heart_disease

October 23, 2023

[ ]:

```
# IMPORTING NECESSARY PACKAGES
import warnings
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import numpy as np
import statsmodels.api as sm
from statsmodels.stats.outliers_influence import variance_inflation_factor
from statsmodels.tools.tools import add_constant

from scipy.stats import chi2_contingency
from scipy.stats import ttest_ind

from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report

from imblearn.over_sampling import SMOTE
from imblearn.under_sampling import RandomUnderSampler
from sklearn.tree import DecisionTreeClassifier

warnings.filterwarnings("ignore", category=DeprecationWarning)
warnings.filterwarnings("ignore", category=FutureWarning)

from sklearn.tree import export_graphviz

# Specify the URL of the dataset
url = "https://raw.githubusercontent.com/AAI-500-Team/aai_500_dataset/main/
 ↪heart_2022_no_nans.csv"

# Use pandas to read the CSV file from the URL into a DataFrame
df = pd.read_csv(url)
```

0.1 Introduction

First, we're going to understand the given dataset.

[ ]:

```
display(df)
```

```
                 State     Sex GeneralHealth  PhysicalHealthDays  \
0              Alabama  Female     Very good                 4.0   
1              Alabama    Male     Very good                 0.0   
2              Alabama    Male     Very good                 0.0   
3              Alabama  Female          Fair                 5.0   
4              Alabama  Female          Good                 3.0   
…                …     …           …                 …   
246017  Virgin Islands    Male     Very good                 0.0   
246018  Virgin Islands  Female          Fair                 0.0   
246019  Virgin Islands    Male          Good                 0.0   
246020  Virgin Islands  Female     Excellent                 2.0   
246021  Virgin Islands    Male     Very good                 0.0   

        MentalHealthDays                                    LastCheckupTime  \
0                    0.0  Within past year (anytime less than 12 months …   
1                    0.0  Within past year (anytime less than 12 months …   
2                    0.0  Within past year (anytime less than 12 months …   
3                    0.0  Within past year (anytime less than 12 months …   
4                   15.0  Within past year (anytime less than 12 months …   
…                  …                                                …   
246017               0.0  Within past 2 years (1 year but less than 2 ye…   
246018               7.0  Within past year (anytime less than 12 months …   
246019              15.0  Within past year (anytime less than 12 months …   
246020               2.0  Within past year (anytime less than 12 months …   
246021               0.0  Within past year (anytime less than 12 months …   

       PhysicalActivities  SleepHours            RemovedTeeth HadHeartAttack  \
0                     Yes         9.0            None of them             No   
1                     Yes         6.0            None of them             No   
2                      No         8.0  6 or more, but not all             No   
3                     Yes         9.0            None of them             No   
4                     Yes         5.0                  1 to 5             No   
…                   …         …                     …            …   
246017                Yes         6.0            None of them             No   
246018                Yes         7.0            None of them             No   
246019                Yes         7.0                  1 to 5             No   
246020                Yes         7.0            None of them             No   
246021                 No         5.0            None of them            Yes   

        … HeightInMeters WeightInKilograms    BMI AlcoholDrinkers  \
0       …           1.60             71.67  27.99              No   
1       …           1.78             95.25  30.13              No   
2       …           1.85            108.86  31.66             Yes   
3       …           1.70             90.72  31.32              No   
4       …           1.55             79.38  33.07              No   
…     …            …               …    …             …   
246017  …           1.78            102.06  32.28             Yes   
246018  …           1.93             90.72  24.34              No   
```

```
246019  …           1.68             83.91  29.86                 Yes
246020  …           1.70             83.01  28.66                  No
246021  …           1.83            108.86  32.55                  No

       HIVTesting FluVaxLast12 PneumoVaxEver  \
0              No          Yes           Yes
1              No          Yes           Yes
2              No           No           Yes
3              No          Yes           Yes
4              No          Yes           Yes
…           …          …           …
246017         No           No            No
246018         No           No            No
246019        Yes          Yes           Yes
246020        Yes          Yes            No
246021        Yes          Yes           Yes

                                        TetanusLast10Tdap HighRiskLastYear  \
0                                       Yes, received Tdap               No
1       Yes, received tetanus shot but not sure what type               No
2       No, did not receive any tetanus shot in the pa…             No
3       No, did not receive any tetanus shot in the pa…             No
4       No, did not receive any tetanus shot in the pa…             No
…                                                    …              …
246017  Yes, received tetanus shot but not sure what type               No
246018  No, did not receive any tetanus shot in the pa…             No
246019  Yes, received tetanus shot but not sure what type               No
246020  Yes, received tetanus shot but not sure what type               No
246021  No, did not receive any tetanus shot in the pa…             No

       CovidPos
0            No
1            No
2           Yes
3           Yes
4            No
…         …
246017       No
246018      Yes
246019      Yes
246020       No
246021      Yes

[246022 rows x 40 columns]
```

[ ]:

```
# Use the describe method to find descriptive statistics (including the 5-summary stats)
```

```
df.describe()
```

[ ]:

```
       PhysicalHealthDays  MentalHealthDays     SleepHours  HeightInMeters  \
count       246022.000000     246022.000000  246022.000000   246022.000000
mean             4.119026          4.167140       7.021331        1.705150
std              8.405844          8.102687       1.440681        0.106654
min              0.000000          0.000000       1.000000        0.910000
25%              0.000000          0.000000       6.000000        1.630000
50%              0.000000          0.000000       7.000000        1.700000
75%              3.000000          4.000000       8.000000        1.780000
max             30.000000         30.000000      24.000000        2.410000

       WeightInKilograms            BMI
count      246022.000000  246022.000000
mean           83.615179      28.668136
std            21.323156       6.513973
min            28.120000      12.020000
25%            68.040000      24.270000
50%            81.650000      27.460000
75%            95.250000      31.890000
max           292.570000      97.650000
```

0.1.1 Conclusion:

The dataset has **40** columns, with numerical and categorical data. Most of the columns are categorical, with **5** numerical columns.

[ ]:

```
rows, columns = df.shape
print(f"Number of rows: {rows}, Number of columns: {columns}")
```

```
Number of rows: 246022, Number of columns: 40
```

0.2 Data Cleaning / Preparation

Let's inspect any missing, incomplete data.

[ ]:

```
print(f"Number of duplicates: {df.duplicated().sum()}")
print(f"Number of missing values: {df.isnull().sum().sum()}")
```

```
Number of duplicates: 9
Number of missing values: 0
Number of missing values: 0
```

There is no missing values, but. there are duplicates. Let's drop them. We're also going to drop BMI, since it is a function of height and weight, and there is multicollinearity. Lastly, we're going to drop the features that are relevant to our research question.

[ ]:

```
# Drop duplicated
df.drop_duplicates(inplace=True)
```

```python
# Drop Unrelated variables and BMI for multicollinearity with Height and Weight
df = df.drop(columns=['State', 'LastCheckupTime','BMI'])
```

[ ]:

```python
# Create lists of numerical variables, categorical variables and target␣
 ↪variable for future use
numerical_vars = ['PhysicalHealthDays', 'MentalHealthDays', 'SleepHours',␣
 ↪'HeightInMeters', 'WeightInKilograms']
categorical_includes_taget = ['Sex', 'GeneralHealth', 'PhysicalActivities',␣
 ↪'RemovedTeeth', 'HadAngina',
       'HadStroke', 'HadAsthma', 'HadSkinCancer', 'HadCOPD',
       'HadDepressiveDisorder', 'HadKidneyDisease', 'HadArthritis',
       'HadDiabetes', 'DeafOrHardOfHearing', 'BlindOrVisionDifficulty',
       'DifficultyConcentrating', 'DifficultyWalking',
       'DifficultyDressingBathing', 'DifficultyErrands', 'SmokerStatus',
       'ECigaretteUsage', 'ChestScan', 'RaceEthnicityCategory', 'AgeCategory',␣
 ↪'AlcoholDrinkers',
       'HIVTesting', 'FluVaxLast12', 'PneumoVaxEver', 'TetanusLast10Tdap',
       'HighRiskLastYear', 'CovidPos','HadHeartAttack']

categorical_vars = ['Sex', 'GeneralHealth', 'PhysicalActivities',␣
 ↪'RemovedTeeth', 'HadAngina',
       'HadStroke', 'HadAsthma', 'HadSkinCancer', 'HadCOPD',
       'HadDepressiveDisorder', 'HadKidneyDisease', 'HadArthritis',
       'HadDiabetes', 'DeafOrHardOfHearing', 'BlindOrVisionDifficulty',
       'DifficultyConcentrating', 'DifficultyWalking',
       'DifficultyDressingBathing', 'DifficultyErrands', 'SmokerStatus',
       'ECigaretteUsage', 'ChestScan', 'RaceEthnicityCategory', 'AgeCategory',␣
 ↪'AlcoholDrinkers',
       'HIVTesting', 'FluVaxLast12', 'PneumoVaxEver', 'TetanusLast10Tdap',
       'HighRiskLastYear', 'CovidPos']
target = 'HadHeartAttack'

print(f"Numerical variables: {numerical_vars}")
print(f"Catergorical variables: {categorical_vars}")
print(f"Target variable: {target}")
```

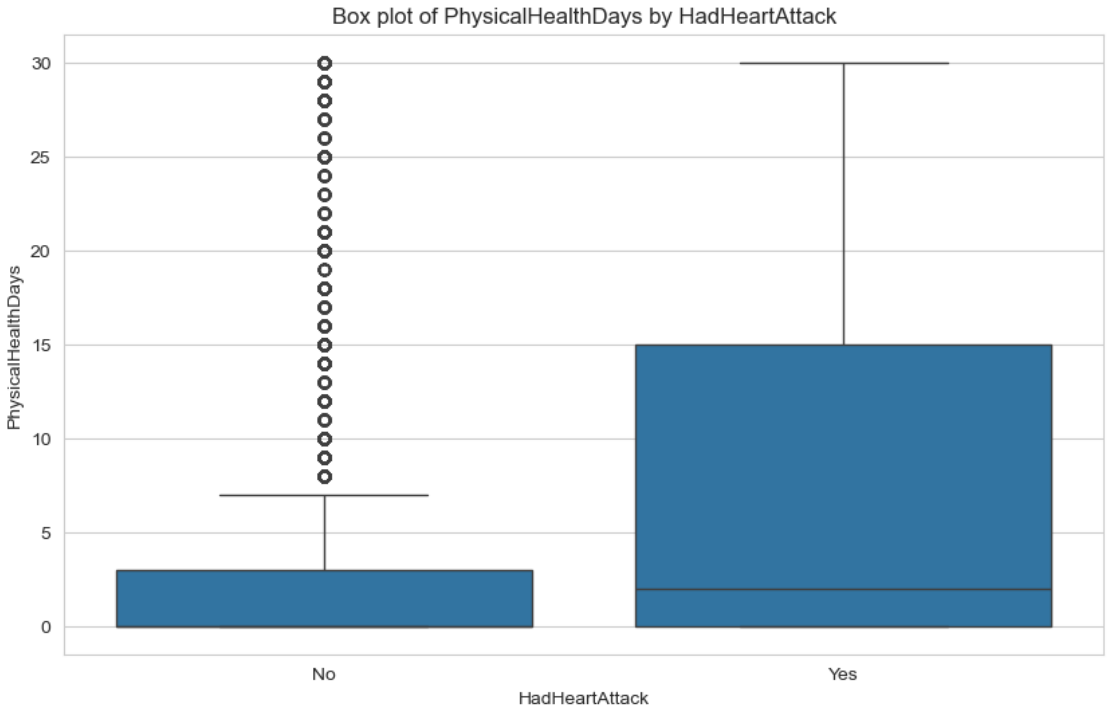
```
Numerical variables: ['PhysicalHealthDays', 'MentalHealthDays', 'SleepHours',
'HeightInMeters', 'WeightInKilograms']
Catergorical variables: ['Sex', 'GeneralHealth', 'PhysicalActivities',
'RemovedTeeth', 'HadAngina', 'HadStroke', 'HadAsthma', 'HadSkinCancer',
'HadCOPD', 'HadDepressiveDisorder', 'HadKidneyDisease', 'HadArthritis',
'HadDiabetes', 'DeafOrHardOfHearing', 'BlindOrVisionDifficulty',
'DifficultyConcentrating', 'DifficultyWalking', 'DifficultyDressingBathing',
'DifficultyErrands', 'SmokerStatus', 'ECigaretteUsage', 'ChestScan',
'RaceEthnicityCategory', 'AgeCategory', 'AlcoholDrinkers', 'HIVTesting',
'FluVaxLast12', 'PneumoVaxEver', 'TetanusLast10Tdap', 'HighRiskLastYear',
'CovidPos']
```

