1)) %>%
  mutate(
    SH_12_T1 == case_when(
      SH_12_T1 == 0 ~ "0 Days",
      SH_12_T1 == 1 ~ "1 Day",
      SH_12_T1 == 2 ~ "2 Days",
      SH_12_T1 == 3 ~ "3 Days",
      SH_12_T1 == 4 ~ "4 Days",
      SH_12_T1 == 5 ~ "5 Days",
      SH_12_T1 == 6 ~ "6 Days",
      SH_12_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_12_T2)) %>%
  mutate(
    SH_12_T2 == case_when(
      SH_12_T2 == 0 ~ "0 Days",
      SH_12_T2 == 1 ~ "1 Day",
      SH_12_T2 == 2 ~ "2 Days",
      SH_12_T2 == 3 ~ "3 Days",
      SH_12_T2 == 4 ~ "4 Days",
      SH_12_T2 == 5 ~ "5 Days",
      SH_12_T2 == 6 ~ "6 Days",
      SH_12_T2 == 7 ~ "7 Days"
```

```
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_13_T1)) %>%
  mutate(
    SH_13_T1 == case_when(
      SH_13_T1 == 0 ~ "0 Days",
      SH_13_T1 == 1 ~ "1 Day",
      SH_13_T1 == 2 ~ "2 Days",
      SH_13_T1 == 3 ~ "3 Days",
      SH_13_T1 == 4 ~ "4 Days",
      SH_13_T1 == 5 ~ "5 Days",
      SH_13_T1 == 6 ~ "6 Days",
      SH_13_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_13_T2)) %>%
  mutate(
    SH_13_T2 == case_when(
      SH_13_T2 == 0 ~ "0 Days",
      SH_13_T2 == 1 ~ "1 Day",
      SH_13_T2 == 2 ~ "2 Days",
      SH_13_T2 == 3 ~ "3 Days",
      SH_13_T2 == 4 ~ "4 Days",
      SH_13_T2 == 5 ~ "5 Days",
      SH_13_T2 == 6 ~ "6 Days",
      SH_13_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_14_T1)) %>%
  mutate(
    SH_14_T1 == case_when(
```

```
      SH_14_T1 == 0 ~ "0 Days",
      SH_14_T1 == 1 ~ "1 Day",
      SH_14_T1 == 2 ~ "2 Days",
      SH_14_T1 == 3 ~ "3 Days",
      SH_14_T1 == 4 ~ "4 Days",
      SH_14_T1 == 5 ~ "5 Days",
      SH_14_T1 == 6 ~ "6 Days",
      SH_14_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_14_T2)) %>%
  mutate(
    SH_14_T2 == case_when(
      SH_14_T2 == 0 ~ "0 Days",
      SH_14_T2 == 1 ~ "1 Day",
      SH_14_T2 == 2 ~ "2 Days",
      SH_14_T2 == 3 ~ "3 Days",
      SH_14_T2 == 4 ~ "4 Days",
      SH_14_T2 == 5 ~ "5 Days",
      SH_14_T2 == 6 ~ "6 Days",
      SH_14_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_15_T1)) %>%
  mutate(
    SH_15_T1 == case_when(
      SH_15_T1 == 0 ~ "0 Days",
      SH_15_T1 == 1 ~ "1 Day",
      SH_15_T1 == 2 ~ "2 Days",
      SH_15_T1 == 3 ~ "3 Days",
      SH_15_T1 == 4 ~ "4 Days",
      SH_15_T1 == 5 ~ "5 Days",
      SH_15_T1 == 6 ~ "6 Days",
      SH_15_T1 == 7 ~ "7 Days"
    )

  )
```

```r
#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_15_T2)) %>%
  mutate(
    SH_15_T2 == case_when(
      SH_15_T2 == 0 ~ "0 Days",
      SH_15_T2 == 1 ~ "1 Day",
      SH_15_T2 == 2 ~ "2 Days",
      SH_15_T2 == 3 ~ "3 Days",
      SH_15_T2 == 4 ~ "4 Days",
      SH_15_T2 == 5 ~ "5 Days",
      SH_15_T2 == 6 ~ "6 Days",
      SH_15_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_16_T1)) %>%
  mutate(
    SH_16_T1 == case_when(
      SH_16_T1 == 0 ~ "0 Days",
      SH_16_T1 == 1 ~ "1 Day",
      SH_16_T1 == 2 ~ "2 Days",
      SH_16_T1 == 3 ~ "3 Days",
      SH_16_T1 == 4 ~ "4 Days",
      SH_16_T1 == 5 ~ "5 Days",
      SH_16_T1 == 6 ~ "6 Days",
      SH_16_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_16_T2)) %>%
  mutate(
    SH_16_T2 == case_when(
      SH_16_T2 == 0 ~ "0 Days",
      SH_16_T2 == 1 ~ "1 Day",
      SH_16_T2 == 2 ~ "2 Days",
      SH_16_T2 == 3 ~ "3 Days",
```

```
      SH_16_T2 == 4 ~ "4 Days",
      SH_16_T2 == 5 ~ "5 Days",
      SH_16_T2 == 6 ~ "6 Days",
      SH_16_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_17_T1)) %>%
  mutate(
    SH_17_T1 == case_when(
      SH_17_T1 == 0 ~ "0 Days",
      SH_17_T1 == 1 ~ "1 Day",
      SH_17_T1 == 2 ~ "2 Days",
      SH_17_T1 == 3 ~ "3 Days",
      SH_17_T1 == 4 ~ "4 Days",
      SH_17_T1 == 5 ~ "5 Days",
      SH_17_T1 == 6 ~ "6 Days",
      SH_17_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_17_T2)) %>%
  mutate(
    SH_17_T2 == case_when(
      SH_17_T2 == 0 ~ "0 Days",
      SH_17_T2 == 1 ~ "1 Day",
      SH_17_T2 == 2 ~ "2 Days",
      SH_17_T2 == 3 ~ "3 Days",
      SH_17_T2 == 4 ~ "4 Days",
      SH_17_T2 == 5 ~ "5 Days",
      SH_17_T2 == 6 ~ "6 Days",
      SH_17_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_18_T1)) %>%
  mutate(
    SH_18_T1 == case_when(
      SH_18_T1 == 0 ~ "0 Days",
      SH_18_T1 == 1 ~ "1 Day",
      SH_18_T1 == 2 ~ "2 Days",
      SH_18_T1 == 3 ~ "3 Days",
      SH_18_T1 == 4 ~ "4 Days",
      SH_18_T1 == 5 ~ "5 Days",
      SH_18_T1 == 6 ~ "6 Days",
      SH_18_T1 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_18_T2)) %>%
  mutate(
    SH_18_T2 == case_when(
      SH_18_T2 == 0 ~ "0 Days",
      SH_18_T2 == 1 ~ "1 Day",
      SH_18_T2 == 2 ~ "2 Days",
      SH_18_T2 == 3 ~ "3 Days",
      SH_18_T2 == 4 ~ "4 Days",
      SH_18_T2 == 5 ~ "5 Days",
      SH_18_T2 == 6 ~ "6 Days",
      SH_18_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```r
combined <- combined %>% filter(!is.na(SH_19_T1)) %>%
  mutate(
    SH_19_T1 == case_when(
      SH_19_T1 == 0 ~ "0 Days",
      SH_19_T1 == 1 ~ "1 Day",
      SH_19_T1 == 2 ~ "2 Days",
      SH_19_T1 == 3 ~ "3 Days",
      SH_19_T1 == 4 ~ "4 Days",
      SH_19_T1 == 5 ~ "5 Days",
      SH_19_T1 == 6 ~ "6 Days",
      SH_19_T1 == 7 ~ "7 Days"
```

```
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

```
combined <- combined %>% filter(!is.na(SH_19_T2)) %>%
  mutate(
    SH_19_T2 == case_when(
      SH_19_T2 == 0 ~ "0 Days",
      SH_19_T2 == 1 ~ "1 Day",
      SH_19_T2 == 2 ~ "2 Days",
      SH_19_T2 == 3 ~ "3 Days",
      SH_19_T2 == 4 ~ "4 Days",
      SH_19_T2 == 5 ~ "5 Days",
      SH_19_T2 == 6 ~ "6 Days",
      SH_19_T2 == 7 ~ "7 Days"
    )

  )

#source: https://fripublichealth.quarto.pub/zerosum/report-preview.html#introduction, r manual
#explanation: Assign labels to each response option for all sleep hygiene items.
```

2.7.2 Remove NAs

```
combined[combined == "NA"] <- NA

#source: https://stackoverflow.com/questions/3357743/replacing-character-values-with-na-in-a-da
#explanation: Register all N/A responses in the combined data set as "NA" in R
```

