

Commands

Code

Text

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## SLEEP HEALTH AND LIFESTYLE ANALYSIS

Name : Anjana Vijayan  
 Organization : Entri Elevate  
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### Overview of Problem Statement:

According to the National Institutes of Health (NIH), quality sleep is as important to good health as diet and exercise. Regularly missing adequate quality sleep can raise the risk of a range of health issues, such as heart disease, stroke, obesity and dementia. The NIH recommends seven to nine hours of sleep a night for the average person.

Sleep health refers to the quality, duration, timing, and regularity of sleep, as well as the behaviors and habits that promote optimal sleep. It encompasses both the physiological aspects of sleep and the psychological and environmental factors that influence sleep patterns. It is essential for one's overall well-being and is associated with numerous physical, cognitive, and emotional benefits.

When sleep health is prioritized, it can lead to improved mood, cognitive function, immune function, cardiovascular health, and overall quality of life. Conversely, chronic sleep deprivation or poor sleep quality can contribute to a range of negative outcomes, including increased risk of obesity, diabetes, cardiovascular disease, depression, and impaired cognitive performance. Therefore, adopting habits and behaviors that support good sleep health is crucial for optimal functioning and well-being.

### Objective:

#### How is Fitness tied to Sleep Health

Fitness plays a significant role in sleep health, as regular physical activity has been shown to positively influence both the quality and duration of sleep. Regular exercise has been associated with shorter sleep onset latency, meaning it may help individuals fall asleep more quickly after going to bed (including those with sleeping disorders). Beyond its direct effects on sleep, regular exercise is associated with numerous health benefits, including reduced risk of stress, obesity, cardiovascular disease, and depression, all of which can impact sleep health.

### Data Description:

**Dataset Overview:** The Sleep Health and Lifestyle Dataset comprises 15000 rows and 13 columns, covering a wide range of variables related to sleep and daily habits. It includes details such as gender, age, occupation, sleep duration, quality of sleep, physical activity level, stress levels, BMI category, blood pressure, heart rate, daily steps, and the presence or absence of sleep disorders.

**Source:** The dataset can be downloaded from the link: [Data](#)

#### Recognizing Variables in the Dataset

1. **Person ID:** An identifier for each individual.
2. **Sex:** The sex of the person (Male/Female).
3. **Age:** The age of the person in years.
4. **Occupation:** The occupation or profession of the person
5. **Sleep Duration (hours):** The number of hours the person sleeps per day.
6. **Quality of Sleep (scale: 1-10):** A subjective rating of the quality of sleep, ranging from 1 to 10.
7. **Physical Activity Level (minutes/day):** The number of minutes the person engages in physical activity daily.
8. **Stress Level (scale: 1-10):** A subjective rating of the stress level experienced by the person, ranging from 1 to 10.
9. **BMI Category:** The BMI category of the person (e.g., Underweight, Normal, Overweight).
10. **Blood Pressure (systolic/diastolic):** The blood pressure measurement of the person, indicated as systolic pressure over diastolic pressure.
11. **Heart Rate (bpm):** The resting heart rate of the person in beats per minute.
12. **Daily Steps:** The number of steps the person takes per day.
13. **Sleep Disorder:** The presence or absence of a sleep disorder in the person (Healthy, Insomnia, Sleep Apnea).

### Sleep Disorder

- **Healthy:** The individual does not exhibit any specific sleep disorder.
- **Insomnia:** The individual experiences difficulty falling asleep or staying asleep, leading to inadequate or poor-quality sleep.
- **Sleep Apnea:** The individual suffers from pauses in breathing during sleep, resulting in disrupted sleep patterns and potential health risks.

#### Importing necessary libraries

```
[1] import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

#### Loading the data set

```
[2] df=pd.read_csv('/content/Sleep_Data_Sampled.csv')
df
```

	Person ID	Gender	Age	Occupation	Sleep Duration	Quality of Sleep	Physical Activity Level	Stress Level	BMI Category	Blood Pressure	Heart Rate	Daily Steps	Sleep Disorder
0	1	Male	35	Doctor	6.65	7	50	7	Normal Weight	120/80	71	7100	Healthy
1	2	Male	42	Teacher	6.90	8	52	4	Normal	135/90	66	7000	Healthy
2	3	Male	34	Software Engineer	6.95	7	66	6	Overweight	126/83	74	6100	Healthy
3	4	Male	32	Doctor	6.90	6	52	7	Normal	120/80	71	6500	Healthy
4	5	Male	37	Lawyer	6.85	7	60	6	Normal	125/80	71	6500	Healthy
...	...	...	...	...	...	...	...	...	...	...	...	...	...
14995	14996	Female	59	Nurse	8.10	9	75	3	Overweight	140/95	68	7000	Sleep Apnea
14996	14997	Female	59	Nurse	8.00	9	75	3	Overweight	140/95	68	7000	Sleep Apnea
14997	14998	Female	59	Nurse	8.10	9	75	3	Overweight	140/95	68	7000	Sleep Apnea
14998	14999	Female	59	Nurse	8.10	9	75	3	Overweight	140/95	68	7000	Sleep Apnea
14999	15000	Female	59	Nurse	8.10	9	75	3	Overweight	140/95	68	7000	Sleep Apnea

15000 rows x 13 columns

Next steps: [Generate code with df](#) [View recommended plots](#) [New interactive sheet](#)

### EXPLORING THE DATA

```

✓ [3] # Display the number of rows and columns
print("The Number of Rows :", df.shape[0])
print("The Number of Columns :", df.shape[1])
→ The Number of Rows : 15000
The Number of Columns : 13

✓ [4] #Identifying the types of data
numerical_columns=df.select_dtypes(include=["float","int"])
categorical_columns=df.select_dtypes(include="object")
print("Numerical Columns :",numerical_columns.columns)
print("Categorical Columns :",categorical_columns.columns)

→ Numerical Columns : Index(['Person ID', 'Age', 'Sleep Duration', 'Quality of Sleep', 'Physical Activity Level', 'Stress Level', 'Heart Rate', 'Daily Steps'], dtype='object')
Categorical Columns : Index(['Gender', 'Occupation', 'BMI Category', 'Blood Pressure', 'Sleep Disorder'], dtype='object')

✓ [5] #Checking the basic informations about the dataset
df.info()

→ <class 'pandas.core.frame.DataFrame'>
RangeIndex: 15000 entries, 0 to 14999
Data columns (total 13 columns):
 #   Column           Non-Null Count  Dtype  
 --- 
  0   Person ID       15000 non-null   int64  
  1   Gender          15000 non-null   object  
  2   Age              15000 non-null   int64  
  3   Occupation      15000 non-null   object  
  4   Sleep Duration  15000 non-null   float64 
  5   Quality of Sleep 15000 non-null   int64  
  6   Physical Activity Level 15000 non-null   int64  
  7   Stress Level    15000 non-null   int64  
  8   BMI Category   15000 non-null   object  
  9   Blood Pressure  15000 non-null   object  
  10  Heart Rate     15000 non-null   int64  
  11  Daily Steps    15000 non-null   int64  
  12  Sleep Disorder 15000 non-null   object  
dtypes: float64(4), int64(7), object(5)
memory usage: 1.5+ MB

```

## DATA PREPROCESSING & ANALYSIS

### Handling Missing Values

```

✓ [6] # To check the missing values in the dataset
df.isnull().sum()

→ <class 'pandas.core.frame.DataFrame'>
   0
Person ID      0
Gender         0
Age            0
Occupation     0
Sleep Duration 0
Quality of Sleep 0
Physical Activity Level 0
Stress Level   0
BMI Category   0
Blood Pressure 0
Heart Rate     0
Daily Steps    0
Sleep Disorder 0
dtype: int64

```

The dataset not have any missing values.

### Handling Duplicates

```

✓ [7] # To check the duplicated entries in the dataset.
df.duplicated().sum()

→ np.int64(0)

The data not have any duplicated entries.

✓ [8] # we don't need the "person ID" column for further processing.so we are dropping the column.
df.drop("Person ID",axis=1,inplace=True)

✓ [9] #Checking descriptive statistics
df.describe()

→ <class 'pandas.core.frame.DataFrame'>
   0
Age        44.130667
Sleep Duration 6.997327
Quality of Sleep 7.131267
Physical Activity Level 59.925000
Stress Level 5.654800
Heart Rate 70.857533
Daily Steps 6795.080000
count 15000.000000
mean 15000.000000
std 6.840091
min 27.000000
25% 40.000000
50% 44.000000
75% 48.000000
max 59.000000

```

No major difference between mean and median of any column except "Daily Steps".We can see some difference between mean and median of "Daily Steps" column.Mean is greater than the median, which indicates that particular column is positively skewed. The difference may also indicates the presence of outliers in the data.

### Handling Skewness

```

✓ [10] # To check the skewness of the data
skewness=df.select_dtypes(include='number').skew()

→ <class 'pandas.core.frame.DataFrame'>
   0
Age        0.097985
Sleep Duration 0.346637
Quality of Sleep -0.070315
Physical Activity Level 0.204935
Stress Level -0.150428
Heart Rate 0.735076
Daily Steps 0.464187
count 15000.000000
mean 15000.000000
std 6.840091
min 27.000000
25% 40.000000
50% 44.000000
75% 48.000000
max 59.000000

```

Heart Rate column is moderately positively skewed.

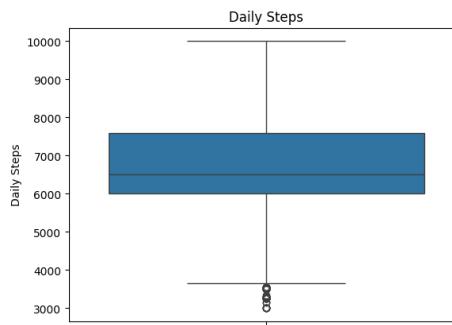
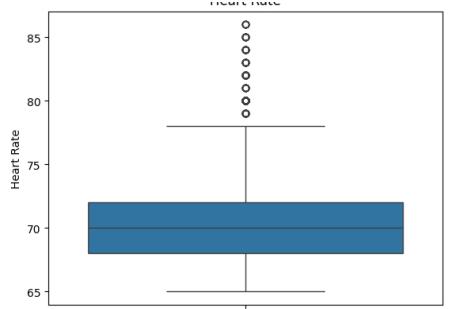
### Handling Outliers

```

✓ [11] # checking outliers visually using boxplot
numerical_columns=df.select_dtypes(include=["float","int"])
for column in numerical_columns:
    sns.boxplot(df[column])
    plt.title(column)
    plt.show()

→ <class 'pandas.core.frame.DataFrame'>
   0
Heart Rate 3.0
count 15000.000000
mean 15000.000000
std 6.840091
min 27.000000
25% 40.000000
50% 44.000000
75% 48.000000
max 59.000000

```

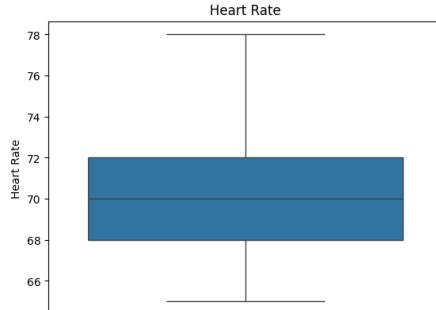
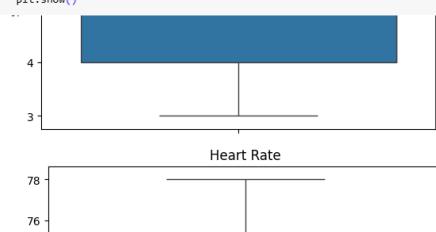


🔴 Daily steps and Heart rate columns contains outliers. we have to treat it properly.