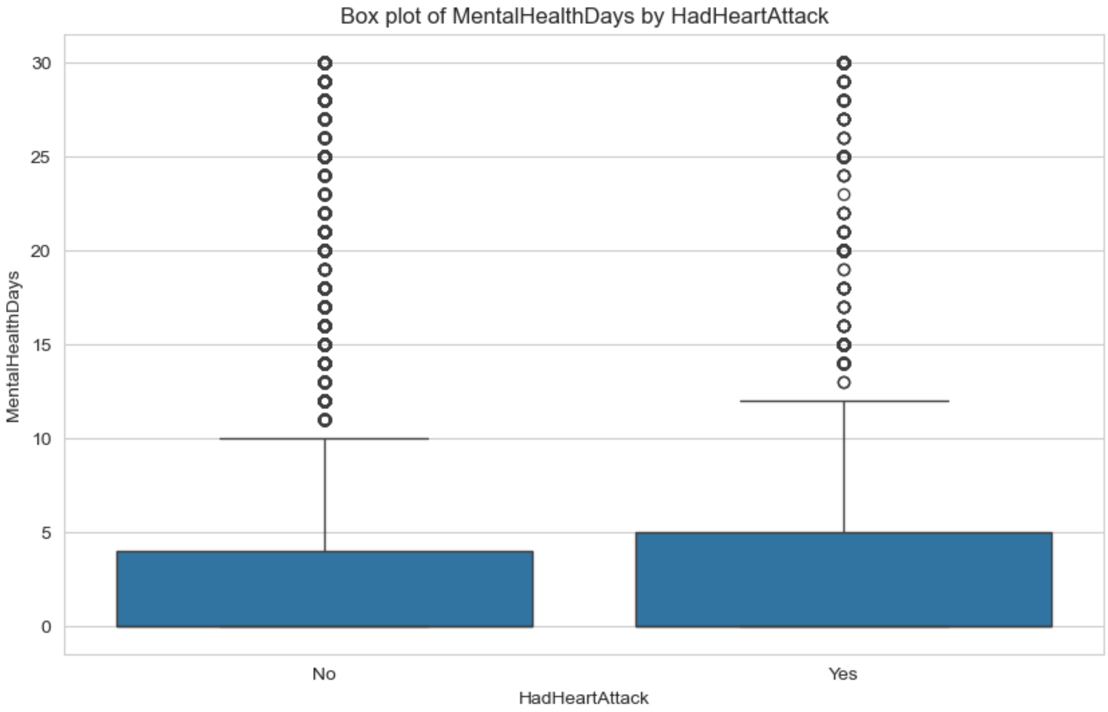
```
Target variable: HadHeartAttack
```

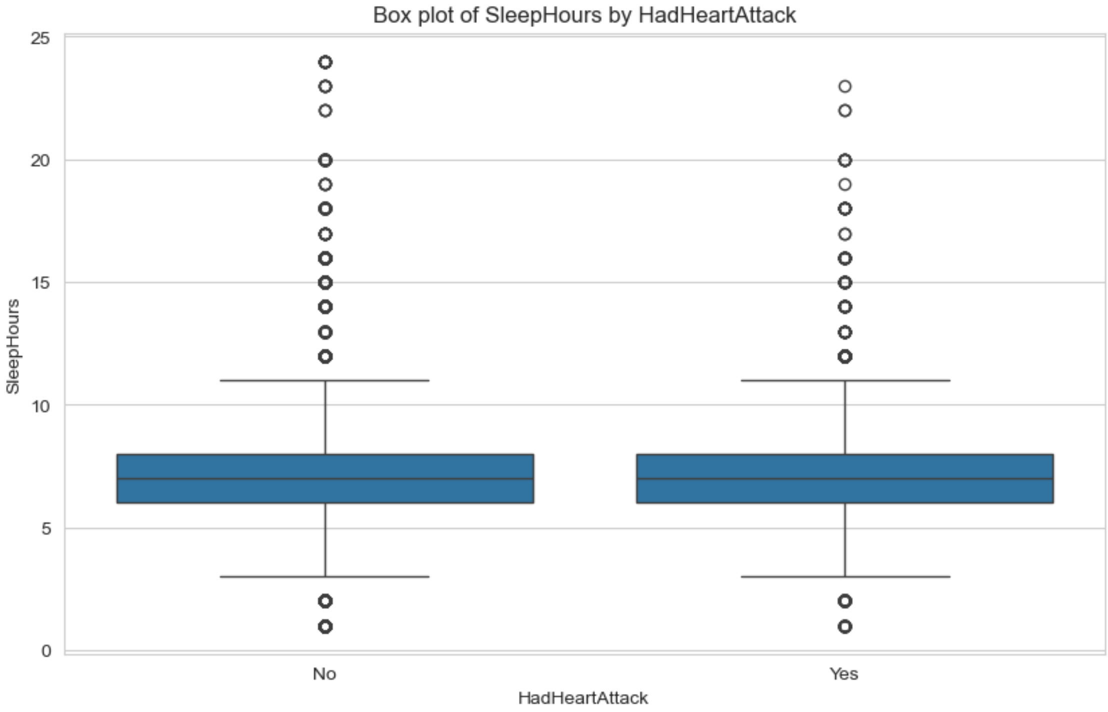
0.3 Exploratory Data Analysis

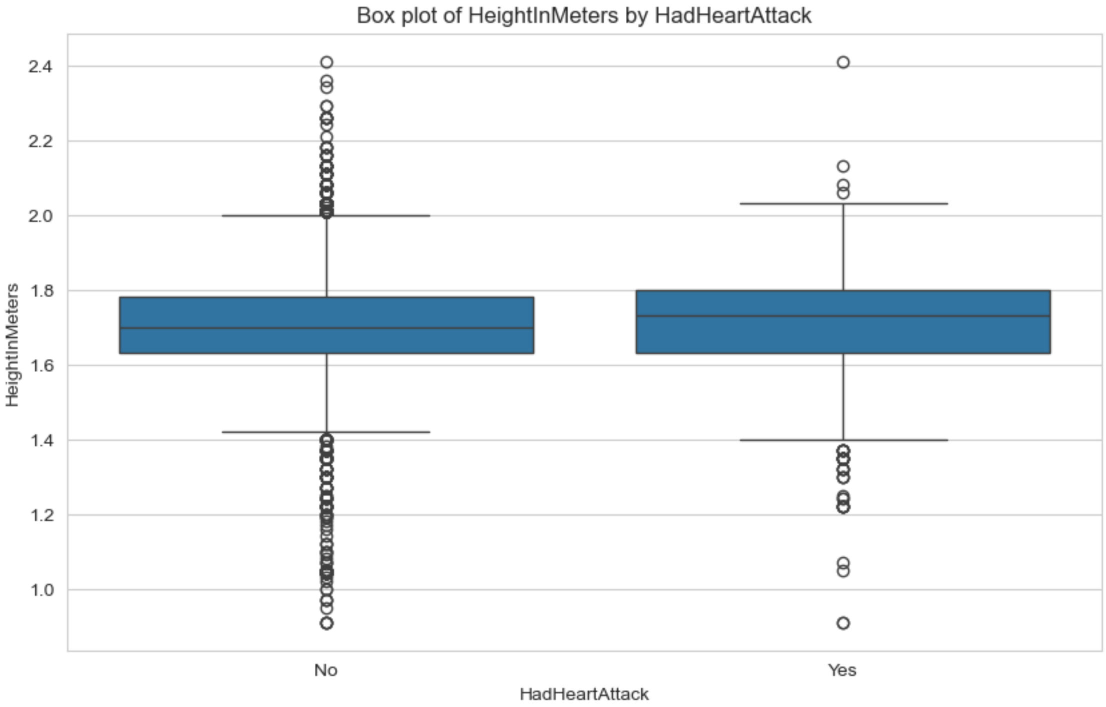
[ ]:

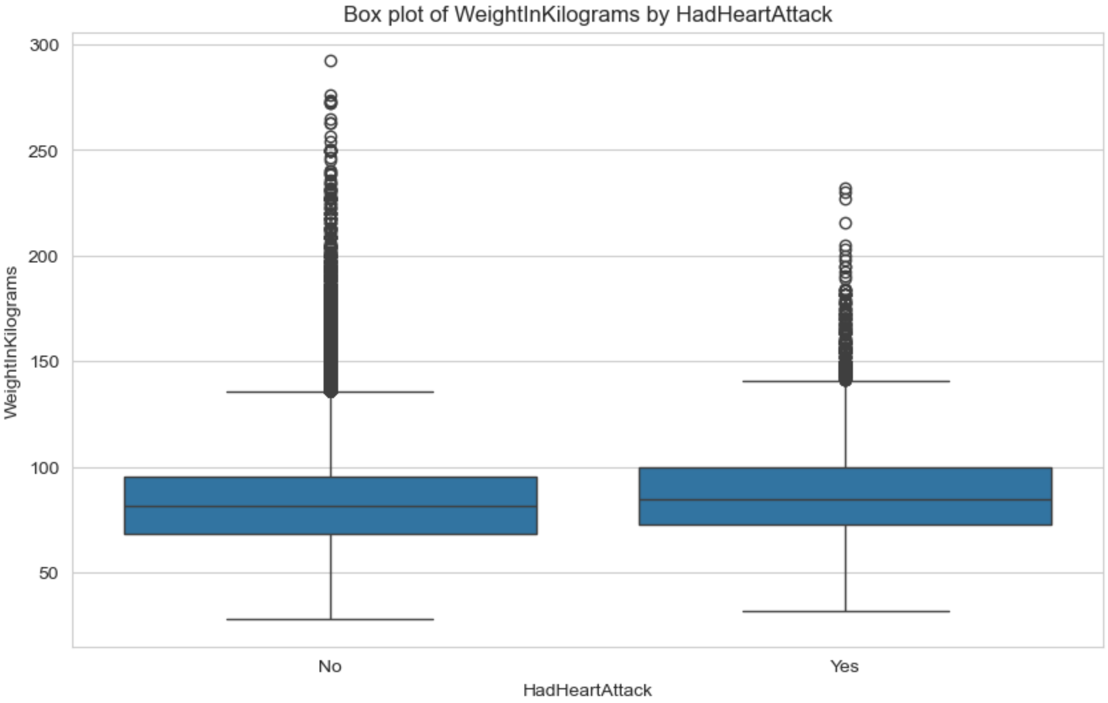
```python
# Create box plots, histograms, and violin plots for numerical data
sns.set_style("whitegrid")
# Box Plots
for var in numerical_vars:
    plt.figure(figsize=(10, 6))
    sns.boxplot(x=target, y=var, data=df)
    plt.title(f"Box plot of {var} by {target}")
    plt.show()
# Histograms
for var in numerical_vars:
    plt.figure(figsize=(10, 6))
    sns.histplot(df, x=var, hue=target, element="step", stat="density", common_norm=False)
    plt.title(f"Histogram of {var} by {target}")
    plt.show()
# Violin Plots
for var in numerical_vars:
    plt.figure(figsize=(10, 6))
    sns.violinplot(x=target, y=var, data=df)
    plt.title(f"Violin plot of {var} by {target}")
    plt.show()
```

