Analysis of sleep patterns

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Aim of the project

The aim of this project is to gain a statistically backed-up insight on sleep patterns by analyzing the impact of various factors on sleep parameters and how these parameters relate to each other.

Describing our dataset

- The dataset for our project has been obtained from Kaggle. Source : "*https://www.kaggle.com/datasets/equilibriumm/sleep-efficiency/data*"
- The dataset contains 452 data points, each representing sleep-related information about a randomly chosen individual.
- Each data point consists of 15 attributes, all of which describe a particular aspect of an individual's sleep habit.

Attributes in our dataset

We classify and briefly describe what each of the 15 attributes convey as follows

1. General information
    a. ID
    b. Age
    c. Gender
2. Sleep attributes
    a. Bedtime
    b. Wakeup time
    c. Sleep duration (total time spent asleep)
    d. Sleep efficiency (fraction of time in bed spent asleep)
    e. REM sleep percentage (fraction of sleep time spent in dreams)
    f. Deep sleep percentage
    g. Light sleep percentage
    h. Awakenings (number of times a person wakes up between his/her sleep)

Attributes in our dataset

3. Beverage consumption and smoking
    a. Coffee consumption (caffeine consumption (in mg) 24 hours prior to bedtime)
    b. Alcohol consumption (alcohol consumption (in oz) 24 hours prior to bedtime)
    c. Smoking status (whether the subject smokes or not)
4. Physical activity
    a. exercise frequency (the number of times the test subject exercises each week)

Sleep Composition

The sleep duration of a person is classified into three components as described below :

- **Light Sleep:** This stage helps with processing new information and keeps you responsive to your surroundings. Tracking light sleep can show if you're getting enough transitions into deeper sleep, which is important for overall rest.
- **Deep Sleep:** The most restorative phase, where the body repairs tissues, strengthens the immune system, and builds energy for the next day. Tracking deep sleep can help assess physical recovery and overall sleep quality.
- **REM Sleep:** This is when dreaming happens, and it plays a big role in problem-solving, emotional balance, and memory. Monitoring REM sleep can help identify stress levels and cognitive health.

Analysing the dataset

We have categorized our analysis into 2 broad sections

1. **External factors :** This section explores how the attributes in the “2. sleep attributes” category discussed earlier are affected by the remaining attributes.
2. **Interdependencies :** Here the relationship within the various sleep attributes are discussed and summarized.

First section

How do external factors influence sleep attributes?

How do sleep patterns change with age?

Classifying on the basis of age

To examine how sleep attributes vary with age, we classified the dataset into three distinct age groups:

1. Young Adults (0-25 years): This group includes individuals in their early years, including students and young professionals.
2. Working Class (25-45 years): This category represents individuals in their working years, balancing career and personal life.
3. Older Adults (45-69 years): This group consists of middle-aged and senior individuals, who may experience age-related changes in sleep patterns.

Statistics Summary

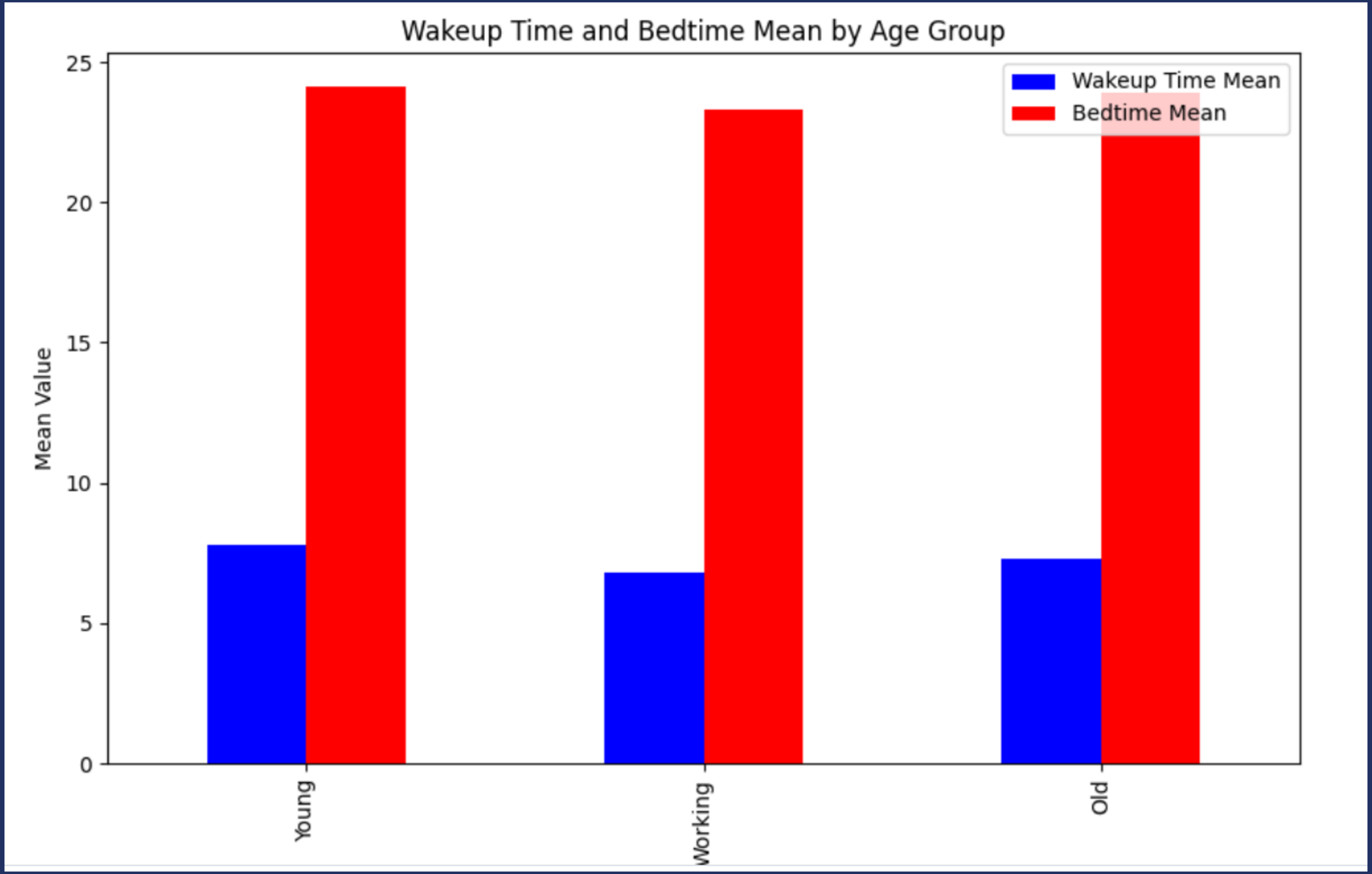
	Bedtime			Wakeup time			Sleep duration			Sleep efficiency		
	Young	Working	Old	Young	Working	Old	Young	Working	Old	Young	Working	Old
mean	24.125	23.30769	23.89429	7.767857	6.785068	7.288571	7.642857	7.477376	7.394286	0.731786	0.791584	0.803829
std	1.446783	1.668664	1.70832	1.651347	1.922405	2.018844	0.767015	0.870963	0.886665	0.134801	0.140579	0.124058
min	21	21	21	3	3	3	6	5	5	0.5	0.5	0.5
25%	23.75	22	22.5	7	5	5.5	7	7	7	0.615	0.71	0.71
50%	24	23	24	8	6.5	7.5	7.5	7.5	7.5	0.77	0.83	0.83
75%	25	24.5	25.5	9	8	9	8	8	8	0.85	0.9	0.91
max	26.5	26.5	26.5	10.5	12.5	12.5	9	10	10	0.95	0.98	0.99
range	5.5	5.5	5.5	7.5	9.5	9.5	3	5	5	0.45	0.48	0.49
IQR	1.25	2.5	3	2	3	3.5	1	1	1	0.235	0.19	0.2

	REM sleep percentage			Deep sleep percentage			Light sleep percentage			Awakenings		
	Young	Working	Old	Young	Working	Old	Young	Working	Old	Young	Working	Old
mean	21.75	22.74208	22.73143	48.25	54.00452	52.79429	30	23.25339	24.47429	2.037736	1.56872	1.607143
std	4.143999	3.575357	3.218461	17.47128	15.2078	15.41953	16.93946	14.76295	15.16151	1.427239	1.351813	1.326992
min	15	15	15	20	20	18	10	7	10	0	0	0
25%	18	20	20	35	55	54	17	13	15	1	1	1
50%	22	22	22	56	60	58	18	17	18	2	1	1
75%	26	25	25	63	65	62	47	21	21	3	3	3
max	28	30	30	75	75	72	55	63	56	4	4	4
range	13	15	15	55	55	54	45	56	46	4	4	4
IQR	8	5	5	28	10	8	30	8	6	2	2	2

(Age -> segregation_age.py)

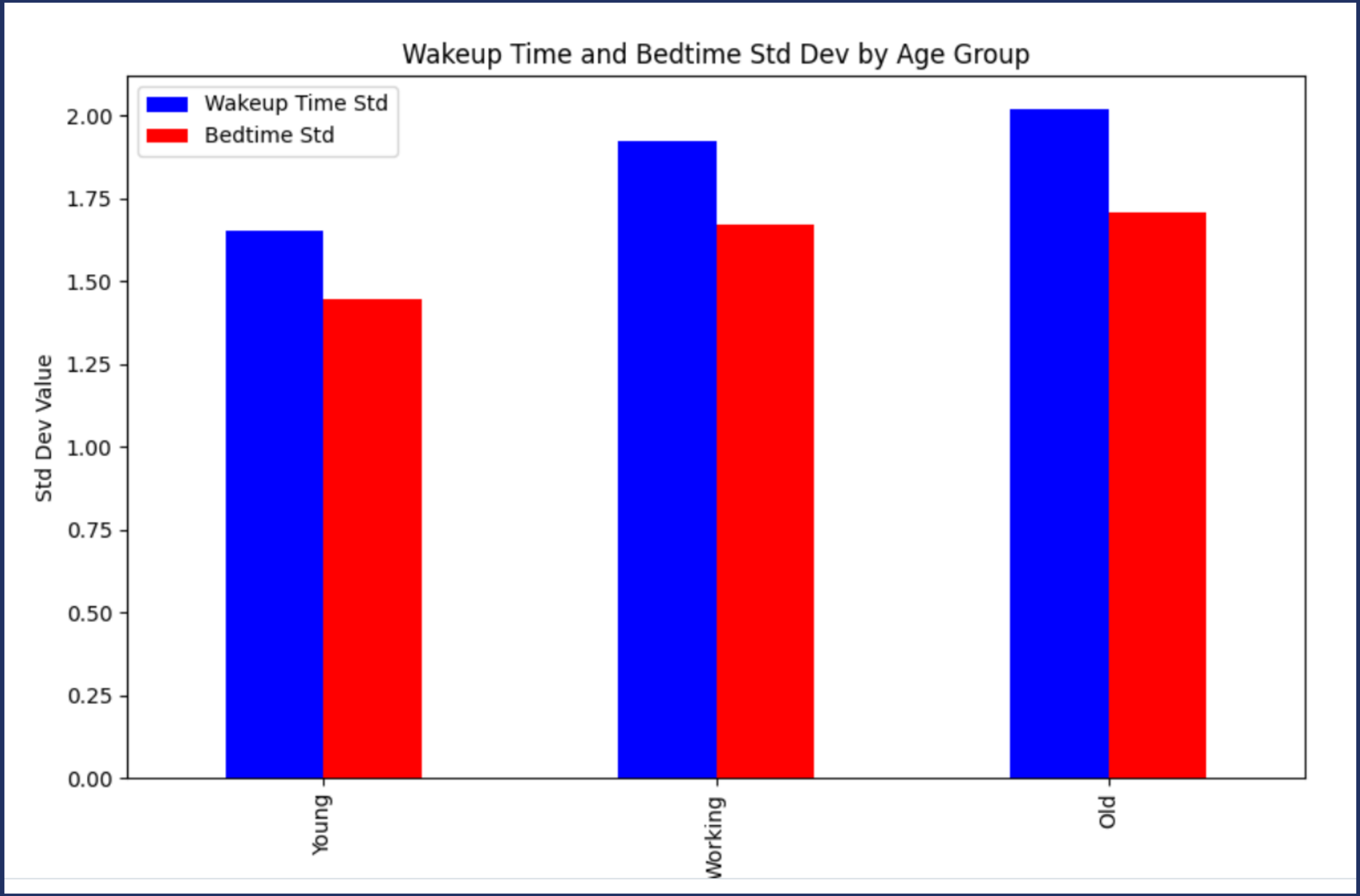
Note: This notation shows a file path: the part before -> is the folder, and the part after is the file name.

