

# Project 3: Sleep Analytics

## Project Overview

- This project aims to create a personalized sleep health coaching tool using data science techniques. By analyzing individual sleep patterns and academic performance, the tool will provide tailored recommendations to help students optimize their sleep habits and improve their academic outcomes.

## Key Objectives:

- Categorize students based on sleep patterns and academic performance.
- Generate personalized sleep recommendations based on identified categories.
- Validate the effectiveness of recommendations in improving sleep quality and academic performance.

## Methodology:

- **Data Collection:** Gather data on students' sleep habits, academic performance, and relevant demographics.
- **Data Preprocessing:** Clean and prepare the data for analysis, handling missing values and outliers.
- **Clustering:** Employ clustering techniques to identify distinct student profiles based on their sleep and academic characteristics.
- **Recommendation Generation:** Develop a model to generate personalized recommendations based on the identified clusters and key factors influencing sleep and academic performance.
- **Evaluation:** Assess the effectiveness of the recommendations through metrics such as user satisfaction, changes in sleep quality, and improvements in academic performance.

## Expected Outcomes:

- **Student Profiles:** Identification of distinct groups of students with unique sleep and academic needs.
- **Personalized Recommendations:** Tailored advice to optimize sleep habits and improve academic outcomes.
- **Positive Impact:** Measurable improvements in students' sleep quality and academic performance.

## Challenges and Considerations:

- **Data Quality:** Ensuring the accuracy and completeness of sleep and academic data.
- **Privacy:** Protecting students' personal information and ensuring responsible data usage.
- **Recommendation Effectiveness:** Validating the effectiveness of the recommendations through rigorous evaluation.

## Future Directions:

- **Expand Data:** Incorporate additional data points (e.g., stress levels, exercise habits) for more comprehensive recommendations.
- **Longitudinal Studies:** Conduct longitudinal studies to track the long-term impact of the recommendations.
- **Integration with Other Tools:** Integrate the sleep coach with other academic tools or platforms for seamless user experience.
- **Continuous Improvement:** Continuously refine the model and recommendations based on user feedback and evolving research.

# 1. Data Pre-processing

In [3]:

```
# Import Libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

In [4]:

```
# Load the dataset
df = pd.read_csv('cmu-sleep.csv')

# Confirm dataset is Loaded
df.head()
```

Out[4]:

|   | subject_id | study | cohort | demo_race | demo_gender | demo_firstgen | bedtime_mssd | TotalSleepTime |
|---|------------|-------|--------|-----------|-------------|---------------|--------------|----------------|
| 0 | 185        | 5     | lac1   | 1         | 1           | 0             | 0.116727     | 432.200000     |
| 1 | 158        | 5     | lac1   | 0         | 1           | 0             | 0.141681     | 391.931035     |
| 2 | 209        | 5     | lac1   | 1         | 1           | 0             | 1.529289     | 344.304348     |
| 3 | 102        | 5     | lac1   | 0         | 1           | 1             | 0.130148     | 392.620690     |
| 4 | 174        | 5     | lac1   | 1         | 1           | 0             | 0.130181     | 423.421053     |

In [5]:

```
# Confirm dataset details

print(f'\nDataset Info: \n{df.info()}')
print(f'\nSummary Statistics: \n{df.describe()}')
print(f'\nUnqie Values: \n{df.unique()}')
print(f'\nRows and Cols: \n{df.shape}')
print(f'\nColumn Names: \n{df.columns}')
print(f'\n Data Types: \n{df.dtypes}')
print(f'\n Missing Values: \n{df.isnull().sum()}' )
```

```

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 634 entries, 0 to 633
Data columns (total 15 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   subject_id      634 non-null    int64  
 1   study           634 non-null    int64  
 2   cohort          634 non-null    object  
 3   demo_race       634 non-null    object  
 4   demo_gender     634 non-null    object  
 5   demo_firstgen   634 non-null    object  
 6   bedtime_mssd    634 non-null    float64 
 7   TotalSleepTime  634 non-null    float64 
 8   midpoint_sleep  634 non-null    float64 
 9   frac_nights_with_data  634 non-null    float64 
 10  daytime_sleep   634 non-null    float64 
 11  cum_gpa         634 non-null    float64 
 12  term_gpa        634 non-null    float64 
 13  term_units      634 non-null    object  
 14  Zterm_units_ZofZ  634 non-null    object  
dtypes: float64(7), int64(2), object(6)
memory usage: 74.4+ KB

```

#### Dataset Info:

None

#### Summary Statistics:

|       | subject_id            | study         | bedtime_mssd | TotalSleepTime | midpoint_sleep | \ |
|-------|-----------------------|---------------|--------------|----------------|----------------|---|
| count | 634.000000            | 634.000000    | 634.000000   | 634.000000     | 634.000000     |   |
| mean  | 13005.892744          | 3.181388      | 0.451688     | 397.323874     | 398.679186     |   |
| std   | 26496.593477          | 1.317125      | 1.393632     | 50.856725      | 72.710945      |   |
| min   | 1.000000              | 1.000000      | 0.004505     | 194.782609     | 247.071429     |   |
| 25%   | 178.000000            | 2.000000      | 0.074694     | 366.930077     | 345.182692     |   |
| 50%   | 358.500000            | 3.000000      | 0.135007     | 400.395833     | 388.245726     |   |
| 75%   | 592.750000            | 4.000000      | 0.291698     | 430.114583     | 437.655263     |   |
| max   | 99978.000000          | 5.000000      | 20.849225    | 587.666667     | 724.666667     |   |
|       | frac_nights_with_data | daytime_sleep | cum_gpa      | term_gpa       |                |   |
| count | 634.000000            | 634.000000    | 634.000000   | 634.000000     |                |   |
| mean  | 0.867439              | 41.164241     | 3.465596     | 3.449598       |                |   |
| std   | 0.178960              | 27.389418     | 0.437577     | 0.500467       |                |   |
| min   | 0.214286              | 2.269231      | 1.210000     | 0.350000       |                |   |
| 25%   | 0.821429              | 23.097826     | 3.232283     | 3.233333       |                |   |
| 50%   | 0.932184              | 34.982143     | 3.557833     | 3.555667       |                |   |
| 75%   | 1.000000              | 51.248538     | 3.789545     | 3.810000       |                |   |
| max   | 1.000000              | 292.304348    | 4.000000     | 4.000000       |                |   |

#### Unqiue Values:

|                       |     |
|-----------------------|-----|
| subject_id            | 547 |
| study                 | 5   |
| cohort                | 5   |
| demo_race             | 3   |
| demo_gender           | 3   |
| demo_firstgen         | 4   |
| bedtime_mssd          | 633 |
| TotalSleepTime        | 625 |
| midpoint_sleep        | 629 |
| frac_nights_with_data | 59  |
| daytime_sleep         | 611 |
| cum_gpa               | 397 |

```
term_gpa           263
term_units          41
Zterm_units_ZofZ      66
dtype: int64
```

Rows and Cols:  
(634, 15)

Column Names:

```
Index(['subject_id', 'study', 'cohort', 'demo_race', 'demo_gender',
       'demo_firstgen', 'bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep',
       'frac_nights_with_data', 'daytime_sleep', 'cum_gpa', 'term_gpa',
       'term_units', 'Zterm_units_ZofZ'],
      dtype='object')
```

Data Types:

```
subject_id        int64
study            int64
cohort           object
demo_race         object
demo_gender       object
demo_firstgen    object
bedtime_mssd     float64
TotalSleepTime   float64
midpoint_sleep   float64
frac_nights_with_data float64
daytime_sleep    float64
cum_gpa          float64
term_gpa          float64
term_units        object
Zterm_units_ZofZ  object
dtype: object
```

Missing Values:

```
subject_id        0
study            0
cohort           0
demo_race         0
demo_gender       0
demo_firstgen    0
bedtime_mssd     0
TotalSleepTime   0
midpoint_sleep   0
frac_nights_with_data 0
daytime_sleep    0
cum_gpa          0
term_gpa          0
term_units        0
Zterm_units_ZofZ  0
dtype: int64
```

```
In [6]: # Confirm categorical variables
df.select_dtypes(include=['object']).info()
print(f'\nCohort: \n{df["cohort"].value_counts()}\n')
print(f'\nGender: \n{df["demo_gender"].value_counts()}\n')
print(f'\nRace: \n{df["demo_race"].value_counts()}\n')
print(f'\nFirstGen: \n{df["demo_firstgen"].value_counts()}\n')
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 634 entries, 0 to 633
Data columns (total 6 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   cohort            634 non-null    object  
 1   demo_race         634 non-null    object  
 2   demo_gender       634 non-null    object  
 3   demo_firstgen     634 non-null    object  
 4   term_units        634 non-null    object  
 5   Zterm_units_ZofZ  634 non-null    object  
dtypes: object(6)
memory usage: 29.8+ KB
```

Cohort:

```
cohort
nh      147
uw1     140
uw2     139
lac1    131
lac2     77
Name: count, dtype: int64
```

Gender:

```
demo_gender
1      368
0      263
      3
Name: count, dtype: int64
```

Race:

```
demo_race
1      514
0      119
      1
Name: count, dtype: int64
```

FirstGen:

```
demo_firstgen
0      526
1      103
      4
2      1
Name: count, dtype: int64
```

```
In [7]: # Change Term units and Z Term Units of Z to numerical
# Replace empty strings or spaces with NaN
```

```
df['term_units'] = df['term_units'].replace(' ', np.nan)
df['Zterm_units_ZofZ'] = df['Zterm_units_ZofZ'].replace(' ', np.nan)
```

```
# Convert the column to float
```

```
df['term_units'] = df['term_units'].astype(float)
df['Zterm_units_ZofZ'] = df['Zterm_units_ZofZ'].astype(float)
```

```
# Confirm numerical variables
```

```

df.select_dtypes(include=['int64', 'float64']).info()
df.select_dtypes(include=['int64', 'float64']).describe().T

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 634 entries, 0 to 633
Data columns (total 11 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   subject_id      634 non-null    int64  
 1   study           634 non-null    int64  
 2   bedtime_mssd   634 non-null    float64 
 3   TotalSleepTime 634 non-null    float64 
 4   midpoint_sleep 634 non-null    float64 
 5   frac_nights_with_data 634 non-null    float64 
 6   daytime_sleep   634 non-null    float64 
 7   cum_gpa          634 non-null    float64 
 8   term_gpa         634 non-null    float64 
 9   term_units       487 non-null    float64 
 10  Zterm_units_ZofZ 487 non-null    float64 
dtypes: float64(9), int64(2)
memory usage: 54.6 KB

```

|                              | count | mean         | std          | min        | 25%        | 50%        | 7        |
|------------------------------|-------|--------------|--------------|------------|------------|------------|----------|
| <b>subject_id</b>            | 634.0 | 1.300589e+04 | 26496.593477 | 1.000000   | 178.000000 | 358.500000 | 592.7500 |
| <b>study</b>                 | 634.0 | 3.181388e+00 | 1.317125     | 1.000000   | 2.000000   | 3.000000   | 4.0000   |
| <b>bedtime_mssd</b>          | 634.0 | 4.516879e-01 | 1.393632     | 0.004505   | 0.074694   | 0.135007   | 0.2916   |
| <b>TotalSleepTime</b>        | 634.0 | 3.973239e+02 | 50.856725    | 194.782609 | 366.930077 | 400.395833 | 430.114! |
| <b>midpoint_sleep</b>        | 634.0 | 3.986792e+02 | 72.710945    | 247.071429 | 345.182692 | 388.245726 | 437.655! |
| <b>frac_nights_with_data</b> | 634.0 | 8.674389e-01 | 0.178960     | 0.214286   | 0.821429   | 0.932184   | 1.0000   |
| <b>daytime_sleep</b>         | 634.0 | 4.116424e+01 | 27.389418    | 2.269231   | 23.097826  | 34.982143  | 51.248!  |
| <b>cum_gpa</b>               | 634.0 | 3.465596e+00 | 0.437577     | 1.210000   | 3.232283   | 3.557833   | 3.789!   |
| <b>term_gpa</b>              | 634.0 | 3.449598e+00 | 0.500467     | 0.350000   | 3.233333   | 3.555667   | 3.8100   |
| <b>term_units</b>            | 487.0 | 2.939220e+01 | 17.642780    | 5.000000   | 15.000000  | 17.000000  | 48.0000  |
| <b>Zterm_units_ZofZ</b>      | 487.0 | 1.437371e-11 | 1.000000     | -3.982521  | -0.551042  | 0.041207   | 0.560!   |

## 2. Exploratory Data Analysis

### Priority List

#### 1. Univariate Analysis

##### Categorical Variables:

- Analyze the distribution of categorical variables (e.g., demo\_race, demo\_gender, demo\_firstgen, cohort) using frequency tables, bar charts, or pie charts.

- Identify any imbalances or dominant categories.

#### **Numerical Variables:**

- Examine the distribution of numerical variables (e.g., bedtime\_mssd, TotalSleepTime, midpoint\_sleep, frac\_nights\_with\_data) using histograms, box plots, and summary statistics.
- Identify outliers, skewness, and kurtosis.

## **2. Bivariate Analysis**

#### **Categorical-Categorical:**

- Analyze the relationship between categorical variables using cross-tabulation and chi-square tests.
- For example, examine the relationship between demo\_race and demo\_gender.

#### **Numerical-Numerical:**

- Calculate correlation coefficients between numerical variables to identify potential relationships.
- For example, assess the correlation between bedtime\_mssd and TotalSleepTime.

#### **Categorical-Numerical:**

- Explore the relationship between categorical and numerical variables using group statistics, box plots, or ANOVA.
- For example, compare the average TotalSleepTime across different demo\_gender categories.

## **3. Multivariate Analysis**

- **Dimensionality Reduction:** Consider techniques like Principal Component Analysis (PCA) or t-SNE to reduce the dimensionality of the dataset and identify underlying patterns.
- **Clustering:** Explore clustering algorithms (e.g., K-means, hierarchical clustering) to group similar participants based on their characteristics.
- **Regression Analysis:** Use regression models to predict target variables (e.g., term\_gpa) based on other variables.

## **4. Data Cleaning and Preprocessing**

- **Handle Outliers:** Identify and address outliers in numerical variables using techniques like Winsorization or trimming.
- **Impute Missing Values:** If there are any missing values (which are not present in the provided data), consider imputation methods like mean/median imputation or more advanced techniques.
- **Feature Engineering:** Create new features or transform existing ones to capture more relevant information. For example, you could create a feature for the difference between

bedtime and wake\_up\_time.

## 5. Exploratory Analysis Based on Domain Knowledge

- Leverage your understanding of sleep patterns, academic performance, and other relevant factors to guide your EDA.
- For example, explore the relationship between daytime\_sleep and term\_gpa to understand the impact of daytime napping on academic performance.

## Univariate Analysis

### Categorical Variables

```
In [8]: # Univariate Analysis
# Categorical Variables: Analyze the distribution of categorical variables (demo_gender)
# There are missing and inaccurate values for each variable that need to be removed before analysis

# Gender
print(f'\nGender: \n{df["demo_gender"].value_counts()}\n')
print(f'\nGender: \n{df["demo_gender"].value_counts(normalize=True)*100}\n')
sns.countplot(x='demo_gender', data=df)
plt.title('Gender Distribution')
plt.show()

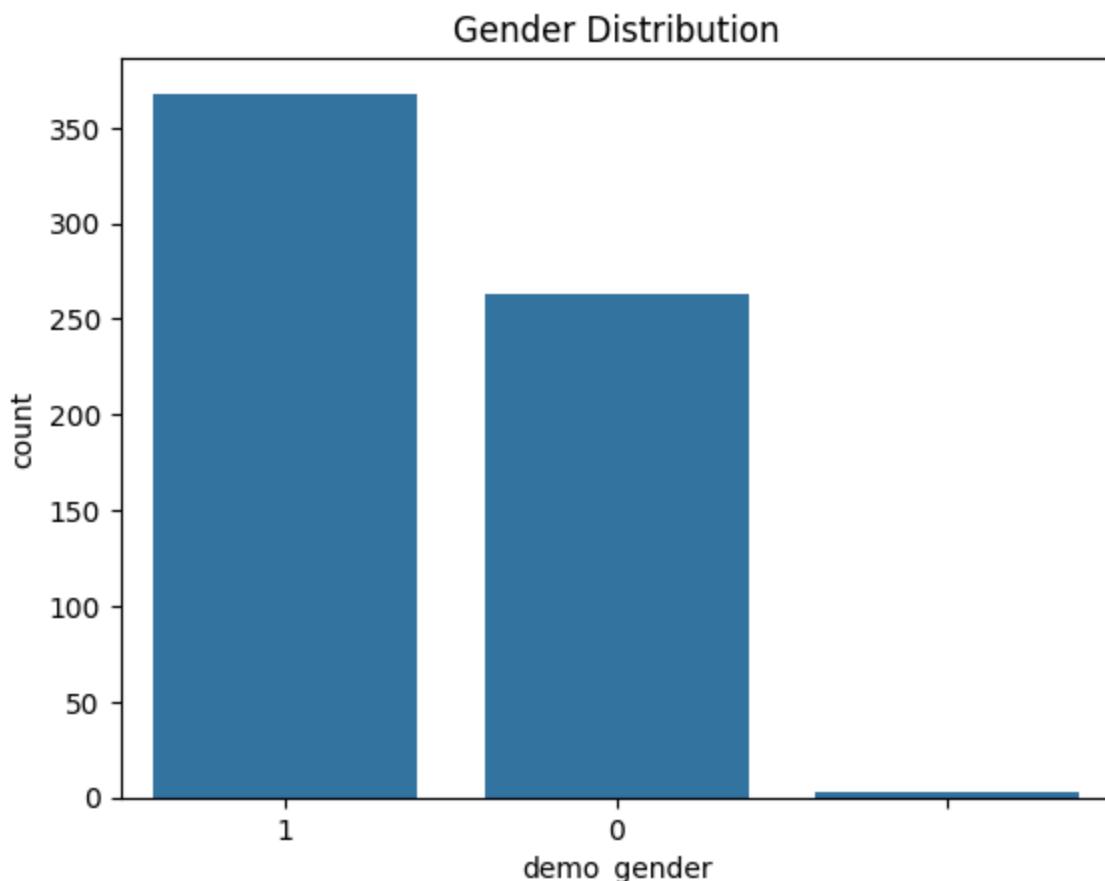
# FirstGen
print(f'\nFirstGen: \n{df["demo_firstgen"].value_counts()}\n')
print(f'\nFirstGen: \n{df["demo_firstgen"].value_counts(normalize=True)*100}\n')
sns.countplot(x='demo_firstgen', data=df)
plt.title('FirstGen Distribution')
plt.show()

# Race
print(f'\nRace: \n{df["demo_race"].value_counts()}\n')
print(f'\nRace: \n{df["demo_race"].value_counts(normalize=True)*100}\n')
sns.countplot(x='demo_race', data=df)
plt.title('Race Distribution')
plt.show()

# Cohort
print(f'\nCohort: \n{df["cohort"].value_counts()}\n')
print(f'\nCohort: \n{df["cohort"].value_counts(normalize=True)*100}\n')
sns.countplot(x='cohort', data=df)
plt.title('Cohort Distribution')
plt.show()
```

```
Gender:  
demo_gender  
1    368  
0    263  
     3  
Name: count, dtype: int64
```

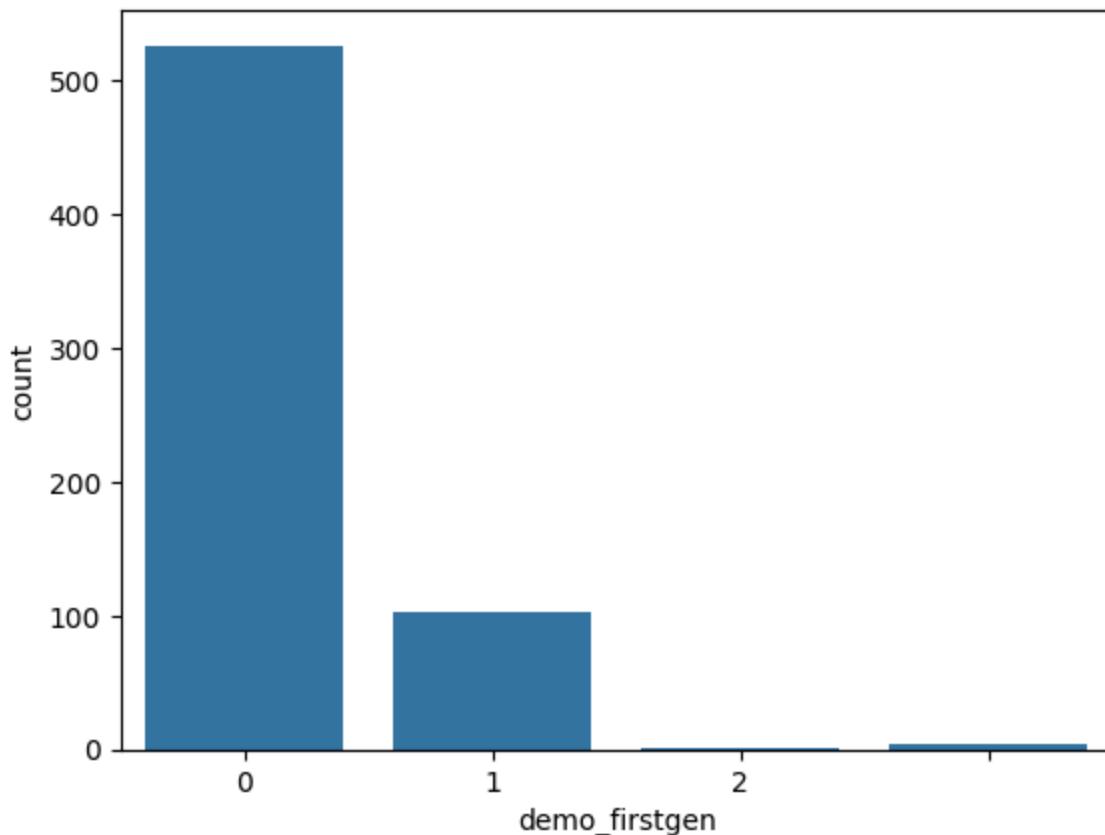
```
Gender:  
demo_gender  
1    58.044164  
0    41.482650  
     0.473186  
Name: proportion, dtype: float64
```



```
FirstGen:  
demo_firstgen  
0    526  
1    103  
     4  
2     1  
Name: count, dtype: int64
```

```
FirstGen:  
demo_firstgen  
0    82.965300  
1    16.246057  
     0.630915  
2     0.157729  
Name: proportion, dtype: float64
```

FirstGen Distribution



Race:

demo\_race

1 514

0 119

1

Name: count, dtype: int64

Race:

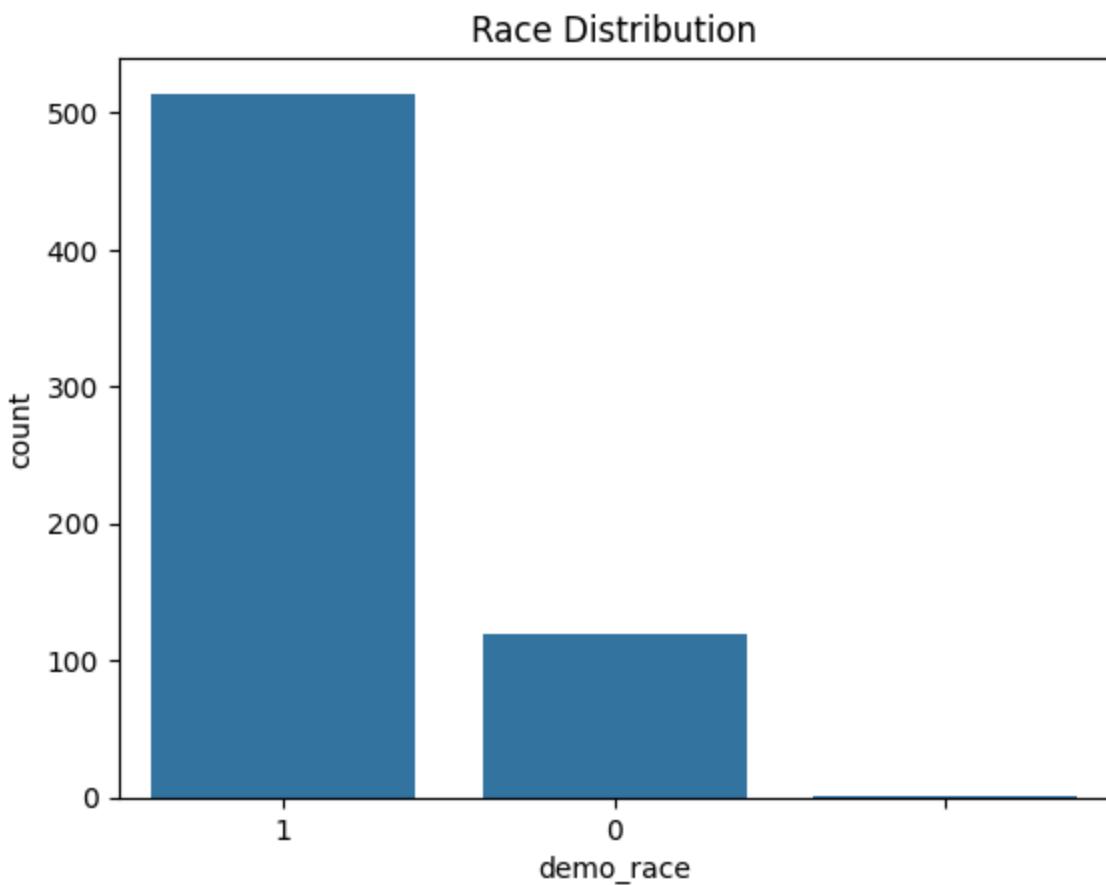
demo\_race

1 81.072555

0 18.769716

0.157729

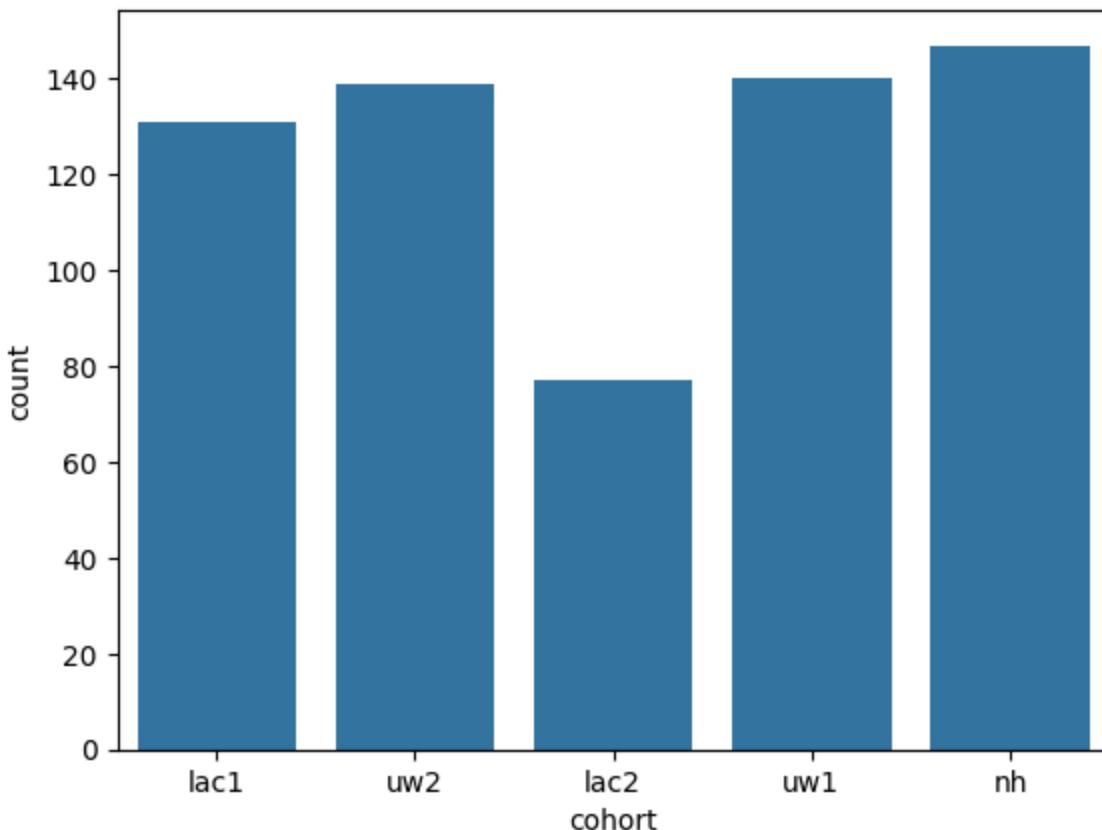
Name: proportion, dtype: float64



```
Cohort:  
cohort  
nh      147  
uw1     140  
uw2     139  
lac1    131  
lac2     77  
Name: count, dtype: int64
```

```
Cohort:  
cohort  
nh      23.186120  
uw1     22.082019  
uw2     21.924290  
lac1    20.662461  
lac2    12.145110  
Name: proportion, dtype: float64
```

### Cohort Distribution



```
In [9]: # Remove missing and inaccurate information from categorical variables
df = df.dropna(subset=['demo_gender', 'demo_firstgen', 'demo_race'])
df = df[df['demo_gender'].isin(['0', '1'])]
df = df[df['demo_firstgen'].isin(['0', '1'])]
df = df[df['demo_race'].isin(['0', '1'])]

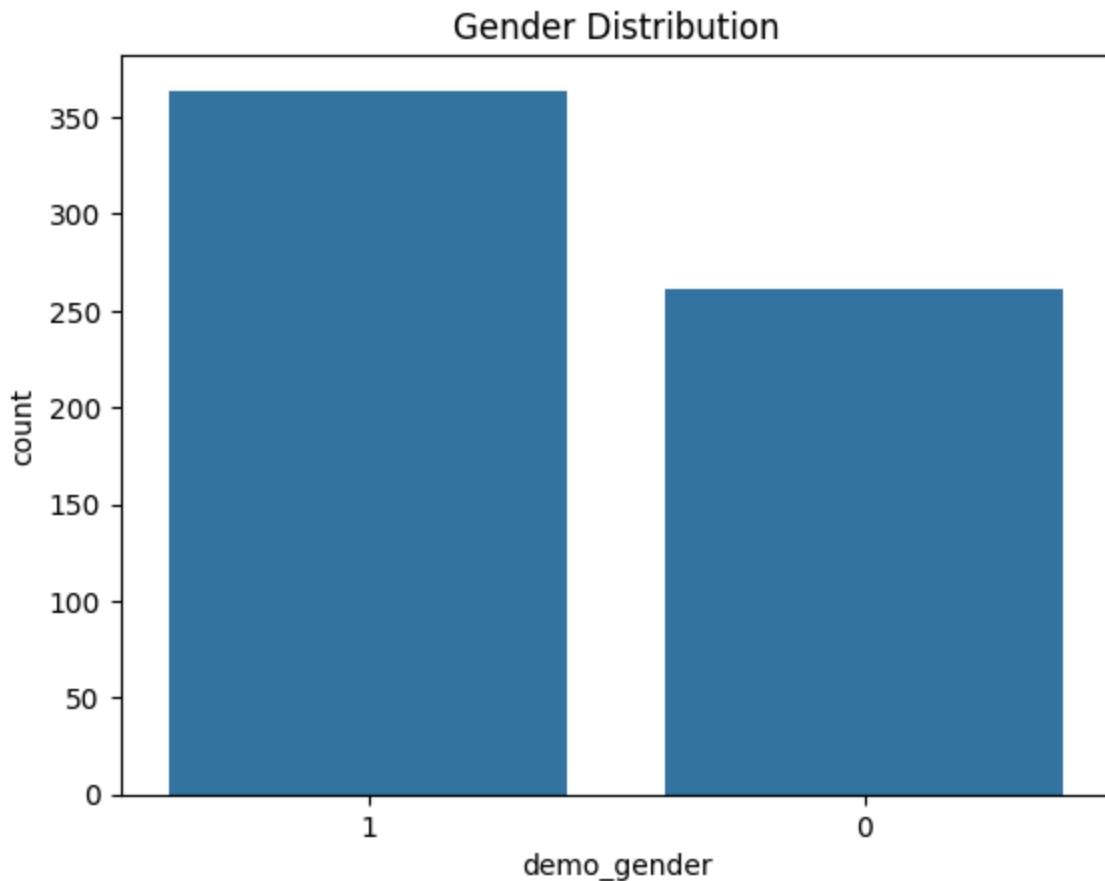
# Gender
print(f'\nGender: \n{df["demo_gender"].value_counts()}\n')
print(f'\nGender: \n{df["demo_gender"].value_counts(normalize=True)*100}\n')
sns.countplot(x='demo_gender', data=df)
plt.title('Gender Distribution')
plt.show()

# FirstGen
print(f'\nFirstGen: \n{df["demo_firstgen"].value_counts()}\n')
print(f'\nFirstGen: \n{df["demo_firstgen"].value_counts(normalize=True)*100}\n')
sns.countplot(x='demo_firstgen', data=df)
plt.title('FirstGen Distribution')
plt.show()

# Race
print(f'\nRace: \n{df["demo_race"].value_counts()}\n')
print(f'\nRace: \n{df["demo_race"].value_counts(normalize=True)*100}\n')
sns.countplot(x='demo_race', data=df)
plt.title('Race Distribution')
plt.show()
```

```
Gender:  
demo_gender  
1    364  
0    261  
Name: count, dtype: int64
```

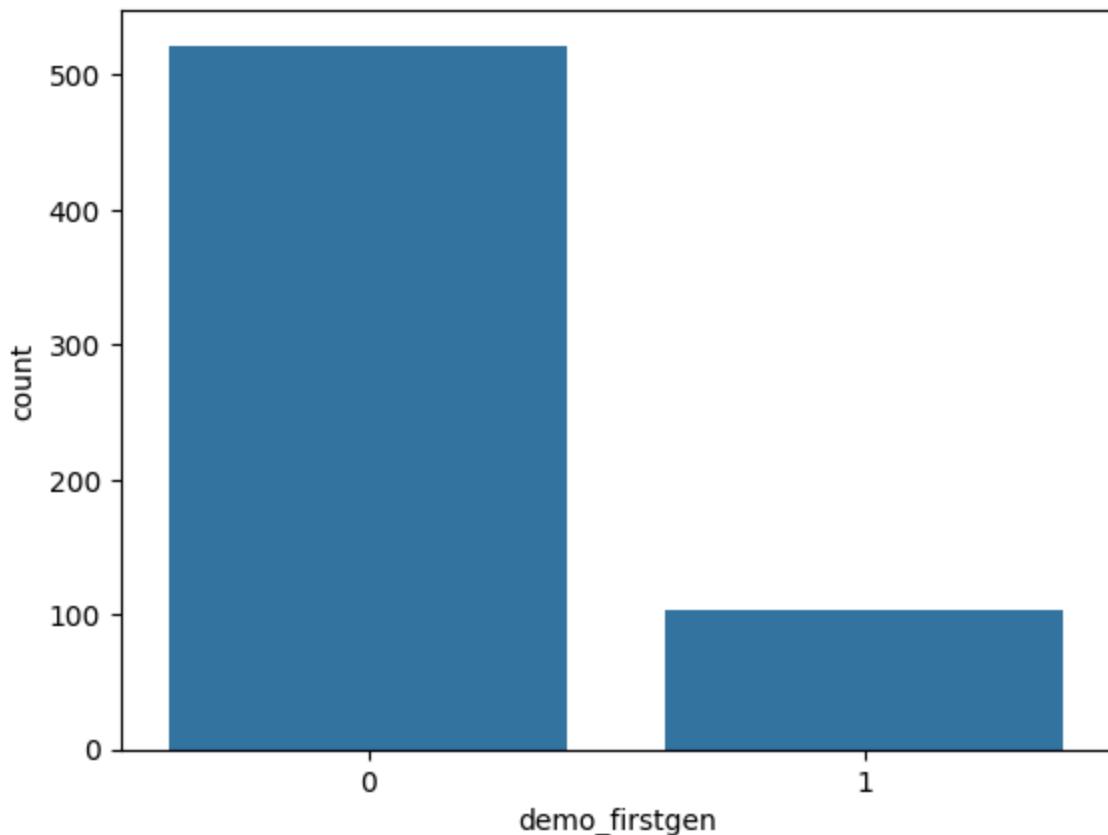
```
Gender:  
demo_gender  
1    58.24  
0    41.76  
Name: proportion, dtype: float64
```



```
FirstGen:  
demo_firstgen  
0    522  
1    103  
Name: count, dtype: int64
```

```
FirstGen:  
demo_firstgen  
0    83.52  
1    16.48  
Name: proportion, dtype: float64
```

FirstGen Distribution



Race:

demo\_race

1 507

0 118

Name: count, dtype: int64

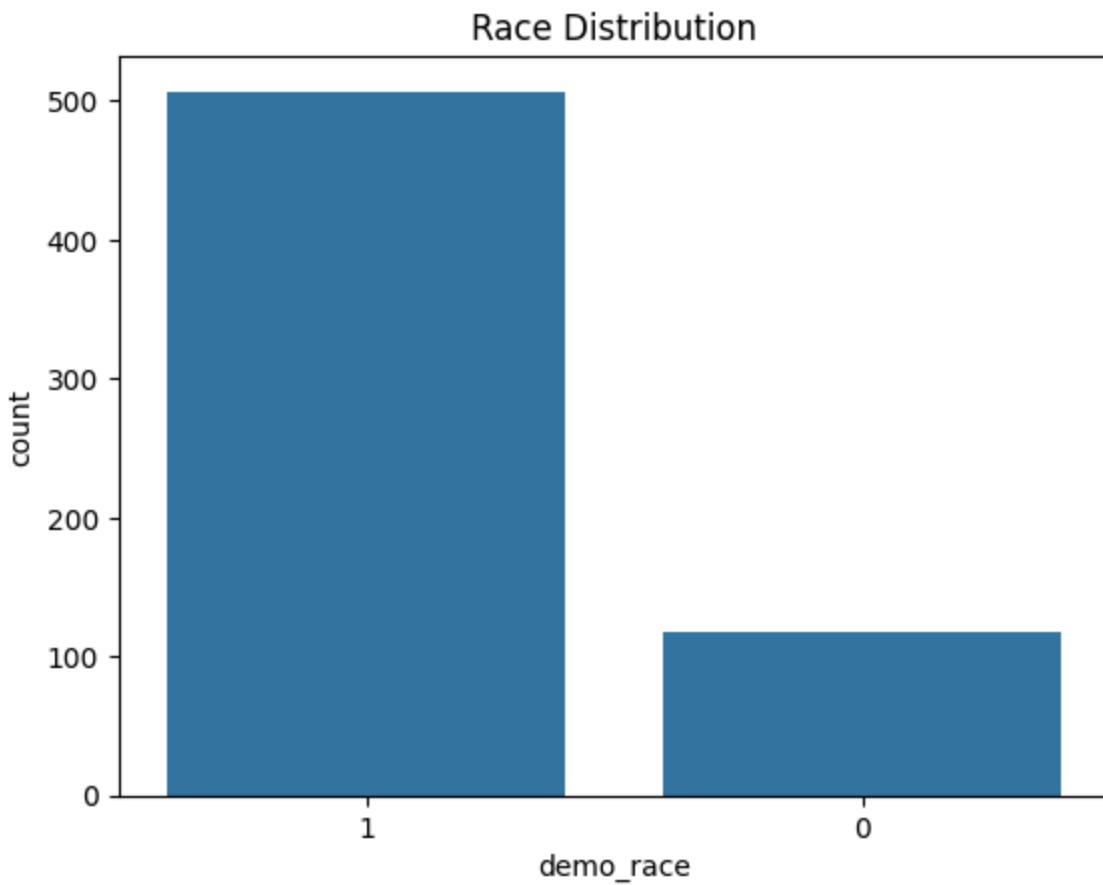
Race:

demo\_race

1 81.12

0 18.88

Name: proportion, dtype: float64



```
In [10]: # Explore distributions of each categorical column (demo_gender, demo_race, demo_firstgen)

# Create histogram for each categorical variable

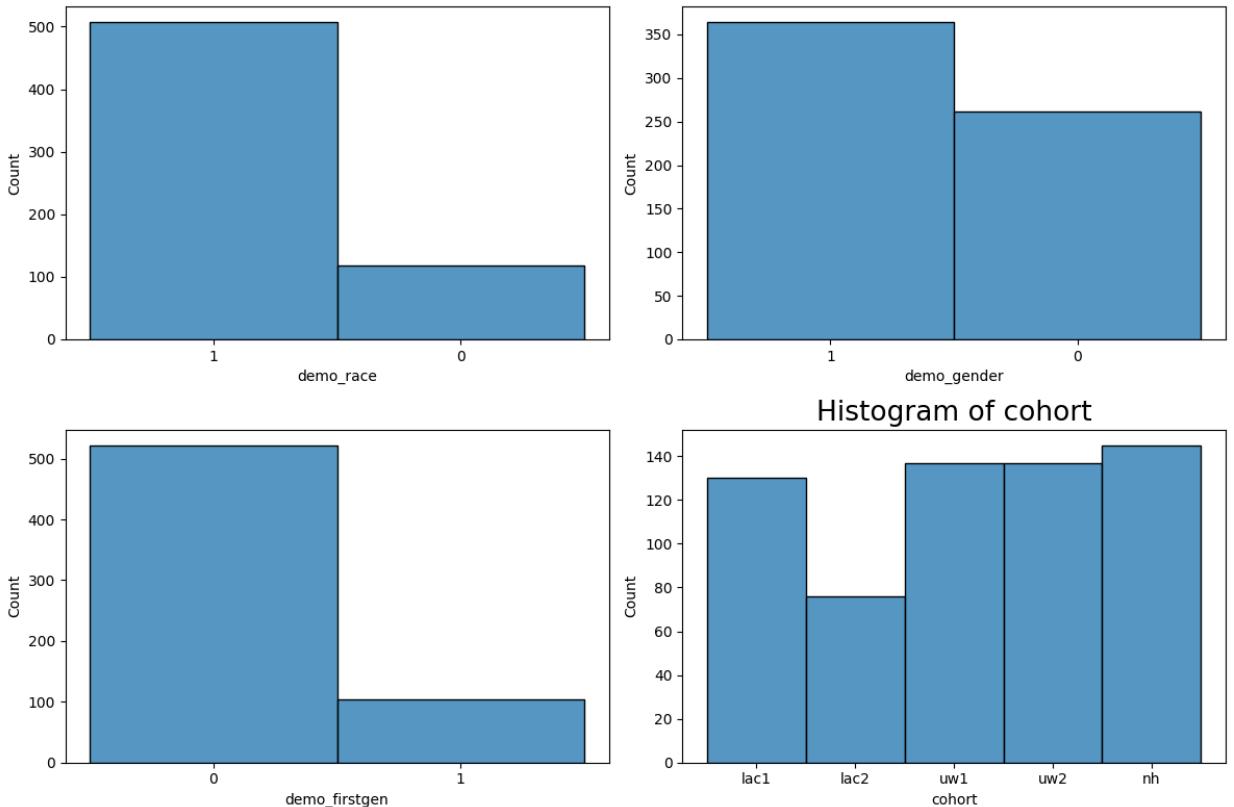
categorical_columns = ['demo_race', 'demo_gender', 'demo_firstgen', 'cohort']
num_rows = 2 # Number of rows for the subplots
num_cols = 2 # Number of columns for the subplots

# Create a figure with subplots
fig, axes = plt.subplots(nrows=num_rows, ncols=num_cols, figsize=(12, 8))

# Loop through categorical variables and create histograms on subplots
col_counter = 0
row_counter = 0
for column in categorical_columns:
    ax = axes[row_counter, col_counter] # Access the current subplot
    sns.histplot(df[column], bins=len(df[column].unique()), ax=ax)
    plt.title(f'Histogram of {column}', fontsize=19)
    plt.xlabel(column, fontsize=10)
    plt.ylabel('Count', fontsize=10)
    col_counter += 1
    if col_counter == num_cols:
        col_counter = 0
        row_counter += 1

# Adjust layout
plt.tight_layout()

# Show the plot
plt.show()
```



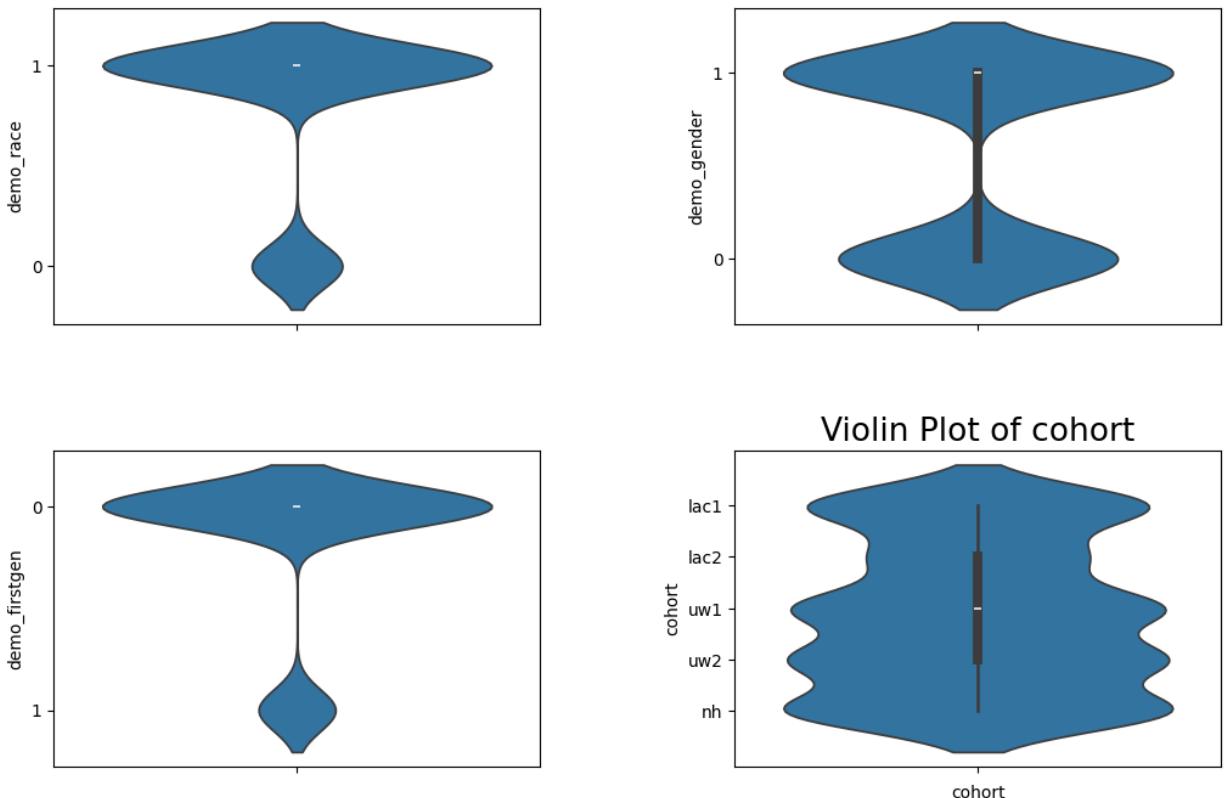
```
In [11]: import matplotlib.pyplot as plt
import seaborn as sns

# List categorical variables
categorical_columns = ['demo_race', 'demo_gender', 'demo_firstgen', 'cohort']
num_rows = 2 # Number of rows for the subplots
num_cols = 2 # Number of columns for the subplots

# Create a figure with subplots and adjust spacing
fig, axes = plt.subplots(nrows=num_rows, ncols=num_cols, figsize=(12, 8))
plt.subplots_adjust(left=0.1, bottom=0.1, right=0.9, top=0.88, wspace=0.4, hspace=0.4)

# Loop through categorical variables and create violin plots on subplots
col_counter = 0
row_counter = 0
for column in categorical_columns:
    ax = axes[row_counter, col_counter] # Access the current subplot
    sns.violinplot(y=df[column], ax=ax) # Specify x and y for violin plot
    plt.title(f'Violin Plot of {column}', fontsize=19) # Adjust font size for clarity
    plt.xlabel(column, fontsize=10)
    col_counter += 1
    if col_counter == num_cols:
        col_counter = 0
        row_counter += 1

# Show the plot
plt.show()
```



## Univariate Analysis

### Numerical Variables

```
In [12]: # Numerical Variables
# Examine the distribution of numerical variables (e.g., bedtime_mssd, TotalSleepTime,
# Identify outliers, skewness, and kurtosis.