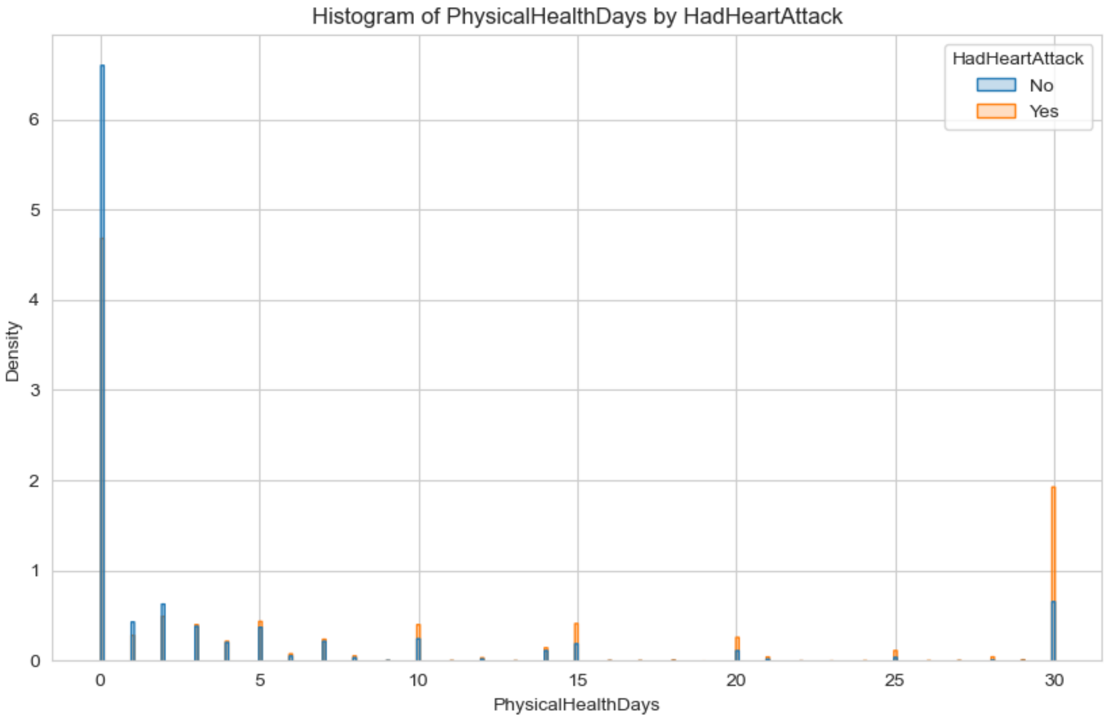


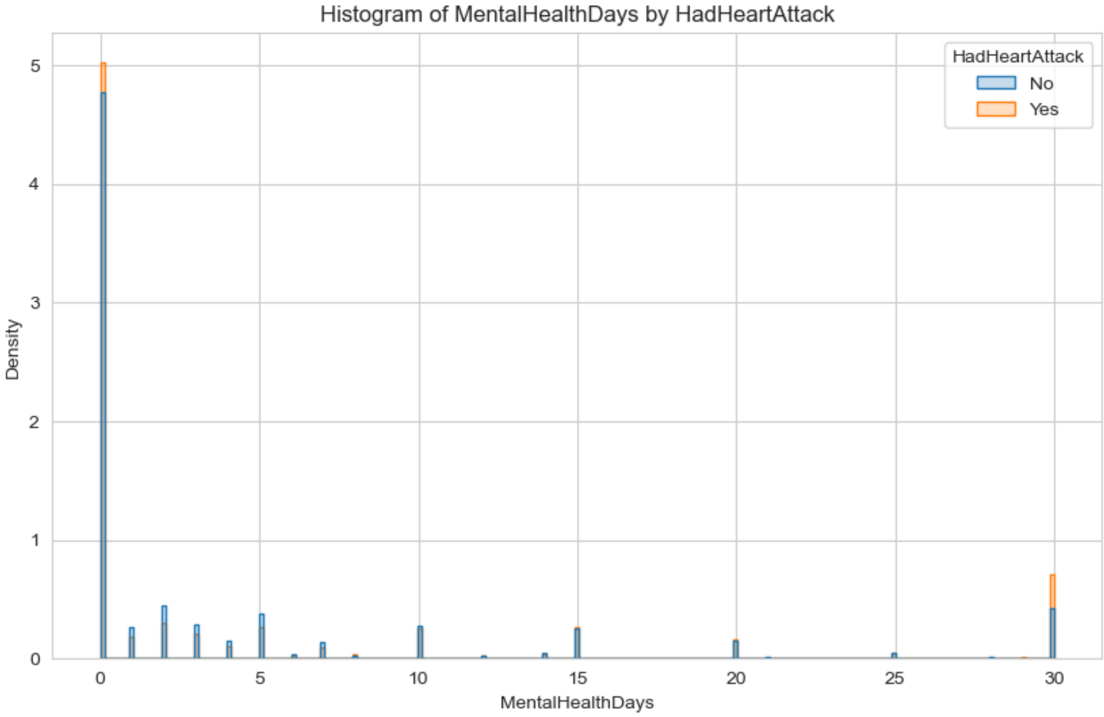

Box plot of MentalHealthDays by HadHeartAttack
MentalHealthDays
0
5
10
15
20
25
30
No
Yes
HadHeartAttack

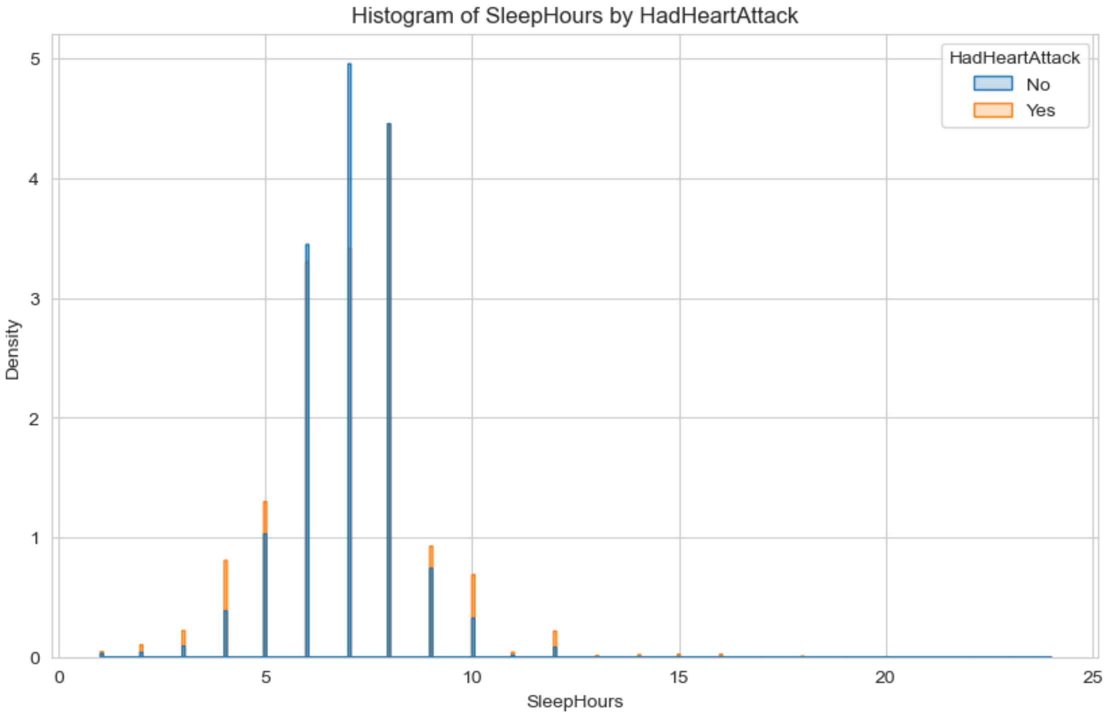

Box plot of SleepHours by HadHeartAttack
SleepHours
0
5
10
15
20
25
No
Yes
HadHeartAttack

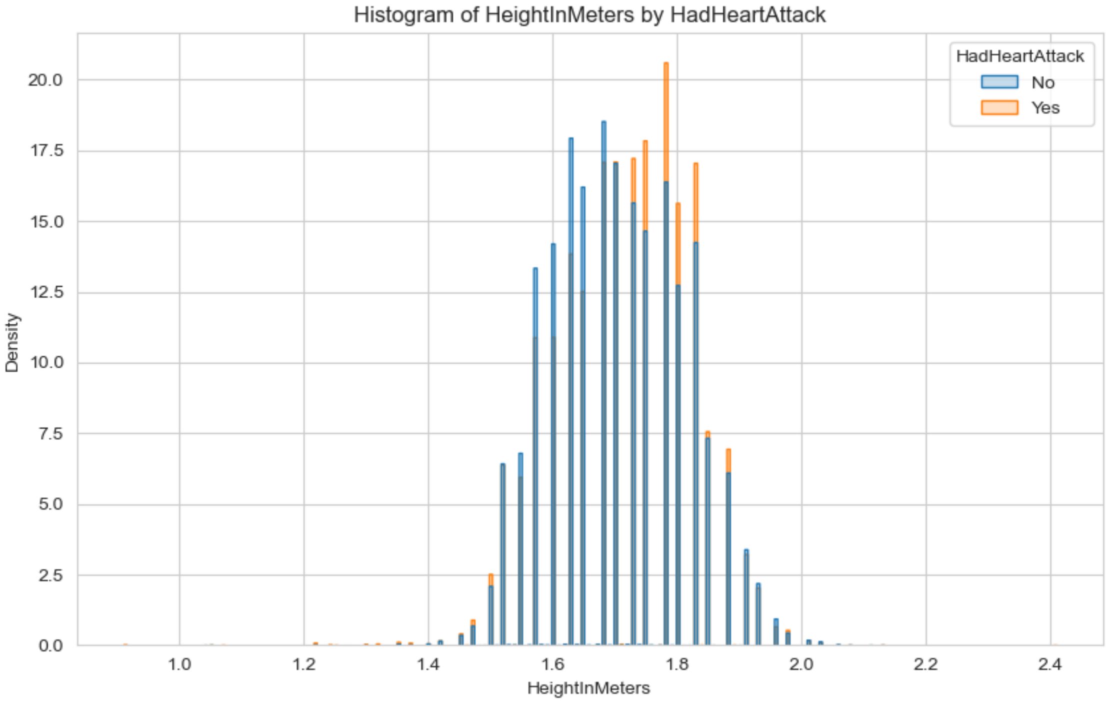

Box plot of HeightInMeters by HadHeartAttack
HeightInMeters
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
No
Yes
HadHeartAttack