2.7.3 Create Composite Score For Sleep Hygiene at Day 1 and Day 7

2.7.3.1 Sleep Hygiene Day 1 Composite

```
library(psych)
SH_T1_keys <- list(
  SLEEPHYGIENE_T1 = c("SH_8_T1", "SH_9_T1", "SH_10_T1", "SH_11_T1", "SH_12_T1", "SH_13_T1", "SH
)

#source: Creating Composite Scorex from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: A composite score for sleep hygiene at day 1 was created to create an average sle
```

```r
library(psych)
# Using scoreItems() - recommended: SH_T1

SH_T1_scores <- scoreItems(SH_T1_keys, combined)

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
```

```r
library(psych)
# Extract
composite_T1_scores <- SH_T1_scores$scores

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
```

```r
# Add to dataframe
combined$SH_T1 <- composite_T1_scores[, "SLEEPHYGIENE_T1"]

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: This final step adds the composite sleep score to the combined data frame
```

```r
scoreItems(keys = SH_T1_keys, items = combined)
```

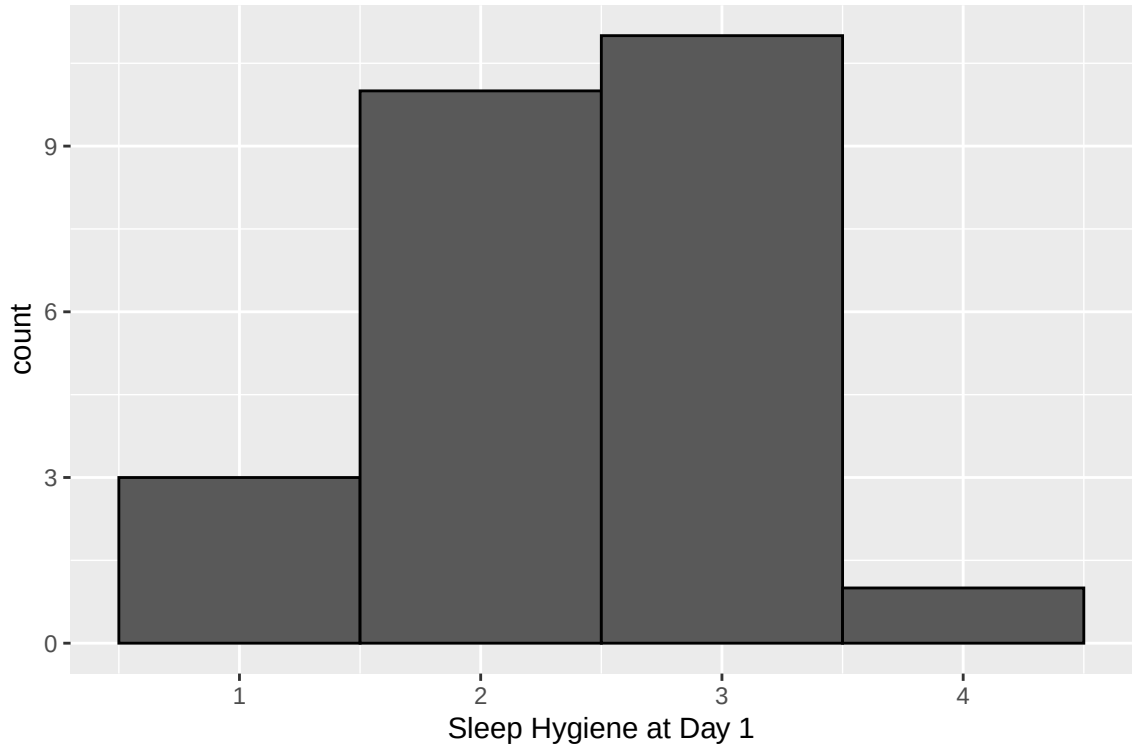
```
Call: scoreItems(keys = SH_T1_keys, items = combined)

(Unstandardized) Alpha:
      SLEEPHYGIENE_T1
alpha            0.23

Standard errors of unstandardized Alpha:
      SLEEPHYGIENE_T1
ASE              0.23

Average item correlation:
          SLEEPHYGIENE_T1
average.r           0.025

Median item correlation:
SLEEPHYGIENE_T1
          0.029

 Guttman 6* reliability:
         SLEEPHYGIENE_T1
Lambda.6            0.69

Signal/Noise based upon av.r :
             SLEEPHYGIENE_T1
Signal/Noise             0.3
```

```
Scale intercorrelations corrected for attenuation
 raw correlations below the diagonal, alpha on the diagonal
 corrected correlations above the diagonal:
                SLEEPHYGIENE_T1
SLEEPHYGIENE_T1            0.23

 Average adjusted correlations within and between scales (MIMS)
[1] 0.02

 Average adjusted item x scale correlations within and between scales (MIMT)
[1] 0.33

 In order to see the item by scale loadings and frequency counts of the data
 print with the short option = FALSE
```

```
#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: This allows us to examine whether the scores on each sleep hygiene item accurate
```

2.7.3.2 Visualize Normality Histogram for Sleep Hygiene at Day 1

```
library(ggplot2)
ggplot(combined, mapping = aes(x = SH_T1)) +
  geom_histogram(binwidth = 1, color = "black") +
  xlab("Sleep Hygiene at Day 1")
```



```
#source: datacamp, ggplot2 cheat sheet
#explanation: Check to see if sleep hygiene scores at day 1 are normally distributed.
```

2.7.3.3 Sleep Hygiene Day 7 Composite

```
library(psych)
SH_T2_keys <- list(
  SLEEPHYGIENE_T2 = c("SH_8_T2", "SH_9_T2", "SH_10_T2", "SH_10_T2", "SH_12_T2", "SH_13_T2", "SH
)

#source: Creating Composite Scorex from Multi-Item Measures (McCarty, 2025): https://shanemccar
#explanation: A composite score for sleep hygiene at day 1 was created to create an average sle
```

```
library(psych)
# Using scoreItems() - recommended: SH_T2

SH_T2_scores <- scoreItems(SH_T2_keys, combined)

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemccar
```

```
library(psych)
# Extract
composite_T2_scores <- SH_T2_scores$scores

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemccar
```

```
# Add to dataframe
combined$SH_T2 <- composite_T2_scores[, "SLEEPHYGIENE_T2"]

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemccar
#explanation: This final step adds the composite sleep score to the combined data frame
```

```
scoreItems(keys = SH_T2_keys, items = combined)
```

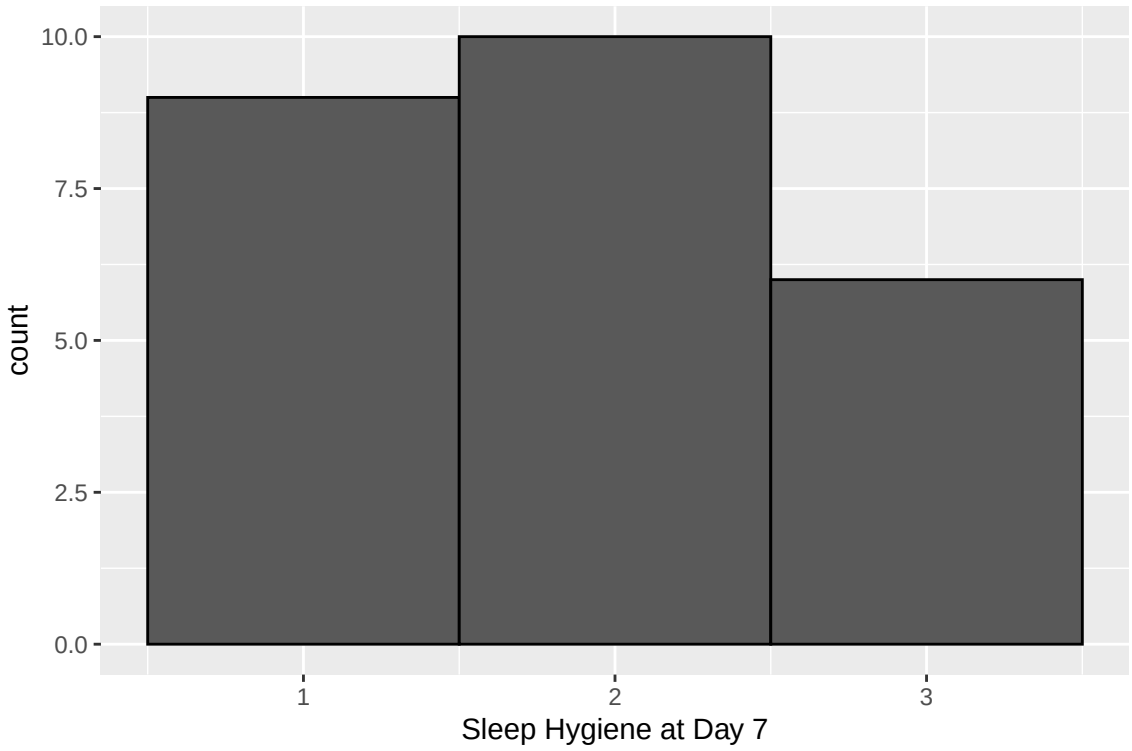
```
Call: scoreItems(keys = SH_T2_keys, items = combined)

(Unstandardized) Alpha:
      SLEEPHYGIENE_T2
alpha            0.57

Standard errors of unstandardized Alpha:
      SLEEPHYGIENE_T2
ASE              0.15
```

```
Average item correlation:
          SLEEPHYGIENE_T2
average.r            0.11

Median item correlation:
SLEEPHYGIENE_T2
          0.083

 Guttman 6* reliability:
         SLEEPHYGIENE_T2
Lambda.6            0.75

Signal/Noise based upon av.r :
             SLEEPHYGIENE_T2
Signal/Noise             1.3

Scale intercorrelations corrected for attenuation
 raw correlations below the diagonal, alpha on the diagonal
 corrected correlations above the diagonal:
                SLEEPHYGIENE_T2
SLEEPHYGIENE_T2            0.57

 Average adjusted correlations within and between scales (MIMS)
[1] 0.11

 Average adjusted item x scale correlations within and between scales (MIMT)
[1] 0.43

 In order to see the item by scale loadings and frequency counts of the data
 print with the short option = FALSE
```

```
#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: This allows us to examine whether the scores on each sleep hygiene item accurate
```