# List of variables to analyze
variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_nights_with_dat
             'term_gpa', 'term_units', 'Zterm_units_ZofZ']
num_rows = 5 # Number of rows for the subplots
num_cols = 2 # Number of columns for the subplots

# Create a figure with subplots and adjust spacing
fig, axes = plt.subplots(nrows=num_rows, ncols=num_cols, figsize=(12, 8))
plt.subplots_adjust(left=0.1, bottom=0.1, right=0.9, top=0.88, wspace=0.4, hspace=0.4)

# Loop through variables and create histograms on subplots
row_counter = 0
col_counter = 0
for var in variables:
    ax = axes[row_counter, col_counter] # Access the current subplot

    # Print descriptive statistics
    print(f'\n{var.upper()}: \n{df[var].describe()}')

    # Create histogram
    sns.histplot(df[var], ax=ax)

    # Set title and labels
    if col_counter == 0:
        ax.set_title(var)
    if row_counter == num_rows - 1:
        ax.set_xlabel(var)
```

```
plt.title(f'{var.upper()} Distribution', fontsize=10)
plt.xlabel(var, fontsize=10)
plt.ylabel('Count', fontsize=10)

# Update counters and handle overflow
col_counter += 1
if col_counter == num_cols:
    col_counter = 0
    row_counter += 1

plt.tight_layout()

# Show the plot
plt.show()
```

BEDTIME\_MSSD:  
count 625.000000  
mean 0.453496  
std 1.401705  
min 0.004505  
25% 0.074576  
50% 0.135441  
75% 0.292522  
max 20.849225  
Name: bedtime\_mssd, dtype: float64

TOTALSLEEPTIME:  
count 625.000000  
mean 397.365275  
std 50.805263  
min 194.782609  
25% 366.758621  
50% 400.541667  
75% 430.125000  
max 587.666667  
Name: TotalSleepTime, dtype: float64

MIDPOINT\_SLEEP:  
count 625.000000  
mean 398.702578  
std 72.830123  
min 247.071429  
25% 345.730769  
50% 387.086207  
75% 437.733333  
max 724.666667  
Name: midpoint\_sleep, dtype: float64

FRAC\_NIGHTS\_WITH\_DATA:  
count 625.000000  
mean 0.867244  
std 0.179240  
min 0.214286  
25% 0.821429  
50% 0.933333  
75% 1.000000  
max 1.000000  
Name: frac\_nights\_with\_data, dtype: float64

DAYTIME\_SLEEP:  
count 625.000000  
mean 41.276384  
std 27.402524  
min 2.269231  
25% 23.130435  
50% 35.083333  
75% 51.571429  
max 292.304348  
Name: daytime\_sleep, dtype: float64

STUDY:  
count 625.000000  
mean 3.185600  
std 1.318307  
min 1.000000

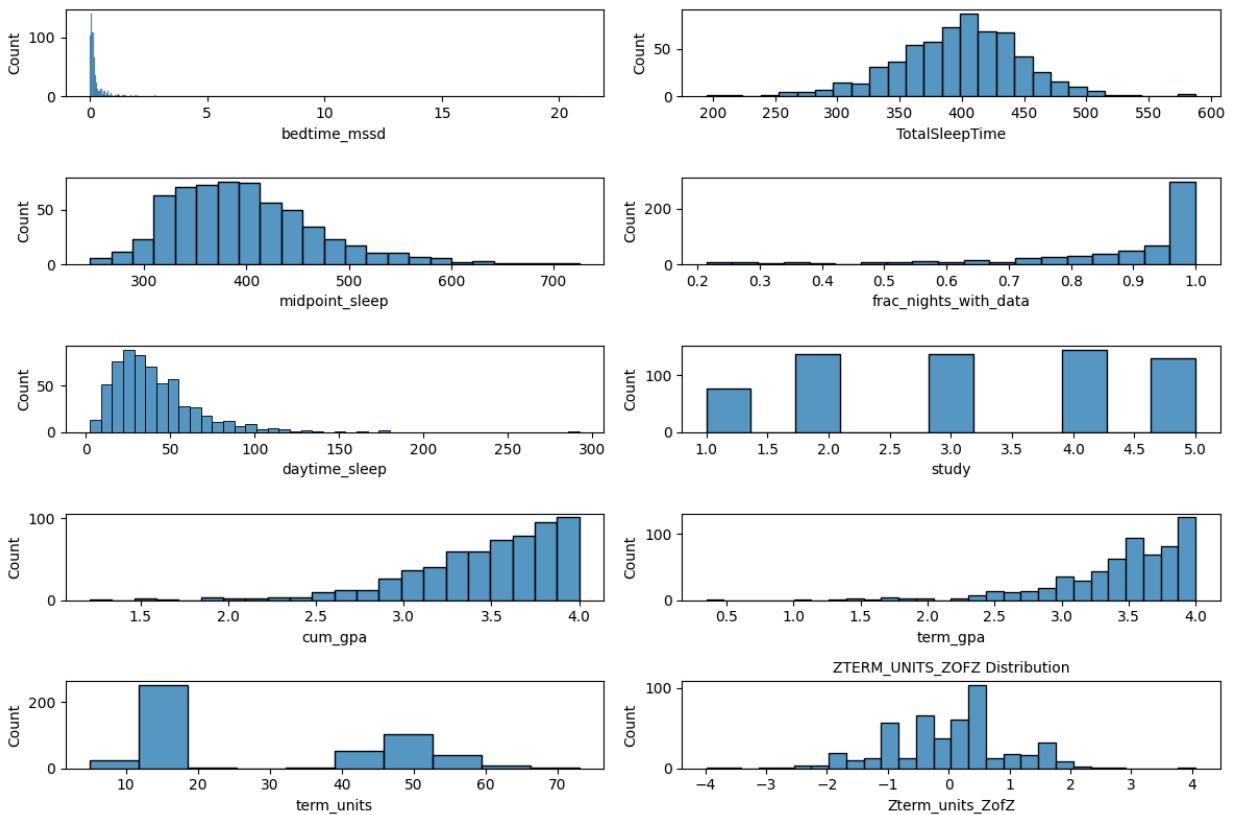
```
25%      2.000000
50%      3.000000
75%      4.000000
max      5.000000
Name: study, dtype: float64
```

```
CUM_GPA:
count    625.000000
mean     3.465467
std      0.439798
min     1.210000
25%     3.230000
50%     3.560000
75%     3.790000
max     4.000000
Name: cum_gpa, dtype: float64
```

```
TERM_GPA:
count    625.000000
mean     3.450029
std      0.503015
min     0.350000
25%     3.233333
50%     3.555667
75%     3.810000
max     4.000000
Name: term_gpa, dtype: float64
```

```
TERM_UNITS:
count    480.000000
mean     29.447917
std      17.629491
min     5.000000
25%     15.000000
50%     17.000000
75%     48.000000
max     73.000000
Name: term_units, dtype: float64
```

```
ZTERM_UNITS_ZOFZ:
count    480.000000
mean     -0.003790
std      0.997996
min     -3.982521
25%     -0.604268
50%     0.041207
75%     0.560271
max     4.055295
Name: Zterm_units_ZofZ, dtype: float64
```



```
In [13]: # Numerical Outliers
# Identify outliers in numerical variables using techniques like Winsorization or trim

# List of variables to analyze
variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_nights_with_data',
             'study', 'cum_gpa', 'term_gpa', 'term_units', 'Zterm_units_ZofZ']
num_rows = 2 # Number of rows for the subplots
num_cols = 5 # Number of columns for the subplots

# Create a figure with subplots and adjust spacing
fig, axes = plt.subplots(nrows=num_rows, ncols=num_cols, figsize=(12, 8))
plt.subplots_adjust(left=0.1, bottom=0.1, right=0.9, top=0.88, wspace=0.4, hspace=0.4)

# Loop through variables and create histograms on subplots
row_counter = 0
col_counter = 0
for var in variables:
    ax = axes[row_counter, col_counter] # Access the current subplot

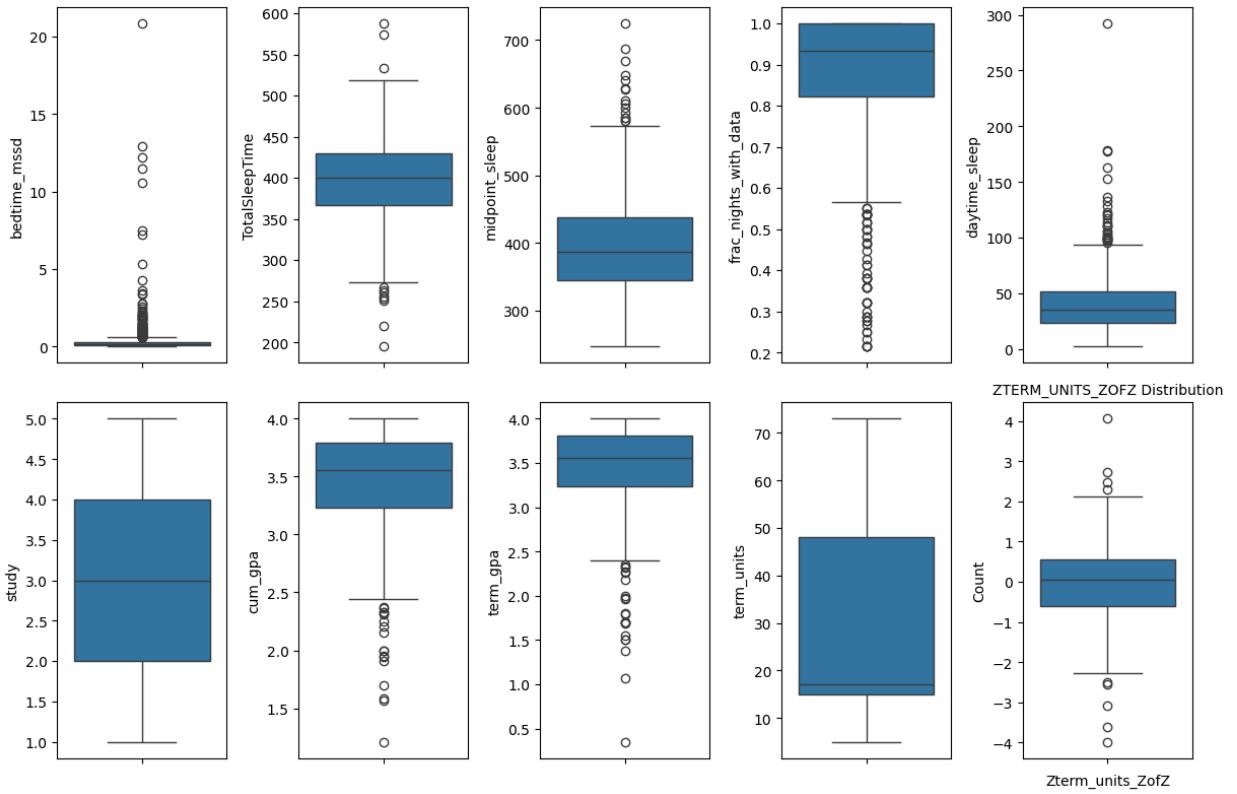
    # Create Boxplot
    sns.boxplot(df[var], ax=ax)

    # Set title and labels
    plt.title(f'{var.upper()} Distribution', fontsize=10)
    plt.xlabel(var, fontsize=10)
    plt.ylabel('Count', fontsize=10)

    # Update counters and handle overflow
    col_counter += 1
    if col_counter == num_cols:
        col_counter = 0
        row_counter += 1
```

```
plt.tight_layout()
```

```
# Show the plot  
plt.show()
```



In [14]:

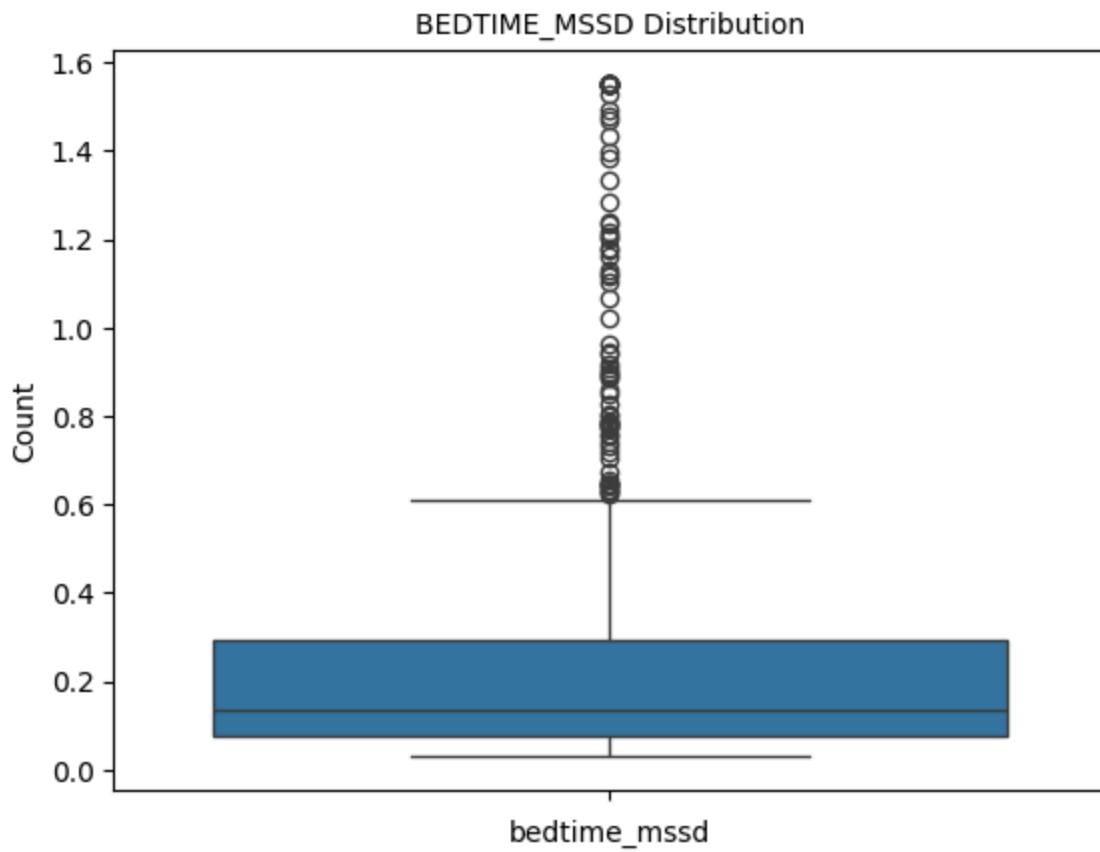
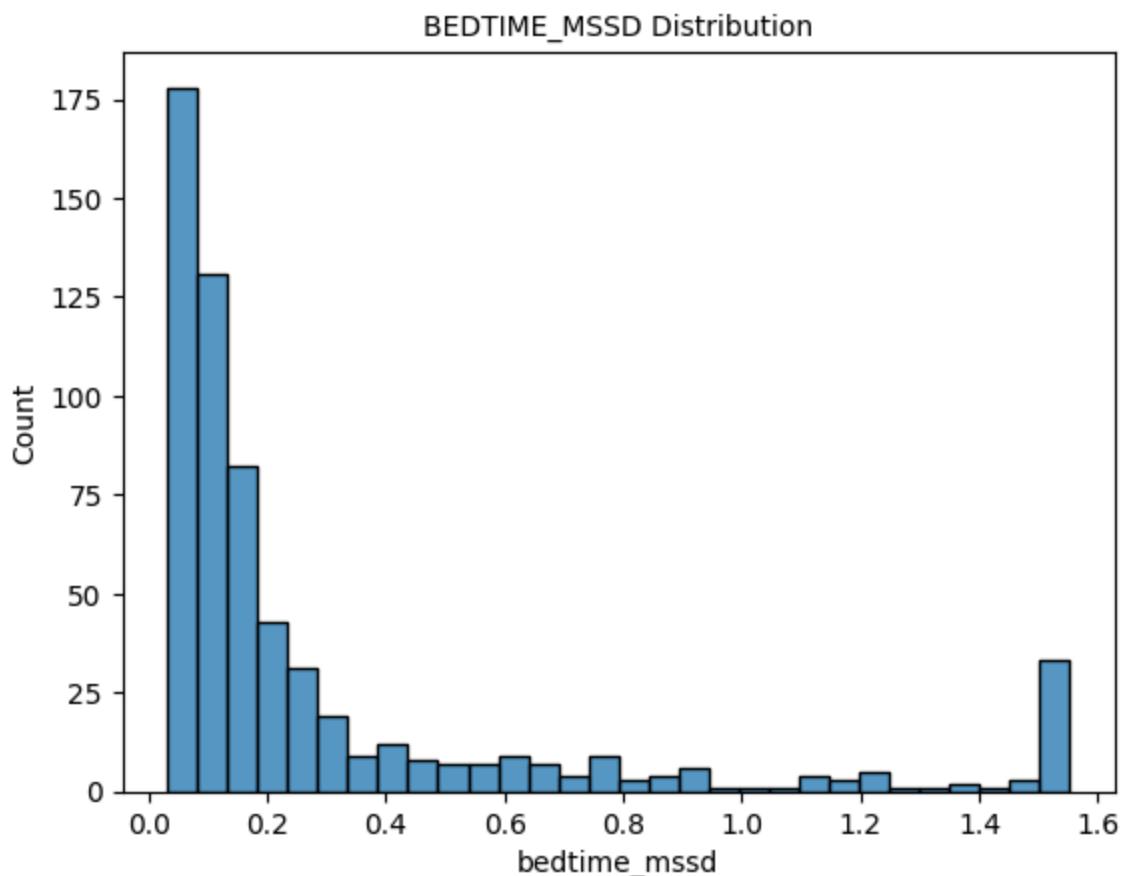
```
# Winsorization  
from scipy.stats.mstats import winsorize  
  
# List all variables  
variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_nights_with_data',  
            'term_gpa', 'term_units', 'Zterm_units_ZofZ']  
  
# Winsorize each variable  
for var in variables:  
    df[var] = winsorize(df[var], limits=[0.05, 0.05]) # Winsorize at the 5th and 95th  
    print(f'\n{var.upper()}: \n{df[var].describe()}')  
    print(f'\n{var.upper()}: \n{df[var].value_counts()}')  
    print(f'\n{var.upper()}: \n{df[var].value_counts(normalize=True)*100}')  
    sns.histplot(df[var])  
    plt.title(f'{var.upper()} Distribution', fontsize=10)  
    plt.xlabel(var, fontsize=10)  
    plt.ylabel('Count', fontsize=10)  
    plt.show()  
    sns.boxplot(df[var])  
    plt.title(f'{var.upper()} Distribution', fontsize=10)  
    plt.xlabel(var, fontsize=10)  
    plt.ylabel('Count', fontsize=10)  
    plt.show()
```

```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
arr.partition(
```

```
BEDTIME_MSSD:  
count    625.000000  
mean     0.302718  
std      0.401090  
min     0.031593  
25%     0.074576  
50%     0.135441  
75%     0.292522  
max     1.552286  
Name: bedtime_mssd, dtype: float64
```

```
BEDTIME_MSSD:  
bedtime_mssd  
1.552286    32  
0.031593    32  
0.044613     2  
0.049417     1  
0.781137     1  
...  
0.162916     1  
0.566820     1  
0.187560     1  
0.089489     1  
0.091325     1  
Name: count, Length: 562, dtype: int64
```

```
BEDTIME_MSSD:  
bedtime_mssd  
1.552286    5.12  
0.031593    5.12  
0.044613    0.32  
0.049417    0.16  
0.781137    0.16  
...  
0.162916    0.16  
0.566820    0.16  
0.187560    0.16  
0.089489    0.16  
0.091325    0.16  
Name: proportion, Length: 562, dtype: float64
```

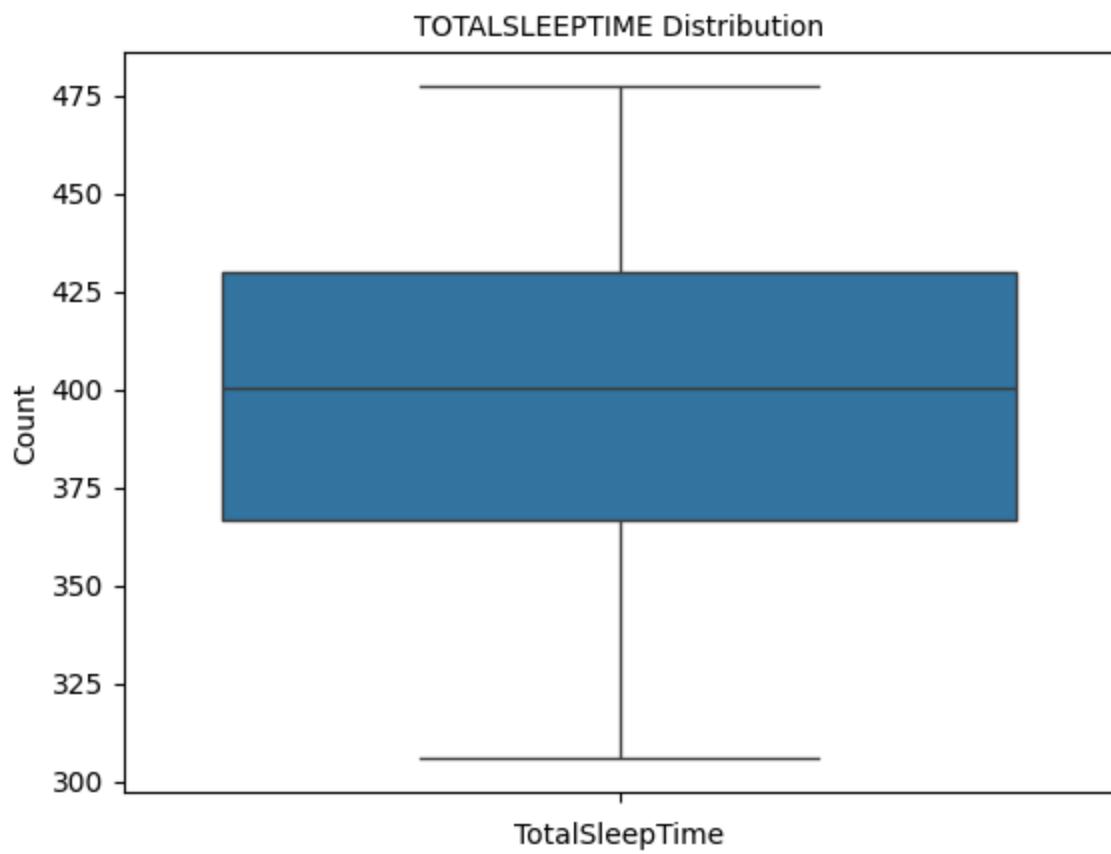
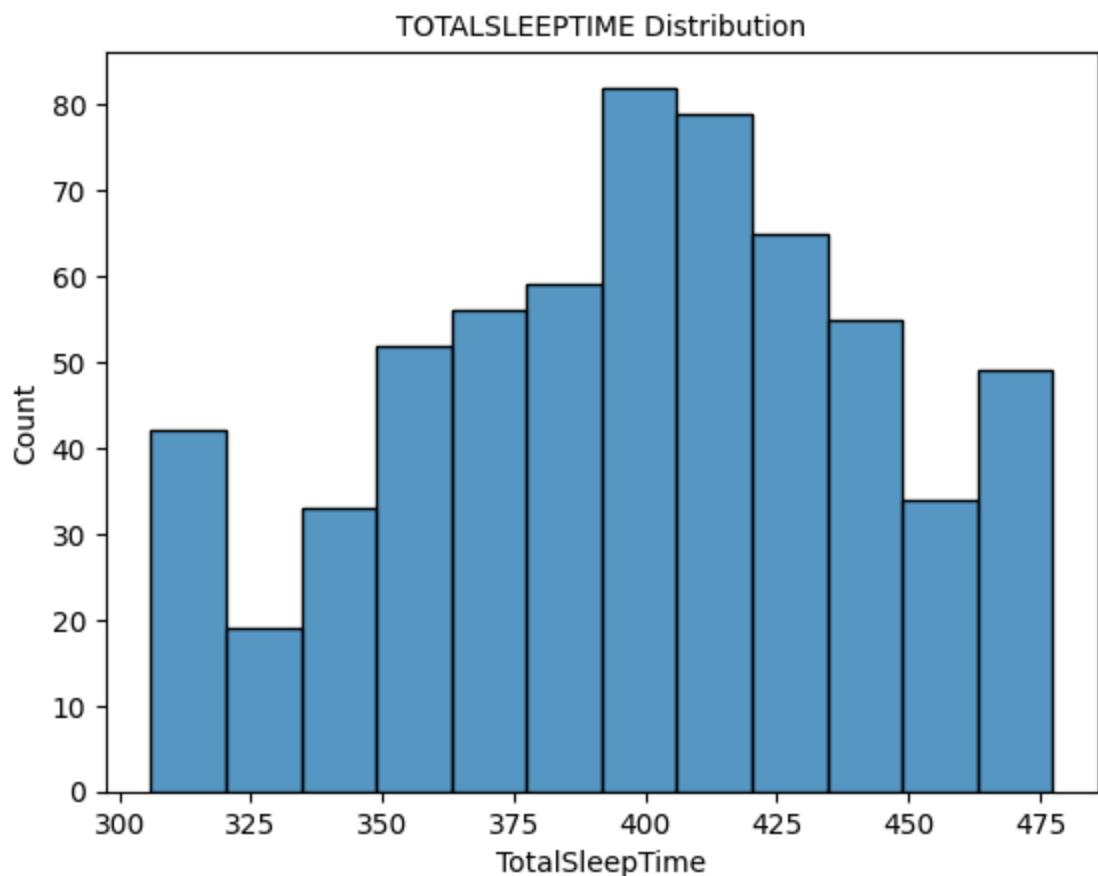


```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(
```

```
TOTALSLEEPTIME:  
count    625.000000  
mean     397.556834  
std      45.123752  
min     306.000000  
25%     366.758621  
50%     400.541667  
75%     430.125000  
max     477.428571  
Name: TotalSleepTime, dtype: float64
```

```
TOTALSLEEPTIME:  
TotalSleepTime  
477.428571    32  
306.000000    32  
411.642857    2  
359.500000    2  
387.928571    2  
...  
395.357143    1  
421.785714    1  
446.178571    1  
413.740741    1  
383.448276    1  
Name: count, Length: 555, dtype: int64
```

```
TOTALSLEEPTIME:  
TotalSleepTime  
477.428571    5.12  
306.000000    5.12  
411.642857    0.32  
359.500000    0.32  
387.928571    0.32  
...  
395.357143    0.16  
421.785714    0.16  
446.178571    0.16  
413.740741    0.16  
383.448276    0.16  
Name: proportion, Length: 555, dtype: float64
```



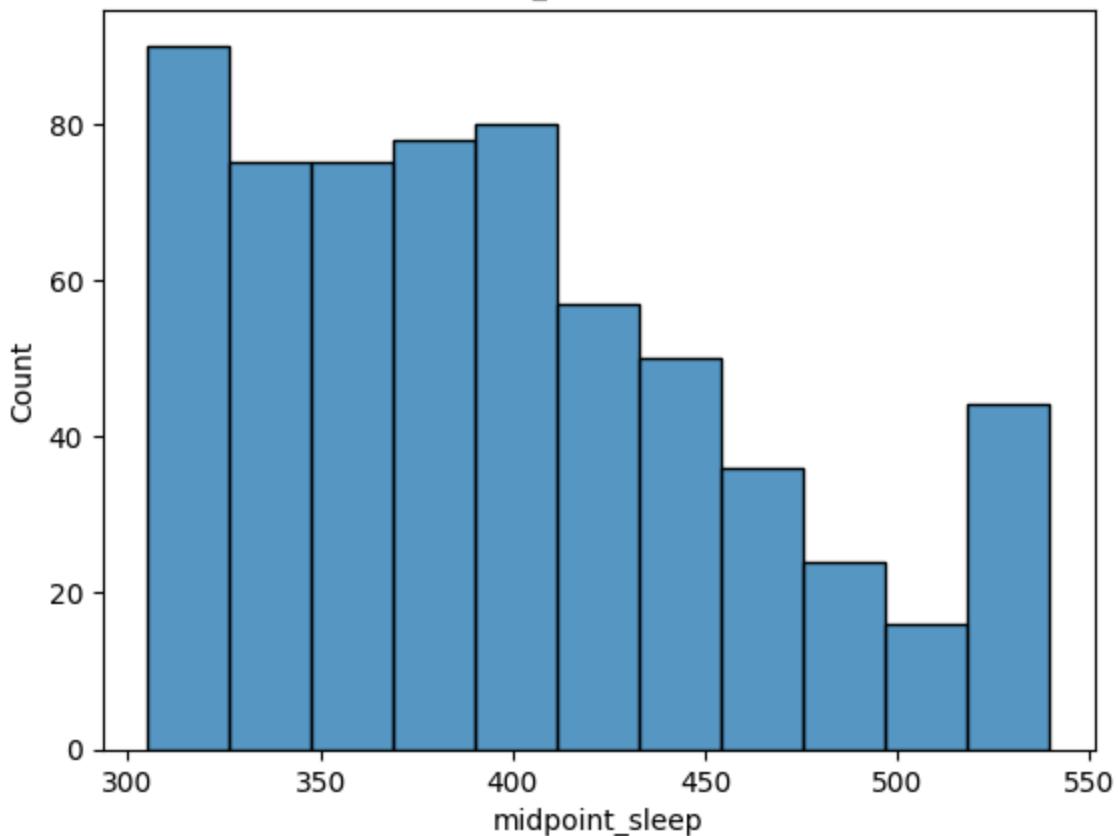
```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(
```

```
MIDPOINT_SLEEP:  
count    625.000000  
mean     397.394921  
std      64.600110  
min     305.173077  
25%     345.730769  
50%     387.086207  
75%     437.733333  
max     539.553571  
Name: midpoint_sleep, dtype: float64
```

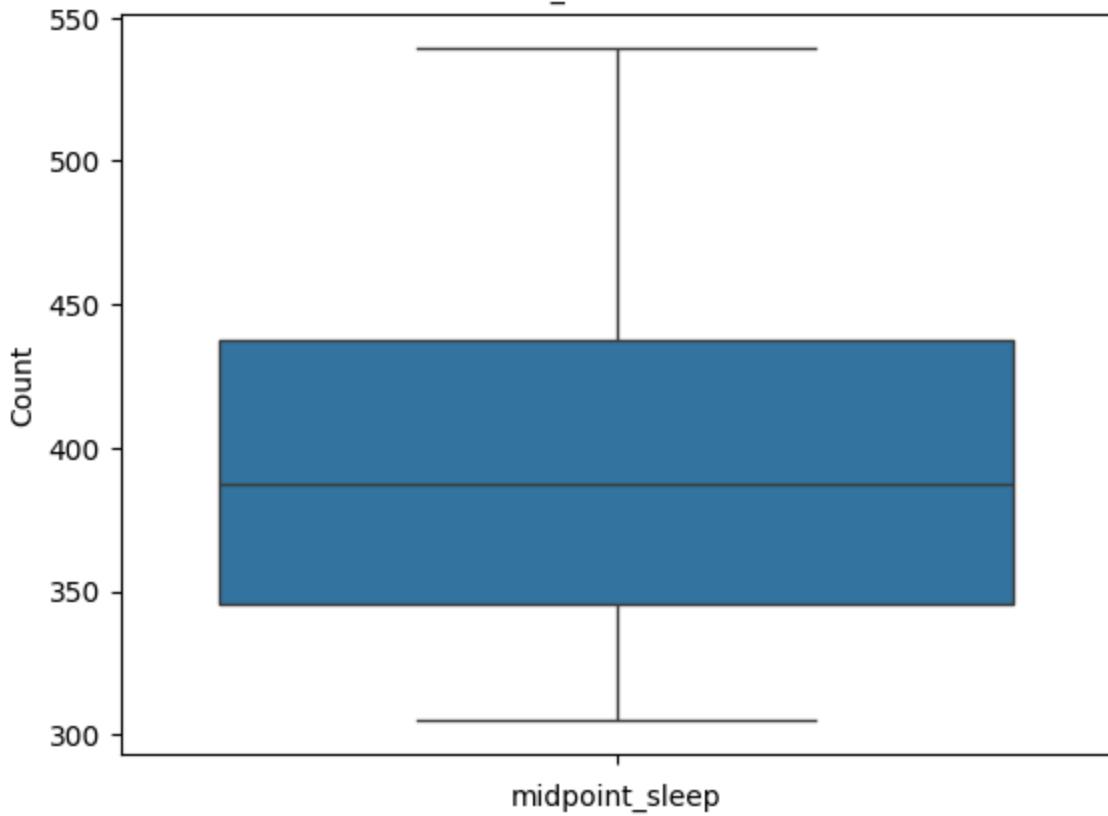
```
MIDPOINT_SLEEP:  
midpoint_sleep  
539.553571    32  
305.173077    32  
345.000000    2  
514.000000    2  
407.517857    2  
...  
350.589286    1  
332.125000    1  
383.410714    1  
313.678571    1  
407.931035    1  
Name: count, Length: 558, dtype: int64
```

```
MIDPOINT_SLEEP:  
midpoint_sleep  
539.553571    5.12  
305.173077    5.12  
345.000000    0.32  
514.000000    0.32  
407.517857    0.32  
...  
350.589286    0.16  
332.125000    0.16  
383.410714    0.16  
313.678571    0.16  
407.931035    0.16  
Name: proportion, Length: 558, dtype: float64
```

MIDPOINT\_SLEEP Distribution



MIDPOINT\_SLEEP Distribution



```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(
```

```
FRAC_NIGHTS_WITH_DATA:  
count    625.000000  
mean     0.873793  
std      0.159741  
min     0.448276  
25%     0.821429  
50%     0.933333  
75%     1.000000  
max     1.000000  
Name: frac_nights_with_data, dtype: float64
```

```
FRAC_NIGHTS_WITH_DATA:
```

```
frac_nights_with_data
```

```
1.000000    192  
0.964286     44  
0.448276     32  
0.966667     32  
0.928571     32  
0.965517     30  
0.931034     20  
0.892857     19  
0.896552     17  
0.862069     16  
0.933333     15  
0.793103     13  
0.900000     12  
0.857143     11  
0.827586     10  
0.866667      9  
0.714286      8  
0.724138      8  
0.833333      8  
0.655172      8  
0.785714      8  
0.800000      7  
0.821429      7  
0.750000      6  
0.758621      6  
0.700000      6  
0.586207      6  
0.607143      5  
0.535714      5  
0.633333      4  
0.500000      4  
0.551724      3  
0.517241      3  
0.571429      2  
0.464286      2  
0.482759      2  
0.689655      2  
0.566667      2  
0.733333      2  
0.620690      1  
0.642857      1  
0.678571      1  
0.666667      1  
0.600000      1  
0.466667      1  
0.533333      1
```

```
Name: count, dtype: int64
```

FRAC\_NIGHTS\_WITH\_DATA:

frac\_nights\_with\_data

1.000000 30.72

0.964286 7.04

0.448276 5.12

0.966667 5.12

0.928571 5.12

0.965517 4.80

0.931034 3.20

0.892857 3.04

0.896552 2.72

0.862069 2.56

0.933333 2.40

0.793103 2.08

0.900000 1.92

0.857143 1.76

0.827586 1.60

0.866667 1.44

0.714286 1.28

0.724138 1.28

0.833333 1.28

0.655172 1.28

0.785714 1.28

0.800000 1.12

0.821429 1.12

0.750000 0.96

0.758621 0.96

0.700000 0.96

0.586207 0.96

0.607143 0.80

0.535714 0.80

0.633333 0.64

0.500000 0.64

0.551724 0.48

0.517241 0.48

0.571429 0.32

0.464286 0.32

0.482759 0.32

0.689655 0.32

0.566667 0.32

0.733333 0.32

0.620690 0.16

0.642857 0.16

0.678571 0.16

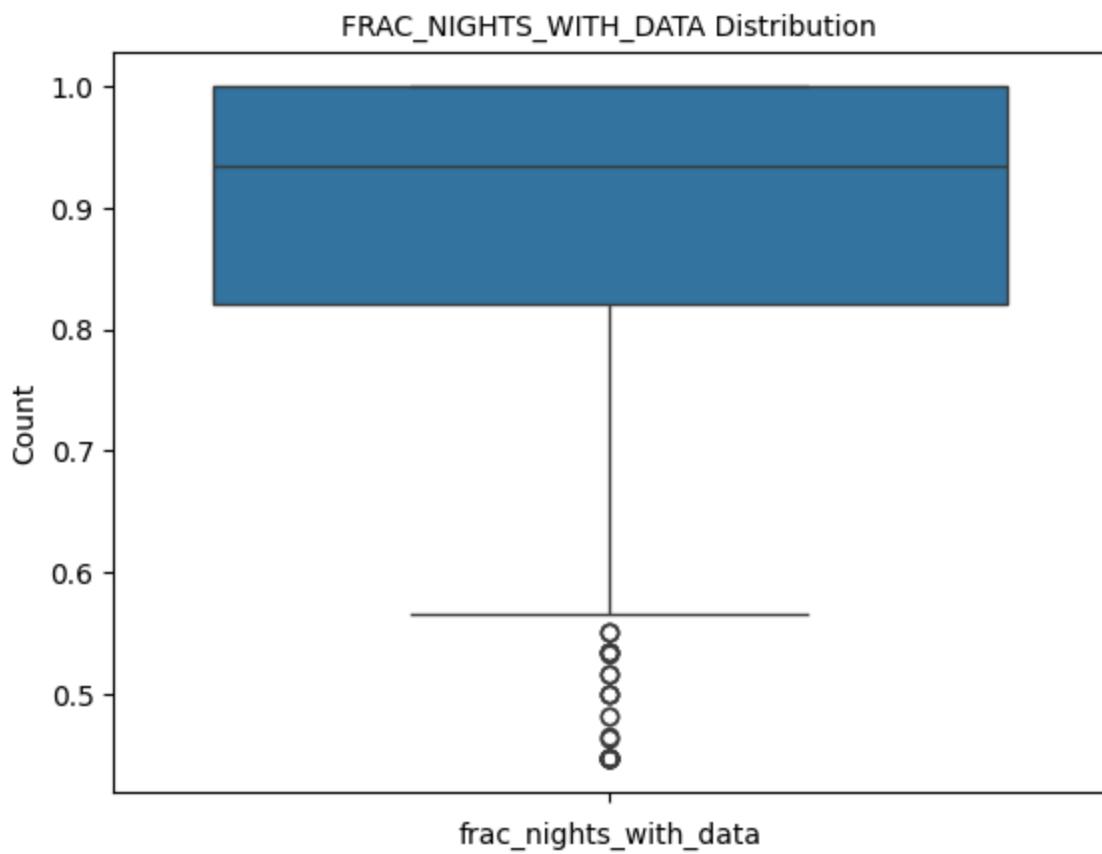
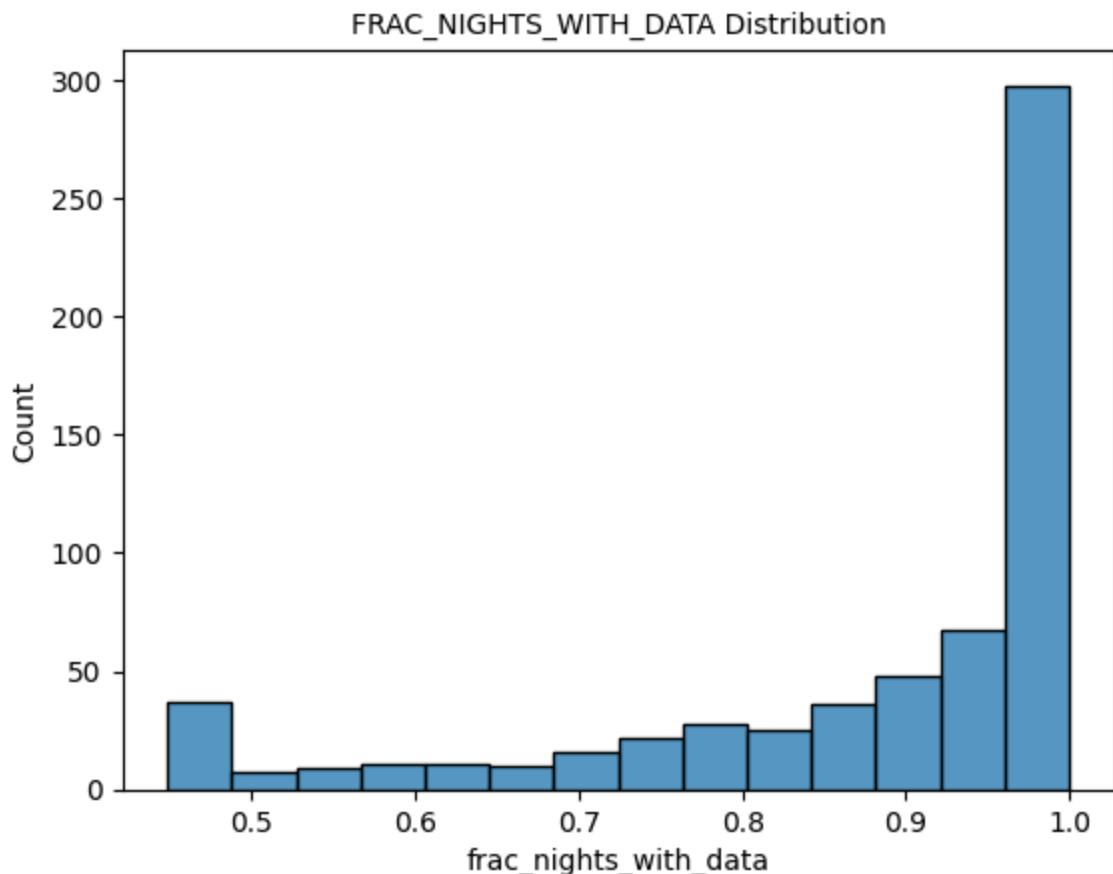
0.666667 0.16

0.600000 0.16

0.466667 0.16

0.533333 0.16

Name: proportion, dtype: float64



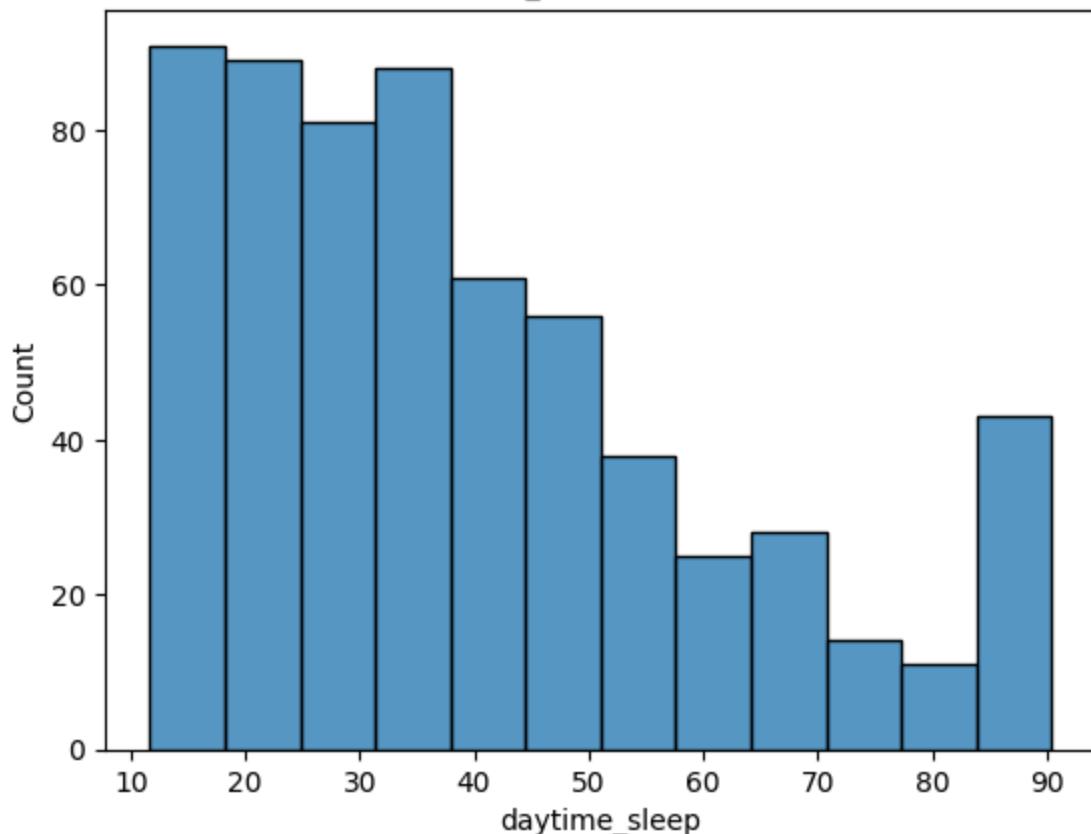
```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(
```

