

Heart Failure Prediction

Context

Cardiovascular diseases (CVDs) are the number 1 cause of death globally, taking an estimated 17.9 million lives each year, which accounts for 31% of all deaths worldwide. Four out of 5 CVD deaths are due to heart attacks and strokes, and one-third of these deaths occur prematurely in people under 70 years of age. Heart failure is a common event caused by CVDs and this dataset contains 11 features that can be used to predict a possible heart disease.

People with cardiovascular disease or who are at high cardiovascular risk (due to the presence of one or more risk factors such as hypertension, diabetes, hyperlipidaemia or already established disease) need early detection and management wherein a machine learning model can be of great help.

Attribute Information

1. Age: age of the patient [years]
2. Sex: sex of the patient [M: Male, F: Female]
3. ChestPainType: chest pain type [TA: Typical Angina, ATA: Atypical Angina, NAP: Non-Anginal Pain, ASY: Asymptomatic]
4. RestingBP: resting blood pressure [mm Hg]
5. Cholesterol: serum cholesterol [mm/dl]
6. FastingBS: fasting blood sugar [1: if FastingBS > 120 mg/dl, 0: otherwise]
7. RestingECG: resting electrocardiogram results [Normal: Normal, ST: having ST-T wave abnormality (T wave inversions and/or ST elevation or depression of > 0.05 mV), LVH: showing probable or definite left ventricular hypertrophy by Estes' criteria]
8. MaxHR: maximum heart rate achieved [Numeric value between 60 and 202]
9. ExerciseAngina: exercise-induced angina [Y: Yes, N: No]
10. Oldpeak: oldpeak = ST [Numeric value measured in depression]
11. ST_Slope: the slope of the peak exercise ST segment [Up: upsloping, Flat: flat, Down: downsloping]
12. HeartDisease: output class [1: heart disease, 0: Normal]

Data Analysis

Importing Libraries

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

import warnings
warnings.filterwarnings('ignore')
```

```
In [2]: # Load dataset
df = pd.read_csv('heart.csv')

# read initial data from dataframe
df.head()
```

Out[2]:

	Age	Sex	ChestPainType	RestingBP	Cholesterol	FastingBS	RestingECG	MaxHR	Exercise/
0	40	M	ATA	140	289	0	Normal	172	
1	49	F	NAP	160	180	0	Normal	156	
2	37	M	ATA	130	283	0	ST	98	
3	48	F	ASY	138	214	0	Normal	108	
4	54	M	NAP	150	195	0	Normal	122	



```
In [3]: # Last five records in dataframe
df.tail()
```

Out[3]:

	Age	Sex	ChestPainType	RestingBP	Cholesterol	FastingBS	RestingECG	MaxHR	Exercise/
913	45	M	TA	110	264	0	Normal	132	
914	68	M	ASY	144	193	1	Normal	141	
915	57	M	ASY	130	131	0	Normal	115	
916	57	F	ATA	130	236	0	LVH	174	
917	38	M	NAP	138	175	0	Normal	173	



Exploratory Data Analysis (EDA)

```
In [4]: # dataframe information  
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>  
RangeIndex: 918 entries, 0 to 917  
Data columns (total 12 columns):  
 #   Column           Non-Null Count  Dtype     
---  --    
 0   Age              918 non-null    int64    
 1   Sex              918 non-null    object    
 2   ChestPainType   918 non-null    object    
 3   RestingBP        918 non-null    int64    
 4   Cholesterol     918 non-null    int64    
 5   FastingBS       918 non-null    int64    
 6   RestingECG      918 non-null    object    
 7   MaxHR            918 non-null    int64    
 8   ExerciseAngina  918 non-null    object    
 9   Oldpeak          918 non-null    float64   
 10  ST_Slope         918 non-null    object    
 11  HeartDisease    918 non-null    int64    
 dtypes: float64(1), int64(6), object(5)  
memory usage: 86.2+ KB
```

```
In [5]: # columns in dataframe  
df.columns
```

```
Out[5]: Index(['Age', 'Sex', 'ChestPainType', 'RestingBP', 'Cholesterol', 'FastingBS',  
             'RestingECG', 'MaxHR', 'ExerciseAngina', 'Oldpeak', 'ST_Slope',  
             'HeartDisease'],  
            dtype='object')
```

```
In [6]: # stats behind dataset  
df.describe()
```

Out[6]:

	Age	RestingBP	Cholesterol	FastingBS	MaxHR	Oldpeak	HeartDisease
count	918.000000	918.000000	918.000000	918.000000	918.000000	918.000000	918.000000
mean	53.510893	132.396514	198.799564	0.233115	136.809368	0.887364	0.553377
std	9.432617	18.514154	109.384145	0.423046	25.460334	1.066570	0.497414
min	28.000000	0.000000	0.000000	0.000000	60.000000	-2.600000	0.000000
25%	47.000000	120.000000	173.250000	0.000000	120.000000	0.000000	0.000000
50%	54.000000	130.000000	223.000000	0.000000	138.000000	0.600000	1.000000
75%	60.000000	140.000000	267.000000	0.000000	156.000000	1.500000	1.000000
max	77.000000	200.000000	603.000000	1.000000	202.000000	6.200000	1.000000

```
In [7]: # stats behind dataset including object datatype  
df.describe(include='object')
```

Out[7]:

	Sex	ChestPainType	RestingECG	ExerciseAngina	ST_Slope
count	918	918	918	918	918
unique	2	4	3	2	3
top	M	ASY	Normal	N	Flat
freq	725	496	552	547	460

```
In [8]: # identifying unique values in every columns  
df.nunique()
```

Out[8]:

Age	50
Sex	2
ChestPainType	4
RestingBP	67
Cholesterol	222
FastingBS	2
RestingECG	3
MaxHR	119
ExerciseAngina	2
Oldpeak	53
ST_Slope	3
HeartDisease	2
dtype: int64	

```
In [9]: # checking null values  
df.isna().sum()
```

Out[9]:

Age	0
Sex	0
ChestPainType	0
RestingBP	0
Cholesterol	0
FastingBS	0
RestingECG	0
MaxHR	0
ExerciseAngina	0
Oldpeak	0
ST_Slope	0
HeartDisease	0
dtype: int64	

```
In [10]: # correlation between features  
df.corr()
```

Out[10]:

	Age	RestingBP	Cholesterol	FastingBS	MaxHR	Oldpeak	HeartDisease
Age	1.000000	0.254399	-0.095282	0.198039	-0.382045	0.258612	0.282039
RestingBP	0.254399	1.000000	0.100893	0.070193	-0.112135	0.164803	0.107589
Cholesterol	-0.095282	0.100893	1.000000	-0.260974	0.235792	0.050148	-0.232741
FastingBS	0.198039	0.070193	-0.260974	1.000000	-0.131438	0.052698	0.267291
MaxHR	-0.382045	-0.112135	0.235792	-0.131438	1.000000	-0.160691	-0.400421
Oldpeak	0.258612	0.164803	0.050148	0.052698	-0.160691	1.000000	0.403951
HeartDisease	0.282039	0.107589	-0.232741	0.267291	-0.400421	0.403951	1.000000

```
In [11]: # make a groupby object for ChestPainType column  
by_cpt = df.groupby('ChestPainType')
```

```
# mean of every chest pain  
by_cpt.mean()
```

Out[11]:

ChestPainType	Age	RestingBP	Cholesterol	FastingBS	MaxHR	Oldpeak	HeartDiseas
ASY	54.959677	133.229839	186.645161	0.284274	128.477823	1.162702	0.79032
ATA	49.242775	130.624277	233.046243	0.109827	150.208092	0.307514	0.13872
NAP	53.310345	130.960591	197.438424	0.201970	143.236453	0.674877	0.35468
TA	54.826087	136.413043	207.065217	0.282609	147.891304	1.036957	0.43478

```
In [12]: # groupby of 'RestingECG' column  
by_recg = df.groupby('RestingECG')
```

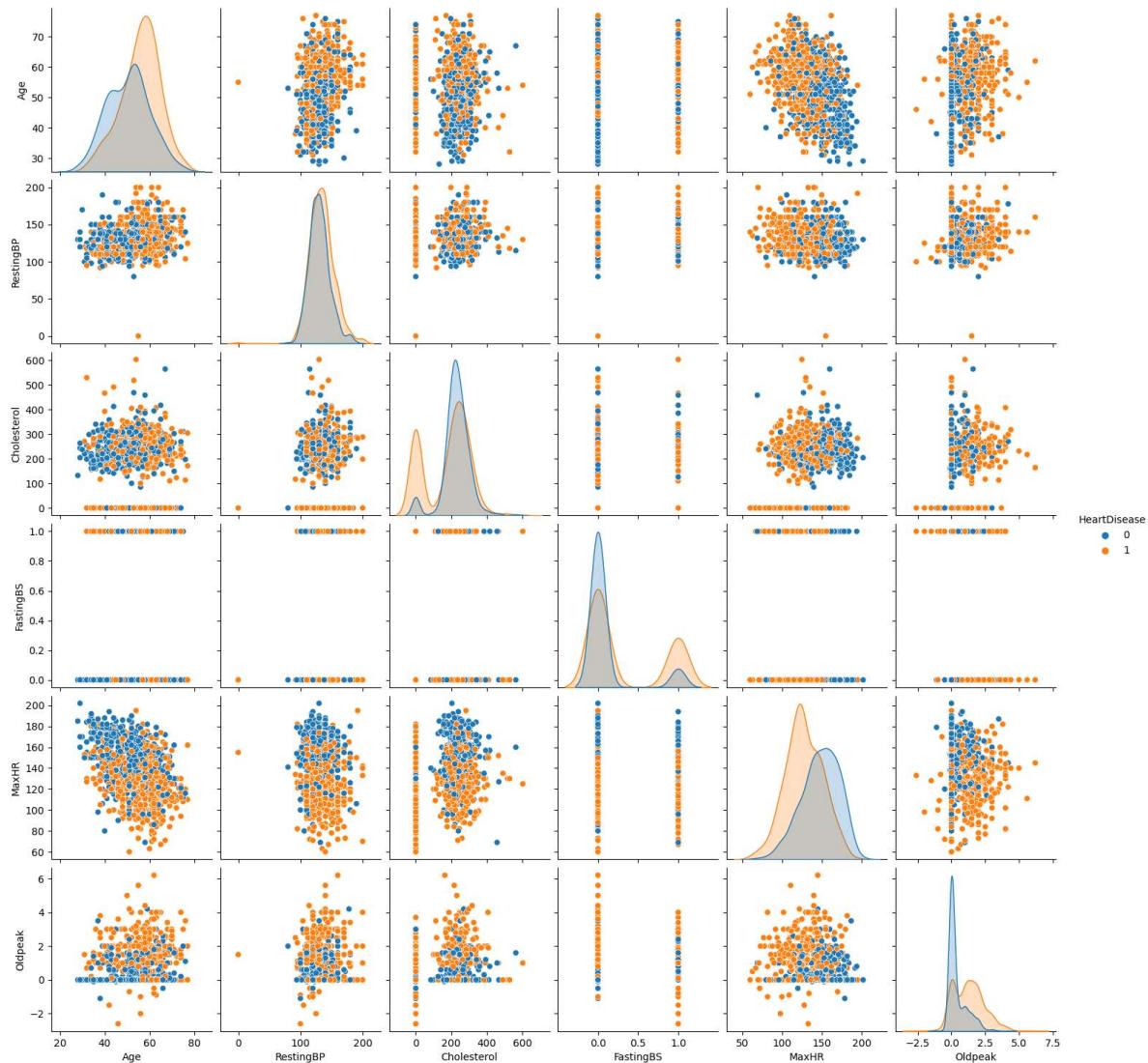
```
# mean of every resting ecg type  
by_recg.mean()
```

Out[12]:

RestingECG	Age	RestingBP	Cholesterol	FastingBS	MaxHR	Oldpeak	HeartDisease
LVH	56.218085	134.335106	236.946809	0.223404	143.117021	1.069681	0.563830
Normal	51.740942	130.635870	195.375000	0.201087	137.302536	0.786051	0.516304
ST	56.140449	135.808989	169.129213	0.342697	128.617978	1.008989	0.657303

```
In [13]: # make a pairplot for complete dataframe  
sns.pairplot(df,hue='HeartDisease')
```

Out[13]: <seaborn.axisgrid.PairGrid at 0x2357fec0550>

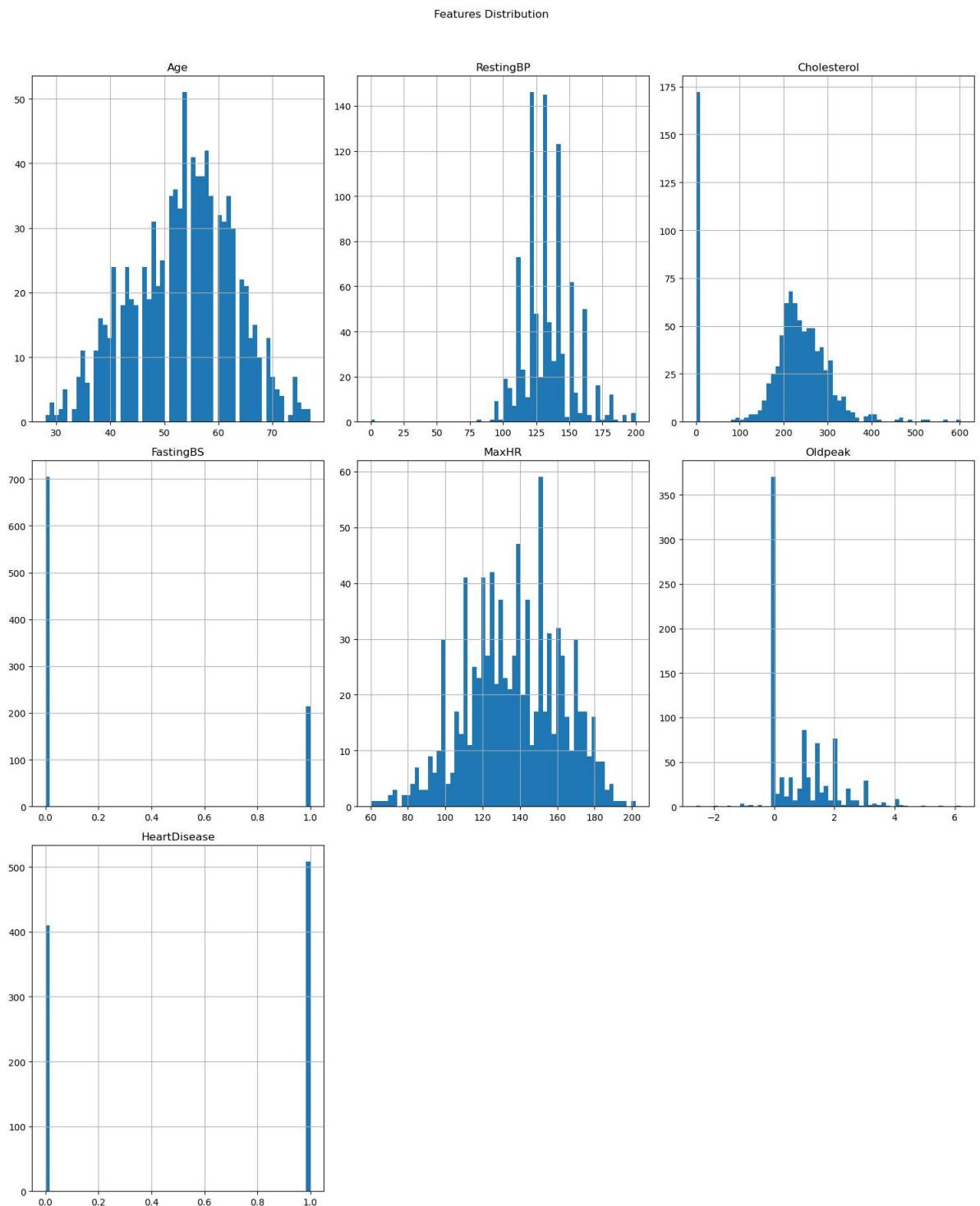


Univariate Analysis