Plots : Bar graph



(Plots_Vinay -> analysis.py)

Plots : Bar Graph



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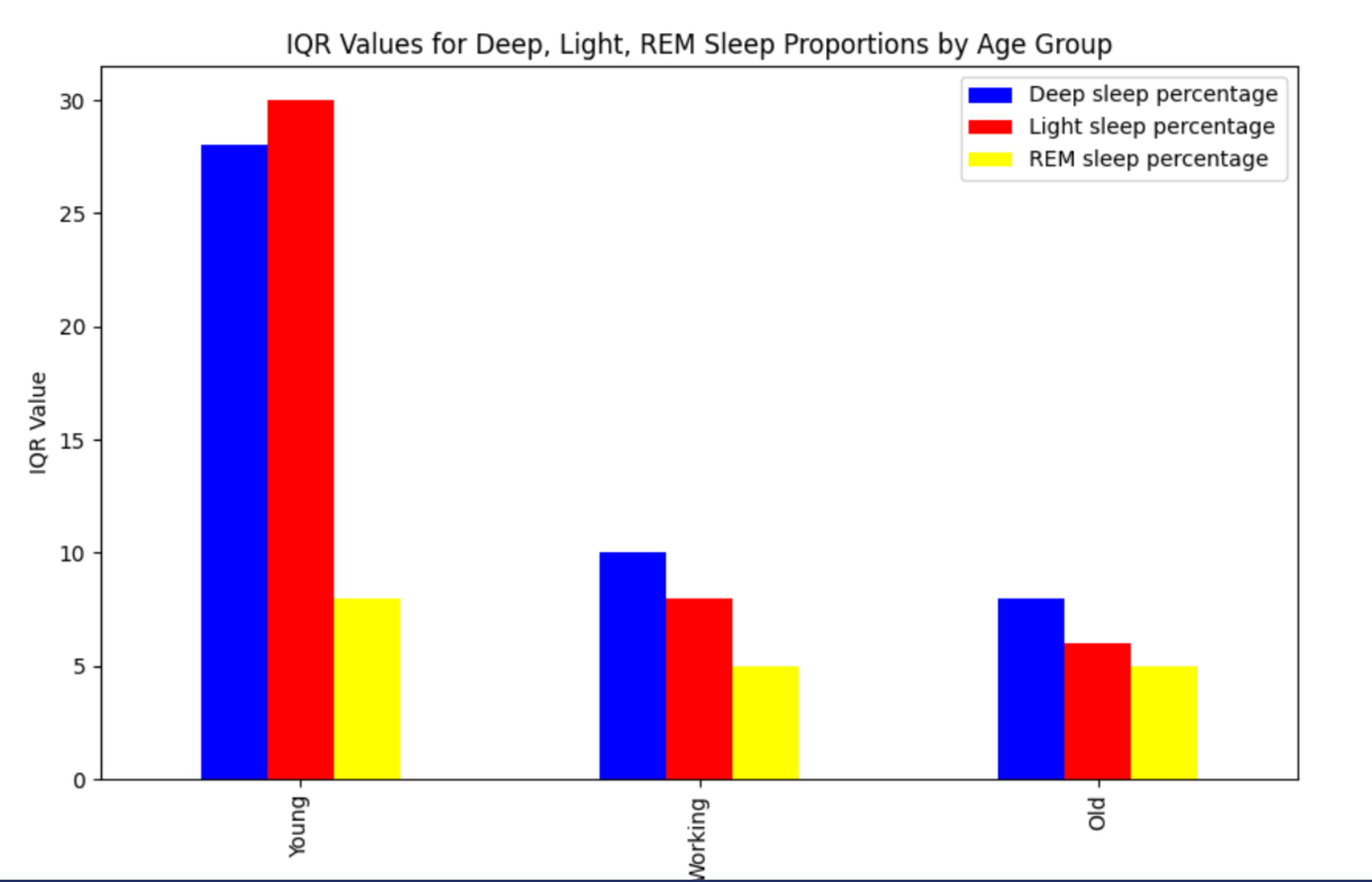


(Plots_Vinay -> analysis.py)

Inferences

- Working-class individuals tend to have earlier bedtimes and wake-up times compared to young and old individuals, as indicated by their average values. This is likely due to work schedules and greater responsibilities.
- As people age, the variability in their bedtimes and wake-up times increases, which can be observed from their standard deviation values. This may arise due to irregular schedules in aged people, possibly influenced by retirement, health conditions, or lifestyle changes.
- The average sleep duration decreases with age, indicating that older individuals tend to sleep less. This could be due to increased sleep division or reduced sleep needs.
- The average sleep efficiency increases with age, suggesting that older individuals make better use of their sleep time. This may be because they sleep less overall but maintain a higher proportion of uninterrupted sleep.

Inferences

- Working-class individuals have the highest deep sleep percentage, possibly due to physical and mental exhaustion from work. Deep sleep is essential for physical recovery, and increased fatigue might lead to longer deep sleep phases.
- This pattern is further supported by the number of awakenings, as more awakenings in the young people suggest a lighter and divided sleep.
- The IQR for sleep parameters is significantly larger for young individuals compared to the other two groups. This suggests that sleep patterns among young people are more varied, possibly due to peer pressure, academic stress, social activities, or inconsistent schedules.

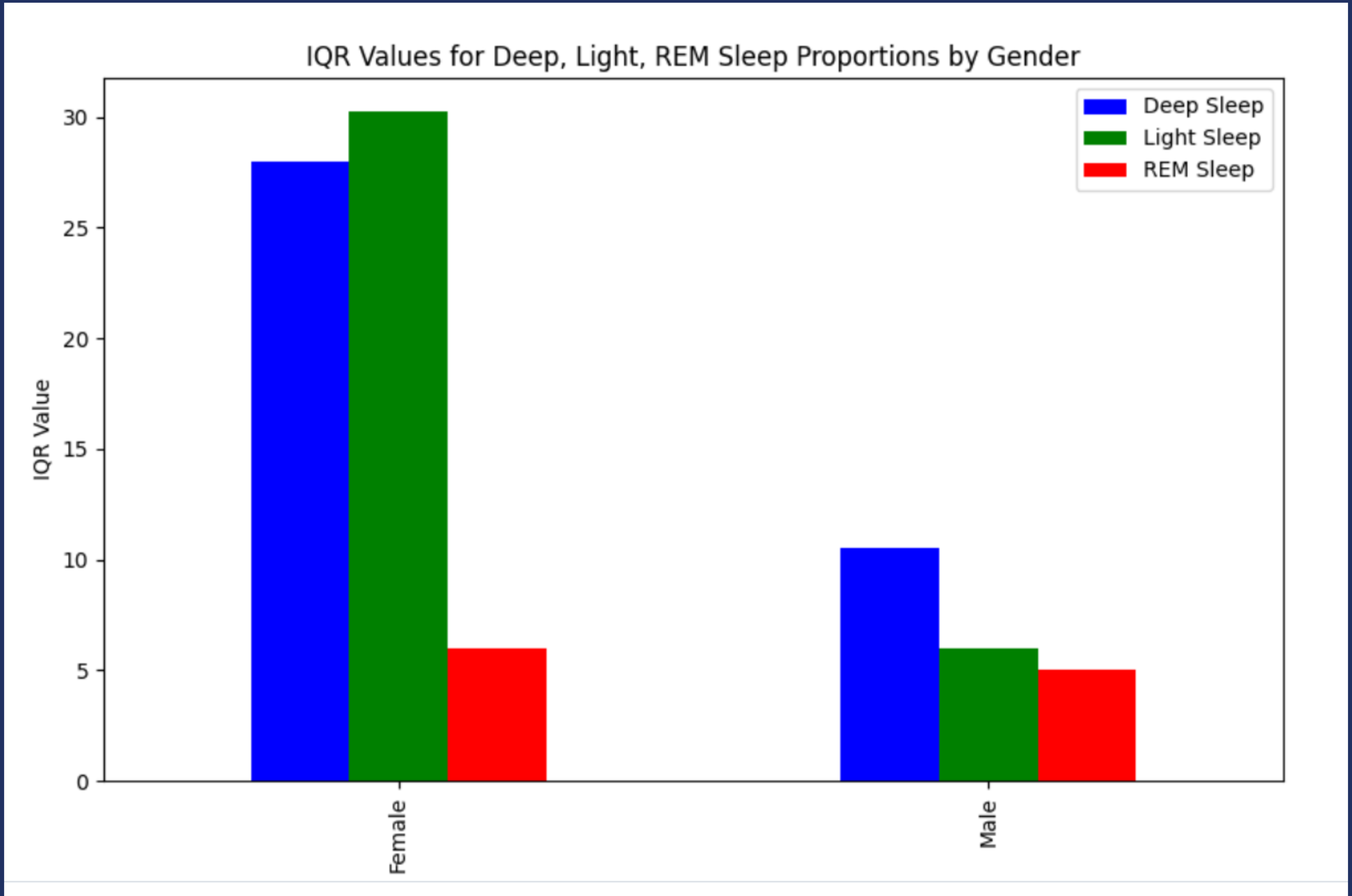
Do sleep patterns vary with gender ?

Statistical summary

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		**Bedtime**		**Wakeup time**		**Sleep duration**		**Sleep efficiency**		**REM sleep %**		**Deep sleep %**		**Light sleep %**		**Awakenings**	
2		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
3																	
4	**mean**	23.6886	23.58259	7.116228	7.087054	7.427632	7.504464	0.790263	0.787545	22.05263	23.1875	54	51.625	23.94737	25.1875	1.743119	1.537383
5	**std**	1.662478	1.714776	1.947742	1.968419	0.866803	0.866661	0.128584	0.141965	3.576335	3.386947	15.61458	15.63836	14.66143	15.95876	1.367184	1.341292
6	**min**	21	21	3	3	5	5	0.5	0.5	15	15	20	18	7	10	0	0
7	**25%**	22	22	5.5	5.5	7	7	0.71	0.67	20	20	54.5	35	15	14.75	1	1
8	**50%**	24	24	7	7.25	7.5	7.5	0.83	0.815	22	23	58	59	18	17	1	1
9	**75%**	25	25	9	8.5	8	8	0.9	0.91	25	26	65	63	21	45	3	3
10	**max**	26.5	26.5	12.5	11.5	10	10	0.99	0.98	30	30	75	72	56	63	4	4
11	**range**	5.5	5.5	9.5	8.5	5	5	0.49	0.48	15	15	55	54	49	53	4	4
12	**IQR**	3	3	3.5	3	1	1	0.19	0.24	5	6	10.5	28	6	30.25	2	2