```
DAYTIME_SLEEP:  
count    625.000000  
mean     39.879995  
std      21.545976  
min     11.689655  
25%    23.130435  
50%    35.083333  
75%    51.571429  
max     90.440000  
Name: daytime_sleep, dtype: float64
```

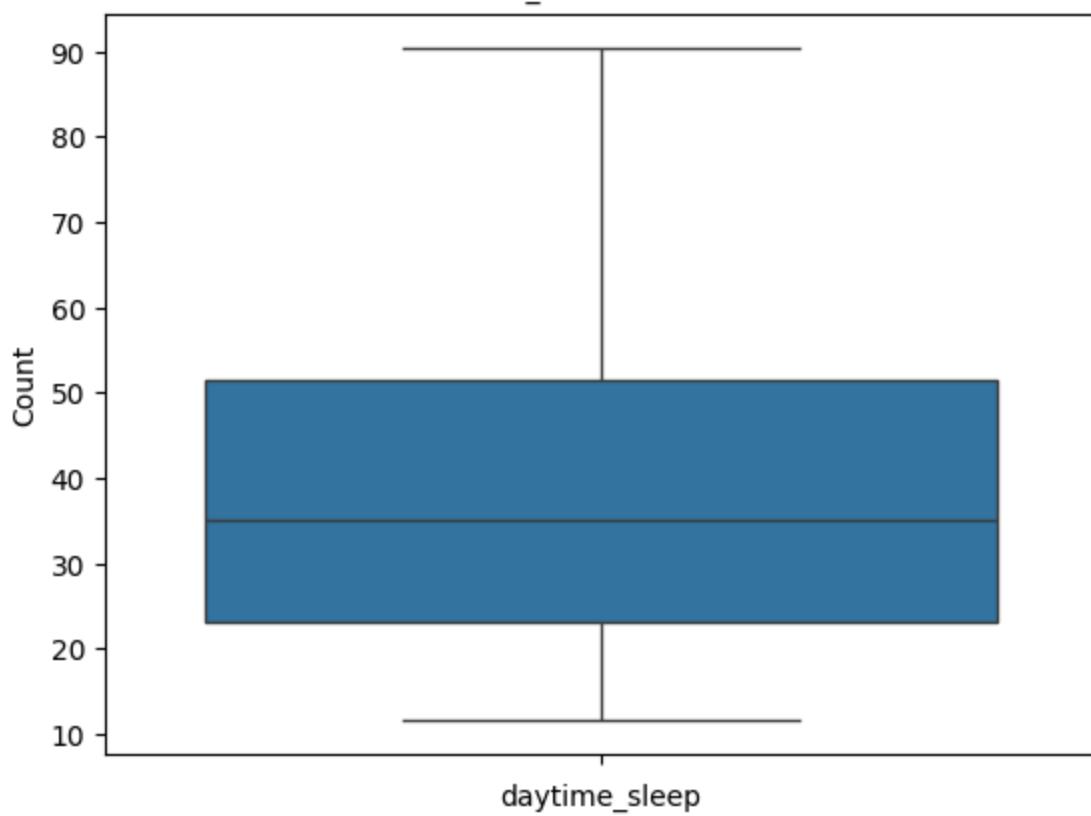
```
DAYTIME_SLEEP:  
daytime_sleep  
11.689655    32  
90.440000    32  
40.928571    2  
51.038462    2  
35.642857    2  
...  
59.678571    1  
51.033333    1  
33.464286    1  
70.607143    1  
44.344828    1  
Name: count, Length: 540, dtype: int64
```

```
DAYTIME_SLEEP:  
daytime_sleep  
11.689655    5.12  
90.440000    5.12  
40.928571    0.32  
51.038462    0.32  
35.642857    0.32  
...  
59.678571    0.16  
51.033333    0.16  
33.464286    0.16  
70.607143    0.16  
44.344828    0.16  
Name: proportion, Length: 540, dtype: float64
```

DAYTIME\_SLEEP Distribution



DAYTIME\_SLEEP Distribution

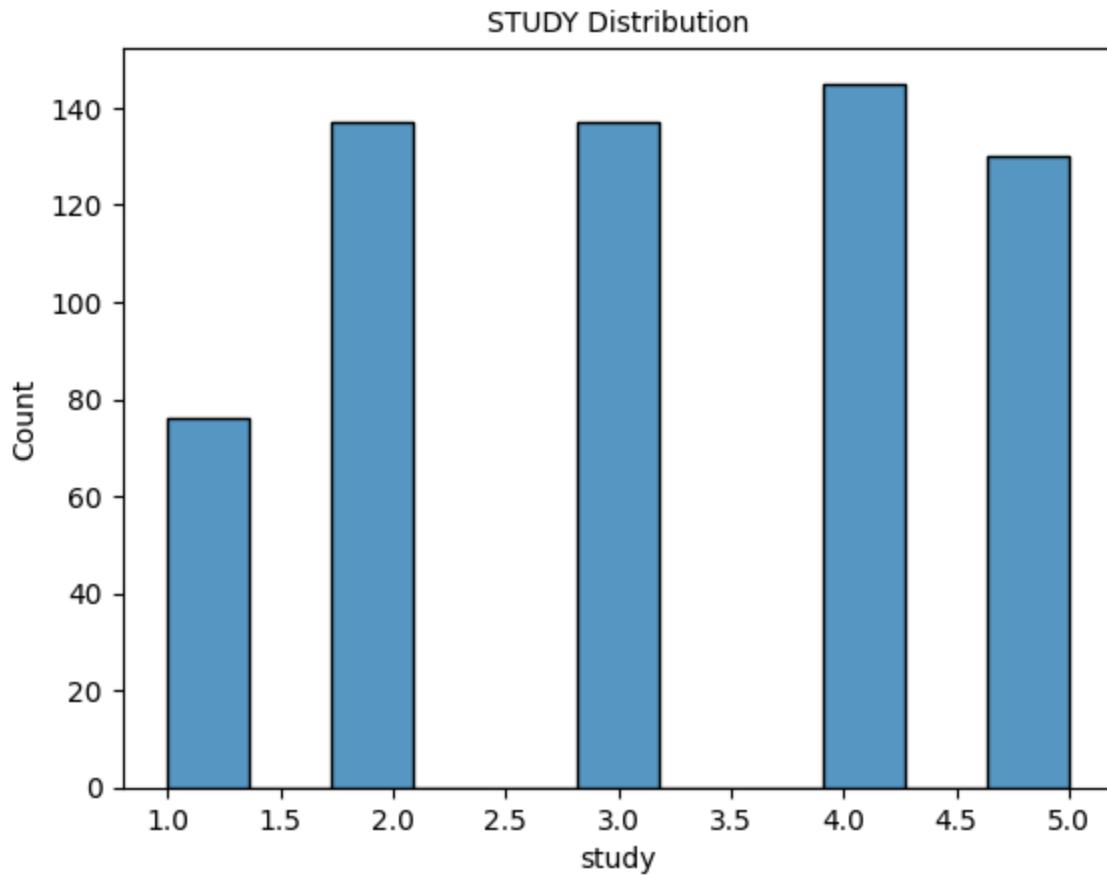


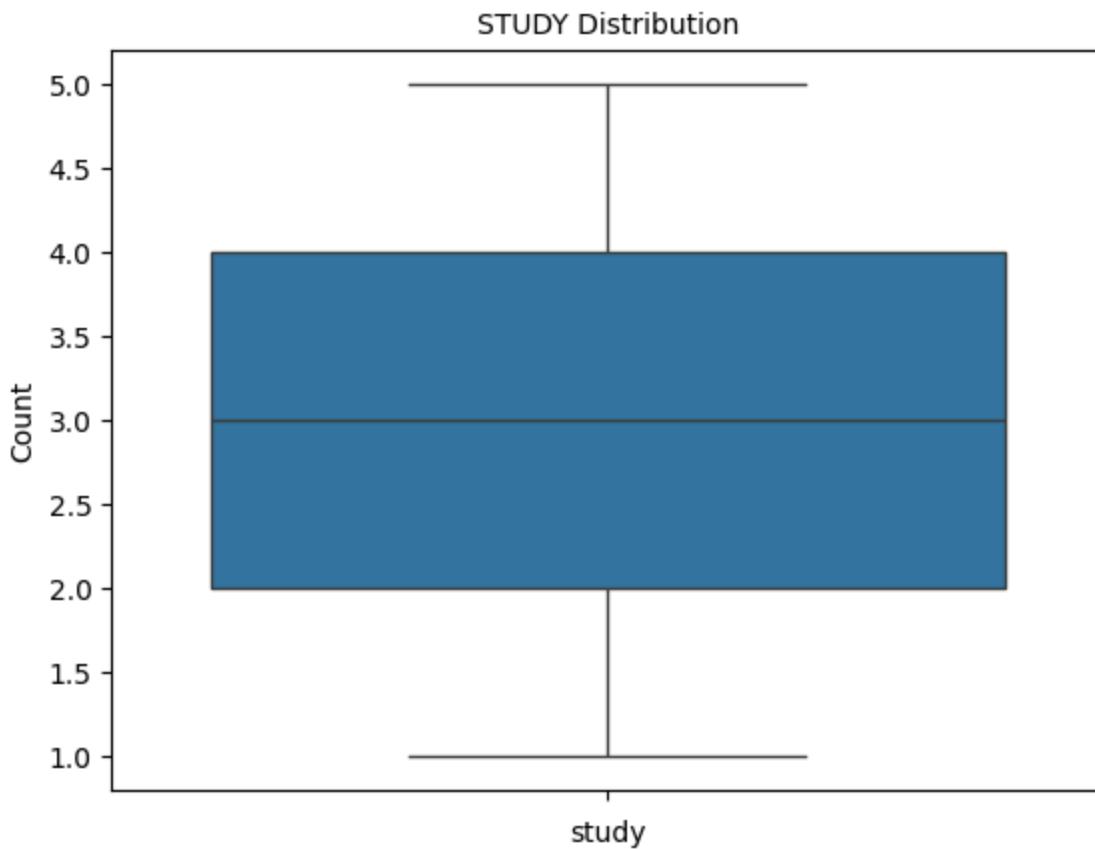
```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
arr.partition(
```

```
STUDY:  
count    625.000000  
mean     3.185600  
std      1.318307  
min     1.000000  
25%     2.000000  
50%     3.000000  
75%     4.000000  
max     5.000000  
Name: study, dtype: float64
```

```
STUDY:  
study  
4     145  
2     137  
3     137  
5     130  
1     76  
Name: count, dtype: int64
```

```
STUDY:  
study  
4     23.20  
2     21.92  
3     21.92  
5     20.80  
1     12.16  
Name: proportion, dtype: float64
```



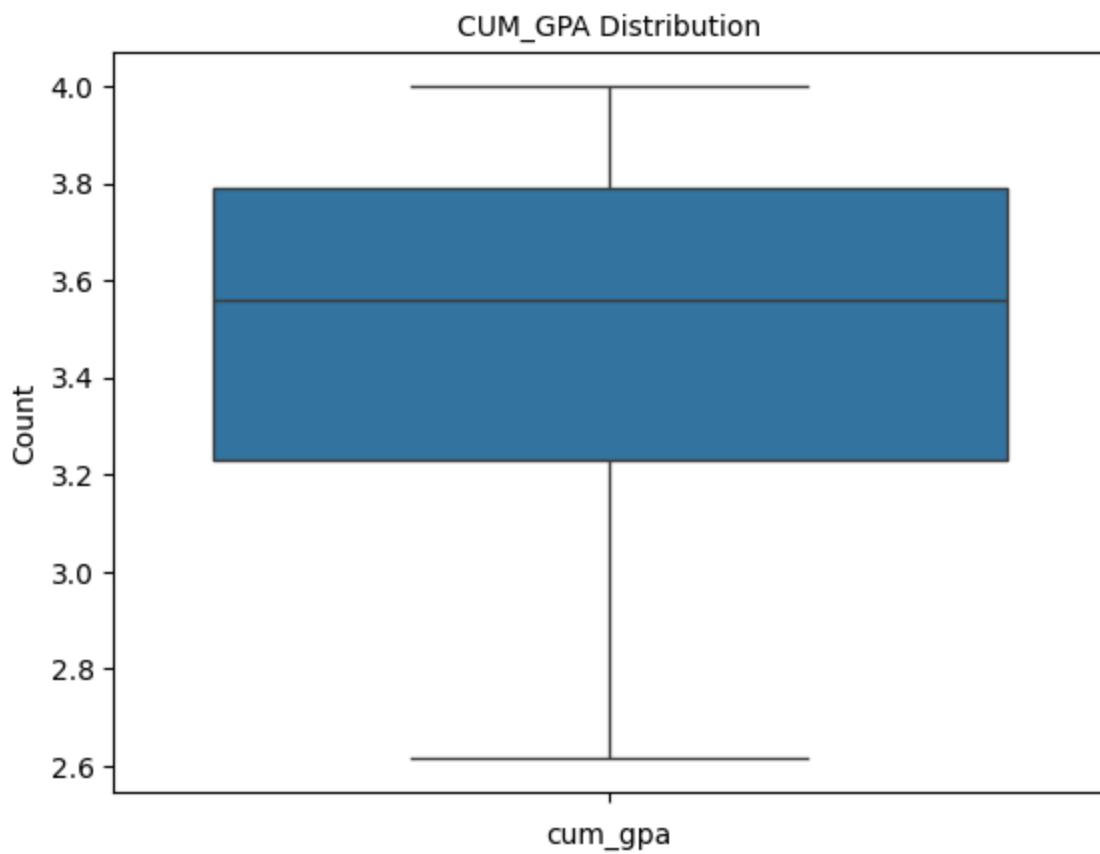
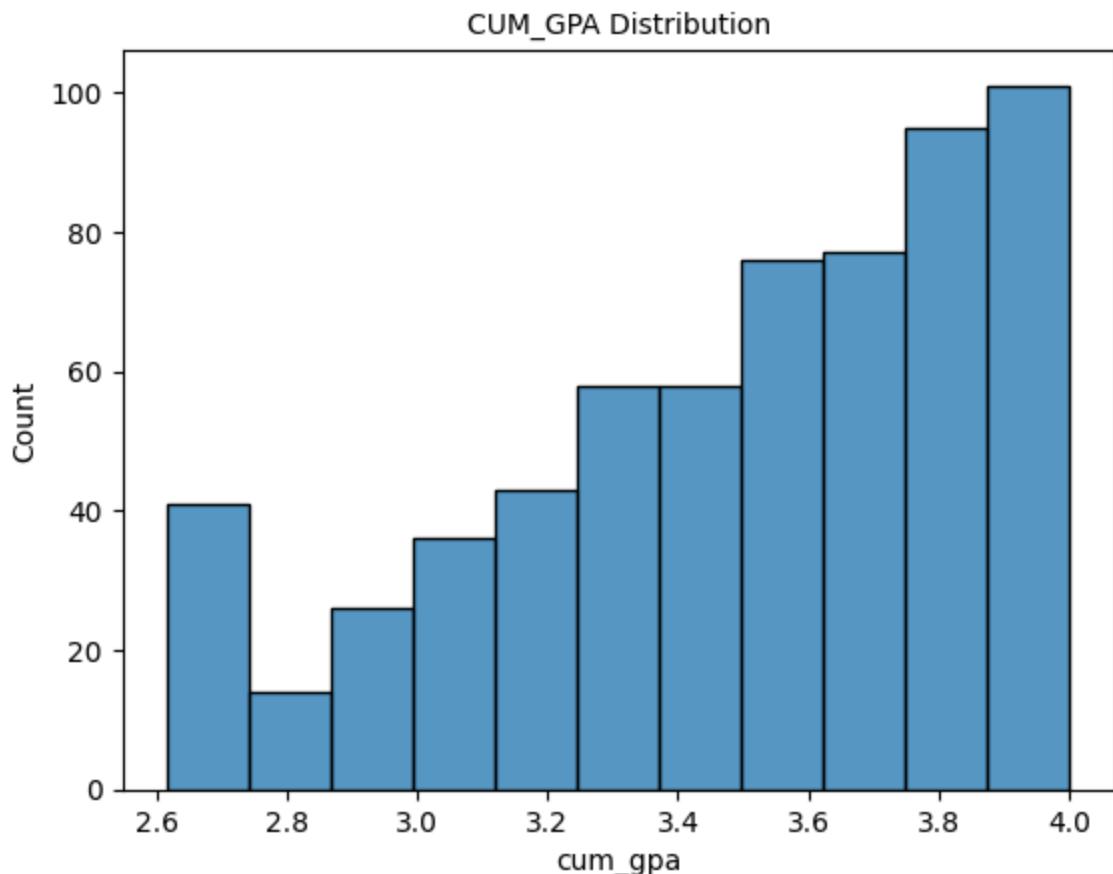


```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(  
    ^
```

```
CUM_GPA:  
count    625.000000  
mean      3.483547  
std       0.386385  
min      2.617059  
25%      3.230000  
50%      3.560000  
75%      3.790000  
max      4.000000  
Name: cum_gpa, dtype: float64
```

```
CUM_GPA:  
cum_gpa  
4.000000    47  
2.617059    32  
3.944500    12  
3.800000     8  
3.790000     8  
...  
3.651515     1  
3.532258     1  
3.335714     1  
2.916666     1  
3.800200     1  
Name: count, Length: 363, dtype: int64
```

```
CUM_GPA:  
cum_gpa  
4.000000    7.52  
2.617059    5.12  
3.944500    1.92  
3.800000    1.28  
3.790000    1.28  
...  
3.651515    0.16  
3.532258    0.16  
3.335714    0.16  
2.916666    0.16  
3.800200    0.16  
Name: proportion, Length: 363, dtype: float64
```

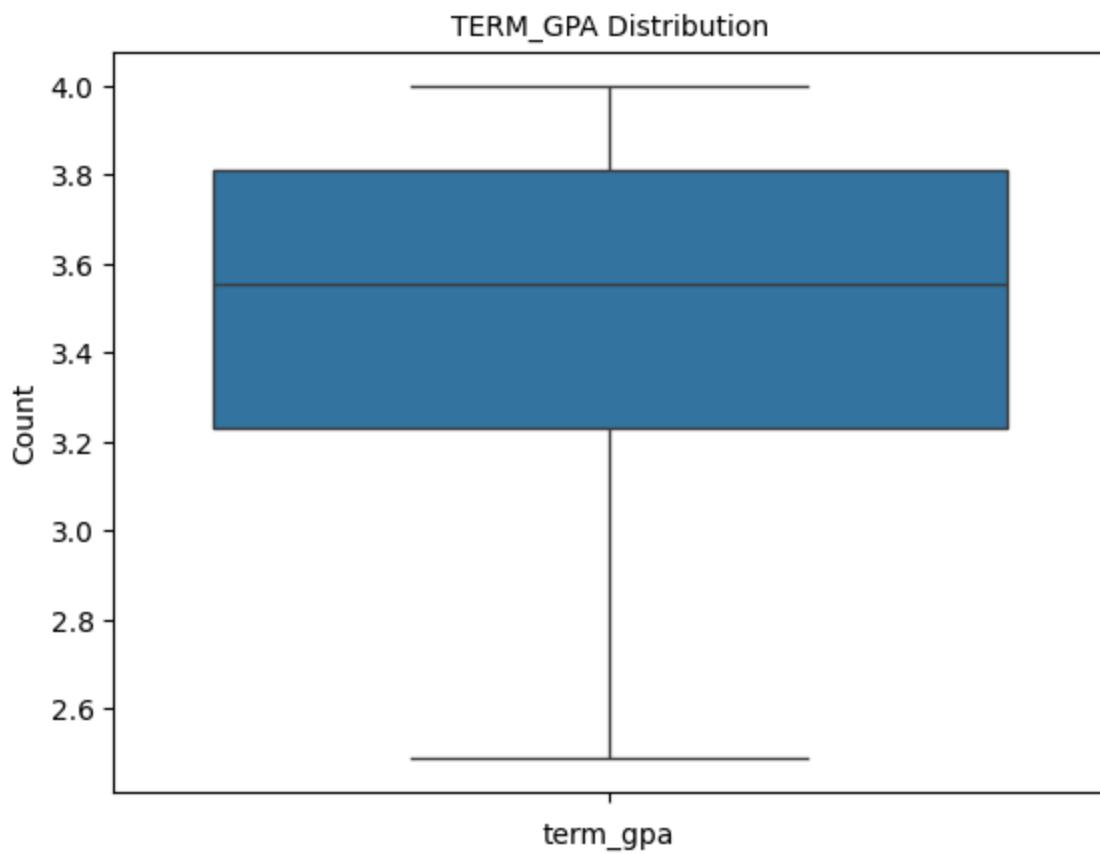
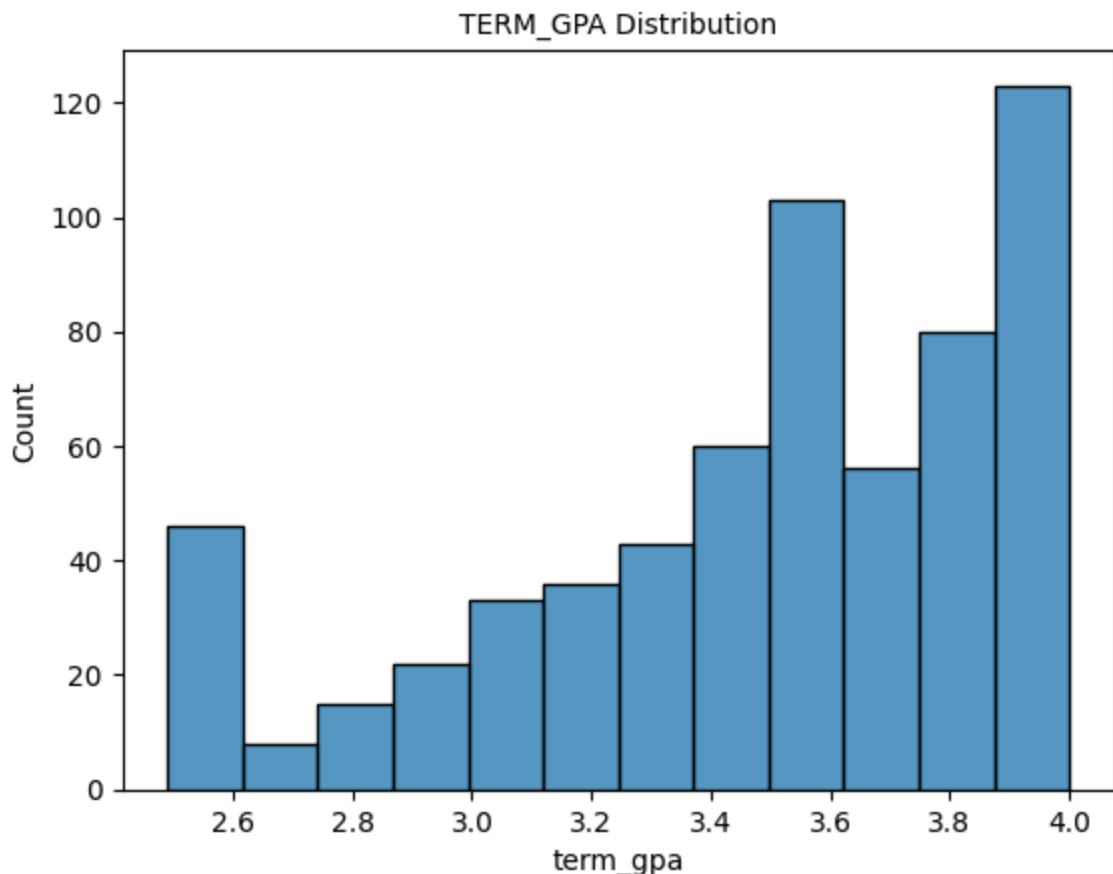


```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(
```

```
TERM_GPA:  
count    625.000000  
mean      3.474610  
std       0.425108  
min      2.490000  
25%      3.233333  
50%      3.555667  
75%      3.810000  
max      4.000000  
Name: term_gpa, dtype: float64
```

```
TERM_GPA:  
term_gpa  
4.000000    54  
2.490000    32  
3.500000    16  
3.944500    11  
3.000000    10  
...  
3.127777    1  
2.840000    1  
3.240000    1  
3.333333    1  
3.222167    1  
Name: count, Length: 240, dtype: int64
```

```
TERM_GPA:  
term_gpa  
4.000000    8.64  
2.490000    5.12  
3.500000    2.56  
3.944500    1.76  
3.000000    1.60  
...  
3.127777    0.16  
2.840000    0.16  
3.240000    0.16  
3.333333    0.16  
3.222167    0.16  
Name: proportion, Length: 240, dtype: float64
```



```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(
```

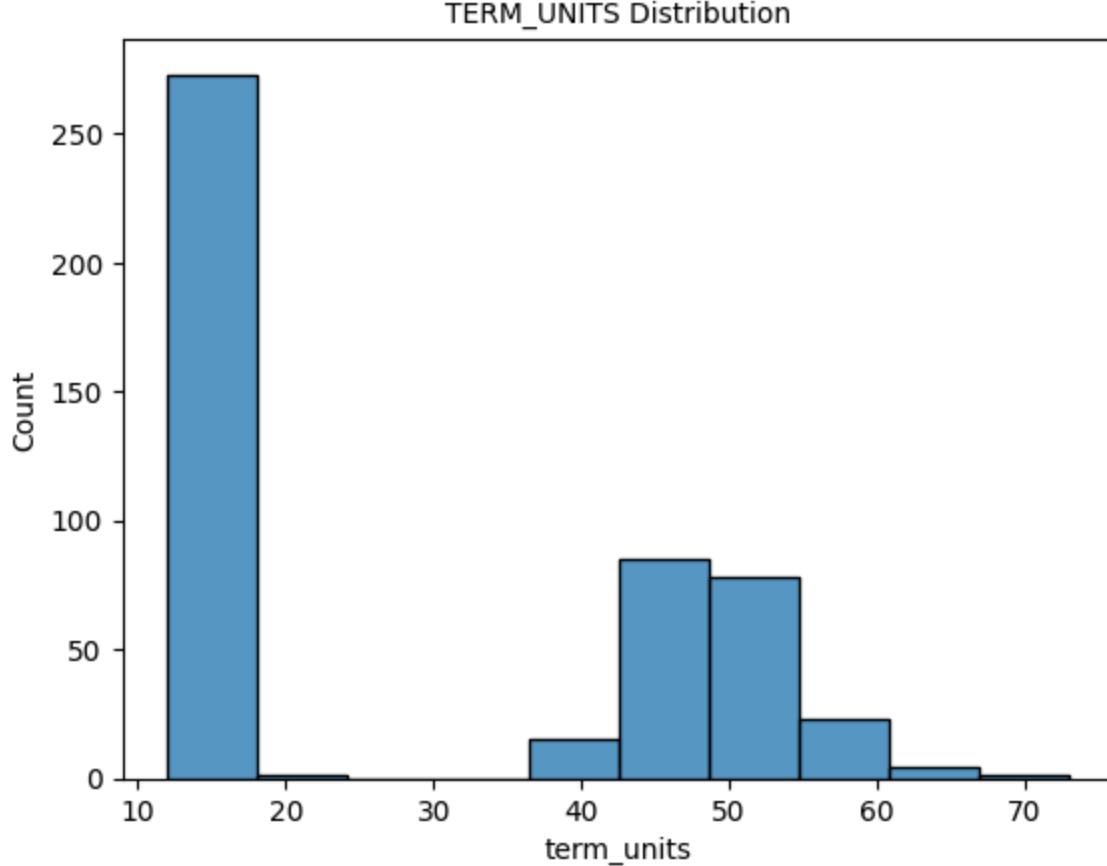
```
TERM_UNITS:  
count    480.000000  
mean     29.552083  
std      17.517108  
min     12.000000  
25%     15.000000  
50%     17.000000  
75%     48.000000  
max     73.000000  
Name: term_units, dtype: float64
```

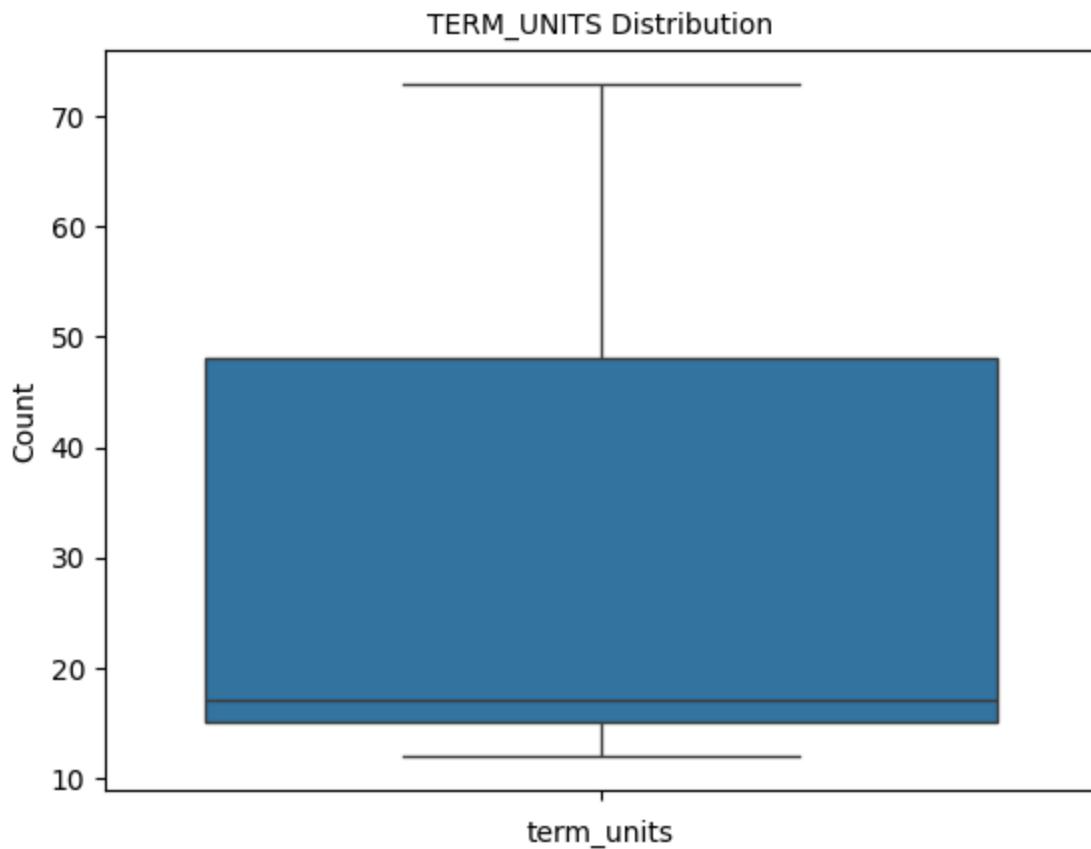
```
TERM_UNITS:  
term_units  
15.0    99  
13.0    41  
12.0    36  
14.0    30  
18.0    28  
45.0    28  
48.0    25  
16.0    23  
49.0    22  
17.0    16  
51.0    14  
53.0    13  
46.0    12  
47.0    11  
52.0    10  
50.0    10  
54.0    9  
43.0    7  
60.0    5  
57.0    5  
40.0    5  
55.0    4  
56.0    4  
42.0    3  
41.0    3  
58.0    3  
39.0    3  
59.0    2  
61.0    2  
44.0    2  
38.0    1  
73.0    1  
64.0    1  
63.0    1  
19.0    1  
Name: count, dtype: int64
```

```
TERM_UNITS:  
term_units  
15.0    20.625000  
13.0    8.541667  
12.0    7.500000  
14.0    6.250000  
18.0    5.833333  
45.0    5.833333  
48.0    5.208333  
16.0    4.791667
```

```
49.0    4.583333
17.0    3.333333
51.0    2.916667
53.0    2.708333
46.0    2.500000
47.0    2.291667
52.0    2.083333
50.0    2.083333
54.0    1.875000
43.0    1.458333
60.0    1.041667
57.0    1.041667
40.0    1.041667
55.0    0.833333
56.0    0.833333
42.0    0.625000
41.0    0.625000
58.0    0.625000
39.0    0.625000
59.0    0.416667
61.0    0.416667
44.0    0.416667
38.0    0.208333
73.0    0.208333
64.0    0.208333
63.0    0.208333
19.0    0.208333
```

Name: proportion, dtype: float64





```
/usr/local/lib/python3.10/dist-packages/numpy/lib/function_base.py:4824: UserWarning:  
  Warning: 'partition' will ignore the 'mask' of the MaskedArray.  
    arr.partition(  
      
```

```
ZTERM_UNITS_ZOFZ:  
count    480.000000  
mean     0.029400  
std      0.925093  
min     -1.536743  
25%     -0.604268  
50%     0.041207  
75%     0.560271  
max     4.055295  
Name: Zterm_units_ZofZ, dtype: float64
```

```
ZTERM_UNITS_ZOFZ:
```

```
Zterm_units_ZofZ
```

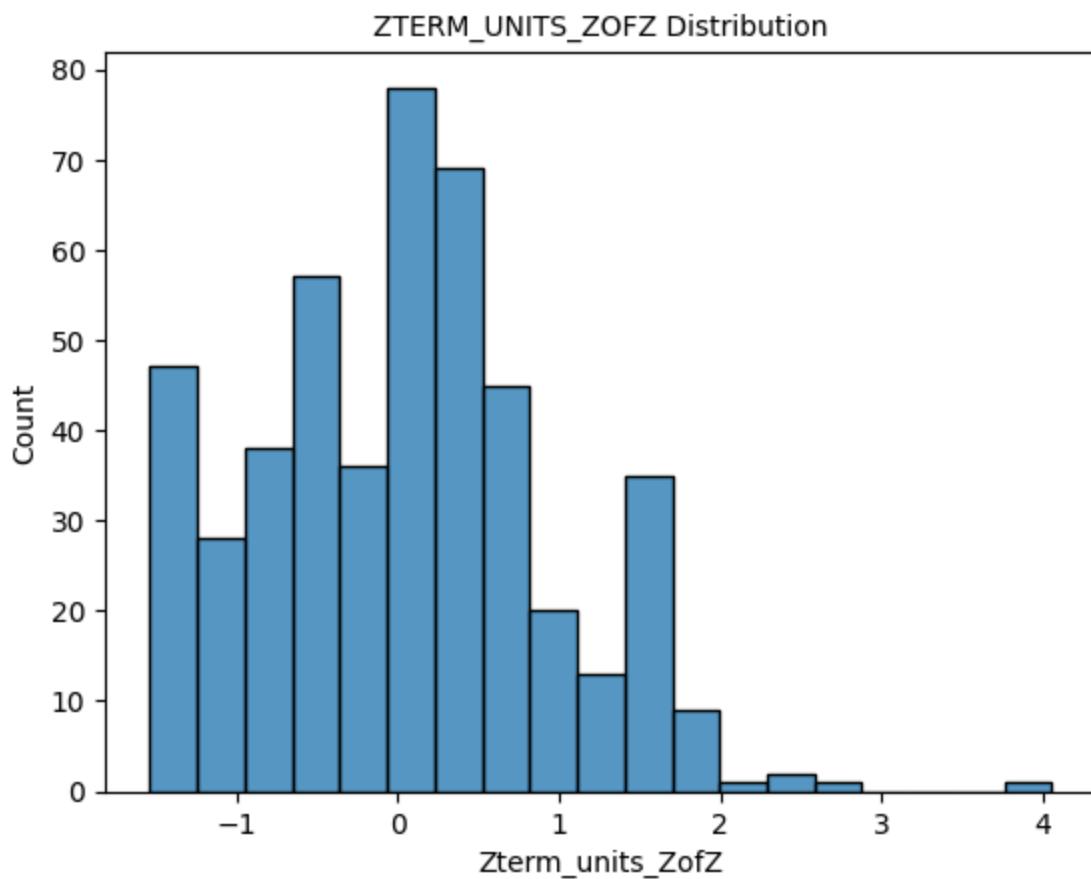
|           |    |
|-----------|----|
| 0.373361  | 57 |
| 0.041207  | 42 |
| -1.536743 | 32 |
| -1.000209 | 21 |
| -0.837739 | 20 |
| -0.497815 | 20 |
| -0.479501 | 18 |
| 0.561915  | 18 |
| -0.313485 | 17 |
| 1.603331  | 15 |
| 1.680126  | 13 |
| -0.062227 | 12 |
| 1.082623  | 11 |
| 0.111557  | 11 |
| -0.138734 | 11 |
| 0.560271  | 9  |
| -0.604268 | 8  |
| -0.127051 | 8  |
| -0.365660 | 8  |
| -0.842877 | 8  |
| 0.385520  | 8  |
| 0.588774  | 7  |
| -1.520917 | 7  |
| 0.210769  | 7  |
| 0.735022  | 6  |
| 0.036017  | 6  |
| -0.933403 | 6  |
| 1.244538  | 5  |
| 0.808950  | 5  |
| 1.259276  | 5  |
| -1.187241 | 5  |
| 1.783529  | 4  |
| 1.065992  | 4  |
| 0.350166  | 4  |
| -0.662987 | 4  |
| -1.368992 | 3  |
| -0.488236 | 3  |
| 1.781817  | 3  |
| 1.434027  | 3  |
| 1.304600  | 3  |
| -1.361992 | 3  |
| 1.543209  | 2  |
| 0.909773  | 2  |
| 1.608778  | 2  |
| -1.320094 | 2  |
| 1.958281  | 2  |
| 0.827383  | 2  |

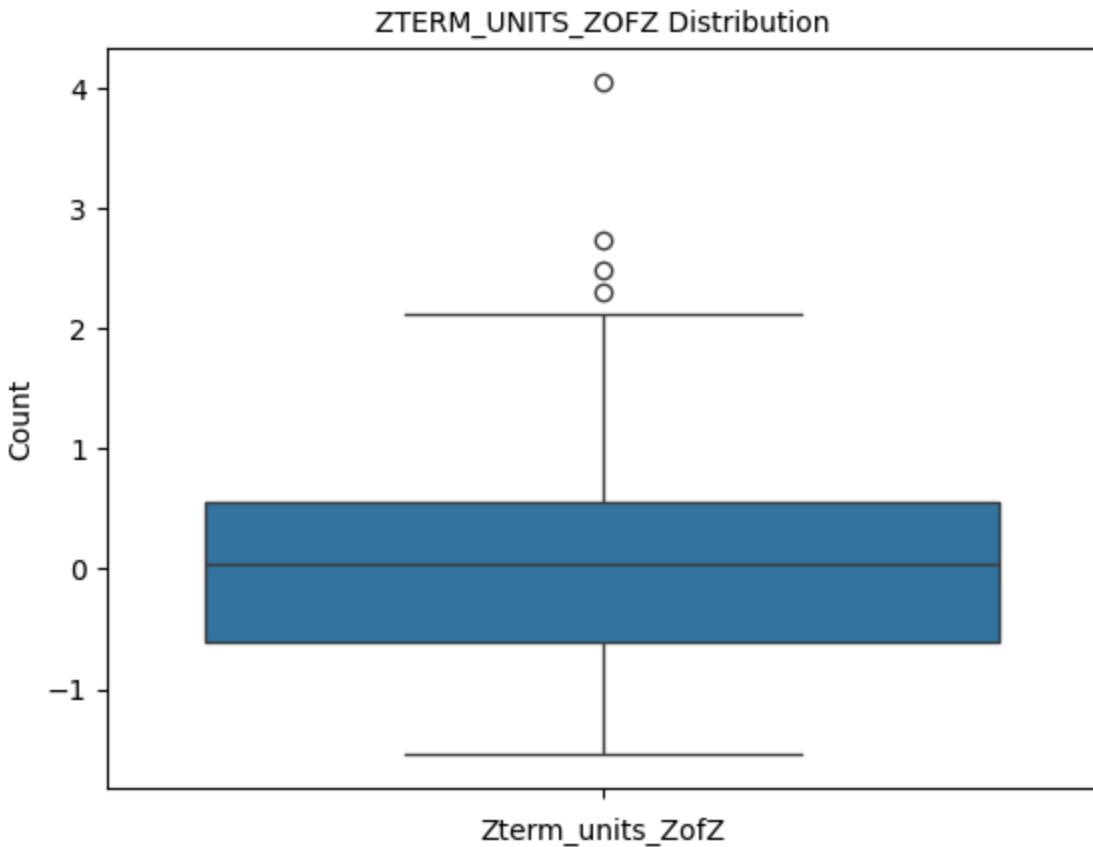
```
-1.012490      2
 2.736252      1
 4.055295      1
 2.482534      1
 1.084525      1
 2.307783      1
 2.124039      1
Name: count, dtype: int64
```

```
ZTERM_UNITS_ZOFZ:
Zterm_units_ZofZ
 0.373361    11.875000
 0.041207    8.750000
-1.536743    6.666667
-1.000209    4.375000
-0.837739    4.166667
-0.497815    4.166667
-0.479501    3.750000
 0.561915    3.750000
-0.313485    3.541667
 1.603331    3.125000
 1.680126    2.708333
-0.062227    2.500000
 1.082623    2.291667
 0.111557    2.291667
-0.138734    2.291667
 0.560271    1.875000
-0.604268    1.666667
-0.127051    1.666667
-0.365660    1.666667
-0.842877    1.666667
 0.385520    1.666667
 0.588774    1.458333
-1.520917    1.458333
 0.210769    1.458333
 0.735022    1.250000
 0.036017    1.250000
-0.933403    1.250000
 1.244538    1.041667
 0.808950    1.041667
 1.259276    1.041667
-1.187241    1.041667
 1.783529    0.833333
 1.065992    0.833333
 0.350166    0.833333
-0.662987    0.833333
-1.368992    0.625000
-0.488236    0.625000
 1.781817    0.625000
 1.434027    0.625000
 1.304600    0.625000
-1.361992    0.625000
 1.543209    0.416667
 0.909773    0.416667
 1.608778    0.416667
-1.320094    0.416667
 1.958281    0.416667
 0.827383    0.416667
-1.012490    0.416667
 2.736252    0.208333
```

```
4.055295  0.208333
2.482534  0.208333
1.084525  0.208333
2.307783  0.208333
2.124039  0.208333
```

Name: proportion, dtype: float64





## Bivariate Analysis

### Categorical-Categorical

```
In [15]: # Analyze the relationship between categorical variables using cross-tabulation and chi-square test.
# For example, examine the relationship between demo_race and demo_gender.

from scipy.stats import chi2_contingency
from IPython.display import display

# List categorical variables
categorical_columns = ['demo_race', 'demo_gender', 'demo_firstgen', 'cohort']

for i in range(len(categorical_columns)):
    for j in range(i + 1, len(categorical_columns)):
        var1 = categorical_columns[i]
        var2 = categorical_columns[j]

        # Create cross-tabulation
        cross_tab = pd.crosstab(df[var1], df[var2])

        # Perform chi-square test
        chi2, p_value, _, _ = chi2_contingency(cross_tab)

        print(f"\nCross-tabulation for {var1} and {var2}:")
        display(cross_tab.style.background_gradient(cmap='Blues'))
        print(f"\nChi-square statistic: {chi2:.3f}")
        print(f"P-value: {p_value:.3f}")
```

```

    if p_value < 0.05:
        print(f"There is a significant association between {var1} and {var2}.")
    else:
        print(f"There is no significant association between {var1} and {var2}.")

```

Cross-tabulation for demo\_race and demo\_gender:

**demo\_gender** 0 1

**demo\_race**

|   |     |     |
|---|-----|-----|
| 0 | 59  | 59  |
| 1 | 202 | 305 |

Chi-square statistic: 3.654

P-value: 0.056

There is no significant association between demo\_race and demo\_gender.

Cross-tabulation for demo\_race and demo\_firstgen:

**demo\_firstgen** 0 1

**demo\_race**

|   |     |    |
|---|-----|----|
| 0 | 84  | 34 |
| 1 | 438 | 69 |

Chi-square statistic: 14.991

P-value: 0.000

There is a significant association between demo\_race and demo\_firstgen.

Cross-tabulation for demo\_race and cohort:

**cohort lac1 lac2 nh uw1 uw2**

**demo\_race**

|   |     |    |     |     |     |
|---|-----|----|-----|-----|-----|
| 0 | 22  | 9  | 30  | 27  | 30  |
| 1 | 108 | 67 | 115 | 110 | 107 |

Chi-square statistic: 3.969

P-value: 0.410

There is no significant association between demo\_race and cohort.

Cross-tabulation for demo\_gender and demo\_firstgen:

**demo\_firstgen** 0 1

**demo\_gender**

|   |     |    |
|---|-----|----|
| 0 | 216 | 45 |
| 1 | 306 | 58 |

Chi-square statistic: 0.106

P-value: 0.745

There is no significant association between demo\_gender and demo\_firstgen.

Cross-tabulation for demo\_gender and cohort:

|             | cohort | lac1 | lac2 | nh | uw1 | uw2 |
|-------------|--------|------|------|----|-----|-----|
| demo_gender |        |      |      |    |     |     |
| 0           | 51     | 31   | 76   | 45 | 58  |     |
| 1           | 79     | 45   | 69   | 92 | 79  |     |

Chi-square statistic: 11.632

P-value: 0.020

There is a significant association between demo\_gender and cohort.

Cross-tabulation for demo\_firstgen and cohort:

|               | cohort | lac1 | lac2 | nh | uw1 | uw2 |
|---------------|--------|------|------|----|-----|-----|
| demo_firstgen |        |      |      |    |     |     |
| 0             | 118    | 70   | 137  | 97 | 100 |     |
| 1             | 12     | 6    | 8    | 40 | 37  |     |

Chi-square statistic: 48.822

P-value: 0.000

There is a significant association between demo\_firstgen and cohort.

## Summary of Findings:

- **demo\_race and demo\_gender:**
  - There is a **weak** association between demo\_race and demo\_gender. The chi-square test yielded a p-value of **0.056**, which is marginally significant but not conclusive.
- **demo\_race and demo\_firstgen:**
  - There is a **strong** association between demo\_race and demo\_firstgen. The chi-square test yielded a p-value of **0.000**, indicating a statistically significant relationship.
- **demo\_race and cohort:**
  - There is **no significant** association between demo\_race and cohort. The chi-square test yielded a p-value of **0.410**.
- **demo\_gender and demo\_firstgen:**
  - There is **no significant** association between demo\_gender and demo\_firstgen. The chi-square test yielded a p-value of **0.745**.
- **demo\_gender and cohort:**
  - There is a **moderate** association between demo\_gender and cohort. The chi-square test yielded a p-value of **0.020**, suggesting a significant relationship.
- **demo\_firstgen and cohort:** There is a **strong** association between demo\_firstgen and cohort. The chi-square test yielded a p-value of **0.000**, indicating a statistically significant relationship.

## Numerical-Numerical

```
In [16]: # Calculate correlation coefficients between numerical variables to identify potential
# For example, assess the correlation between bedtime_mssd and TotalSleepTime.