```
In [14]: # making a features distribution histogram plot
df.hist(figsize=(15,18),bins=60)

# adding title
plt.suptitle('Features Distribution',x=0.5,y=1.02,ha='center',fontsize='large')

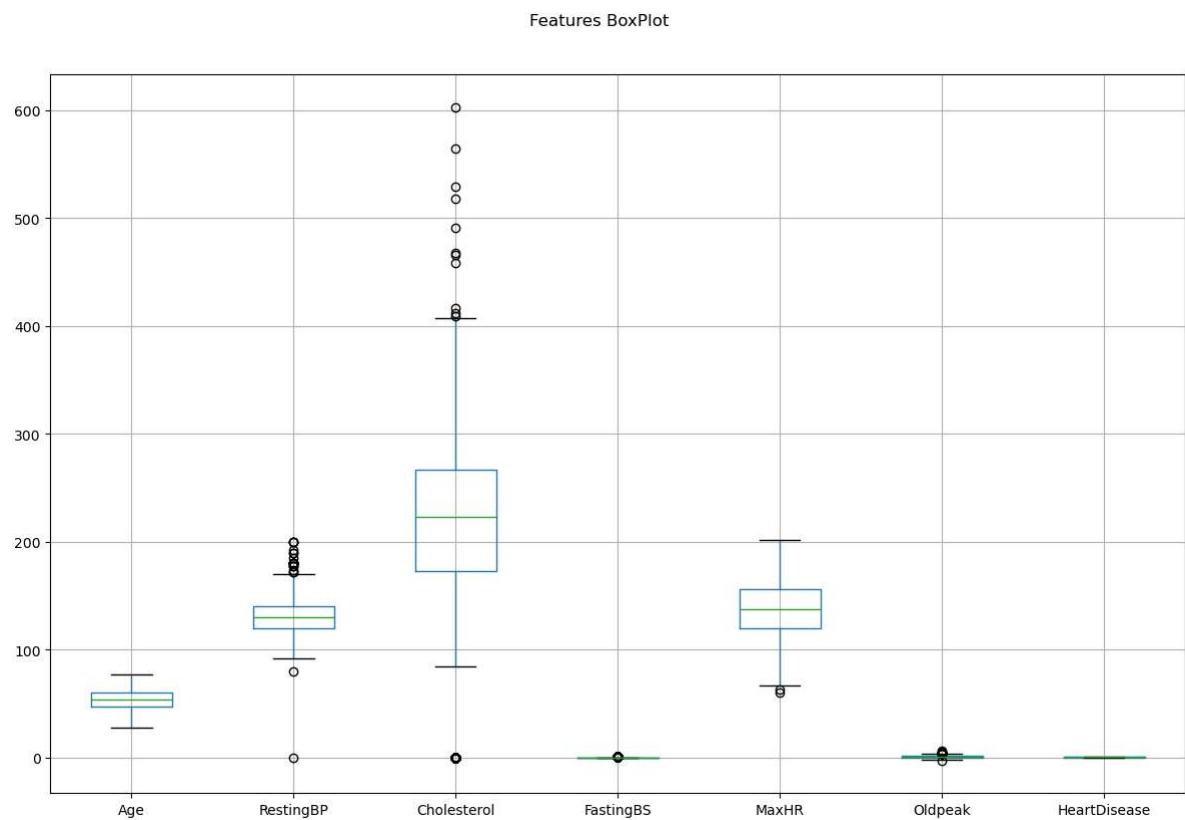
# adjust the plots gaps
plt.tight_layout()
```



```
In [15]: # making boxplot for all features
df.boxplot(figsize=(12,8))

# adding title
plt.suptitle('Features BoxPlot',x=0.5,y=1.02,ha='center',fontsize='large')

# adjust the plots gaps
plt.tight_layout()
```



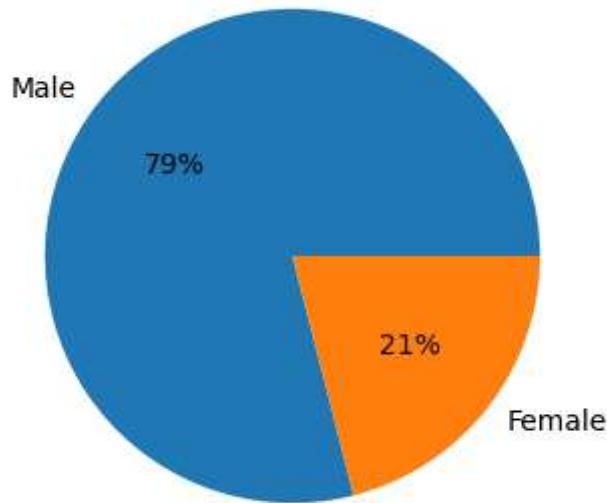
```
In [16]: # List for the sex column
gender = ['Male', 'Female']

# make an object which store value count of the elements in sex column
gender_data = pd.Series(df['Sex']).value_counts()

# adjust size of the pie chart
plt.figure(figsize=(4,4))

# plotting pie chart
plt.pie(gender_data, labels=gender, autopct='%.0f%%')
```

```
Out[16]: ([<matplotlib.patches.Wedge at 0x235059cfe50>,
<matplotlib.patches.Wedge at 0x235059db550>],
[Text(-0.8686626780128878, 0.6748519480800795, 'Male'),
Text(0.8686626780128874, -0.67485194808008, 'Female')],
[Text(-0.47381600618884784, 0.3681010625891342, '79%'),
Text(0.4738160061888476, -0.3681010625891345, '21%')])
```



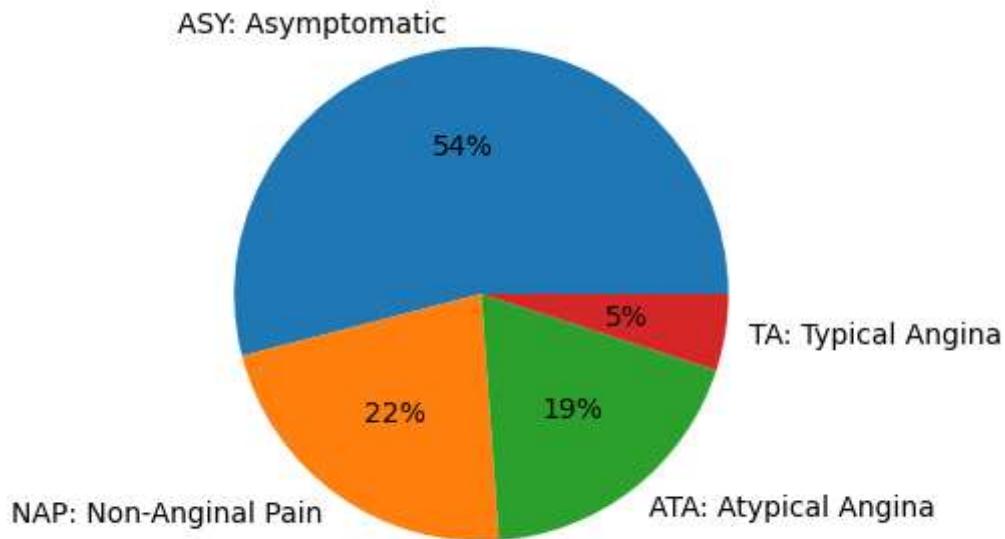
```
In [17]: # List for the chest pain type column
chest_pain = ['ASY: Asymptomatic', 'NAP: Non-Anginal Pain', 'ATA: Atypical Ang
             'TA: Typical Angina']

# make an object which store value count of the elements in chest pain type co
cp_data = pd.Series(df['ChestPainType']).value_counts()

# adjust size of the pie chart
plt.figure(figsize=(4,4))

# plotting pie chart
plt.pie(cp_data,labels=chest_pain,autopct='%.0f%%')
```

```
Out[17]: ([<matplotlib.patches.Wedge at 0x23505a1f370>,
<matplotlib.patches.Wedge at 0x23505a1fa90>,
<matplotlib.patches.Wedge at 0x23505a2a1f0>,
<matplotlib.patches.Wedge at 0x23505a2a910>],
[Text(-0.13891224983042616, 1.0911935606697143, 'ASY: Asymptomatic'),
Text(-0.641681260491555, -0.8934456670296014, 'NAP: Non-Anginal Pain'),
Text(0.677820807686612, -0.8663480551528173, 'ATA: Atypical Angina'),
Text(1.0863982306333049, -0.1724496578043122, 'TA: Typical Angina')],
[Text(-0.07577031808932334, 0.5951964876380259, '54%'),
Text(-0.35000796026812087, -0.48733400019796436, '22%'),
Text(0.3697204405563338, -0.4725534846288094, '19%'),
Text(0.5925808530727117, -0.09406344971144302, '5%')])
```



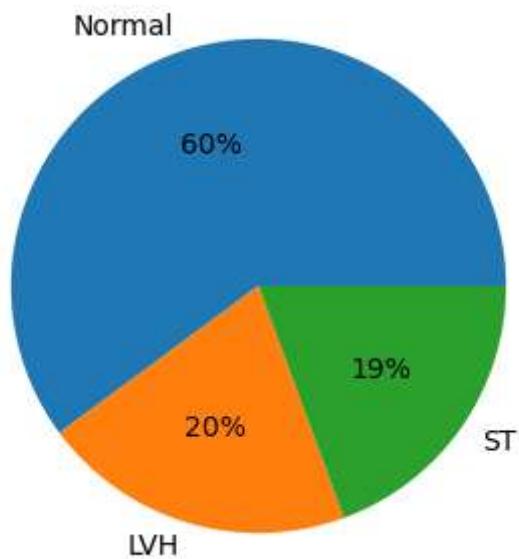
```
In [18]: # List for the resting ecg column
rest_ecg = ['Normal','LVH','ST']

# make an object which store value count of the elements in chest pain type co
recg_data = pd.Series(df['RestingECG']).value_counts()

# adjust size of the pie chart
plt.figure(figsize=(4,4))

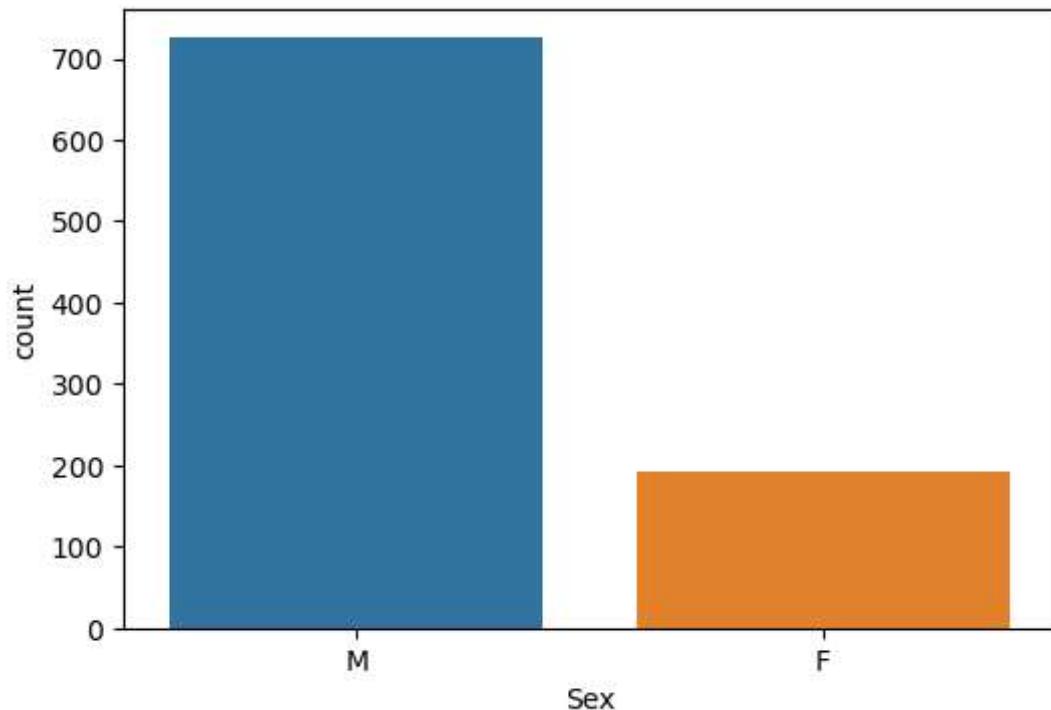
# plotting pie chart
plt.pie(recg_data,labels=rest_ecg,autopct='%.0f%%')
```

```
Out[18]: ([<matplotlib.patches.Wedge at 0x23505a6e8b0>,
<matplotlib.patches.Wedge at 0x23505a6efd0>,
<matplotlib.patches.Wedge at 0x23505a79730>],
[Text(-0.34421212269343693, 1.0447573950879114, 'Normal'),
Text(-0.31548342260471296, -1.0537885034776269, 'LVH'),
Text(0.9021455870071273, -0.6293912454456019, 'ST')],
[Text(-0.18775206692369284, 0.5698676700479517, '60%'),
Text(-0.17208186687529795, -0.5747937291696146, '20%'),
Text(0.4920794110947967, -0.34330431569760095, '19%')])
```



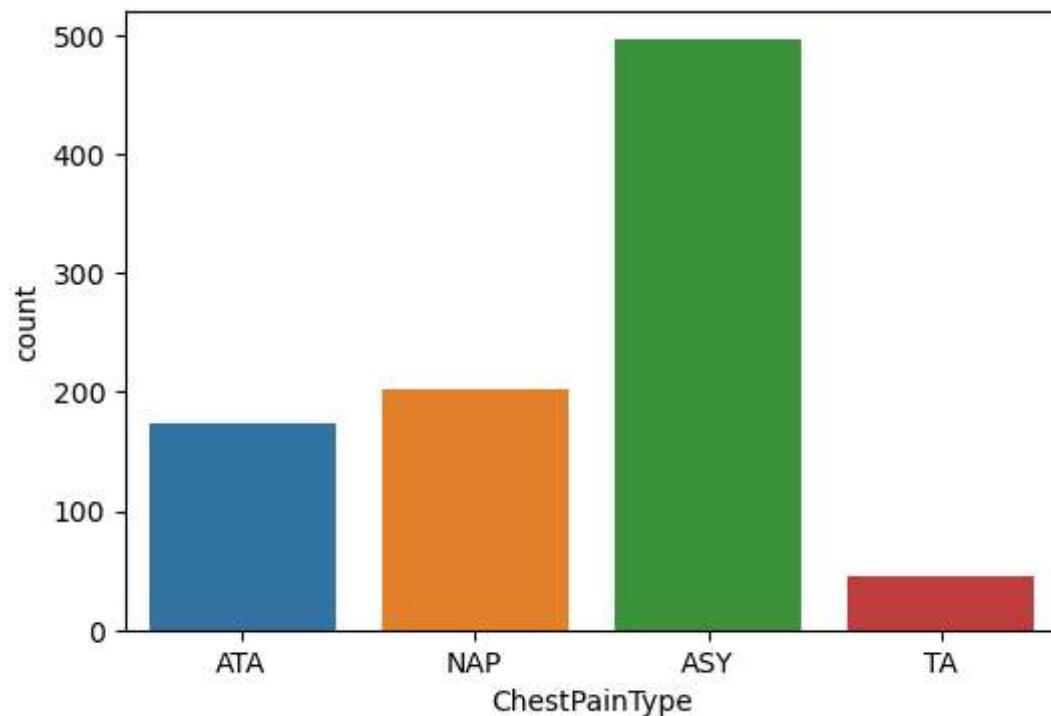
```
In [19]: # count plot for sex column  
plt.figure(figsize=(6,4))  
sns.countplot(data=df,x='Sex')
```