```
[12] # To handle outliers using IQR Method
def handling_outliers(df,columns):
    for column in columns:
        if df[column].dtype in ["float","int"]:
            Q1=df[column].quantile(0.25)
            Q3=df[column].quantile(0.75)
            IQR=Q3-Q1
            lower_bound=Q1-1.5*IQR
            upper_bound=Q3+1.5*IQR
            # To clip the outliers
            df[column]=df[column].clip(lower_bound,upper_bound)
    return df
```

```
[13] # cleaning the data using the 'handle_outliers' function.
df=handling_outliers(df,df.columns)
```

```
[14] # Visually checking whether the outliers are handled properly or not.
numerical_columns=df.select_dtypes(include=["float","int"])
for column in numerical_columns:
    sns.boxplot(df[column])
    plt.title(column)
    plt.show()
```



🔴 The outliers are handled properly.

```
[15] # Checking skewness of the data after handling the outliers
skewness=df.select_dtypes(include='number').skew()
```

	0
Age	0.098136
Sleep Duration	0.346637
Quality of Sleep	-0.070315
Physical Activity Level	0.204935
Stress Level	-0.150428
Heart Rate	0.424716
Daily Steps	0.476226

dtype: float64

🔴 Age,Sleep Duration,Physical Activity Level,Heart Rate and Daily Steps columns are slightly positively skewed.Quality of Sleep and Stress Level columns are slightly negatively skewed.But the skewness values are closer to zero (between -0.5 to 0.5) so we don't need to apply any transformation to the data.

```
[16] # displaying the cleaned data(df)
df.head()
```

	Gender	Age	Occupation	Sleep Duration	Quality of Sleep	Physical Activity Level	Stress Level	BMI Category	Blood Pressure	Heart Rate	Daily Steps	Sleep Disorder
0	Male	35	Doctor	6.65	7	50	7	Normal Weight	120/80	71	7100	Healthy
1	Male	42	Teacher	6.90	8	52	4	Normal	135/90	66	7000	Healthy
2	Male	34	Software Engineer	6.95	7	66	6	Overweight	126/83	74	6100	Healthy
3	Male	32	Doctor	6.90	6	52	7	Normal	120/80	71	6500	Healthy
4	Male	37	Lawyer	6.85	7	60	6	Normal	125/80	71	6500	Healthy

Next steps: [Generate code with df](#) [View recommended plots](#) [New interactive sheet](#)

## DATA ANALYSIS

### Exploratory Data Analysis (EDA)

```
[17] # checking unique values
unique_values=[]
for column in df.columns:
    count=df[column].value_counts().count()
    unique_values.append(count)
pd.DataFrame(unique_values,index=df.columns,columns=["Total Unique Values"])
```

	Total Unique Values
Gender	2
Age	32
Occupation	11
Sleep Duration	55
Quality of Sleep	6
Physical Activity Level	37
Stress Level	6
BMI Category	4
Blood Pressure	25
Heart Rate	14
Daily Steps	74
Sleep Disorder	3

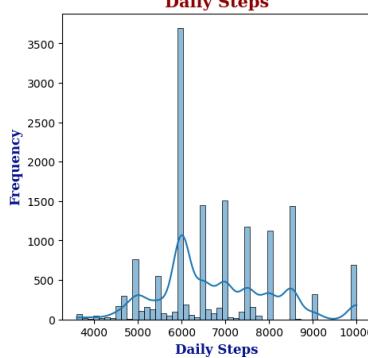
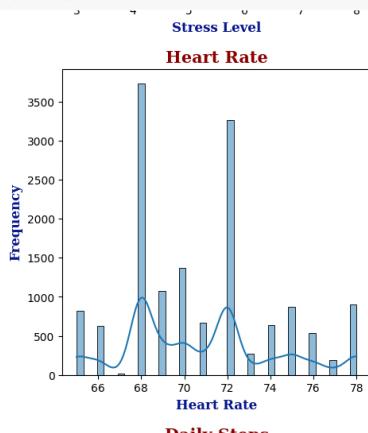
```
[18] # Checking the statistical summary of the data
df.describe()
```

	Age	Sleep Duration	Quality of Sleep	Physical Activity Level	Stress Level	Heart Rate	Daily Steps
count	15000.000000	15000.000000	15000.000000	15000.000000	15000.000000	15000.000000	15000.000000
mean	44.130733	6.997327	7.131267	59.925000	5.654800	70.771533	6795.880000
std	6.839929	0.615187	1.053111	16.814374	1.393568	3.395188	1327.673607
min	28.000000	5.800000	4.000000	30.000000	3.000000	65.000000	3600.000000
25%	40.000000	6.500000	6.000000	45.000000	4.000000	68.000000	6000.000000
50%	44.000000	7.000000	7.000000	60.000000	6.000000	70.000000	6500.000000
75%	48.000000	7.450000	8.000000	75.000000	6.000000	72.000000	7600.000000
max	59.000000	8.500000	9.000000	90.000000	8.000000	78.000000	10000.000000

The data seems uniformly distributed. We can not see any major difference between mean and median. A minute difference is there in 'Daily Steps' column which is due to the slight skewness in that particular column. We have already treated the outliers so the statistical summary gives an over view of cleaned data.

#### Univariate Analysis

```
[19] # Analysing numerical variables using Histogram
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
numerical_columns=df.select_dtypes(include=["float","int"])
for column in numerical_columns:
    plt.figure(figsize=(5,5))
    sns.histplot(df[column],kde=True)
    plt.title(column,fontdict=title_font)
    plt.xlabel(column,fontdict=axis_font)
    plt.ylabel("Frequency",fontdict=axis_font)
    plt.show()
```

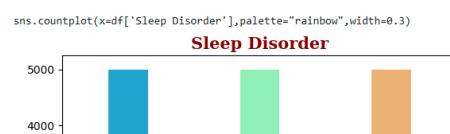


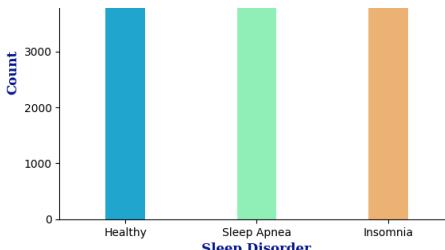
#### Insights:

- Age Distribution: The age distribution has uniform distribution with multiple peaks, indicating that the dataset might contain people from different age groups.
- Sleep Duration: The histogram shows a peak around 6-7 hours, that is 6.5 hrs. The majority seem to fall within this range..
- Physical Activity Level: The data has sharp peaks, indicating that certain activity levels are more common than others.
- Stress Level: The stress level data shows a similar pattern to sleep quality. Most of the data has a stress level of 6.
- Heart Rate: The heart rate histogram has multiple peaks.
- Daily Steps: The distribution is spread out, with higher frequencies in certain ranges. This could indicate that certain activity levels are more common.
- Some variables (Quality of Sleep, Stress Level, Physical Activity) seem to have discrete values rather than continuous distributions.
- There are multiple peaks in several distributions, which may indicate clustering or distinct groups within the dataset.
- Some data distributions appear skewed, suggesting that certain behaviors or characteristics are widespread..

```
[20] #count plot for categorical columns-Sleep Disorder
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
sns.countplot(x=df['Sleep Disorder'],palette="rainbow",width=0.3)
plt.title('Sleep Disorder',fontdict=title_font)
plt.xlabel('Sleep Disorder',fontdict=axis_font)
plt.ylabel('Count',fontdict=axis_font)
plt.show()
```

<ipython-input-20-95baa698f5ed>: FutureWarning:  
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.



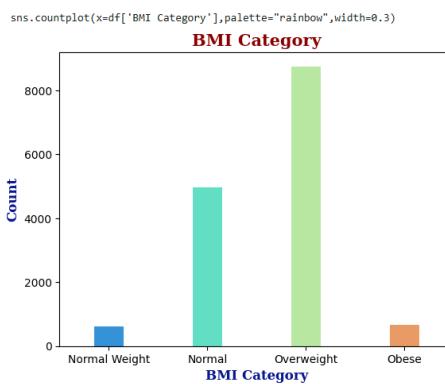


#### ✓ Insights:

- Sleep Disorder is the target column of this dataset. The data is equally distributed among different classes like 'Healthy','Sleep Apnea' and 'Insomnia'.
- The data is balanced.

```
[21] #count plot for categorical columns-BMI Category
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
sns.countplot(x=df['BMI Category'],palette="rainbow",width=0.3)
plt.title('BMI Category',fontdict=title_font)
plt.xlabel('BMI Category',fontdict=axis_font)
plt.ylabel('Count',fontdict=axis_font)
plt.show()
```

⚠ <ipython-input-21-7a5c56766cdf>:4: FutureWarning:  
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

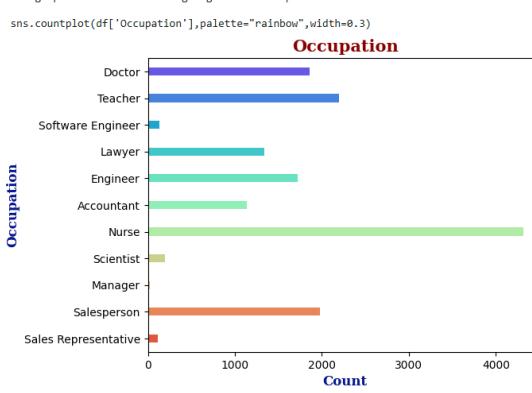


#### ✓ Insights:

- There 4 kinds of BMI categories.
- Most of the people belongs to the 'Overweight' category.
- 'Normal' and 'Obese' categories holds the second and Obese' holds the third positions respectively.
- 'Normal Weight' category has the minimum number of entries.