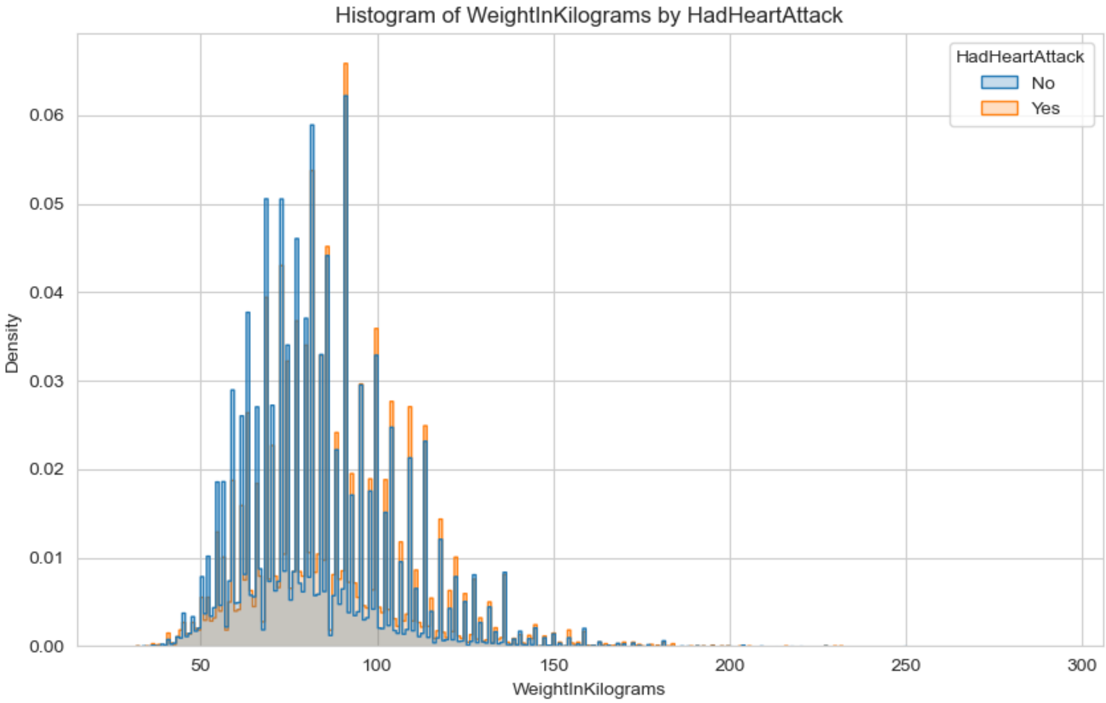

Box plot of WeightInKilograms by HadHeartAttack
WeightInKilograms
300
250
200
150
100
50
No
Yes
HadHeartAttack

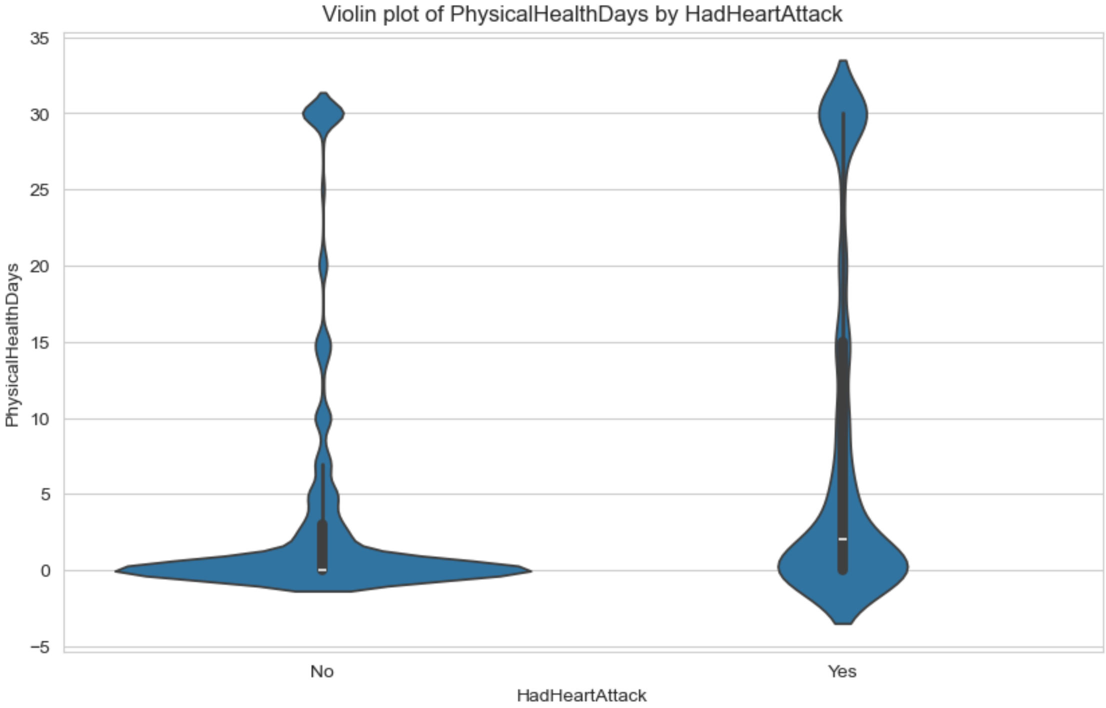

Histogram of PhysicalHealthDays by HadHeartAttack
HadHeartAttack
No
Yes
Density
0
1
2
3
4
5
6
0
5
10
15
20
25
30
PhysicalHealthDays

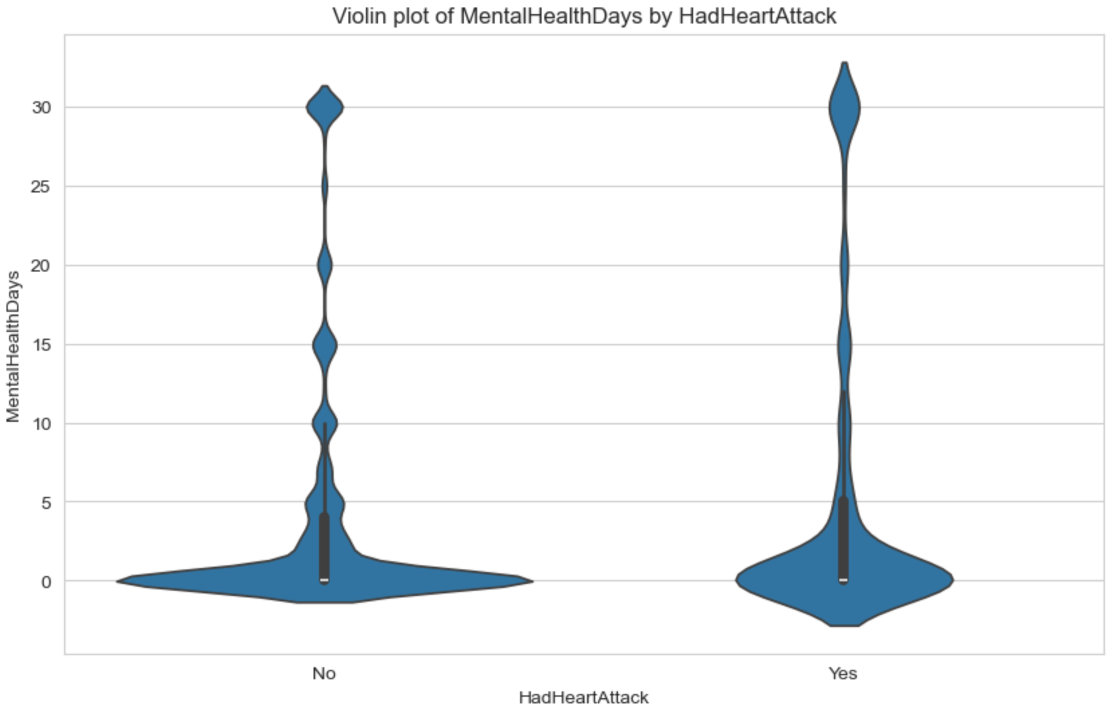

Histogram of MentalHealthDays by HadHeartAttack
HadHeartAttack
No
Yes
Density
0
1
2
3
4
5
0
5
10
15
20
25
30
MentalHealthDays

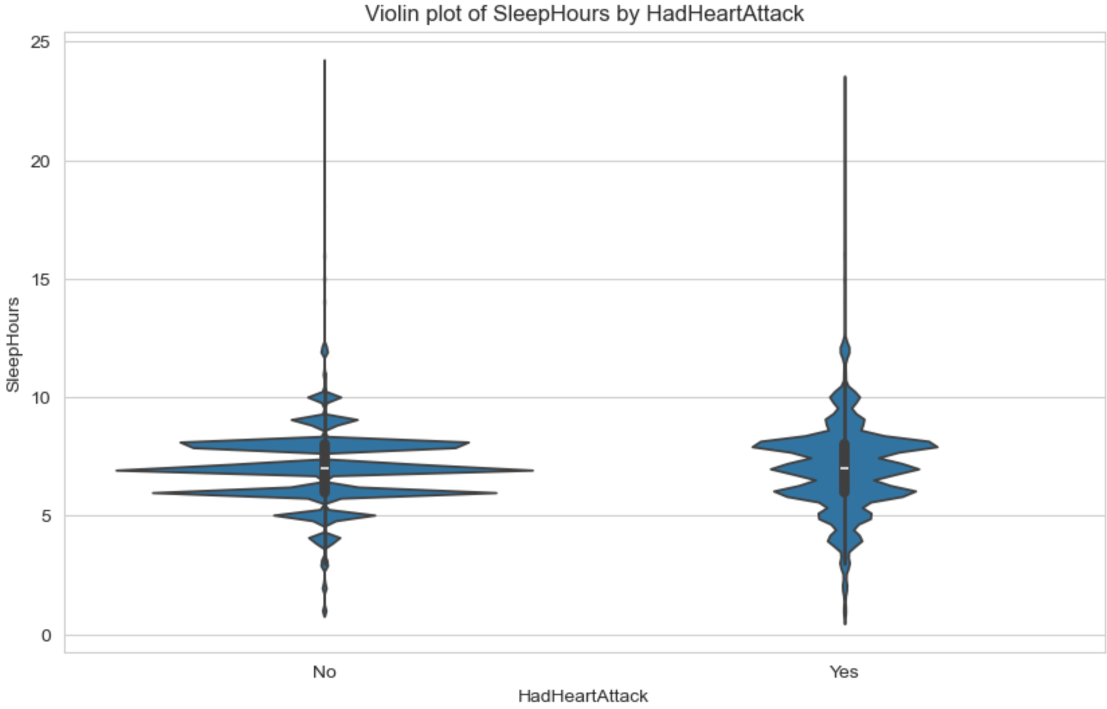

Histogram of SleepHours by HadHeartAttack
Density
SleepHours
0
1
2
3
4
5
0
5
10
15
20
25
HadHeartAttack
No
Yes

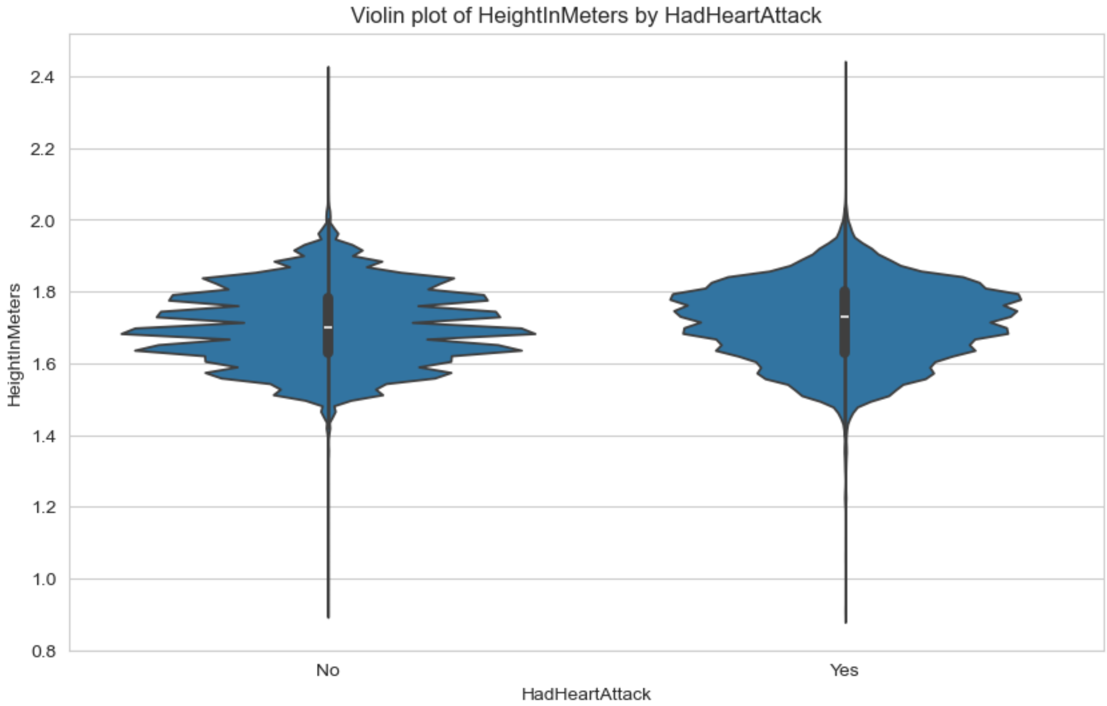

Histogram of HeightInMeters by HadHeartAttack
Density
HeightInMeters
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
HadHeartAttack
No
Yes