```
Out[19]: <AxesSubplot:xlabel='Sex', ylabel='count'>
```



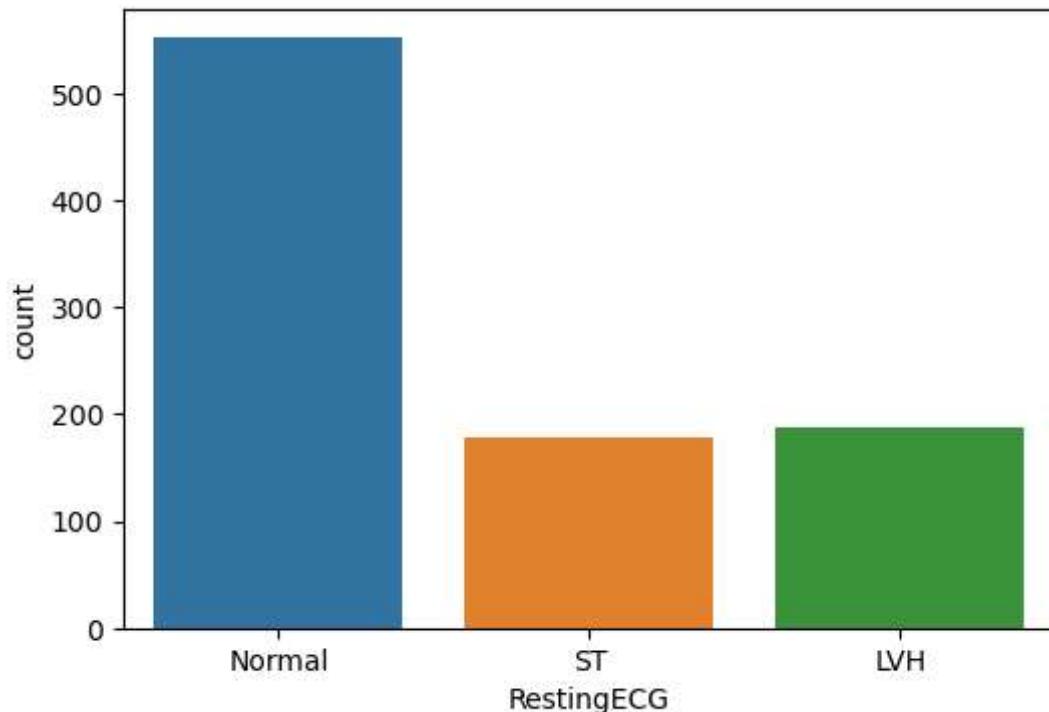
```
In [20]: # count plot for chest pain type column  
plt.figure(figsize=(6,4))  
sns.countplot(data=df,x='ChestPainType')
```

```
Out[20]: <AxesSubplot:xlabel='ChestPainType', ylabel='count'>
```



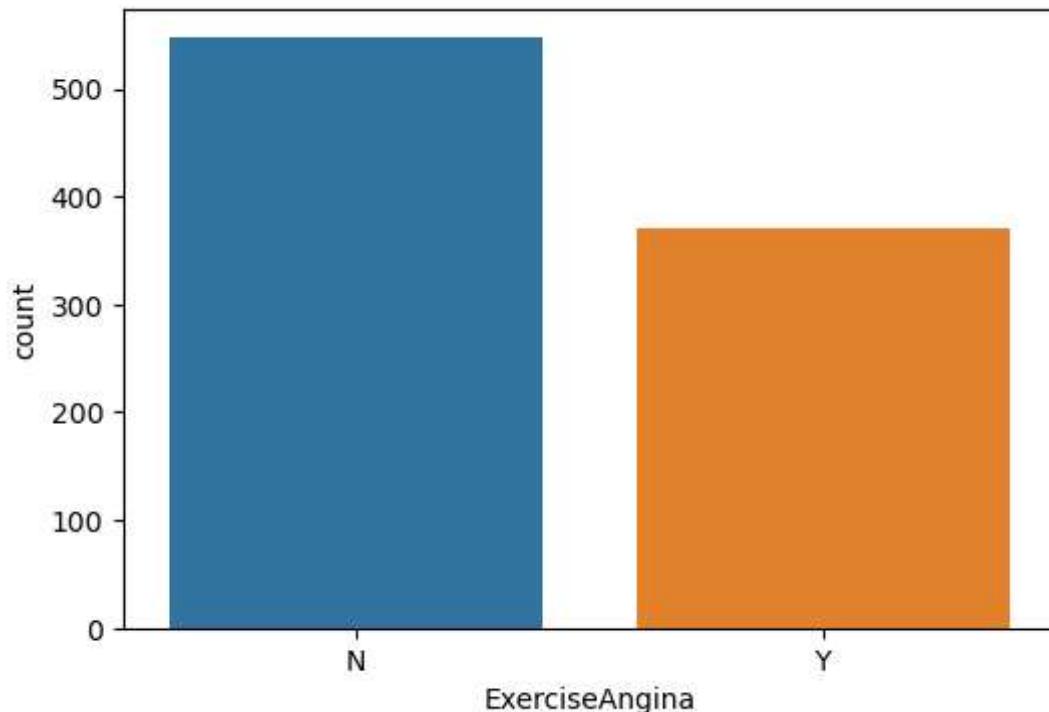
```
In [21]: # count plot for resting ecg column  
plt.figure(figsize=(6,4))  
sns.countplot(data=df,x='RestingECG')
```

```
Out[21]: <AxesSubplot:xlabel='RestingECG', ylabel='count'>
```



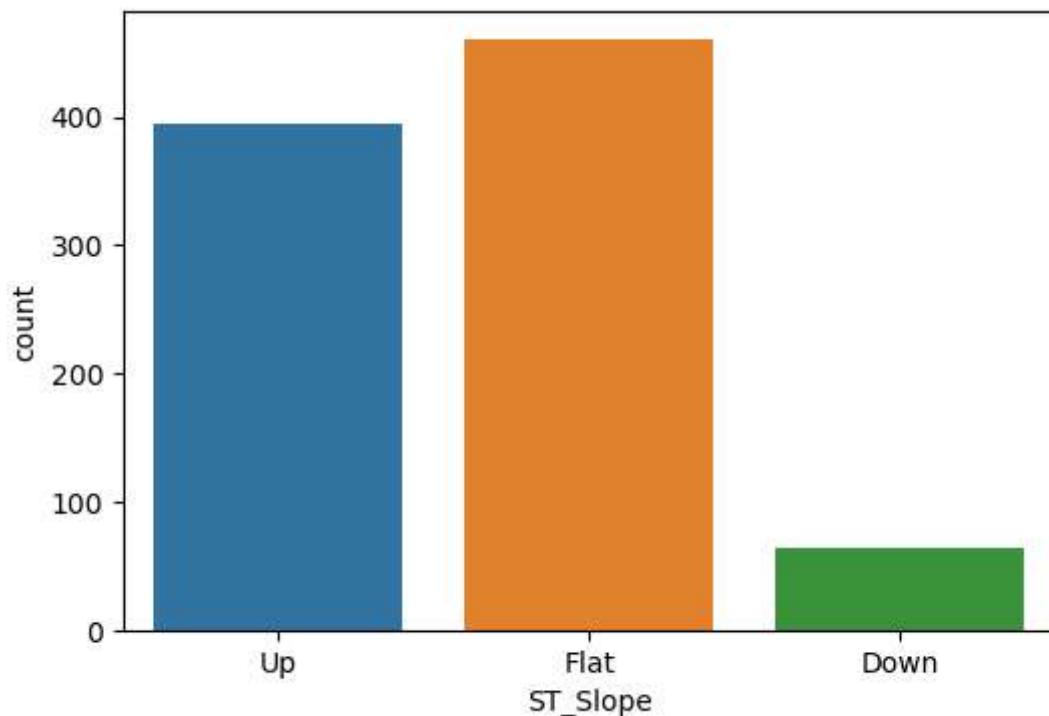
```
In [22]: # count plot for excercise angina column  
plt.figure(figsize=(6,4))  
sns.countplot(data=df,x='ExerciseAngina')
```

```
Out[22]: <AxesSubplot:xlabel='ExerciseAngina', ylabel='count'>
```



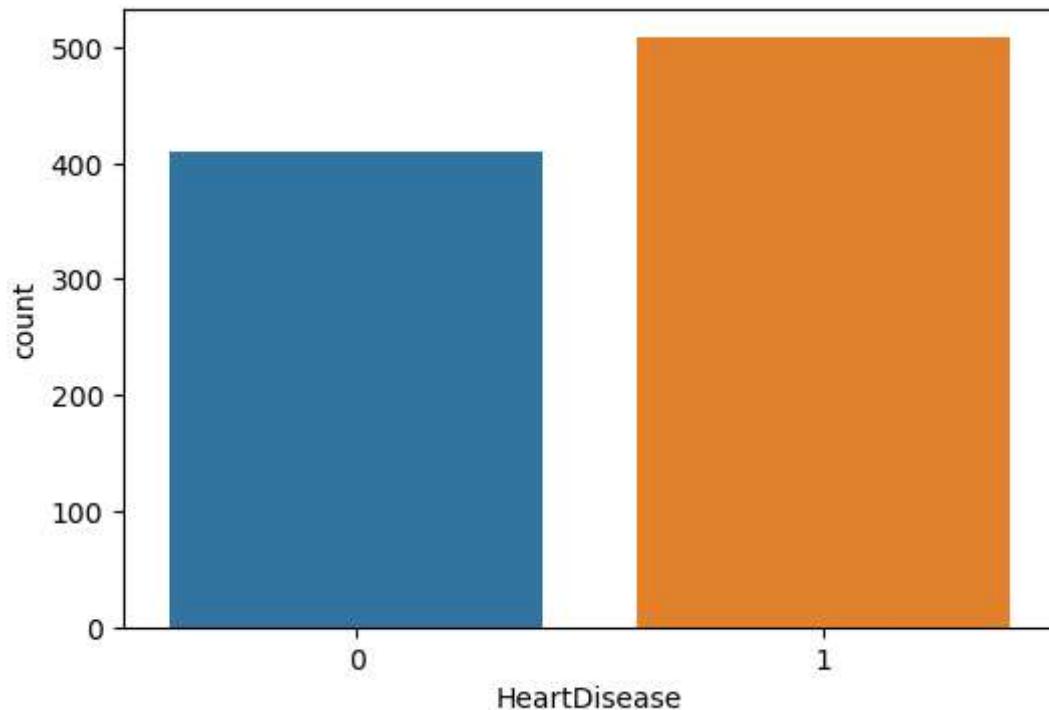
```
In [23]: # count plot for st_slope column  
plt.figure(figsize=(6,4))  
sns.countplot(data=df,x='ST_Slope')
```

```
Out[23]: <AxesSubplot:xlabel='ST_Slope', ylabel='count'>
```



```
In [24]: # count plot for heart disease column  
plt.figure(figsize=(6,4))  
sns.countplot(data=df,x='HeartDisease')
```

```
Out[24]: <AxesSubplot:xlabel='HeartDisease', ylabel='count'>
```



```
In [25]: df.columns
```

```
Out[25]: Index(['Age', 'Sex', 'ChestPainType', 'RestingBP', 'Cholesterol', 'FastingBS',  
       'RestingECG', 'MaxHR', 'ExerciseAngina', 'Oldpeak', 'ST_Slope',  
       'HeartDisease'],  
      dtype='object')
```

```
In [26]: # making histogram with kde to see the distribution of features
plt.figure(figsize=(15,15))

plt.subplot(3,2,1)
sns.distplot(x=df[ 'Age' ],kde=True)
plt.title('Age')

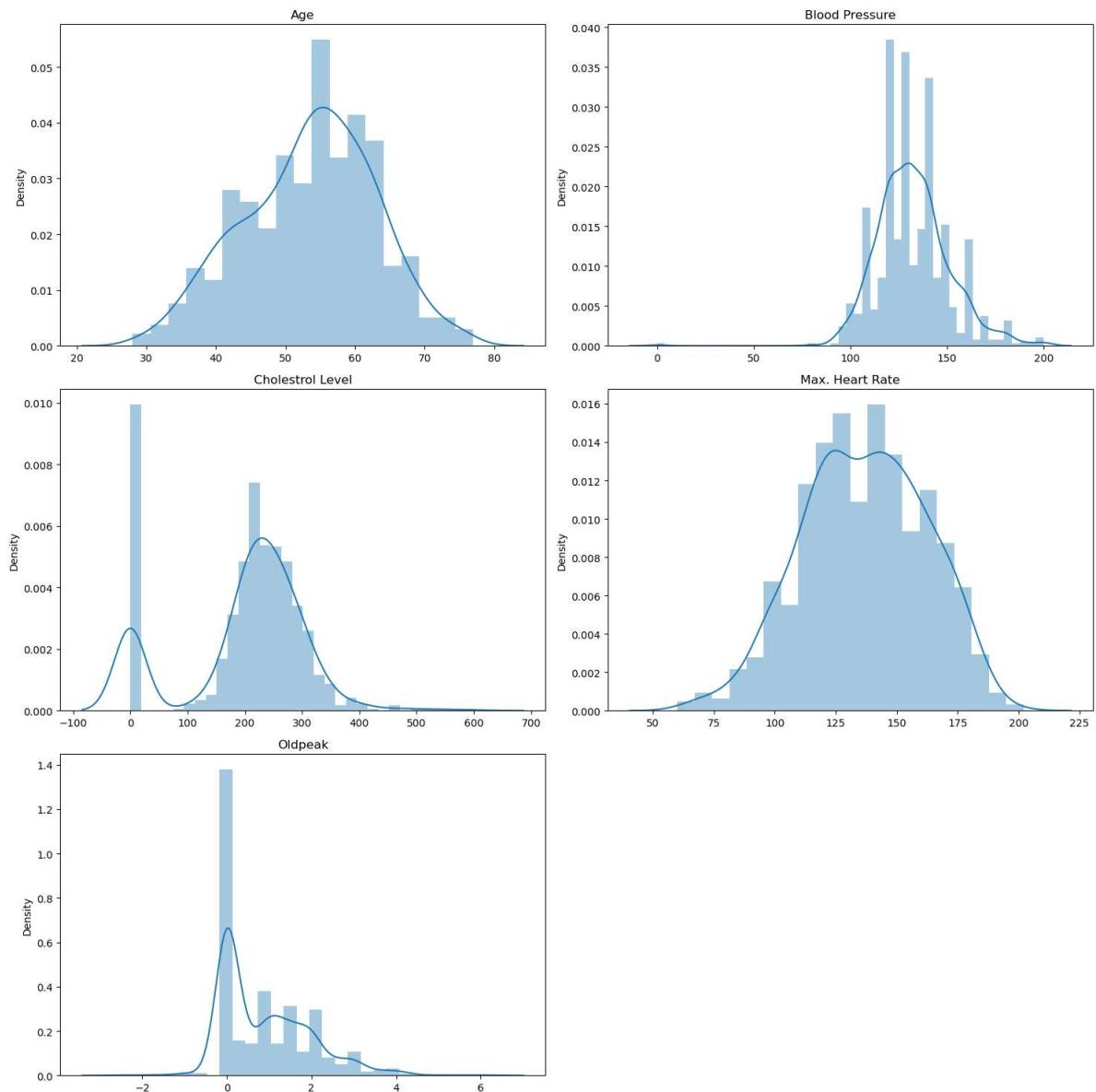
plt.subplot(3,2,2)
sns.distplot(x=df[ 'RestingBP' ],kde=True)
plt.title('Blood Pressure')

plt.subplot(3,2,3)
sns.distplot(x=df[ 'Cholesterol' ],kde=True)
plt.title('Cholestrol Level')

plt.subplot(3,2,4)
sns.distplot(x=df[ 'MaxHR' ],kde=True)
plt.title('Max. Heart Rate')

plt.subplot(3,2,5)
sns.distplot(x=df[ 'Oldpeak' ],kde=True)
plt.title('Oldpeak')

plt.tight_layout()
```



Bivariate Analysis

```
In [27]: # making boxplots to see the distribution
plt.figure(figsize=(15,15))

plt.subplot(3,2,1)
sns.boxplot(x=df['HeartDisease'],y=df['Age'])
plt.title('Age')