```
[22] #count plot for categorical columns-BMI Category
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
sns.countplot(df['Occupation'],palette="rainbow",width=0.3)
plt.title('Occupation',fontdict=title_font)
plt.xlabel('Count',fontdict=axis_font)
plt.ylabel('Occupation',fontdict=axis_font)
plt.show()
```

⚠ <ipython-input-22-3622560be6d1>:4: FutureWarning:  
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `y` variable to `hue` and set `legend=False` for the same effect.



#### ✓ Insights:

- 'Nurses' have the highest representation in the dataset, significantly higher than all other occupations.
- 'Teachers', 'Salespersons' and 'Doctors' also have relatively high counts, suggesting these professions are well-represented in the dataset.
- 'Managers', 'Software Engineers', 'Scientists', and 'Sales Representatives' have the lowest representation.
- Since 'Nurses' and 'Doctors' have comparatively higher count, the data is highly representing healthcare sector compared to other professions.

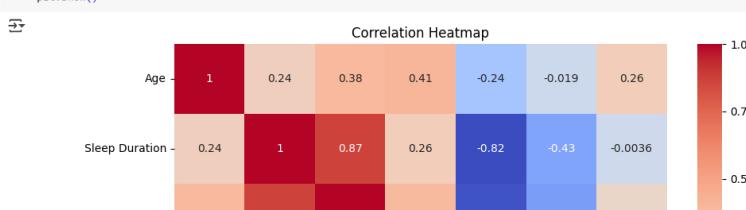
#### Bivariate Analysis

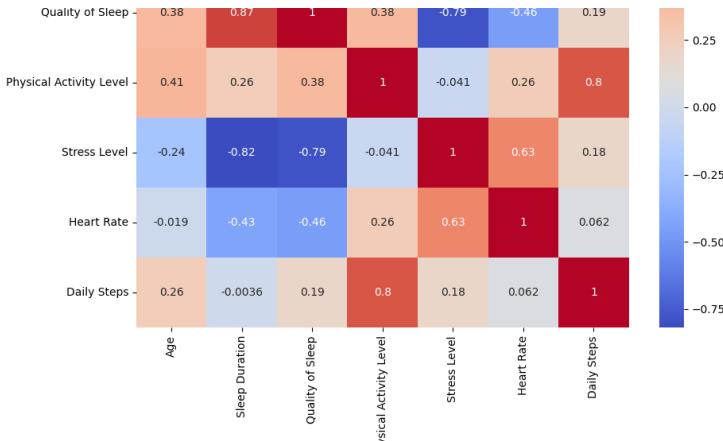
```
[23] # checking the correlation between the features.
correlation=df.select_dtypes("number").corr()
correlation
```

	Age	Sleep Duration	Quality of Sleep	Physical Activity Level	Stress Level	Heart Rate	Daily Steps
Age	1.00000	0.242350	0.382185	0.405466	-0.236079	-0.019318	0.257976
Sleep Duration	0.242350	1.00000	0.871070	0.258421	-0.619078	-0.426138	-0.003600
Quality of Sleep	0.382185	0.871070	1.00000	0.381601	-0.785485	-0.457982	0.188231
Physical Activity Level	0.405466	0.258421	0.381601	1.00000	-0.040732	0.100000	0.802956
Stress Level	-0.236079	-0.819078	-0.785485	-0.040732	1.00000	0.629591	0.184221
Heart Rate	-0.019318	-0.426138	-0.457982	0.261873	0.629591	1.00000	0.062251
Daily Steps	0.257976	-0.003600	0.188231	0.802956	0.184221	0.062251	1.00000

Next steps: [Generate code with correlation](#) [View recommended plots](#) [New interactive sheet](#)

```
[24] # visually analyzing the correlation between the features using Heatmap.
plt.figure(figsize=(10,8))
sns.heatmap(correlation, annot=True, cmap="coolwarm")
plt.title("Correlation Heatmap")
plt.show()
```





#### ▼ Insights:

##### Strong Positive Correlations:

- Sleep duration has a high positive correlation with Quality of sleep(0.87).
- Higher Physical activity levels correspond to more Daily steps.(0.80)
- Stress level and Heart rate has positive correlation each other(0.63).Higher stress level associated with increased Heart rate.

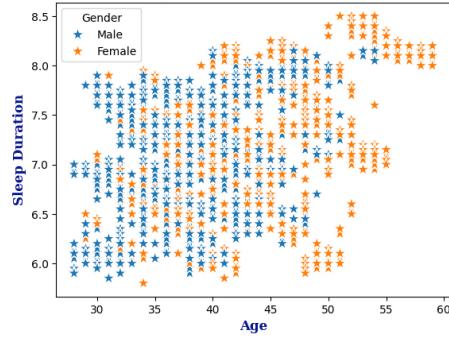
##### Strong Negative Correlations:

- Sleep Duration & Stress Level (-0.82): People who sleep longer tend to have lower stress levels.
- Quality of Sleep & Stress Level (-0.79): Better sleep quality is associated to lower stress.
- Heart Rate & Quality of Sleep (-0.46): Higher heart rates are associated with poorer sleep quality.

```
[25] # Scatter plot-Age vs Sleep Duration
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
sns.scatterplot(data=df,x="Age",y="Sleep Duration",hue=df["Gender"],marker="*",s=150)
plt.xlabel("Age",fontdict=axis_font)
plt.ylabel("Sleep Duration",fontdict=axis_font)
plt.title("Age vs Sleep Duration",fontdict=title_font)
plt.show()
```



**Age vs Sleep Duration**



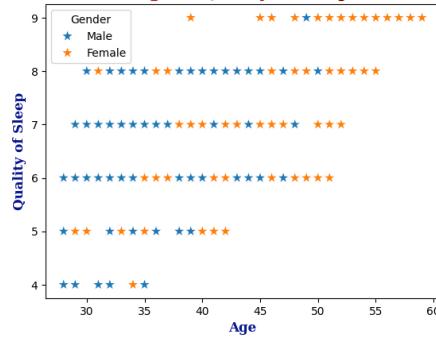
#### ▼ Insights:

- Younger individuals have a wide range of sleep duration
- The sleep duration is maximum in the 55-60 age group, they are sleeping for almost 8.5 hrs.
- Both male and females exhibit a similar distribution in sleep duration, but females shows slightly longer sleep duration in the older ages.
- Between ages 30–50, sleep duration is mostly concentrated around 6.5 to 7.5 hours.

```
[26] # Scatter Plot- Age vs Sleep Duration
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
sns.scatterplot(data=df,x="Age",y="Quality of Sleep",hue=df["Gender"],color="orange",marker="*",s=150)
plt.xlabel("Age",fontdict=axis_font)
plt.ylabel("Quality of Sleep",fontdict=axis_font)
plt.title("Age vs Quality of Sleep",fontdict=title_font)
plt.show()
```



**Age vs Quality of Sleep**



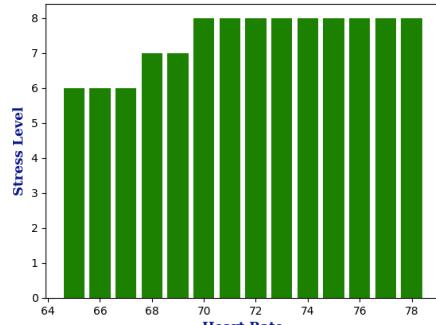
#### ▼ Insights:

- we have seen in the scatterplot of Age vs Sleep Duration, the quality of sleep is maximum in the age group 55-60.
- In the older age groups, female shows high quality of sleep compared to male.
- Most of the people have the sleep quality lies in the range of 6-8.

```
[27] # Heart Rate vs Stress Level
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
plt.bar(df["Heart Rate"],df["Stress Level"],color="g")
plt.xlabel("Heart Rate",fontdict=axis_font)
plt.ylabel("Stress Level",fontdict=axis_font)
plt.title("Heart Rate vs Stress Level",fontdict=title_font)
plt.show()
```



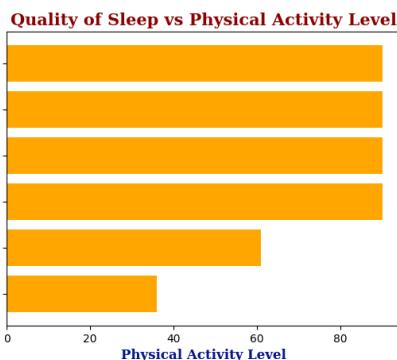
**Heart Rate vs Stress Level**



#### ▼ Insights:

- The heart rate is increasing as the stress level increases.
- The people with high stress level also have an increased heart rate compared to others.
- When the Heart rate is 70 or higher, the Stress level reaches the maximum (8).

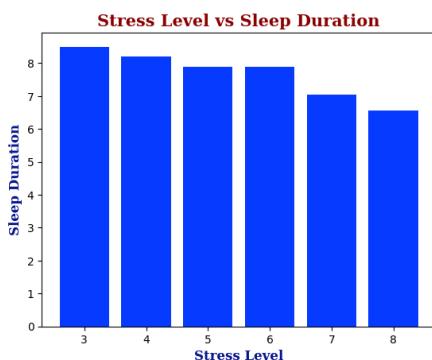
```
[28] # Quality of Sleep vs Physical Activity Level
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
plt.barh(df['Quality of Sleep'],df['Physical Activity Level'],color="orange")
plt.xlabel('Physical Activity Level',fontdict=axis_font)
plt.ylabel('Quality of Sleep',fontdict=axis_font)
plt.title('Quality of Sleep vs Physical Activity Level',fontdict=title_font)
plt.show()
```



#### Insights:

- The quality of sleep is increasing with the intensity of physical activity increases.
- The people who are physically more active, they are getting good quality sleep.

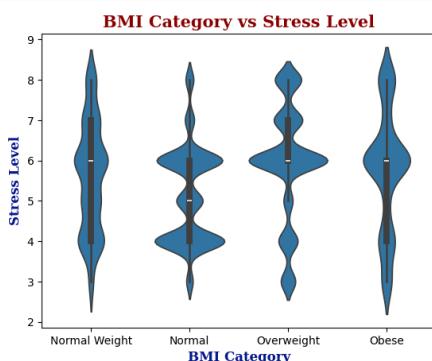
```
[29] # Stress Level vs Sleep Duration
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
plt.barh(df['Stress Level'],df['Sleep Duration'],color="blue")
plt.xlabel('Stress Level',fontdict=axis_font)
plt.ylabel('Sleep Duration',fontdict=axis_font)
plt.title('Stress Level vs Sleep Duration',fontdict=title_font)
plt.show()
```



#### Insights:

- It is clearly visible that people with high stress level have comparatively low sleep duration.
- As the stress level increases, the sleep duration decreases.

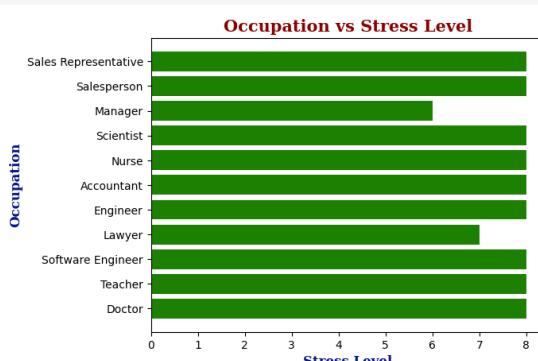
```
[30] # violin plot - BMI Category vs Stress Level
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
sns.violinplot(x=df['BMI Category'],y=df['Stress Level'])
plt.xlabel('BMI Category',fontdict=axis_font)
plt.ylabel('Stress Level',fontdict=axis_font)
plt.title('BMI Category vs Stress Level',fontdict=title_font)
plt.show()
```



#### Insights:

- All BMI categories show a wide distribution of stress levels, indicating that individuals in each category experience a range of stress.
- The median stress level (6) appears higher for overweight and obese individuals compared to normal-weight individuals.