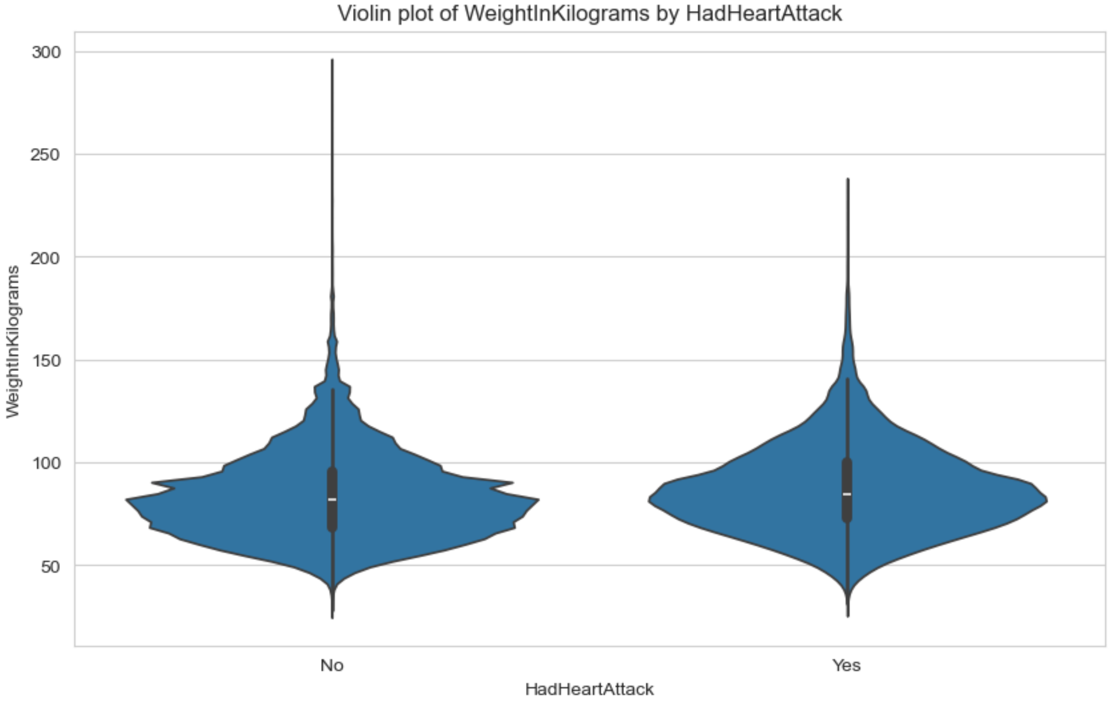

Histogram of WeightInKilograms by HadHeartAttack
HadHeartAttack
No
Yes
Density
0.00
0.01
0.02
0.03
0.04
0.05
0.06
50
100
150
200
250
300
WeightInKilograms


Violin plot of PhysicalHealthDays by HadHeartAttack
PhysicalHealthDays
35
30
25
20
15
10
5
0
−5
No
Yes
HadHeartAttack


Violin plot of MentalHealthDays by HadHeartAttack
MentalHealthDays
30
25
20
15
10
5
0
No
Yes
HadHeartAttack

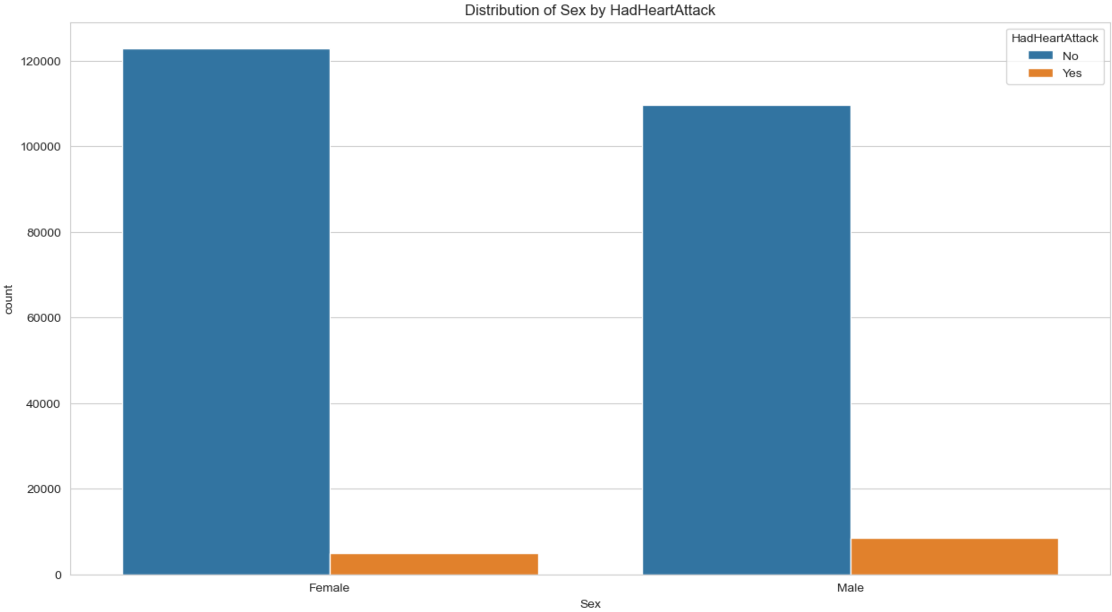

Violin plot of SleepHours by HadHeartAttack
SleepHours
25
20
15
10
5
0
No
Yes
HadHeartAttack


Violin plot of HeightInMeters by HadHeartAttack
HeightInMeters
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
No
Yes
HadHeartAttack

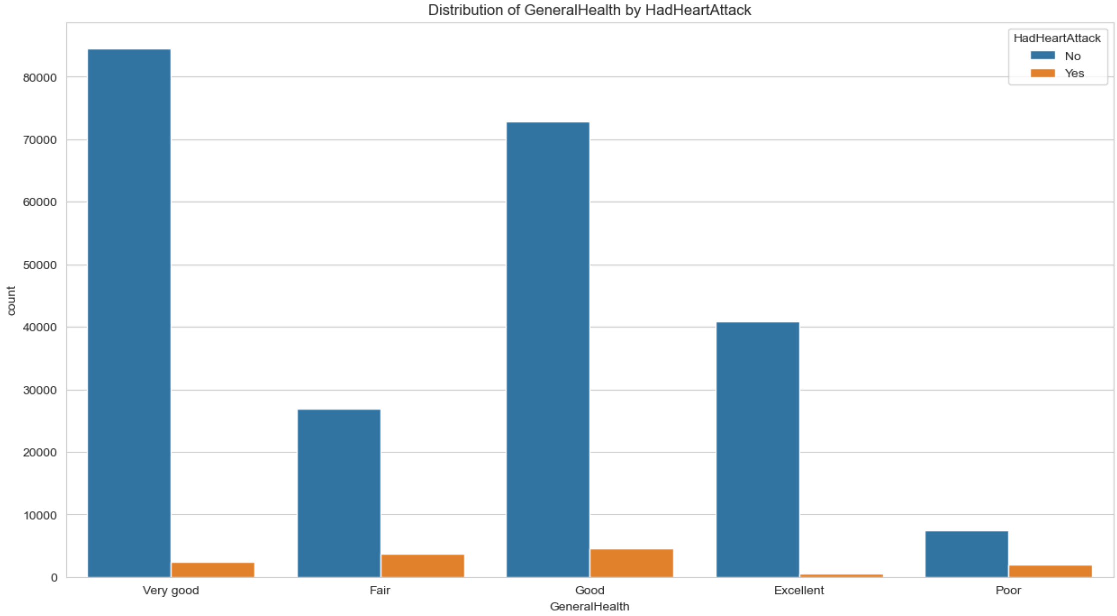

Violin plot of WeightInKilograms by HadHeartAttack
WeightInKilograms
300
250
200
150
100
50
No
Yes
HadHeartAttack

```
[ ]: # Dataframe to store result of Chi2 test
     results_df_cat = pd.DataFrame(columns=['Feature', 'Chi2', 'P-Value'])

     # Copy to keep the original dataframe
     cat_df = df.copy()
     cat_df["HadHeartAttack"] = cat_df["HadHeartAttack"].astype('category')

     # For each categorical ver perform Chi2 test
     # Print results, create bar plot
     for var in categorical_vars:
       cat_df[var] = cat_df[var].astype('category')
       contingency_table = pd.crosstab(cat_df[var], cat_df["HadHeartAttack"])
       chi2, p, _, _ = chi2_contingency(contingency_table)
       print(contingency_table)
       print(f"Chi-Squared Test for {var} and {target}")
       print(f"Chi2 value = {chi2}, p-value = {p}\n")
       # Add the results to the DataFrame
       new_row = {'Feature': var, 'Chi2': chi2, 'P-Value': p}
       results_df_cat = pd.concat([results_df_cat, pd.DataFrame(new_row,␣
      ↪index=[0])], ignore_index=True)
       # Bar Plots
       plt.figure(figsize=(15, 8))
       sns.countplot(data=df, x=var, hue=target)
       plt.title(f"Distribution of {var} by {target}")
       plt.show()
```

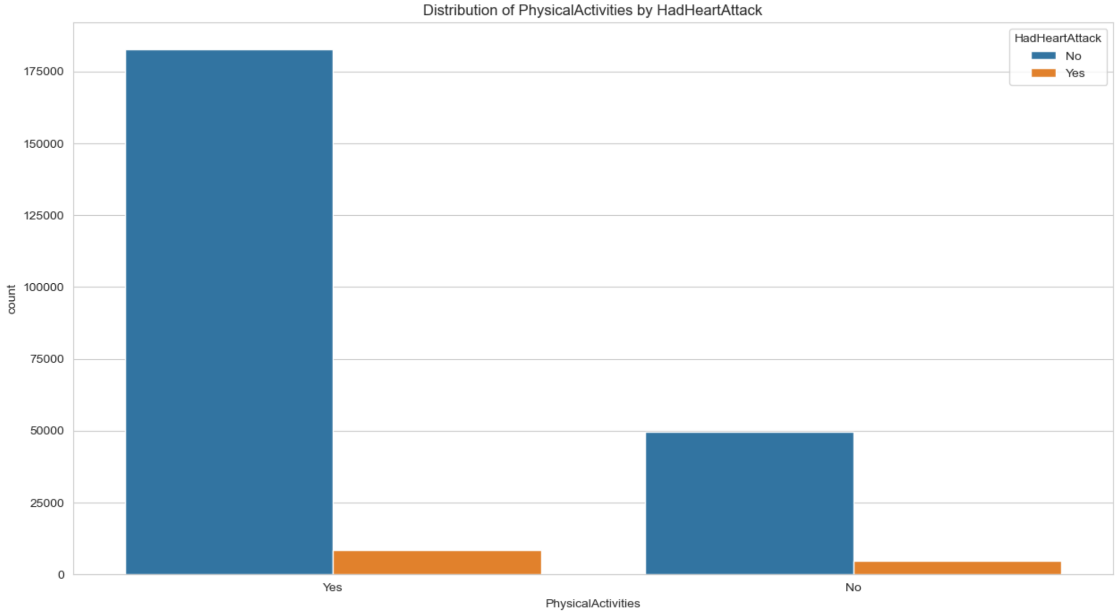
```
HadHeartAttack      No   Yes
Sex
Female          122874  4932
Male            109704  8503
Chi-Squared Test for Sex and HadHeartAttack
Chi2 value = 1321.7634745274654, p-value = 2.1073833823909984e-289
```