2.7.3.4 Visualize Normality Histogram for Sleep Hygiene at Day 7

```
library(ggplot2)
ggplot(combined, mapping = aes(x = SH_T2)) +
  geom_histogram(binwidth = 1, color = "black") +
  xlab("Sleep Hygiene at Day 7")
```




```
#source: datacamp, ggplot2 cheat sheet
#explanation: Check to see if sleep hygiene scores at day 7 are normally distributed.
```

2.7.4 Create Composite Score for Sleep Scores

```
library(psych)
SLEEPSCORE_keys <- list(
  SLEEPSCORE = c("SLEEPSCORE_T2", "SLEEPSCORE_T3", "SLEEPSCORE_T4", "SLEEPSCORE_T5", "SLEEPSCOR
)

#source: Creating Composite Scorex from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: A composite score for sleep score was created to create an average sleep score f
#note: remove T1 because all NAs
```

```
combined[unlist(SLEEPSCORE_keys)] <- lapply(combined[unlist(SLEEPSCORE_keys)], function(x) as.n

#source: https://r4ds.hadley.nz/data-transform.html
#explanation: Originally listed as character vectors, so must be changed to numeric vectors
```

```
library(psych)
# Using scoreItems() - recommended: SLEEPSCORE

SLEEPSCORE_scores <- scoreItems(SLEEPSCORE_keys, combined)
```

```r
#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
```

```r
library(psych)
# Extract
composite_SLEEPSCORE_scores <- SLEEPSCORE_scores$scores

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
```

```r
# Add to dataframe
combined$SLEEPSCORE <- composite_SLEEPSCORE_scores[, "SLEEPSCORE"]

#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: This final step adds the composite sleep score to the combined data frame
```

```r
scoreItems(keys = SLEEPSCORE_keys, items = combined)
```

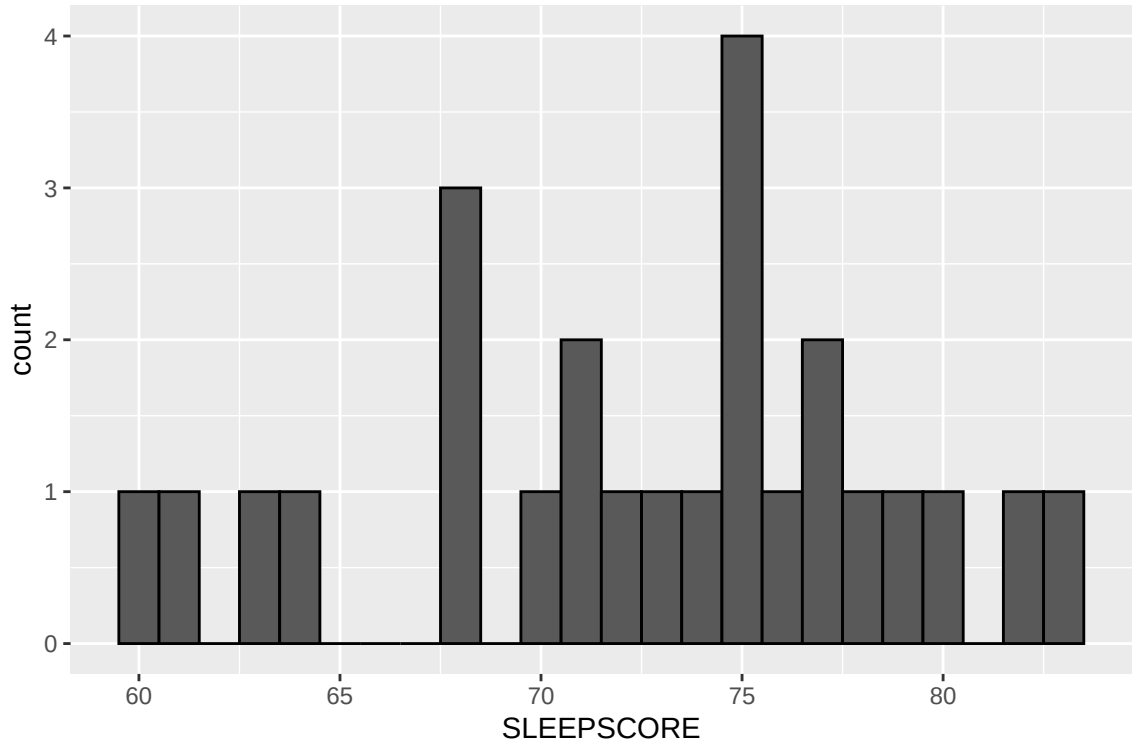
```
Number of categories should be increased  in order to count frequencies.

Call: scoreItems(keys = SLEEPSCORE_keys, items = combined)

(Unstandardized) Alpha:
      SLEEPSCORE
alpha       0.51

Standard errors of unstandardized Alpha:
      SLEEPSCORE
ASE         0.19

Average item correlation:
          SLEEPSCORE
average.r       0.15

Median item correlation:
SLEEPSCORE
      0.13

 Guttman 6* reliability:
         SLEEPSCORE
Lambda.6       0.55

Signal/Noise based upon av.r :
             SLEEPSCORE
Signal/Noise          1

Scale intercorrelations corrected for attenuation
```

```
 raw correlations below the diagonal, alpha on the diagonal
 corrected correlations above the diagonal:
           SLEEPSCORE
SLEEPSCORE       0.51

 Average adjusted correlations within and between scales (MIMS)
[1] 0.15

 Average adjusted item x scale correlations within and between scales (MIMT)
[1] 0.55

 In order to see the item by scale loadings and frequency counts of the data
 print with the short option = FALSE
```

```
#source: Creating Composite Scores from Multi-Item Measures (McCarty, 2025): https://shanemcca
#explanation: This allows us to examine whether the sleep scores for each individual day accura
```

2.7.5 Visualize Normality Histogram for Sleep Score

```
library(ggplot2)
ggplot(combined, mapping = aes(x = SLEEPSCORE)) +
  geom_histogram(binwidth = 1, color = "black")
```



```
#source: datacamp, ggplot2 cheat sheet
#explanation: Check to see if sleep scores are normally distributed.
```

3 Results

3.1 Summary of Sleep Hygiene and Sleep Quality Variables

Before examining associations between sleep hygiene behaviors and sleep quality, descriptive statistics, including means, medians, standard deviations, and ranges were calculated for the three sleep hygiene items at pre- and post-assessment as well as for the composite sleep score. Bedtime Worrying and Bed Lounging showed moderate variability across the sample, with means generally falling between 2.8 and 4.9 across time points. In contrast, Bright Bedtime Environment scores were low, with medians of 0 at both assessments, indicating that most participants rarely slept under conditions that were too bright. Composite sleep scores demonstrated higher consistency and less variability than the individual behavior items. Overall, the descriptive results suggest that participants tended to report relatively healthy sleep environments, with more variation observed in cognitive habits, such as worrying, and behavioral tendencies, such as lounging.

3.1.1 Descriptive Statistics for 3 Sleep Hygiene Items

3.1.1.1 Means

```
mean(combined$SH_11_T1)
```

```
[1] 4.88
```

```
#source: datacamp
#explanation: calculate mean of bedtime worrying at day 1
```

```
mean(combined$SH_11_T2)
```

```
[1] 3.92
```

```
#source: datacamp
#explanation: calculate mean of bedtime worrying at day 7
```

```
mean(combined$SH_14_T1)
```

```
[1] 4.2
```

```
#source: datacamp
#explanation: calculate mean of bed lounging at day 1
```

```
mean(combined$SH_14_T2)
```

```
[1] 2.8
```

```
#source: datacamp
#explanation: calculate mean of bed lounging at day 7
```

```
mean(combined$SH_19_T1)
```

```
[1] 0.72
```

```
#source: datacamp
#explanation: calculate mean of bright bedttime environment at day 1
```

```
mean(combined$SH_19_T2)
```

```
[1] 1
```

```
#source: datacamp
#explanation: calculate mean of bright bedttime environment at day 7
```

```
mean(combined$SLEEPSCORE)
```

```
[1] 72.60667
```

```
#source: datacamp
#explanation: calculate mean of composite sleep score
```