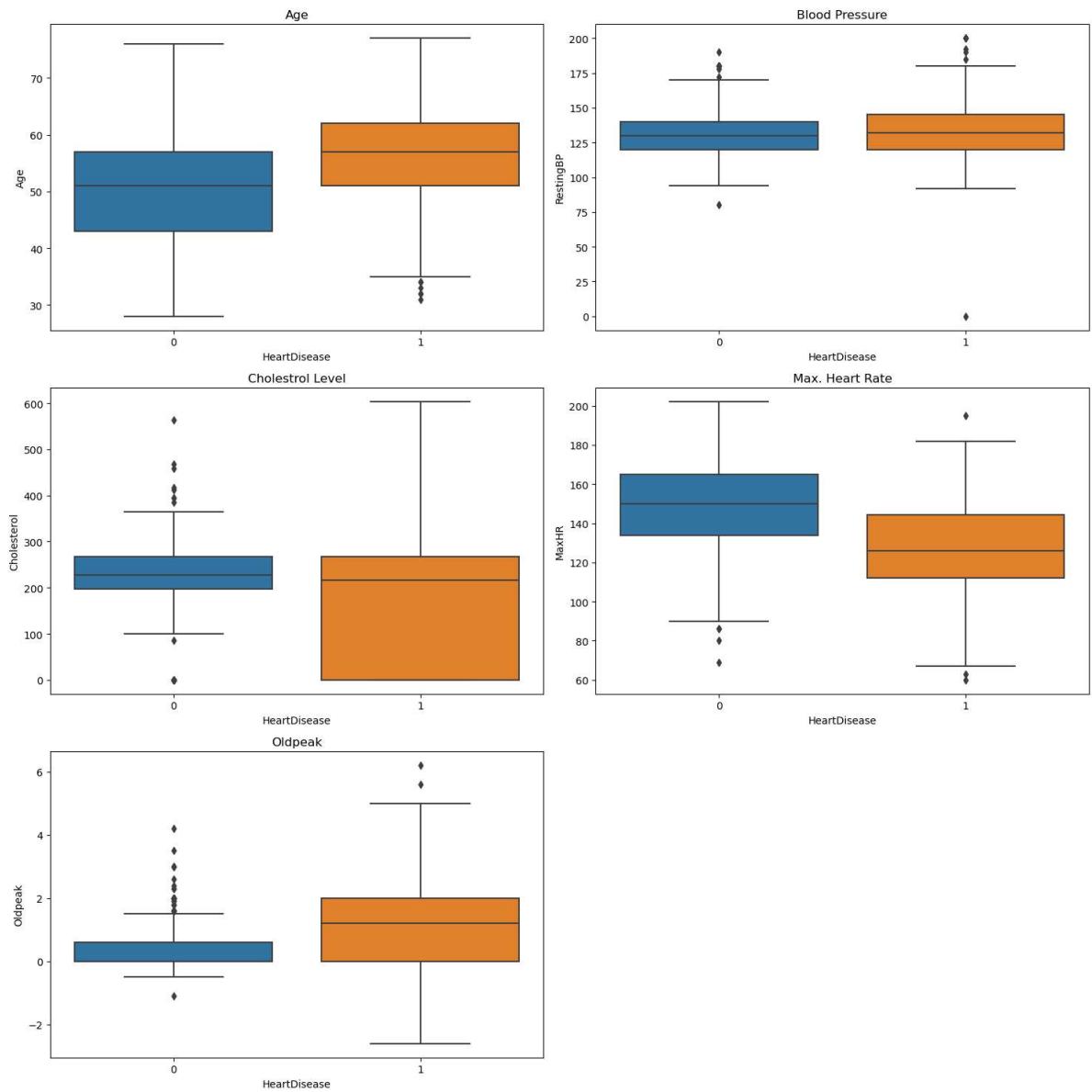
plt.subplot(3,2,2)
sns.boxplot(x=df['HeartDisease'],y=df['RestingBP'])
plt.title('Blood Pressure')

plt.subplot(3,2,3)
sns.boxplot(x=df['HeartDisease'],y=df['Cholesterol'])
plt.title('Cholesterol Level')

plt.subplot(3,2,4)
sns.boxplot(x=df['HeartDisease'],y=df['MaxHR'])
plt.title('Max. Heart Rate')

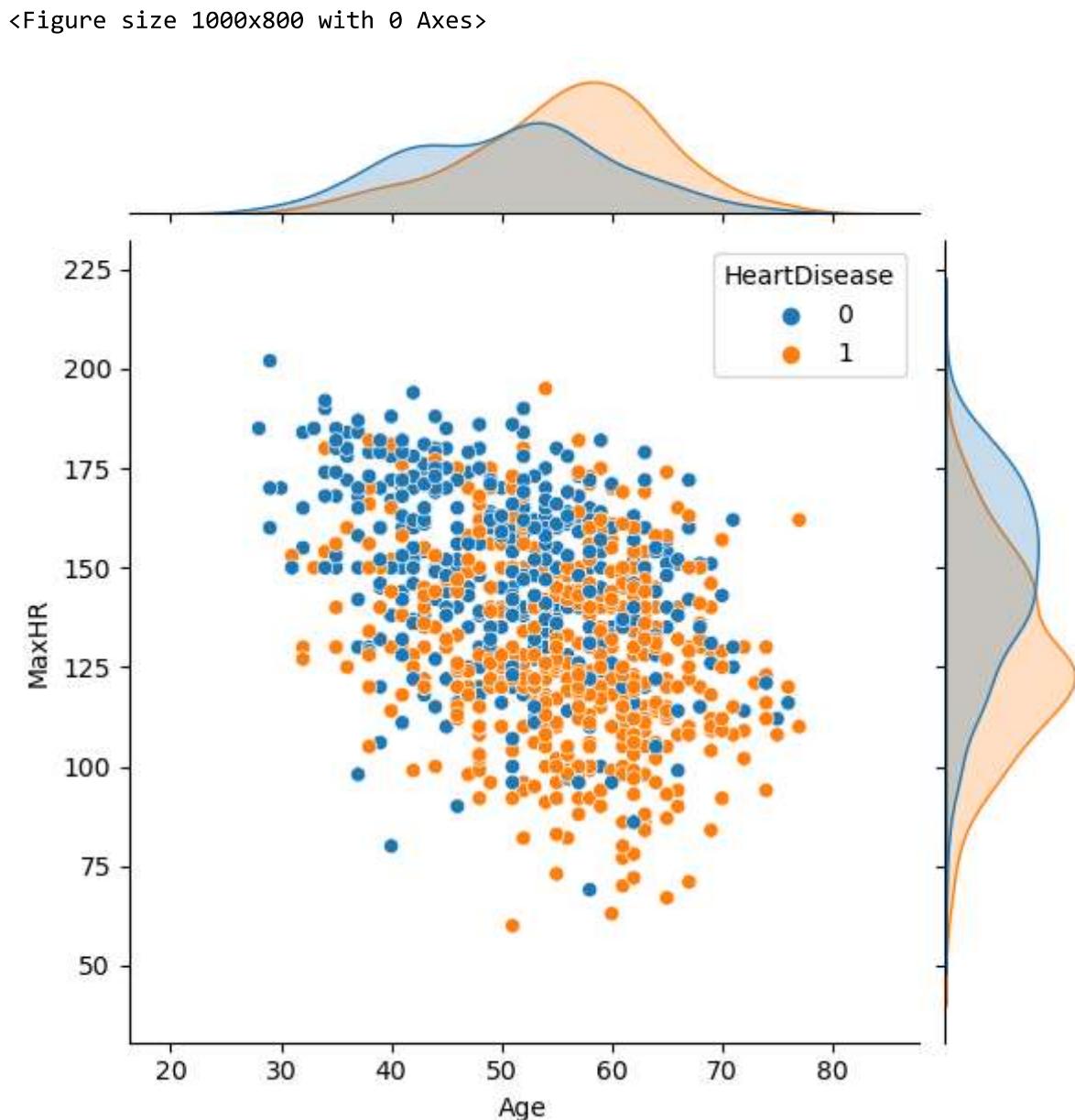
plt.subplot(3,2,5)
sns.boxplot(x=df['HeartDisease'],y=df['Oldpeak'])
plt.title('Oldpeak')

plt.tight_layout()
```



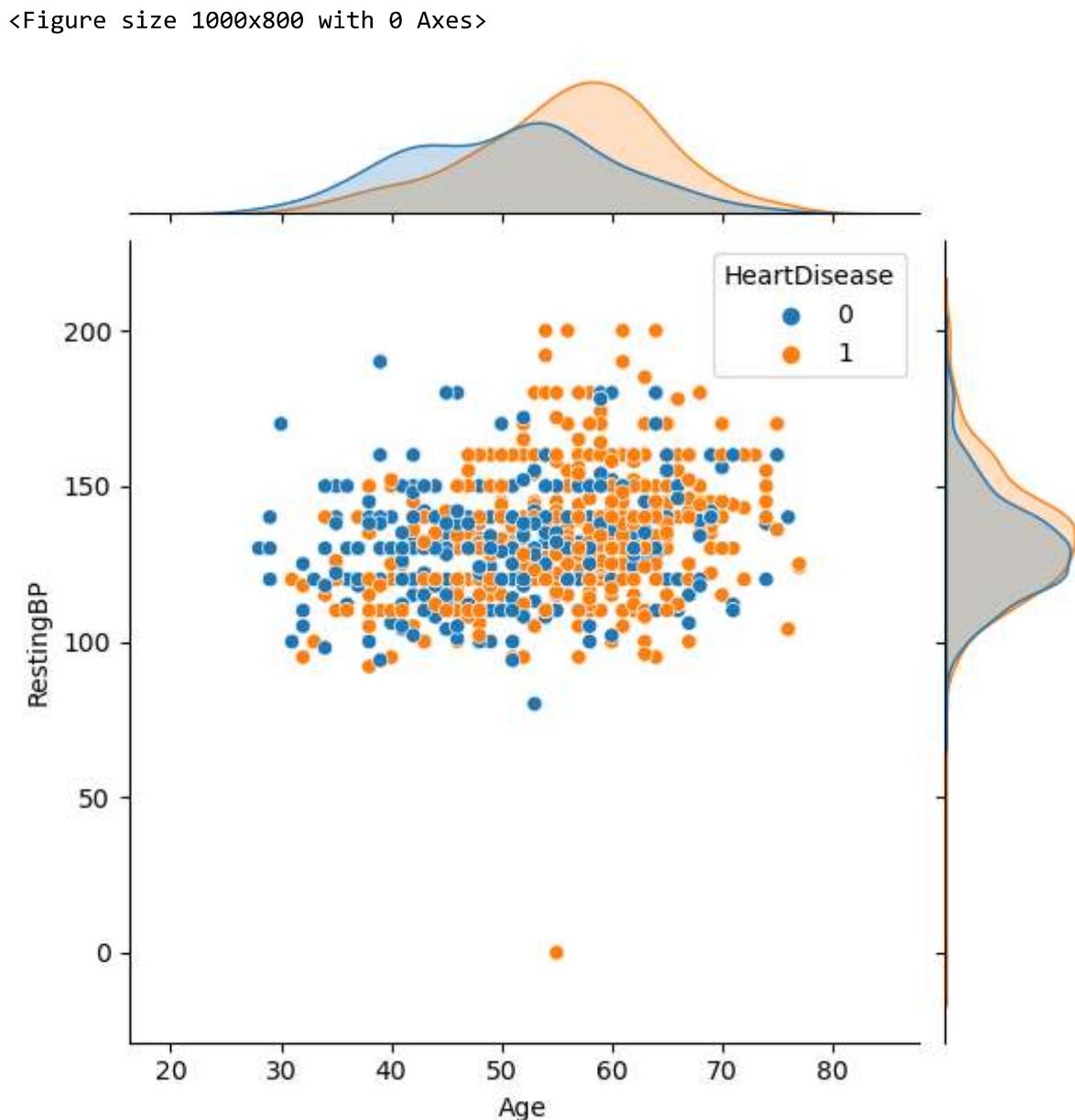
```
In [28]: # jointplot for 'Age' vs 'Max. Heart Rate'  
plt.figure(figsize=(10,8))  
sns.jointplot(data=df,x='Age',y='MaxHR',hue='HeartDisease')
```

```
Out[28]: <seaborn.axisgrid.JointGrid at 0x2350579cb20>
```



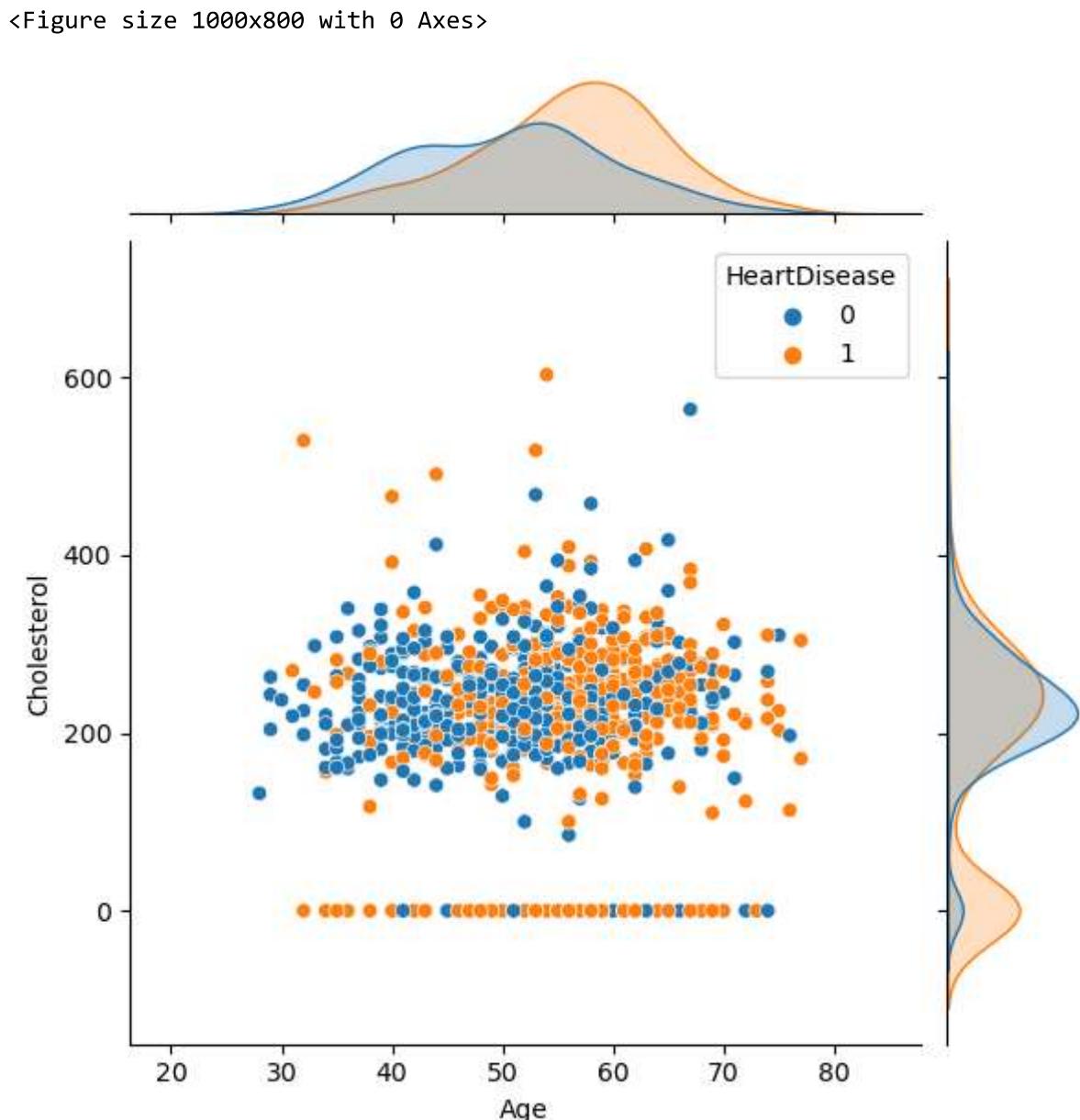
```
In [29]: # jointplot for 'Age' vs 'Blood Pressure'  
plt.figure(figsize=(10,8))  
sns.jointplot(data=df,x='Age',y='RestingBP',hue='HeartDisease')
```

```
Out[29]: <seaborn.axisgrid.JointGrid at 0x23505395a90>
```



```
In [30]: # jointplot for 'Age' vs 'Cholesterol'
plt.figure(figsize=(10,8))
sns.jointplot(data=df,x='Age',y='Cholesterol',hue='HeartDisease')
```

```
Out[30]: <seaborn.axisgrid.JointGrid at 0x235053956d0>
```



Plotting violinplot for the 'Heart Disease' (target feature) vs 'All numeric features'. It used to visualize the distribution of numerical data.