```
[31] # Occupation vs Stress Level
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"bold","size":12}
plt.barh(df['Occupation'],df['Stress Level'],color="green")
plt.xlabel('Occupation',fontdict=axis_font)
plt.ylabel('Occupation',fontdict=axis_font)
plt.title('Occupation vs Stress Level',fontdict=title_font)
plt.show()
```

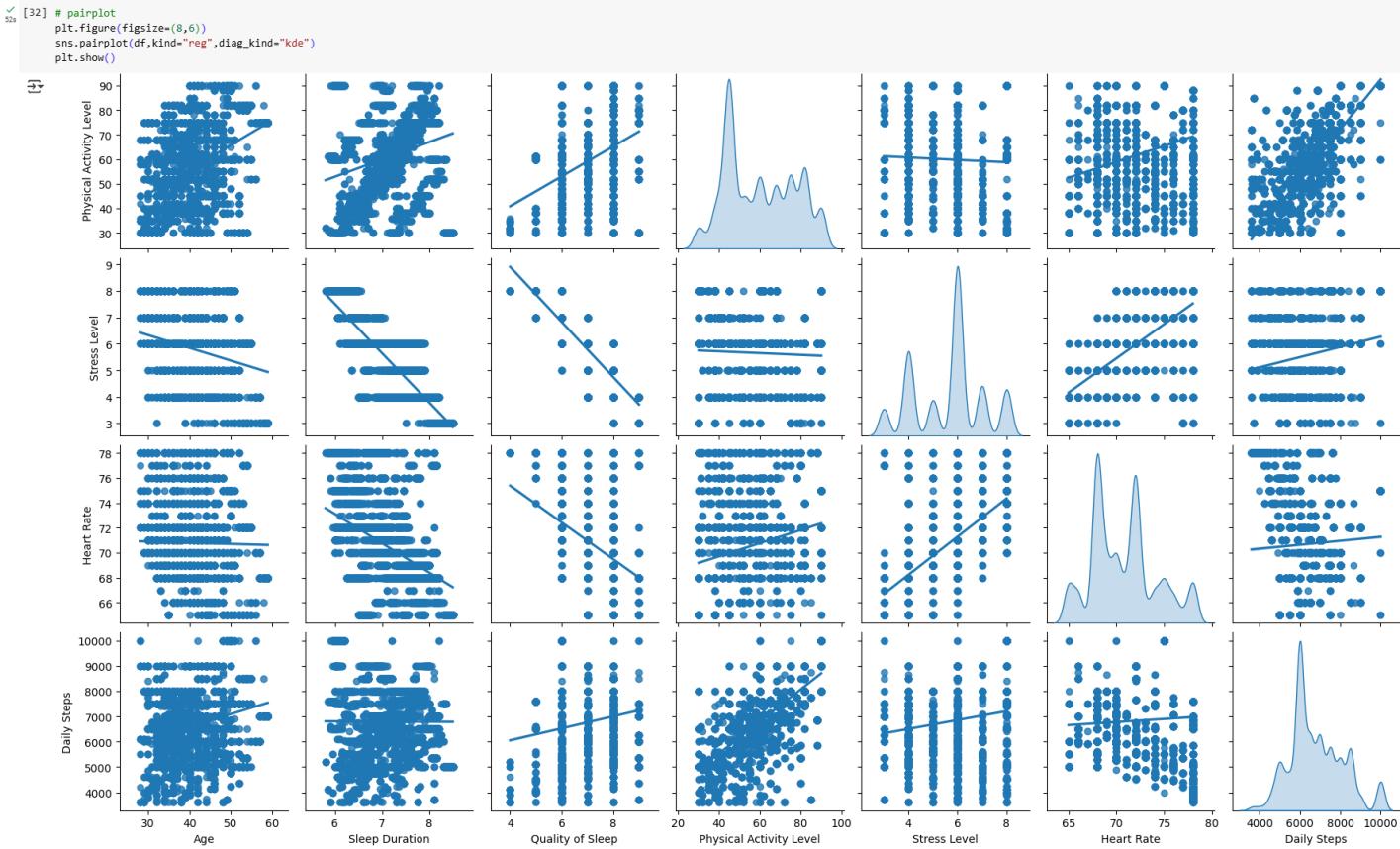


#### Insights:

- The stress level is high for almost all the occupation types.
- Manager and Lawyer have the lowest reported stress levels in this chart.

- Managers and Lawyers have the lowest reported stress levels in this chart.
- So irrespective of the occupation type, the stress level is highly depends on other fitness factors of the body.

#### ▼ Multivariate Analysis



#### ▼ Insights:

- we can see how the data is distributed among different features and how the features are related to eachother.
- Diagonal graphs are univariate kde plots.
- Age has a positive correlation with Quality of sleep and slight negative correlation with stress level.
- Sleep duration has high positive correlation with Quality of sleep and a high negative correlation with Stress level.
- Quality of sleep has positive correlation with Age, Sleep duration, Physical activity level and daily steps. But it has a negative correlation with Stress level and Heart rate.
- Physical activity level has a positive correlation with all other features except stress level.
- Stress level has negative correlation with all other features except Heart rate.
- Some variables show a clear linear relationship(Sleep Duration vs Quality of sleep)

```
[33] # To analyse the class balance
y=df['Sleep Disorder'] # target
class_balance=df['Sleep Disorder'].value_counts()
class_balance
```

Sleep Disorder	count
Healthy	5000
Sleep Apnea	5000
Insomnia	5000

**dtype: int64**

The data is equally distributed in the 3 different classes. So the data is balanced.

## FEATURE ENGINEERING

#### ▼ Feature Encoding

Encoding is the process of converting categorical or textual data into numerical formats. Most of the Machine Learning models can not work directly with non-numerical data, so encoding is one of the most essential steps to transform the data for Machine Learning algorithms. Label Encoding, One-Hot Encoding, Target Encoding etc are commonly used encoding techniques. I am using One-Hot Encoding and Target Encoding techniques for encoding my dataset.

```
[34] # Importing One-Hot Encoder and Target Encoder
from sklearn.preprocessing import OneHotEncoder,TargetEncoder
```

```
[35] X=df.drop('Sleep Disorder',axis=1) #Features
y=df['Sleep Disorder'] #Target
```

```
[36] # analysing the categorical features
categorical_features=X.select_dtypes(include="object")
categorical_features.head()
```

	Gender	Occupation	BMI Category	Blood Pressure
0	Male	Doctor	Normal Weight	120/80
1	Male	Teacher	Normal	135/90
2	Male	Software Engineer	Overweight	126/83
3	Male	Doctor	Normal	120/80
4	Male	Lawyer	Normal	125/80

Next steps: [Generate code with categorical\\_features](#) [View recommended plots](#) [New interactive sheet](#)

```
[37] # checking unique values in categorical features
unique_values=[]
for column in categorical_features.columns:
    count=categorical_features[column].value_counts().count()
    unique_values.append(count)
pd.DataFrame(unique_values,index=categorical_features.columns,columns=["Total Unique Values"])
```

	Total Unique Values
Gender	2
Occupation	11
BMI Category	4
Blood Pressure	25

\*Blood Pressure\* contains 25 unique values. \*Gender\* has 2, \*Occupation\* has 11 and \*BMI Category\* has 4 unique values. One Hot Encoding is using to encode categorical features such as \*Gender\*, \*Occupation\*, \*Blood Pressure\* and \*BMI Category\*.

#### ▼ One-Hot Encoding

One-hot encoding transforms categorical values into a series of binary vectors, where each category is represented as a unique vector with a single 1 and all other values as 0.

```
[38] # Encoding "Gender","Occupation", "Blood Pressure" and "BMI Category" columns using OneHotEncoder
X_encoded=pd.get_dummies(X,columns=["Gender","Occupation","BMI Category", "Blood Pressure"],drop_first=True,dtype="int")
X_encoded.head()
```

	Age	Sleep Duration	Quality of Sleep	Physical Activity Level	Stress Level	Heart Rate	Daily Steps	Gender_Male	Occupation_Doctor	Occupation_Engineer	...	Blood Pressure_130/85	Blood Pressure_130/86	Blood Pressure_131/86	Blood Pressure_132/87	Blood Pressure_135/88	Blood Pressure_135/90	Blood Pressure_139/88	Blood Pressure_139/91	Blood Pressure_139/92
0	35	6.65	7	50	7	71	7100	1	1	0	...	0	0	0	0	0	0	0	0	0
1	42	6.90	8	52	4	66	7000	1	0	0	...	0	0	0	0	0	0	0	1	0
2	34	6.95	7	66	6	74	6100	1	0	0	0	0	0	0	0	0	0	0	0	0
3	32	6.90	6	52	7	71	6500	1	1	0	...	0	0	0	0	0	0	0	0	0
4	37	6.85	7	60	6	71	6500	1	0	0	0	0	0	0	0	0	0	0	0	0

5 rows x 45 columns

```
[39] # Checking the basic information about the encoded features
X_encoded.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 15000 entries, 0 to 14999
Data columns (total 45 columns):
 #   Column           Non-Null Count  Dtype  
 ---  -- 
 0   Age              15000 non-null   int64  
 1   Sleep Duration  15000 non-null   float64 
 2   Quality of Sleep 15000 non-null   int64  
 3   Physical Activity Level 15000 non-null   int64  
 4   Stress Level    15000 non-null   int64  
 5   Heart Rate      15000 non-null   int64  
 6   Daily Steps     15000 non-null   int64  
 7   Gender_Male     15000 non-null   int64  
 8   Occupation_Doctor 15000 non-null   int64  
 9   Occupation_Engineer 15000 non-null   int64  
 10  Occupation_Lawyer 15000 non-null   int64  
 11  Occupation_Manager 15000 non-null   int64  
 12  Occupation_Nurse 15000 non-null   int64  
 13  Occupation_Salesperson 15000 non-null   int64  
 14  Occupation_Secretary 15000 non-null   int64  
 15  Occupation_Software Engineer 15000 non-null   int64  
 16  Occupation_Teacher 15000 non-null   int64  
 17  BMI Category_Normal Weight 15000 non-null   int64  
 18  BMI Category_Obese 15000 non-null   int64  
 19  BMI Category_Overweight 15000 non-null   int64  
 20  Blood Pressure_115/78 15000 non-null   int64  
 21  Blood Pressure_117/76 15000 non-null   int64  
 22  Blood Pressure_118/75 15000 non-null   int64  
 23  Blood Pressure_118/76 15000 non-null   int64  
 24  Blood Pressure_119/77 15000 non-null   int64  
 25  Blood Pressure_120/80 15000 non-null   int64  
 26  Blood Pressure_120/88 15000 non-null   int64  
 27  Blood Pressure_121/79 15000 non-null   int64  
 28  Blood Pressure_122/80 15000 non-null   int64  
 29  Blood Pressure_125/80 15000 non-null   int64  
 30  Blood Pressure_125/82 15000 non-null   int64  
 31  Blood Pressure_126/83 15000 non-null   int64  
 32  Blood Pressure_128/84 15000 non-null   int64  
 33  Blood Pressure_128/85 15000 non-null   int64  
 34  Blood Pressure_129/84 15000 non-null   int64  
 35  Blood Pressure_130/85 15000 non-null   int64  
 36  Blood Pressure_130/86 15000 non-null   int64  
 37  Blood Pressure_131/86 15000 non-null   int64  
 38  Blood Pressure_132/87 15000 non-null   int64  
 39  Blood Pressure_135/88 15000 non-null   int64  
 40  Blood Pressure_135/90 15000 non-null   int64  
 41  Blood Pressure_139/91 15000 non-null   int64  
 42  Blood Pressure_140/90 15000 non-null   int64  
 43  Blood Pressure_140/95 15000 non-null   int64  
 44  Blood Pressure_142/92 15000 non-null   int64  
dtypes: float64(1), int64(44)
memory usage: 5.1 MB
```

After encoding, we have got 45 features. So we have to select the features with more importance to train the ML model to avoid over fitting or under fitting. The next step will be Feature selection.

## Feature Selection

Feature selection is the process of choosing the most relevant features (independent variables) for a machine learning model. It helps improve model accuracy, reduce overfitting, and speed up training by eliminating irrelevant or redundant features. Mainly there are two methods for feature selection,

1. Select K Best using Cross-Validation (CV)
2. Feature Selection Using Random Forest

Here I am using "Feature Selection Using Random Forest"

**Feature Selection Using Random Forest** Random Forest is an ensemble learning method that provides built-in feature importance based on how much a feature contributes to reducing impurity (Gini or MSE).

- ✓ Handles non-linearity and complex feature interactions.
- ✓ Works well with high-dimensional data.
- ✓ Fast & scalable compared to wrapper methods.
- ✓ No need for additional feature selection techniques.