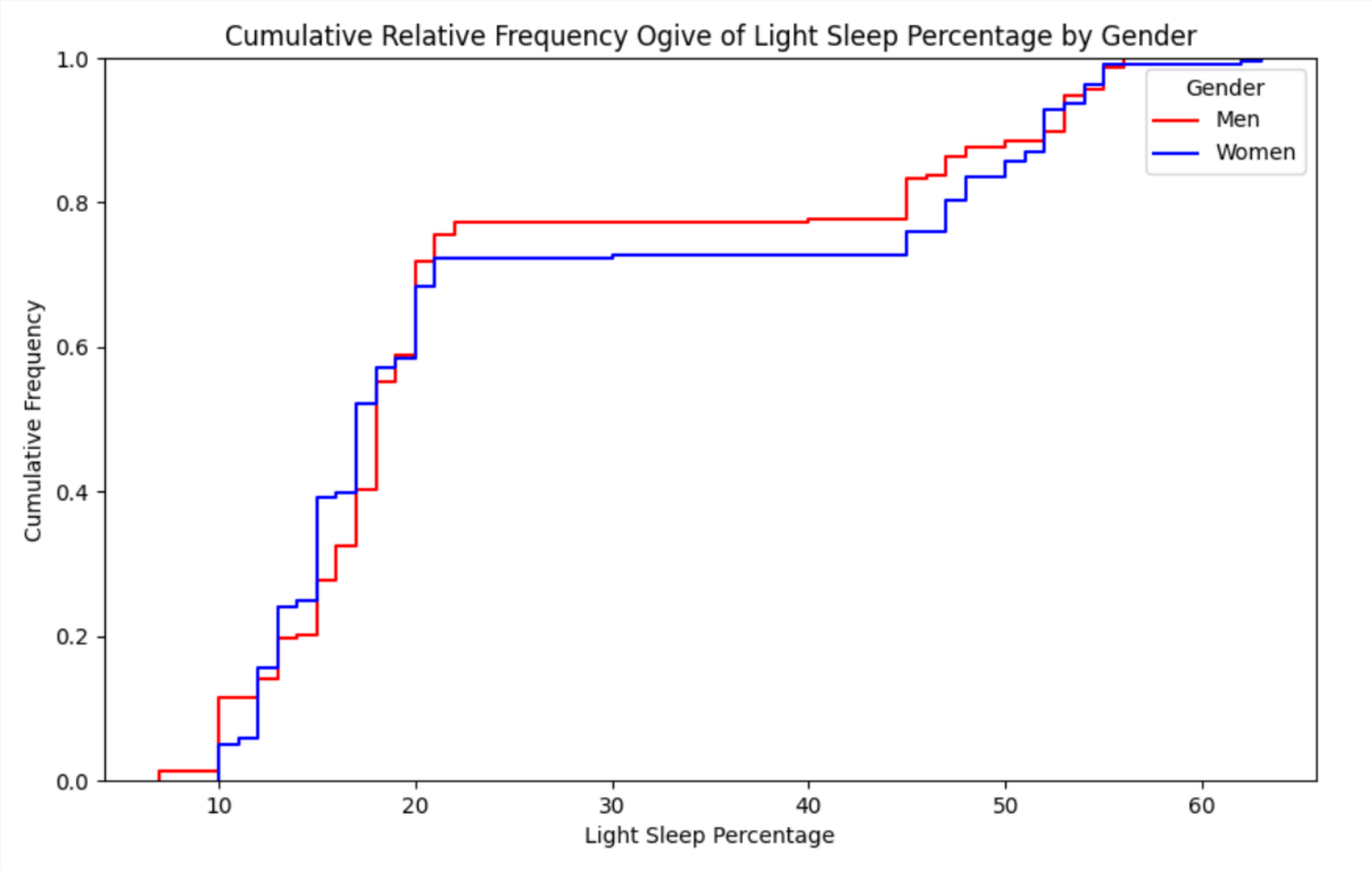
(Gender -> combined_analysis.py)

Plot : Bar Graph



(Plots_Vinay -> analysis.py)

Plot : Ogive



(Plots_Vinay -> analysis.py)

Inferences

- In general, the gender of a person does not adversely impact their sleeping habits, as indicated by the nearly equal statistical measures for male and female data points.
- On an average, women spend slightly more of their sleep time in REM state as compared to men, possibly indicating a stronger sense of emotional understanding and creativity among women.
- Additionally, the mean deep sleep proportion is slightly more for men than women, which may imply a better physical recovery through sleep in men.
- While the range of light sleep percentage is nearly the same for both genders, the interquartile range (IQR) is significantly larger for women. This suggests that the middle 50% of women’s data is more spread out, indicating a higher variability in light sleep patterns among women compared to men. Similar patterns are observed in the deep sleep percentage.

Effects of Caffeine consumption

Analysis

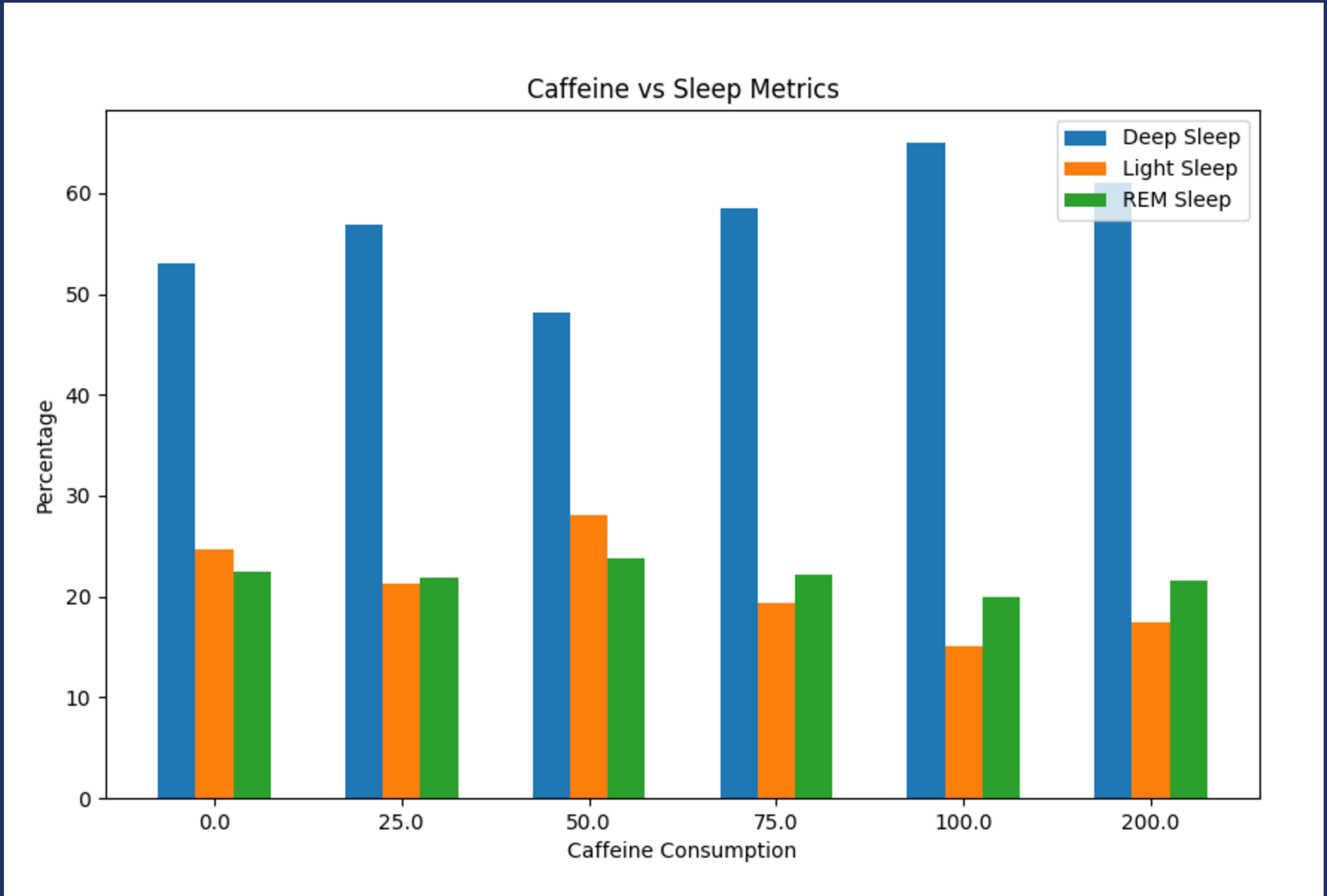
	Bedtime		Wakeup time		Sleep duration		Sleep efficiency		REM sleep %		Deep sleep %		Light sleep %		Awakenings	
Caffeine intake	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**
mean	23.37	23.83	6.808	7.336	7.436	7.505	0.786	0.793	22.4	22.8	53	52.8	24.6	24.3	1.74	1.53
std	1.665	1.682	1.975	1.939	0.859	0.893	0.137	0.133	3.59	3.41	15.6	15.6	15.1	15.4	1.37	1.35
min	21	21	3	3	5	5	0.5	0.5	15	15	20	18	7	7	0	0
25%	22	22.88	5	6	7	7	0.69	0.71	20	20	45.5	52	15	15	1	0
50%	23	24	7	7.5	7.5	7.5	0.82	0.825	22	22	58	60	18	17	1	1
75%	25	25.5	8	9	8	8	0.9	0.9	25	25	61	65	33.5	21	3	2.25
max	26.5	26.5	12.5	11.5	10	10	0.99	0.98	30	30	75	72	56	63	4	4
median	23	24	7	7.5	7.5	7.5	0.82	0.825	22	22	58	60	18	17	1	1
mode	24	23	7	9	7	7	0.93	0.9	20	20	60	65	20	15	1	1

(Caffeine -> analysis.py)

Histogram

Caffeine vs Sleep Metrics

(Tanmay_plots -> analysis.py



Inferences

- People with higher caffeine consumption have slightly lower sleep efficiency, with a 0.85% drop compared to those with lower caffeine intake.
- Higher caffeine consumption leads to a slight increase in light sleep percentage (1.3%) and a minor decrease in deep sleep percentage (0.26%), while REM sleep remains unchanged.
- The minimal changes suggest that caffeine intake may have a less pronounced effect on sleep structure compared to other factors like smoking or alcohol. However, the small reduction in deep sleep and increase in light sleep could still contribute to less restorative sleep and slight sleep fragmentation.

Age & Caffeine analysis

age_group	caffeine level	mean sleep duration	mean sleep efficiency	Mean REM sleep	mean deep sleep	mean light sleep	mean_awakenings	caffeine consumed (in mg)
young	low	7.620689655	0.677931034	21.44827586	42.68965517	35.86206897	2.142857143	0
young	high	7.75	0.793181818	22.13636364	53.81818182	24.04545455	1.761904762	43.18181818
working	low	7.442857143	0.805571429	21.88571429	56.85714286	21.25714286	1.71641791	0
working	high	7.503731343	0.786791045	23.19402985	53.05970149	23.74626866	1.480314961	48.50746269
old	low	7.383928571	0.802142857	22.95535714	53.22321429	23.82142857	1.642201835	0
old	high	7.416666667	0.806333333	22.33333333	52	25.66666667	1.553571429	44.16666667

(Age and Caffeine -> Combined_analysis.py)

Conclusion

- For young individuals, higher caffeine consumption increases sleep efficiency (by ~11.5%), raises REM sleep (by 0.7%), and significantly improves deep sleep (by ~11.1%), while light sleep drops (by ~11.8%) and awakenings decrease.
- For the working class, higher caffeine consumption reduces deep sleep (by ~3.8%) but increases REM (by ~1.3%) and light sleep (by ~2.5%), while sleep efficiency slightly declines.
- For older individuals, higher caffeine consumption lowers deep sleep (by ~1.2%) while light sleep increases (by ~1.8%), with minimal impact on REM sleep and sleep efficiency, suggesting relatively stable sleep patterns despite caffeine intake.