```
In [31]: # making violinplots for features ('Heart Disease' vs 'All numeric features')
plt.figure(figsize=(15,15))

plt.subplot(3,2,1)
sns.violinplot(x=df[ 'HeartDisease' ],y=df[ 'Age' ])
plt.title('Age')

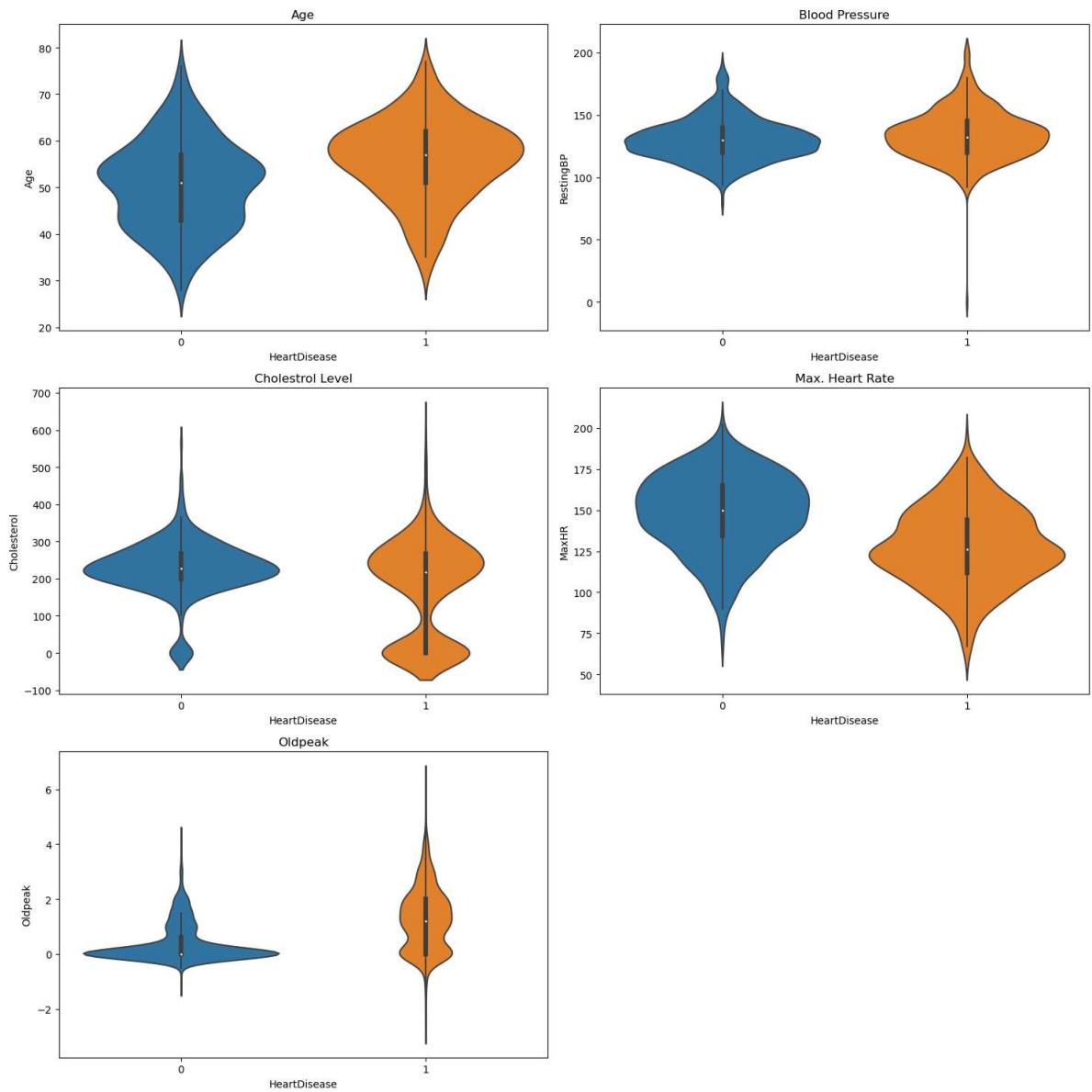
plt.subplot(3,2,2)
sns.violinplot(x=df[ 'HeartDisease' ],y=df[ 'RestingBP' ])
plt.title('Blood Pressure')

plt.subplot(3,2,3)
sns.violinplot(x=df[ 'HeartDisease' ],y=df[ 'Cholesterol' ])
plt.title('Cholestrol Level')

plt.subplot(3,2,4)
sns.violinplot(x=df[ 'HeartDisease' ],y=df[ 'MaxHR' ])
plt.title('Max. Heart Rate')

plt.subplot(3,2,5)
sns.violinplot(x=df[ 'HeartDisease' ],y=df[ 'Oldpeak' ])
plt.title('Oldpeak')

plt.tight_layout()
```



Plotting violinplot for the 'Sex' vs 'All numeric features'. It used to visualize the distribution of numerical data.

```
In [32]: # making violinplots for features ('Sex' vs 'All numeric features')
plt.figure(figsize=(15,15))

plt.subplot(3,2,1)
sns.violinplot(x=df[ 'Sex' ],y=df[ 'Age' ])
plt.title('Age')

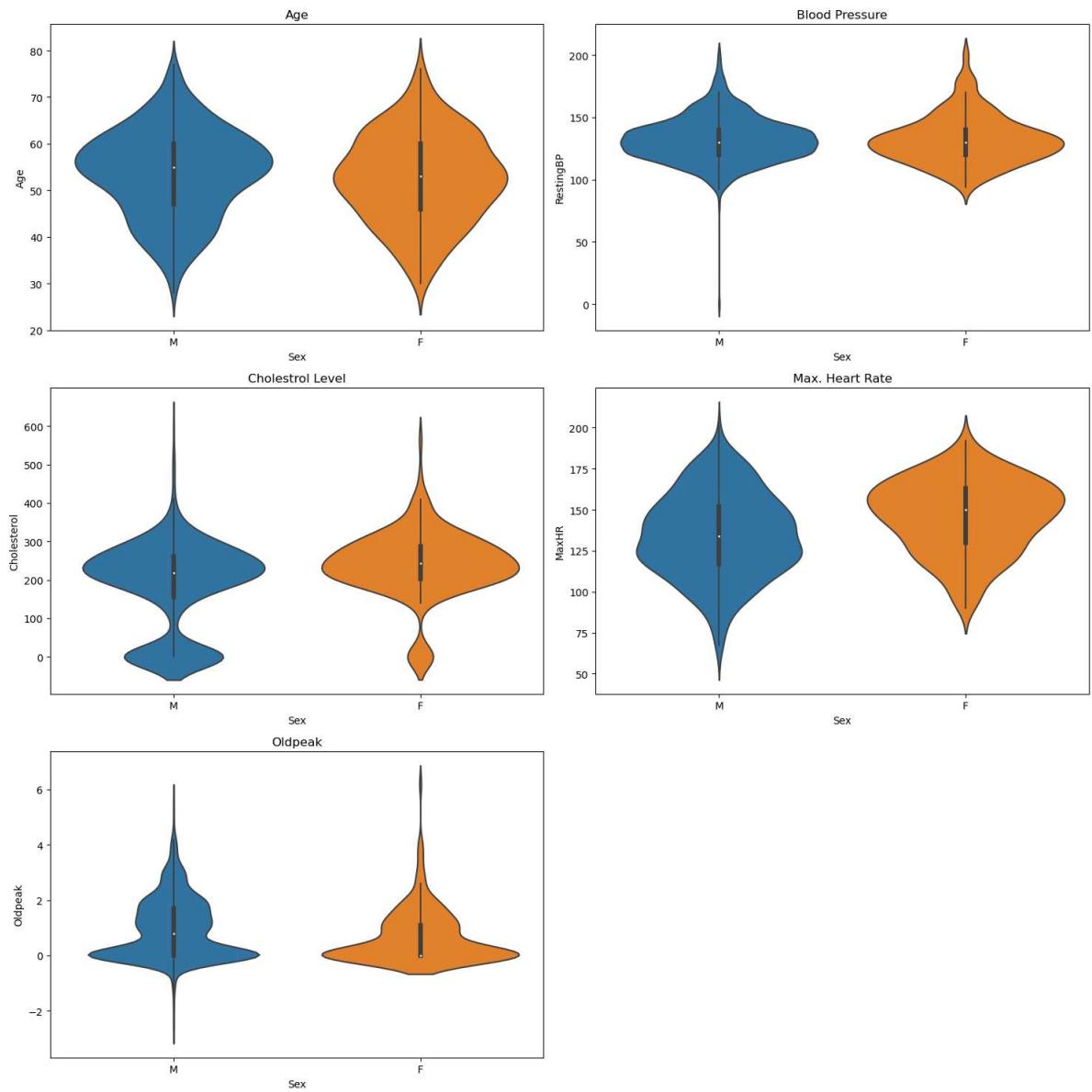
plt.subplot(3,2,2)
sns.violinplot(x=df[ 'Sex' ],y=df[ 'RestingBP' ])
plt.title('Blood Pressure')

plt.subplot(3,2,3)
sns.violinplot(x=df[ 'Sex' ],y=df[ 'Cholesterol' ])
plt.title('Cholestrol Level')

plt.subplot(3,2,4)
sns.violinplot(x=df[ 'Sex' ],y=df[ 'MaxHR' ])
plt.title('Max. Heart Rate')

plt.subplot(3,2,5)
sns.violinplot(x=df[ 'Sex' ],y=df[ 'Oldpeak' ])
plt.title('Oldpeak')

plt.tight_layout()
```



Plotting heatmap to check the correlation of features in visual or colorful way.

```
In [33]: # Heatmap of complete numeric dataframe (before one-hot encoding)

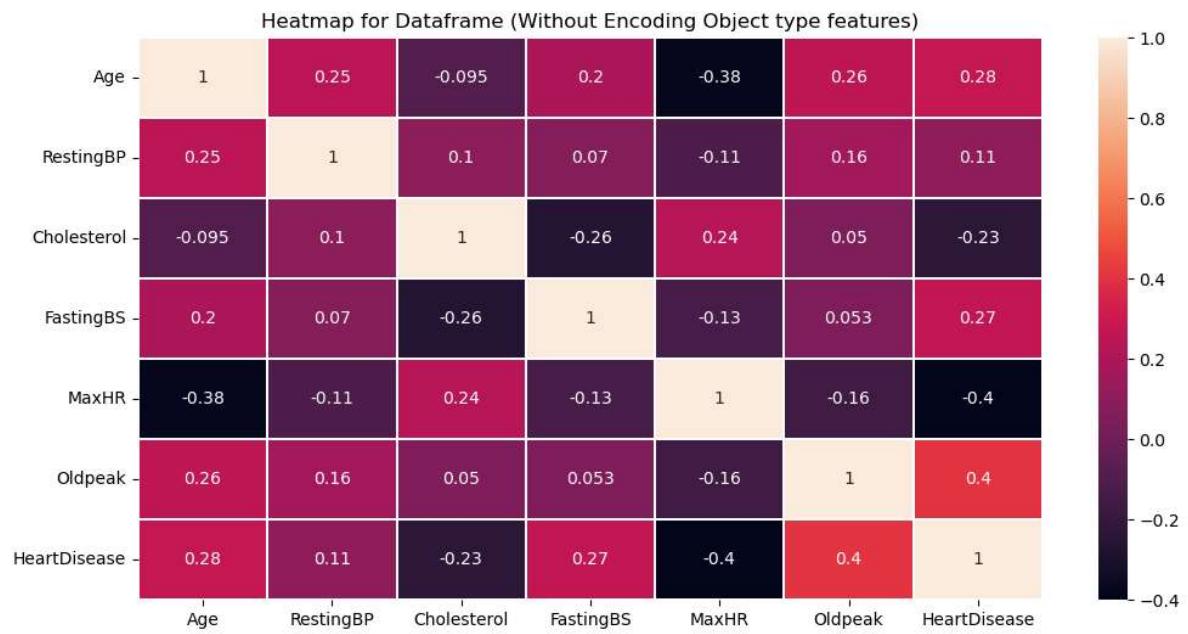
#making an object variable for heatmap
df_corr = df.corr()

# adjust the size
plt.figure(figsize=(12,6))

# setup a title
plt.title('Heatmap for Dataframe (Without Encoding Object type features)')

# plotting of heatmap
sns.heatmap(df_corr, annot=True, linecolor='white', linewidths=0.2)
```

Out[33]: <AxesSubplot:title={'center':'Heatmap for Dataframe (Without Encoding Object type features)'}>



One Hot Encoding

One Hot Encoding can be defined as a process of transforming categorical variables into numerical format before fitting and training a Machine Learning algorithm.

One-Hot Encoding of 'Sex', 'Chest Pain Type', 'Resting ECG', 'Exercise Angina' and 'ST Slope'.

```
In [34]: # one-hot encoding for 'Sex' column
one_hot_encoded_sex = pd.get_dummies(df,columns=['Sex'],drop_first=True)

one_hot_encoded_sex.head()
```

Out[34]:

	Age	ChestPainType	RestingBP	Cholesterol	FastingBS	RestingECG	MaxHR	ExerciseAngina
0	40	ATA	140	289	0	Normal	172	N
1	49	NAP	160	180	0	Normal	156	N
2	37	ATA	130	283	0	ST	98	N
3	48	ASY	138	214	0	Normal	108	Y
4	54	NAP	150	195	0	Normal	122	N



```
In [35]: # one-hot encoding for 'Chest Pain Type' column
one_hot_encoded_cpt = pd.get_dummies(one_hot_encoded_sex,columns=['ChestPainTy
one_hot_encoded_cpt.head()
```

Out[35]:

	Age	RestingBP	Cholesterol	FastingBS	RestingECG	MaxHR	ExerciseAngina	Oldpeak	ST_Slope
0	40	140	289	0	Normal	172		N	0.0
1	49	160	180	0	Normal	156		N	1.0
2	37	130	283	0	ST	98		N	0.0
3	48	138	214	0	Normal	108		Y	1.5
4	54	150	195	0	Normal	122		N	0.0



```
In [36]: # one-hot encoding for 'RestingECG' column
one_hot_encoded_recg = pd.get_dummies(one_hot_encoded_cpt,columns=['RestingECG
one_hot_encoded_recg.head()
```

Out[36]:

	Age	RestingBP	Cholesterol	FastingBS	MaxHR	ExerciseAngina	Oldpeak	ST_Slope	HeartD
0	40	140	289	0	172		N	0.0	Up
1	49	160	180	0	156		N	1.0	Flat
2	37	130	283	0	98		N	0.0	Up
3	48	138	214	0	108		Y	1.5	Flat
4	54	150	195	0	122		N	0.0	Up



```
In [37]: # one-hot encoding for 'ExerciseAngina' column
one_hot_encoded_exa = pd.get_dummies(one_hot_encoded_recg,columns=['ExerciseAngina'])

one_hot_encoded_exa.head()
```

Out[37]:

	Age	RestingBP	Cholesterol	FastingBS	MaxHR	Oldpeak	ST_Slope	HeartDisease	Sex_M	ChestPainType
0	40	140	289	0	172	0.0	Up	0	1	ATA
1	49	160	180	0	156	1.0	Flat	1	0	NAP
2	37	130	283	0	98	0.0	Up	0	1	TA
3	48	138	214	0	108	1.5	Flat	1	0	Normal
4	54	150	195	0	122	0.0	Up	0	1	ST