```
[40] from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestClassifier

# Split data
X_train,X_test,y_train,y_test=train_test_split(X_encoded,y,test_size=0.2,random_state=42)

# Train Random Forest Model
model = RandomForestClassifier(n_estimators=100, random_state=42)
model.fit(X_train, y_train)

# Get feature importance
feature_importance=pd.Series(model.feature_importances_)

# Create a DataFrame to display feature importances
feature_importance = pd.DataFrame({'Feature': X_encoded.columns,
                                    'Importance': feature_importance}).sort_values(by='Importance', ascending=False)
print(feature_importance)
```

	Feature	Importance
0	Age	0.119545
43	Blood Pressure_140/95	0.103430
1	Sleep Duration	0.089177
12	Occupation_Nurse	0.082968
20	BMI Category_Overweight	0.087449
3	Physical Activity Level	0.085151
6	Daily Steps	0.082499
5	Heart Rate	0.076648
2	Quality of Sleep	0.047854
4	Stress Level	0.027894
40	Blood Pressure_135/90	0.023178
29	Blood Pressure_125/88	0.020354
14	Occupation_Salesperson	0.019566
35	Blood Pressure_130/85	0.017490
17	Occupation_Teacher	0.013383
7	Gender_Male	0.011958
8	Occupation_Doctor	0.010696
9	Occupation_Engineer	0.010648
19	BMI Category_Obese	0.009267
10	Occupation_Lawyer	0.009233
26	Blood Pressure_120/80	0.008593
18	BMI Category_Normal Weight	0.008214
44	Blood Pressure_142/92	0.008062
13	Occupation_Sales Representative	0.0082751
41	Blood Pressure_139/91	0.008294
15	Occupation_Scientist	0.008233
42	Blood Pressure_140/99	0.008164
30	Blood Pressure_125/82	0.008131
39	Blood Pressure_135/88	0.0081564
38	Blood Pressure_132/87	0.0081395
33	Blood Pressure_128/85	0.0081380
31	Blood Pressure_126/83	0.0081230
16	Occupation_Software Engineer	0.0081190
34	Blood Pressure_129/84	0.0081131
37	Blood Pressure_131/86	0.0081045
36	Blood Pressure_130/86	0.0080923
22	Blood Pressure_117/76	0.0080612
11	Occupation_Manager	0.0080555
32	Blood Pressure_128/84	0.0080523
23	Blood Pressure_118/75	0.0080356
25	Blood Pressure_119/77	0.0080302
28	Blood Pressure_122/89	0.0080097
21	Blood Pressure_115/78	0.0080096
27	Blood Pressure_121/79	0.0080070
24	Blood Pressure_118/76	0.0080019

```
[41] # Create the plot with sorted feature importances
plt.figure(figsize=(8,8))
plt.barh(feature_importance["Feature"],feature_importance["Importance"], color='purple')

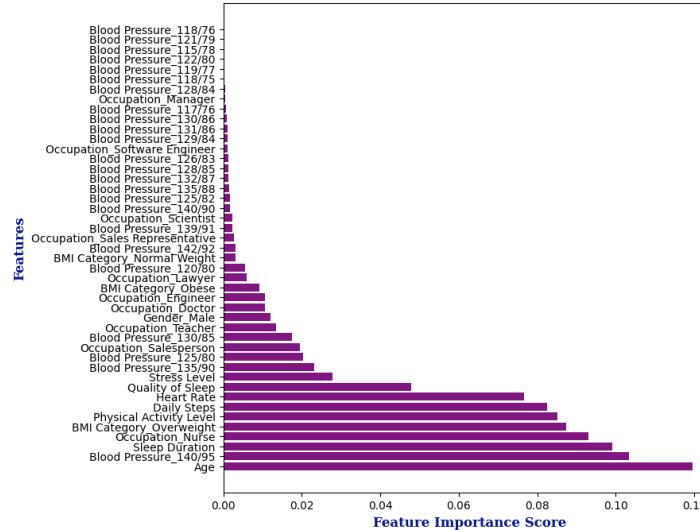
# Add labels to your graph
title_font={"family":"serif","color":"darkred","weight":"bold","size":15}
axis_font={"family":"serif","color":"darkblue","weight":"normal","size":12}
```

```

plt.xlabel('Feature Importance Score',fontdict=axis_font)
plt.ylabel('Features',fontdict=axis_font)
plt.title("Visualizing Important Features",fontdict=title_font)
plt.show()

```

### Visualizing Important Features



The graph represents the feature importance of different features after encoding the data. When selecting the features using Random Forest Classifier/Regressor, we can set a threshold which helps in adjusting decision boundaries. Here I am setting a threshold of >0.02 and selecting the features with feature importance above the threshold.

```

[42] # Setting the threshold
threshold = 0.02

# Select features with importance above the threshold
selected_features = feature_importance[feature_importance['Importance'] > threshold]

print("Selected Features:")
print(selected_features)

```

	Feature	Importance
0	Age	0.119545
43	Blood Pressure_140/95	0.103438
1	Sleep Duration	0.099177
12	Occupation_Nurse	0.092968
20	BMI Category_Overweight	0.087449
3	Physical Activity Level	0.085151
6	Daily Steps	0.082499
5	Heart Rate	0.076648
2	Quality of Sleep	0.047854
4	Stress Level	0.027894
40	Blood Pressure_135/90	0.023178
29	Blood Pressure_125/80	0.020354

```
[43] len(selected_features)
```

12

We have got 12 selected features which has an importance above the threshold(0.02).

```

[44] X_selected=X_encoded[selected_features['Feature']]
X_selected.head()

```

	Age	Blood Pressure_140/95	Sleep Duration	Occupation_Nurse	BMI Category_Overweight	Physical Activity Level	Daily Steps	Heart Rate	Quality of Sleep	Stress Level	Blood Pressure_135/90	Blood Pressure_125/80
0	35	0	6.65	0		0	50	7100	71	7	7	0
1	42	0	6.90	0		0	52	7000	66	8	4	1
2	34	0	6.95	0		1	66	6100	74	7	6	0
3	32	0	6.90	0		0	52	6500	71	6	7	0
4	37	0	6.85	0		0	60	6500	71	7	6	0

Next steps: [Generate code with X\\_selected](#) [View recommended plots](#) [New interactive sheet](#)

```

[45] # checking the information about selected features(X_selected)
X_selected.info()

```

```

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 15000 entries, 0 to 14999
Data columns (total 12 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   Age              15000 non-null   int64  
 1   Blood Pressure_140/95    15000 non-null   int64  
 2   Sleep Duration     15000 non-null   float64 
 3   Occupation_Nurse   15000 non-null   int64  
 4   BMI Category_Overweight 15000 non-null   int64  
 5   Physical Activity Level 15000 non-null   int64  
 6   Daily Steps        15000 non-null   int64  
 7   Heart Rate         15000 non-null   int64  
 8   Quality of Sleep    15000 non-null   int64  
 9   Stress Level       15000 non-null   int64  
 10  Blood Pressure_135/90 15000 non-null   int64  
 11  Blood Pressure_125/80 15000 non-null   int64  
dtypes: float64(1), int64(11)
memory usage: 1.4 MB

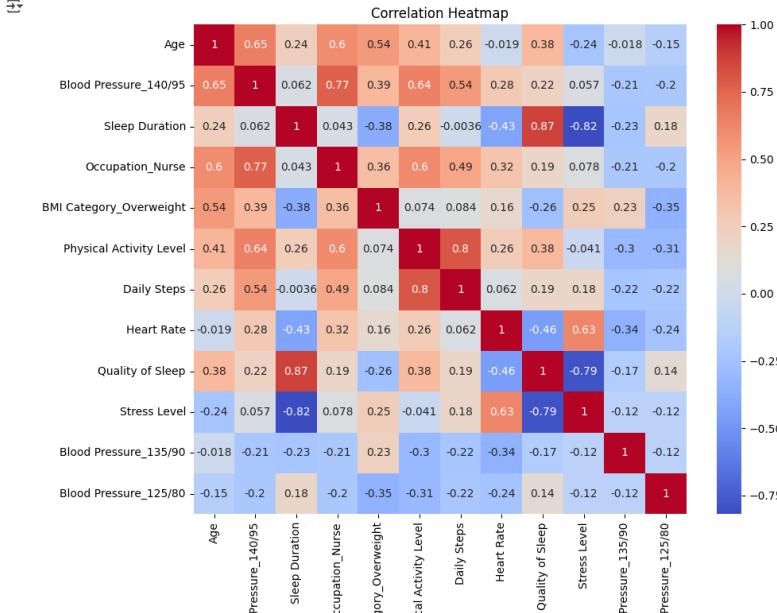
```

X\_selected has 12 columns(features) and 15000 rows.

```

[46] #Checking the correlation between selected features
correlation=X_selected.corr()
plt.figure(figsize=(10,8))
sns.heatmap(correlation,annot=True,cmap="coolwarm")
plt.title("Correlation Heatmap")
plt.show()

```



## ✓ Insights

### ✓ Strong Correlations (>|0.7|)

- Sleep Duration ↔ Quality of Sleep:+0.87
- Physical Activity Level ↔ Daily Steps:+0.80
- Stress Level ↔ Quality of Sleep:-0.79
- Sleep Duration ↔ Stress Level:-0.82
- Occupation\_Nurse ↔ Blood Pressure\_140/95:+0.77

⚡ The correlation heat map is giving **Multicollinearity Alert**. So we need to apply PCA to this features. We need to do feature scaling before applying PCA.

## ✓ Feature Scaling

**Standardization:** Standardization allows the model to learn better by equalizing feature ranges, avoiding biases that arise from unbalanced ranges. Standard Scaler and Min Max Scaler are the most commonly used scaling methods. Here I am going to use standard scaler method.

⚡ Usually we do not scale binary columns. So before scaling, we have to identify binary columns and non binary columns.

```
✓ [47] # Identify Binary Columns (Columns with Only 2 Unique Values)
binary_columns=[column for column in X_selected.columns if X_selected[column].nunique()==2]

# Identify Non-Binary Numeric Columns
numerical_columns=X_selected.select_dtypes(include=["float","int"]).columns
non_binary_columns=[column for column in numerical_columns if column not in binary_columns]

print("Binary columns:", binary_columns)
print("Non Binary columns:",non_binary_columns)

⚡ Binary columns: ['Blood Pressure_140/95', 'Occupation_Nurse', 'BMI Category_Overweight', 'Blood Pressure_135/90', 'Blood Pressure_125/80']
Non Binary columns: ['Age', 'Sleep Duration', 'Physical Activity Level', 'Daily Steps', 'Heart Rate', 'Quality of Sleep', 'Stress Level']

✓ [48] from sklearn.preprocessing import StandardScaler
scaler=StandardScaler()

X_selected_scaled = pd.DataFrame() # Initialize as an empty DataFrame

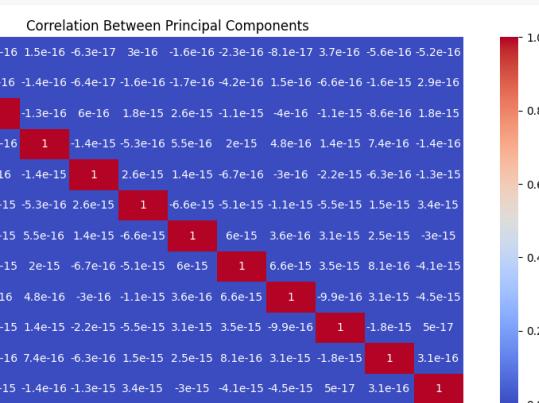
# Apply StandardScaler only to Non-Binary Columns of X_selected
X_selected_scaled[binary_columns]= X_selected[binary_columns]
X_selected_scaled[non_binary_columns]=scaler.fit_transform(X_selected[non_binary_columns])
```

## ✓ PCA (Dimensionality Reduction)

PCA (Principal Component Analysis) is a dimensionality reduction technique. It transforms your high-dimensional data (with possibly correlated features) into a new set of fewer, uncorrelated features called principal components, while keeping as much information (variance) as possible.