3.1.1.2 Standard Deviations

```
sd(combined$SH_11_T1)
```

```
[1] 2.06801
```

```
#source: datacamp
#explanation: calculate standard deviation of bedtime worrying at day 1
```

```
sd(combined$SH_11_T2)
```

```
[1] 2.215852
```

```
#source: datacamp
#explanation: calculate standard deviation of bedtime worrying at day 7
```

```
sd(combined$SH_14_T1)
```

```
[1] 2.43242
```

```
#source: datacamp
#explanation: calculate standard deviation of bed lounging at day 1
```

```
sd(combined$SH_14_T2)
```

```
[1] 2.27303
```

```
#source: datacamp
#explanation: calculate standard deviation of bed lounging at day 7
```

```
sd(combined$SH_19_T1)
```

```
[1] 1.275408
```

```
#source: datacamp
#explanation: calculate standard deviation of bright bedtime environment at day 1
```

```
sd(combined$SH_19_T2)
```

```
[1] 1.683251
```

```
#source: datacamp
#explanation: calculate standard deviation of bright bedtime environment at day 7
```

```
sd(combined$SLEEPSCORE)
```

```
[1] 6.304784
```

```
#source: datacamp
#explanation: calculate standard deviation of composite sleep score
```

3.1.1.3 Medians

```
median(combined$SH_11_T1)
```

```
[1] 5
```

```
#source: datacamp
#explanation: calculate median of bedtime worrying at day 1
```

```
median(combined$SH_11_T2)
```

```
[1] 4
```

```
#source: datacamp
#explanation: calculate median of bedtime worrying at day 7
```

```
median(combined$SH_14_T1)
```

```
[1] 4
```

```
#source: datacamp
#explanation: calculate median of bed lounging at day 1
```

```
median(combined$SH_14_T2)
```

```
[1] 2
```

```
#source: datacamp
#explanation: calculate median of bed lounging at day 7
```

```
median(combined$SH_19_T1)
```

```
[1] 0
```

```
#source: datacamp
#explanation: calculate median of bright bedtime environment at day 1
```

```
median(combined$SH_19_T2)
```

```
[1] 0
```

```
#source: datacamp
#explanation: calculate median of bright bedtime environment at day 7
```

```
median(combined$SLEEPSCORE)
```

```
[1] 74.16667
```

```
#source: datacamp
#explanation: calculate median of composite sleep score
```

3.1.1.4 Ranges

```
range(combined$SH_11_T1)
```

```
[1] 0 7
```

```
#source: datacamp
#explanation: calculate range of bedtime worrying at day 1
```

```
range(combined$SH_11_T2)
```

```
[1] 0 7
```

```
#source: datacamp
#explanation: calculate range of bedtime worrying at day 7
```

```
range(combined$SH_14_T1)
```

```
[1] 0 7
```

```
#source: datacamp
#explanation: calculate range of bed lounging at day 1
```

```
range(combined$SH_14_T2)
```

```
[1] 0 7
```

```
#source: datacamp
#explanation: calculate range of bed lounging at day 7
```

```
range(combined$SH_19_T1)
```

```
[1] 0 4
```

```
#source: datacamp
#explanation: calculate range of bright bedtime environment at day 1
```

```
range(combined$SH_19_T2)
```

```
[1] 0 7
```

```
#source: datacamp
#explanation: calculate range of bright bedtime environment at day 7
```

```
range(combined$SLEEPSCORE)
```

```
[1] 60.25000 83.33333
```

```
#source: datacamp
#explanation: calculate range of composite sleep score
```

3.2 Bedtime Worrying at Day 1 and 7 with Sleep Score

3.2.1 Bedtime Worrying at Day 1 vs. Sleep Score

Figure 1 shows a scatterplot of Bedtime Worrying at Day 1 (SH_11_T1) and composite sleep score. A majority of the sample (n = 13) scored 4.5 or above this for sleep hygiene item, with only 4 participants scoring below 4.5. Scores were somewhat clustered at the higher end, with sleep score ranges from approximately 60 to 82. Visual inspection of the scatterplot suggests no clear trend between these two variables, which was confirmed with a Pearson correlation which showed a very weak negative association that was not statistically significant (r = -.07, p = .756).

```
SH_11_T1_vs_SS <- ggplot(data = combined,
       mapping = aes(
         x = SH_11_T1,
         y = SLEEPSCORE)) + geom_point() +
  geom_smooth(method = "lm") +
  xlab("Bedtime Worrying at Day 1") +
  ylab("Sleep Score")


SH_11_T1_vs_SS
```

```
`geom_smooth()` using formula = 'y ~ x'
```

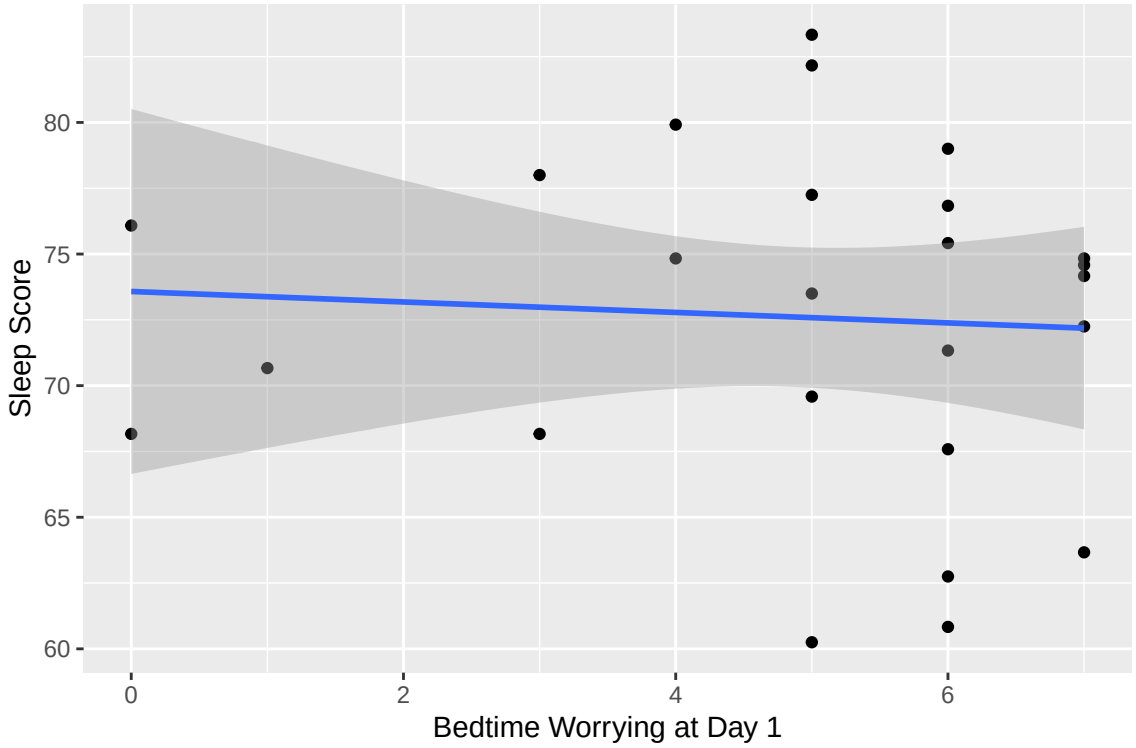


Figure 1: Figure 1. Relationship Between Bedtime Worrying at Day 1 and Sleep Score. A scatterplot displays individual participants' sleep scores plotted against their values for Bedtime Worrying at Day 1, with a linear regression line and 95% confidence band overlaid. The fitted line shows a very slight negative slope, indicating no meaningful association between Bedtime Worrying at Day 1 and overall sleep score.

```
#source: Visualize in ggplot (Silhavy & McCarty, 2025): https://shanemccarty.github.io/FRIplayb
#explanation: create scatter plot to visualize the relationship between bedtime worrying at day
```

```
ggsave("plots/plot1_SH_11_T1_vs_SS.png",
       plot = SH_11_T1_vs_SS,
       width = 10, height = 8, dpi = 300)
```

```
`geom_smooth()` using formula = 'y ~ x'
```

```
#explanation: save the plot to the "plots" folder
```

```
#correlation_SS_vs_SH_11_T1
cor.test(combined$SH_11_T1, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_11_T1 and combined$SLEEPSCORE
t = -0.31378, df = 23, p-value = 0.7565
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.4488401  0.3385772
sample estimates:
        cor
-0.06528813
```

```
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

3.2.2 Bedtime Worrying at Day 7 vs. Sleep Score

Figure 2 presents the same relationship at Day 7. Here, bedtime worrying scores were more variable, with a few participants reporting lower worrying scores. The scatterplot shows a slight downward slope, indicating a weak negative correlation that was confirmed by calculating a Pearson correlation; however this relationship was also nonsignificant (r = -.29, p = .156).