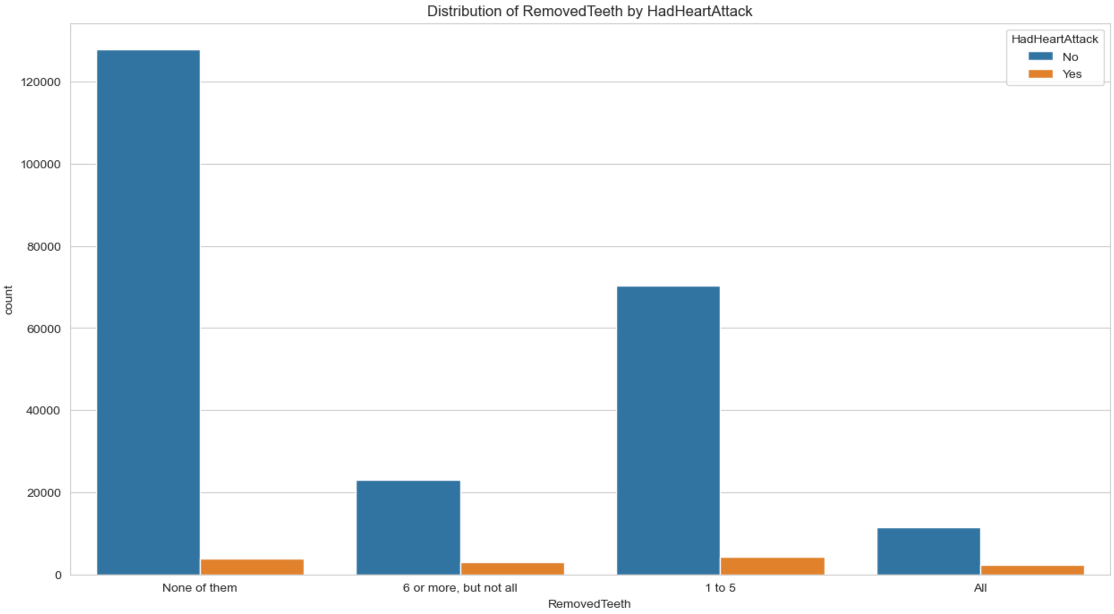
```
HadHeartAttack      No   Yes
GeneralHealth
Excellent        40928   594
Fair             26910  3748
Good             72808  4599
Poor              7406  2024
Very good        84526  2470
Chi-Squared Test for GeneralHealth and HadHeartAttack
Chi2 value = 9893.539444125969, p-value = 0.0
```



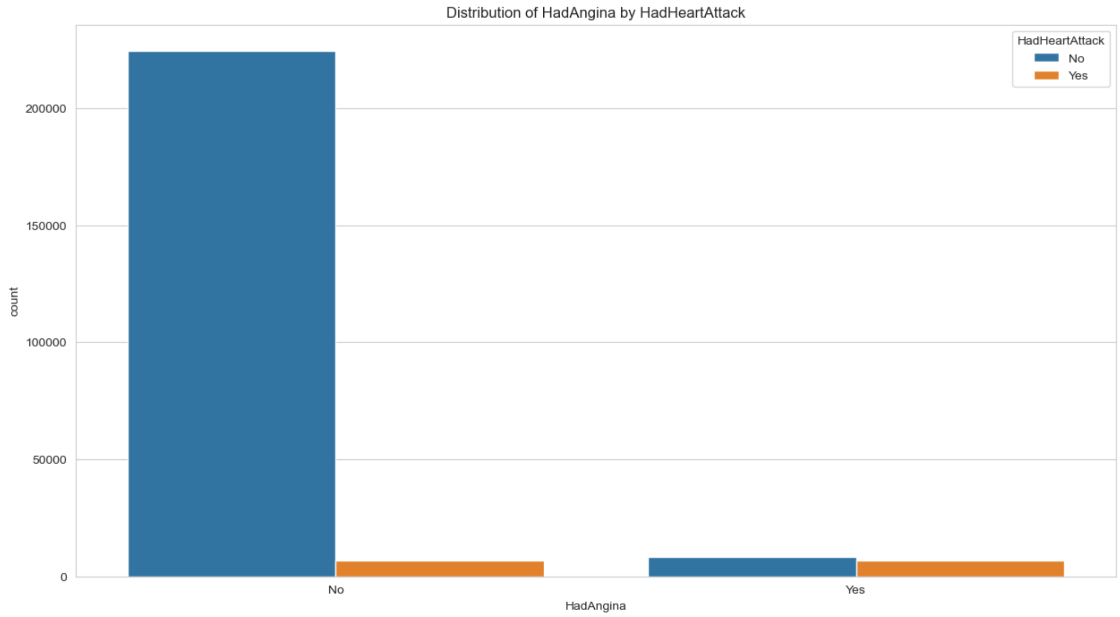
```
HadHeartAttack          No   Yes
PhysicalActivities
No                   49782  4921
Yes                 182796  8514
Chi-Squared Test for PhysicalActivities and HadHeartAttack
Chi2 value = 1701.5150212822982, p-value = 0.0
```



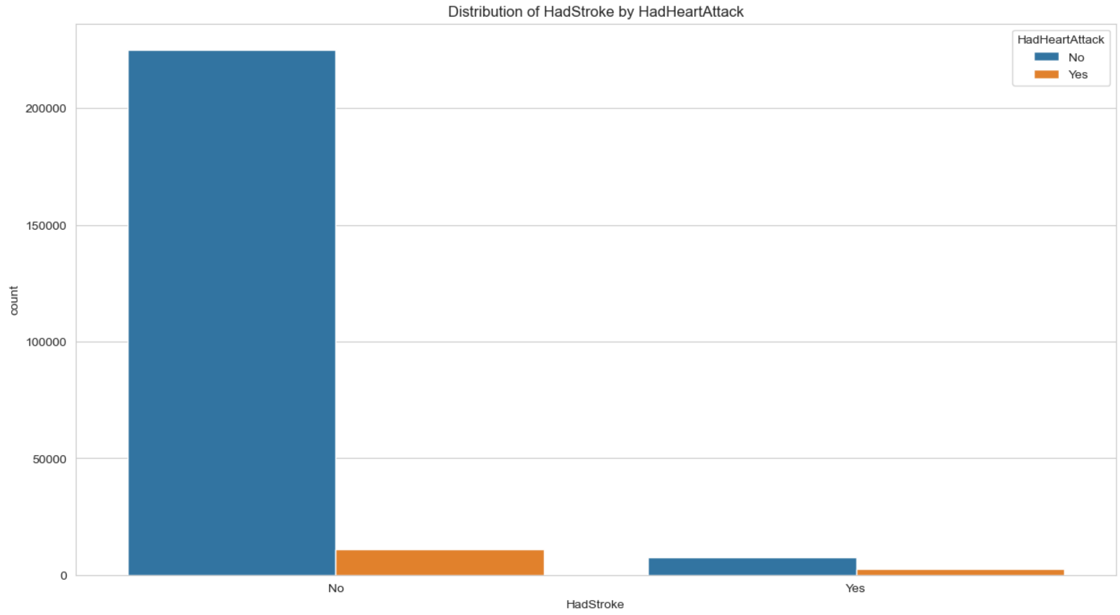
```
HadHeartAttack              No   Yes
RemovedTeeth
1 to 5                   70342  4359
6 or more, but not all   22944  3005
All                      11476  2302
None of them            127816  3769
Chi-Squared Test for RemovedTeeth and HadHeartAttack
Chi2 value = 6996.544849252672, p-value = 0.0
```



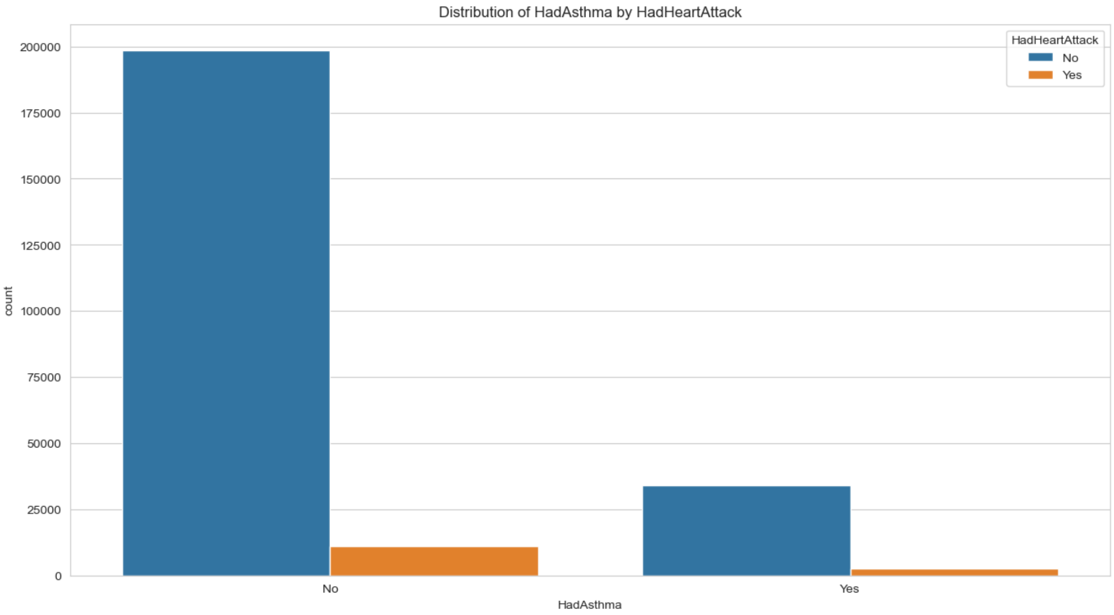
```
HadHeartAttack      No   Yes
HadAngina
No              224397  6663
Yes               8181  6772
Chi-Squared Test for HadAngina and HadHeartAttack
Chi2 value = 48906.22074894924, p-value = 0.0
```