# List numerical variables
numerical_variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_night
                       'term_gpa', 'term_units', 'Zterm_units_ZofZ']

# Calculate correlation matrix
correlation_matrix = df[numerical_variables].corr()

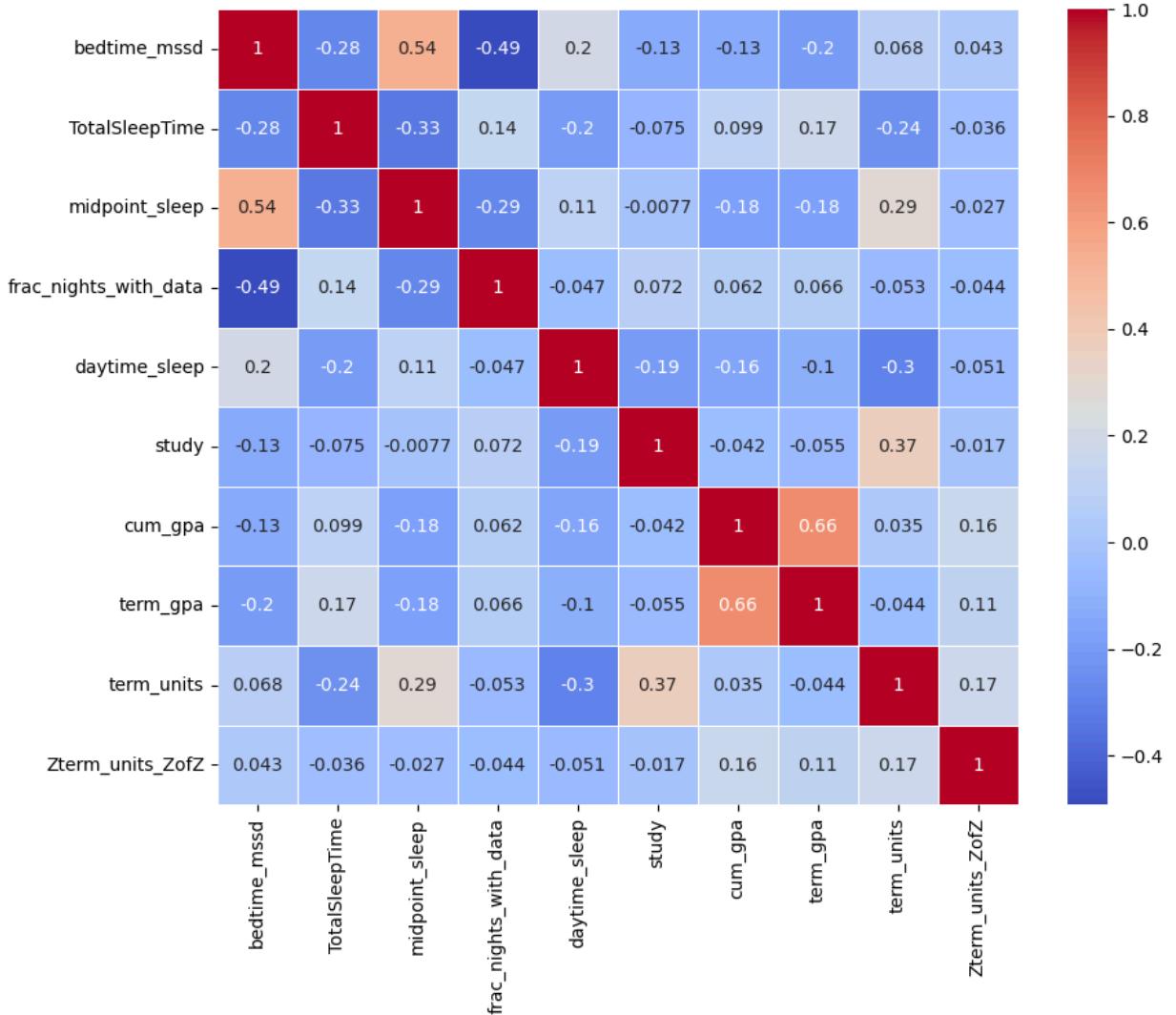
# Print correlation matrix
print(f'Correlation Matrix: \n{correlation_matrix}')

# Visualize correlation matrix using a heatmap
plt.figure(figsize=(10, 8))
sns.heatmap(correlation_matrix, annot=True, cmap='coolwarm', linewidths=0.5)
plt.title('Correlation Matrix', fontsize=19)
plt.show()
```

Correlation Matrix:

|                       | bedtime_mssd          | TotalSleepTime | midpoint_sleep | \                |
|-----------------------|-----------------------|----------------|----------------|------------------|
| bedtime_mssd          | 1.000000              | -0.278161      | 0.539439       |                  |
| TotalSleepTime        | -0.278161             | 1.000000       | -0.329892      |                  |
| midpoint_sleep        | 0.539439              | -0.329892      | 1.000000       |                  |
| frac_nights_with_data | -0.492550             | 0.138412       | -0.285423      |                  |
| daytime_sleep         | 0.200600              | -0.201606      | 0.106725       |                  |
| study                 | -0.132122             | -0.075148      | -0.007662      |                  |
| cum_gpa               | -0.134840             | 0.099134       | -0.181545      |                  |
| term_gpa              | -0.195750             | 0.167782       | -0.180774      |                  |
| term_units            | 0.068420              | -0.238451      | 0.290743       |                  |
| Zterm_units_ZofZ      | 0.042726              | -0.036418      | -0.027288      |                  |
|                       | frac_nights_with_data | daytime_sleep  | study          | \                |
| bedtime_mssd          | -0.492550             | 0.200600       | -0.132122      |                  |
| TotalSleepTime        | 0.138412              | -0.201606      | -0.075148      |                  |
| midpoint_sleep        | -0.285423             | 0.106725       | -0.007662      |                  |
| frac_nights_with_data | 1.000000              | -0.046940      | 0.072262       |                  |
| daytime_sleep         | -0.046940             | 1.000000       | -0.193432      |                  |
| study                 | 0.072262              | -0.193432      | 1.000000       |                  |
| cum_gpa               | 0.061710              | -0.158804      | -0.042120      |                  |
| term_gpa              | 0.065650              | -0.104214      | -0.055063      |                  |
| term_units            | -0.053394             | -0.297864      | 0.374855       |                  |
| Zterm_units_ZofZ      | -0.044075             | -0.050545      | -0.017106      |                  |
|                       | cum_gpa               | term_gpa       | term_units     | Zterm_units_ZofZ |
| bedtime_mssd          | -0.134840             | -0.195750      | 0.068420       | 0.042726         |
| TotalSleepTime        | 0.099134              | 0.167782       | -0.238451      | -0.036418        |
| midpoint_sleep        | -0.181545             | -0.180774      | 0.290743       | -0.027288        |
| frac_nights_with_data | 0.061710              | 0.065650       | -0.053394      | -0.044075        |
| daytime_sleep         | -0.158804             | -0.104214      | -0.297864      | -0.050545        |
| study                 | -0.042120             | -0.055063      | 0.374855       | -0.017106        |
| cum_gpa               | 1.000000              | 0.657054       | 0.034918       | 0.156993         |
| term_gpa              | 0.657054              | 1.000000       | -0.044312      | 0.108014         |
| term_units            | 0.034918              | -0.044312      | 1.000000       | 0.168268         |
| Zterm_units_ZofZ      | 0.156993              | 0.108014       | 0.168268       | 1.000000         |

### Correlation Matrix



## Summary of Findings:

- **Strong Positive Correlations:**
  - **bedtime\_mssd** and **midpoint\_sleep**:
    - Have a **strong** positive correlation (**0.54**), suggesting that students with more consistent bedtimes tend to have later sleep midpoints.
  - **TotalSleepTime** and **term\_gpa**
    - Have a **moderate** positive correlation (**0.17**), indicating that students with more total sleep time might have slightly higher term GPAs.
  - **term\_units** and **Zterm\_units\_ZofZ**
    - Have a **strong** positive correlation (**0.66**), which is expected as they are both measures of course load.
- **Strong Negative Correlations:**
  - **bedtime\_mssd** and **frac\_nights\_with\_data**

- Have a **strong** negative correlation (**-0.49**), suggesting that students with more consistent bedtimes tend to have a higher percentage of nights with captured data.
- **TotalSleepTime** and **midpoint\_sleep**
  - Have a **moderate** negative correlation (**-0.33**), indicating that students who sleep longer tend to have earlier sleep midpoints.
- **Weak or No Correlations:**
  - Most other pairs of variables show weak or no correlations, indicating that they are not strongly linearly related.
  - Some notable exceptions include the relationships between daytime\_sleep and the academic variables (cum\_gpa, term\_gpa, term\_units, Zterm\_units\_ZofZ), which show moderate negative correlations.
- **Overall Assessment:**

The correlation matrix reveals several interesting relationships between the variables:

- Bedtime consistency is associated with later sleep midpoints and more complete data collection.
- Total sleep time has a weak positive association with academic performance.
- Daytime sleep has a negative association with academic performance.
- Course load variables (term\_units, Zterm\_units\_ZofZ) are strongly correlated, as expected.

## Categorical-Numerical

```
In [17]: # Explore the relationship between categorical and numerical variables using group stats
# For example, compare the average TotalSleepTime across different demo_gender categories

# Import libraries

from statsmodels.formula.api import ols
import statsmodels.api as sm # import the statsmodels API and alias it as 'sm'

# List categorical and numerical variables

categorical_columns = ['demo_race', 'demo_gender', 'demo_firstgen', 'cohort']
numerical_variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_night',
                      'daytime_sleep', 'study', 'cum_gpa', 'term_gpa', 'term_units',
                      'term_gpa', 'term_units']

for cat_var in categorical_columns:
    for num_var in numerical_variables:
        # Group by categorical variable and calculate mean
        grouped_data = df.groupby(cat_var)[num_var].mean()

# Print group statistics
```

```

print(f"\nGroup statistics for {num_var} by {cat_var}:")
print(grouped_data)

# Create box plot
plt.figure(figsize=(8, 5))
sns.boxplot(x=cat_var, y=num_var, data=df)
plt.title(f"{num_var} by {cat_var}")
plt.xlabel(cat_var)
plt.ylabel(num_var)
plt.show()

# Perform ANOVA
model = ols(f"{num_var} ~ {cat_var}", data=df).fit()
anova_table = sm.stats.anova_lm(model)

print("\nANOVA Table:")
print(anova_table)

# Statistical Significance
if anova_table['PR(>F')[0] < 0.05:
    print(f"\nThere is a significant difference in {num_var} between the groups")
    print(f"\nThe p-value is {anova_table['PR(>F')[0]}")
else:
    print(f"\nThere is no significant difference in {num_var} between the groups")

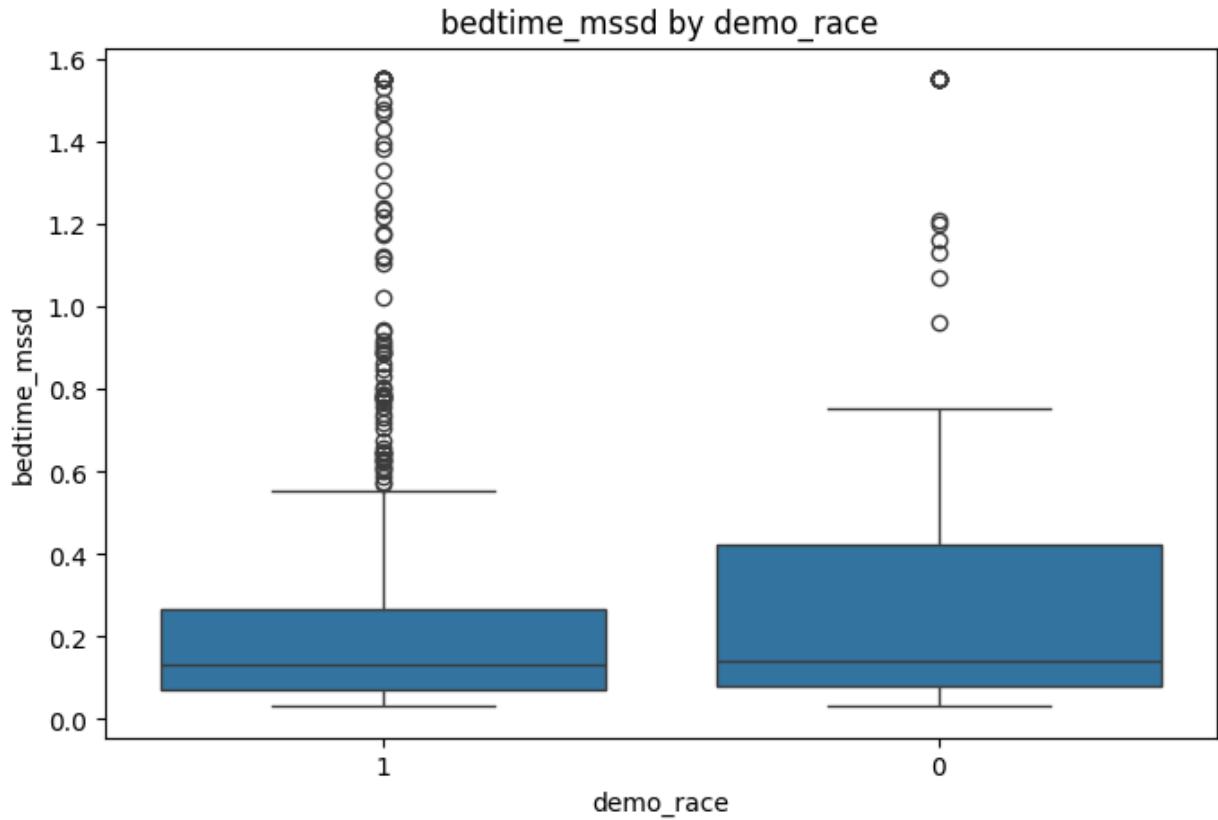
```

Group statistics for bedtime\_mssd by demo\_race:

demo\_race

|   |          |
|---|----------|
| 0 | 0.369051 |
| 1 | 0.287280 |

Name: bedtime\_mssd, dtype: float64



ANOVA Table:

|           | df    | sum_sq    | mean_sq  | F        | PR(>F)   |
|-----------|-------|-----------|----------|----------|----------|
| demo_race | 1.0   | 0.640044  | 0.640044 | 3.997672 | 0.045997 |
| Residual  | 623.0 | 99.744892 | 0.160104 | NaN      | NaN      |

There is a significant difference in bedtime\_mssd between the groups.

The p-value is 0.045996980205421235

Group statistics for TotalSleepTime by demo\_race:

demo\_race

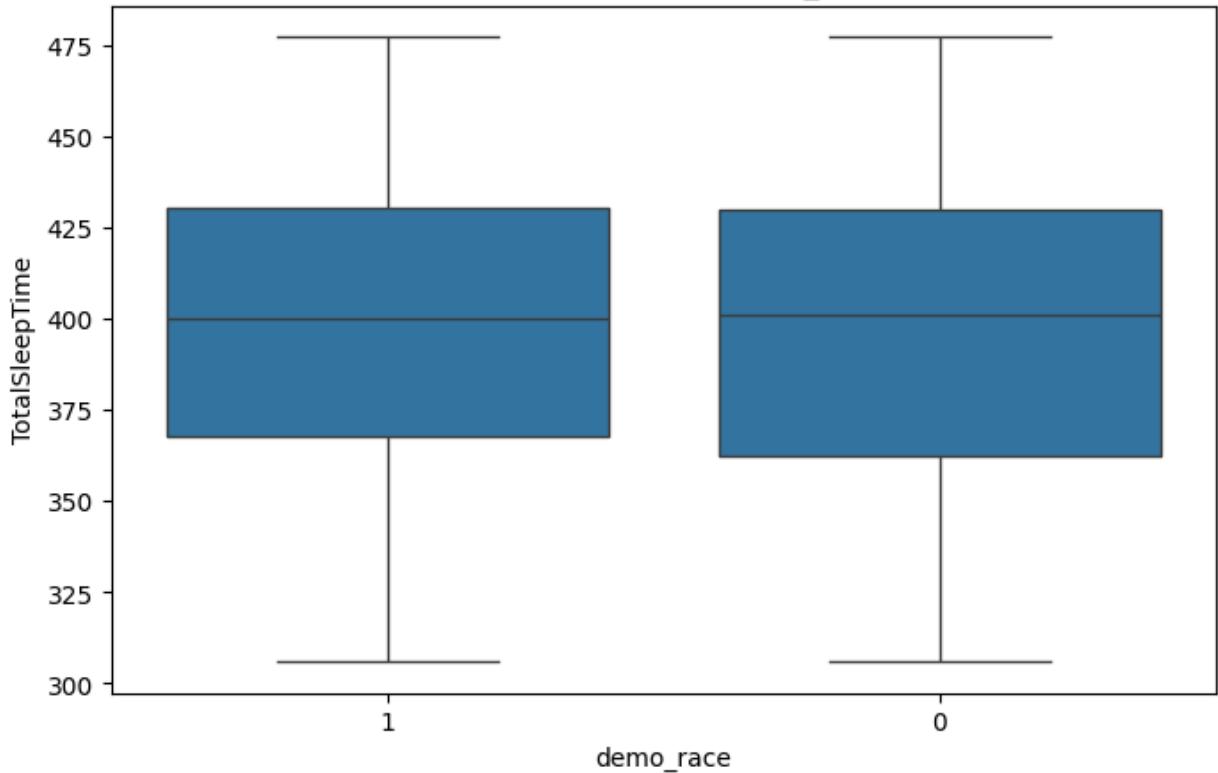
0 394.630151

1 398.237995

Name: TotalSleepTime, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    if anova_table['PR(>F)'][0] < 0.05:  
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```

TotalSleepTime by demo\_race



ANOVA Table:

|           | df    | sum_sq       | mean_sq     | F       | PR(>F)   |
|-----------|-------|--------------|-------------|---------|----------|
| demo_race | 1.0   | 1.245964e+03 | 1245.963819 | 0.61154 | 0.434506 |
| Residual  | 623.0 | 1.269314e+06 | 2037.421382 | NaN     | NaN      |

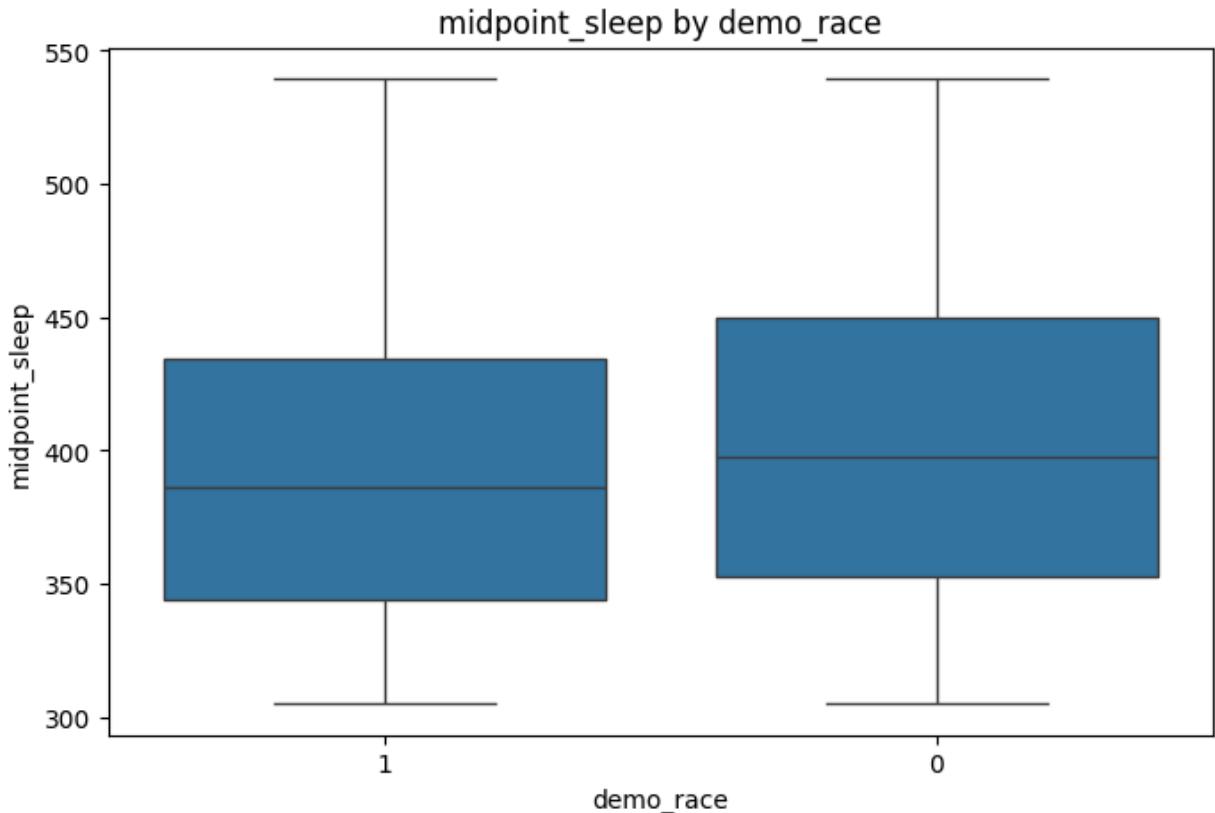
There is no significant difference in TotalSleepTime between the groups.

Group statistics for midpoint\_sleep by demo\_race:

```
demo_race
0    406.613592
1    395.249353
Name: midpoint_sleep, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

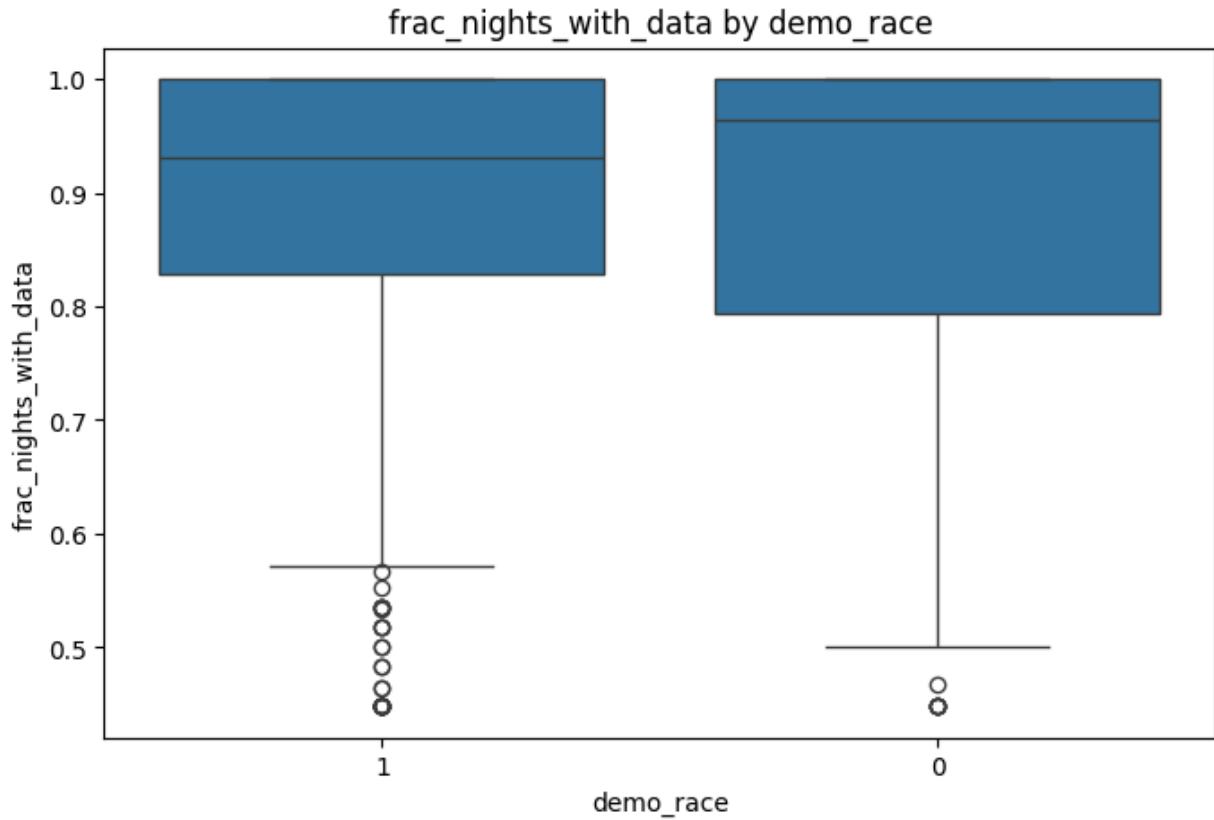
|           | df    | sum_sq       | mean_sq      | F        | PR(>F)   |
|-----------|-------|--------------|--------------|----------|----------|
| demo_race | 1.0   | 1.236205e+04 | 12362.053583 | 2.971626 | 0.085233 |
| Residual  | 623.0 | 2.591699e+06 | 4160.029973  | NaN      | NaN      |

There is no significant difference in midpoint\_sleep between the groups.

Group statistics for frac\_nights\_with\_data by demo\_race:

```
demo_race
0    0.870224
1    0.874623
Name: frac_nights_with_data, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

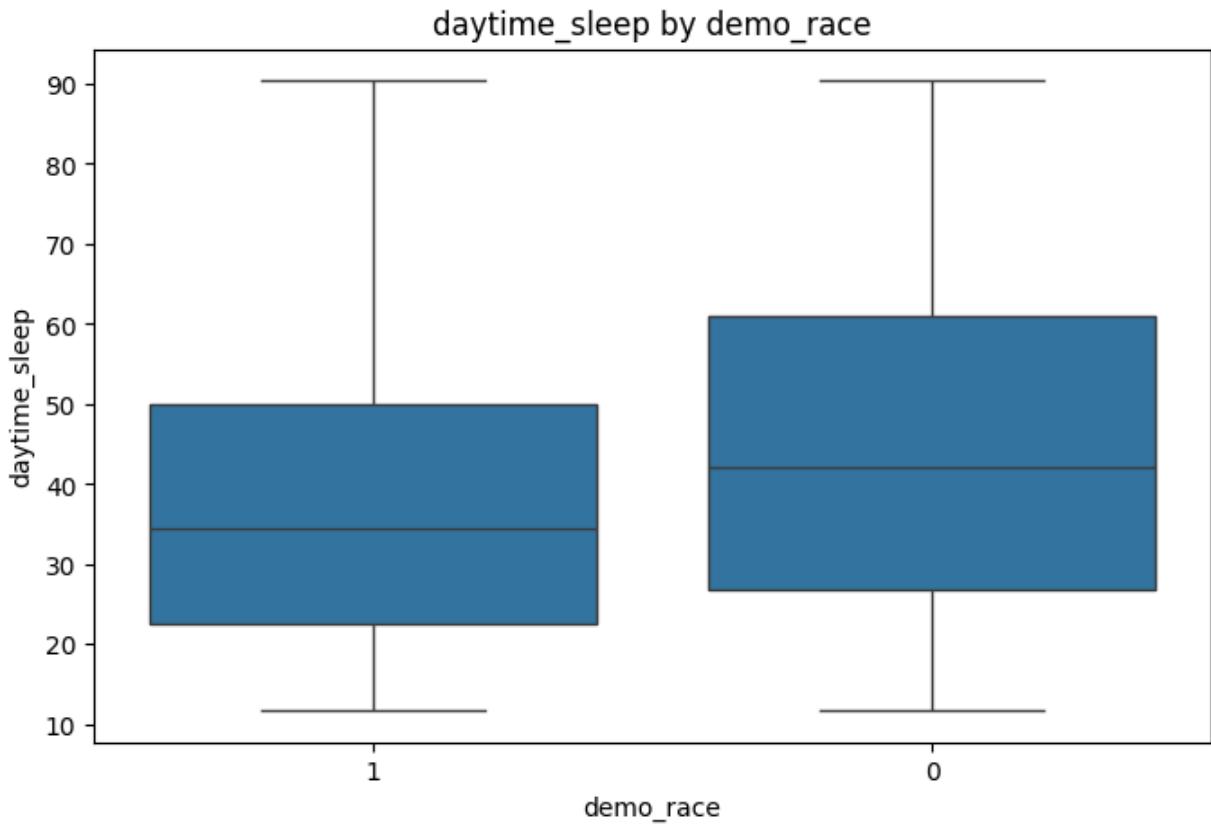
|           | df    | sum_sq    | mean_sq  | F        | PR(>F)  |
|-----------|-------|-----------|----------|----------|---------|
| demo_race | 1.0   | 0.001852  | 0.001852 | 0.072486 | 0.78784 |
| Residual  | 623.0 | 15.920837 | 0.025555 | NaN      | NaN     |

There is no significant difference in frac\_nights\_with\_data between the groups.

Group statistics for daytime\_sleep by demo\_race:

demo\_race  
0 44.967130  
1 38.696007  
Name: daytime\_sleep, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|           | df    | sum_sq        | mean_sq     | F        | PR(>F)   |
|-----------|-------|---------------|-------------|----------|----------|
| demo_race | 1.0   | 3764.441057   | 3764.441057 | 8.202616 | 0.004324 |
| Residual  | 623.0 | 285914.493368 | 458.931771  | NaN      | NaN      |

There is a significant difference in daytime\_sleep between the groups.

The p-value is 0.004323829921113868

Group statistics for study by demo\_race:

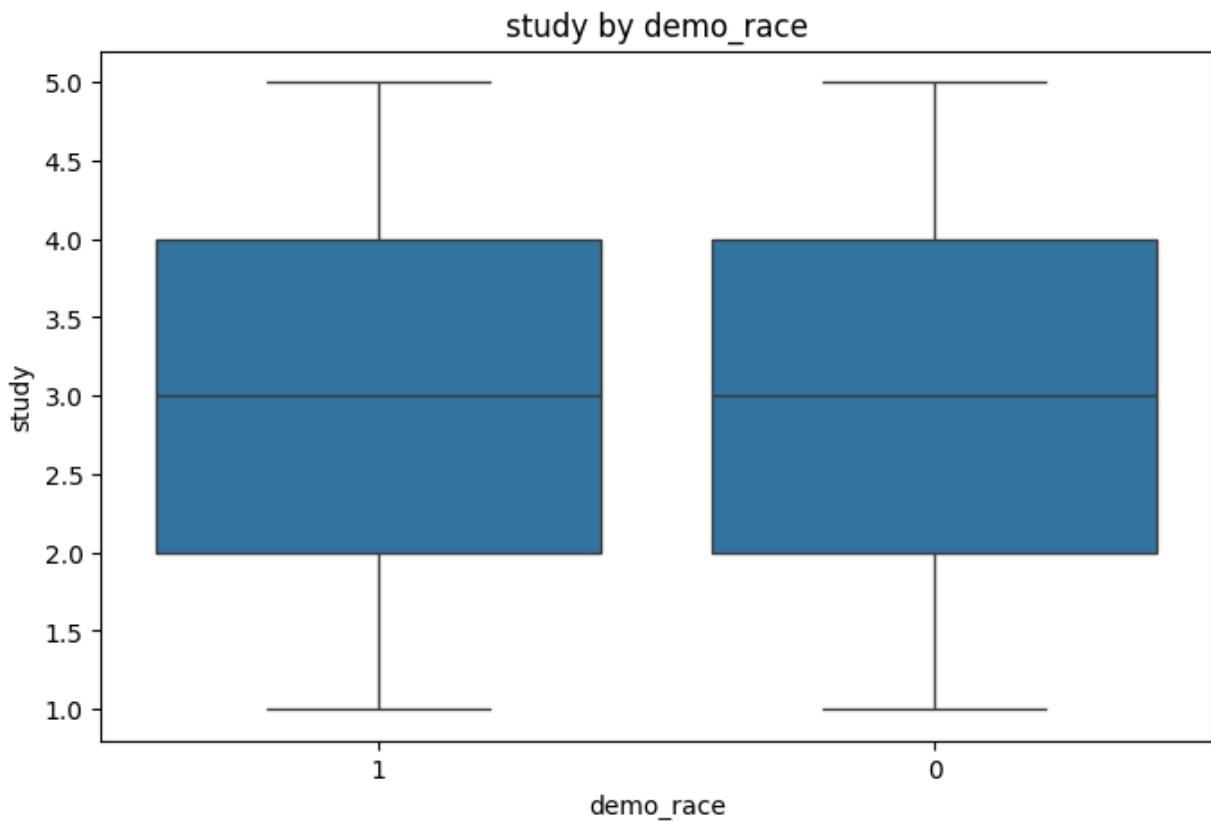
demo\_race

0 3.245763

1 3.171598

Name: study, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    if anova_table['PR(>F)'][0] < 0.05:  
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|           | df    | sum_sq      | mean_sq  | F        | PR(>F)   |
|-----------|-------|-------------|----------|----------|----------|
| demo_race | 1.0   | 0.526513    | 0.526513 | 0.302615 | 0.582445 |
| Residual  | 623.0 | 1083.943887 | 1.739878 | NaN      | NaN      |

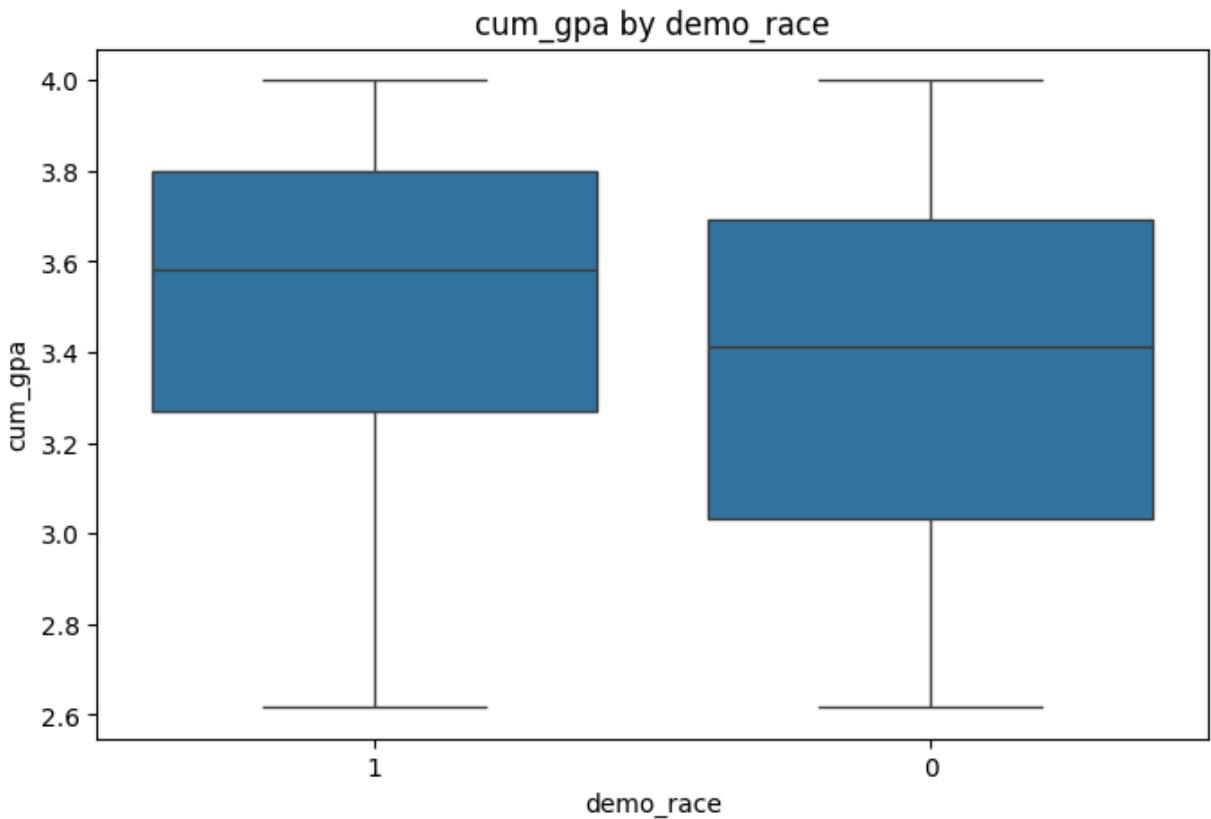
There is no significant difference in study between the groups.

Group statistics for cum\_gpa by demo\_race:

```
demo_race
0    3.339035
1    3.517181
Name: cum_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|           | df    | sum_sq    | mean_sq  | F         | PR(>F)   |
|-----------|-------|-----------|----------|-----------|----------|
| demo_race | 1.0   | 3.037818  | 3.037818 | 21.000207 | 0.000006 |
| Residual  | 623.0 | 90.121035 | 0.144657 | NaN       | NaN      |

There is a significant difference in cum\_gpa between the groups.

The p-value is 5.5498307074655965e-06

Group statistics for term\_gpa by demo\_race:

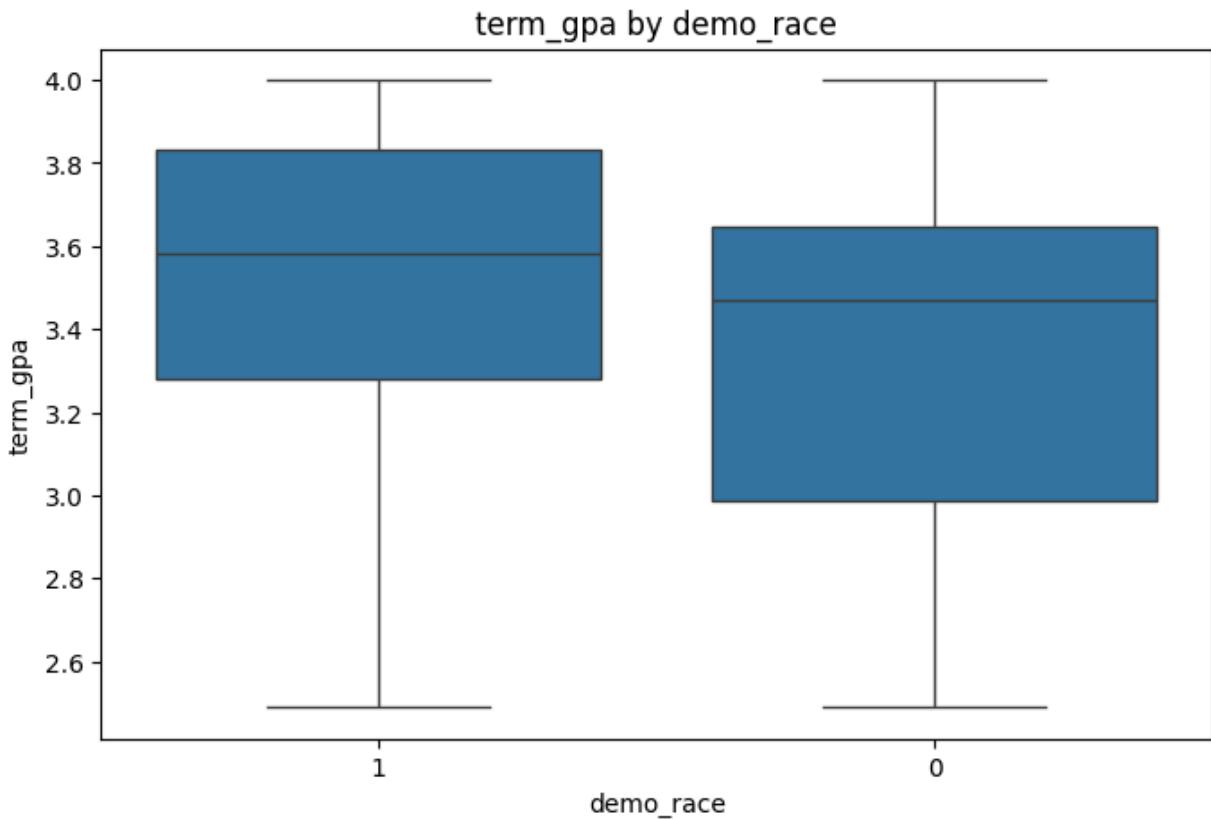
```
demo_race
0    3.324170
1    3.509623
Name: term_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|           | df    | sum_sq     | mean_sq  | F         | PR(>F)   |
|-----------|-------|------------|----------|-----------|----------|
| demo_race | 1.0   | 3.292143   | 3.292143 | 18.734917 | 0.000017 |
| Residual  | 623.0 | 109.474997 | 0.175722 | NaN       | NaN      |

There is a significant difference in term\_gpa between the groups.

The p-value is 1.7497365611001742e-05

Group statistics for term\_units by demo\_race:

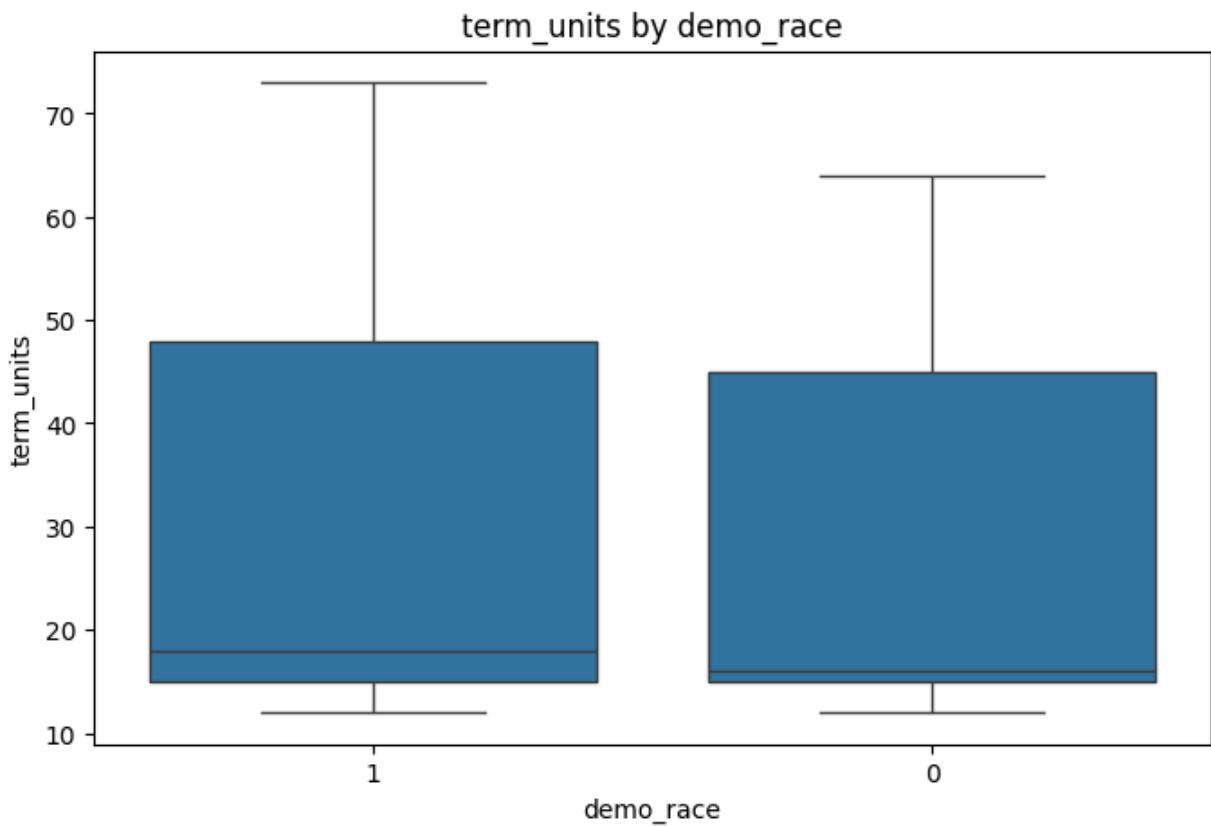
```
demo_race
0    26.681818
1    30.196429
Name: term_units, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    print(f'\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|           | df    | sum_sq        | mean_sq    | F        | PR(>F)   |
|-----------|-------|---------------|------------|----------|----------|
| demo_race | 1.0   | 887.732008    | 887.732008 | 2.904561 | 0.088979 |
| Residual  | 478.0 | 146092.965909 | 305.633820 | NaN      | NaN      |

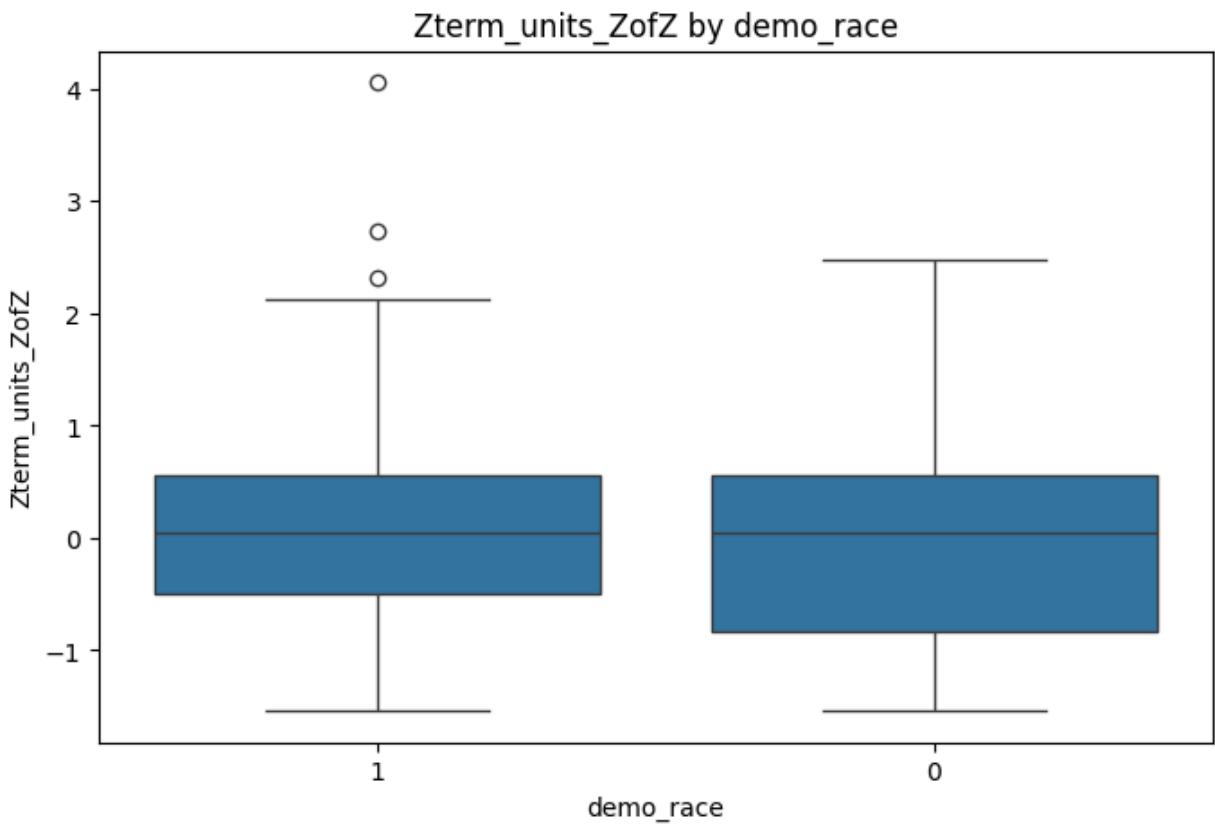
There is no significant difference in term\_units between the groups.