```
SH_11_T2_vs_SS <- ggplot(data = combined,
       mapping = aes(
         x = SH_11_T2,
         y = SLEEPSCORE)) + geom_point() +
  geom_smooth(method = "lm") +
  xlab("Bedtime Worrying at Day 7") +
  ylab("Sleep Score")


SH_11_T2_vs_SS
```

```
`geom_smooth()` using formula = 'y ~ x'
```

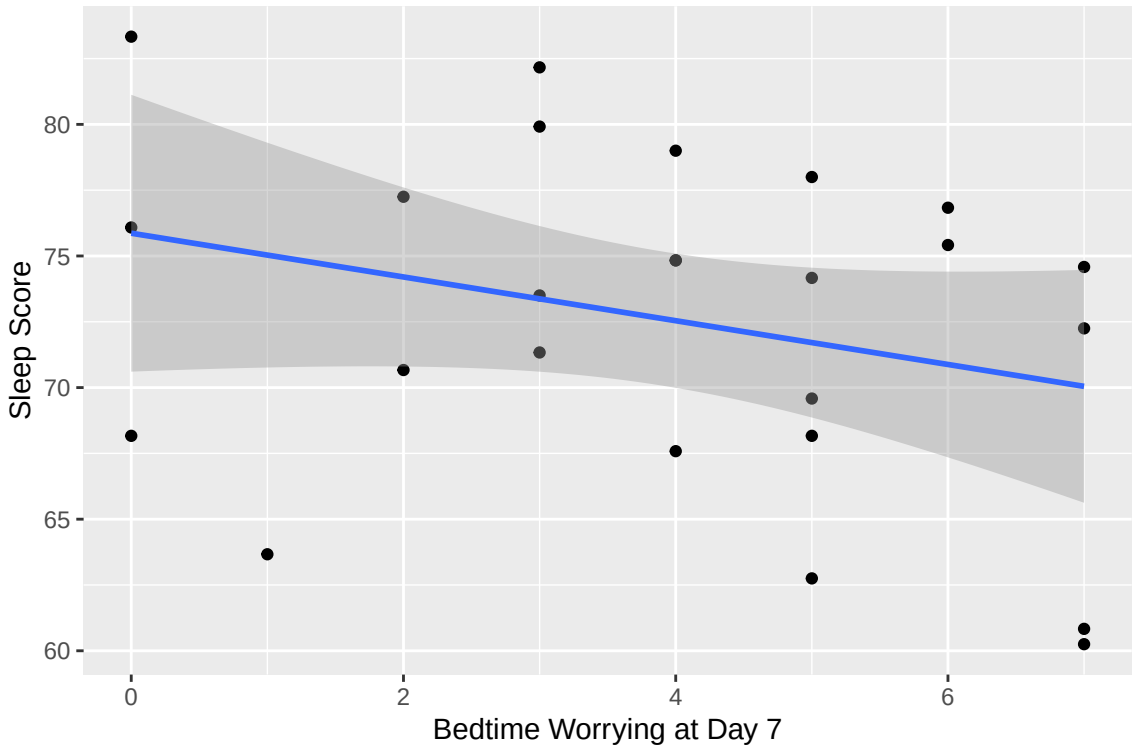


Figure 2: Figure 2. Relationship Between Bedtime Worrying at Day 7 and Sleep Score. A scatterplot displays individual participants' sleep scores plotted against their values for Bedtime Worrying at Day 7, with a linear regression line and 95% confidence band overlaid. The fitted line shows a slight downward slope, indicating a weak negative relationship between Bedtime Worrying at Day 7 and sleep score.

```
#source: Visualize in ggplot (Silhavy & McCarty, 2025): https://shanemccarty.github.io/FRIplayb
#explanation: create scatter plot to visualize the relationship between bedtime worrying at day
```

```
ggsave("plots/plot2_SH_11_T2_vs_SS.png",
       plot = SH_11_T2_vs_SS,
       width = 10, height = 8, dpi = 300)
```

```
`geom_smooth()` using formula = 'y ~ x'
```

```
#explanation: save the plot to the "plots" folder
```

```
#correlation_SS_vs_SH_11_T2
cor.test(combined$SH_11_T2, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_11_T2 and combined$SLEEPSCORE
```

```
t = -1.465, df = 23, p-value = 0.1565
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.6161496  0.1164266
sample estimates:
      cor
-0.292144
```

```
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

3.3 Bed Lounging at Day 1 and 7 with Sleep Score

3.3.1 Bed Lounging at Day 1 vs. Sleep Score

Figure 3 depicts a scatterplot of Bed Lounging at Day 1 (SH_14_T1) and sleep score. Most participants scored in the midrange, with few scoring higher or lower. The scatterplot shows a slight negative slope, suggesting a very weak negative relationship with sleep score. This observation was also represented through a nonsignificant Pearson correlation (r = -.19, p = .352).

```
SH_14_T1_vs_SS <- ggplot(data = combined,
       mapping = aes(
         x = SH_14_T1,
         y = SLEEPSCORE)) + geom_point() +
  geom_smooth(method = "lm") +
  xlab("Bed Lounging at Day 1") +
  ylab("Sleep Score")


SH_14_T1_vs_SS
```

```
`geom_smooth()` using formula = 'y ~ x'
```

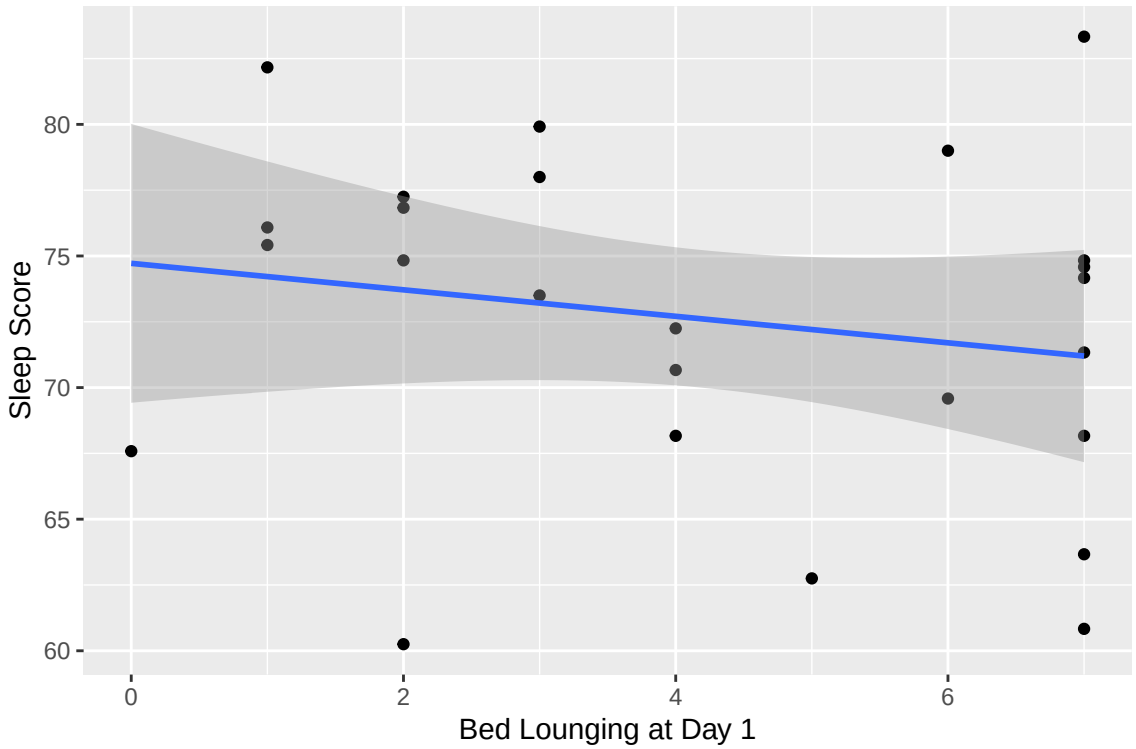


Figure 3: Figure 3. Association between Bed Lounging at Day 1 (T1) and overall sleep score. Each point represents an individual participant's score for Bed Lounging at Day 1 plotted against their corresponding composite sleep score. A simple linear regression line with 95% confidence interval (grey band) is overlaid to illustrate the overall trend, which shows a slight negative association between Bed Lounging at Day 1 and sleep score.

```
#source: Visualize in ggplot (Silhavy & McCarty, 2025): https://shanemccarty.github.io/FRIplayb
#explanation: create scatter plot to visualize the relationship between bed lounging at day 1 v
```

```
ggsave("plots/plot3_SH_14_T1_vs_SS.png",
       plot = SH_14_T1_vs_SS,
       width = 10, height = 8, dpi = 300)
```

```
`geom_smooth()` using formula = 'y ~ x'
```

```
#explanation: save the plot to the "plots" folder
```

```
#correlation_SS_vs_SH_14_T1
cor.test(combined$SH_14_T1, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_14_T1 and combined$SLEEPSCORE
```

```
t = -0.94905, df = 23, p-value = 0.3525
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.5472774  0.2177046
sample estimates:
       cor
-0.1941253
```

```
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

3.3.2 Bed Lounging at Day 7 vs. Sleep Score

Similarly, figure 4 represents a visualization of the relationship between Bed Lounging at Day 7 (SH_14_T2) and sleep score through a scatterplot. Scores were more evenly spread at this post-assessment observation, but the scatterplot indicates virtually no association between bed lounging and sleep score, confirmed by a nonsignificant Pearson correlation (r = .00, p = .997).