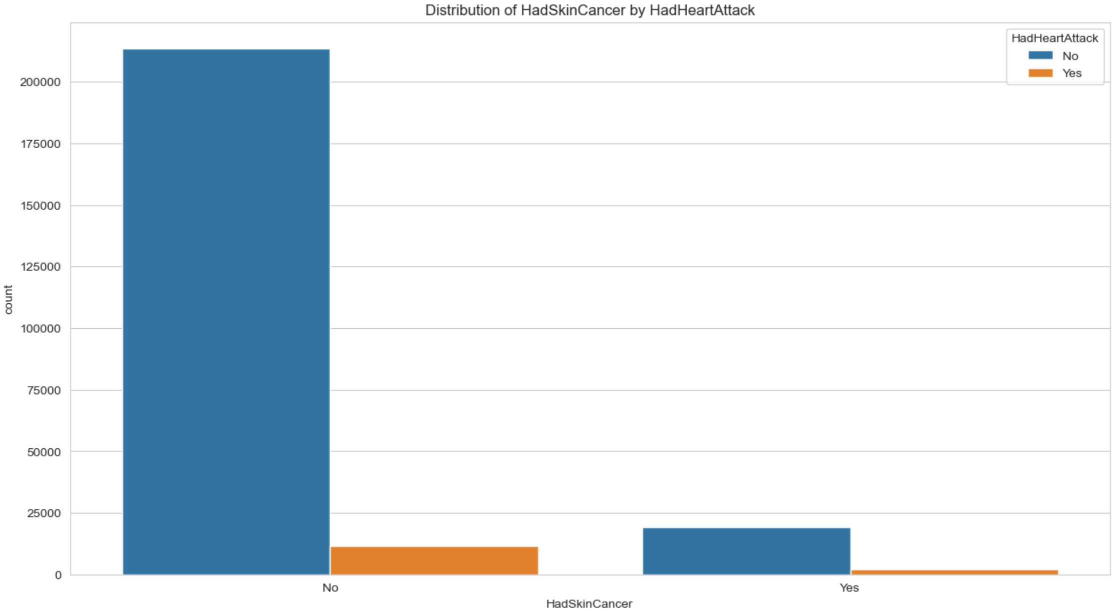
```
HadHeartAttack      No    Yes
HadStroke
No              224985  10917
Yes               7593   2518
Chi-Squared Test for HadStroke and HadHeartAttack
Chi2 value = 7716.361887180489, p-value = 0.0
```



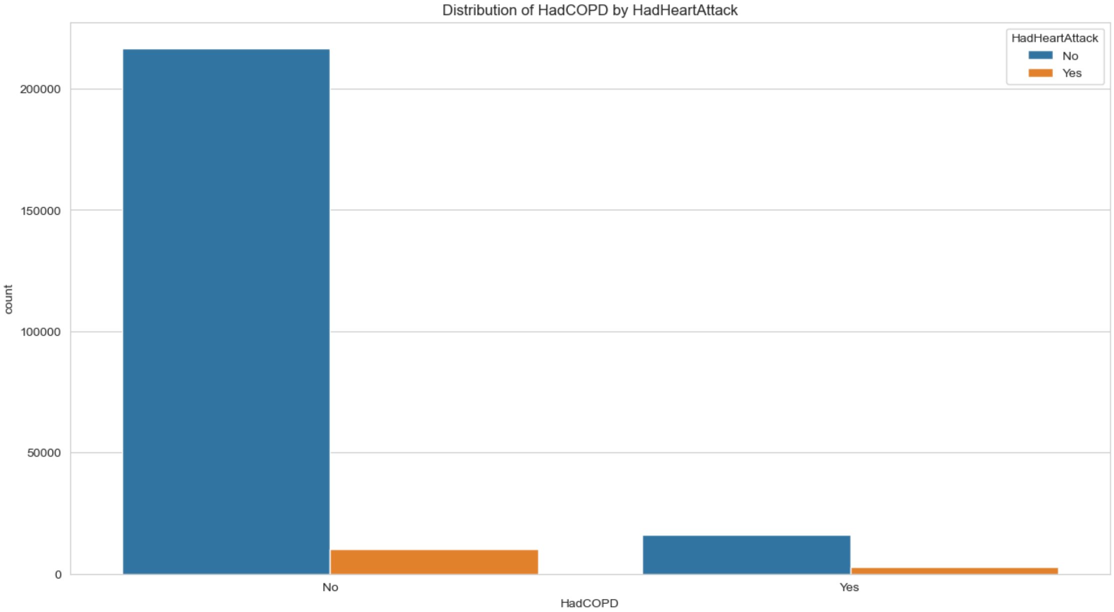
```
HadHeartAttack      No    Yes
HadAsthma
No              198518  10968
Yes              34060   2467
Chi-Squared Test for HadAsthma and HadHeartAttack
Chi2 value = 138.57317541492714, p-value = 5.460574633393451e-32
```



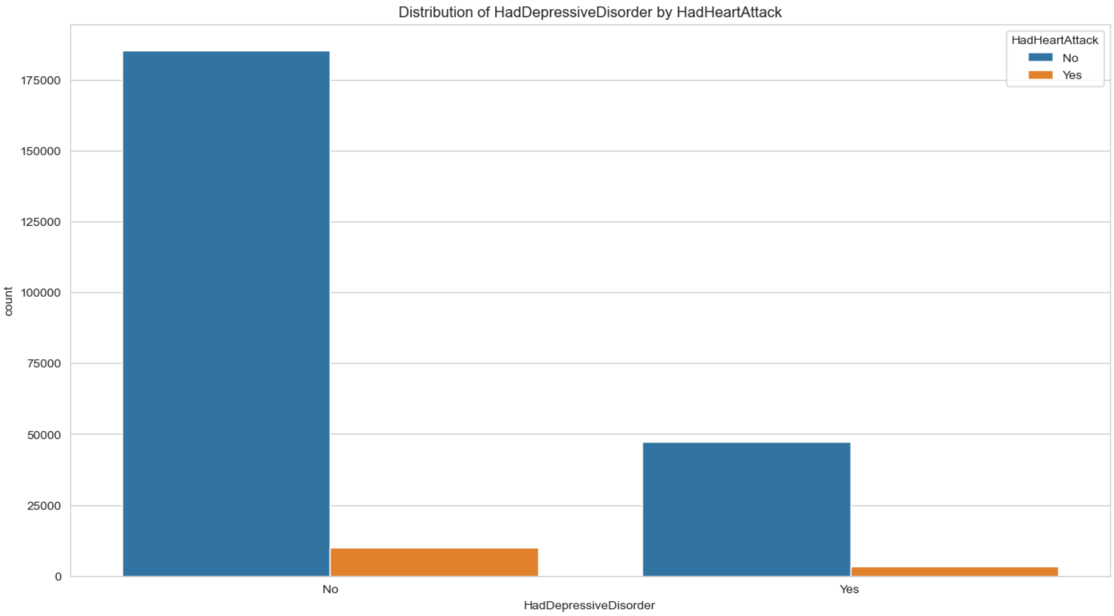
```
HadHeartAttack      No    Yes
HadSkinCancer
No              213479  11515
Yes              19099   1920
Chi-Squared Test for HadSkinCancer and HadHeartAttack
Chi2 value = 599.9377487258555, p-value = 1.7271862867830458e-132
```



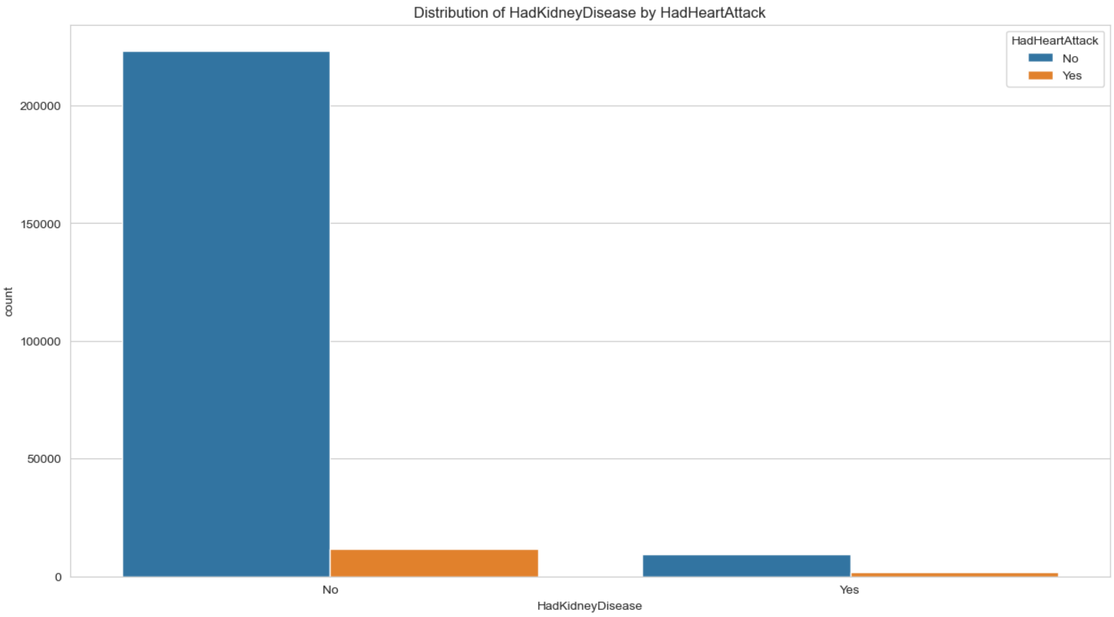
```
HadHeartAttack      No    Yes
HadCOPD
No              216609  10410
Yes              15969   3025
Chi-Squared Test for HadCOPD and HadHeartAttack
Chi2 value = 4363.963228084566, p-value = 0.0
```



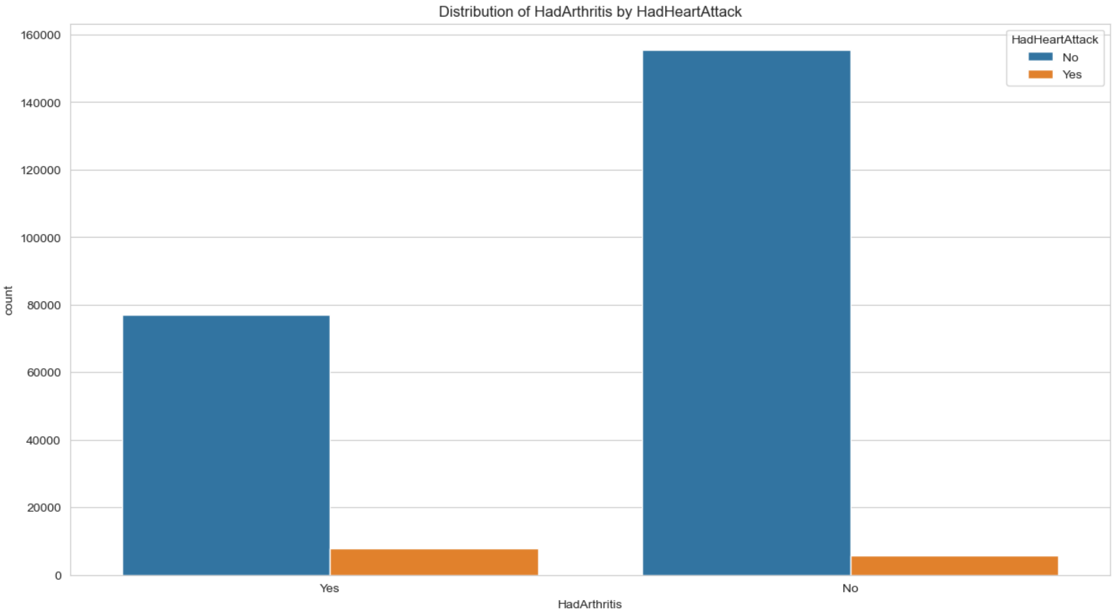
```
HadHeartAttack             No    Yes
HadDepressiveDisorder
No                     185258  10135
Yes                     47320   3300
Chi-Squared Test for HadDepressiveDisorder and HadHeartAttack
Chi2 value = 137.94235523398163, p-value = 7.502329516886957e-32
```