```
✓ [49] from sklearn.decomposition import PCA
pca = PCA()
X_pca = pca.fit_transform(X_selected_scaled)

✓ [50] #Checking correlation between features after PCA.
X_pca_df = pd.DataFrame(X_pca)
plt.figure(figsize=(12,6))
sns.heatmap(X_pca_df.corr(), annot=True, cmap='coolwarm')
plt.title("Correlation Between Principal Components")
plt.show()
```



⚡ This heatmap confirms that our principal components are uncorrelated.

## ✓ Split Data into Training and Testing Sets:

```
✓ [51] from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X_pca, y, test_size=0.2, random_state=42)

print("Training data feature shape(X_train):",X_train.shape)
print("Training data target shape(y_train):",y_train.shape)
print("Testing data feature shape(X_test):", X_test.shape)
print("Testing data target shape(y_test):", y_test.shape)

⚡ Training data feature shape(X_train): (12000, 12)
Training data target shape(y_train): (12000,)
Testing data feature shape(X_test): (3000, 12)
Testing data target shape(y_test): (3000,)
```

## ✓ Handling Imbalanced Data

```
✓ [52] # Calculate class Imbalance Ratio
# target="y", we have already split the data.
major_class=y.value_counts().max()
minor_class=y.value_counts().min()
imbalance_ratio=major_class/minor_class
print("Imbalance Ratio: ",imbalance_ratio)

⚡ Imbalance Ratio: 1.0
```

⚡ We have got an imbalance ratio "1", which indicates the data is properly balanced. So we don't need to apply any techniques to balance it. We can move to model building process.

## ✓ BUILD THE MACHINE LEARNING MODELS

⚡ It is a classification problems. The classification models are:

- Support Vector Machine(SVC-Support Vector Classifier)
- KNeighbors Classifier
- Naive Bayes
- Decision Tree Classifier
- Random Forest Classifier
- Gradient Boosting Classifier

```
✓ [53] #Importing required models
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.naive_bayes import GaussianNB
from sklearn.metrics import accuracy_score
```

## ✓ 1 Support Vector Classifier-SVC

## Support Vector Classifier

### How it Works:

- SVC uses a set of labeled training examples to find a decision boundary that separates the data points into different classes.
- The decision boundary is represented as a linear function, and the goal is to find the boundary that maximizes the separation between the classes.

#### Why it's suitable:

- Works well when features are properly scaled.
- Performs well for high-dimensional data, like this dataset with 30 features.
- SVC is commonly used in image recognition, text classification, and medical diagnosis.

```
[54] svc=SVC()
svc.fit(X_train,y_train)

[55] #Creating a dictionary to store accuracy scores
Accuracy_scores={

    "Model": [],
    "Train Accuracy Score": [],
    "Test Accuracy Score": []
}

[56] svc_y_pred=svc.predict(X_test)
train_accuracy=accuracy_score(y_train,svc.predict(X_train))
Test_accuracy=accuracy_score(y_test,svc_y_pred)
Accuracy_scores["Model"].append("Support Vector Classifier-SVC")
Accuracy_scores["Train Accuracy Score"].append(Train_accuracy)
Accuracy_scores["Test Accuracy Score"].append(Test_accuracy)
print("Train Accuracy-svc:",Train_accuracy)
print("Test Accuracy-svc:",Test_accuracy)

Train Accuracy-svc: 0.94875
Test Accuracy-svc: 0.9476666666666667
```

## 2.K-Nearest Neighbors Classifier

### How it works:

- A non-parametric, instance-based algorithm that classifies a new point based on the majority class among its k closest neighbors.
- Uses distance metrics (e.g., Euclidean distance) to determine proximity.

#### Why it's suitable:

- It is Simple.
- Can handle non-linear decision boundaries.
- Sensitive to feature scaling and computationally expensive for large datasets.
- Works well if patterns exist in proximity.

```
[57] knn=KNeighborsClassifier()
knn.fit(X_train,y_train)

[58] knn_y_pred=knn.predict(X_test)
Train_accuracy=accuracy_score(y_train,knn.predict(X_train))
Test_accuracy=accuracy_score(y_test,knn_y_pred)
Accuracy_scores["Model"].append("KNeighbors Classifier")
Accuracy_scores["Train Accuracy Score"].append(Train_accuracy)
Accuracy_scores["Test Accuracy Score"].append(Test_accuracy)
print("Train Accuracy-KNN:",Train_accuracy)
print("Test Accuracy-KNN:",Test_accuracy)

Train Accuracy-KNN: 0.9653333333333334
Test Accuracy-KNN: 0.958
```

## 3.Naive Bayes

### How it works:

- A probabilistic model based on Bayes' theorem.
- Assumes that features are independent, which is often unrealistic but works well in many cases.

#### Why it's suitable:

- Good if Sleep Disorder has strong feature-dependent probabilities.
- Less effective if there are strong feature correlations.

```
[59] gnb=GaussianNB()
gnb.fit(X_train,y_train)

[60] gnb_y_pred=gnb.predict(X_test)
Train_accuracy=accuracy_score(y_train,gnb.predict(X_train))
Test_accuracy=accuracy_score(y_test,gnb_y_pred)
Accuracy_scores["Model"].append("Naive Bayes")
Accuracy_scores["Train Accuracy Score"].append(Train_accuracy)
Accuracy_scores["Test Accuracy Score"].append(Test_accuracy)
print("Train Accuracy-GNB:",Train_accuracy)
print("Test Accuracy-GNB:",Test_accuracy)

Train Accuracy-GNB: 0.8870833333333333
Test Accuracy-GNB: 0.8873333333333333
```

## 4.Decision Tree Classifier

### How it Work :

- A Decision Tree is a supervised learning algorithm used for classification and regression tasks.
- The structure resembles a tree, with nodes representing decisions, branches representing choices, and leaves representing outcomes or predictions.

#### Why it's suitable:

- Easy to interpret and visualize, making it useful in medical applications.
- Handles non-linearly separable data.
- Can automatically capture interactions between features.
- Good for interpreting which factors influence sleep disorders.

```
[61] dtcl=DecisionTreeClassifier()
dtcl.fit(X_train,y_train)

[62] dtcl_y_pred=dtcl.predict(X_test)
Train_accuracy=accuracy_score(y_train,dtcl.predict(X_train))
Test_accuracy=accuracy_score(y_test,dtcl_y_pred)
Accuracy_scores["Model"].append("Decision Tree Classifier")
Accuracy_scores["Train Accuracy Score"].append(Train_accuracy)
Accuracy_scores["Test Accuracy Score"].append(Test_accuracy)
print("Train Accuracy-DTCL:",Train_accuracy)
print("Test Accuracy-DTCL:",Test_accuracy)

Train Accuracy-DTCL: 0.9834166666666667
Test Accuracy-DTCL: 0.9626666666666667
```

## 5.Random Forest Classifier

### How it Works:

- Random Forest is an ensemble learning method that builds multiple Decision Trees and averages their predictions to improve accuracy and reduce overfitting.
- Each tree is built on a random subset of data and features.

#### Why it's suitable:

- More accurate and robust than a single Decision Tree.

- Less prone to overfitting due to averaging across trees.
- Can handle large feature sets and complex relationships in data.

```
[63] rfc1=RandomForestClassifier()
rfc1.fit(X_train,y_train)

[64] rfc1_y_pred=rfc1.predict(X_test)
Train_accuracy=accuracy_score(y_train,rfc1.predict(X_train))
Test_accuracy=accuracy_score(y_test,rfc1_y_pred)
Accuracy_scores["Model"].append("Random Forest Classifier")
Accuracy_scores["Train Accuracy Score"].append(Train_accuracy)
Accuracy_scores["Test Accuracy Score"].append(Test_accuracy)
print("Train Accuracy-RFCL:",Train_accuracy)
print("Test Accuracy-RFCL:",Test_accuracy)

Train Accuracy-RFCL: 0.9834166666666667
Test Accuracy-RFCL: 0.9676666666666667
```

## 6. Gradient Boosting Classifier

### How it Works:

- Gradient Boosting Classifier is an ensemble learning method that builds multiple Trees.
- Builds trees sequentially, with each tree correcting the errors of the previous one.
- More powerful than Random Forest but computationally expensive.

### Why it's suitable:

- More accurate and robust.
- If your dataset has complex relationships and requires high accuracy, Gradient Boosting is likely the best.
- Works well on structured data like this.

```
[65] gbcl=GradientBoostingClassifier()
gbcl.fit(X_train,y_train)

[66] gbcl_y_pred=gbcl.predict(X_test)
Train_accuracy=accuracy_score(y_train,gbcl.predict(X_train))
Test_accuracy=accuracy_score(y_test,gbcl_y_pred)
Accuracy_scores["Model"].append("Gradient Boosting Classifier")
Accuracy_scores["Train Accuracy Score"].append(Train_accuracy)
Accuracy_scores["Test Accuracy Score"].append(Test_accuracy)
print("Train Accuracy-GBCL:",Train_accuracy)
print("Test Accuracy-GBCL:",Test_accuracy)

Train Accuracy-GBCL: 0.9641666666666666
Test Accuracy-GBCL: 0.9553333333333334
```

## MODEL EVALUATION

```
[67] from sklearn.metrics import accuracy_score,f1_score,precision_score,recall_score,confusion_matrix,classification_report

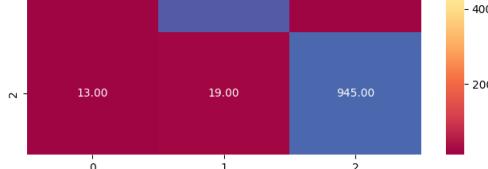
[68] # Define models
Models = [
    'Support Vector Classifier' : SVC(),
    'K-Nearest Neighbors' : KNeighborsClassifier(),
    'Naive Bayes' : GaussianNB(),
    'Decision Tree Classifier' : DecisionTreeClassifier(),
    'Random Forest Classifier' : RandomForestClassifier(),
    'Gradient Boosting Classifier' : GradientBoostingClassifier(),
]

# predictions
predictions= {
    "Support Vector Classifier":svc_y_pred,
    "K-Nearest Neighbors":knn_y_pred,
    "Naive Bayes":gnb_y_pred,
    "Decision Tree Classifier":dtcl_y_pred,
    "Random Forest Classifier":rfcl_y_pred,
    "Gradient Boosting Classifier":gbcl_y_pred
}