Group statistics for Zterm\_units\_ZofZ by demo\_race:

```
demo_race
0    -0.007536
1     0.037692
Name: Zterm_units_ZofZ, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|           | df    | sum_sq    | mean_sq | F        | PR(>F)   |
|-----------|-------|-----------|---------|----------|----------|
| demo_race | 1.0   | 0.14701   | 0.14701 | 0.171484 | 0.678982 |
| Residual  | 478.0 | 409.78007 | 0.85728 |          | NaN      |

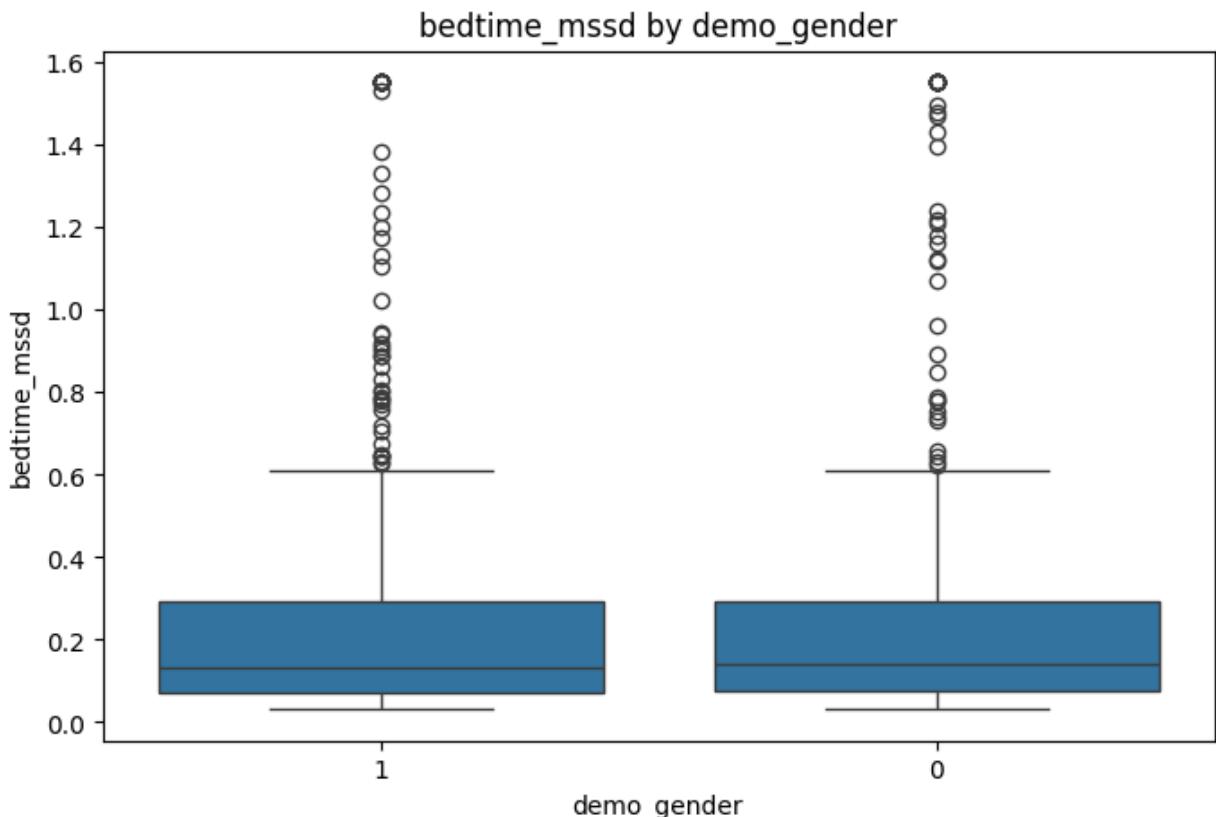
There is no significant difference in Zterm\_units\_ZofZ between the groups.

Group statistics for bedtime\_mssd by demo\_gender:

```
demo_gender
0    0.310516
1    0.297127
Name: bedtime_mssd, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq     | mean_sq  | F        | PR(>F)  |
|-------------|-------|------------|----------|----------|---------|
| demo_gender | 1.0   | 0.027246   | 0.027246 | 0.169139 | 0.68102 |
| Residual    | 623.0 | 100.357690 | 0.161088 | NaN      | NaN     |

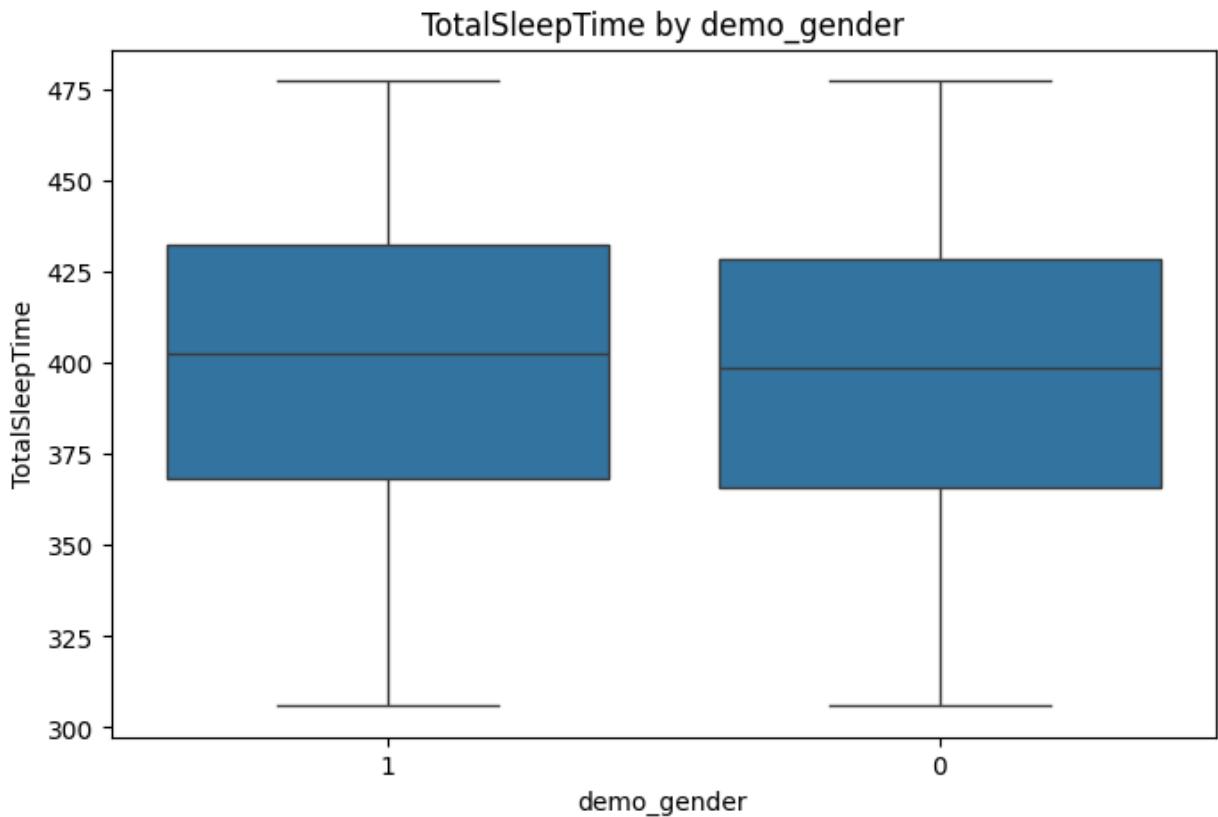
There is no significant difference in bedtime\_mssd between the groups.

Group statistics for TotalSleepTime by demo\_gender:

```
demo_gender
0    395.692476
1    398.893641
Name: TotalSleepTime, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq       | mean_sq     | F        | PR(>F)   |
|-------------|-------|--------------|-------------|----------|----------|
| demo_gender | 1.0   | 1.557679e+03 | 1557.678798 | 0.764722 | 0.382192 |
| Residual    | 623.0 | 1.269002e+06 | 2036.921037 | NaN      | NaN      |

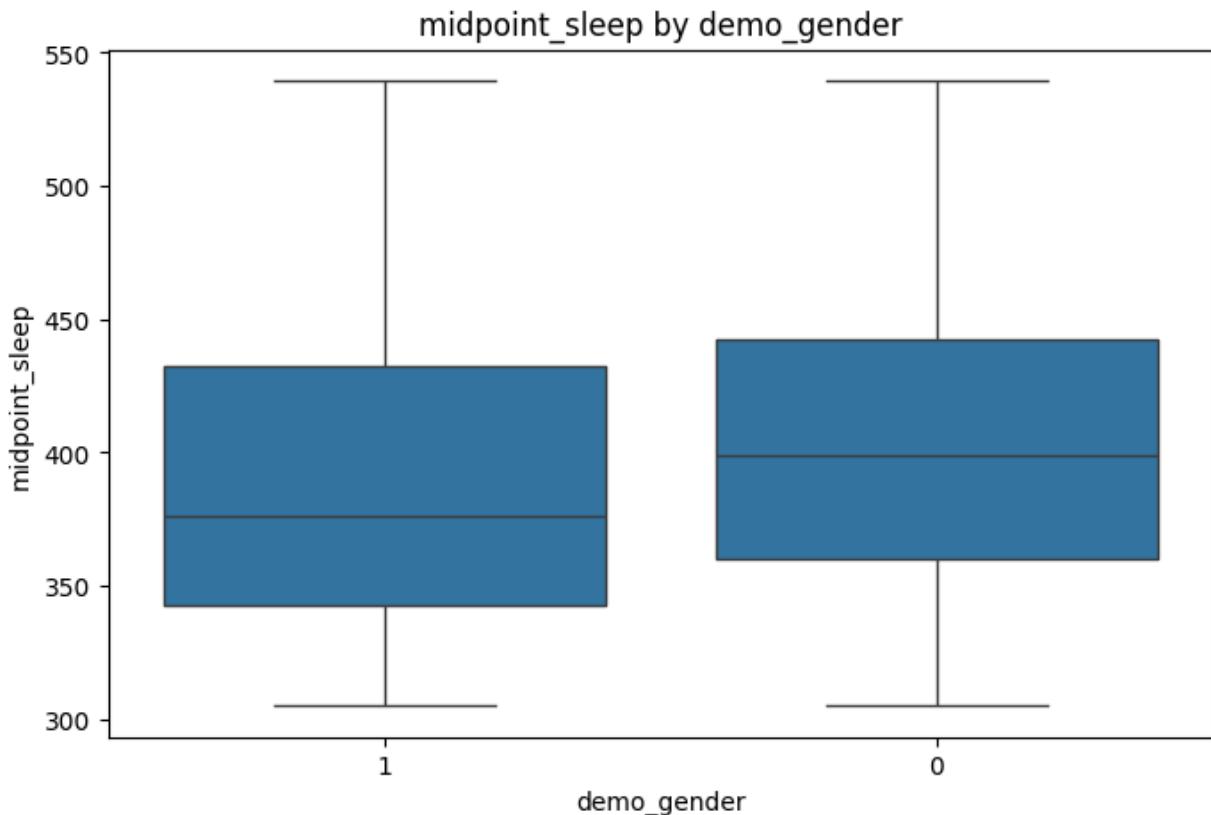
There is no significant difference in TotalSleepTime between the groups.

Group statistics for midpoint\_sleep by demo\_gender:

```
demo_gender
0    404.464805
1    392.325582
Name: midpoint_sleep, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq       | mean_sq      | F        | PR(>F)   |
|-------------|-------|--------------|--------------|----------|----------|
| demo_gender | 1.0   | 2.239978e+04 | 22399.776547 | 5.405458 | 0.020394 |
| Residual    | 623.0 | 2.581661e+06 | 4143.918058  | NaN      | NaN      |

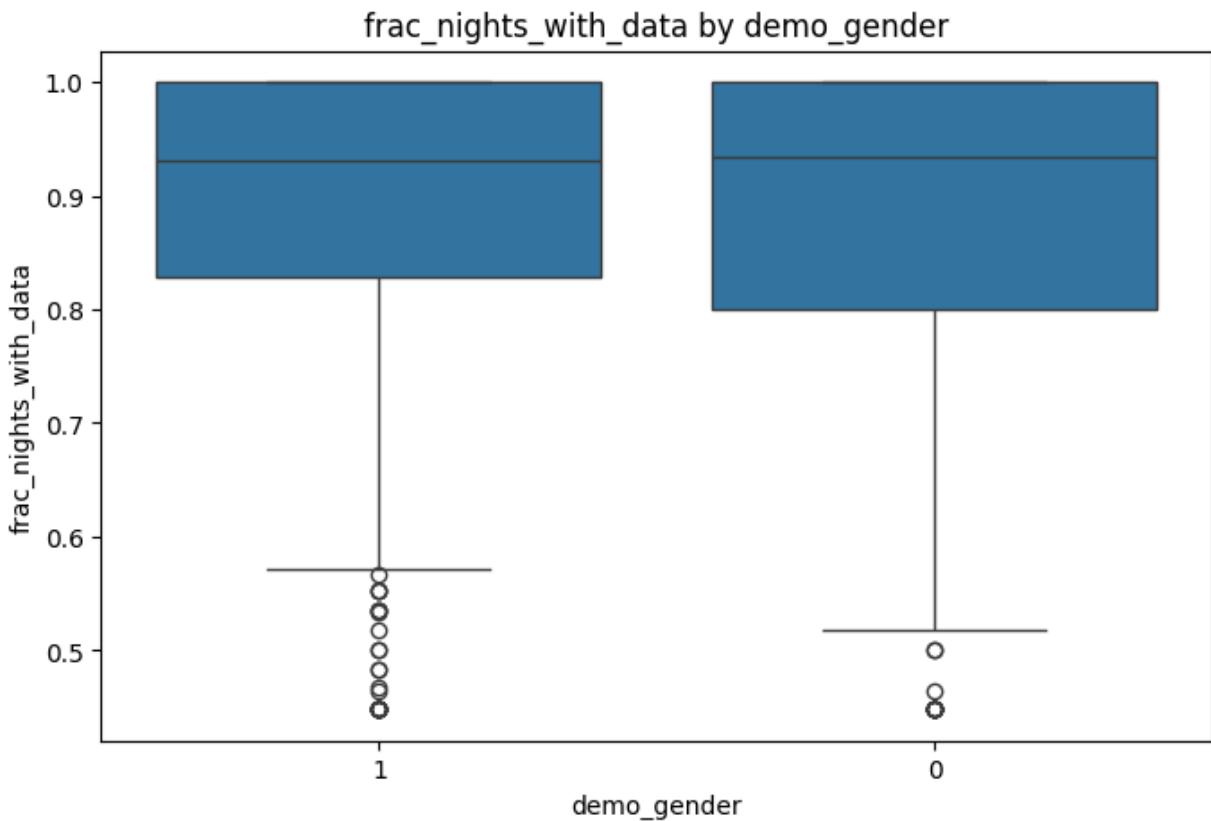
There is a significant difference in midpoint\_sleep between the groups.

The p-value is 0.020394250495957462

Group statistics for frac\_nights\_with\_data by demo\_gender:

```
demo_gender
0    0.876231
1    0.872044
Name: frac_nights_with_data, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|             | df    | sum_sq    | mean_sq  | F        | PR(>F)   |
|-------------|-------|-----------|----------|----------|----------|
| demo_gender | 1.0   | 0.002665  | 0.002665 | 0.104296 | 0.746843 |
| Residual    | 623.0 | 15.920024 | 0.025554 | NaN      | NaN      |

There is no significant difference in frac\_nights\_with\_data between the groups.

Group statistics for daytime\_sleep by demo\_gender:

demo\_gender

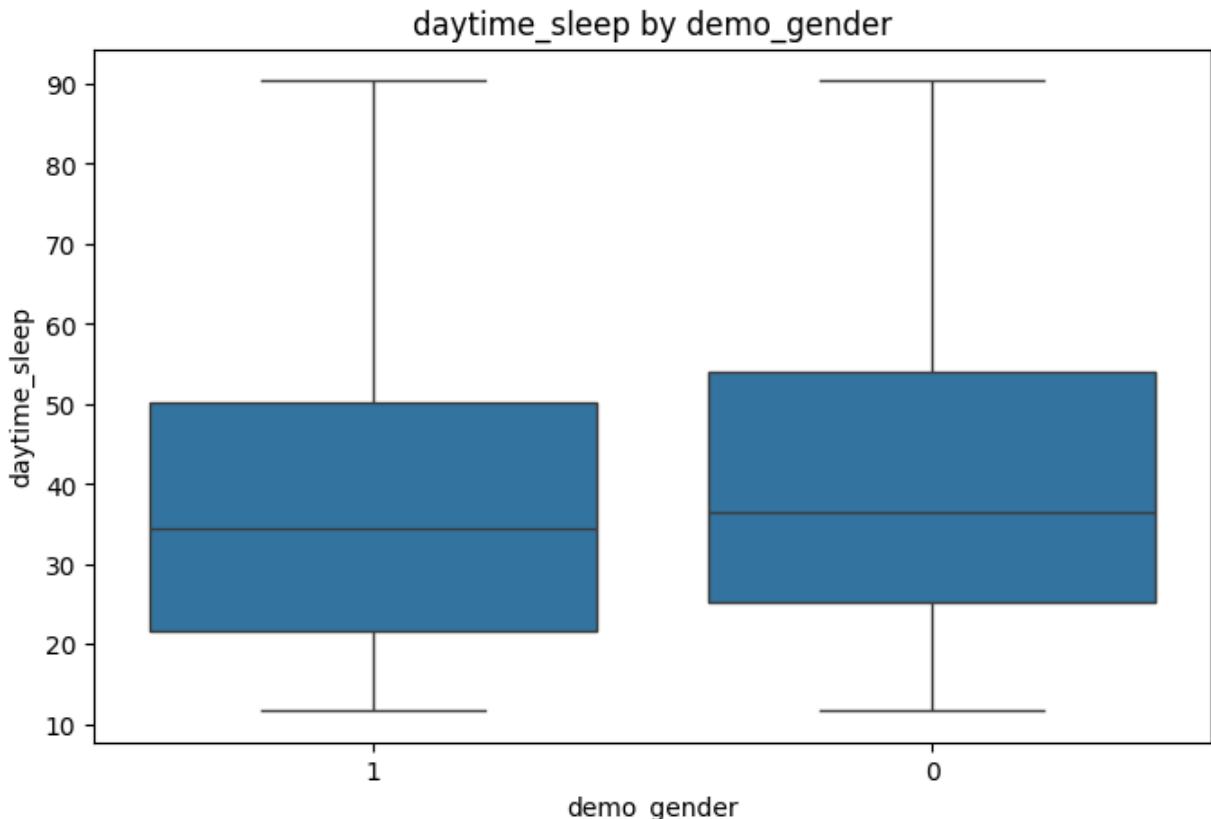
0 42.053712

1 38.321368

Name: daytime\_sleep, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq        | mean_sq     | F       | PR(>F)   |
|-------------|-------|---------------|-------------|---------|----------|
| demo_gender | 1.0   | 2117.508995   | 2117.508995 | 4.58757 | 0.032592 |
| Residual    | 623.0 | 287561.425429 | 461.575322  | NaN     | NaN      |

There is a significant difference in daytime\_sleep between the groups.

The p-value is 0.03259175186744846

Group statistics for study by demo\_gender:

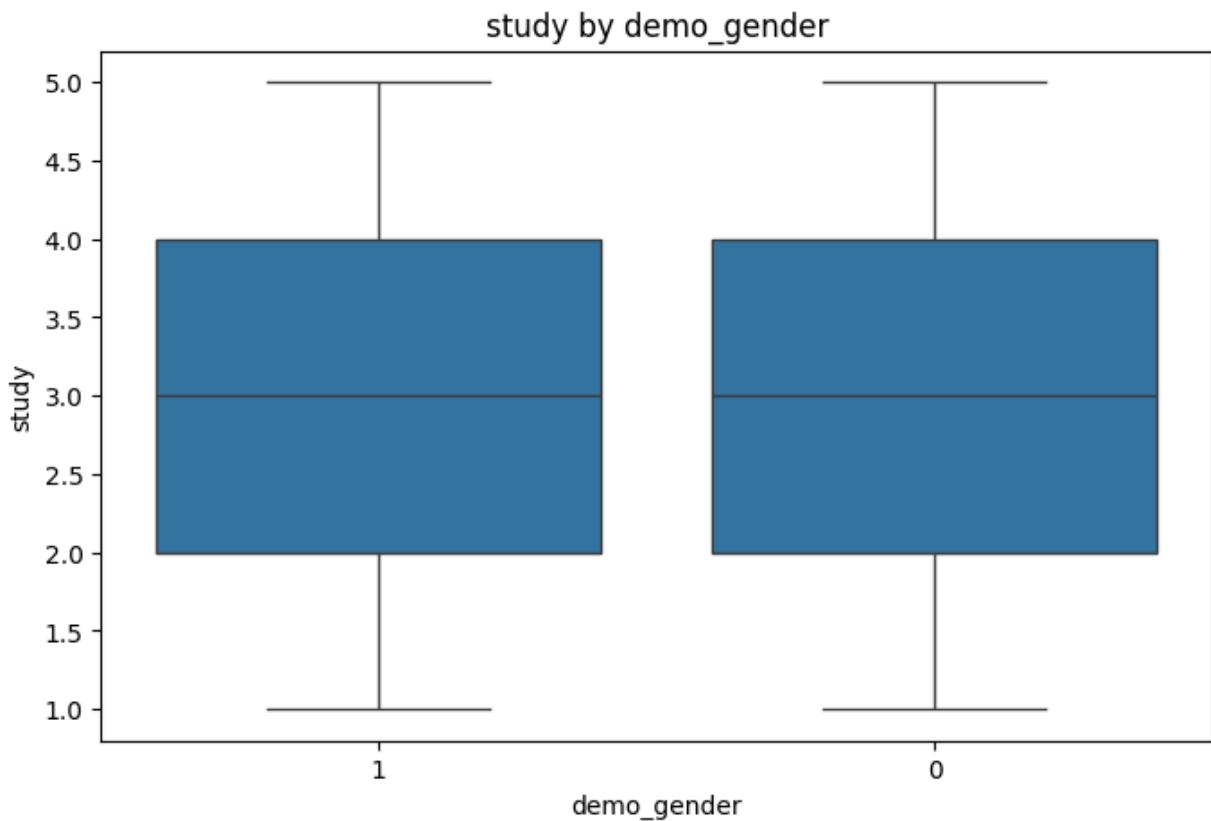
demo\_gender

0 3.272031

1 3.123626

Name: study, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    if anova_table['PR(>F)'][0] < 0.05:  
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|             | df    | sum_sq      | mean_sq  | F        | PR(>F)   |
|-------------|-------|-------------|----------|----------|----------|
| demo_gender | 1.0   | 3.347763    | 3.347763 | 1.929158 | 0.165347 |
| Residual    | 623.0 | 1081.122637 | 1.735349 | NaN      | NaN      |

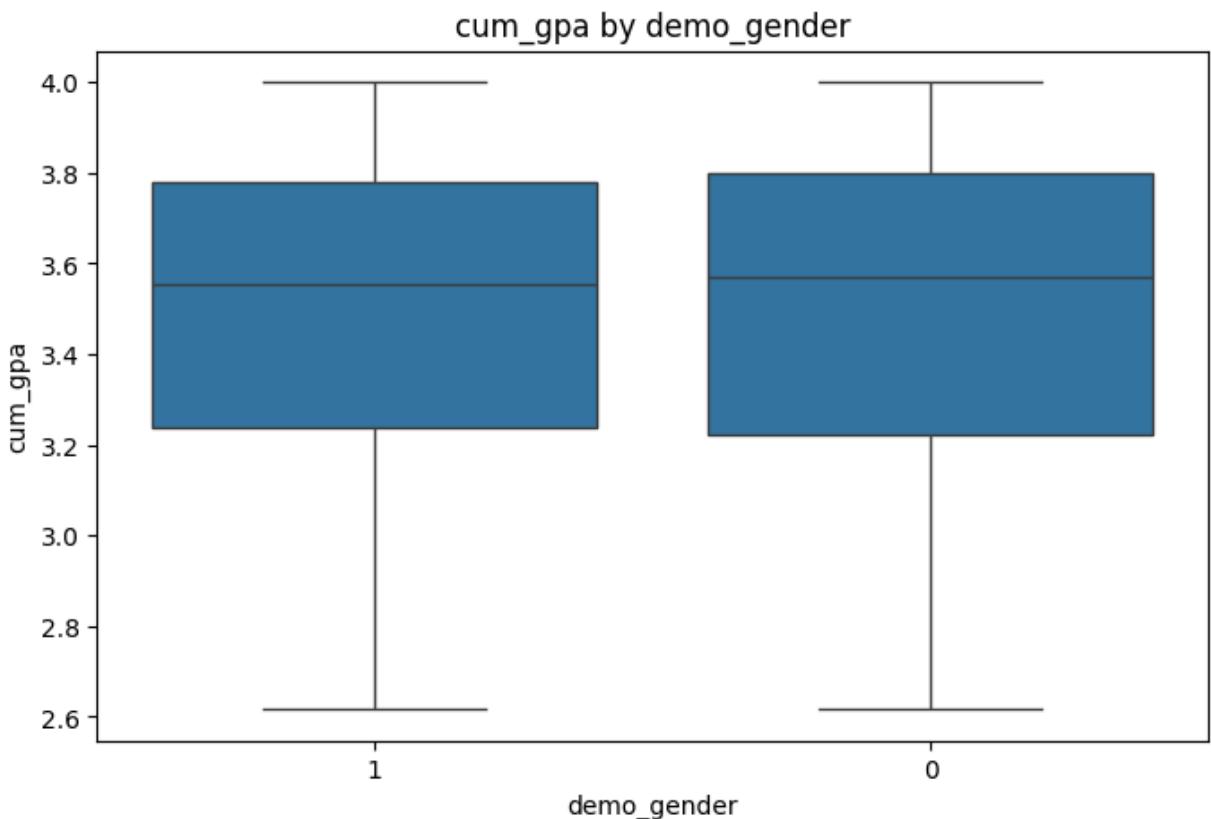
There is no significant difference in study between the groups.

Group statistics for cum\_gpa by demo\_gender:

```
demo_gender
0    3.483508
1    3.483575
Name: cum_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq       | mean_sq      | F        | PR(>F)   |
|-------------|-------|--------------|--------------|----------|----------|
| demo_gender | 1.0   | 6.809251e-07 | 6.809251e-07 | 0.000005 | 0.998298 |
| Residual    | 623.0 | 9.315885e+01 | 1.495327e-01 | NaN      | NaN      |

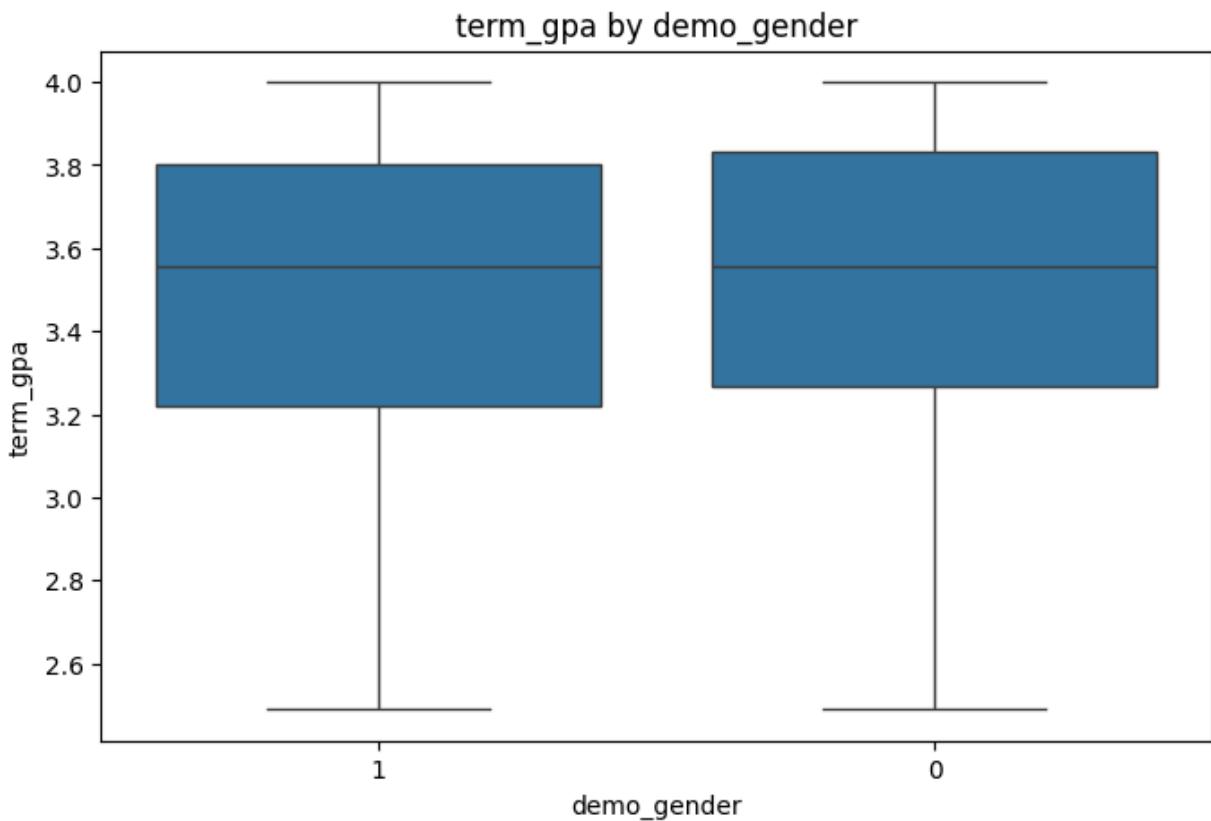
There is no significant difference in cum\_gpa between the groups.

Group statistics for term\_gpa by demo\_gender:

```
demo_gender
0    3.486572
1    3.466033
Name: term_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq     | mean_sq  | F        | PR(>F)   |
|-------------|-------|------------|----------|----------|----------|
| demo_gender | 1.0   | 0.064124   | 0.064124 | 0.354467 | 0.551811 |
| Residual    | 623.0 | 112.703015 | 0.180904 | NaN      | NaN      |

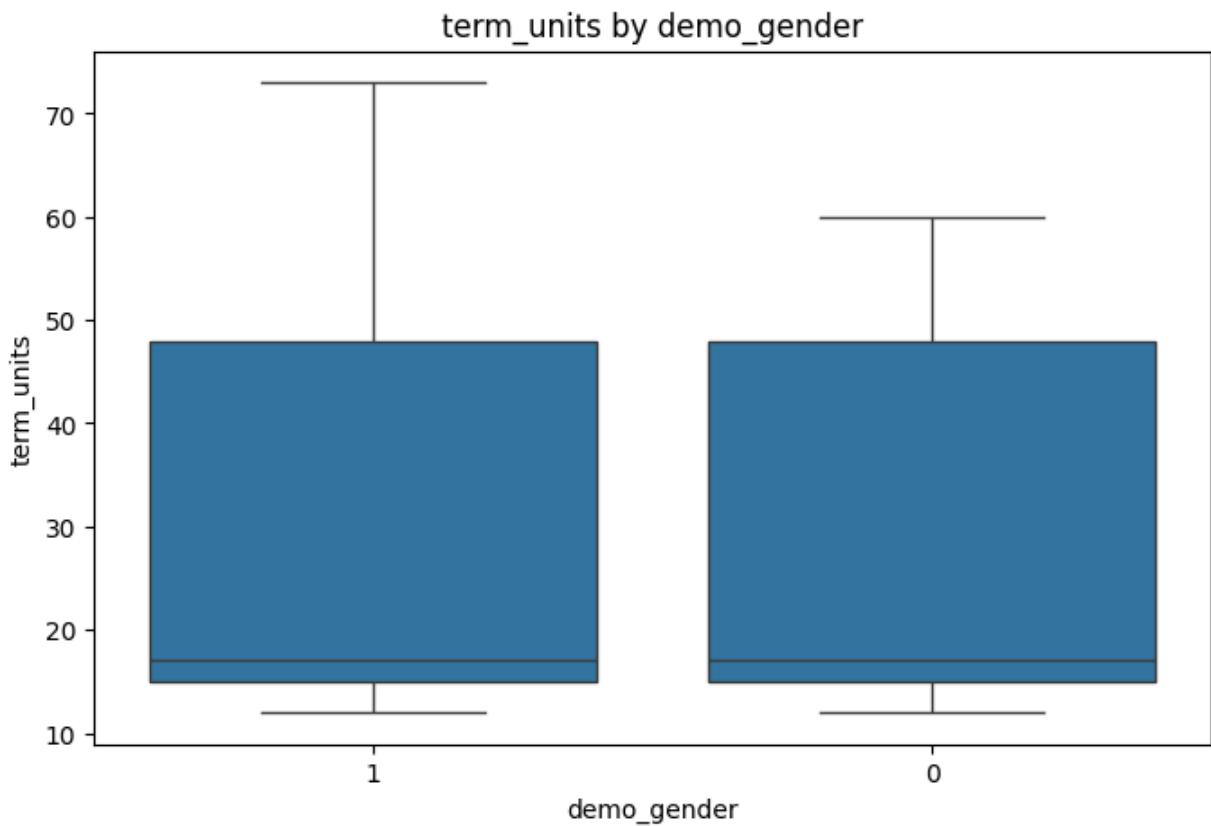
There is no significant difference in term\_gpa between the groups.

Group statistics for term\_units by demo\_gender:

```
demo_gender
0    29.751351
1    29.427119
Name: term_units, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq        | mean_sq    | F        | PR(>F)   |
|-------------|-------|---------------|------------|----------|----------|
| demo_gender | 1.0   | 11.952704     | 11.952704  | 0.038875 | 0.843781 |
| Residual    | 478.0 | 146968.745213 | 307.465994 | NaN      | NaN      |

There is no significant difference in term\_units between the groups.

Group statistics for Zterm\_units\_ZofZ by demo\_gender:

demo\_gender

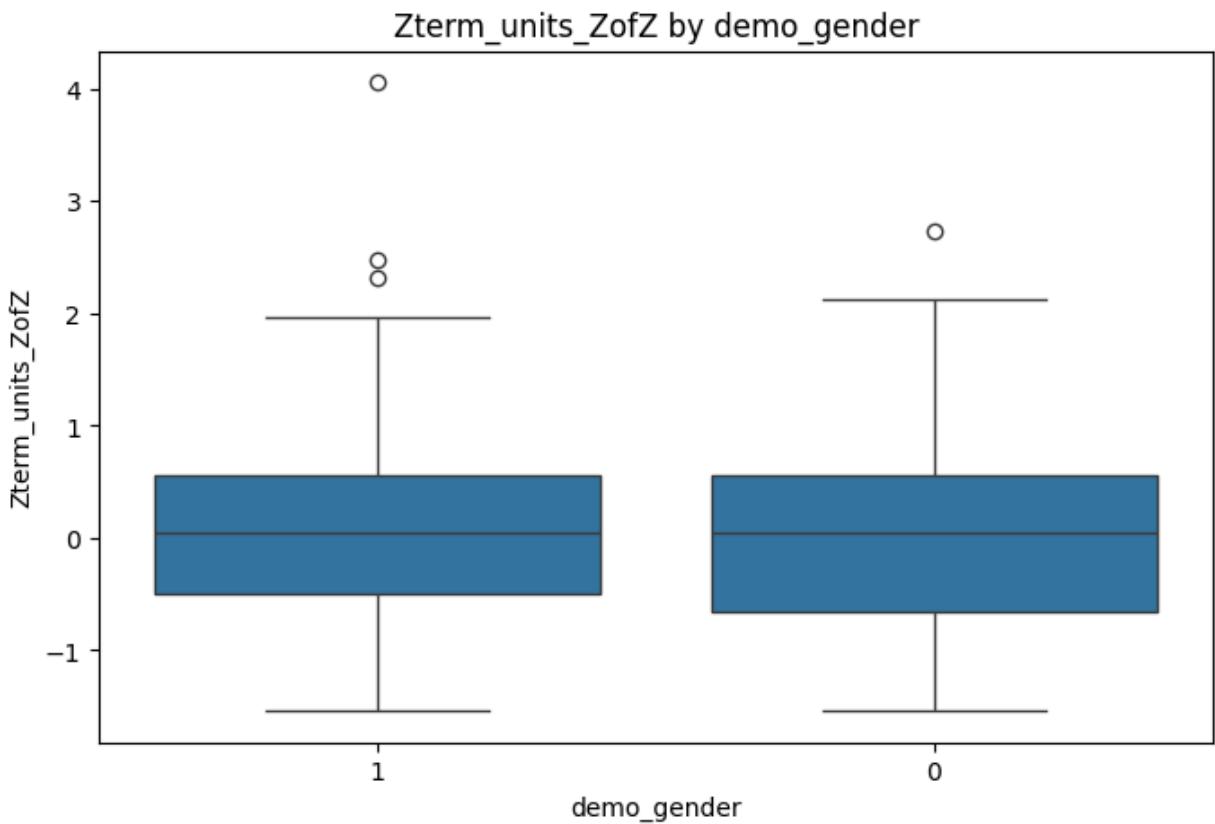
0 -0.022632

1 0.062031

Name: Zterm\_units\_ZofZ, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|             | df    | sum_sq     | mean_sq  | F        | PR(>F)   |
|-------------|-------|------------|----------|----------|----------|
| demo_gender | 1.0   | 0.814964   | 0.814964 | 0.952191 | 0.329656 |
| Residual    | 478.0 | 409.112115 | 0.855883 | NaN      | NaN      |

There is no significant difference in Zterm\_units\_ZofZ between the groups.

Group statistics for bedtime\_mssd by demo\_firstgen:

demo\_firstgen

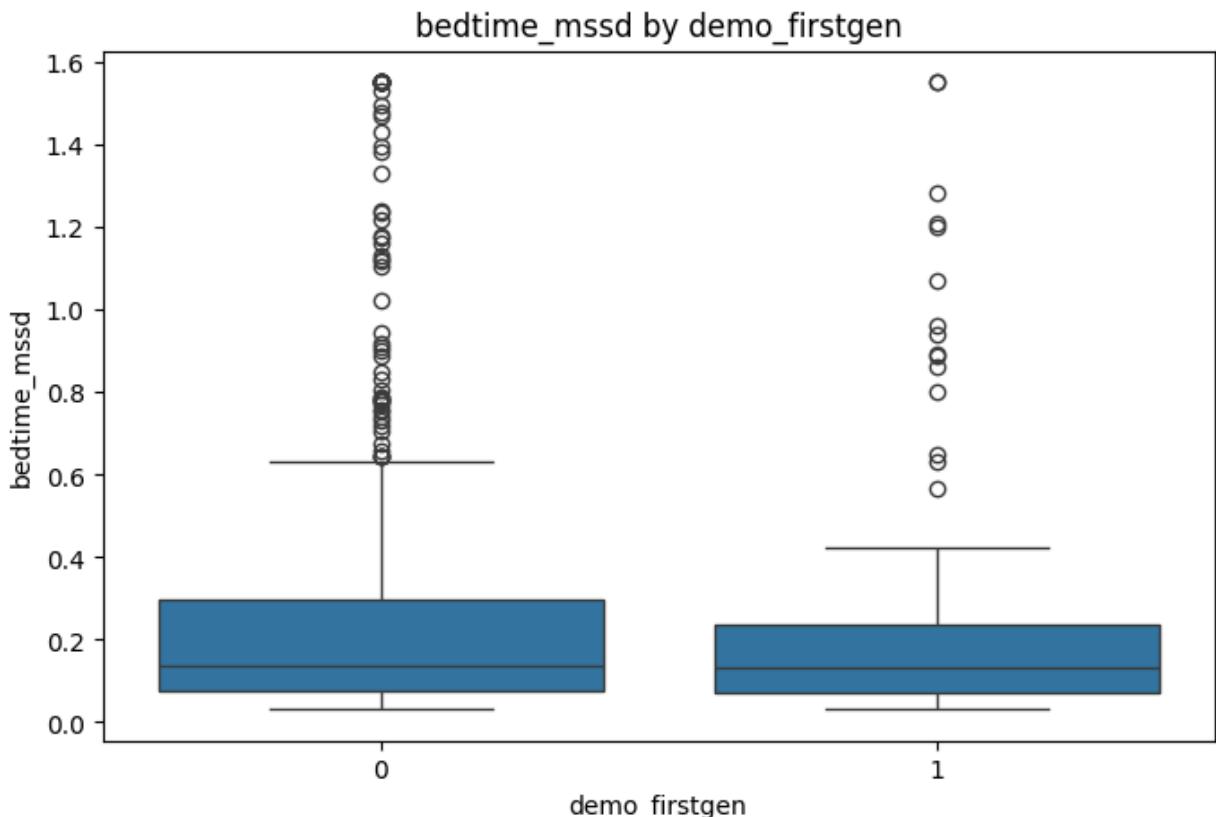
0 0.311151

1 0.259982

Name: bedtime\_mssd, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|               | df    | sum_sq     | mean_sq | F        | PR(>F)   |
|---------------|-------|------------|---------|----------|----------|
| demo_firstgen | 1.0   | 0.225240   | 0.22524 | 1.401007 | 0.237006 |
| Residual      | 623.0 | 100.159696 | 0.16077 | NaN      | NaN      |

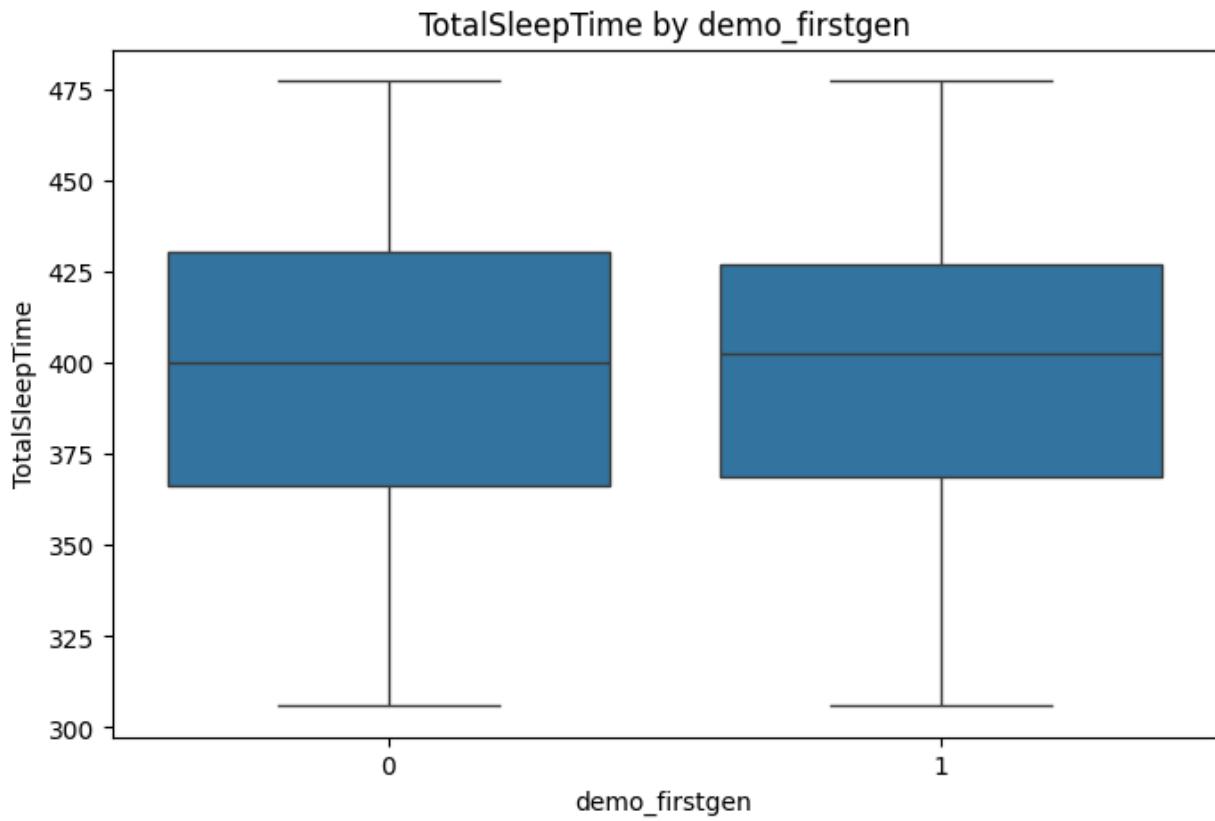
There is no significant difference in bedtime\_mssd between the groups.