Effects of Alcohol consumption

Analysis

	Bedtime		Wakeup time		Sleep duration		Sleep efficiency	
Alcohol	Low	High	Low	High	Low	High	Low	High
mean	23.64024	23.69531	7.099593	7.171875	7.45935	7.476563	0.832033	0.733385
std	1.785327	1.551769	2.061117	1.837407	0.869186	0.871733	0.109693	0.144731
min	21	21	3	3	5	5	0.51	0.5
25%	22	22.5	5.5	6	7	7	0.78	0.63
50%	24	24	7	7	7.5	7.5	0.86	0.72
75%	25	25	9	8.625	8	8	0.9175	0.87
max	26.5	26.5	12.5	11.5	10	10	0.98	0.99

	REM sleep %		Deep sleep %		Light sleep %		Awakenings	
Alcohol	Low	High	Low	High	Low	High	Low	High
mean	22.76423	22.46875	57.42276	46.78125	19.81301	30.75	1.4375	1.910112
std	3.454855	3.50901	11.82423	17.79535	11.46056	17.42208	1.317825	1.362454
min	15	15	20	18	10	7	0	0
25%	20	20	57	28	13	15	0	1
50%	23	22	60	55	17	20	1	1
75%	25	25	63	63	20	50	2	3
max	30	30	72	75	56	63	4	4

(Alcohol -> analysis.py)

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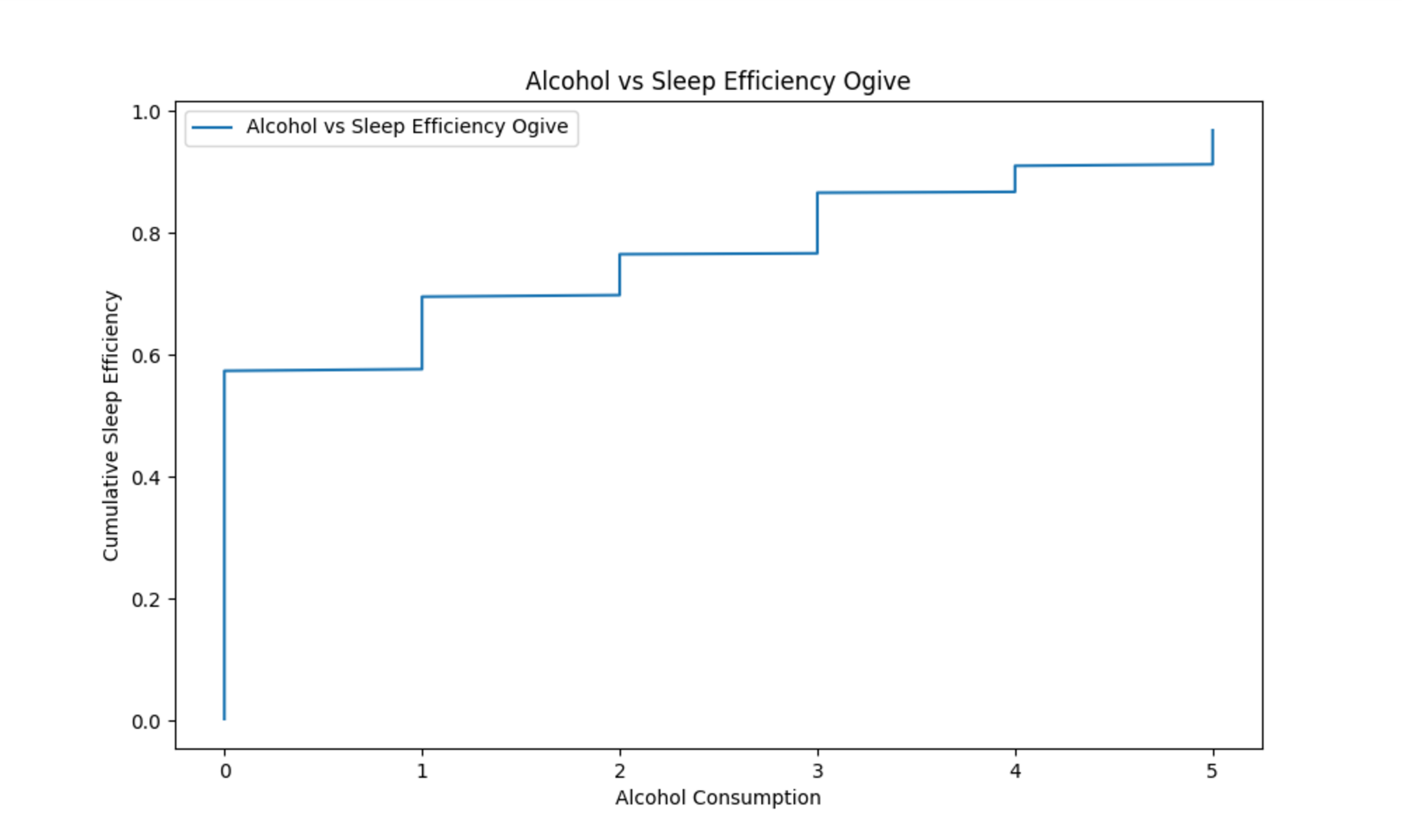
Alcohol vs sleep efficiency

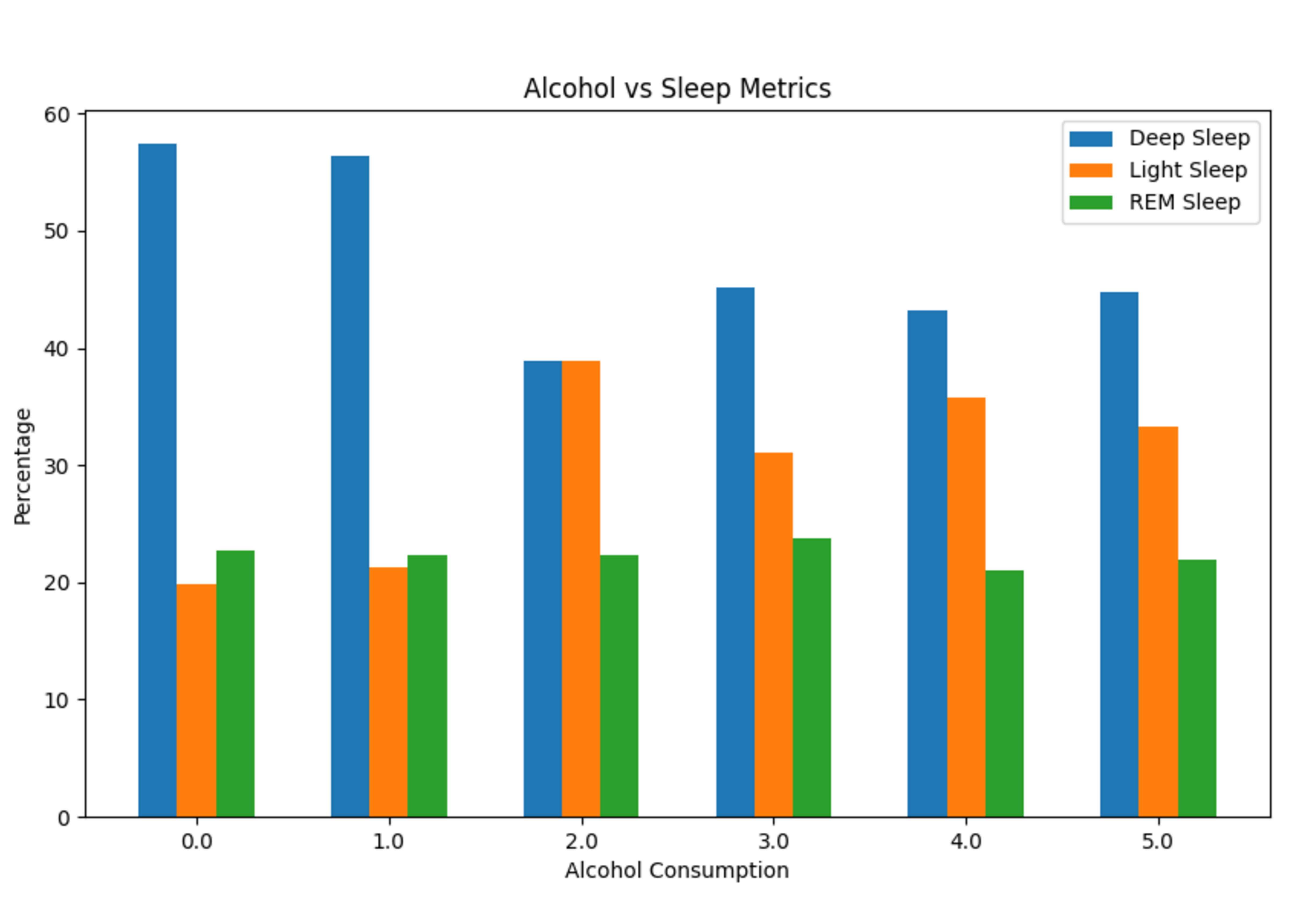


(Tanmay_plots -> analysis.py

Histogram

Alcohol vs Sleep metrics

(Tanmay_plots -> analysis.py



Inferences

- People with higher alcohol consumption tend to have lower sleep efficiency with a 10% drop in sleep efficiency.
- Higher alcohol consumption leads to a higher light sleep percentage with a spike of 55.3% relative to people with lower alcohol consumption. In addition, leading to a lower deep sleep percentage with a relative dip of 18.6% with the percentage of REM sleep remaining constant.
- The increase in light sleep, decrease in deep sleep and increase in awakenings suggest that people with high alcohol consumption may wake up feeling less refreshed and experience more night time disturbances on average.

Effects of Smoking

Analysis

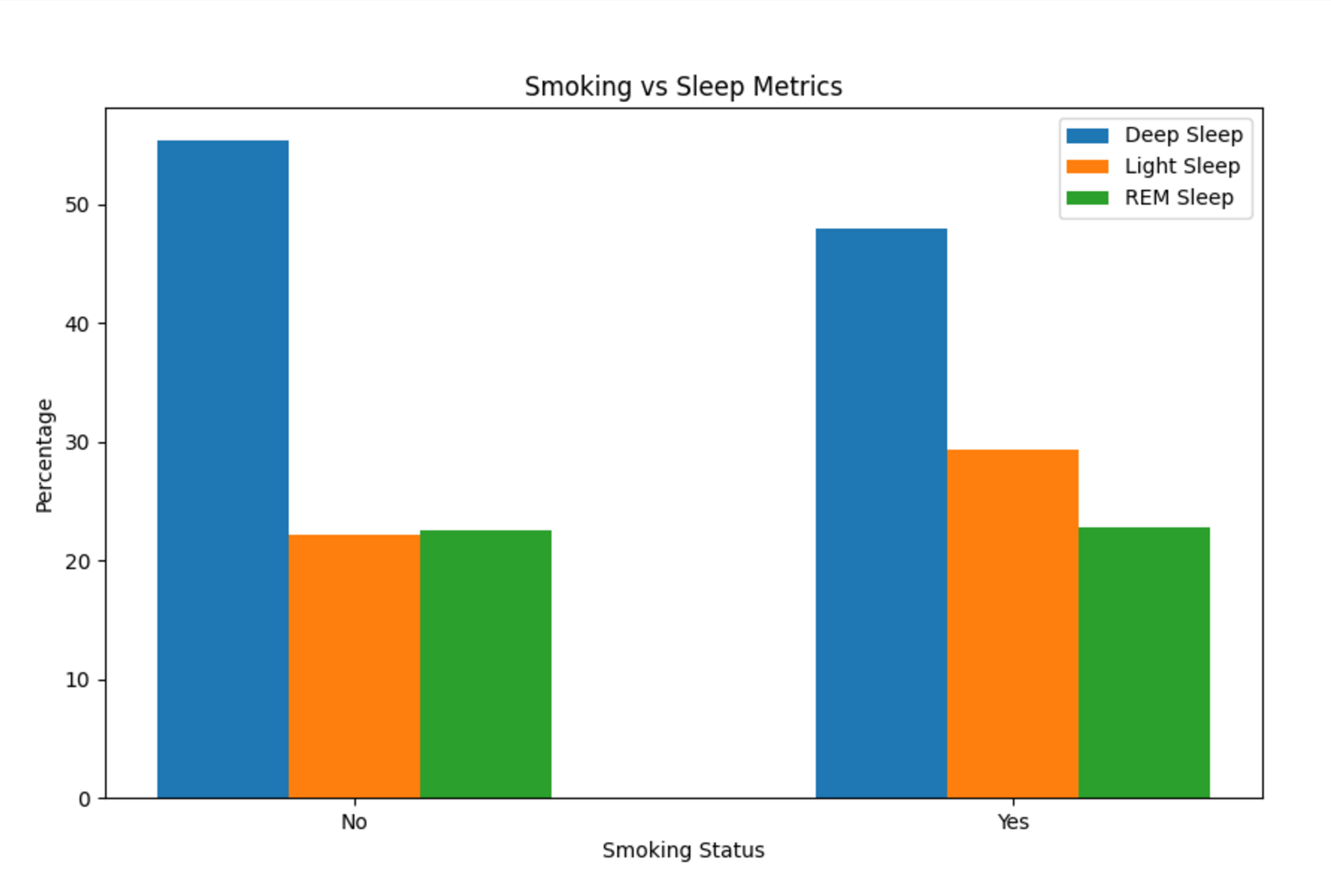
	Bedtime		Wakeup time		Sleep duration		Sleep efficiency		REM sleep %		Deep sleep %		Light sleep %		Awakenings	
Smokers	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
mean	24.1	23.4	7.614	6.837	7.471	7.463	0.7344	0.8171	22.8	22.5	47.89	55.37	29.34	22.09	1.6	1.66
std	1.64	1.65	1.87	1.95	0.977	0.805	0.1617	0.1094	3.48	3.55	17.92	13.69	17.56	13.39	1.29	1.39
min	21	21	3	3	5	5	0.5	0.52	15	15	20	18	10	7	0	0
25%	23	22	6.5	5	7	7	0.55	0.73	20	20	28.5	55	15	15	1	1
50%	24.5	23	7.5	6.5	7.5	7.5	0.78	0.84	23	22	57	59	18	18	1	1
75%	25.5	25	9	8.5	8	8	0.88	0.91	25	25	63	65	48	20	3	3
max	26.5	26.5	12.5	12.5	10	10	0.97	0.99	30	30	72	75	63	56	4	4