# Analysing the metrics
for model_name,y_pred in predictions.items():

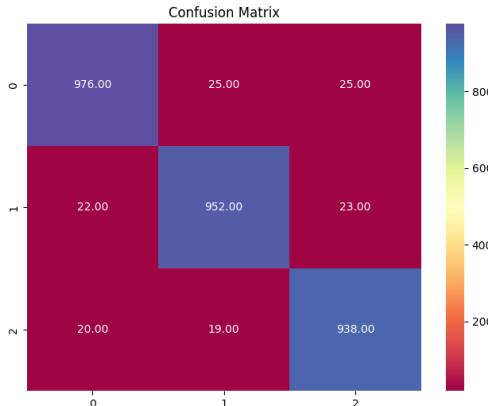
    print("Model:",model_name)
    print("Accuracy:", accuracy_score(y_test, y_pred))
    print("Classification Report :")
    print(classification_report(y_test, y_pred))

    Confusion_matrix = confusion_matrix(y_test, y_pred)
    plt.figure(figsize=(8, 6))
    sns.heatmap(Confusion_matrix, annot=True, fmt=".2f", cmap='Spectral')
    plt.title("Confusion Matrix")
    plt.show()
```



Model: Gradient Boosting Classifier  
Accuracy: 0.9553333333333334  
Classification Report :

	precision	recall	f1-score	support
Healthy	0.96	0.95	0.95	1826
Insomnia	0.96	0.95	0.96	997
Sleep Apnea	0.95	0.96	0.96	977
accuracy	0.96	0.96	0.96	3800
macro avg	0.96	0.96	0.96	3800
weighted avg	0.96	0.96	0.96	3800



### Insights:

- Random Forest Classifier model shows the highest accuracy 96.7 % indicating strong predictive capabilities.
- Decision Tree Classifier & K-Nearest Neighbors models hold the second and third highest accuracies(96.2 % and 95.8%).
- Gradient Boosting Classifier is performing well with 95.5% accuracy.
- Support Vector Classifier is also performing well and it has an accuracy of 94.7%.
- Gaussian Naive Bayes is the least performing model compared to others. It shows an accuracy of 88.7% only.

## Model Comparison

```
[69]
# predictions
predictions= {
    "Support Vector Classifier":svc_y_pred,
    "K-Nearest Neighbors":knn_y_pred,
    "Naive Bayes":gnb_y_pred,
    "Decision Tree Classifier":dtcl_y_pred,
    "Random Forest Classifier":rfcl_y_pred,
    "Gradient Boosting Classifier":gbcl_y_pred
}

# Store results
Results= {"Model":[],
          "Accuracy Score":[],
          "Precision Score":[],
          "Recall Score":[],
          "F1 Score":[]}

# Append metrics
for model_name,y_pred in predictions.items():

    Results["Model"].append(model_name)
    Results["Accuracy Score"].append(accuracy_score(y_test,y_pred))
    Results["Precision Score"].append(precision_score(y_test,y_pred,average="weighted"))
    Results["Recall Score"].append(recall_score(y_test,y_pred,average="weighted"))
    Results["F1 Score"].append(f1_score(y_test,y_pred,average="weighted"))

# Convert to DataFrame and sort results
Results=pd.DataFrame(Results)
Results.sort_values(by=["Accuracy Score"],ascending=False,inplace=True)
Results
```

	Model	Accuracy Score	Precision Score	Recall Score	F1 Score
4	Random Forest Classifier	0.967667	0.967679	0.967667	0.967665
3	Decision Tree Classifier	0.962667	0.962710	0.962667	0.962675
1	K-Nearest Neighbors	0.958000	0.958295	0.958000	0.957976
5	Gradient Boosting Classifier	0.955333	0.955355	0.955333	0.955332
0	Support Vector Classifier	0.947667	0.948005	0.947667	0.947664
2	Naive Bayes	0.887333	0.888247	0.887333	0.886825

Next steps: [Generate code with Results](#) [View recommended plots](#) [New interactive sheet](#)

#### Insights:

The table above presents the evaluation scores of different Machine Learning models. Based on the accuracy scores:

##### 1. Best Performing Model:

- Random Forest Classifier achieves the highest accuracy of 96.7 %, making it the top-performing model.

##### 2. High-Performing Models:

- Decision Tree Classifier ranks second with 96.2 % accuracy.
- K-Nearest Neighbors (KNN) follows closely in third place with 95.8% accuracy.
- Gradient Boosting Classifier holds the fourth position with 95.5% accuracy.
- Support Vector Classifier (SVC) secures the fifth position with 94.7% accuracy.

##### 3. Lowest Performing Model:

- Gaussian Naive Bayes performs the worst, with an accuracy of 88.7%, significantly lower than other models.

##### 4. Overall Observations:

- All models except Gaussian Naive Bayes achieve 90% or above accuracy, indicating strong performance across most models.

#### Analysing the models for over fitting

```
[70] # Converting the "Accuracy_scores" that we already created to a DataFrame

Accuracy_scores=pd.DataFrame(Accuracy_scores)
Accuracy_scores.sort_values(by=["Test Accuracy Score"],ascending=False,inplace=True)
Accuracy_scores
```

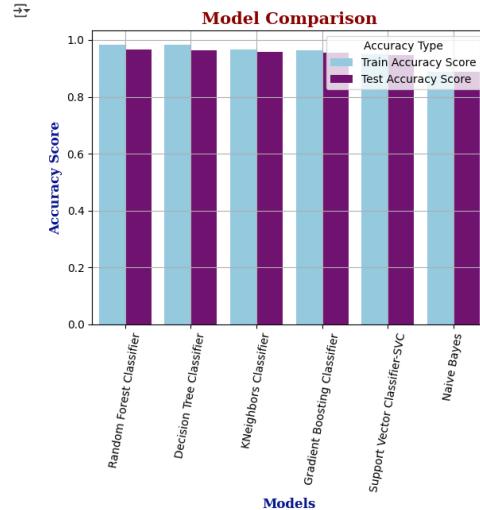
	Model	Train Accuracy Score	Test Accuracy Score
4	Random Forest Classifier	0.983417	0.967667
3	Decision Tree Classifier	0.983417	0.962667
1	KNeighbors Classifier	0.965333	0.958000
5	Gradient Boosting Classifier	0.964167	0.955333
0	Support Vector Classifier-SVC	0.948750	0.947667
2	Naive Bayes	0.887083	0.887333

Next steps: [Generate code with Accuracy\\_scores](#) [View recommended plots](#) [New interactive sheet](#)

```
[71] # Creating a DataFrame to combine 'Train Accuracy Score' and 'Test Accuracy Score' into a single column

Accuracy= pd.melt(Accuracy_scores, id_vars=['Model'], value_vars=['Train Accuracy Score', 'Test Accuracy Score'], var_name='Accuracy Type', value_name='Accuracy Score')

# Now plot using the melted DataFrame
sns.barplot(x="Model", y="Accuracy Score", hue="Accuracy Type", data=Accuracy, palette=(("Train Accuracy Score": "skyblue", "Test Accuracy Score": "purple")))
plt.xticks(rotation=90)
plt.xlabel("Models",fontdict=axis_font)
plt.ylabel("Accuracy Score",fontdict=axis_font)
plt.title("Model Comparison",fontdict=title_font)
plt.grid(True)
plt.show()
```



#### Insights:

From the bar plot it is clear that, there is no significant difference between the Train accuracy and the Test accuracy of any of the models. It indicates there is no overfitting or underfitting.

#### Regularization

Regularization is a technique in machine learning used to prevent overfitting by adding a penalty to the loss function. This ensures that the model generalizes well to unseen data. Examples for common types of regularization: L1 (Lasso) and L2 (Ridge).

Since none of the models showing overfitting, we don't need to perform any regularization techniques.

#### HYPERPARAMETER TUNING

Hyperparameter tuning is the process of selecting the best set of hyperparameters to optimize a machine learning model's performance.  
Unlike model parameters (learned from data), hyperparameters are set manually before training.

- Improves Accuracy – Finds the best settings for better predictions.
- Prevents Overfitting/Underfitting – Balances model complexity.
- Enhances Generalization – Ensures the model works well on unseen data.
- GridSearchCV, RandomizedSearchCV, and Bayesian Optimization are some methods for hyperparameter tuning.

📌 I am selecting first two best performing models and the worst performing model for hyperparameter tuning.

- Random Forest Classifier
- Decision Tree Classifier
- Gaussian Naïve Bayes

```
[72] from sklearn.model_selection import RandomizedSearchCV,GridSearchCV
      from sklearn.tree import DecisionTreeClassifier
      from sklearn.ensemble import RandomForestClassifier

[73] #Creating a dictionary to store new accuracy scores
Performance = {
    "Model": [],
    "Train Accuracy-Before Tuning": [],
    "Train Accuracy-After Tuning": [],
    "Test Accuracy-Before Tuning": [],
    "Test Accuracy-After Tuning": []
}

#Appending the accuracy score before tuning
# Random Forest Classifier
Train_accuracy_before=accuracy_score(y_train,rfcl.predict(X_train))
Test_accuracy_before=accuracy_score(y_test,rfcl_y_pred)
Performance["Model"].append("Random Forest Classifier")
Performance["Train Accuracy-Before Tuning"].append(Train_accuracy_before)
Performance["Test Accuracy-Before Tuning"].append(Test_accuracy_before)

#Decision Tree Classifier
Train_accuracy_before=accuracy_score(y_train,dctl.predict(X_train))
Test_accuracy_before=accuracy_score(y_test,dctl_y_pred)
Performance["Model"].append("Decision Tree Classifier")
Performance["Train Accuracy-Before Tuning"].append(Train_accuracy_before)
Performance["Test Accuracy-Before Tuning"].append(Test_accuracy_before)

#Gaussian Naïve Bayes
Train_accuracy_before=accuracy_score(y_train,gnb.predict(X_train))
Test_accuracy_before=accuracy_score(y_test,gnb_y_pred)
Performance["Model"].append(" Gaussian Naïve Bayes")
Performance["Train Accuracy-Before Tuning"].append(Train_accuracy_before)
Performance["Test Accuracy-Before Tuning"].append(Test_accuracy_before)
```

#### Random Forest Classifier

```
[74] # Define hyperparameters and their possible values
rf_params = {
    'n_estimators': [10,20,50,100,200],
    'max_depth': [None, 5,10,15],
    'min_samples_split': [2, 5, 10],
}

#Define Random Forest model
rf=RandomForestClassifier()
random_search_rf=RandomizedSearchCV(rf,rf_params,n_iter=10, cv=5, random_state=42)
random_search_rf.fit(X_train,y_train)

print("Best Hyperparameters:",random_search_rf.best_params_)

Best Hyperparameters: {'n_estimators': 200, 'min_samples_split': 5, 'max_depth': 15}
```

```
[75] #Training the New Random Forest model
rf_new=RandomForestClassifier(n_estimators=200, min_samples_split=5, max_depth= 15)
rf_new.fit(X_train,y_train)

RandomForestClassifier(max_depth=15, min_samples_split=5, n_estimators=200)
```

```
[76] # Predictions with the New Random Forest model
rf_new_y_pred=rf_new.predict(X_test)
Train_accuracy_after=accuracy_score(y_train,rf_new.predict(X_train))
Test_accuracy_after=accuracy_score(y_test,rf_new_y_pred)
Performance["Train Accuracy-After Tuning"].append(Train_accuracy_after)
Performance["Test Accuracy-After Tuning"].append(Test_accuracy_after)
```

#### Decision Tree Classifier

```
[77] # Define hyperparameters and their possible values
dt_params = {
    'criterion': ['gini', 'entropy'],
    'max_depth': [3, 5, 10, None],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}