```
SH_14_T2_vs_SS <- ggplot(data = combined,
       mapping = aes(
         x = SH_14_T2,
         y = SLEEPSCORE)) + geom_point() +
  geom_smooth(method = "lm") +
  xlab("Bed Lounging at Day 7") +
  ylab("Sleep Score")


SH_14_T2_vs_SS
```

```
`geom_smooth()` using formula = 'y ~ x'
```

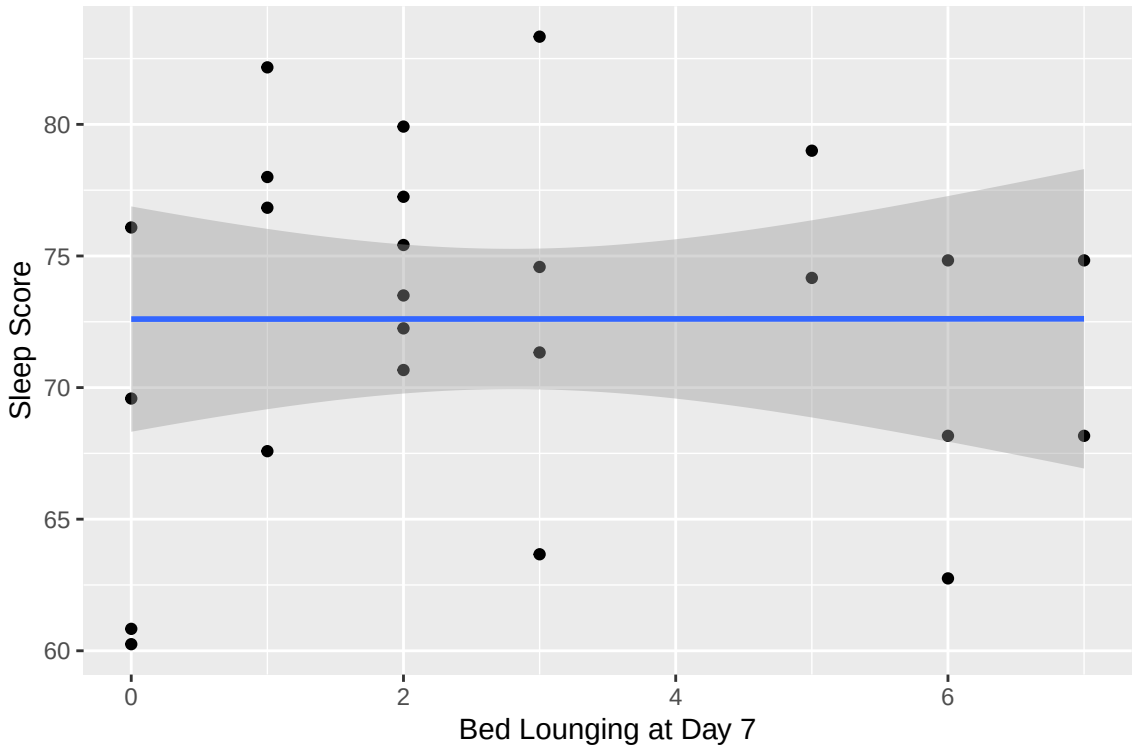


Figure 4: Figure 4. Scatterplot showing the association between Bed Lounging at Day 7 scores and sleep score. A linear regression line with a 95% confidence interval indicates no meaningful relationship between Bed Lounging at Day 7 and participants' sleep scores.

```
#source: Visualize in ggplot (Silhavy & McCarty, 2025): https://shanemccarty.github.io/FRIplayb
#explanation: create scatter plot to visualize the relationship between bed lounging at day 7 v
```

```
ggsave("plots/plot4_SH_14_T2_vs_SS.png",
       plot = SH_14_T2_vs_SS,
       width = 10, height = 8, dpi = 300)
```

```
`geom_smooth()` using formula = 'y ~ x'
```

```
#explanation: save the plot to the "plots" folder
```

```
#correlation_SS_vs_SH_14_T2
cor.test(combined$SH_14_T2, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_14_T2 and combined$SLEEPSCORE
t = 0.0027887, df = 23, p-value = 0.9978
alternative hypothesis: true correlation is not equal to 0
```

```
95 percent confidence interval:
 -0.3946401  0.3956215
sample estimates:
         cor
0.0005814914
```

```
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

3.4 Bright Bedtime Environment at Day 1 and 7 with Sleep Score

3.4.1 Bright Bedtime Environment at Day 1 vs. Sleep Score

Figure 5 illustrates Bright Bedtime Environment at Day 1 (SH_19_T1) versus composite sleep score. Notably, a majority of participants (n = 13) noted no exposure to bright environments at bedtime (score = 0), with only 4 participants scoring 0.5 or higher. The scatterplot shows no meaningful pattern, and the Pearson Correlation indicates a nonsignificant, very weak positive association with sleep score in this sample (r = .04, p = .845).

```
SH_19_T1_vs_SS <- ggplot(data = combined,
       mapping = aes(
         x = SH_19_T1,
         y = SLEEPSCORE)) + geom_point() +
  geom_smooth(method = "lm") +
  xlab("Bright Bedtime Environment at Day 1") +
  ylab("Sleep Score")


SH_19_T1_vs_SS
```

```
`geom_smooth()` using formula = 'y ~ x'
```

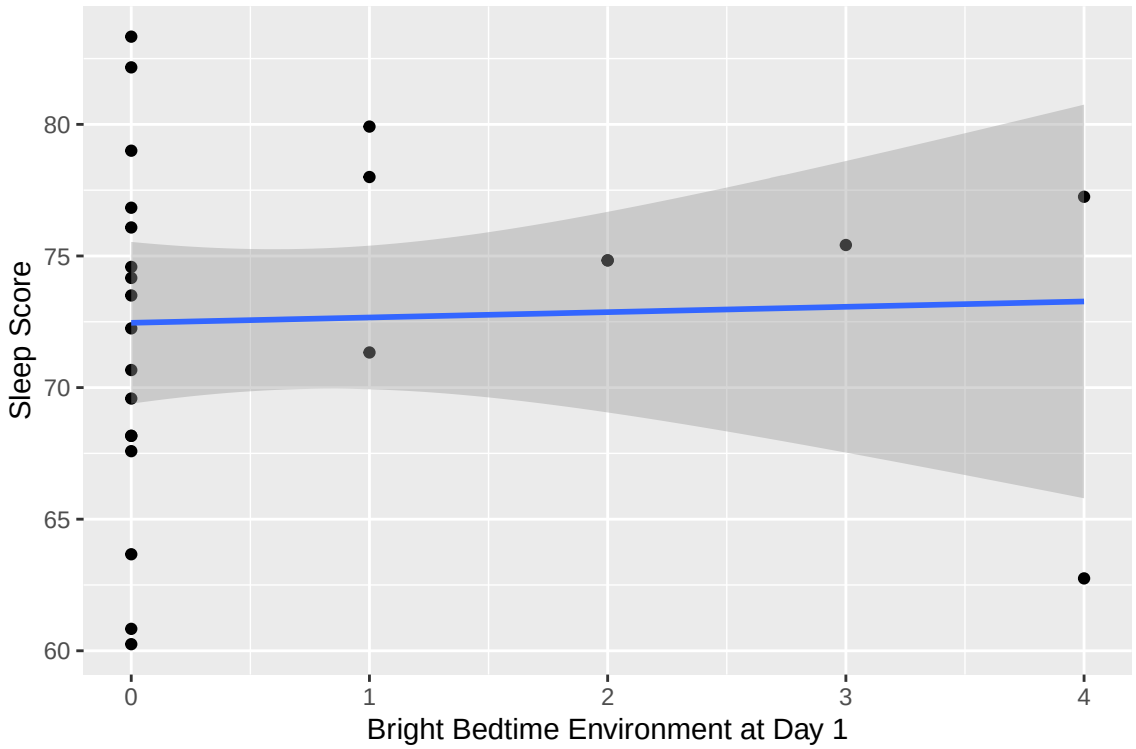


Figure 5: Figure 5. Association between Bright Bedtime Environment at Day 1 and Sleep Score. A scatterplot shows individual participant scores of Bright Bedtime Environment at Day 1 plotted against their sleep scores, with a linear regression line and 95% confidence interval. The model indicates no meaningful linear relationship between Bright Bedtime Environment at Day 1 and overall sleep score.

```
#source: Visualize in ggplot (Silhavy & McCarty, 2025): https://shanemccarty.github.io/FRIplayb
#explanation: create scatter plot to visualize the relationship between bright bedtime environm
```

```
ggsave("plots/plot5_SH_19_T1_vs_SS.png",
       plot = SH_19_T1_vs_SS,
       width = 10, height = 8, dpi = 300)
```

```
`geom_smooth()` using formula = 'y ~ x'
```

```
#explanation: save the plot to the "plots" folder
```

```
#correlation_SS_vs_SH_19_T1
cor.test(combined$SH_19_T1, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_19_T1 and combined$SLEEPSCORE
```

```
t = 0.19681, df = 23, p-value = 0.8457
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.3599587  0.4291815
sample estimates:
       cor
0.04100424
```

```
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

3.4.2 Bright Bedtime Environment at Day 7 vs. Sleep Score

At Day 7 (SH_19_T2), shown in Figure 6, only 7 participants scored above 0 for this sleep hygiene item, with a majority (n = 10) indicating, similar to the pre-assessment, that they did not sleep in an environment that was too bright over the previous 7 days. The scatterplot suggests a slight downward trend, reflecting a weak to moderate negative correlation with sleep score; however this result did not reach statistical significance (r = -.39, p = .054).