(smoking -> analysis.py)

Histogram

Smoking vs Sleep metrics

(Tanmay_plots -> analysis.py



Inferences

- People who smoke tend to have lower sleep efficiency, with a 10.3% drop compared to non-smokers.
- Smokers also experience a higher light sleep percentage, with a 32.8% increase, and a lower deep sleep percentage, with a 13.5% decrease, while no significant change in REM sleep and number of awakenings.
- The increase in light sleep and reduction in deep sleep suggest that smokers may experience more fragmented sleep, wake up feeling less refreshed, and have poorer overall sleep quality.

Effects of Physical activity

Classifying the dataset

We have classified the dataset into three different categories on the basis of exercise frequency as follows

1. No exercise (0-1) : Exercise frequency is 0
2. Light exercise (1-3) : Exercise frequency is between 1 and 2 (inclusive)
3. Regular exercise (3-5) : Exercise frequency is between 3 and 5 (inclusive)

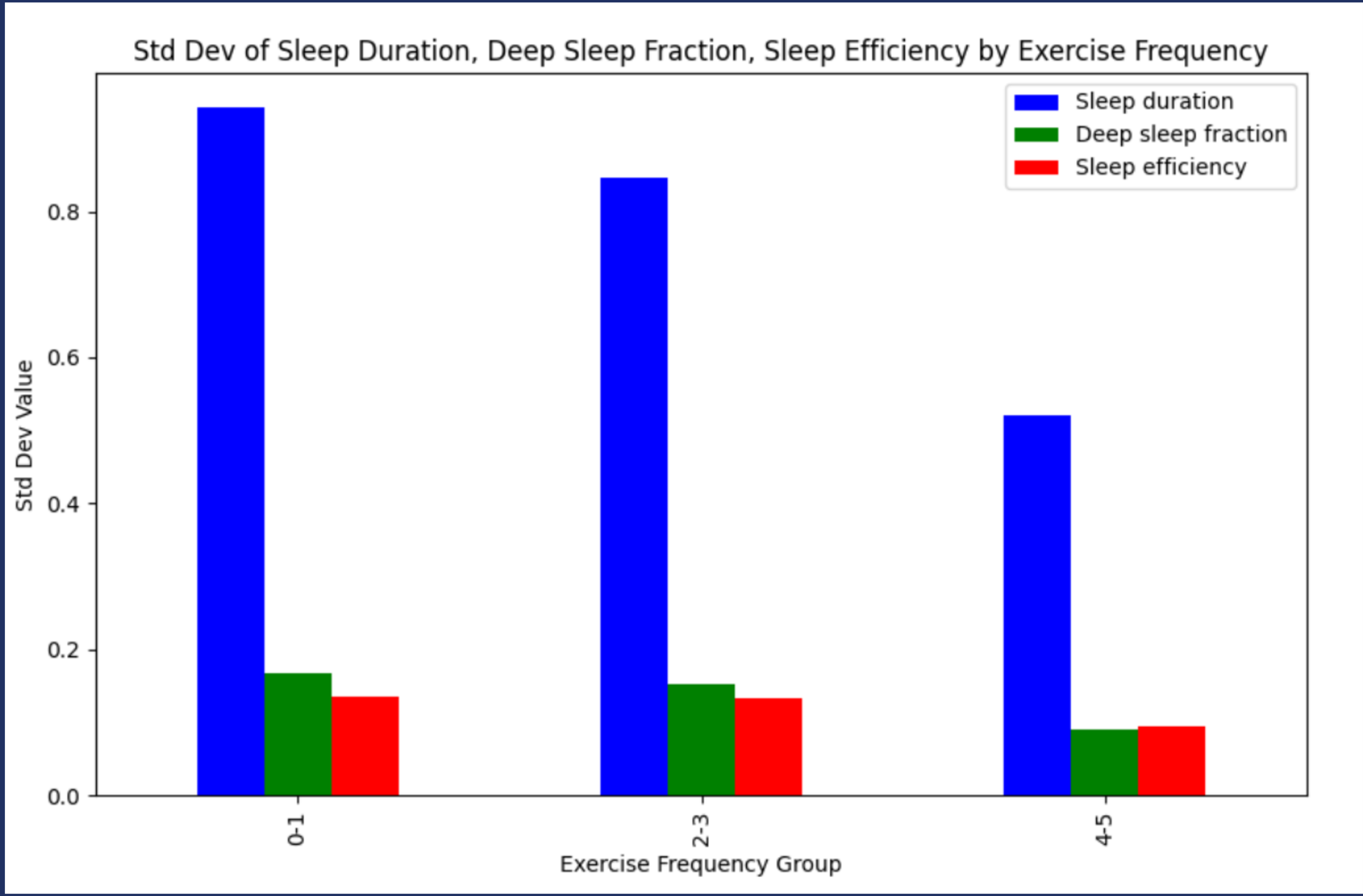
Statistics Summary

	Bedtime			Wakeup time			Sleep duration			Sleep efficiency		
	No exercise	Light exercise	Regular exercise	No exercise	Light exercise	Regular exercise	No exercise	Light exercise	Regular exercise	No exercise	Light exercise	Regular exercise
mean	24	24.0894	23.0419	7.594828	7.453642	6.497207	7.594828	7.364238	7.455307	0.743879	0.786954	0.820335
std	1.389401	1.756973	1.632596	1.793604	1.991943	1.898031	0.950775	0.907256	0.764899	0.136883	0.128509	0.132036
min	21	21	21	3.5	3	3	5	5	5	0.5	0.5	0.5
25%	23	23	22	6.875	6	5	7	7	7	0.64	0.71	0.75
50%	24	24	22.5	8	7.5	6	7.5	7.5	7.5	0.74	0.82	0.87
75%	25	25.5	24.5	9	9	7.5	8	8	8	0.86	0.88	0.92
max	26	26.5	26.5	11.5	12.5	12.5	10	10	10	0.98	0.98	0.99
range	5	5.5	5.5	8	9.5	9.5	5	5	5	0.48	0.48	0.49
IQR	4	4.5	3.5	5.5	6	4.5	3	3	3	0.36	0.38	0.42

(Exercise -> analysis.py)

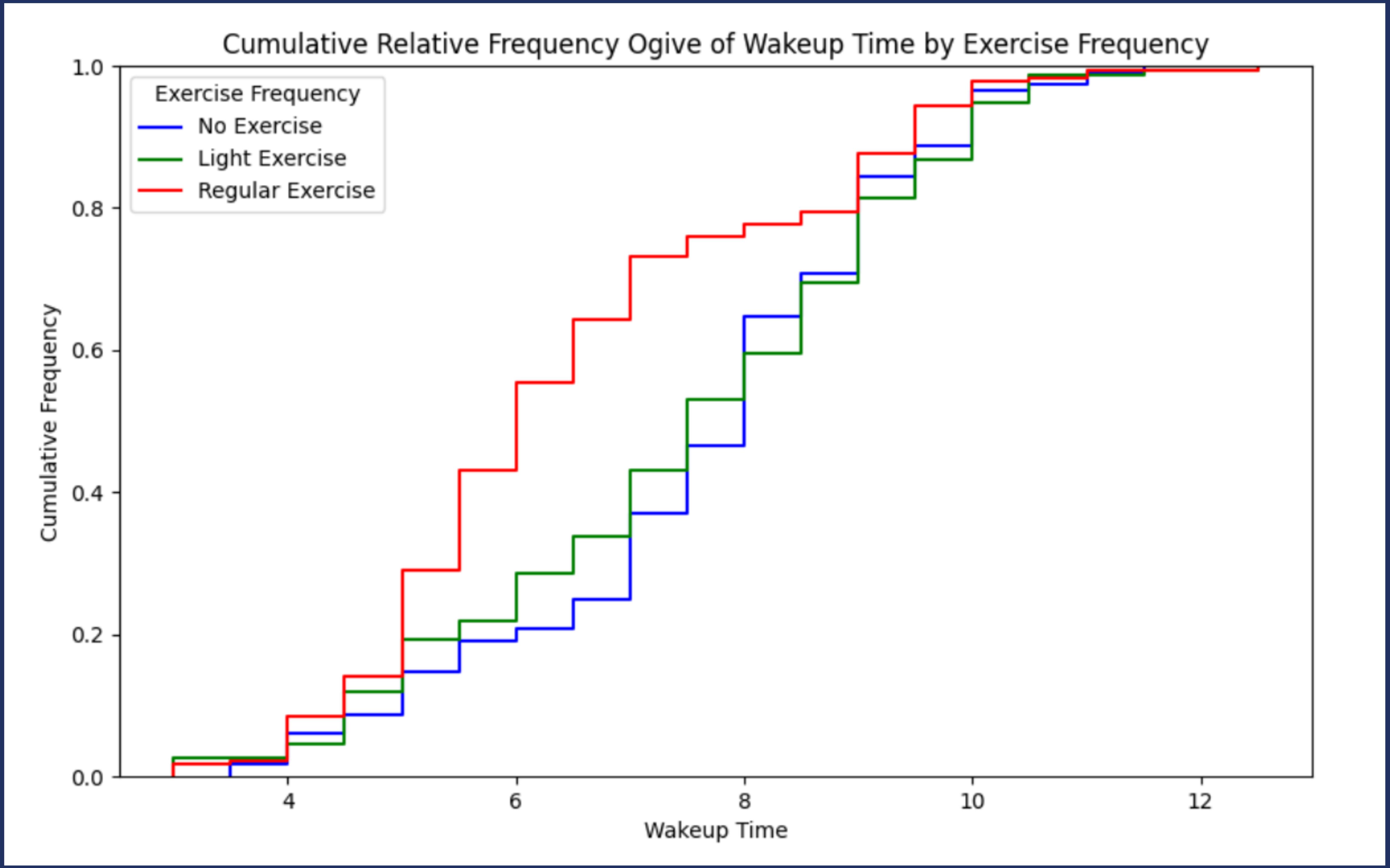
	REM sleep %			Deep sleep %			Light sleep %			Awakenings		
	No exercise	Light exercise	Regular exercise	No exercise	Light exercise	Regular exercise	No exercise	Light exercise	Regular exercise	No exercise	Light exercise	Regular exercise
mean	21.87069	22.9404	22.93296	48.19828	53.87417	54.69274	29.93103	23.18543	22.3743	1.946903	1.724138	1.339286
std	2.243949	3.690044	3.878199	16.87149	16.10396	13.94292	16.96735	15.28415	13.46571	1.368267	1.386857	1.256506
min	18	15	15	22	18	20	10	7	7	0	0	0
25%	20	20	20	31.5	55	55	15	13	15	1	1	0
50%	22	23	22	57	60	57	20	17	18	2	1	1
75%	23	26	27	60.75	63	63	48	20.5	21	3	3	2
max	28	28	30	70	75	72	56	55	63	4	4	4
range	10	13	15	48	57	52	46	48	56	4	4	4
IQR	3	6	7	29.25	8	8	33	7.5	6	2	2	2

Plot : Bar Graph



(Plots_Vinay -> analysis.py)

Plot : Ogive



(Plots_Vinay -> analysis.py)

Inferences

- The average sleep efficiency progressively increases with the amount of exercise performed by the individual, possibly indicating that regular exercise promotes a better sleep quality.
- On average, individuals who exercise regularly experience fewer awakenings during sleep, which aligns with common intuition, since they feel physically exhausted. Additionally, exercise appears to promote higher proportions of both REM and deep sleep on an average basis.
- Individuals who engage in more exercise tend to have earlier bedtimes and wake-up times, possibly indicating that they follow a more structured daily routine or that they exercise early in the morning.
- Furthermore, the standard deviation of sleep duration is lower among individuals with higher exercise frequency compared to those with little to no physical activity. This suggests that regular exercisers maintain more consistent sleep schedules, which can enhance mental health and create a positive feedback loop for overall well-being.