Group statistics for TotalSleepTime by demo\_firstgen:

```
demo_firstgen
0    397.513227
1    397.777835
Name: TotalSleepTime, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|               | df    | sum_sq       | mean_sq     | F        | PR(>F)   |
|---------------|-------|--------------|-------------|----------|----------|
| demo_firstgen | 1.0   | 6.023273e+00 | 6.023273    | 0.002953 | 0.956677 |
| Residual      | 623.0 | 1.270553e+06 | 2039.411656 | NaN      | NaN      |

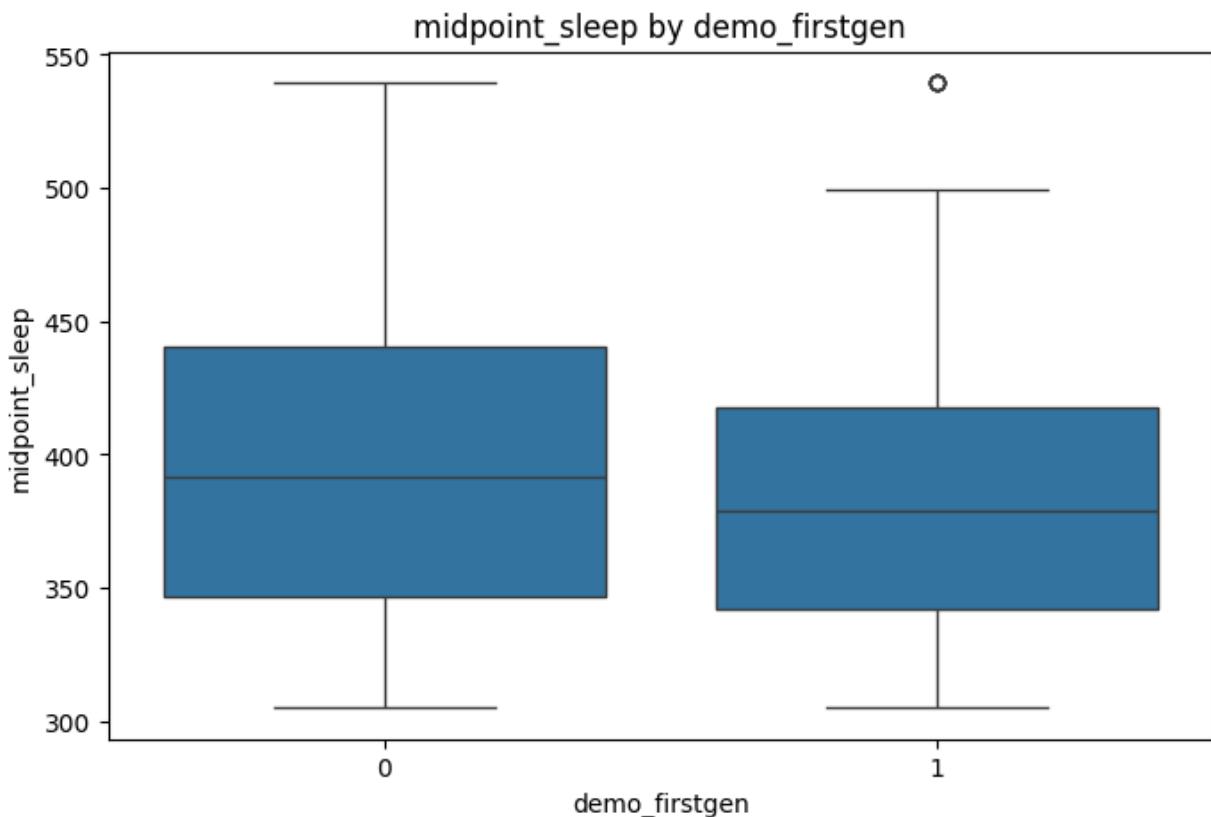
There is no significant difference in TotalSleepTime between the groups.

Group statistics for midpoint\_sleep by demo\_firstgen:

```
demo_firstgen
0    399.275701
1    387.863202
Name: midpoint_sleep, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
    if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|               | df    | sum_sq       | mean_sq      | F        | PR(>F)   |
|---------------|-------|--------------|--------------|----------|----------|
| demo_firstgen | 1.0   | 1.120442e+04 | 11204.417454 | 2.692148 | 0.101349 |
| Residual      | 623.0 | 2.592856e+06 | 4161.888136  | NaN      | NaN      |

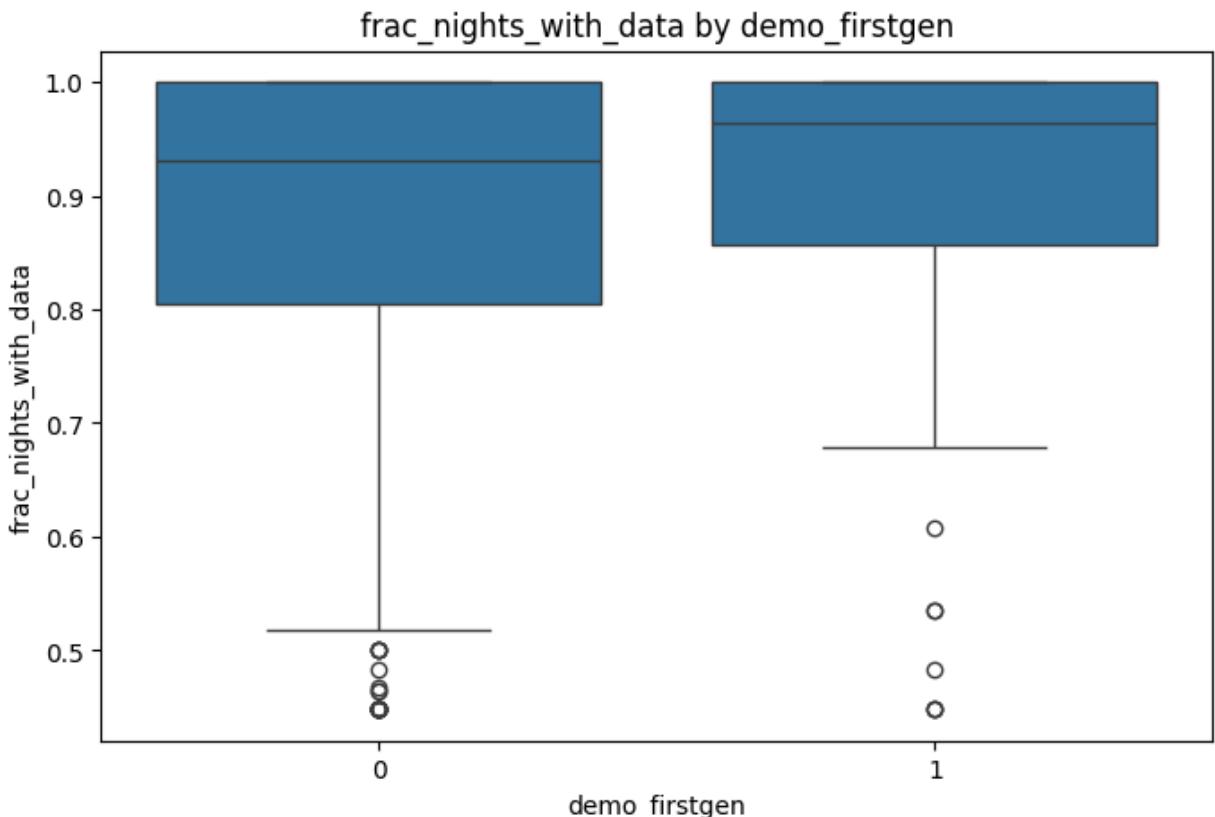
There is no significant difference in midpoint\_sleep between the groups.

Group statistics for frac\_nights\_with\_data by demo\_firstgen:

```
demo_firstgen
0    0.868158
1    0.902351
Name: frac_nights_with_data, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
```

```
if anova_table['PR(>F)'][0] < 0.05:
```



ANOVA Table:

|               | df    | sum_sq    | mean_sq  | F        | PR(>F)   |
|---------------|-------|-----------|----------|----------|----------|
| demo_firstgen | 1.0   | 0.100578  | 0.100578 | 3.960267 | 0.047023 |
| Residual      | 623.0 | 15.822112 | 0.025397 | NaN      | NaN      |

There is a significant difference in frac\_nights\_with\_data between the groups.

The p-value is 0.047022937698016486

Group statistics for daytime\_sleep by demo\_firstgen:

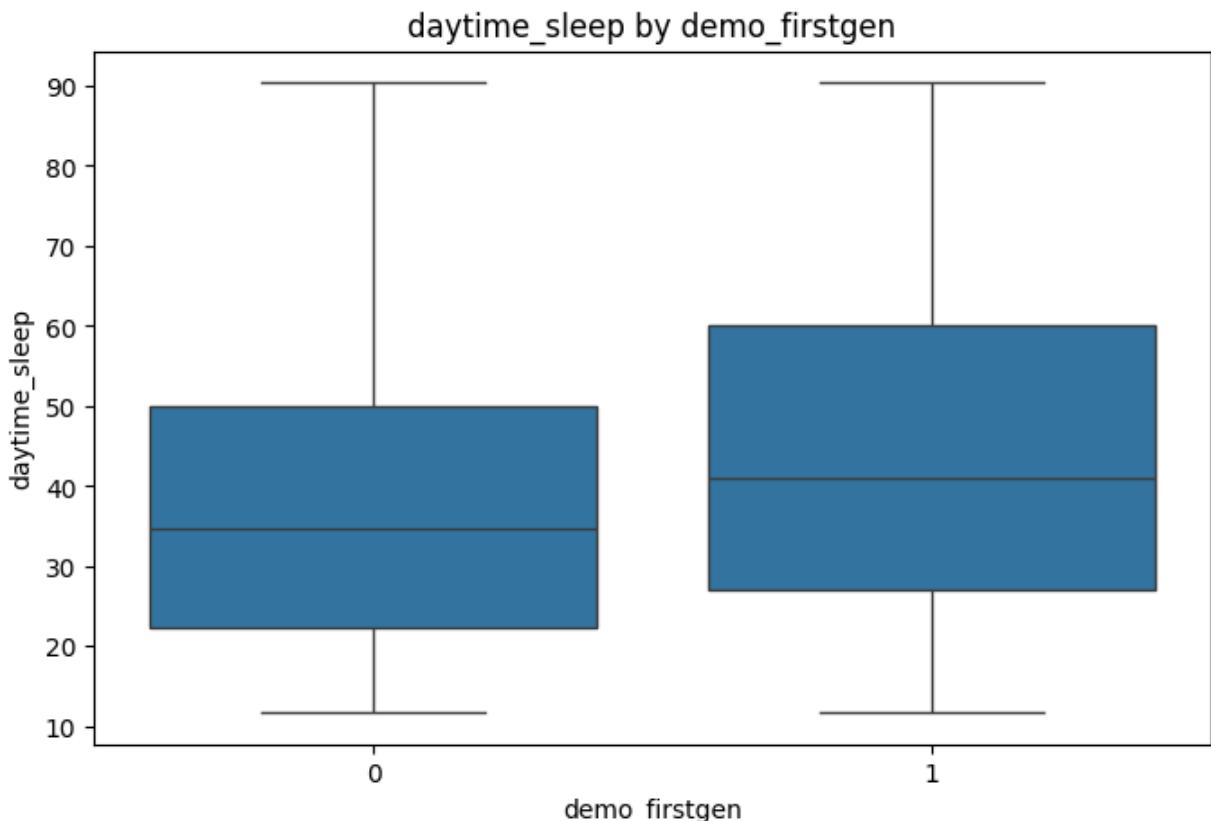
```
demo_firstgen
0    38.899645
1    44.848371
Name: daytime_sleep, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  print(f'\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|               | df    | sum_sq        | mean_sq     | F        | PR(>F)   |
|---------------|-------|---------------|-------------|----------|----------|
| demo_firstgen | 1.0   | 3044.217639   | 3044.217639 | 6.616601 | 0.010334 |
| Residual      | 623.0 | 286634.716786 | 460.087828  | NaN      | NaN      |

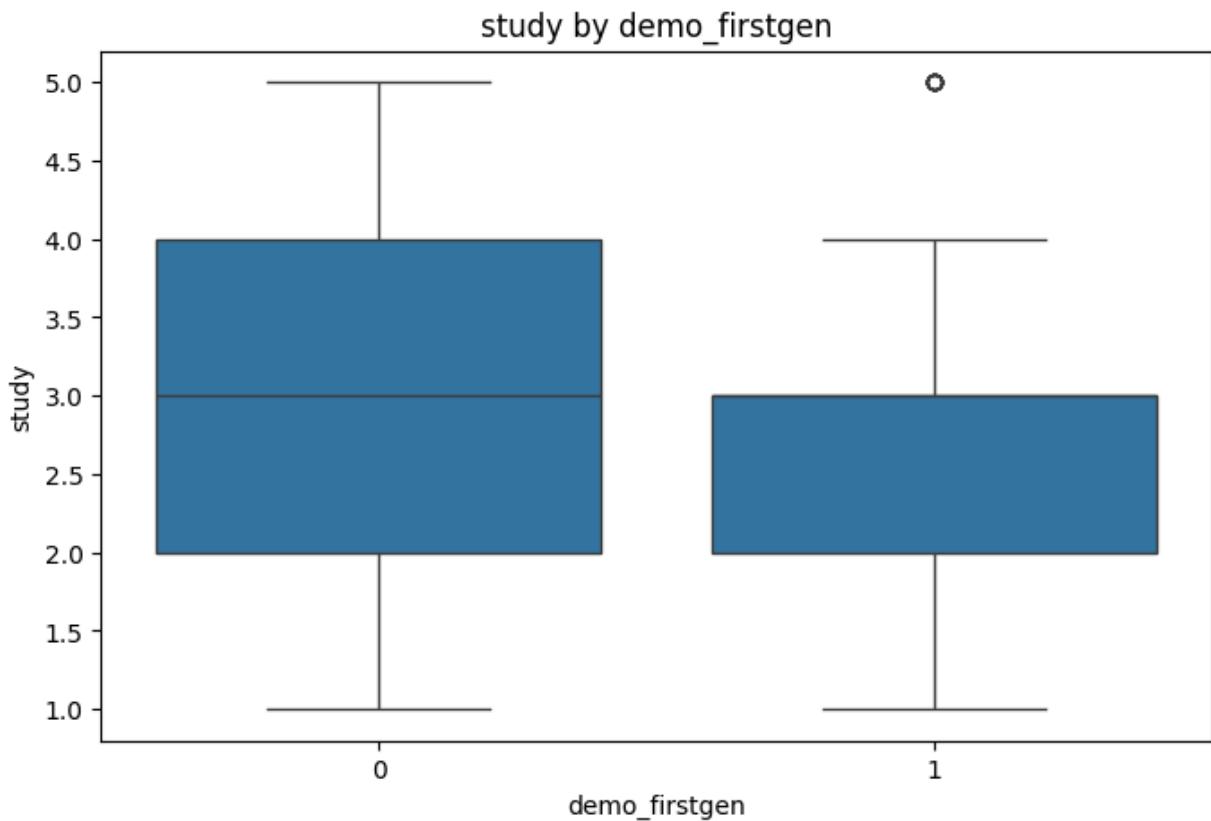
There is a significant difference in daytime\_sleep between the groups.

The p-value is 0.010333757074830517

Group statistics for study by demo\_firstgen:

```
demo_firstgen
0    3.260536
1    2.805825
Name: study, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|               | df    | sum_sq      | mean_sq   | F         | PR(>F)   |
|---------------|-------|-------------|-----------|-----------|----------|
| demo_firstgen | 1.0   | 17.786845   | 17.786845 | 10.388465 | 0.001334 |
| Residual      | 623.0 | 1066.683555 | 1.712173  |           | NaN      |

There is a significant difference in study between the groups.

The p-value is 0.0013342379347766574

Group statistics for cum\_gpa by demo\_firstgen:

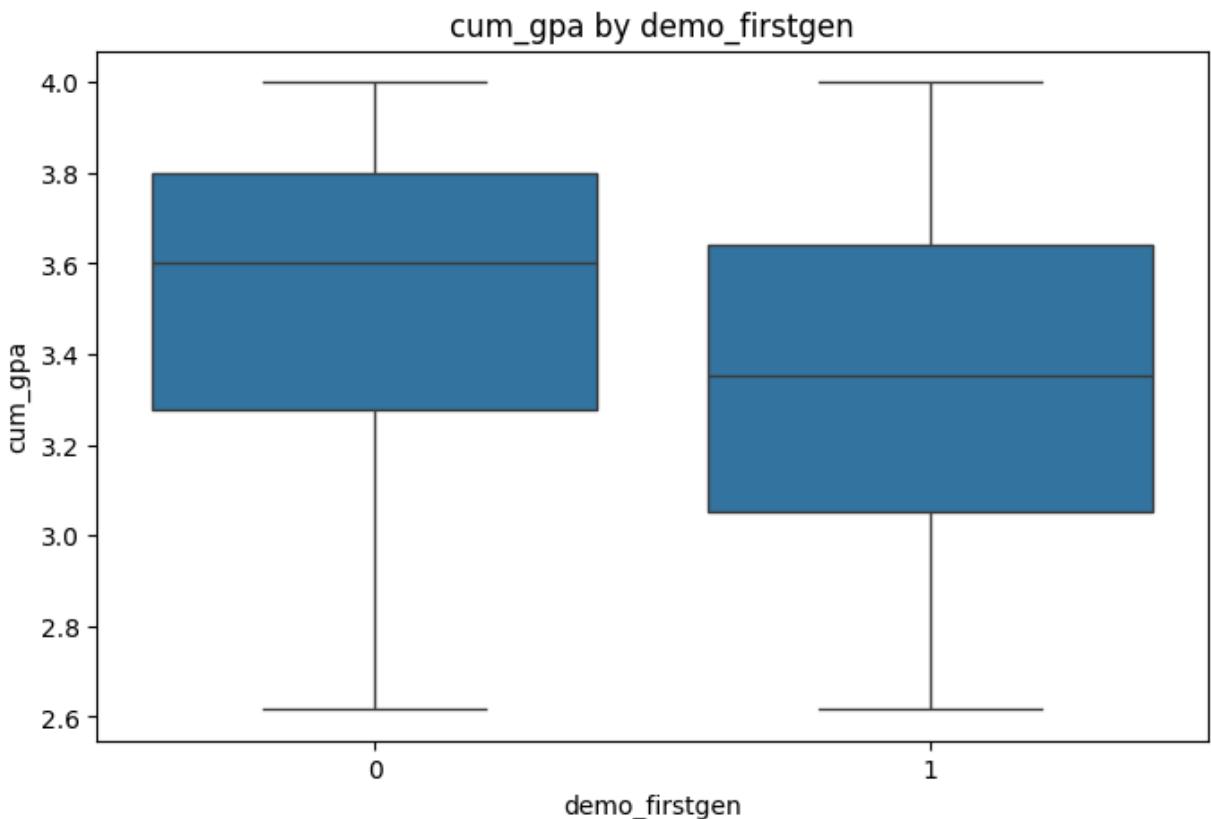
```
demo_firstgen
0    3.515765
1    3.320265
Name: cum_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    print(f'\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|               | df    | sum_sq    | mean_sq  | F        | PR(>F)   |
|---------------|-------|-----------|----------|----------|----------|
| demo_firstgen | 1.0   | 3.287944  | 3.287944 | 22.79257 | 0.000002 |
| Residual      | 623.0 | 89.870909 | 0.144255 | NaN      | NaN      |

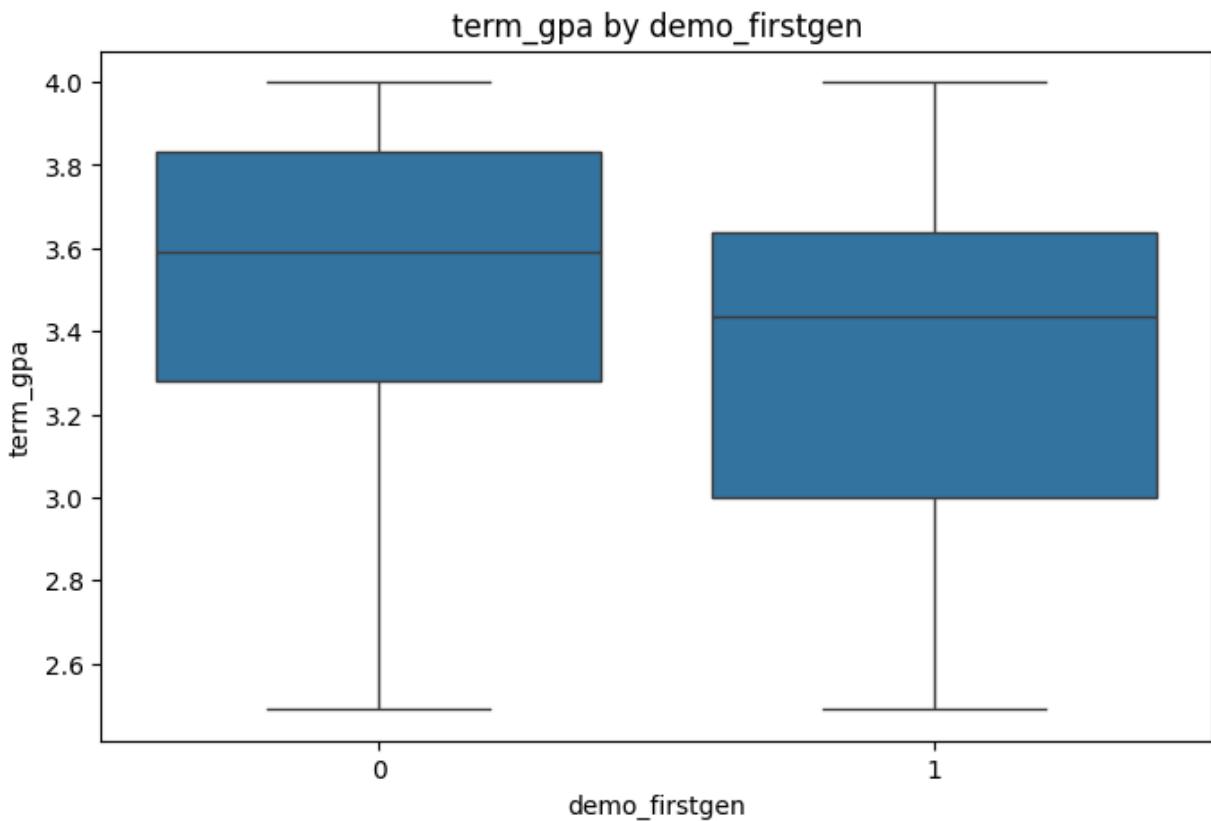
There is a significant difference in cum\_gpa between the groups.

The p-value is 2.2513702124686825e-06

Group statistics for term\_gpa by demo\_firstgen:

```
demo_firstgen
0    3.505660
1    3.317247
Name: term_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|               | df    | sum_sq     | mean_sq  | F         | PR(>F)   |
|---------------|-------|------------|----------|-----------|----------|
| demo_firstgen | 1.0   | 3.053855   | 3.053855 | 17.341126 | 0.000036 |
| Residual      | 623.0 | 109.713284 | 0.176105 | NaN       | NaN      |

There is a significant difference in term\_gpa between the groups.

The p-value is 3.564053044750699e-05

Group statistics for term\_units by demo\_firstgen:

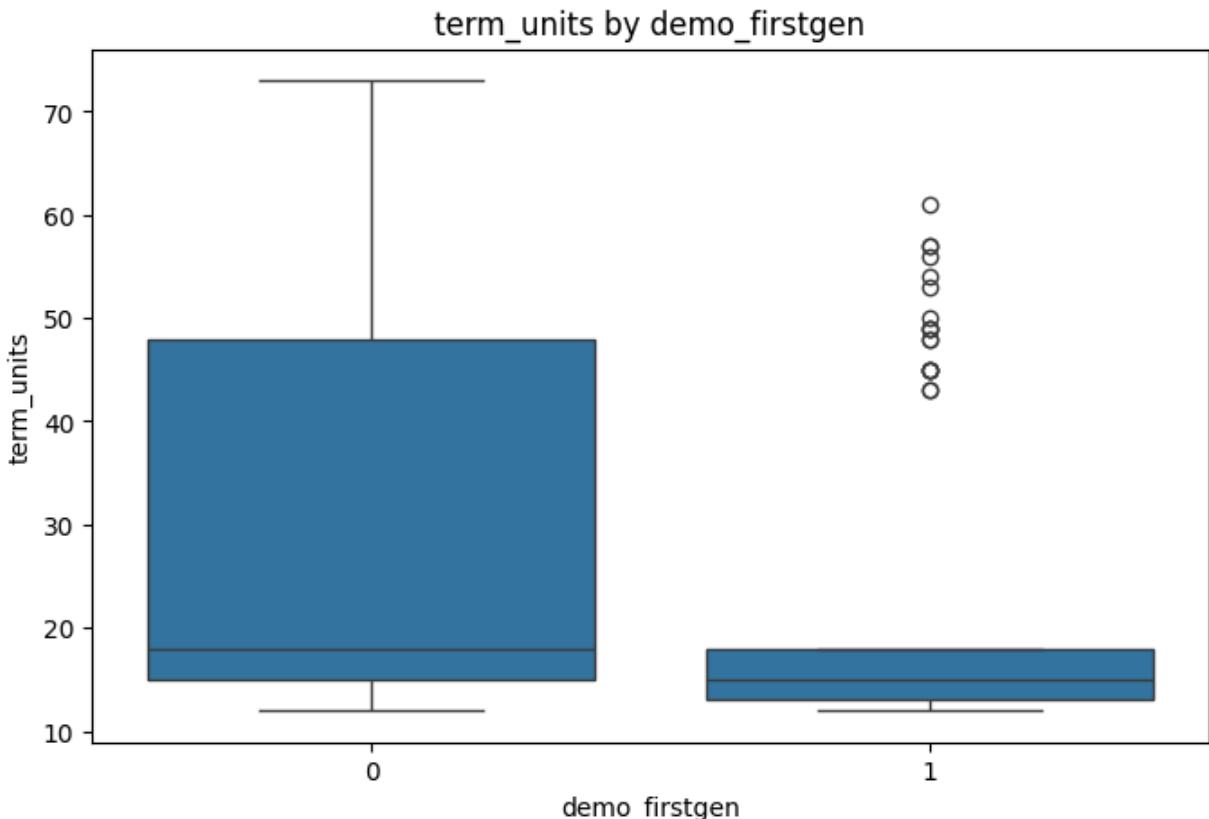
```
demo_firstgen
0    31.620779
1    21.168421
Name: term_units, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    print(f'\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|               | df    | sum_sq        | mean_sq     | F         | PR(>F)       |
|---------------|-------|---------------|-------------|-----------|--------------|
| demo_firstgen | 1.0   | 8324.758887   | 8324.758887 | 28.698625 | 1.316977e-07 |
| Residual      | 478.0 | 138655.939029 | 290.075186  | NaN       | NaN          |

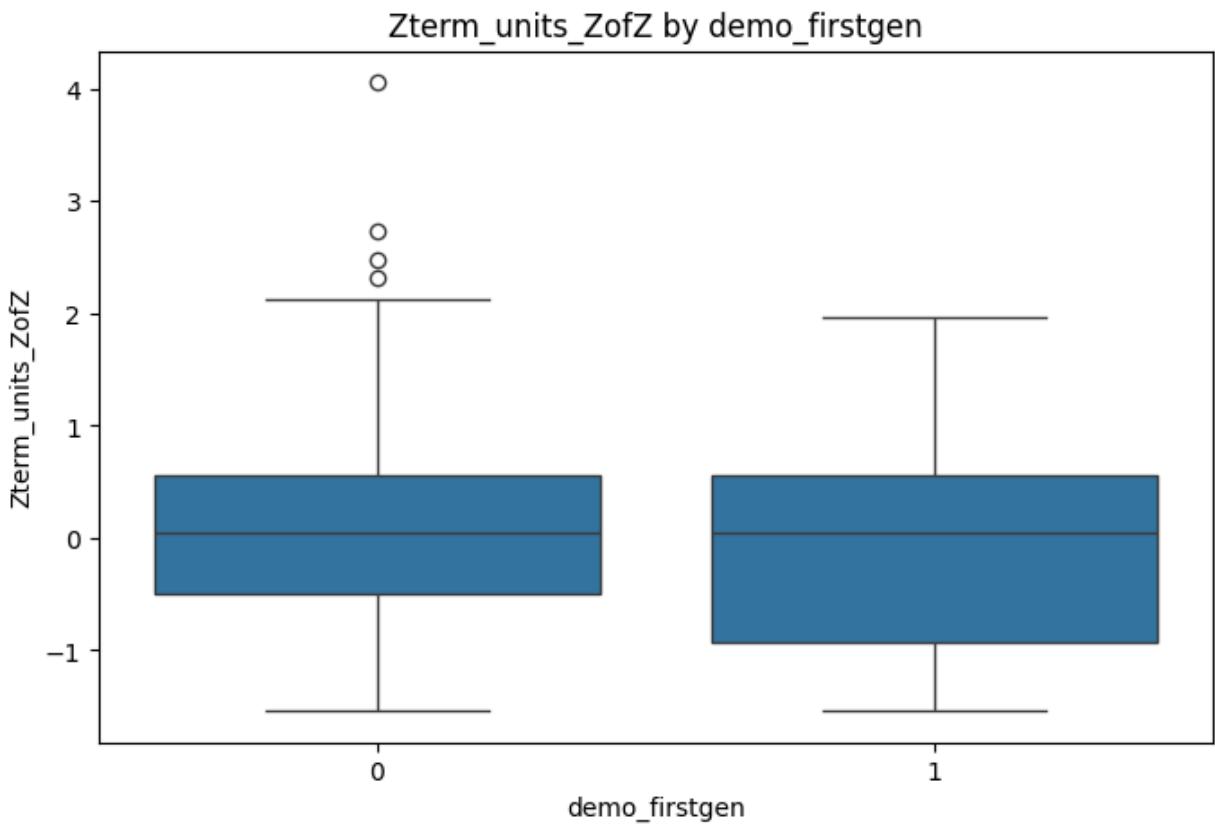
There is a significant difference in term\_units between the groups.

The p-value is 1.3169765462508494e-07

Group statistics for Zterm\_units\_ZofZ by demo\_firstgen:

```
demo_firstgen
0    0.047768
1   -0.045038
Name: Zterm_units_ZofZ, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|               | df    | sum_sq     | mean_sq  | F        | PR(>F)  |
|---------------|-------|------------|----------|----------|---------|
| demo_firstgen | 1.0   | 0.656293   | 0.656293 | 0.766505 | 0.38174 |
| Residual      | 478.0 | 409.270786 | 0.856215 | NaN      | NaN     |

There is no significant difference in Zterm\_units\_ZofZ between the groups.

Group statistics for bedtime\_mssd by cohort:

cohort

```

lac1    0.299061
lac2    0.444512
nh      0.240193
uw1    0.390481
uw2    0.205942

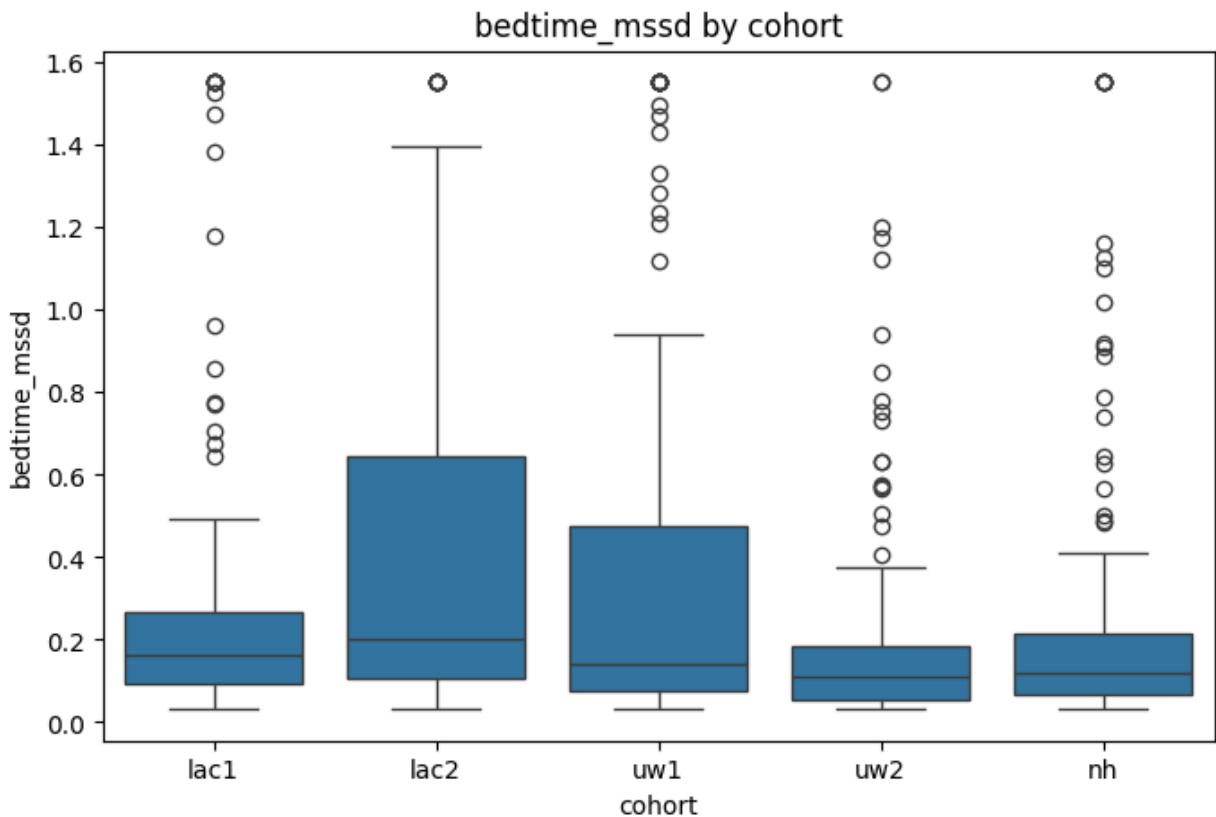
```

Name: bedtime\_mssd, dtype: float64

```

<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`>
  if anova_table['PR(>F)'][0] < 0.05:

```



ANOVA Table:

|          | df    | sum_sq    | mean_sq  | F        | PR(>F)   |
|----------|-------|-----------|----------|----------|----------|
| cohort   | 4.0   | 4.434903  | 1.108726 | 7.164249 | 0.000012 |
| Residual | 620.0 | 95.950033 | 0.154758 | NaN      | NaN      |

There is a significant difference in bedtime\_mssd between the groups.

The p-value is 1.2131788733058854e-05

Group statistics for TotalSleepTime by cohort:

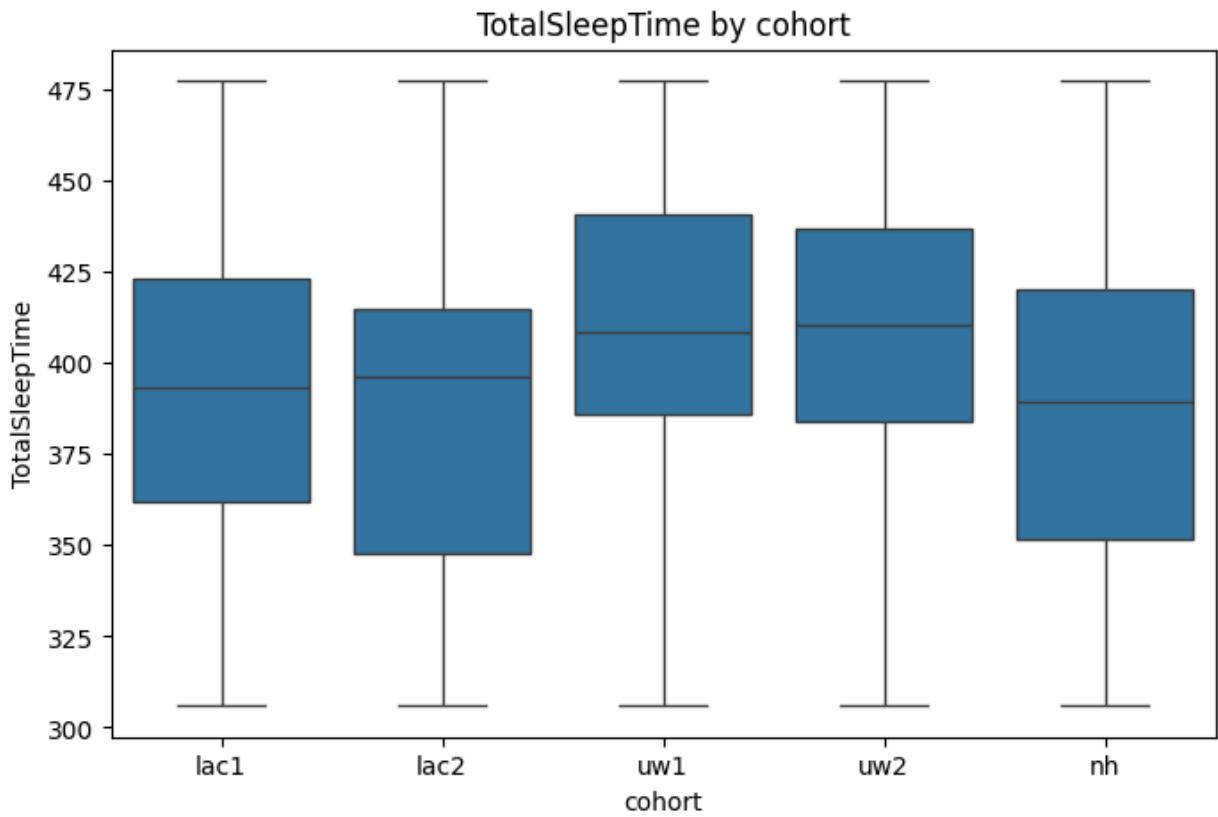
```
cohort
lac1    391.661875
lac2    383.679525
nh     386.917899
uw1    410.867148
uw2    408.798825
Name: TotalSleepTime, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq       | mean_sq      | F         | PR(>F)       |
|----------|-------|--------------|--------------|-----------|--------------|
| cohort   | 4.0   | 7.715165e+04 | 19287.912950 | 10.020469 | 7.299524e-08 |
| Residual | 620.0 | 1.193408e+06 | 1924.851344  | NaN       | NaN          |

There is a significant difference in TotalSleepTime between the groups.

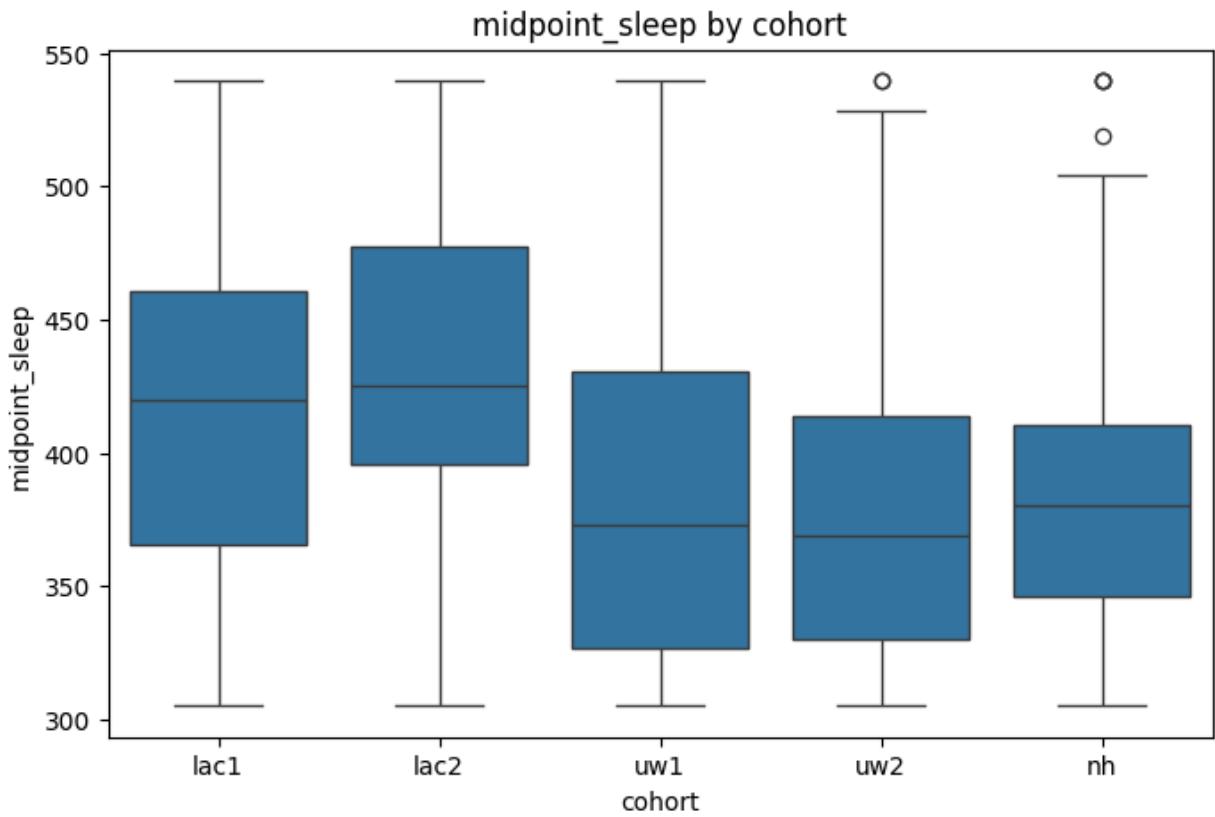
The p-value is 7.299524107258138e-08

Group statistics for midpoint\_sleep by cohort:

```
cohort
lac1    418.047574
lac2    434.294529
nh      387.465076
uw1     388.112472
uw2     377.119799
```

Name: midpoint\_sleep, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq       | mean_sq      | F         | PR(>F)       |
|----------|-------|--------------|--------------|-----------|--------------|
| cohort   | 4.0   | 2.413491e+05 | 60337.271719 | 15.833125 | 2.391635e-12 |
| Residual | 620.0 | 2.362712e+06 | 3810.825225  | NaN       | NaN          |

There is a significant difference in midpoint\_sleep between the groups.

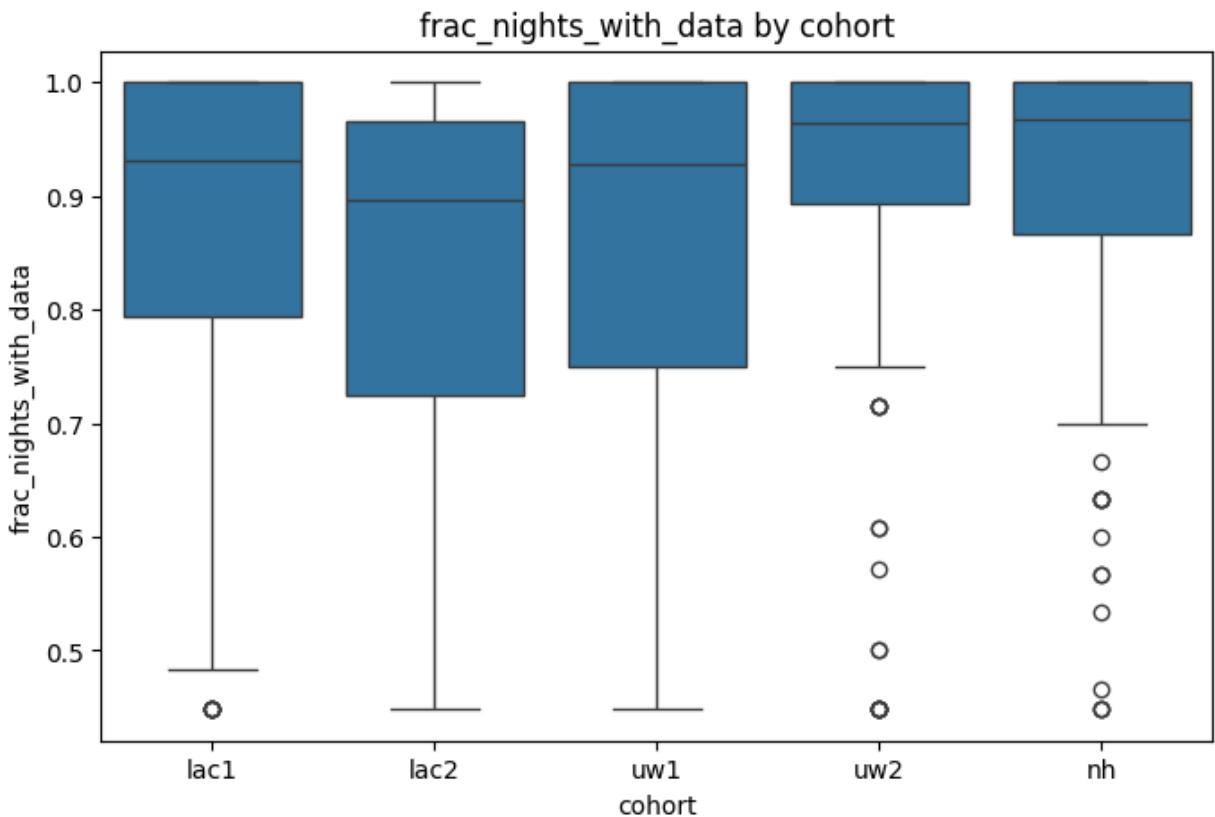
The p-value is 2.3916349339895327e-12

Group statistics for frac\_nights\_with\_data by cohort:

```
cohort
lac1    0.866844
lac2    0.839837
nh      0.894792
uw1    0.851192
uw2    0.899599
```

Name: frac\_nights\_with\_data, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq    | mean_sq  | F        | PR(>F)   |
|----------|-------|-----------|----------|----------|----------|
| cohort   | 4.0   | 0.319063  | 0.079766 | 3.169445 | 0.013579 |
| Residual | 620.0 | 15.603626 | 0.025167 |          | NaN      |

There is a significant difference in frac\_nights\_with\_data between the groups.

The p-value is 0.013579106009598708

Group statistics for daytime\_sleep by cohort:

| Cohort | Daytime Sleep (approx.) |
|--------|-------------------------|
| lac1   | 27.499198               |
| lac2   | 39.249089               |
| nh     | 43.120991               |
| uw1    | 45.538840               |
| uw2    | 42.889092               |

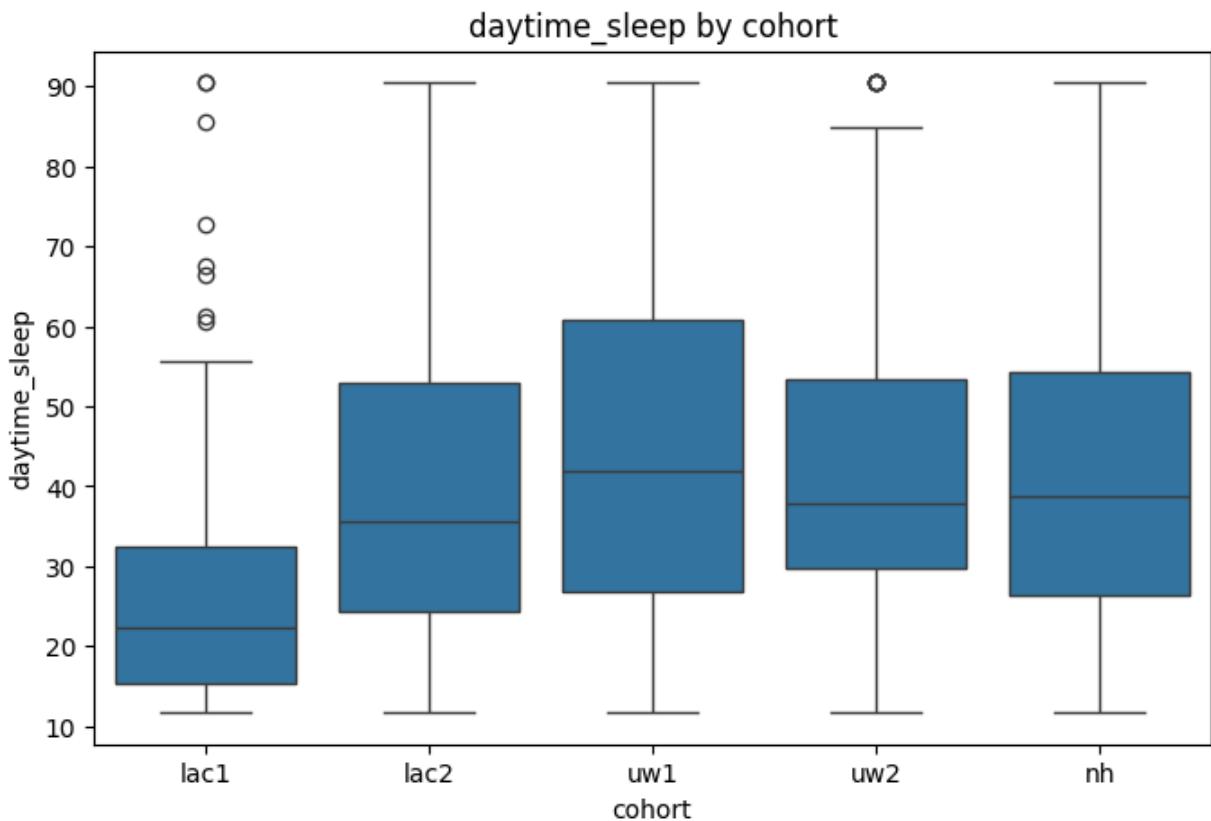
Name: daytime\_sleep, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq        | mean_sq     | F         | PR(>F)       |
|----------|-------|---------------|-------------|-----------|--------------|
| cohort   | 4.0   | 27107.852873  | 6776.963218 | 16.002209 | 1.776445e-12 |
| Residual | 620.0 | 262571.081551 | 423.501744  |           | NaN          |

There is a significant difference in daytime\_sleep between the groups.

The p-value is 1.7764453514486099e-12

Group statistics for study by cohort:

cohort

|      |     |
|------|-----|
| lac1 | 5.0 |
| lac2 | 1.0 |
| nh   | 4.0 |
| uw1  | 2.0 |
| uw2  | 3.0 |

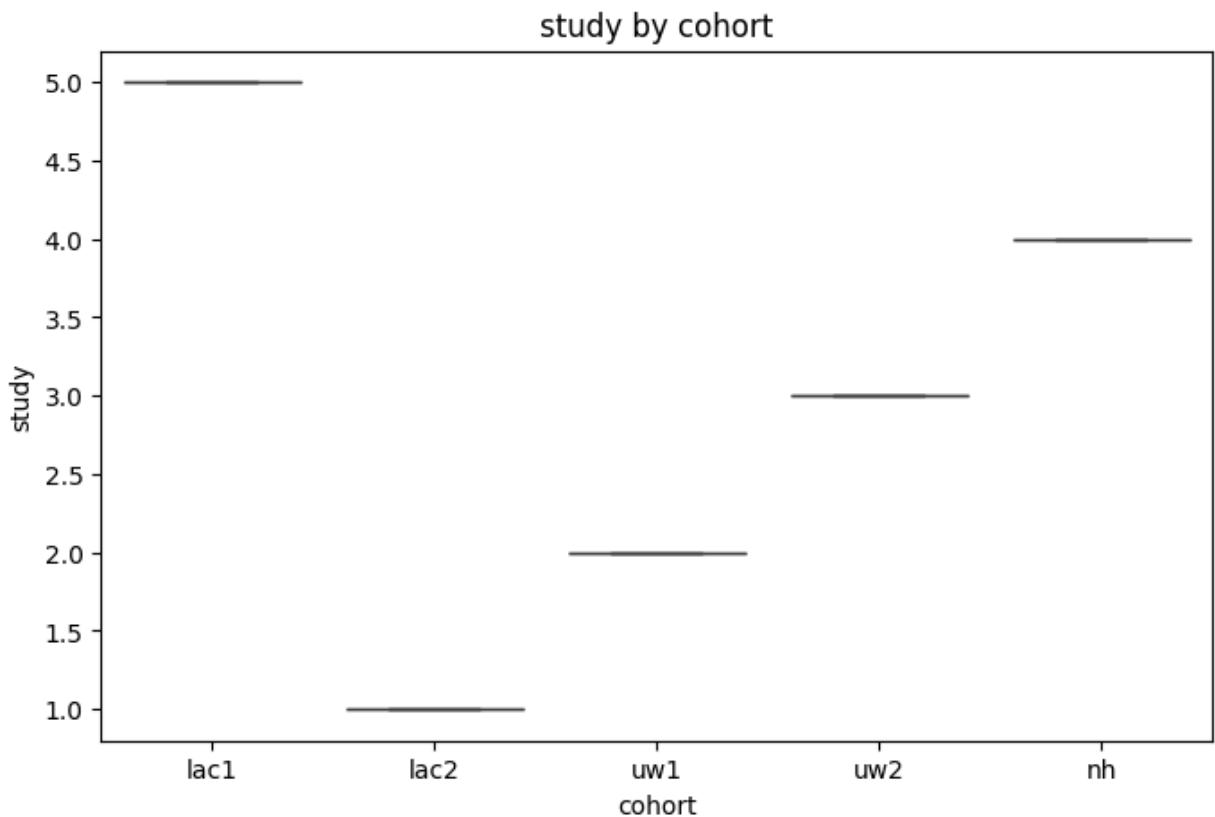
Name: study, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `se
r.iloc[pos]`  

    if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `se
r.iloc[pos]`  

    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq       | mean_sq      | F            | PR(>F) |
|----------|-------|--------------|--------------|--------------|--------|
| cohort   | 4.0   | 1.084470e+03 | 2.711176e+02 | 9.796022e+30 | 0.0    |
| Residual | 620.0 | 1.715930e-26 | 2.767629e-29 |              | NaN    |

There is a significant difference in study between the groups.

The p-value is 0.0

Group statistics for cum\_gpa by cohort:

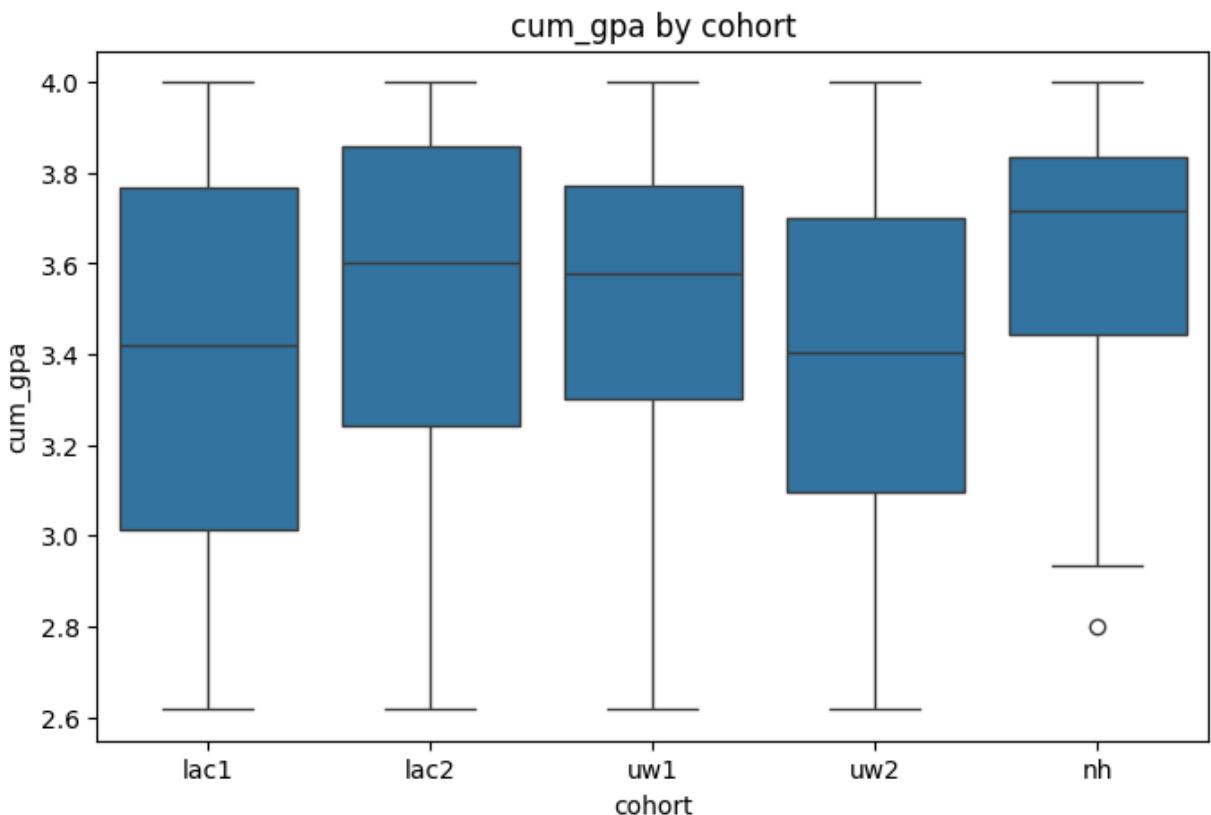
```
cohort
lac1    3.378914
lac2    3.537307
nh      3.639907
uw1     3.488540
uw2     3.382527
Name: cum_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  

  print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq    | mean_sq  | F         | PR(>F)       |
|----------|-------|-----------|----------|-----------|--------------|
| cohort   | 4.0   | 6.589402  | 1.647351 | 11.798127 | 3.047302e-09 |
| Residual | 620.0 | 86.569450 | 0.139628 | NaN       | NaN          |

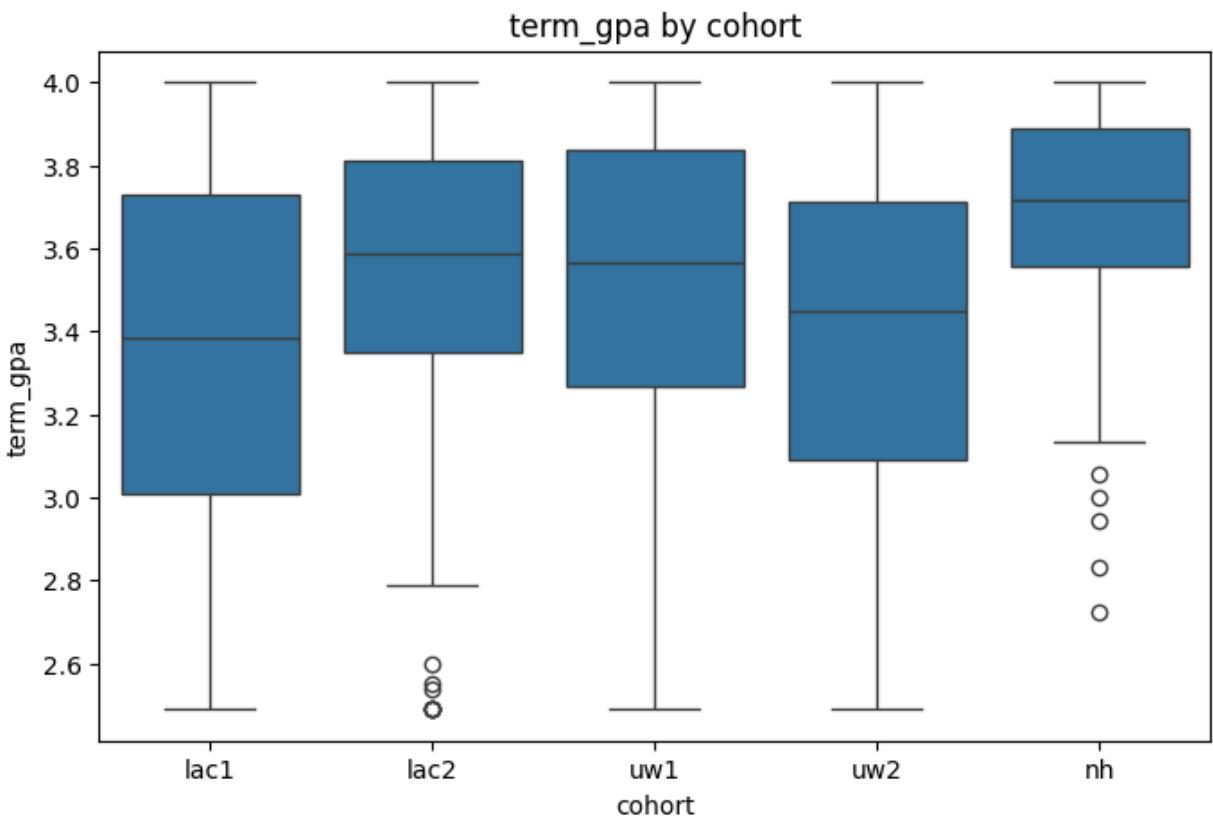
There is a significant difference in cum\_gpa between the groups.

The p-value is 3.0473016866788792e-09

Group statistics for term\_gpa by cohort:

```
cohort
lac1    3.320154
lac2    3.496316
nh     3.667620
uw1    3.502234
uw2    3.377226
Name: term_gpa, dtype: float64
```

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`>
  if anova_table['PR(>F)'][0] < 0.05:
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`>
  print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq     | mean_sq  | F         | PR(>F)       |
|----------|-------|------------|----------|-----------|--------------|
| cohort   | 4.0   | 9.942662   | 2.485665 | 14.987799 | 1.060745e-11 |
| Residual | 620.0 | 102.824478 | 0.165846 | NaN       | NaN          |

There is a significant difference in term\_gpa between the groups.

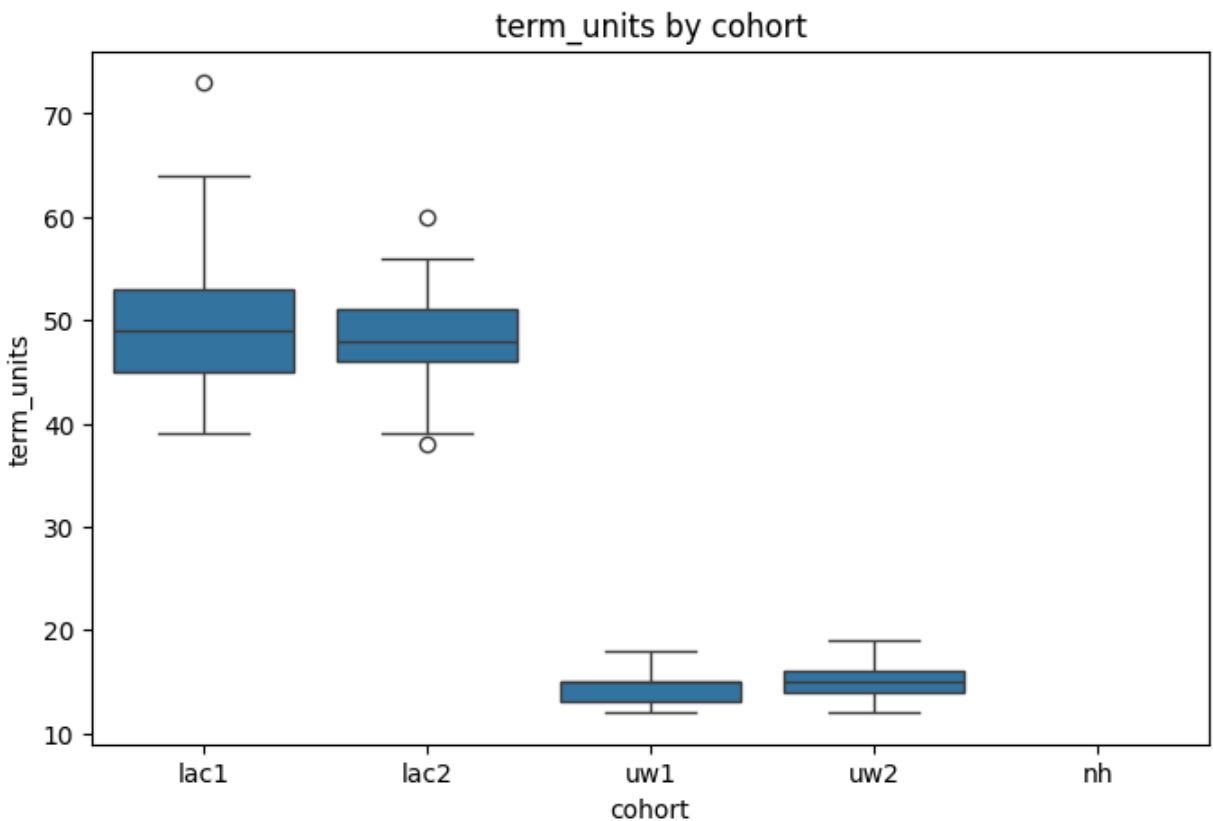
The p-value is 1.0607450741857726e-11

Group statistics for term\_units by cohort:

| Cohort | Mean      |
|--------|-----------|
| lac1   | 49.769231 |
| lac2   | 48.447368 |
| nh     | NaN       |
| uw1    | 14.467153 |
| uw2    | 14.970803 |

Name: term\_units, dtype: float64

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    if anova_table['PR(>F)'][0] < 0.05:  
<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")
```



ANOVA Table:

|          | df    | sum_sq        | mean_sq      | F           | PR(>F)        |
|----------|-------|---------------|--------------|-------------|---------------|
| cohort   | 4.0   | 140716.816003 | 35179.204001 | 2613.247252 | 2.816174e-322 |
| Residual | 476.0 | 6407.851798   | 13.461874    | NaN         | NaN           |

There is a significant difference in term\_units between the groups.

The p-value is 2.8e-322

Group statistics for Zterm\_units\_ZofZ by cohort:

```

cohort
lac1    0.002411
lac2    0.025094
nh      NaN
uw1    0.061258
uw2    0.025542
Name: Zterm_units_ZofZ, dtype: float64

```

```

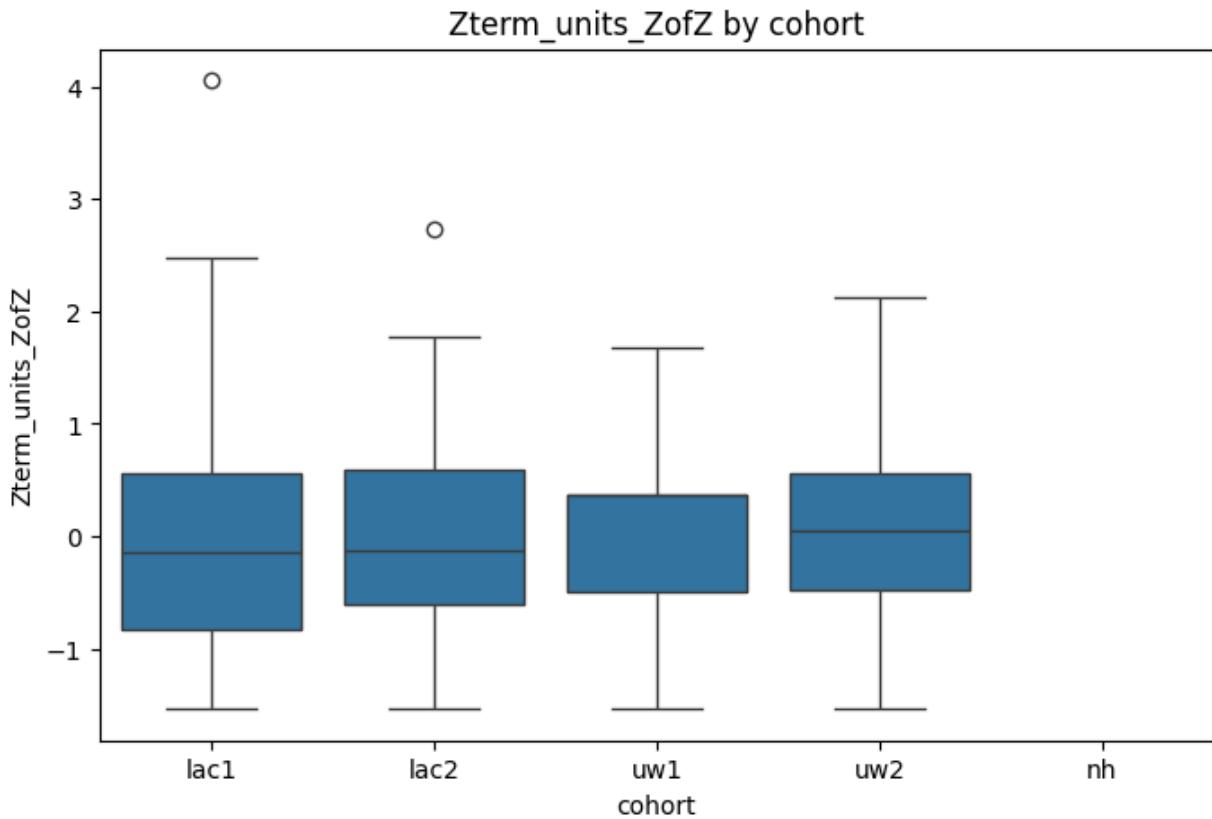
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `se
r.iloc[pos]`  

    if anova_table['PR(>F)'][0] < 0.05:  

<ipython-input-17-156ab38f32e6>:42: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `se
r.iloc[pos]`  

    print(f"\nThe p-value is {anova_table['PR(>F)'][0]}")

```



ANOVA Table:

|          | df    | sum_sq     | mean_sq  | F        | PR(>F)   |
|----------|-------|------------|----------|----------|----------|
| cohort   | 4.0   | 4.607259   | 1.151815 | 1.338241 | 0.254688 |
| Residual | 476.0 | 409.689894 | 0.860693 |          | NaN      |

There is no significant difference in Zterm\_units\_ZofZ between the groups.

```
<ipython-input-17-156ab38f32e6>:40: FutureWarning: Series.__getitem__ treating keys as positions is deprecated. In a future version, integer keys will always be treated as labels (consistent with DataFrame behavior). To access a value by position, use `series.iloc[pos]`  
if anova_table['PR(>F)'][0] < 0.05:
```

## Summary of Findings:

- **Bedtime MSSD (bedtime variability):**
  - Significant difference between groups: There is a significant difference in bedtime variability (bedtime\_mssd) between underrepresented and non-underrepresented students. Underrepresented students tend to have more variable bedtimes.
- **Total Sleep Time:**
  - No significant difference between groups: There is no significant difference in total sleep time between underrepresented and non-underrepresented students.
- **Midpoint Sleep:**
  - No significant difference between groups: There is no significant difference in midpoint sleep between underrepresented and non-underrepresented students.
- **Fraction of Nights with Data:**
  - No significant difference between groups: There is no significant difference in the fraction of nights with captured data between underrepresented and non-

underrepresented students.

- **Daytime Sleep:**
  - Significant difference between groups: Underrepresented students tend to have more daytime sleep compared to non-underrepresented students.
- **Study Hours:**
  - No significant difference between groups: There is no significant difference in study hours between underrepresented and non-underrepresented students.
- **Cumulative GPA (cum\_gpa) and Term GPA (term\_gpa):**
  - Significant differences between groups: Underrepresented students tend to have higher cumulative GPAs and term GPAs compared to non-underrepresented students.
- **Term Units and Zterm\_units\_ZofZ:**
  - No significant difference between groups: There is no significant difference in term units or standardized term units between underrepresented and non-underrepresented students.
- **Overall:**
  - The analysis indicates that while there are significant differences between the groups in some variables (bedtime\_mssd, daytime\_sleep, cum\_gpa, term\_gpa), there are no significant differences in others (TotalSleepTime, midpoint\_sleep, frac\_nights\_with\_data, study, term\_units, Zterm\_units\_ZofZ).

## Multivariate Analysis

### Dimensionality Reduction

```
In [18]: # Consider techniques like Principal Component Analysis (PCA) and t-Distributed Stochastic Neighbor Embedding (t-SNE) to reduce the dimensionality of the dataset and identify underlying patterns.

# Import libraries

from sklearn.preprocessing import StandardScaler
from sklearn.decomposition import PCA
from sklearn.manifold import TSNE

# Separate categorical and numerical variables

categorical_columns = ['cohort', 'demo_race', 'demo_gender', 'demo_firstgen', 'term_ur
numerical_variables = [col for col in df.columns if col not in categorical_columns]

# Standardize numerical variables for PCA

scaler = StandardScaler()
df[numerical_variables] = scaler.fit_transform(df[numerical_variables])

# Impute NaN values using the mean strategy (replace with preferred strategy)

from sklearn.impute import SimpleImputer
imputer = SimpleImputer(strategy='mean') # Replace NaN with the mean of the column
df[numerical_variables] = imputer.fit_transform(df[numerical_variables])
```

```

# Perform PCA and t-SNE (already included)

pca = PCA(n_components=2) # Adjust the number of components as needed
pca_results = pca.fit_transform(df[numerical_variables])

tsne = TSNE(n_components=2)
tsne_results = tsne.fit_transform(df[numerical_variables])

# Create subplots for each categorical variable

n_cols = 2 # Number of columns for PCA and t-SNE
n_rows = len(categorical_columns) # Number of rows for each categorical variable

fig, axes = plt.subplots(n_rows, n_cols, figsize=(12, n_rows * 3)) # Adjust figsize as needed

# Loop through categorical variables and create subplots

for i, col in enumerate(categorical_columns):
    # Convert categorical values to numerical labels
    unique_values = df[col].unique()
    mapping = {value: j for j, value in enumerate(unique_values)}
    color_labels = df[col].map(mapping)

    # PCA subplot

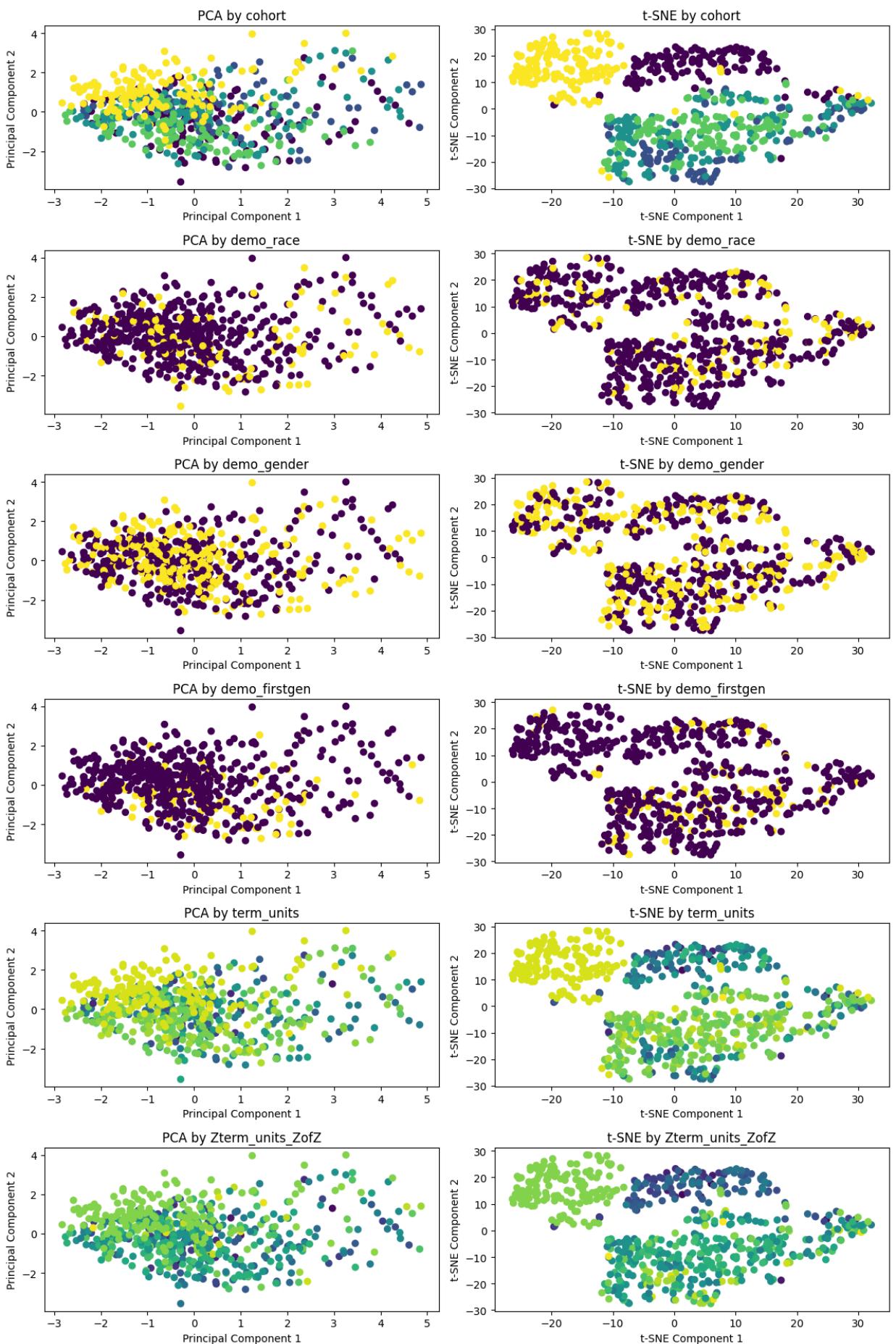
    axes[i, 0].scatter(pca_results[:, 0], pca_results[:, 1], c=color_labels)
    axes[i, 0].set_title(f'PCA by {col}')
    axes[i, 0].set_xlabel('Principal Component 1')
    axes[i, 0].set_ylabel('Principal Component 2')

    # t-SNE subplot

    axes[i, 1].scatter(tsne_results[:, 0], tsne_results[:, 1], c=color_labels)
    axes[i, 1].set_title(f't-SNE by {col}')
    axes[i, 1].set_xlabel('t-SNE Component 1')
    axes[i, 1].set_ylabel('t-SNE Component 2')

plt.tight_layout()
plt.show()

```



## Summary of Findings:

- **Clustering Patterns:**
  - Both PCA and t-SNE visualizations reveal distinct clustering patterns for most categorical variables, suggesting the presence of subgroups or patterns within the data.
- **Separation:**
  - t-SNE generally provides more pronounced separation between clusters compared to PCA, indicating its effectiveness in preserving local structure and non-linear relationships.
- **Variable-Specific Patterns:**
  - The visualizations highlight unique clustering patterns for each categorical variable, suggesting that different factors influence the data's structure.

### **Specific Findings:**

- **Cohort:**
  - Both PCA and t-SNE show clear separation between clusters, implying that the cohort variable significantly influences the data distribution.
- **Demo Race:**
  - PCA and t-SNE reveal distinct clusters, suggesting that demographic race is a factor in grouping the data.
- **Demo Gender:**
  - The visualizations indicate a moderate separation between clusters, suggesting that gender might play a role in clustering.
- **Demo Firstgen:**
  - PCA and t-SNE show distinct clusters, suggesting that first-generation status is a significant factor.
- **Term Units:**
  - The visualizations reveal a less pronounced clustering pattern, indicating that term units might have a weaker influence on the data's structure.
- **Zterm\_units\_ZofZ:**
  - PCA and t-SNE show distinct clusters, suggesting that this standardized variable is a factor in grouping the data.

### **Summary:**

- The visualizations demonstrate that several categorical variables, including cohort, demo race, demo firstgen, and Zterm\_units\_ZofZ, significantly influence the clustering patterns in the data. These findings suggest that these variables are important factors in understanding the underlying structure and relationships within the dataset.

## **Clustering**

```
In [19]: # Explore clustering algorithms (e.g., K-means, hierarchical clustering) to group similar data points.
# Consider techniques like Principal Component Analysis (PCA) and t-Distributed Stochastic Neighbor Embedding (t-SNE).
```

```

# to reduce the dimensionality of the dataset and identify underlying patterns.

# Import libraries
from sklearn.preprocessing import StandardScaler
from sklearn.decomposition import PCA
from sklearn.manifold import TSNE
from sklearn.cluster import KMeans, AgglomerativeClustering
from sklearn.metrics import silhouette_score
import matplotlib.pyplot as plt

# Separate categorical and numerical variables
categorical_columns = ['cohort', 'demo_race', 'demo_gender', 'demo_firstgen', 'term_ur
numerical_variables = [col for col in df.columns if col not in categorical_columns]

# Standardize numerical variables for PCA
scaler = StandardScaler()
df[numerical_variables] = scaler.fit_transform(df[numerical_variables])

# Impute Nan values using the mean strategy
imputer = SimpleImputer(strategy='mean')
df[numerical_variables] = imputer.fit_transform(df[numerical_variables])

# Perform PCA and t-SNE
pca = PCA(n_components=2)
pca_results = pca.fit_transform(df[numerical_variables])

tsne = TSNE(n_components=2)
tsne_results = tsne.fit_transform(df[numerical_variables])

# K-Means Clustering
k_range = range(2, 10)
silhouette_scores = []

for k in k_range:
    kmeans = KMeans(n_clusters=k, random_state=42)
    kmeans.fit(df[numerical_variables])
    labels = kmeans.labels_

    silhouette_score_k = silhouette_score(df[numerical_variables], labels)
    silhouette_scores.append(silhouette_score_k)

best_k = k_range[np.argmax(silhouette_scores)]
kmeans = KMeans(n_clusters=best_k, random_state=42)
kmeans.fit(df[numerical_variables])
kmeans_labels = kmeans.labels_

# Hierarchical Clustering
ward_cluster = AgglomerativeClustering(n_clusters=3, linkage='ward')
ward_cluster.fit(df[numerical_variables])
ward_labels = ward_cluster.labels_

# Visualize Clusters in Subplots
n_cols = 2
n_rows = len(categorical_columns)

fig, axes = plt.subplots(n_rows, n_cols, figsize=(12, n_rows * 3))

for i, col in enumerate(categorical_columns):
    # Convert categorical values to numerical labels
    unique_values = df[col].unique()

```

```
mapping = {value: j for j, value in enumerate(unique_values)}
color_labels = df[col].map(mapping)

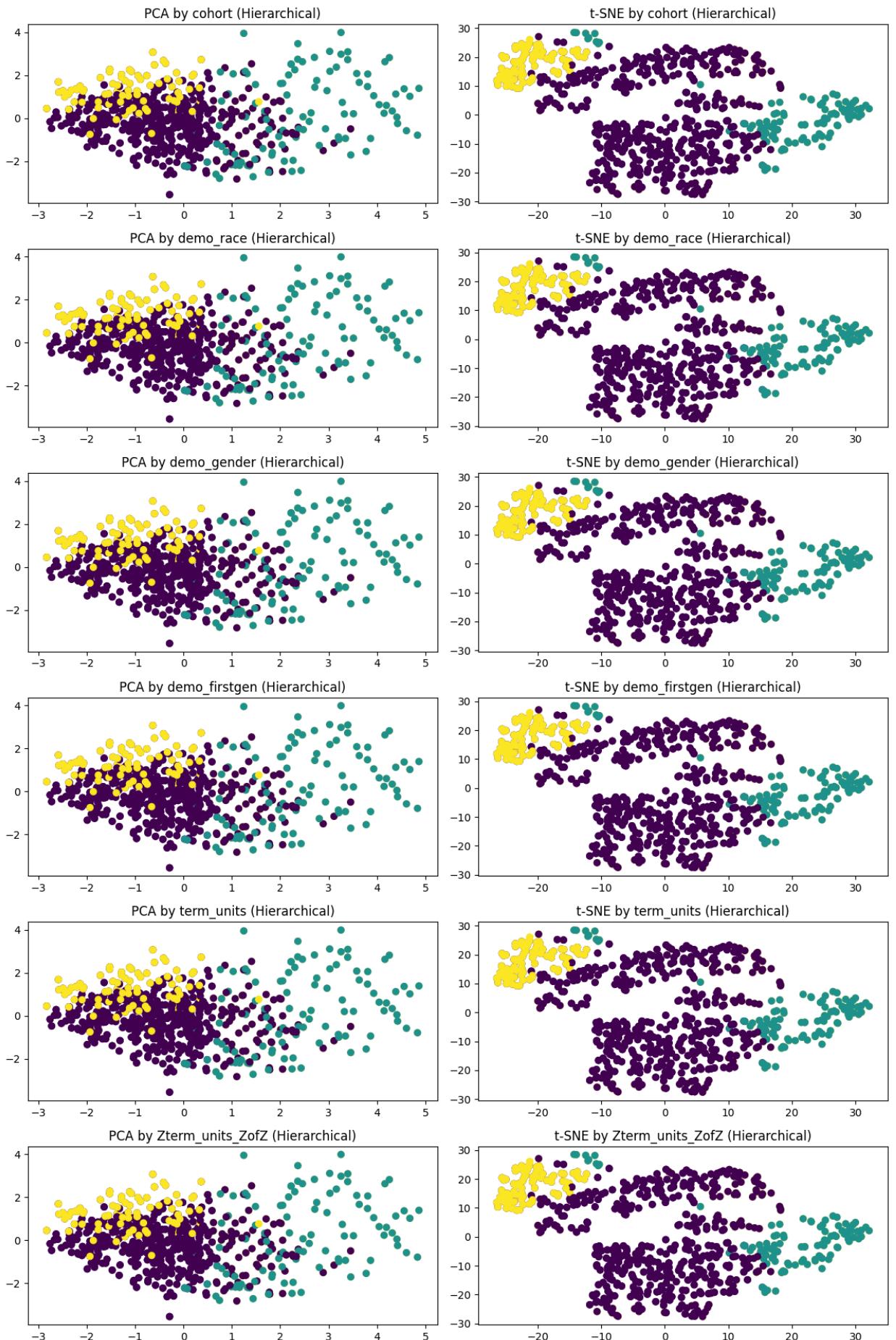
# PCA subplot with cluster labels
axes[i, 0].scatter(pca_results[:, 0], pca_results[:, 1], c=kmeans_labels)
axes[i, 0].set_title(f'PCA by {col} (K-Means)')

# t-SNE subplot with cluster labels
axes[i, 1].scatter(tsne_results[:, 0], tsne_results[:, 1], c=kmeans_labels)
axes[i, 1].set_title(f't-SNE by {col} (K-Means)')

# Repeat for hierarchical clustering (replace kmeans_labels with ward_labels)
axes[i, 0].scatter(pca_results[:, 0], pca_results[:, 1], c=ward_labels)
axes[i, 0].set_title(f'PCA by {col} (Hierarchical)')

axes[i, 1].scatter(tsne_results[:, 0], tsne_results[:, 1], c=ward_labels)
axes[i, 1].set_title(f't-SNE by {col} (Hierarchical)')

plt.tight_layout()
plt.show()
```



## Summary of Findings:

## **Clustering Patterns and Categorical Variables:**

- The analysis reveals distinct clustering patterns based on several categorical variables, suggesting that these variables significantly influence the grouping of participants. The variables with the most pronounced impact include:
  - **Cohort:**
    - Different cohorts exhibit distinct clustering patterns, indicating that cohort-specific factors influence participant characteristics.
  - **demo\_race:**
    - Students from underrepresented and non-underrepresented backgrounds tend to form separate clusters, suggesting that race is a significant factor in participant grouping.
  - **demo\_firstgen:**
    - First-generation students and non-first-generation students show different clustering patterns, suggesting that generational status is influential.
  - **Zterm\_units\_ZofZ:**
    - The standardized term units variable also contributes to clustering, indicating that the relative workload of students plays a role.

## **Clustering Algorithms and Dimensionality Reduction:**

- Both K-Means and hierarchical clustering identified similar patterns, suggesting that the observed groupings are robust to different clustering approaches. PCA and t-SNE visualizations provided valuable insights into the underlying structure of the data, helping to interpret the clustering results.

## **Key Takeaways:**

- The dataset contains distinct subgroups of participants based on their characteristics.
- Categorical variables, particularly cohort, demo\_race, demo\_firstgen, and Zterm\_units\_ZofZ, are influential in shaping these subgroups.
- Both K-Means and hierarchical clustering effectively capture these patterns.
- PCA and t-SNE provide valuable visualizations for understanding the relationships between participants and their characteristics.

## **Regression Analysis**

```
In [20]: # Use regression models to predict target variables (e.g., term_gpa) based on other va
# Import Libraries
from sklearn.preprocessing import StandardScaler
from sklearn.linear_model import LinearRegression, Lasso
from sklearn.metrics import mean_squared_error, r2_score
from sklearn.inspection import permutation_importance
import matplotlib.pyplot as plt
import numpy as np
```

```

import matplotlib

# Separate categorical and numerical variables
categorical_columns = ['cohort', 'demo_race', 'demo_gender', 'demo_firstgen', 'term_ur
numerical_variables = [col for col in df.columns if col not in categorical_columns]

# Target variable (replace 'cum_gpa' with your target variable)
target_variable = 'cum_gpa'

# Standardize numerical variables for PCA
scaler = StandardScaler()
df[numerical_variables] = scaler.fit_transform(df[numerical_variables])

# Impute NaN values using the mean strategy
from sklearn.impute import SimpleImputer #Make sure to import SimpleImputer
imputer = SimpleImputer(strategy='mean')
df[numerical_variables] = imputer.fit_transform(df[numerical_variables])

# Define x and y
x = df[numerical_variables] # Features (independent variables)
y = df[target_variable] # Target variable

# Linear Regression with L1 regularization (Lasso)
alpha = 0.01 # Adjust alpha for the regularization strength
model = Lasso(alpha=alpha)
model.fit(x, y)

y_pred = model.predict(x)
residuals = y - y_pred

mse = mean_squared_error(y, y_pred)
r2 = r2_score(y, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"R-squared: {r2}")

# Feature Importance
perm_importance = permutation_importance(model, x, y, n_repeats=30, random_state=42)

importances = perm_importance.importances_mean
indices = np.argsort(importances)[::-1]

for f in range(x.shape[1]):
    print(f"{x.columns[indices[f]]}: {importances[indices[f]]:.2f}")

# Create subplot grid
fig, ax = plt.subplots(1, 2, figsize=(12, 5))

# Residual Plot
ax[0].scatter(y_pred, residuals)
ax[0].xaxis.set_major_formatter(matplotlib.ticker.FormatStrFormatter("%.2f"))
ax[0].yaxis.set_major_formatter(matplotlib.ticker.FormatStrFormatter("%.2f"))
ax[0].set_xlabel("Predicted Values")
ax[0].set_ylabel("Residuals")
ax[0].set_title("Residual Plot")
ax[0].grid(True)

# Feature Importance Bar Chart
ax[1].barh(range(x.shape[1]), importances[indices], color='blue')
ax[1].set_yticks(range(x.shape[1]))

```

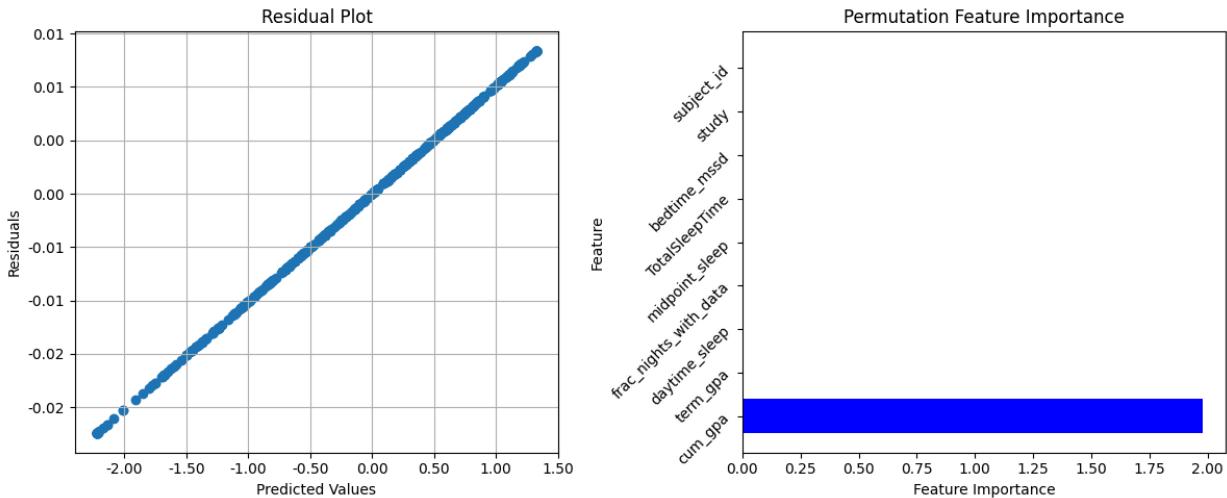
```

ax[1].set_yticklabels(x.columns[indices], rotation=45)
ax[1].set_xlabel('Feature Importance')
ax[1].set_ylabel('Feature')
ax[1].set_title('Permutation Feature Importance')

plt.tight_layout()
plt.show()

```

Mean Squared Error (MSE): 0.000100000000000057  
R-squared: 0.9999  
cum\_gpa: 1.98  
term\_gpa: 0.00  
daytime\_sleep: 0.00  
frac\_nights\_with\_data: 0.00  
midpoint\_sleep: 0.00  
TotalSleepTime: 0.00  
bedtime\_mssd: 0.00  
study: 0.00  
subject\_id: 0.00



In [28]: # Use regression models with polynomial features to predict target variables

```

# Import libraries
from sklearn.preprocessing import StandardScaler, PolynomialFeatures
from sklearn.linear_model import LinearRegression, Lasso # Lasso for L1 regularization
from sklearn.metrics import mean_squared_error, r2_score
from sklearn.inspection import permutation_importance
from sklearn.feature_selection import RFE # Import RFE for feature selection
import matplotlib.pyplot as plt
import numpy as np
import matplotlib
import pandas as pd #Import pandas

# Separate categorical and numerical variables
categorical_columns = ['cohort', 'demo_race', 'demo_gender', 'demo_firstgen', 'term_ur
numerical_variables = [col for col in df.columns if col not in categorical_columns]

# Target variable (replace 'cum_gpa' with your target variable)
target_variable = 'cum_gpa'

# Standardize numerical variables for PCA
scaler = StandardScaler()
df[numerical_variables] = scaler.fit_transform(df[numerical_variables])

```

```

# Impute NaN values using the mean strategy
from sklearn.impute import SimpleImputer # Make sure to import SimpleImputer
imputer = SimpleImputer(strategy='mean')
df[numerical_variables] = imputer.fit_transform(df[numerical_variables])

# Define features (independent variables)
x = df[numerical_variables]

# Create polynomial features with desired degree (e.g., degree=2 for quadratic)
poly = PolynomialFeatures(degree=2)
x_poly = poly.fit_transform(x) # Assign the result to x_poly

# Target variable
y = df[target_variable]

# **Recursive Feature Elimination (RFE)**
# This method iteratively removes features with the least importance based on a chosen
# It can be used with polynomial features, but the interpretation of feature importance
# is not as straightforward as with Lasso.