#Define Random Forest model
dt=DecisionTreeClassifier()
random_search_dt=RandomizedSearchCV(dt,dt_params,n_iter=10, cv=5, random_state=42)
random_search_dt.fit(X_train,y_train)

print("Best Hyperparameters:",random_search_dt.best_params_)

Best Hyperparameters: {'min_samples_split': 5, 'min_samples_leaf': 1, 'max_depth': None, 'criterion': 'gini'}
```

```
[78] #Training the New Decision Tree model
dt_new=DecisionTreeClassifier(min_samples_split=5, min_samples_leaf= 1, max_depth= None, criterion='gini')
dt_new.fit(X_train,y_train)

DecisionTreeClassifier(min_samples_split=5)
```

```
[79] # Predictions with the New Decision Tree model
dt_new_y_pred=dt_new.predict(X_test)
Train_accuracy_after=accuracy_score(y_train,dt_new.predict(X_train))
Test_accuracy_after=accuracy_score(y_test,dt_new_y_pred)
Performance["Train Accuracy-After Tuning"].append(Train_accuracy_after)
Performance["Test Accuracy-After Tuning"].append(Test_accuracy_after)
```

#### Gaussian Naïve Bayes

```
[80] # Define hyperparameters and their possible values
gnb_params = {
    'var_smoothing': np.logspace(-9, 0, 50)
}

#Define Gaussian Naïve Bayes
gnb = GaussianNB()
grid_search_gnb=GridSearchCV(gnb,gnb_params, cv=5, scoring='accuracy', n_jobs=-1)
grid_search_gnb.fit(X_train,y_train)

print("Best Hyperparameters:",grid_search_gnb.best_params_)

Best Hyperparameters: {'var_smoothing': np.float64(0.014563484775012445)}
```

```
[81] gnb_new=GaussianNB(var_smoothing=np.float64(0.014563484775012445))
gnb_new.fit(X_train,y_train)

GaussianNB(var_smoothing=np.float64(0.014563484775012445))
```

```
[82] # Predictions with the New Gaussian Naïve Bayes model
gnb_new_y_pred=gnb_new.predict(X_test)
Train_accuracy_after=accuracy_score(y_train,gnb_new.predict(X_train))
Test_accuracy_after=accuracy_score(y_test,gnb_new_y_pred)
Performance["Train Accuracy-After Tuning"].append(Train_accuracy_after)
Performance["Test Accuracy-After Tuning"].append(Test_accuracy_after)
```

```
[83] Performance=pd.DataFrame(Performance)
```

	Model	Train Accuracy-Before Tuning	Train Accuracy-After Tuning	Test Accuracy-Before Tuning	Test Accuracy-After Tuning
0	Random Forest Classifier	0.983417	0.982750	0.967667	0.970333

1	Decision Tree Classifier	0.983417	0.982333	0.962667	0.962667
2	Gaussian Naive Bayes	0.887063	0.899167	0.887333	0.899333

Next steps: [Generate code with Performance](#) [View recommended plots](#) [New interactive sheet](#)

The table shows the train and test accuracy scores before and after hyper parameter tuning.

- Overall, hyperparameter tuning did not result in significant accuracy improvements for most models.

#### Random Forest Classifier:

- The Test accuracy Random Forest Classifier is slightly increased from 96.7 to 97 % after hyperparameter tuning.

#### Decision Tree Classifier:

- The test accuracy of the Decision Tree classifier remained the same (96.2%) even after hyperparameter tuning.

#### Gaussian Naive Bayes (GNB):

- Significant Improvement after hyperparameter tuning.
- Both Train accuracy and Test accuracy has increased significantly for Gaussian Naive Bayes model.
- The Test accuracy increased from 88.7 to 89.9 %.

[84]	Best_Model=Performance.sort_values(by=["Test Accuracy-After Tuning"], ascending=False).head(1)	Best_Model	Model	Train Accuracy-Before Tuning	Train Accuracy-After Tuning	Test Accuracy-Before Tuning	Test Accuracy-After Tuning	
0	Random Forest Classifier	0.983417	0.98275	0.967667	0.970333	0.967667	0.970333	

#### Best performing Model:

- Best Model: Random Forest Classifier
- Best Hyperparameters: n\_estimators= 200, min\_samples\_split= 5, max\_depth= 15
- Best Accuracy: 97 %

### SAVE THE MODEL

[85]	# Importing library import joblib  # Saving the trained model joblib.dump(rf_new, "The_Best_Model.joblib") print("Best Model:","Random Forest Classifier") print("Best Hyperparameters:","n_estimators= 200, min_samples_split= 5, max_depth= 15") print("Best Accuracy:","accuracy_score(y_test,rf_new_y_pred)") print("Model saved successfully!")
27	Best Model: Random Forest Classifier Best Hyperparameters: n_estimators= 200, min_samples_split= 5, max_depth= 15 Best Accuracy: 0.9703333333333334 Model saved successfully!

### Pipeline For ML Model

A machine learning pipeline was implemented to automate data preprocessing, feature selection, and model training, ensuring efficiency and reproducibility.

- Data Preprocessing: Missing values were handled using an imputer, feature encoding is performed by OneHotEncoder and feature scaling was applied using StandardScaler
- Feature Selection: Feature Selection Using Random Forest was used to select the most relevant features.
- Model Training: Random Forest was chosen as the final model after hyperparameter tuning.

[86]	from sklearn.pipeline import Pipeline from sklearn.compose import ColumnTransformer from sklearn.impute import SimpleImputer from sklearn.preprocessing import OneHotEncoder, StandardScaler from sklearn.feature_selection import SelectFromModel from sklearn.ensemble import RandomForestClassifier from sklearn.model_selection import train_test_split from imblearn.pipeline import Pipeline as ImbPipeline import pandas as pd import joblib  # Splitting the data to features and target. 'df' is the dataframe. X = df.drop(columns=["Sleep Disorder"]) # Features y = df["Sleep Disorder"] # Target variable  # Split data into training and testing sets X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)  # Identify numerical and categorical columns numerical_features = X.select_dtypes(include=['int64', 'float64']).columns categorical_features = X.select_dtypes(include=['object', 'category']).columns  # Define transformations num_transformer = Pipeline([ ('imputer', SimpleImputer(strategy='mean')), # Handle missing numerical values ('scaler', StandardScaler()) # Scale numerical features ])  cat_transformer = Pipeline([ ('imputer', SimpleImputer(strategy='most_frequent')), # Handle missing categorical values ('encoder', OneHotEncoder(handle_unknown="ignore", sparse_output=False)) # One-hot encoder for categorical features ])  # Combine transformations preprocessor = ColumnTransformer([ ('num', num_transformer, numerical_features), ('cat', cat_transformer, categorical_features) ])  # Define the pipeline pipeline = ImbPipeline([ ('preprocessor', preprocessor), ('feature_selection', SelectFromModel(RandomForestClassifier(n_estimators=200, random_state=42), threshold=0.02)), ('classifier', joblib.load("The_Best_Model.joblib")) ])  # Train the pipeline pipeline.fit(X_train, y_train)
27	

[87]	# Saving the Pipeline joblib.dump(pipeline, 'Sleep_Health_Analysis_pipeline.joblib') print("Pipeline saved successfully!")
27	Pipeline saved successfully!

### TEST WITH UNSEEN DATA

[88]	#Loading the unseen data unseen_data=pd.read_csv("/content/Unseen_Data.csv") unseen_data.head()	Gender	Age	Occupation	Sleep Duration	Quality of Sleep	Physical Activity Level	Stress Level	BMI Category	Blood Pressure	Heart Rate	Daily Steps	
0	Female	44.0	Teacher	6.55	6	45	6	Overweight	135/90	68	6000		
1	Female	32.0	Scientist	6.75	6	54	7	Normal	131/86	76	6600		
2	Female	18.0	Teacher	7.10	6	56	4	Normal	135/80	75	6500		

1	Female	40.0	Teacher	1.40	0	30	4	Normal	130/85	70	6500
3	Male	35.0	Lawyer	6.65	7	45	6	Normal	130/85	70	6500
4	Female	44.0	Nurse	6.75	6	75	6	Obese	140/95	78	6650

Next steps: [Generate code with unseen\\_data](#) [View recommended plots](#) [New interactive sheet](#)

✓ [89] `unseen_data.info()`

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 20 entries, 0 to 19
Data columns (total 11 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   Gender          20 non-null      object  
 1   Age              20 non-null      float64 
 2   Occupation       20 non-null      object  
 3   Sleep Duration   20 non-null      float64 
 4   Quality of Sleep 20 non-null      int64  
 5   Physical Activity Level 20 non-null      int64  
 6   Stress Level     20 non-null      int64  
 7   BMI Category    20 non-null      object  
 8   Blood Pressure   20 non-null      object  
 9   Heart Rate       20 non-null      int64  
 10  Daily Steps     20 non-null      int64  
dtypes: float64(2), int64(5), object(4)
memory usage: 1.8+ KB
```

✓ [90] `#Testing with Unseen Data`

```
# Load the saved pipeline
loaded_pipe = joblib.load('Sleep_Health_Analysis_pipeline.joblib')

# Make predictions on the test data
predictions = loaded_pipe.predict(unseen_data)

# Print the predictions
print(predictions)
```

```
['Insomnia' 'Sleep Apnea' 'Insomnia' 'Healthy' 'Sleep Apnea' 'Sleep Apnea'
```

```
'Healthy' 'Healthy' 'Healthy' 'Healthy' 'Healthy' 'Insomnia'
```

```
'Sleep Apnea' 'Sleep Apnea' 'Sleep Apnea' 'Sleep Apnea' 'Insomnia'
```

```
'Insomnia' 'Sleep Apnea']
```

## ✓ Insights

Random Forest Classifier successfully predicted all three target classes. Out of 20 predictions:

- Healthy = 7
- Insomnia = 5
- Sleep Apnea=8

Which indicates the Random Forest Classifier effectively identifies patterns and distinguishes between different sleep conditions.

## ✓ CONCLUSION :

- The Random Forest Classifier achieved 97 % accuracy, the highest among all six models. This demonstrates its strong ability to predict Sleep Disorders based on various features.
- When tested with unseen data, the Random Forest Classifier successfully predicted all three target classes: "Healthy," "Insomnia," and "Sleep Apnea." This indicates that the model effectively identifies patterns and distinguishes between different sleep conditions.
- The dataset was well-balanced, with no missing values or duplicates. Various preprocessing techniques such as encoding, feature selection, and scaling contributed to all models achieving over 90% accuracy, except for the Gaussian Naive Bayes model.
- Hyperparameter tuning had no significant impact on the performance of the Random Forest Classifier and Decision Tree Classifier. These models remained the top performers, each achieving over 96% accuracy.
- Gaussian Naive Bayes showed a dramatic improvement after hyperparameter tuning, with accuracy increasing from 88.7% to 89.9%, highlighting the importance of tuning for this model.

## ✓ FUTURE WORK:

- **Model Updates:** Periodically update the model with new data to ensure it adapts to changing trends and behaviors over time.
- **Imbalanced Data Handling:** Implement resampling techniques, like oversampling or undersampling, to address any class imbalances in the dataset, ensuring the model is not biased.
- **Feature Engineering:** Consider adding more features or engineering existing ones to capture more nuanced patterns that could enhance the model's predictive power.

### Best Model:

The Random Forest Classifier model, with an accuracy of 97 %, has been saved as `The_Best_Model.joblib` for future use.

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