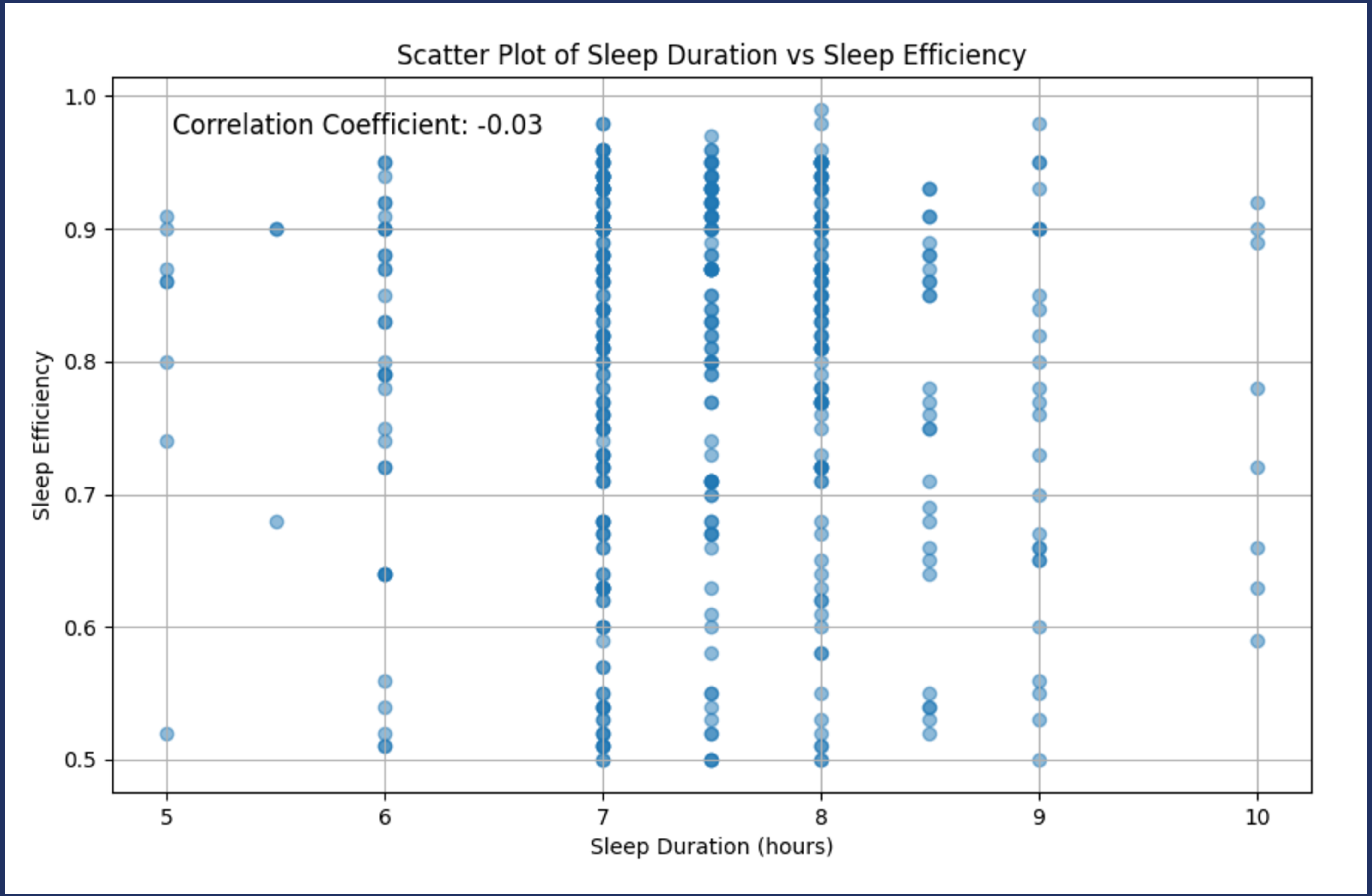
Second section

Interdependency of Sleep parameters

Sleep efficiency vs sleep duration

Analysis

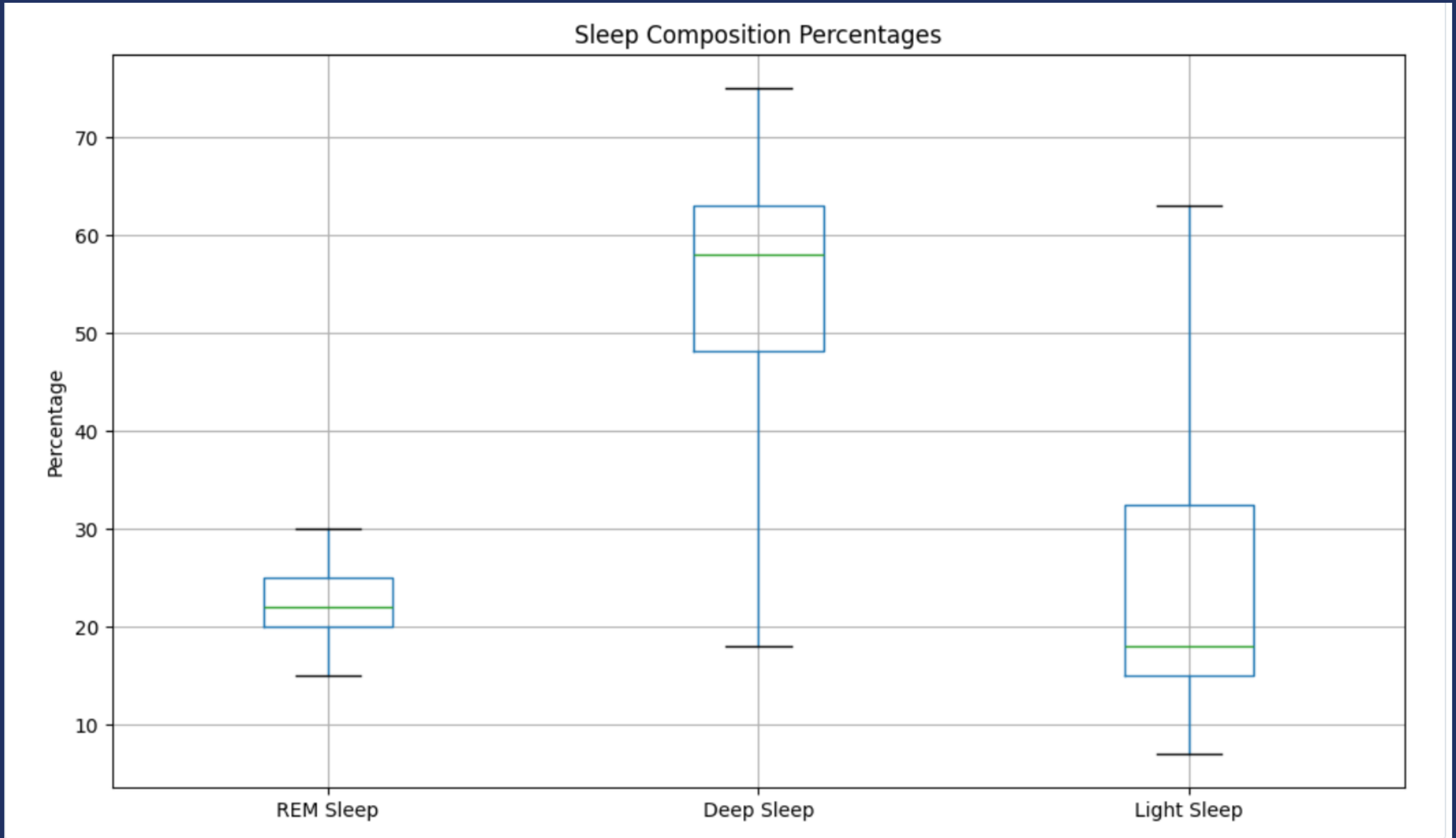
The scatter plot shows no significant correlation between sleep duration and sleep efficiency (correlation coefficient: -0.03), indicating that longer or shorter sleep durations do not strongly impact sleep efficiency.



(sleep duration vs efficiency -> analysis.py)

Sleep composition analysis

Plot : Box plot



(Sleep Composition -> box_plots.py)

Inferences

- The range for REM sleep proportion is much smaller compared to deep and light sleep, possibly due to biological constraints regulating REM cycles.
- Although deep sleep and light sleep have similar overall ranges, their medians are significantly different. The median deep sleep proportion is noticeably higher than the median light sleep proportion, indicating that, on average, people tend to spend more time in deep sleep than in light sleep.
- The quartiles for deep sleep and light sleep follow a similar trend but are vertically shifted apart. This reinforces the idea that individuals generally spend a greater proportion of their sleep in deep sleep rather than light sleep.
- Light sleep has the widest spread, which could be linked to factors such as sleep disturbances, stress levels, or inconsistent sleep schedules. In contrast, deep sleep is more concentrated within a smaller range, implying that while deep sleep duration can vary, it is less extreme compared to light sleep.