```
In [38]: # one-hot encoding for 'ST_Slope' column
final_df = pd.get_dummies(one_hot_encoded_exa,columns=['ST_Slope'],drop_first=True)

final_df.head()
```

Out[38]:

	Age	RestingBP	Cholesterol	FastingBS	MaxHR	Oldpeak	HeartDisease	Sex_M	ChestPainTy	ST_Slope
0	40	140	289	0	172	0.0	0	1	ATA	Up
1	49	160	180	0	156	1.0	1	0	NAP	Flat
2	37	130	283	0	98	0.0	0	1	TA	Up
3	48	138	214	0	108	1.5	1	0	Normal	Flat
4	54	150	195	0	122	0.0	0	1	ST	Up

Data Preprocessing

```
In [39]: # rename columns in final dataframe
final_df.rename(columns={'Sex_M':'Sex', 'ExerciseAngina_Y':'ExerciseAngina'},inplace=True)

# renamed columns in final dataframe
final_df.columns
```

```
Out[39]: Index(['Age', 'RestingBP', 'Cholesterol', 'FastingBS', 'MaxHR', 'Oldpeak',
       'HeartDisease', 'Sex', 'ChestPainType_ATA', 'ChestPainType_NAP',
       'ChestPainType_TA', 'RestingECG_Normal', 'RestingECG_ST',
       'ExerciseAngina', 'ST_Slope_Flat', 'ST_Slope_Up'],
      dtype='object')
```

```
In [40]: # information of final dataframe  
final_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>  
RangeIndex: 918 entries, 0 to 917  
Data columns (total 16 columns):  
 #   Column           Non-Null Count  Dtype    
---  --    
 0   Age              918 non-null    int64    
 1   RestingBP        918 non-null    int64    
 2   Cholesterol      918 non-null    int64    
 3   FastingBS        918 non-null    int64    
 4   MaxHR            918 non-null    int64    
 5   Oldpeak          918 non-null    float64    
 6   HeartDisease     918 non-null    int64    
 7   Sex               918 non-null    uint8    
 8   ChestPainType_ATA 918 non-null    uint8    
 9   ChestPainType_NAP 918 non-null    uint8    
 10  ChestPainType_TA 918 non-null    uint8    
 11  RestingECG_Normal 918 non-null    uint8    
 12  RestingECG_ST     918 non-null    uint8    
 13  ExerciseAngina    918 non-null    uint8    
 14  ST_Slope_Flat     918 non-null    uint8    
 15  ST_Slope_Up       918 non-null    uint8    
dtypes: float64(1), int64(6), uint8(9)  
memory usage: 58.4 KB
```

As we see, number of features is increased due to one-hot encoding.

```
In [41]: # Heatmap of complete numeric dataframe (after one-hot encoding)

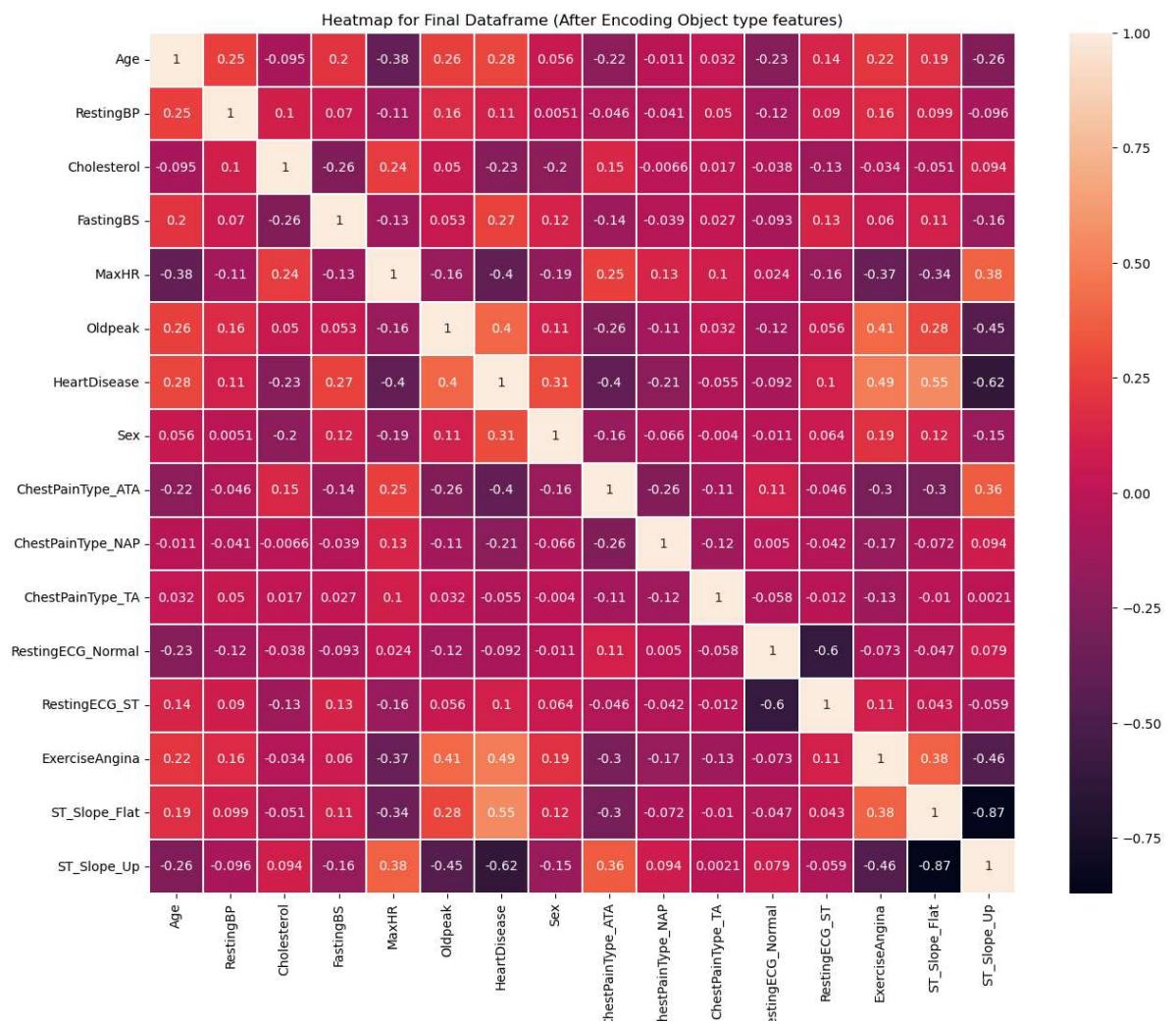
#making an object variable for heatmap
final_df_corr = final_df.corr()

# adjust the size
plt.figure(figsize=(15,12))

# setup a title
plt.title('Heatmap for Final Dataframe (After Encoding Object type features)')

# plotting of heatmap
sns.heatmap(final_df_corr, annot=True, linecolor='white', linewidths=0.2)
```

Out[41]: <AxesSubplot:title={'center':'Heatmap for Final Dataframe (After Encoding Object type features)'}>



Machine Learning

Import ML Libraries

```
In [42]: from sklearn.model_selection import train_test_split
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import accuracy_score,log_loss
from sklearn.metrics import classification_report,confusion_matrix
from sklearn.metrics import roc_curve,roc_auc_score
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.naive_bayes import CategoricalNB
import shap
```

Train Test and Split Data

```
In [43]: # splitting data into X and y variables

# data or dependent variable
X = final_df.drop('HeartDisease',axis=1)

# target or independent variable
y = final_df['HeartDisease']
```

```
In [44]: # splitting data into train and test variables
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, rando
```

```
In [45]: # check the shapes of all variables which we create above
X_train.shape, X_test.shape, y_train.shape, y_test.shape
```

```
Out[45]: ((642, 15), (276, 15), (642,), (276,))
```

```
In [46]: # scaling or normalize train and test data
scaler = MinMaxScaler()

# X train data
X_train = scaler.fit_transform(X_train)

# X test data
X_test = scaler.transform(X_test)
```

Finding Best Three Algorithms for Problem

```
In [47]: # create object for all algorithms
lr = LogisticRegression()
dtree = DecisionTreeClassifier()
rfc = RandomForestClassifier(n_estimators=200)
svm = SVC(probability=True)
knn = KNeighborsClassifier(n_neighbors=5)
nb = CategoricalNB(force_alpha=True)
```

Check the accuracy and log loss for all algorithms after train and test the data

```
In [48]: # making a list of all algorithms object
algos = [lr,dtree,rfc,svm,knn,nb]
ml_algo = ['Logistic Regs','Decision Tree','Random Forest','SVM','KNNeighbors']

# making a for loop to work on all algorithms
for i,j in zip(algos,ml_algo):
    i.fit(X_train,y_train)
    pred = i.predict(X_test)
    print(j,':\n')
    print('Accuracy Score:{:.2f}%'.format(accuracy_score(y_test,pred)*100))
    print('Log Loss:{:.2f}'.format(log_loss(y_test,pred)))
    print('='*40)
```

Logistic Regs :

Accuracy Score:87.68%
Log Loss:4.44

=====

Decision Tree :

Accuracy Score:77.54%
Log Loss:8.10

=====

Random Forest :

Accuracy Score:88.77%
Log Loss:4.05

=====

SVM :

Accuracy Score:85.87%
Log Loss:5.09

=====

KNNeighbors :

Accuracy Score:85.51%
Log Loss:5.22

=====

Naive Bayes :

Accuracy Score:82.97%
Log Loss:6.14

=====

As we can see, all our algorithms works great expect Decision Tree (accuracy:77.54% and log loss:8.10). So, it's time to select top three algorithm to continue further and building our model. Let's see the algorithms with their accuracy and log loss:

Algorithms	Accuracy	Log Loss
1. Logistic Regs.	87.68%	4.44
2. Random Forest	88.77%	4.05
3. SVM	85.87%	5.09

Important Terms

1. Confusion Matrix: A confusion matrix is a table used in machine learning and statistics to assess the performance of a classification model. It summarizes the results of classification by showing the counts of true positive, true negative, false positive, and false negative predictions.
2. Classification Report: This is the summary of the quality of classification made by the constructed ML model. It comprises mainly 5 columns and (N+3) rows. The first column is the class label's name and followed by Precision, Recall, F1-score, and Support. N rows are for N class labels and other three rows are for accuracy, macro average, and weighted average.
3. Shap Values: SHAP values are a common way of getting a consistent and objective explanation of how each feature impacts the model's prediction. SHAP values are based on game theory and assign an importance value to each feature in a model.
4. ROC Curve: An ROC curve (receiver operating characteristic curve) is a graph showing the performance of a classification model at all classification thresholds. This curve plots two parameters: True Positive Rate.
5. ROC AUC Score: The ROC AUC score tells us how efficient the model is. The higher the AUC, the better the model's performance at distinguishing between the positive and negative classes. An AUC score of 1 means the classifier can perfectly distinguish between all the Positive and the Negative class points.

Logistic Regression

```
In [49]: # fitting the training data
lr.fit(X_train,y_train)

# prediction on test data
lr_pred = lr.predict(X_test)

# check the classification report of Logistic regression model
print('Classification Report of Logistic Regression:\n')
print(classification_report(y_test,lr_pred))
```

Classification Report of Logistic Regression:

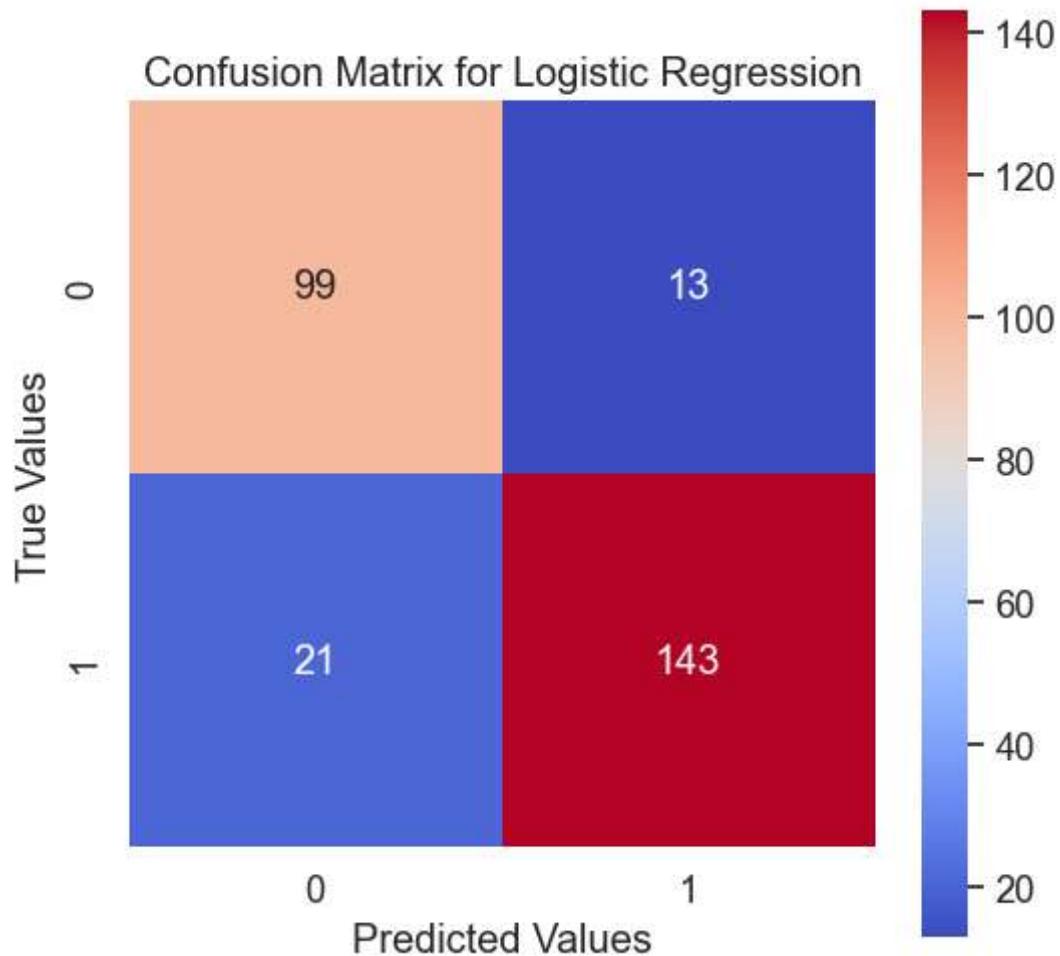
	precision	recall	f1-score	support
0	0.82	0.88	0.85	112
1	0.92	0.87	0.89	164
accuracy			0.88	276
macro avg	0.87	0.88	0.87	276
weighted avg	0.88	0.88	0.88	276

```
In [50]: # create an instance of the confusion matrix
lr_cm = confusion_matrix(y_test,lr_pred)