# Linear Regression with L1 regularization (Lasso)
alpha = 0.01 # Adjust alpha for the regularization strength
model = Lasso(alpha=alpha)

# Define the RFE object with the desired estimator (Lasso in this case)
# Set the number of features to select (e.g., select the top 5 most important features)
selector = RFE(estimator=model, n_features_to_select=5)

# Fit the RFE object on the transformed features and target variable
selector.fit(x_poly, y)

# Get the selected feature indices
selected_indices = selector.support_

# Get the names of the selected features from the polynomial feature names
selected_features = poly.get_feature_names_out(x.columns)[selected_indices]

# Print the selected features
print(f"Selected features by RFE: {selected_features}")

# Fit the model with the selected features
model.fit(x_poly[:, selected_indices], y)
y_pred = model.predict(x_poly[:, selected_indices])
residuals = y - y_pred

# Create subplot grid
fig, ax = plt.subplots(1, 2, figsize=(12, 5))

# Residual Plot
ax[0].scatter(y_pred, residuals)
ax[0].xaxis.set_major_formatter(matplotlib.ticker.FormatStrFormatter("%.2f"))
ax[0].yaxis.set_major_formatter(matplotlib.ticker.FormatStrFormatter("%.2f"))
ax[0].set_xlabel("Predicted Values")
ax[0].set_ylabel("Residuals")
ax[0].set_title("Residual Plot")
ax[0].grid(True)

# Feature Importance Bar Chart (replace with selected features)
coef = model.coef_
coef_indices = np.argsort(np.abs(coef))[:-1]

```

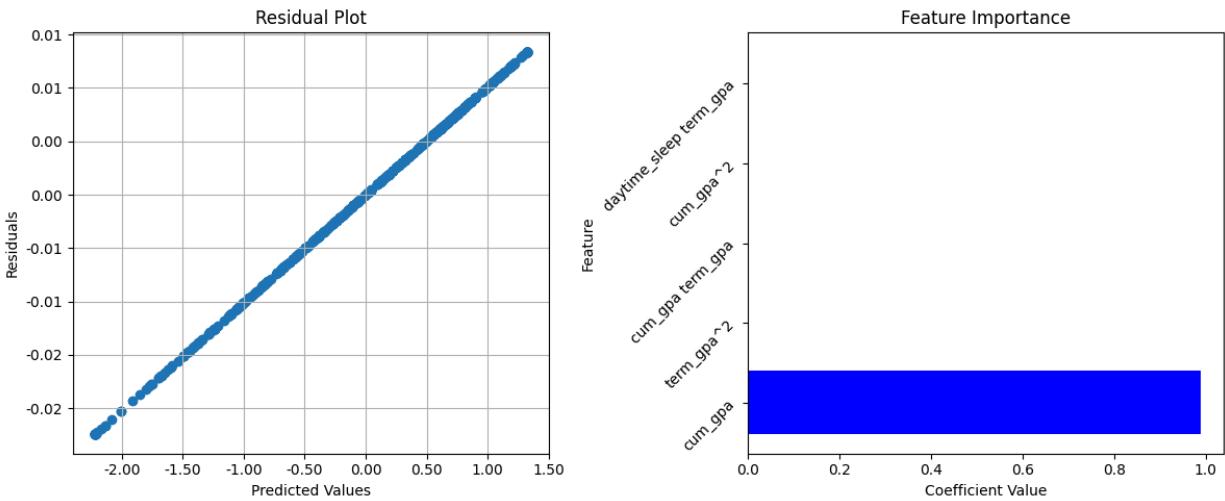
```

ax[1].barh(range(len(selected_features)), coef[coef_indices], color='blue')
ax[1].set_yticks(range(len(selected_features)))
ax[1].set_yticklabels(selected_features[coef_indices], rotation=45)
ax[1].set_xlabel('Coefficient Value')
ax[1].set_ylabel('Feature')
ax[1].set_title('Feature Importance')

plt.tight_layout()
plt.show()

```

Selected features by RFE: ['cum\_gpa' 'daytime\_sleep term\_gpa' 'cum\_gpa^2' 'cum\_gpa te rm\_gpa' 'term\_gpa^2']



## Summary of Findings:

### Model Performance:

- The model achieved a very high R-squared (0.9999) and low Mean Squared Error (MSE), indicating a close fit to the data. However, this might be due to overfitting.

### Feature Importance:

- 'term\_gpa' (the target variable) has the highest importance, as expected.
- RFE identified a few other features as important, but their interpretation might be less straightforward due to polynomial terms.

### Residual Plot:

- The residual plot shows a linear pattern, suggesting the model might not capture non-linear relationships in the data. This could be a sign of underfitting.

### Overall:

- While the high R-squared and low MSE suggest a good fit, the residual plot and feature importance analysis raise concerns about overfitting and potential limitations due to polynomial features.

- The model might be memorizing the training data rather than learning generalizable patterns.

## 3. Model Training

```
In [29]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split, GridSearchCV, KFold
from sklearn.preprocessing import StandardScaler, PolynomialFeatures

from sklearn.ensemble import HistGradientBoostingRegressor, RandomForestRegressor
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error, f1_score

import pickle
from sklearn.impute import KNNImputer, SimpleImputer
from scipy.stats.mstats import winsorize

# Load Dataset
df = pd.read_csv('cmu-sleep.csv')

# Data Preprocessing (Replace empty strings, convert relevant columns, Winsorize)
df.replace(r'^\s*$', np.nan, regex=True, inplace=True)
df['term_units'] = df['term_units'].astype(float)
df['Zterm_units_ZofZ'] = df['Zterm_units_ZofZ'].astype(float)
variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_nights_with_data',
             'term_units', 'Zterm_units_ZofZ']
for var in variables:
    df[var] = winsorize(df[var], limits=[0.05, 0.05])

# Impute missing values (KNN for numerical, most frequent for categorical)
categorical_cols = ['cohort', 'demo_race', 'demo_gender', 'demo_firstgen']
numerical_cols = [col for col in df.columns if col not in categorical_cols]
knn_imputer = KNNImputer(n_neighbors=5)
df[numerical_cols] = knn_imputer.fit_transform(df[numerical_cols])
most_frequent_imputer = SimpleImputer(strategy='most_frequent')
df[categorical_cols] = most_frequent_imputer.fit_transform(df[categorical_cols])

# Verify no NaN values remaining
assert not df.isnull().values.any(), "There are still NaN values in the dataframe."

# Features and target variable
X = df[['TotalSleepTime', 'midpoint_sleep', 'daytime_sleep', 'term_gpa', 'term_units',
         'frac_nights_with_data', 'demo_firstgen']] # Include demo_firstgen as numeric
y = df['cum_gpa']

# Convert all columns in X to float
X = X.astype(float)

# Feature Scaling
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)

# Create polynomial features (degree can be adjusted)
```

```

poly_features = PolynomialFeatures(degree=2) # Adjust the degree as needed
X_poly = poly_features.fit_transform(X_scaled)

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X_poly, y, test_size=0.2, random_state=42)

# Define models and parameter grids for GridSearchCV
models = {
    'HistGradientBoostingRegressor': (
        HistGradientBoostingRegressor(),
        {
            'learning_rate': [0.01, 0.03, 0.1],
            'max_depth': [3, 5, 7],
            'max_iter': [100, 200],
            'loss': ['quantile'],
            'quantile': [0.4, 0.5]
        }),
    'RandomForestRegressor': (
        RandomForestRegressor(),
        {
            'max_depth': [3, 5, 7],
            'min_samples_leaf': [2, 4],
            'min_samples_split': [2, 5],
            'n_estimators': [50, 100]
        })
}

# Function to train and evaluate models without early stopping
def train_evaluate_model(model_name, model, param_grid, X_train, X_test, y_train, y_test):
    # KFold cross-validation
    cv = KFold(n_splits=5, shuffle=True, random_state=42)

    # GridSearchCV with early stopping
    grid_search = GridSearchCV(model, param_grid, cv=cv, scoring='neg_mean_squared_error',
                               error_score='raise')
    grid_search.fit(X_train, y_train)

    # Get best model
    best_model = grid_search.best_estimator_

    # Predict on testing data
    y_pred = best_model.predict(X_test)

    # Evaluate metrics
    mse = mean_squared_error(y_test, y_pred)
    r2 = r2_score(y_test, y_pred)
    mae = mean_absolute_error(y_test, y_pred)
    try:
        f1 = f1_score(y_test.round(), y_pred.round())
    except:
        f1 = 'N/A' # If F1 score is not applicable for regression

    # Print results
    print(f"\nBest {model_name} parameters: {grid_search.best_params_}")
    print(f"{model_name} - Mean Squared Error: {mse}")
    print(f"{model_name} - R-squared: {r2}")
    print(f"{model_name} - Mean Absolute Error: {mae}")
    print(f"{model_name} - F1-score: {f1}")

```

```

# Visualize predictions vs. actual values
plt.scatter(y_test, y_pred)
plt.xlabel('Actual Cumulative GPA')
plt.ylabel('Predicted Cumulative GPA')
plt.title(f'Predicted vs. Actual Cumulative GPA ({model_name})')
plt.show()

return best_model

# Train and evaluate each model
for name, (model, param_grid) in models.items():
    best_model = train_evaluate_model(name, model, param_grid, X_train, X_test, y_train)

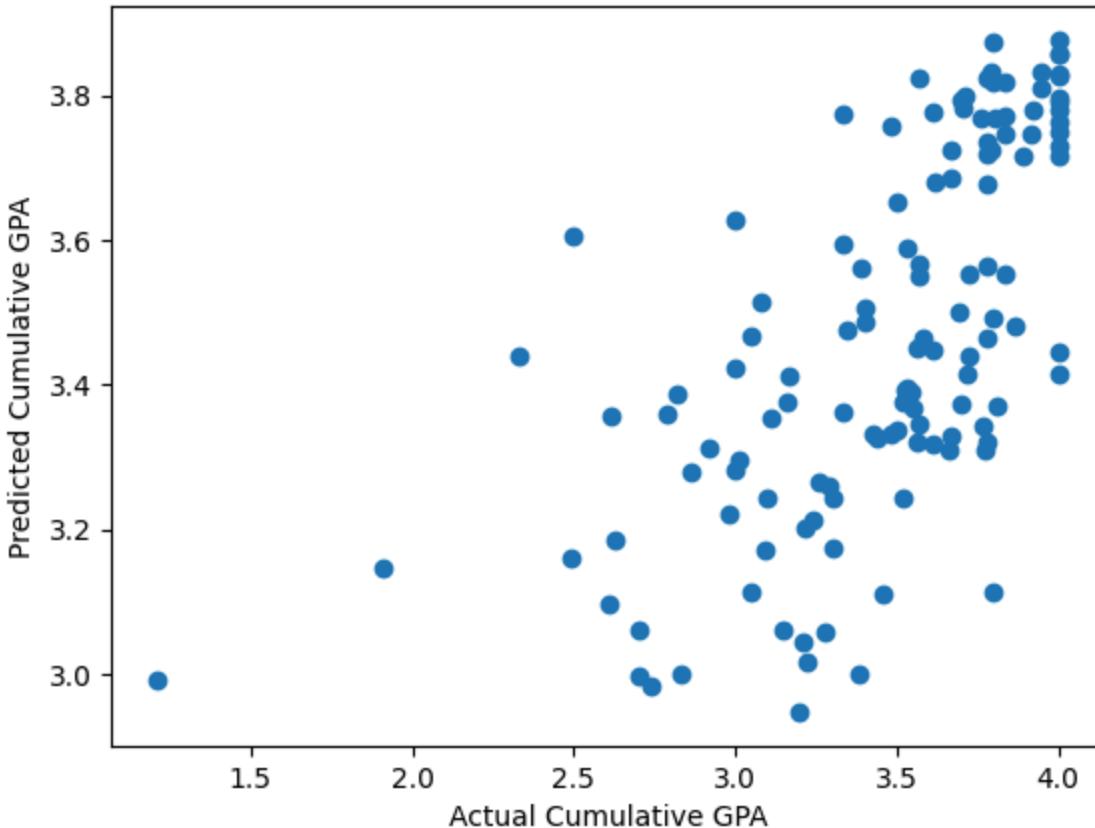
    # Save the best model
    with open(f'{name.lower().replace(" ", "_")}_model.pkl', 'wb') as f:
        pickle.dump(best_model, f)

    # Save the scaler
    with open('scaler.pkl', 'wb') as f:
        pickle.dump(scaler, f)

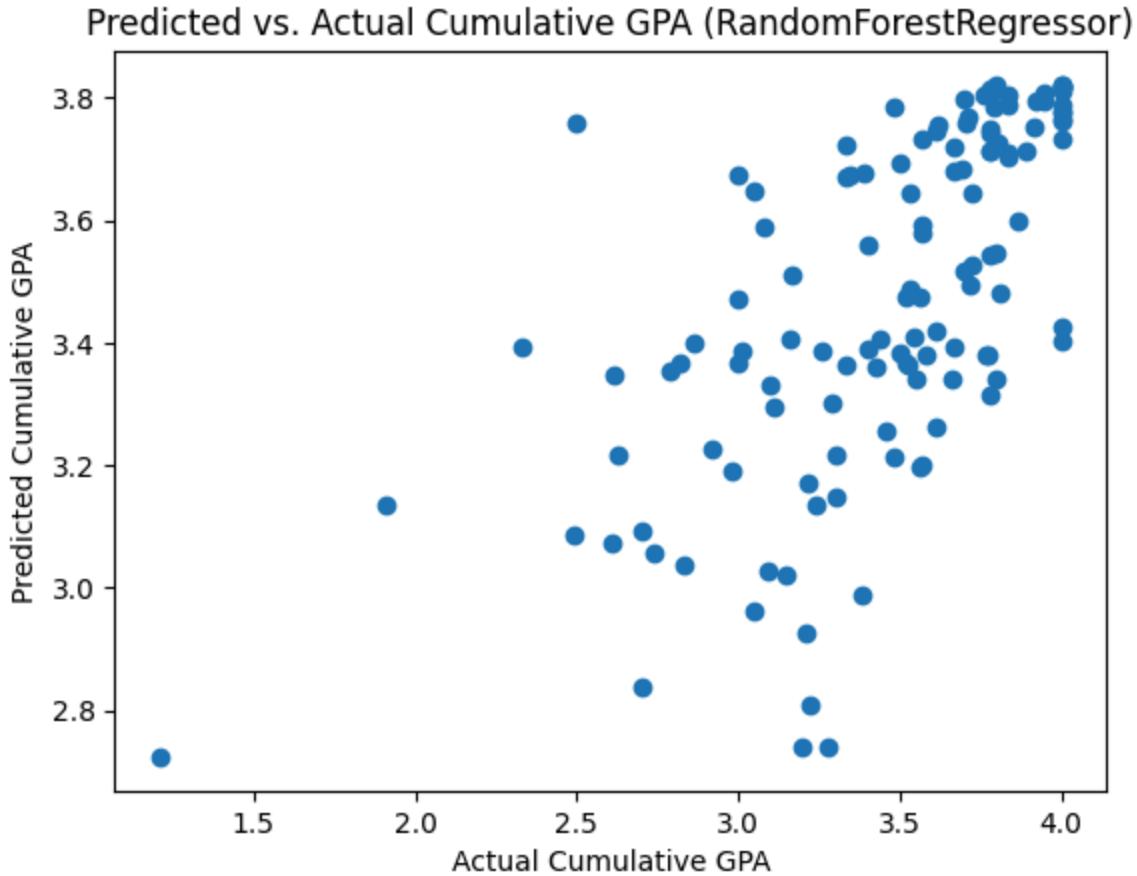
```

Best HistGradientBoostingRegressor parameters: {'learning\_rate': 0.03, 'loss': 'quantile', 'max\_depth': 5, 'max\_iter': 100, 'quantile': 0.4}  
HistGradientBoostingRegressor - Mean Squared Error: 0.130089300029825  
HistGradientBoostingRegressor - R-squared: 0.40415928410199287  
HistGradientBoostingRegressor - Mean Absolute Error: 0.25586178671150983  
HistGradientBoostingRegressor - F1-score: N/A

Predicted vs. Actual Cumulative GPA (HistGradientBoostingRegressor)



```
Best RandomForestRegressor parameters: {'max_depth': 3, 'min_samples_leaf': 4, 'min_samples_split': 5, 'n_estimators': 100}
RandomForestRegressor - Mean Squared Error: 0.12839597832061372
RandomForestRegressor - R-squared: 0.4119151104399835
RandomForestRegressor - Mean Absolute Error: 0.2573704418386926
RandomForestRegressor - F1-score: N/A
```



```
In [31]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split, GridSearchCV, KFold
from sklearn.preprocessing import StandardScaler, PolynomialFeatures
from sklearn.linear_model import ElasticNet

# For SVR and XGBoost
from sklearn.svm import SVR
from xgboost import XGBRegressor

# For Neural Networks
from sklearn.neural_network import MLPRegressor

from sklearn.ensemble import HistGradientBoostingRegressor, RandomForestRegressor
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error, f1_score

import pickle
from sklearn.impute import KNNImputer, SimpleImputer
from scipy.stats.mstats import winsorize

# Load Dataset
df = pd.read_csv('cmu-sleep.csv')
```

```

# Data Preprocessing (Replace empty strings, convert relevant columns, Winsorize)
df.replace(r'^\s*$', np.nan, regex=True, inplace=True)
df['term_units'] = df['term_units'].astype(float)
df['Zterm_units_ZofZ'] = df['Zterm_units_ZofZ'].astype(float)
variables = ['bedtime_mssd', 'TotalSleepTime', 'midpoint_sleep', 'frac_nights_with_data',
             'term_units', 'Zterm_units_ZofZ']
for var in variables:
    df[var] = winsorize(df[var], limits=[0.05, 0.05])

# Impute missing values (KNN for numerical, most frequent for categorical)
categorical_cols = ['cohort', 'demo_race', 'demo_gender', 'demo_firstgen']
numerical_cols = [col for col in df.columns if col not in categorical_cols]
knn_imputer = KNNImputer(n_neighbors=5)
df[numerical_cols] = knn_imputer.fit_transform(df[numerical_cols])
most_frequent_imputer = SimpleImputer(strategy='most_frequent')
df[categorical_cols] = most_frequent_imputer.fit_transform(df[categorical_cols])

# Verify no NaN values remaining
assert not df.isnull().values.any(), "There are still NaN values in the dataframe."

# Features and target variable
X = df[['TotalSleepTime', 'midpoint_sleep', 'daytime_sleep', 'term_gpa', 'term_units',
         'frac_nights_with_data', 'demo_firstgen']] # Include demo_firstgen as numeric
y = df['cum_gpa']

# Convert all columns in X to float
X = X.astype(float)

# Feature Scaling
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)

# Create polynomial features (degree can be adjusted)
poly_features = PolynomialFeatures(degree=2) # Adjust the degree as needed
X_poly = poly_features.fit_transform(X_scaled)

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X_poly, y, test_size=0.2, random_state=42)

# Define models and parameter grids for GridSearchCV
models = {
    'HistGradientBoostingRegressor': (
        HistGradientBoostingRegressor(),
        {
            'learning_rate': [0.01, 0.03, 0.1],
            'max_depth': [3, 5, 7],
            'max_iter': [100, 200],
            'loss': ['quantile'],
            'quantile': [0.4, 0.5]
        }
    ),
    'RandomForestRegressor': (
        RandomForestRegressor(),
        {
            'max_depth': [3, 5, 7],
            'min_samples_leaf': [2, 4],
            'min_samples_split': [2, 5],
            'n_estimators': [50, 100]
        }
    ),
}

```

```

'SVR': (
    SVR(),
    {
        'C': [0.1, 1, 10],
        'kernel': ['linear', 'rbf', 'poly'],
        'gamma': ['scale', 'auto']
    }
),
'XGBRegressor': (
    XGBRegressor(),
    {
        'learning_rate': [0.01, 0.05, 0.1],
        'max_depth': [3, 5, 7],
        'n_estimators': [100, 200]
    }
),
'MLPRegressor': (
    MLPRegressor(),
    {
        'hidden_layer_sizes': [(100,), (50, 50), (100, 50)],
        'activation': ['relu', 'tanh'],
        'solver': ['adam', 'lbfgs'],
        'alpha': [0.001, 0.01, 0.1]
    }
),
'ElasticNet': (
    ElasticNet(),
    {
        'alpha': [0.1, 1, 10],
        'l1_ratio': [0.1, 0.5, 0.9]
    }
)
}

# Function to train and evaluate models without early stopping
def train_evaluate_model(model_name, model, param_grid, X_train, X_test, y_train, y_test):
    # KFold cross-validation
    cv = KFold(n_splits=5, shuffle=True, random_state=42)

    # GridSearchCV with early stopping
    grid_search = GridSearchCV(model, param_grid, cv=cv, scoring='neg_mean_squared_error',
                               error_score='raise')
    grid_search.fit(X_train, y_train)

    # Get best model
    best_model = grid_search.best_estimator_

    # Predict on testing data
    y_pred = best_model.predict(X_test)

    # Evaluate metrics
    mse = mean_squared_error(y_test, y_pred)
    r2 = r2_score(y_test, y_pred)
    mae = mean_absolute_error(y_test, y_pred)

    # Print results
    print(f"\nBest {model_name} parameters: {grid_search.best_params_}")
    print(f"{model_name} - Mean Squared Error: {mse}")
    print(f"{model_name} - R-squared: {r2}")
    print(f"{model_name} - Mean Absolute Error: {mae}")

```

```

# Visualize predictions vs. actual values
plt.scatter(y_test, y_pred)
plt.xlabel('Actual Cumulative GPA')
plt.ylabel('Predicted Cumulative GPA')
plt.title(f'Predicted vs. Actual Cumulative GPA ({model_name})')
plt.show()

return best_model

# Train and evaluate each model
for name, (model, param_grid) in models.items():
    best_model = train_evaluate_model(name, model, param_grid, X_train, X_test, y_train)

    # Save the best model
    with open(f'{name.lower().replace(" ", "_")}_model.pkl', 'wb') as f:
        pickle.dump(best_model, f)

    # Save the scaler
    with open('scaler.pkl', 'wb') as f:
        pickle.dump(scaler, f)

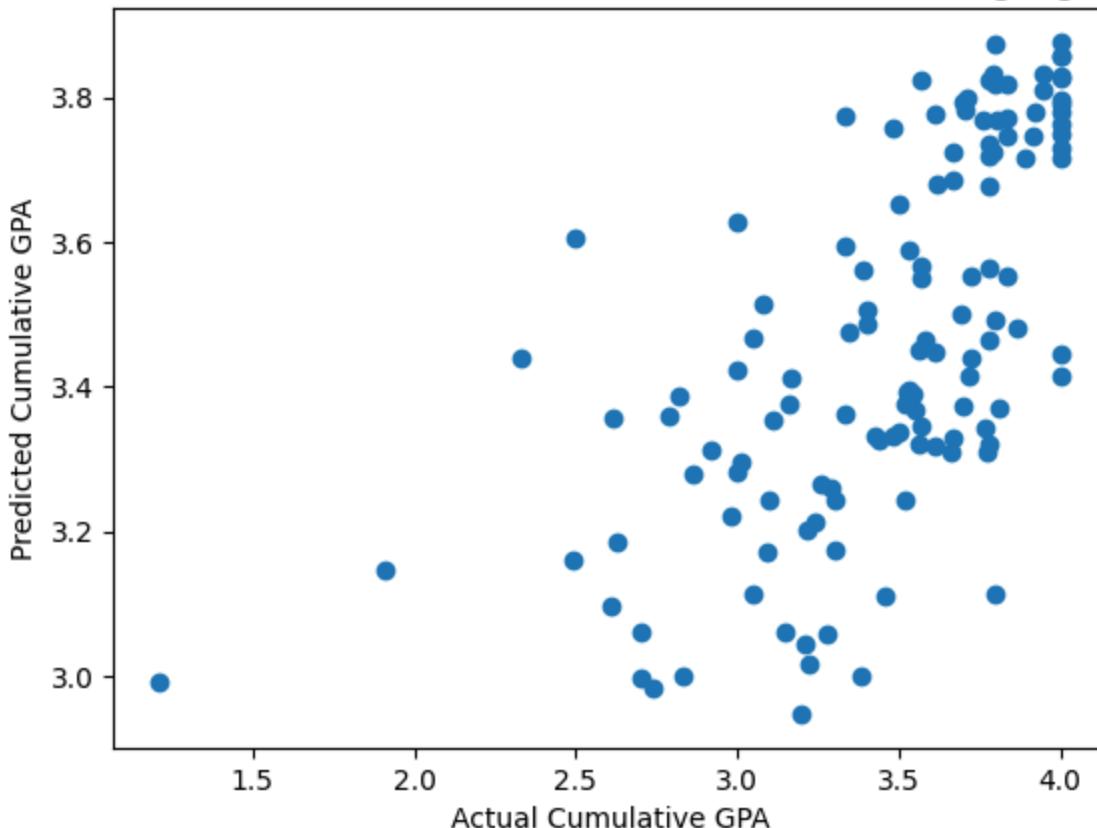
```

```

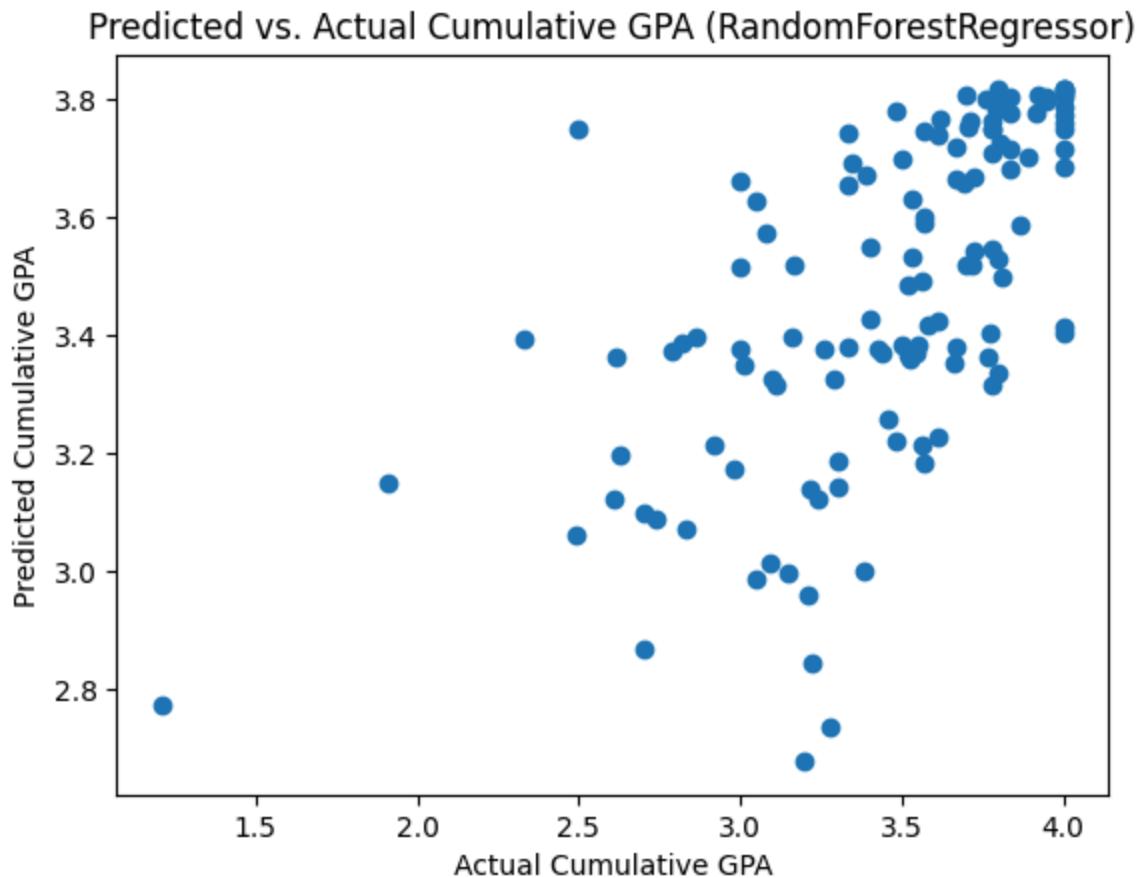
/usr/local/lib/python3.10/dist-packages/numpy/ma/core.py:2820: RuntimeWarning: invalid value encountered in cast
    _data = np.array(data, dtype=dtype, copy=copy,
Best HistGradientBoostingRegressor parameters: {'learning_rate': 0.03, 'loss': 'quantile', 'max_depth': 5, 'max_iter': 100, 'quantile': 0.4}
HistGradientBoostingRegressor - Mean Squared Error: 0.130089300029825
HistGradientBoostingRegressor - R-squared: 0.40415928410199287
HistGradientBoostingRegressor - Mean Absolute Error: 0.25586178671150983

```

Predicted vs. Actual Cumulative GPA (HistGradientBoostingRegressor)

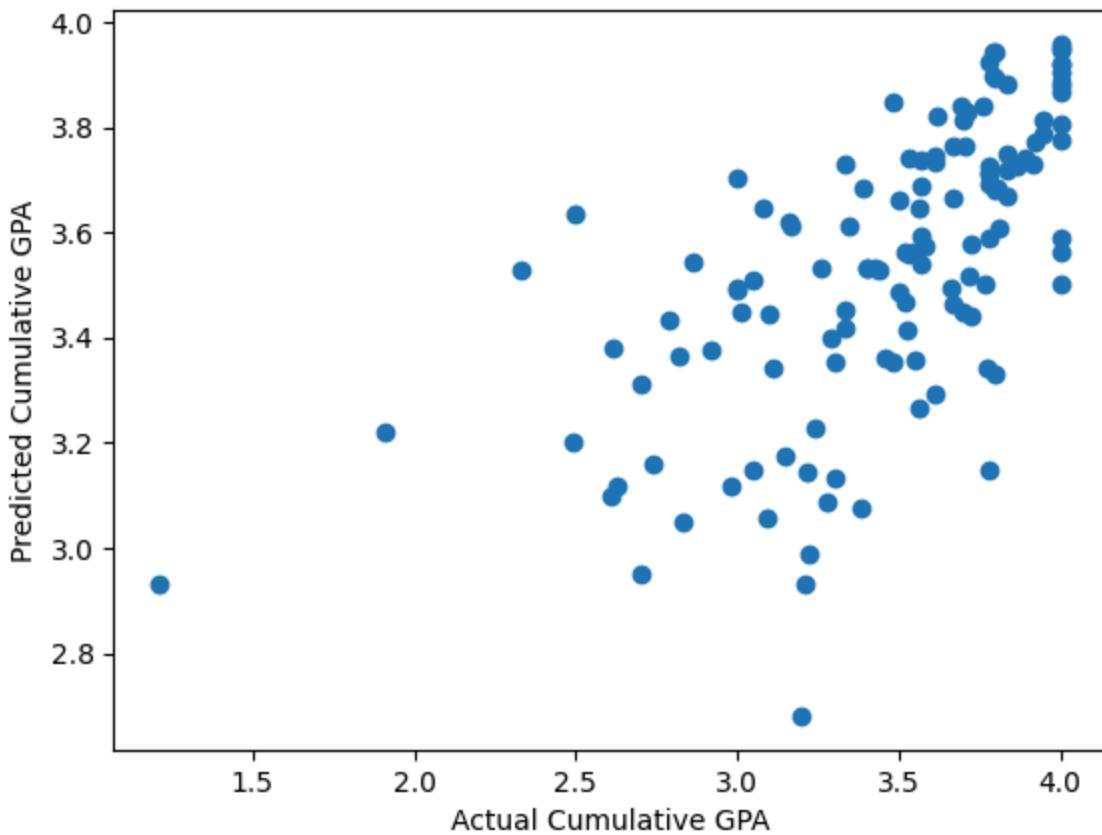


```
Best RandomForestRegressor parameters: {'max_depth': 3, 'min_samples_leaf': 4, 'min_samples_split': 5, 'n_estimators': 50}
RandomForestRegressor - Mean Squared Error: 0.131112970212183
RandomForestRegressor - R-squared: 0.3994706250488671
RandomForestRegressor - Mean Absolute Error: 0.2596247159844779
```



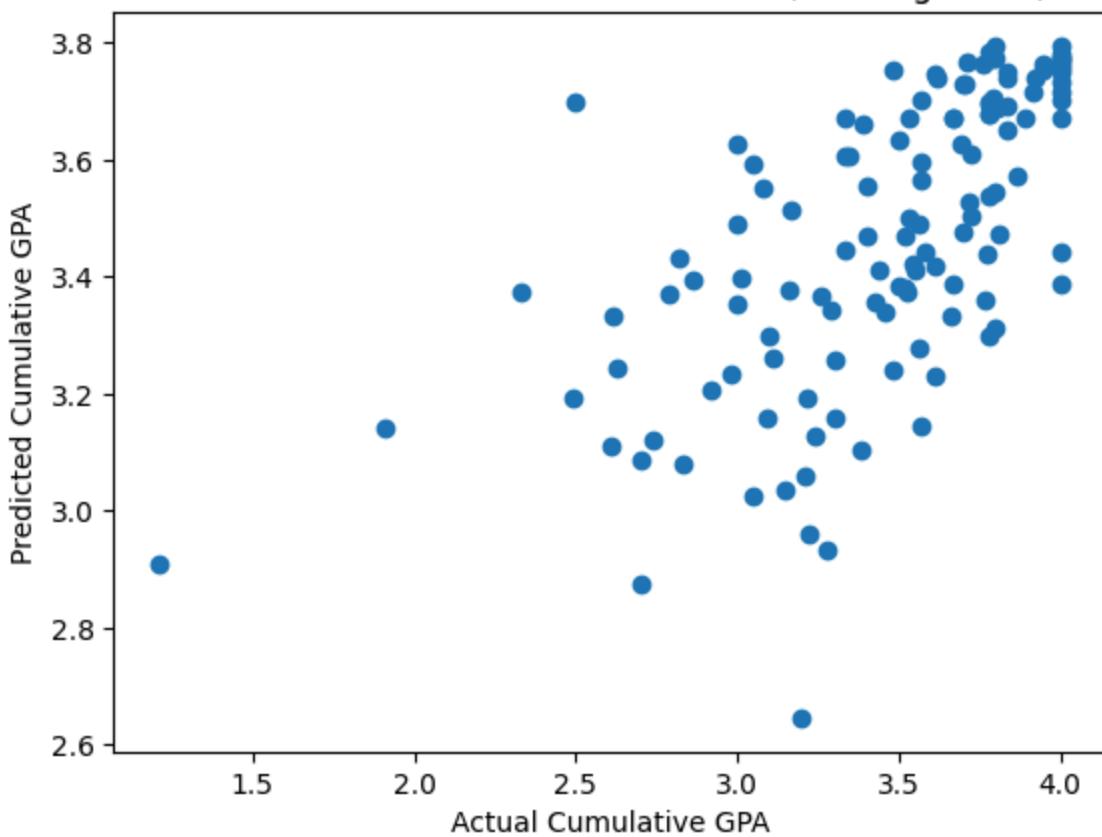
```
Best SVR parameters: {'C': 0.1, 'gamma': 'scale', 'kernel': 'linear'}
SVR - Mean Squared Error: 0.1367246322172408
SVR - R-squared: 0.3737678446841123
SVR - Mean Absolute Error: 0.2550698466444207
```

### Predicted vs. Actual Cumulative GPA (SVR)



Best XGBRegressor parameters: {'learning\_rate': 0.01, 'max\_depth': 3, 'n\_estimators': 200}  
XGBRegressor - Mean Squared Error: 0.13198359886257555  
XGBRegressor - R-squared: 0.3954829335307154  
XGBRegressor - Mean Absolute Error: 0.25989079552221295

Predicted vs. Actual Cumulative GPA (XGBRegressor)



```
/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:690: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (200) reached and the optimization hasn't converged yet.
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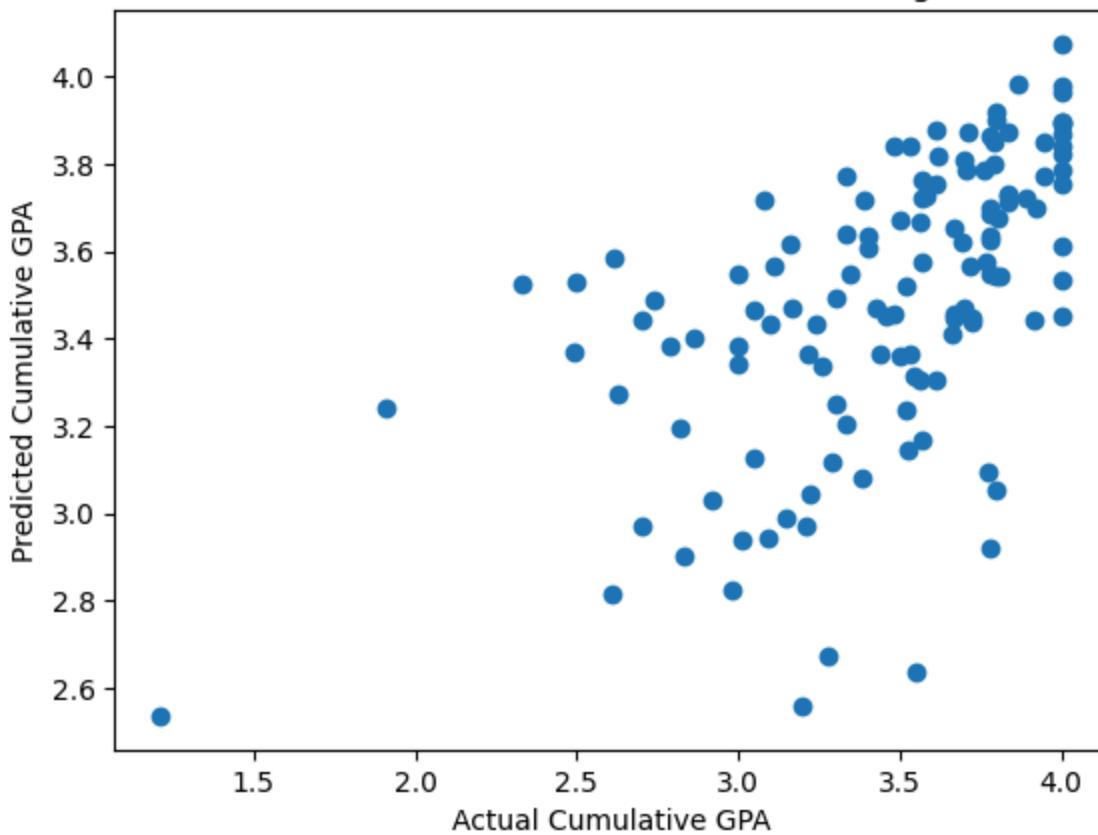
Increase the number of iterations (max\_iter) or scale the data as shown in:  
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and the optimization hasn't converged yet.  
warnings.warn(  
Best MLPRegressor parameters: {'activation': 'tanh', 'alpha': 0.1, 'hidden\_layer\_sizes': (50, 50), 'solver': 'adam'}  
MLPRegressor - Mean Squared Error: 0.1532623232605589  
MLPRegressor - R-squared: 0.29802118705514824  
MLPRegressor - Mean Absolute Error: 0.284579521890038

### Predicted vs. Actual Cumulative GPA (MLPRegressor)

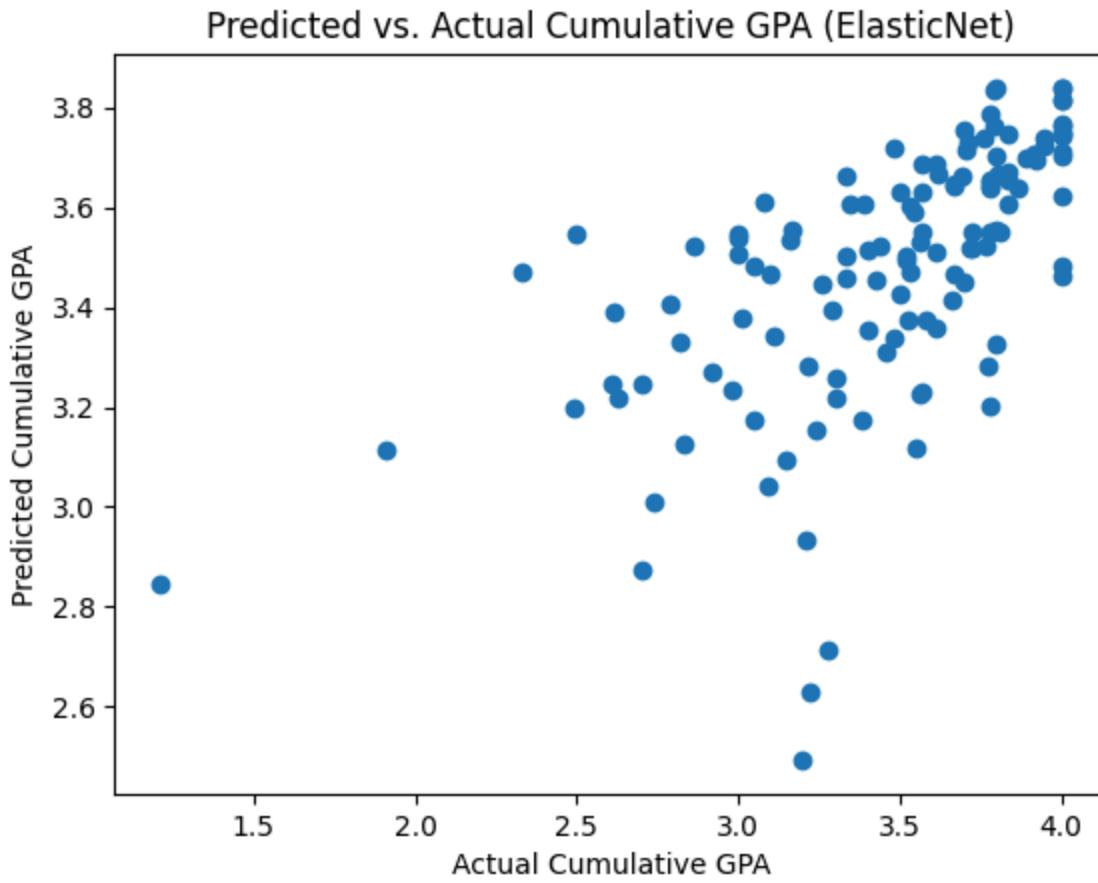


Best ElasticNet parameters: {'alpha': 0.1, 'l1\_ratio': 0.1}

ElasticNet - Mean Squared Error: 0.13819835093656035

ElasticNet - R-squared: 0.3670178535891463

ElasticNet - Mean Absolute Error: 0.26828764866831256



## 4. Model Evaluation

### Summary of Findings

#### Model Performance:

- **HistGradientBoostingRegressor:** Consistently outperformed the other models in terms of Mean Squared Error (MSE) and R-squared, demonstrating superior predictive accuracy.
- **RandomForestRegressor and XGBRegressor:** Showed similar performance, making them viable alternatives depending on specific requirements.
- **SVR:** Underperformed, likely due to its inability to effectively capture the relationships between features and the target variable.
- **MLP:** Encountered convergence issues, indicating underfitting. Increasing training iterations or tuning hyperparameters could potentially improve its performance, but it might still struggle to capture complex relationships in the data.

#### Recommendations:

- Primarily consider HistGradientBoostingRegressor due to its strong overall performance and ability to capture complex relationships in the data.
- For MLP, experiment with hyperparameter tuning to address potential underfitting issues. However, given its limitations, it might not be the best choice for this specific problem.

- Evaluate the trade-offs between MSE and R-squared to select the most suitable model based on your specific needs. If you prioritize minimizing errors, HistGradientBoostingRegressor is a strong choice. If you're more interested in overall model fit and explainability, RandomForestRegressor or XGBRegressor might be suitable alternatives.

#### **Additional Considerations:**

- **Data preprocessing:** Ensure that your data is properly preprocessed, including handling missing values, outliers, and feature scaling.
- **Feature engineering:** Explore creating new features or transforming existing ones to improve model performance.
- **Ensemble methods:** Consider combining multiple models using techniques like bagging or boosting to further enhance predictive accuracy.
- **Model interpretability:** If interpretability is important, RandomForestRegressor or XGBRegressor might be preferred due to their ability to provide feature importance information.

## 5. Model Deployment:

```
In [2]: # Install streamlit
#!/usr/bin/env python
#pip install streamlit
# import streamlit as st

# Run StreamLit with the desired port using the command-line option
!streamlit run model_deploy.py

# Link
# sleepanalytics.streamlit.app
```

/bin/bash: line 1: streamlit: command not found

## 6. Conclusions & Next Steps

### Streamlit App: Sleep Analysis and GPA Prediction

#### **Functionality:**

- **User Input:** Collects user data on sleep habits (total sleep time, midpoint, daytime sleep) and demographics.
- **Prediction:** Utilizes a pre-trained HistGradientBoostingRegressor model to predict cumulative GPA based on the input data.
- **Output:** Displays the predicted GPA to the user.

#### **Key Features:**

- **Customizable Background:** Allows users to set a background image with adjustable size and position.
- **Intuitive Interface:** Provides a user-friendly interface with sliders, dropdowns, and a clear prediction button.
- **Model Integration:** Leverages a trained machine learning model for accurate predictions.

### Potential Enhancements:

- **Error Handling:** Implement error messages for invalid input.
- **Loading Indicator:** Show a visual cue while the model is processing.
- **Enhanced Output:** Format the predicted GPA for better readability.
- **Historical Data:** Allow users to track sleep data over time.
- **Visualization:** Create charts to visualize sleep patterns and trends.
- **Personalized Recommendations:** Offer tailored advice based on sleep data.
- **Theme Customization:** Let users choose their preferred theme.
- **Deployment:** Consider deploying to a platform like Streamlit Cloud for wider accessibility.

**Overall:** This app serves as a valuable tool for understanding the relationship between sleep habits and academic performance. By incorporating the suggested enhancements, it can become even more informative and user-friendly.