Correlation matrix

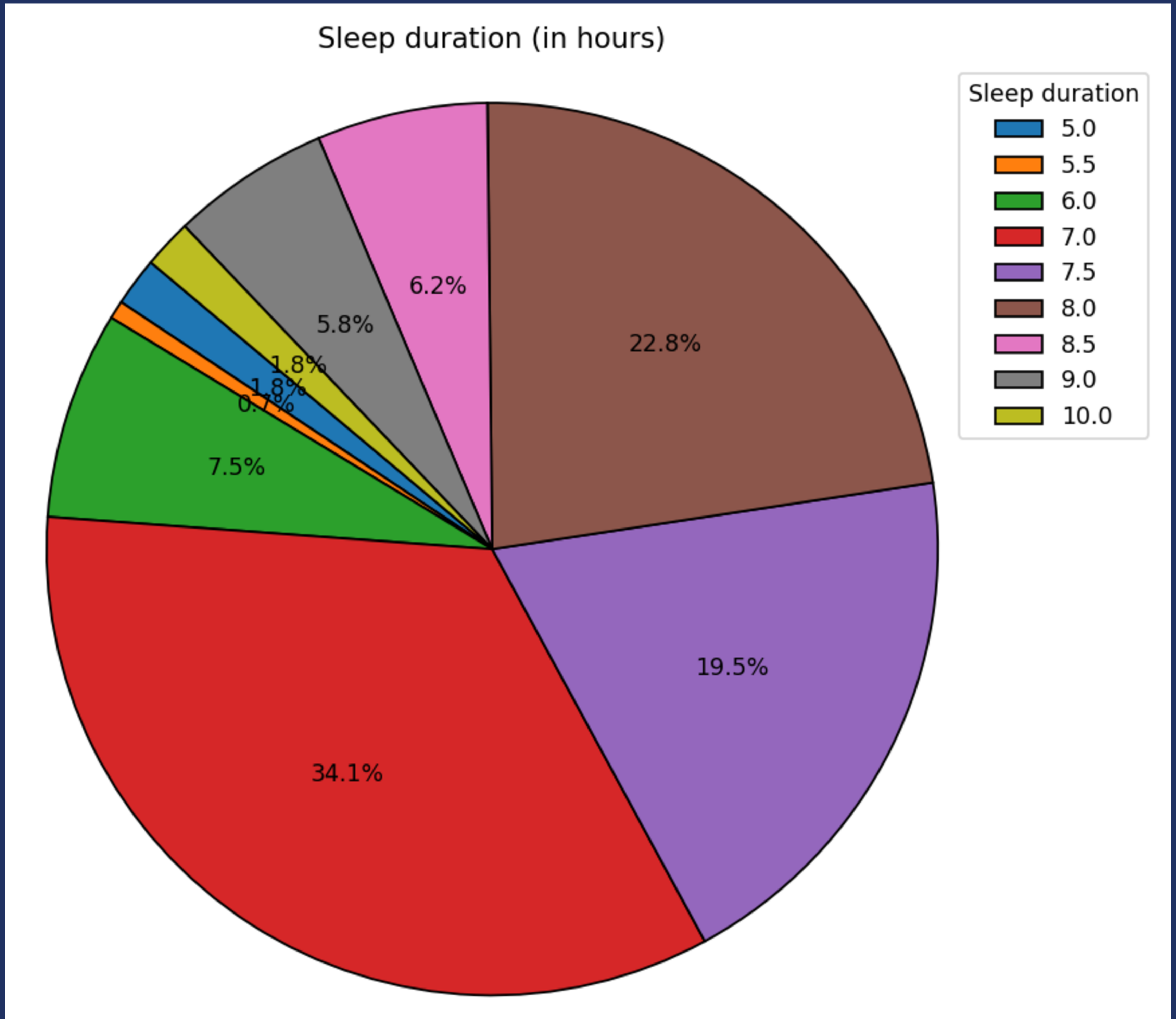
	Sleep efficiency	REM sleep %	Deep sleep %	Light sleep %
Sleep efficiency	1	0.062362	0.787335	-0.8192
REM sleep %	0.062362	1	-0.20816	-0.01746
Deep sleep %	0.787335	-0.20816	1	-0.97431
Light sleep %	-0.8192	-0.01746	-0.97431	1

- As the name suggests, a correlation matrix presents the sample correlation coefficients between different sleep composition parameters in a structured matrix format.
- In particular, the (i, j)^th entry in the matrix represents the sample correlation coefficient of the attributes in the i^th row and the j^th column.

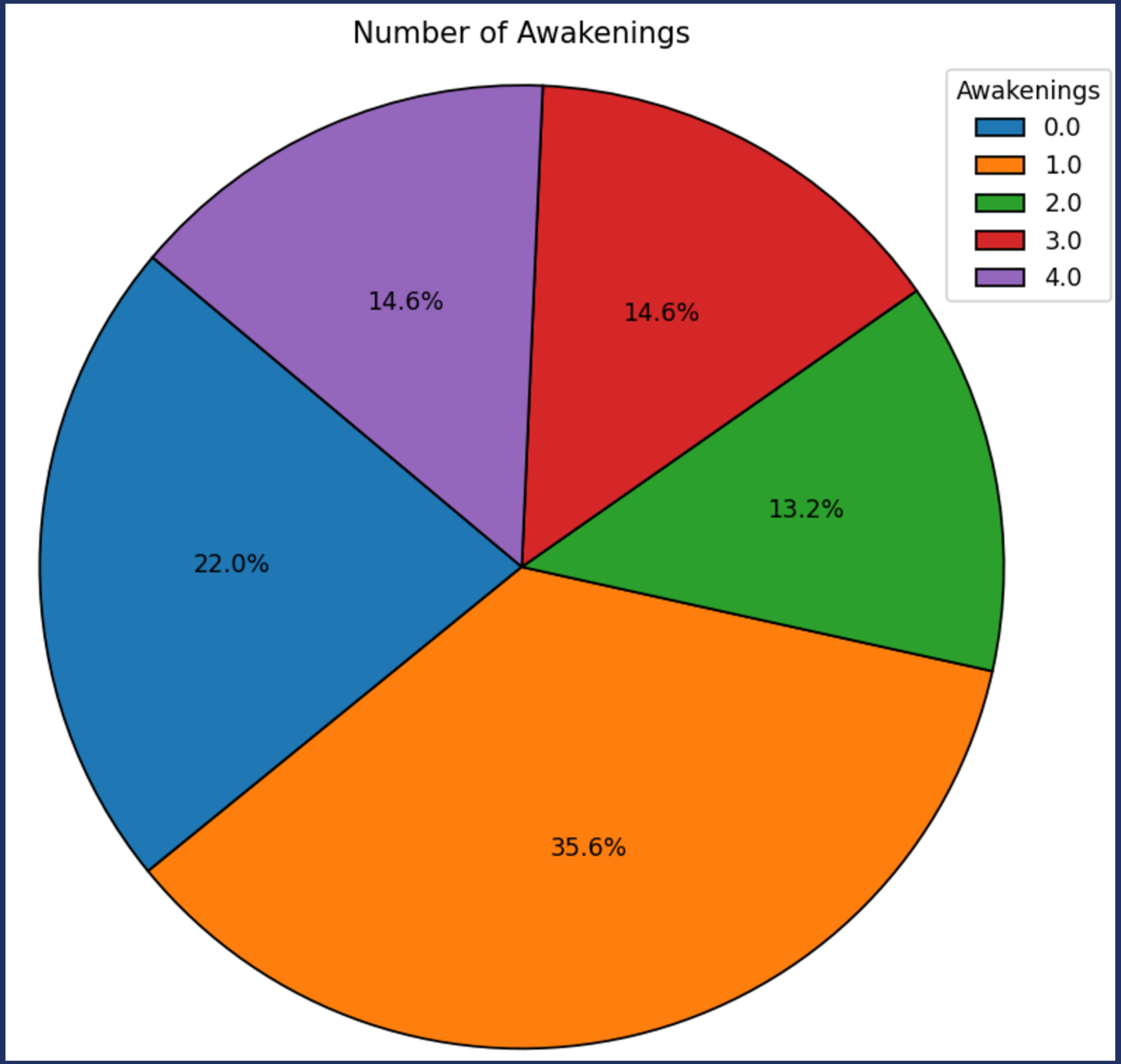
Inferences

- As expected, the diagonal entries are 1 since they represent the correlation coefficient of an attribute with itself. Additionally, the matrix is symmetric.
- Light sleep and sleep efficiency exhibit a strong negative correlation, as expected to be, while deep sleep and sleep efficiency show a strong positive correlation.
- Light sleep and deep sleep have an almost linear negative relationship, indicating that an increase in one tends to result in a decrease in the other.
- Sleep efficiency has a very weak positive correlation with REM sleep, indicating that variations in REM sleep proportion have minimal effect on overall sleep efficiency.
- Similarly, REM sleep and light sleep proportions have a near-zero correlation, suggesting that changes in REM sleep percentage do not significantly impact the amount of light sleep.
- Additionally, REM sleep and deep sleep have a weak negative correlation, implying that neither of them are greatly affected by each other.

Additional Pie Charts



(sleep_duration.py)



(awakenings.py)

Applying CLT on the dataset

What attributes are chosen ?

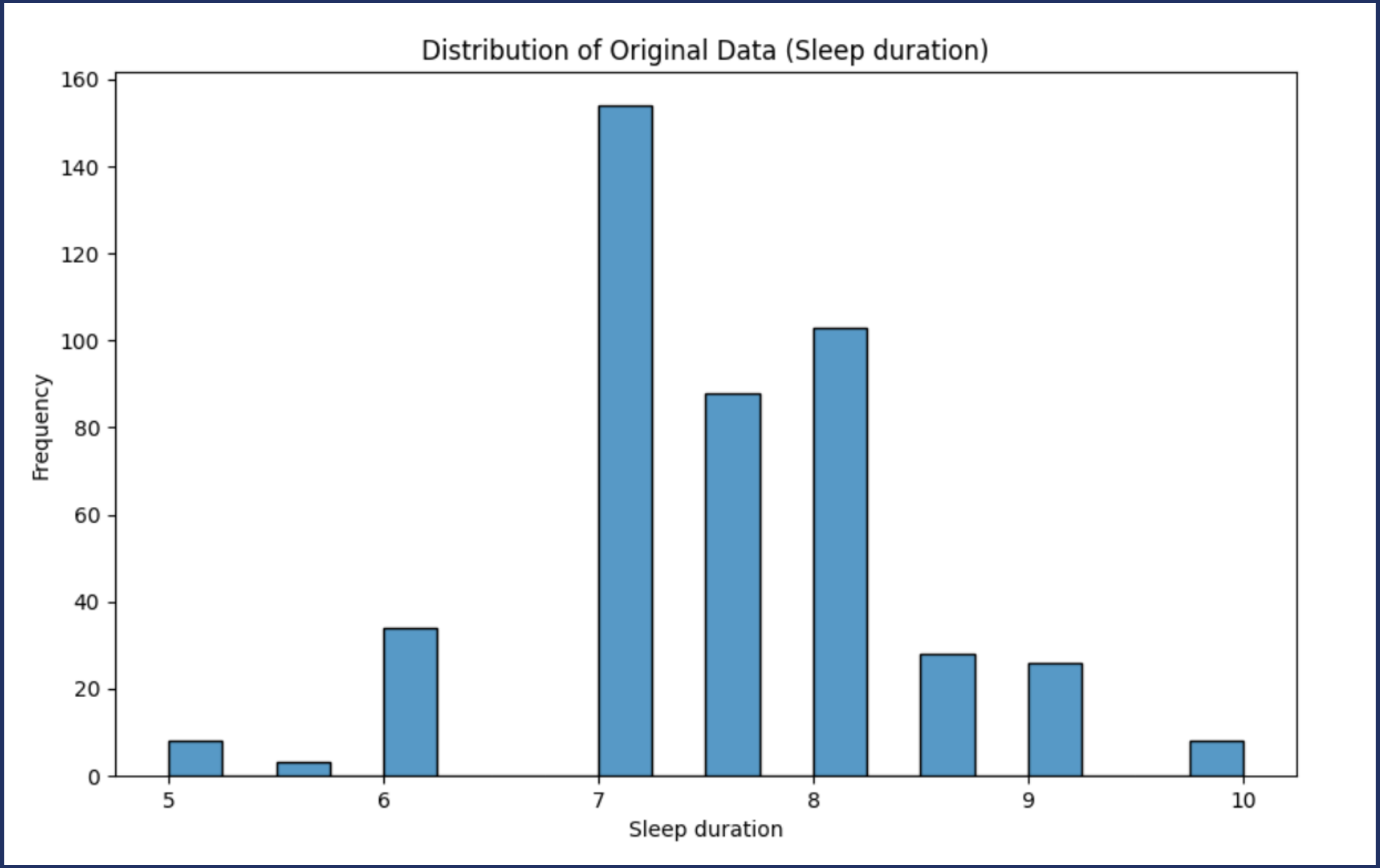
- We apply the Central Limit Theorem to approximate the density function of the sample means for sleep duration and sleep efficiency respectively.
- To achieve this, we randomly select 2,000 samples from the dataset each containing 50 data points. For each sample, we compute its mean, resulting in a total of 2,000 sample means.
- Using these computed means, we then plot the probability mass function of the sample mean. Since the number of samples is sufficiently large, the distribution of the sample mean can be approximated by a normal distribution, as stated by the CLT.
- We now compute the population mean and population variance using two different approaches and compare the results to check for consistency.

What attributes are chosen ?

- The first method assumes that our complete dataset is a randomly chosen sample from the bigger population, implying that the mean and variance of the population is estimated by the sample mean and variance respectively. This is denoted as the “actual” mean and variance.
- The second method computes the population mean and variance by computing the mean and variance of the sample means respectively. Using CLT, the “expected” mean will be the mean of the sample means and the “expected” variance will be the variance of the sample means times the total number of samples
- Finally, we plot the probability density function (PDF) of the normal distribution using the mean and variance obtained via CLT and compare it with the empirical distribution of the sample means to assess how well they align. The above discussed values are given in the plot itself.