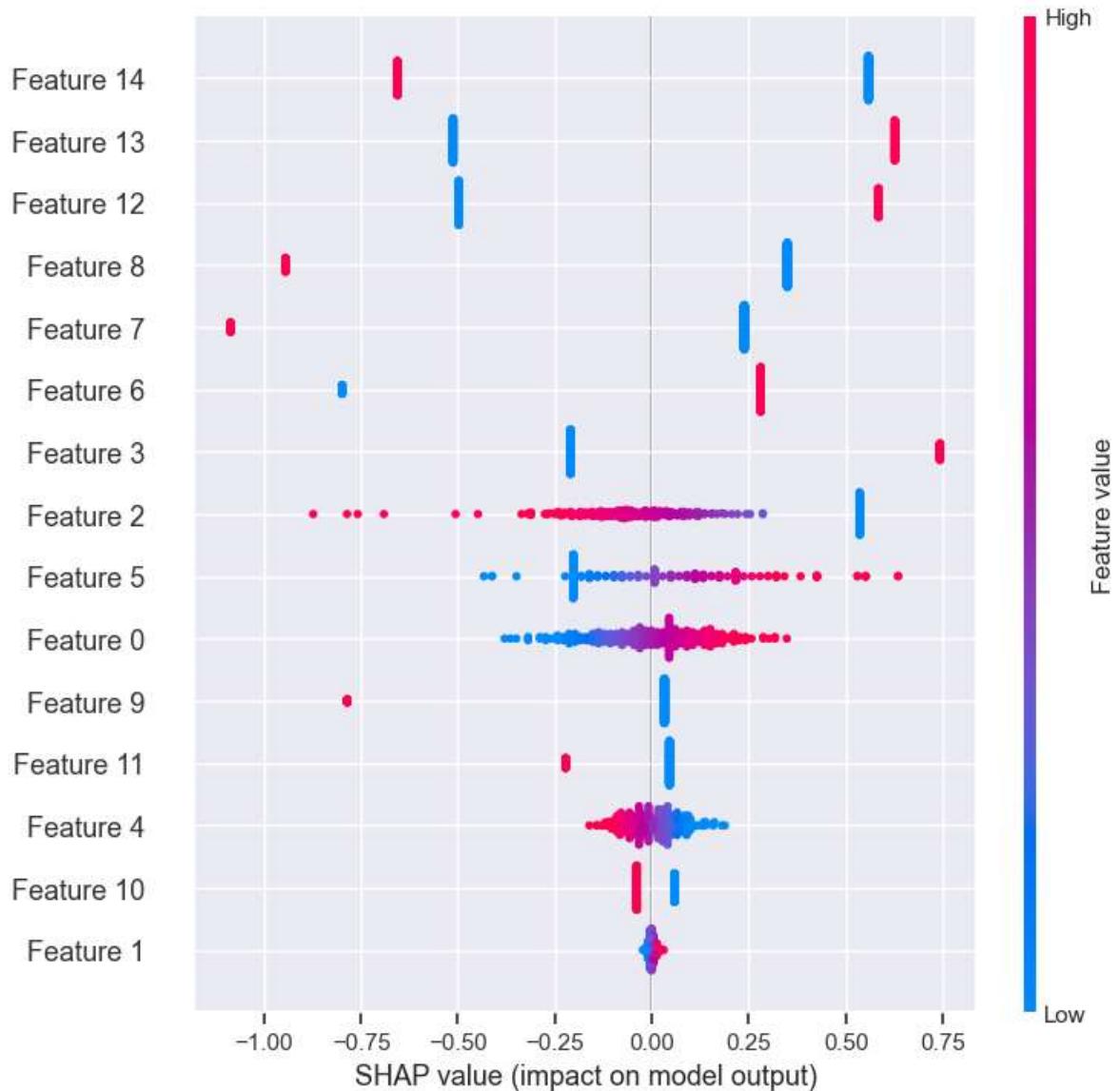
# adjust the size of the confusion matrix
plt.figure(figsize=(6, 6))
sns.set(font_scale=1.2)
# create a heatmap which show the confusion matrix of Logistic Reg. model
sns.heatmap(lr_cm, annot=True, fmt='d', cmap='coolwarm', square=True,xticklabe

plt.xlabel('Predicted Values') # x Label of the confusion matrix
plt.ylabel('True Values') # y Label of the confusion matrix
plt.title('Confusion Matrix for Logistic Regression') # title of the confusion
```

Out[50]: Text(0.5, 1.0, 'Confusion Matrix for Logistic Regression')



```
In [51]: # shap is used to check the most important or importance of features for the L
plt.figure(figsize=(12,8))
masker = shap.maskers.Independent(data = X_train)
explainer_of_dtc = shap.LinearExplainer(lr,masker=masker)
shap_value = explainer_of_dtc.shap_values(X_test)
shap.summary_plot(shap_value,X_test)
```



```
In [52]: # create a ROC Curve and AUC plot to assess the overall diagnostic performance
# two or more diagnostic tests.

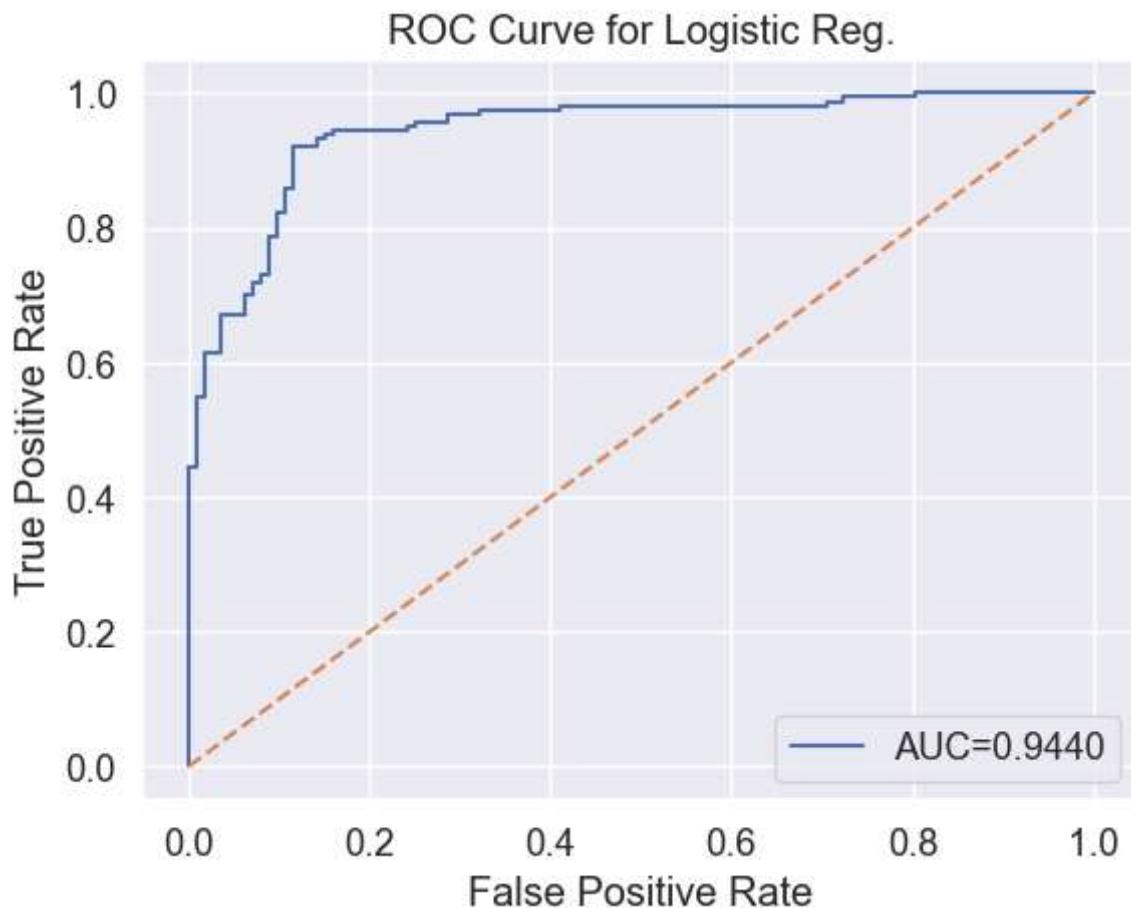
lr_pred_prob = lr.predict_proba(X_test)[:, :, 1]

lr_actual_predict = pd.concat([pd.DataFrame(np.array(y_test), columns=['y actual'],
                                             pd.DataFrame(lr_pred_prob, columns=['y pred prob'])
lr_actual_predict.index = y_test.index

fpr, tpr, tr = roc_curve(lr_actual_predict['y actual'], lr_actual_predict['y pred prob'])
auc = roc_auc_score(lr_actual_predict['y actual'], lr_actual_predict['y pred prob'])

plt.plot(fpr, tpr, label='AUC=%4f'%auc)
plt.plot(fpr, fpr, linestyle='--')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Logistic Reg.')
plt.legend()
```

Out[52]: <matplotlib.legend.Legend at 0x235082fa310>



Random Forest

```
In [53]: # fitting the training data
rfc.fit(X_train,y_train)

# prediction on test data
rfc_pred = rfc.predict(X_test)

# check the classification report of Random forest model
print('Classification Report of Random Forest:\n')
print(classification_report(y_test,rfc_pred))
```

Classification Report of Random Forest:

	precision	recall	f1-score	support
0	0.84	0.85	0.84	112
1	0.90	0.89	0.89	164
accuracy			0.87	276
macro avg	0.87	0.87	0.87	276
weighted avg	0.87	0.87	0.87	276

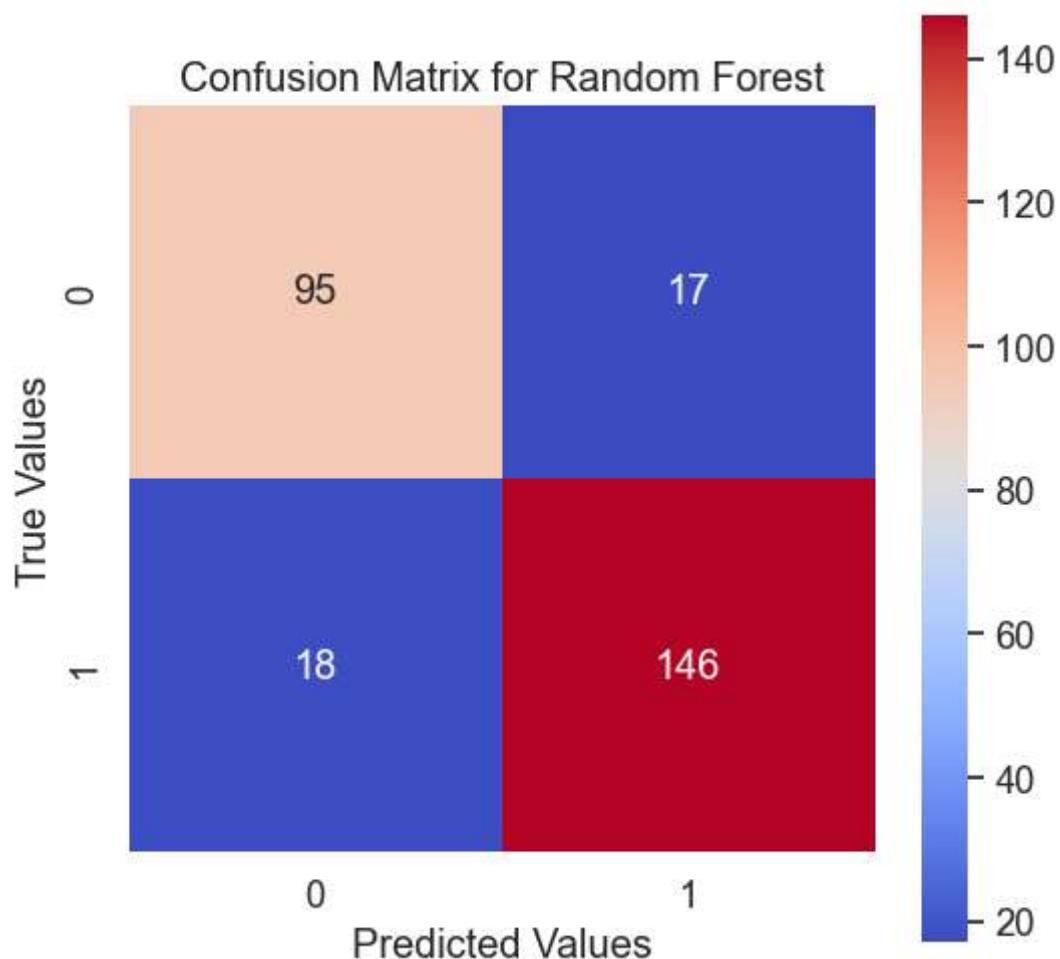
```
In [54]: # create an instance for the random forest confusion matrix
rfc_cm = confusion_matrix(y_test, rfc_pred)

# adjust the size of the confusion matrix
plt.figure(figsize=(6, 6))
sns.set(font_scale=1.2)

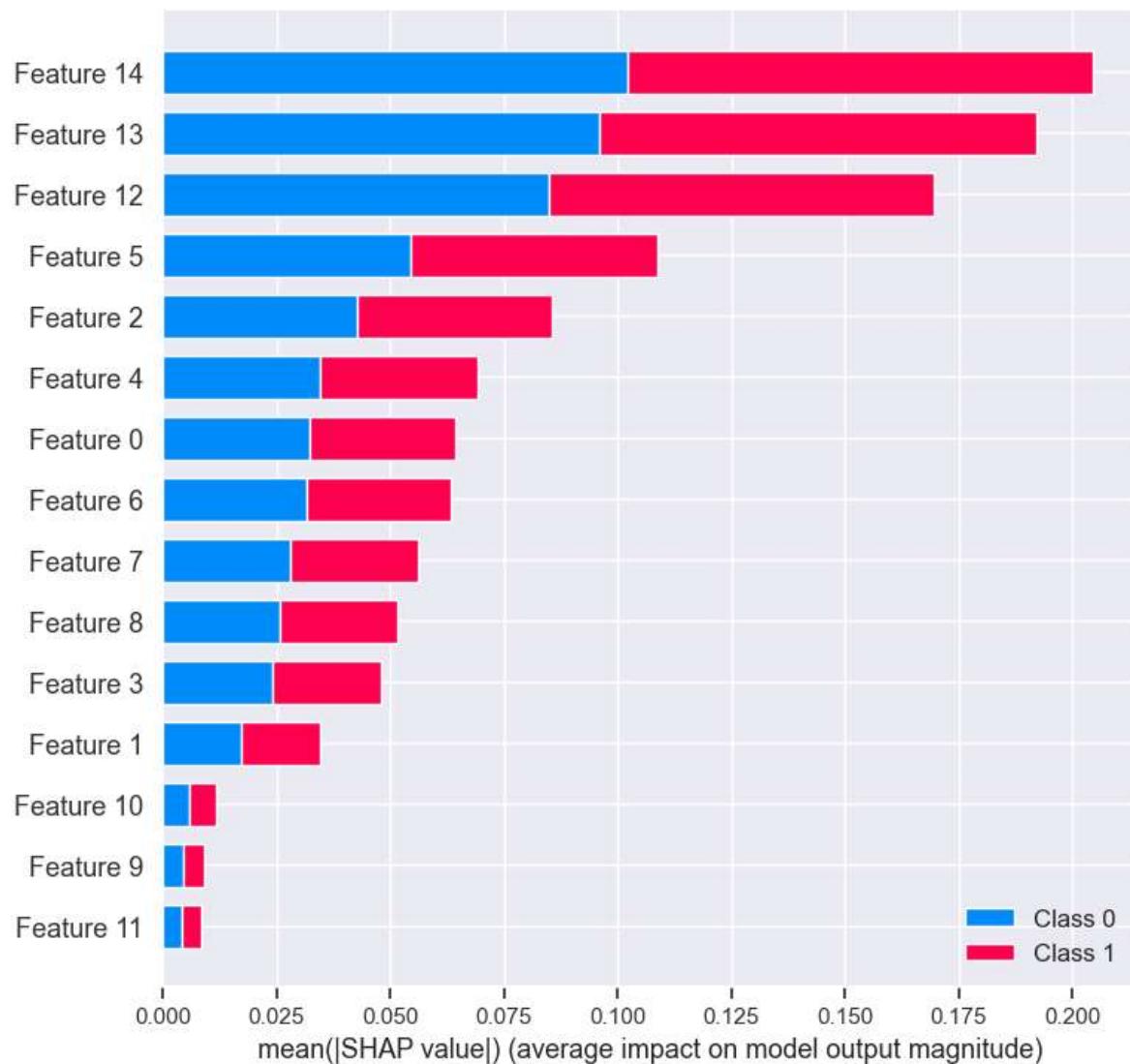
# create a heatmap which show the confusion matrix of the random forest model
sns.heatmap(rfc_cm, annot=True, fmt='d', cmap='coolwarm', square=True, xticklabels=['0', '1'], yticklabels=['0', '1'])

plt.xlabel('Predicted Values') # x Label of the confusion matrix
plt.ylabel('True Values') # y Label of the confusion matrix
plt.title('Confusion Matrix for Random Forest') # title of the confusion matrix
```

Out[54]: Text(0.5, 1.0, 'Confusion Matrix for Random Forest')