```
SH_19_T2_vs_SS <- ggplot(data = combined,
       mapping = aes(
         x = SH_19_T2,
         y = SLEEPSCORE)) + geom_point() +
  geom_smooth(method = "lm") +
  xlab("Bright Bedtime Environment at Day 7") +
  ylab("Sleep Score")


SH_19_T2_vs_SS
```

```
`geom_smooth()` using formula = 'y ~ x'
```

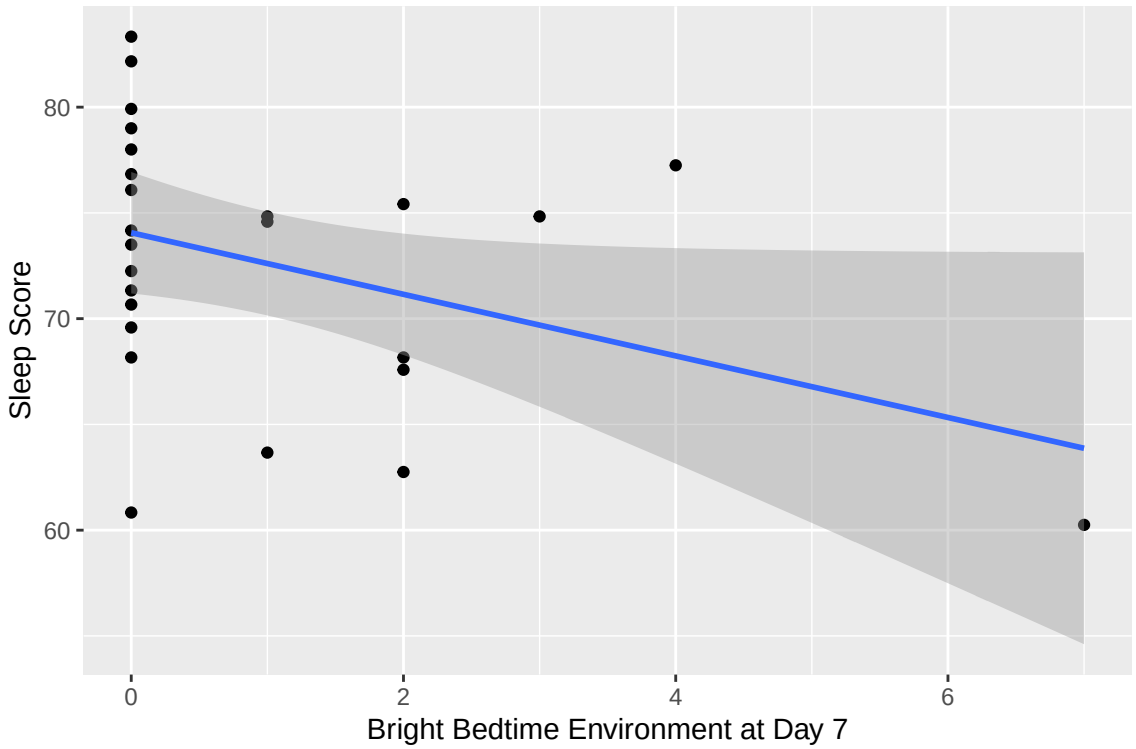


Figure 6: Figure 6. Relationship between Bright Bedtime Environment at Day 7 and sleep score. The scatterplot illustrates individual values for Bright Bedtime Environment at Day 7 versus sleep score, with a fitted linear regression line and confidence band showing a modeate negative association between Bright Bedtime Environment at Day 7 and sleep quality.

```
#source: Visualize in ggplot (Silhavy & McCarty, 2025): https://shanemccarty.github.io/FRIplayb
#explanation: create scatter plot to visualize the relationship between bright bedtime environm
```

```
ggsave("plots/plot6_SH_19_T2_vs_SS.png",
       plot = SH_19_T2_vs_SS,
       width = 10, height = 8, dpi = 300)
```

```
`geom_smooth()` using formula = 'y ~ x'
```

```
#explanation: save the plot to the "plots" folder
```

```
#correlation_SS_vs_SH_19_T2
cor.test(combined$SH_19_T2, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_19_T2 and combined$SLEEPSCORE
```

```
t = -2.0232, df = 23, p-value = 0.05483
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.679467030  0.007607986
sample estimates:
       cor
-0.3886914
```

```
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

Because of the non-significant p-values of all of the correlations between these three sleep hygiene items at pre- and post-assessment and composite sleep score, and because all of their confidence intervals contain zero, the null hypothesis that sleep hygiene behaviors are not associated with sleep score fails to be rejected.

3.5 Sleep Hygiene at Pre- and Post-Assessment

3.5.1 3 Sleep Hygiene Items at Day 1 and Day 7

To examine changes in sleep hygiene behavior over time, data was cleaned to remove any missing values, and only the relevant sleep hygiene and sleep score variables were included. Figure 7 represents violin plots of SH_11, SH_14, and SH_19 from pre-assessment to post-assessment. These plots show that distributions of Bedtime Worrying and Bed Lounging were relatively broad, while Bright Bedtime Environment scores were concentrated near zero at both time points. Median scores appeared largely stable across time points, with no pronounced shifts.

```
SHplotdata <- data.frame(
  Score = c(combined$SH_11_T1, combined$SH_11_T2,
            combined$SH_14_T1, combined$SH_14_T2,
            combined$SH_19_T1, combined$SH_19_T2),
  Group = rep(c("SH_11_T1", "SH_11_T2",
                "SH_14_T1", "SH_14_T2",
                "SH_19_T1", "SH_19_T2"),
              each = nrow(combined))
)

#source: r 4 data science manual
#explanation: make data frame for data to be plotted
```

```
library(dplyr)
SHplotdata <- SHplotdata %>%
  mutate(
    SH = sub("_T[12]", "", Group),      # e.g., SH_11, SH_14, SH_19
    Time = sub(".*_T", "T", Group)      # T1 or T2
  ) %>%
```

```
  mutate(
    Time = factor(Time, levels = c("T1", "T2")),
    SH = factor(SH, levels = c("SH_11", "SH_14", "SH_19"))
  )

#source: r 4 data science manual
#explanation: create variables to group the plot by
```

```
library(ggplot2)
plot_3SH_changes <- ggplot(SHplotdata,
       aes(x = interaction(SH, Time),   # combination like "SH_11.T1", "SH_11.T2", etc.
           y = Score,
           fill = SH)) +
  geom_violin(trim = TRUE, position = position_nudge(x = 0.15)) +
  geom_boxplot(width = .1,
               outlier.shape = NA,
               position = position_nudge(x = -0.15)) +
  geom_point(position = position_nudge(x = -0.35),
             alpha = 0.6) +
  scale_fill_manual(
    name = "Sleep Hygiene Item",
    values = c(
    "SH_11" = "#673888",
    "SH_14" = "#ef4f91",
    "SH_19" = "#c79dd7"
  )) +
  scale_x_discrete(labels = c(
    "SH_11.T1" = "Bedtime Worring at Day 1",
    "SH_11.T2" = "Bedtime Worring at Day 7",
    "SH_14.T1" = "Bed Lounging at Day 1",
    "SH_14.T2" = "Bed Lounging at Day 7",
    "SH_19.T1" = "Bright Bedtime Environment at Day 1",
    "SH_19.T2" = "Bright Bedtime Environment at Day 7"
  )) +
  labs(title = "Change in Sleep Hygiene Scores from Day 1 to Day 7",
       x = "Condition × Time",
       y = "Score (0 Days to 7 Days)") +
  theme_minimal(base_size = 14) +
theme(
  axis.text.x = element_text(angle = 45, hjust = 1),
  plot.margin = margin(t = 10, r = 10, b = 10, l = 25)
)


plot_3SH_changes
```