Applying CLT on sleep duration

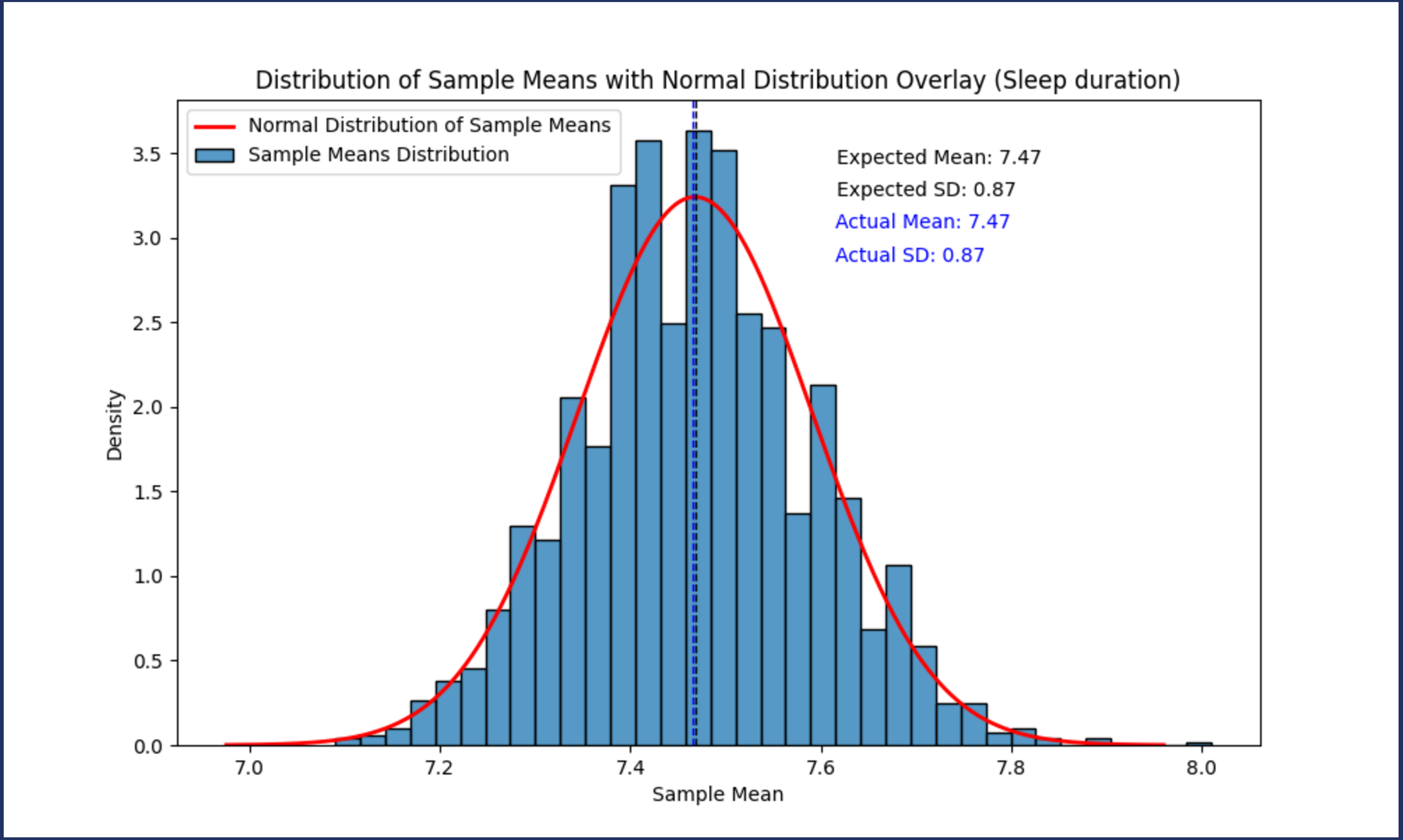
Plot : Frequency Bar Graph



We observe that the distribution for the sleep duration data values is approximately normal, although the order of similarity is quite low.

(CLT -> Clt.py)

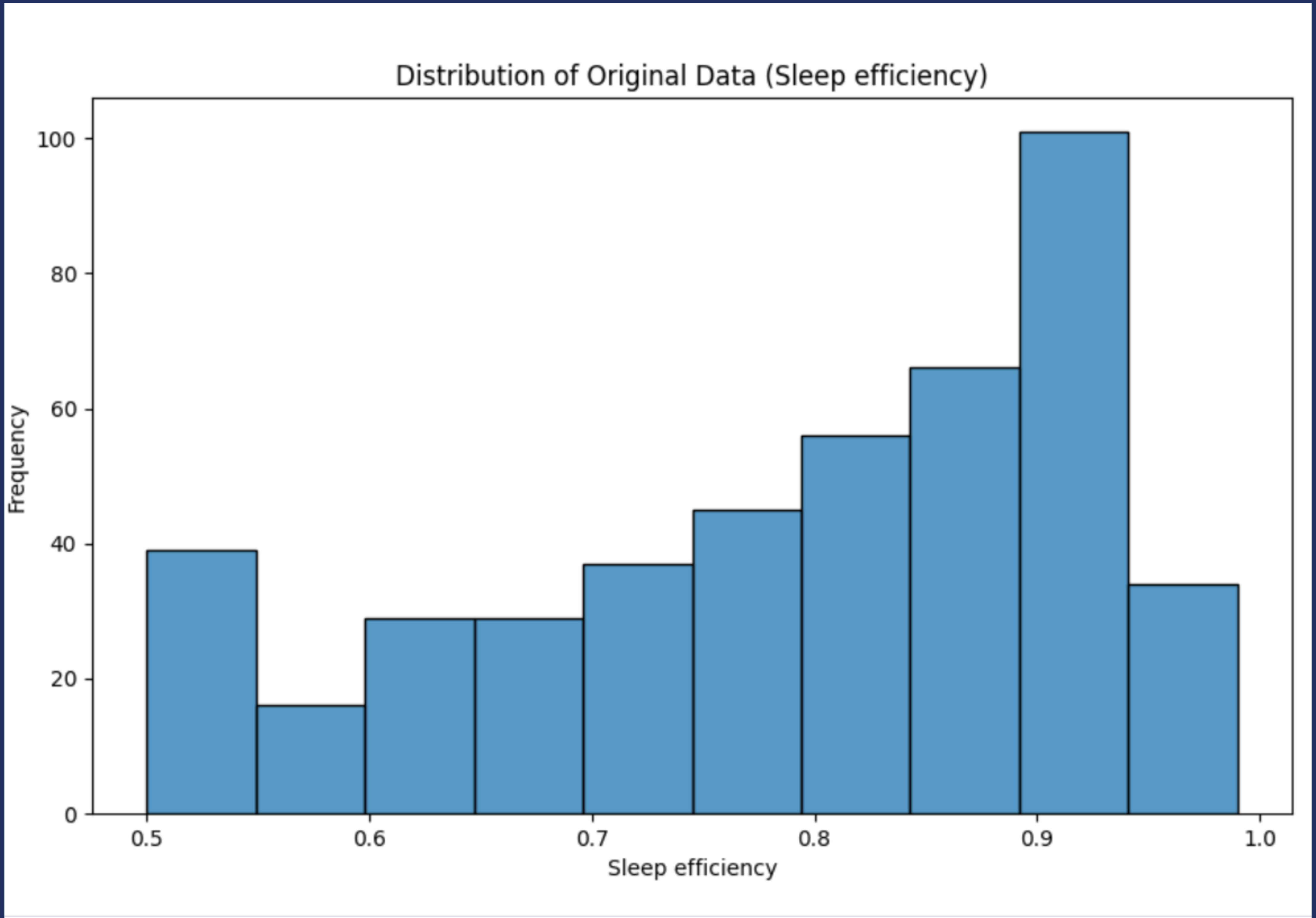
Plot : pmf and pdf of sample mean



(CLT -> Clt.py)

Applying CLT on sleep efficiency

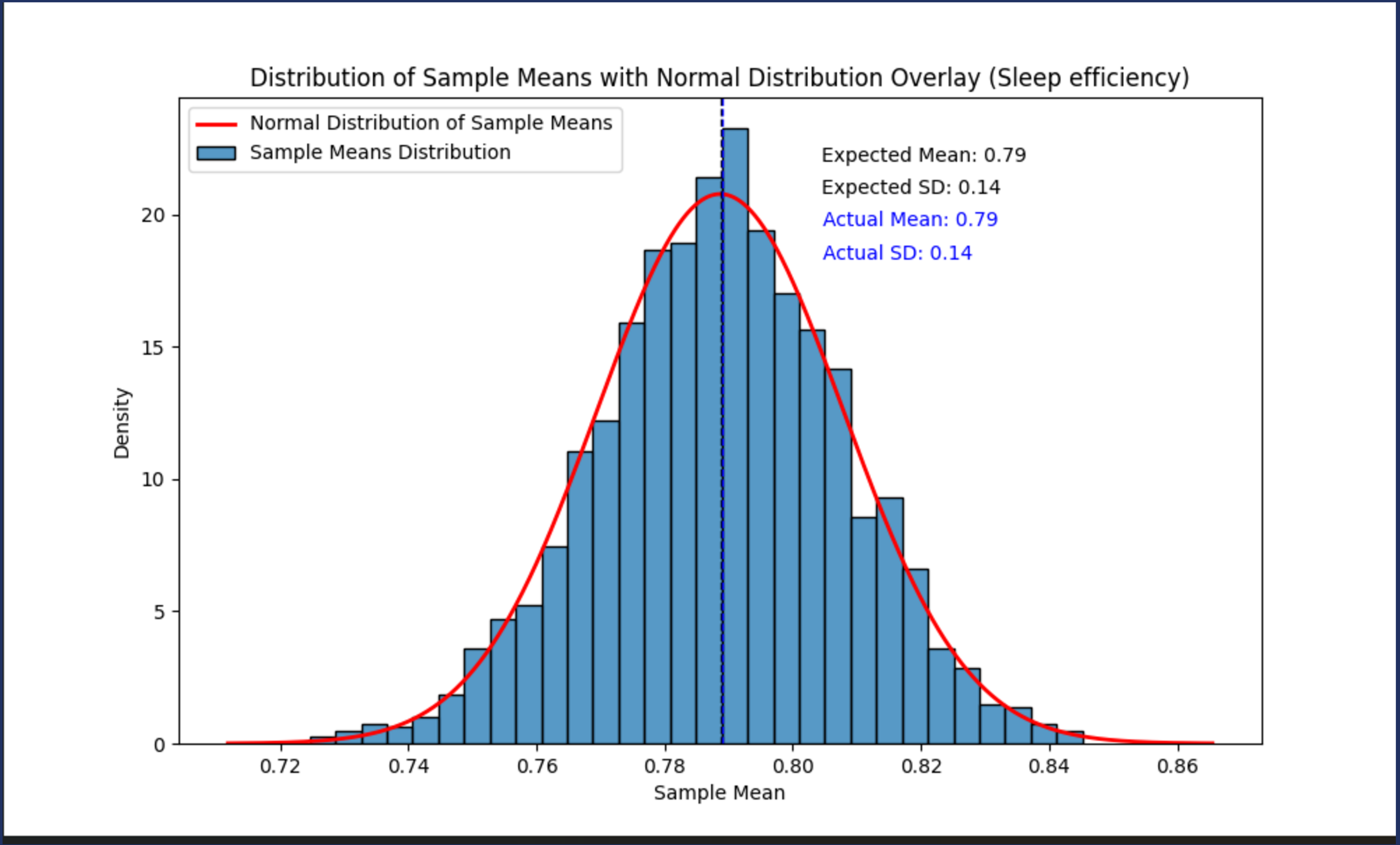
Plot : Frequency Bar Graph



(CLT_sleep_efficiency -> Clt_sleep_efficiency.py)

We observe that the distribution for the sleep duration data values is left skewed.

Plot : pmf and pdf of sample mean



(CLT_sleep_efficiency -> Clt_sleep_efficiency.py)

Thank You