```
In [55]: # shap plot for the random forest model  
explainer_of_rfc = shap.TreeExplainer(rfc)  
shap_value = explainer_of_rfc.shap_values(X_test)  
shap.summary_plot(shap_value,X_test)
```



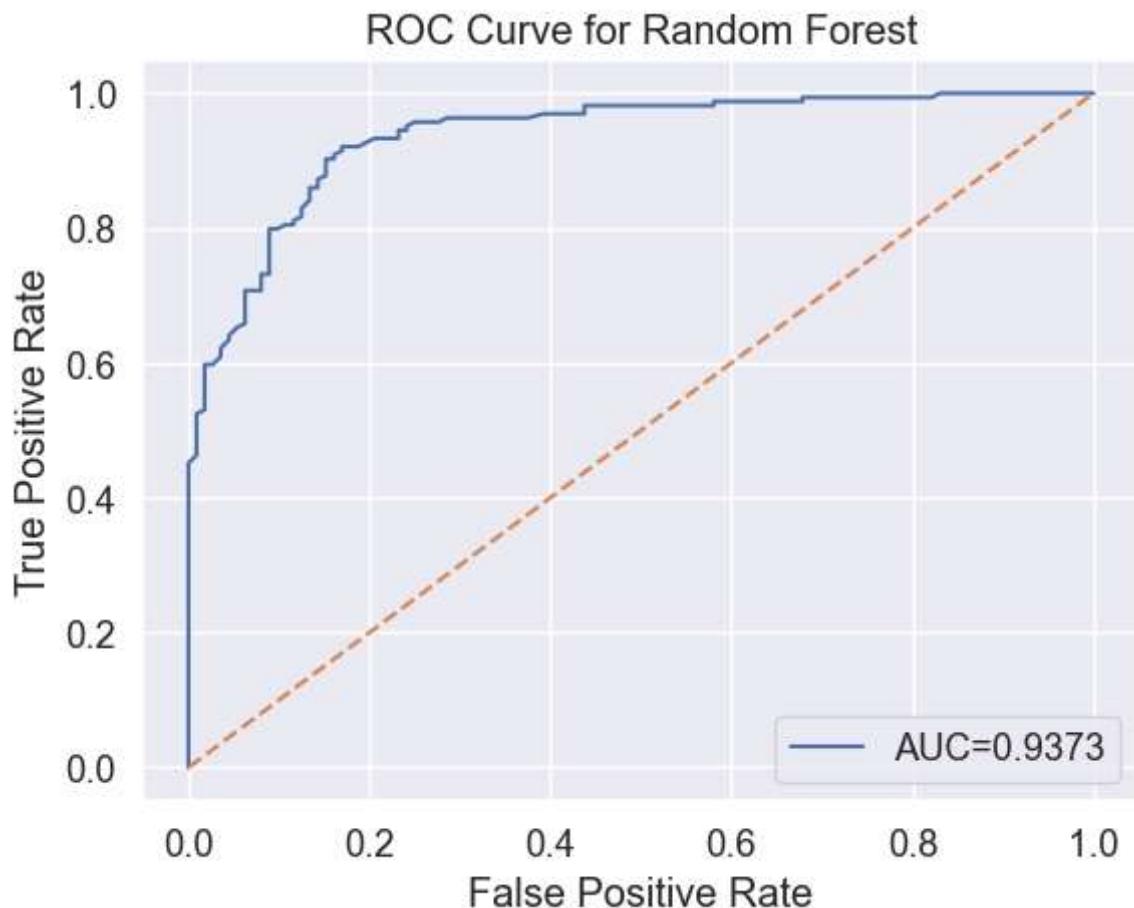
```
In [56]: # ROC and AUC score for the random forest model
rfc_pred_prob = rfc.predict_proba(X_test)[:, :, 1]

rfc_actual_predict = pd.concat([pd.DataFrame(np.array(y_test), columns=['y actual'],
                                             columns=rfc_pred_prob, columns=['y pred prob']),
                                 rfc_actual_predict.index = y_test.index

fpr, tpr, tr = roc_curve(rfc_actual_predict['y actual'], rfc_actual_predict['y pred prob'])
auc = roc_auc_score(rfc_actual_predict['y actual'], rfc_actual_predict['y pred prob'])

plt.plot(fpr, tpr, label='AUC=%4f' % auc)
plt.plot(fpr, fpr, linestyle='--')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Random Forest')
plt.legend()
```

Out[56]: <matplotlib.legend.Legend at 0x2350a564280>



Support Vector Machine (SVM)

```
In [57]: # fitting the training data
svm.fit(X_train,y_train)

# prediction on test data
svm_pred = svm.predict(X_test)

# check the classification report of SVM model
print('Classification Report of SVM:\n')
print(classification_report(y_test,svm_pred))
```

Classification Report of SVM:

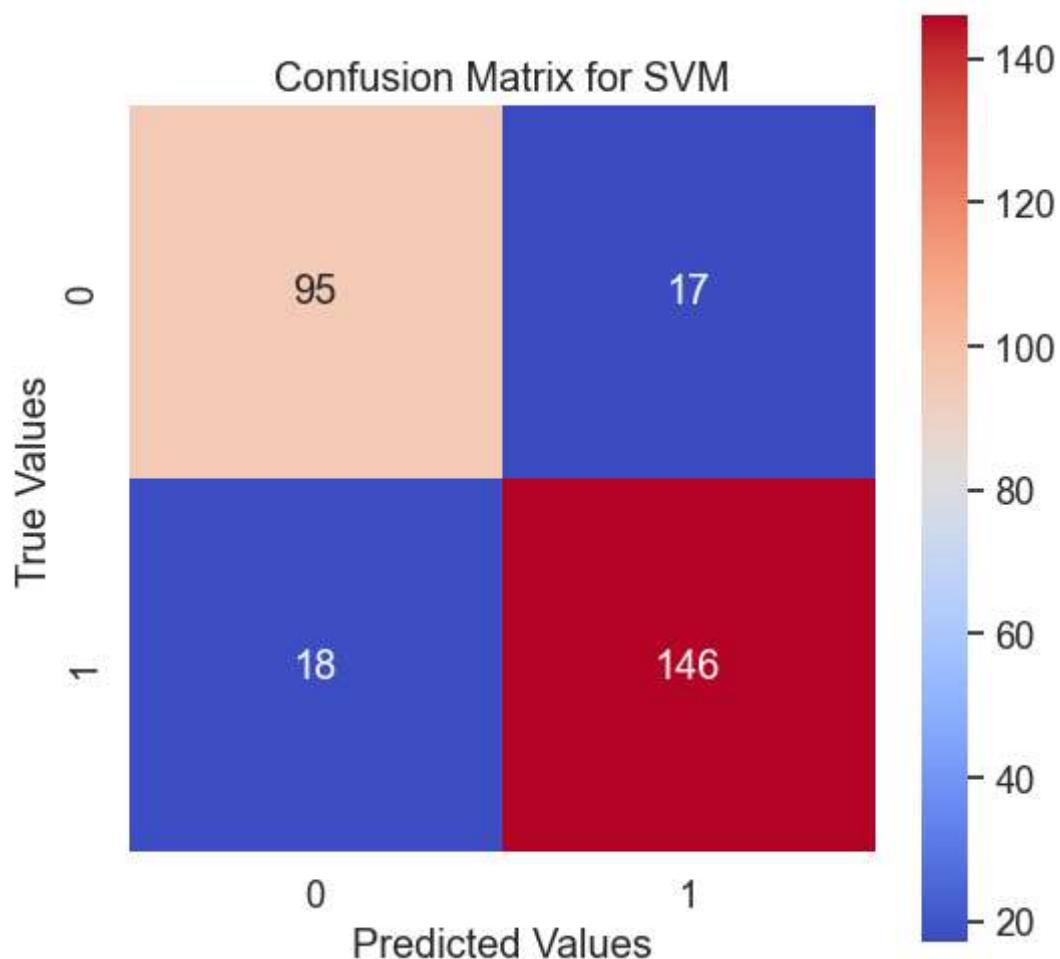
	precision	recall	f1-score	support
0	0.81	0.85	0.83	112
1	0.89	0.87	0.88	164
accuracy			0.86	276
macro avg	0.85	0.86	0.85	276
weighted avg	0.86	0.86	0.86	276

```
In [58]: # create an instance for the SVM confusion matrix
svm_cm = confusion_matrix(y_test, rfc_pred)

# adjust the size of the confusion matrix
plt.figure(figsize=(6, 6))
sns.set(font_scale=1.2)

# create a heatmap which show the confusion matrix of the SVM model
sns.heatmap(svm_cm, annot=True, fmt='d', cmap='coolwarm', square=True, xticklab
plt.xlabel('Predicted Values') # x Label of the confusion matrix
plt.ylabel('True Values') # y Label of the confusion matrix
plt.title('Confusion Matrix for SVM') # title of the confusion matrix
```

Out[58]: Text(0.5, 1.0, 'Confusion Matrix for SVM')



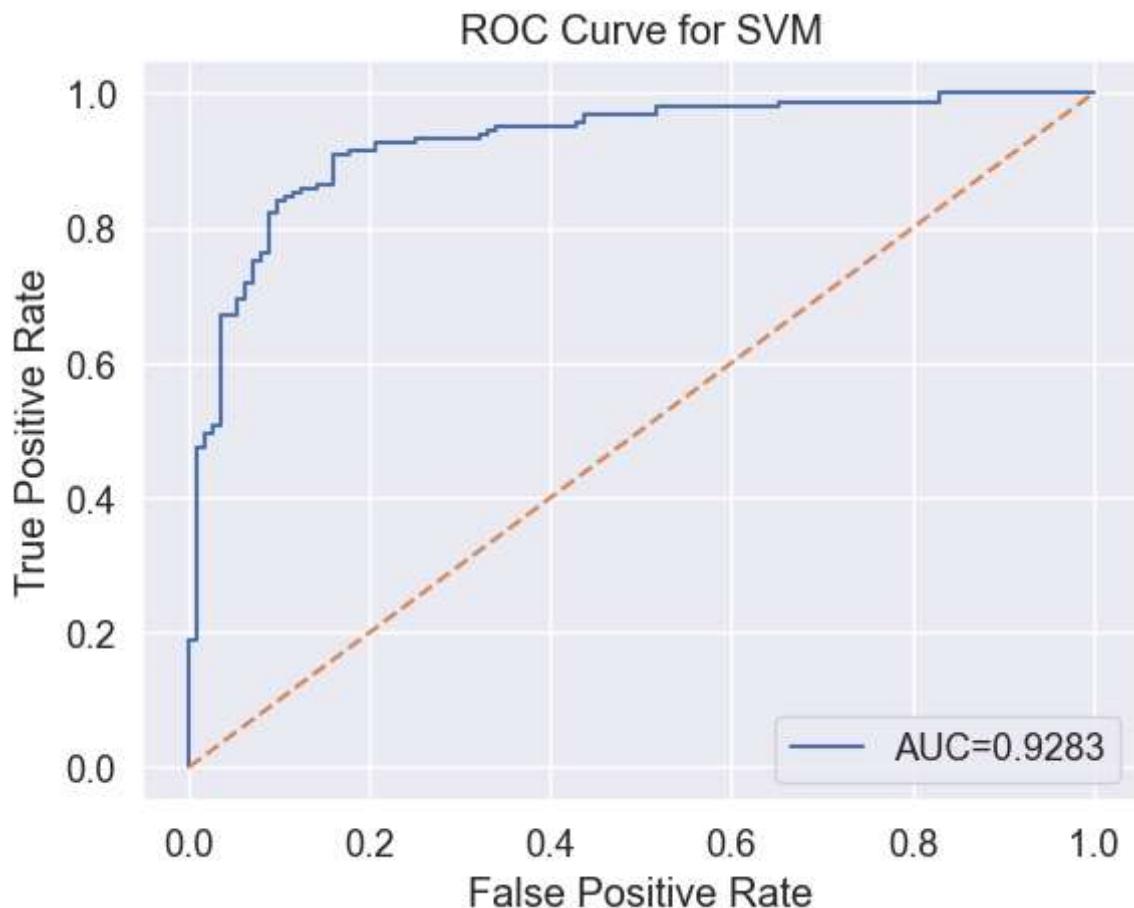
```
In [59]: # ROC and AUC score for the SVM model
svm_pred_prob = svm.predict_proba(X_test)[:, :, 1]

svm_actual_predict = pd.concat([pd.DataFrame(np.array(y_test), columns=['y actual'],
                                             columns=svm_pred_prob, columns=['y pred prob']),
                                 svm_actual_predict.index = y_test.index

fpr, tpr, tr = roc_curve(svm_actual_predict['y actual'], svm_actual_predict['y pred prob'])
auc = roc_auc_score(svm_actual_predict['y actual'], svm_actual_predict['y pred prob'])

plt.plot(fpr, tpr, label='AUC=%4f' % auc)
plt.plot(fpr, fpr, linestyle='--')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for SVM')
plt.legend()
```

Out[59]: <matplotlib.legend.Legend at 0x2350bf5a400>



Comparison of Different Models Confusion Matrix

```
In [60]: # making a List of different model confusion matrix
cm_models = [lr_cm, rfc_cm, svm_cm]
cm_model = ['Logistic Regs.', 'Random Forest', 'SVM']
# making a for loop
for i,j in zip(cm_models, cm_model):
    print(j, 'Confusion Matrix:\n')
    print(i)
    print('='*30)
```

Logistic Regs. Confusion Matrix:

```
[[ 99  13]
 [ 21 143]]
=====
Random Forest Confusion Matrix:
```

```
[[ 95  17]
 [ 18 146]]
=====
SVM Confusion Matrix:
```

```
[[ 95  17]
 [ 18 146]]
=====
```

Conclusion

Hence, as we see all our three models, among all of those 'Random Forest' model performing well, because of evaluations like:- accuracy: 88.77%, log_loss:4.05, classification report, confusion matrix and roc_curve/roc_auc_score. But, In classification report all of these models are predicting correct values/class for 1(presence of heart disease, which is around 85%) as compare to 0(absence of heart disease, which is around 90%). But, well it depends on dataset and we can apply some of other techniques to increase the model accuracy like:- PCA (bcz we have 15 features, which might be large to train model, we have reduce the dimensions using it), Hyperparameter Tuning (extracting the best parameters of our models) and etc.

Now, all of our model performing well but, we need one model to make unseen or new data prediction. So, we are going to use 'Random Forest' due to evaluations I mentioned above.

Saving Model

```
In [64]: import pickle
```

```
In [65]: # use dump() function to save the model with pickle  
save_rfc_model = pickle.dumps(rfc)  
  
# use load() function to Loading the saved model  
rfc_from_pickle = pickle.loads(save_rfc_model)  
  
# after loading, use test data to predict the outcome  
rfc_from_pickle.predict(X_test)
```

```
Out[65]: array([0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1,  
    0, 0, 1, 1, 0, 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1,  
    0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 1,  
    1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 0, 1, 0, 1, 1,  
    0, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1,  
    1, 1, 0, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1,  
    1, 0, 1, 0, 0, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0,  
    1, 0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,  
    0, 1, 0, 1, 1, 1, 0, 1, 0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 0, 0, 0,  
    1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 0,  
    1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1,  
    1, 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1,  
    1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1,  
    1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1],  
    dtype=int64)
```

```
In [66]: final_df.head()
```

```
Out[66]:
```

ATA	ChestPainType_NAP	ChestPainType_TA	RestingECG_Normal	RestingECG_ST	ExerciseAngina
1	0	0	1	0	0
0	1	0	1	0	0
1	0	0	0	1	0
0	0	0	1	0	1
0	1	0	1	0	0



```
In [67]: rfc_from_pickle.predict([[30,158,220,0,160,1.3,1,0,0,1,1,0,0,0,0]])
```

```
Out[67]: array([0], dtype=int64)
```

```
In [68]: with open('heart_disease_model.pkl', 'wb') as file:  
    pickle.dump(rfc_from_pickle, file)
```

```
In [ ]:
```