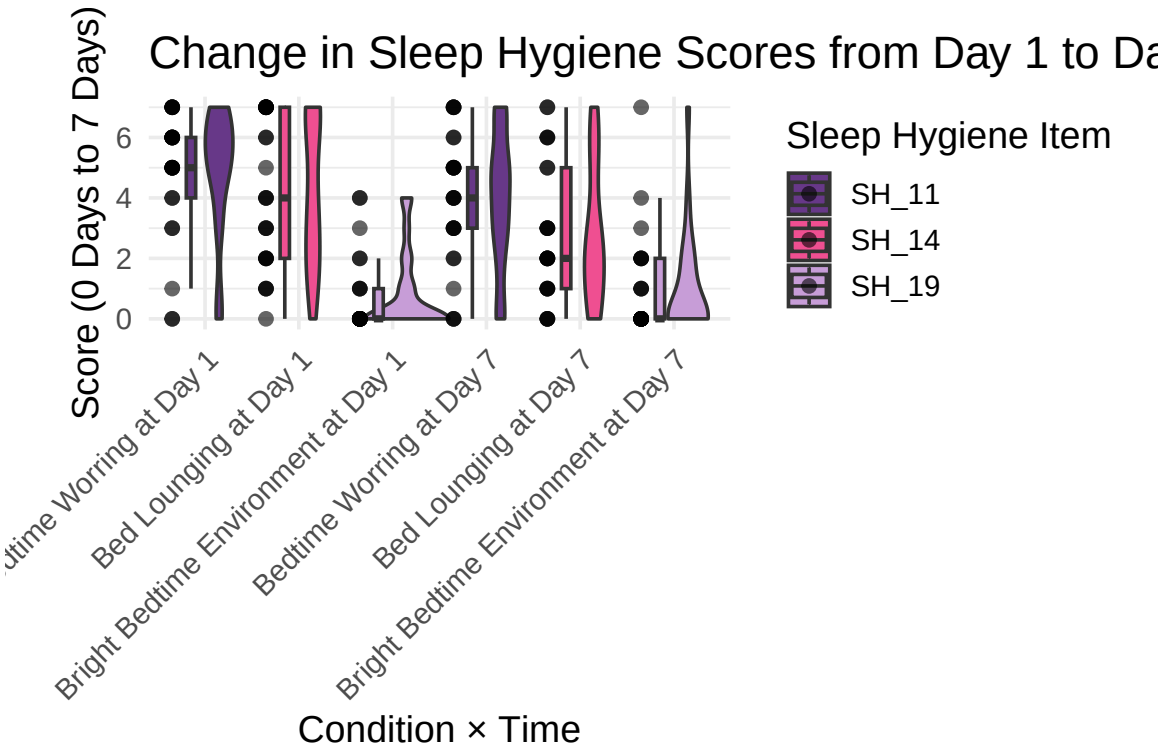


Figure 7: Figure 7. Change in SH scores from Day 1 (T1) to Day 7 (T2) across three SH conditions: Bedtime worrying (SH_11), Bed Lounging (SH_14), and Bright Bedtime Environment (SH_19). Violin plots display the distribution of scores (0–7 days), with overlaid boxplots indicating medians and interquartile ranges and jittered points representing individual participant data.

```
#source: Visualizing pre/post score (Sava, 2025): https://shanemccarty.github.io/FRIplaybook/vi
#explanation: create violin plot to visualize the 3 sleep hygiene items at day 1 and day 7
```

```
ggsave("plots/plot7_3SH.png",
       plot = plot_3SH_changes,
       width = 10, height = 8, dpi = 300)

#explanation: save the plot to the "plots" folder
```

3.5.2 Correlations for Sleep Hygiene at Day 1 and 7 vs. Sleep Score

Additionally, Pearson correlations were calculated to assess the relationship between composite sleep hygiene scores for pre- and post-assessment and composite sleep score. At pre-assessment, there was a nonsignificant, very weak positive association between sleep hygiene scores and sleep scores ($r = .04$, $p = .826$), and at post-assessment there was a nonsignificant, weak negative association between these two variables ($r = -.20$, $p = .339$). These results suggest that in this sample, composite sleep hygiene scores were not related to composite sleep quality.

```r
#correlation_SS_vs_SH_T1
cor.test(combined$SH_T1, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_T1 and combined$SLEEPSCORE
t = 0.22156, df = 23, p-value = 0.8266
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.3554636  0.4333775
sample estimates:
      cor
0.0461492
```

```r
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

```r
#correlation_SS_vs_SH_T2
cor.test(combined$SH_T2, combined$SLEEPSCORE, method = 'pearson')
```

```
    Pearson's product-moment correlation

data:  combined$SH_T2 and combined$SLEEPSCORE
t = -0.97611, df = 23, p-value = 0.3392
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.5511416  0.2124272
sample estimates:
       cor
-0.1994444
```

```r
#source: https://www.r-bloggers.com/2021/10/pearson-correlation-in-r/, https://www.onlinespss.
#explanation: calculate pearson correlation to quantify the strength of the relationship betwe
```

4 Discussion

The primary aim of this study was to examine whether behavioral sleep hygiene practices were associated with sleep quality among university students participating in a structured research program. Contrary to our hypothesis and the health promotion and prevention model — which suggests that engaging in health-supportive behaviors should protect against poor outcomes (Kia-Keating et al., 2011) — no significant correlations were found between sleep hygiene scores and

objective sleep quality as measured by the MUSE-S headband. Thus, the null hypothesis is not rejected, suggesting that behavioral sleep hygiene does not influence sleep quality in this sample.

These findings must be interpreted in context. This study was conducted with a small, homogenous cohort from a single university program, limiting statistical power and variability in sleep hygiene behaviors. As such, the absence of a significant association does not necessarily indicate that sleep hygiene has no relationship with sleep quality; instead, it may reflect sampling limitations. Additionally, while the health promotion and prevention model would predict better sleep among individuals who engage in healthy sleep behaviors, the current results suggest that behavioral intentions or self-reported practices may not consistently translate into measurable physiological sleep outcomes in this population.

These findings should be understood in light of the broader public health context outlined in the introduction. As noted earlier, university students are experiencing rising rates of mental distress (Choudhry et al., 2016), and high-quality sleep is increasingly recognized as a protective factor for emotional well-being, cognitive functioning, and long-term mental health (Bodziony & Stetson, 2024; Palmer & Alfano, 2017). This study was designed to address the methodological gap in the literature by pairing a self-report sleep hygiene measure with the MUSE-S device in order to capture physiological sleep quality aligned with the NIMH's RDoC framework (Michelini et. al., 2021). Although our hypothesis was not supported, the absence of a significant association between sleep hygiene and MUSE-S sleep score underscores the complexity of sleep as a health behavior and suggests that subjective perceptions of "good sleep habits" may not uniformly translate into measurable physiological benefits — at least within short observational periods among college students. Rather than contradicting the broader literature linking sleep and well-being, these findings may instead highlight the importance of both accurate self-monitoring and sufficient time for behavioral change to meaningfully influence biological sleep outcomes.

4.1 Physiological Vs. Self-Report Measures

A key feature of this study was the integration of an older, self-report sleep hygiene questionnaire with modern wearable sleep technology. The discrepancy between these measures may be due to several factors. Self-reported sleep hygiene relies on perception, recall accuracy, and subjective interpretation of habits, which may not fully capture the consistency or quality of sleep behaviors. Participants may overestimate their adherence due to social desirability or misjudge the quality of their routines. In contrast, the MUSE-S provides continuous, objective physiological data, capturing sleep duration and quality moment-to-moment. Therefore, it is plausible that while participants believed they engaged in strong sleep hygiene practices, these behaviors were not sufficient to materially influence their physiological sleep outcomes. It is also possible that the components most strongly affecting sleep physiology (e.g., stress, caffeine timing, circadian rhythm stability) were not fully reflected in the self-report instrument used.

4.2 Pre- and Post-Assessment Differences

While correlations across both pre- and post-assessments were non-significant, slight directional variation was observed, with sleep hygiene behaviors becoming more predictive of sleep quality at time 2 (Table 2). One potential explanation for these shifts is that, prior to the study, participants were not actively tracking or reflecting on their sleep habits, leading to less accurate or less intentional

self-reporting. Participating in a week-long sleep study likely increased awareness of individual sleep behaviors, which may have either improved reporting accuracy or prompted participants to modify their behaviors in real time. In other words, being monitored may have influenced both perception and action — a "measurement reactivity" effect commonly observed in behavioral research. As such, the post-assessment correlations may capture more accurate self-monitoring and/or early behavior change attempts, even if those changes were not yet sufficient to produce measurable improvements in physiological sleep metrics.

4.2.1 Broader Implications

Although this study did not find support for a protective relationship between sleep hygiene and sleep outcomes, it highlights the growing importance of integrating subjective and objective measures in behavioral health research. University students face unique stressors and irregular schedules, which may blunt the effects of even well-intentioned sleep hygiene behaviors. These findings may therefore encourage public health and campus wellness initiatives to move beyond education alone and incorporate structured sleep support interventions, such as behavioral coaching, stress-reduction programs, and more.

4.2.2 Limitations

This study is limited by its small, program-specific sample, and the use of one self-report scale alongside one physiological metric. Additionally, sleep hygiene behaviors were not experimentally manipulated, meaning that causal conclusions cannot be drawn. Despite these limitations, the study demonstrates feasibility of wearable-integrated sleep research in undergraduate settings and highlights key methodological considerations for future work.

4.2.3 Future Directions

Future research should recruit larger and more diverse student samples to improve generalizability and statistical power. Researchers may also benefit from incorporating multi-method sleep assessments, such as ecological momentary assessment, sleep diaries, or actigraphy, to bridge self-report and physiological measures. A novel next step would be to experimentally manipulate specific sleep hygiene behaviors — such as consistent wake times or evening screen-use reductions — to determine whether objective sleep improvements follow. If given the opportunity to extend this research, we would conduct a semester-long randomized intervention pairing behavioral sleep hygiene training with wearable feedback, allowing for real-time correction and assessment of sleep behavior change over time.