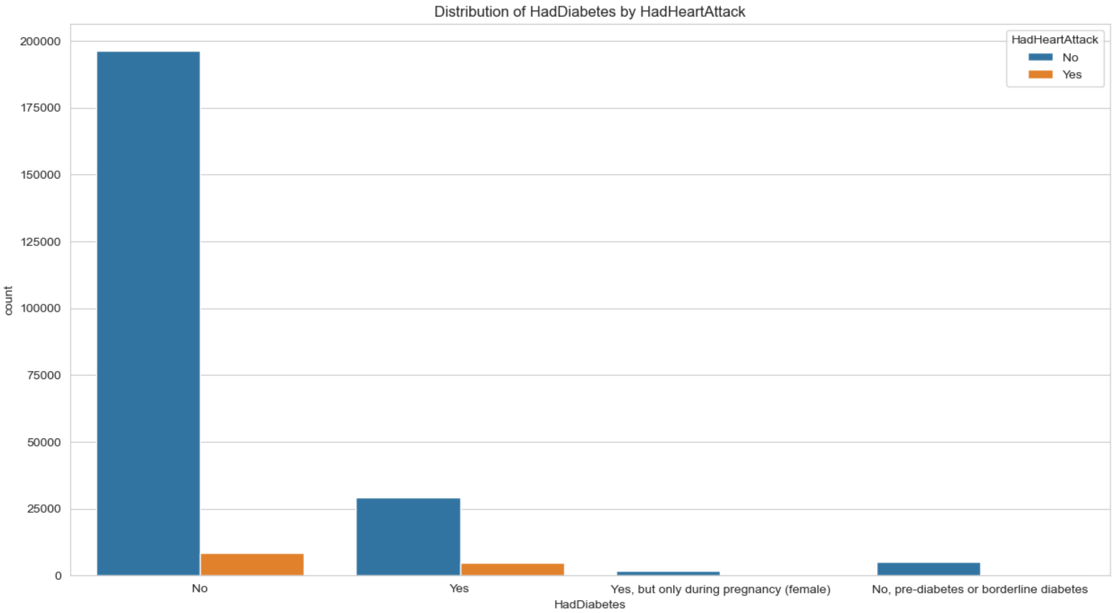
```
HadHeartAttack        No    Yes
HadKidneyDisease
No                223189  11540
Yes                 9389   1895
Chi-Squared Test for HadKidneyDisease and HadHeartAttack
Chi2 value = 2939.5670891414943, p-value = 0.0
```



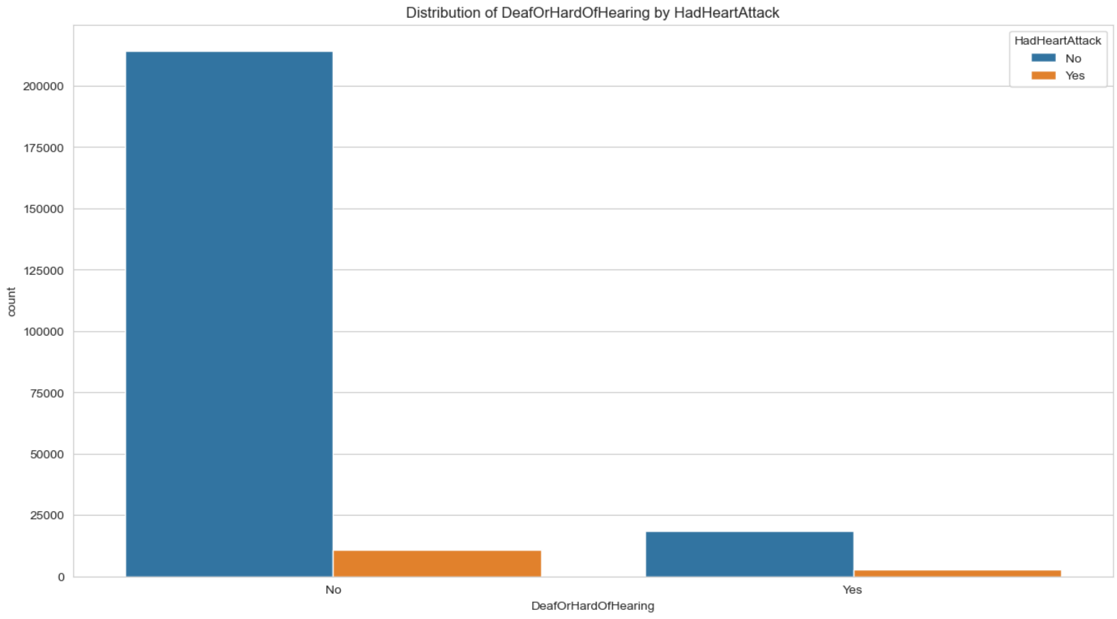
```
HadHeartAttack      No   Yes
HadArthritis
No              155462  5670
Yes              77116  7765
Chi-Squared Test for HadArthritis and HadHeartAttack
Chi2 value = 3411.190093972503, p-value = 0.0
```



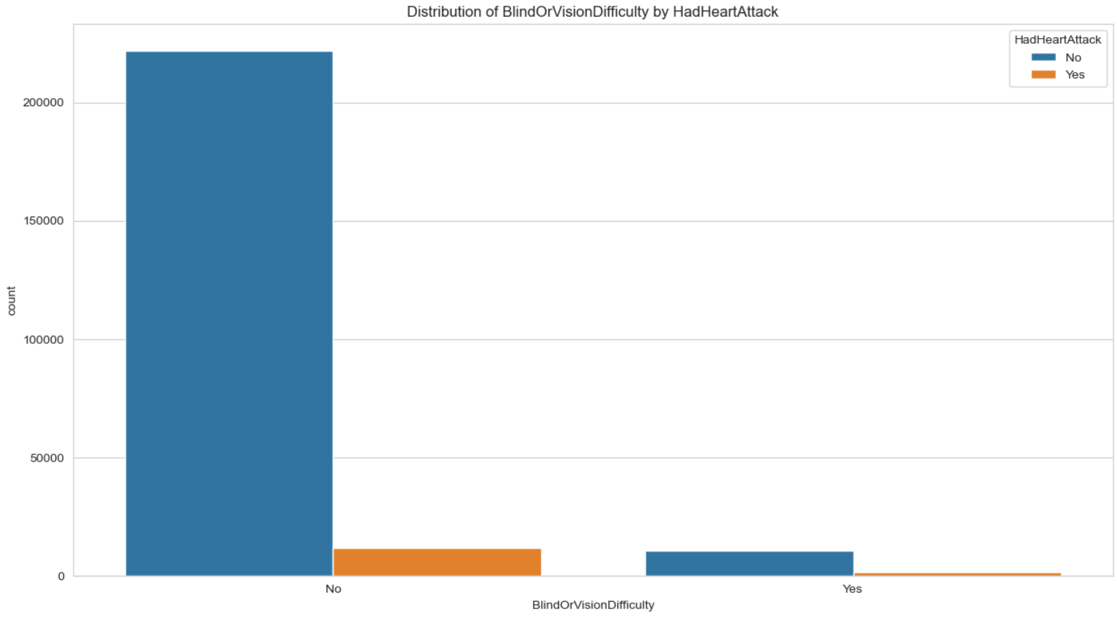
```
HadHeartAttack                                   No   Yes
HadDiabetes
No                                           196494  8333
No, pre-diabetes or borderline diabetes        5000   392
Yes                                           29157  4654
Yes, but only during pregnancy (female)        1927    56
Chi-Squared Test for HadDiabetes and HadHeartAttack
Chi2 value = 5345.9912570977585, p-value = 0.0
```



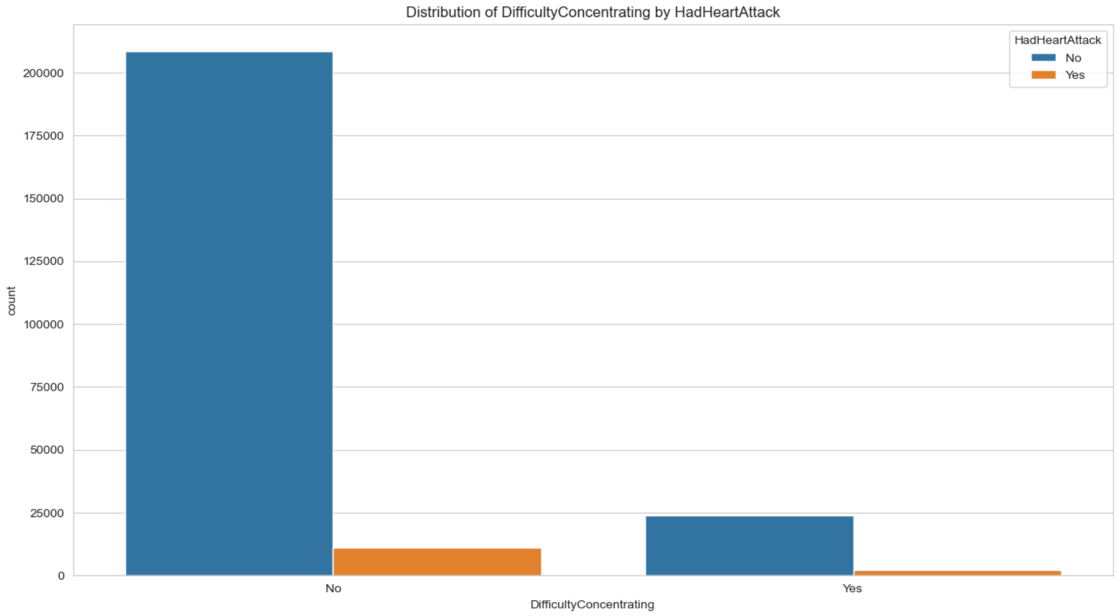
```
HadHeartAttack            No    Yes
DeafOrHardOfHearing
No                    214221  10760
Yes                    18357   2675
Chi-Squared Test for DeafOrHardOfHearing and HadHeartAttack
Chi2 value = 2344.8042006382593, p-value = 0.0
```



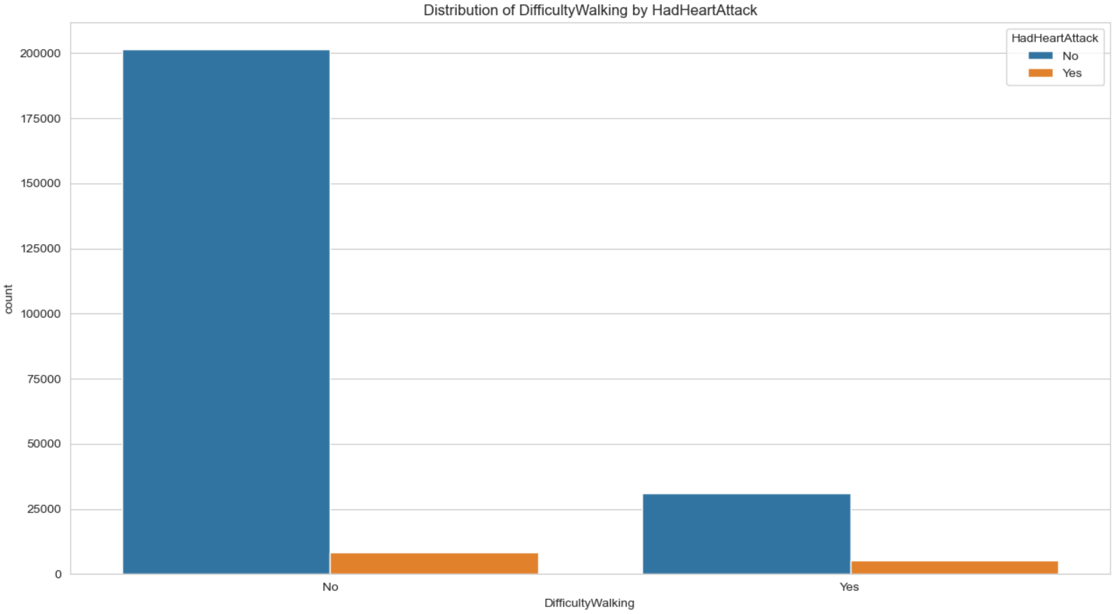
```
HadHeartAttack              No    Yes
BlindOrVisionDifficulty
No                      221906  11881
Yes                      10672   1554
Chi-Squared Test for BlindOrVisionDifficulty and HadHeartAttack
Chi2 value = 1308.1593754891833, p-value = 1.9058085152167356e-286
```



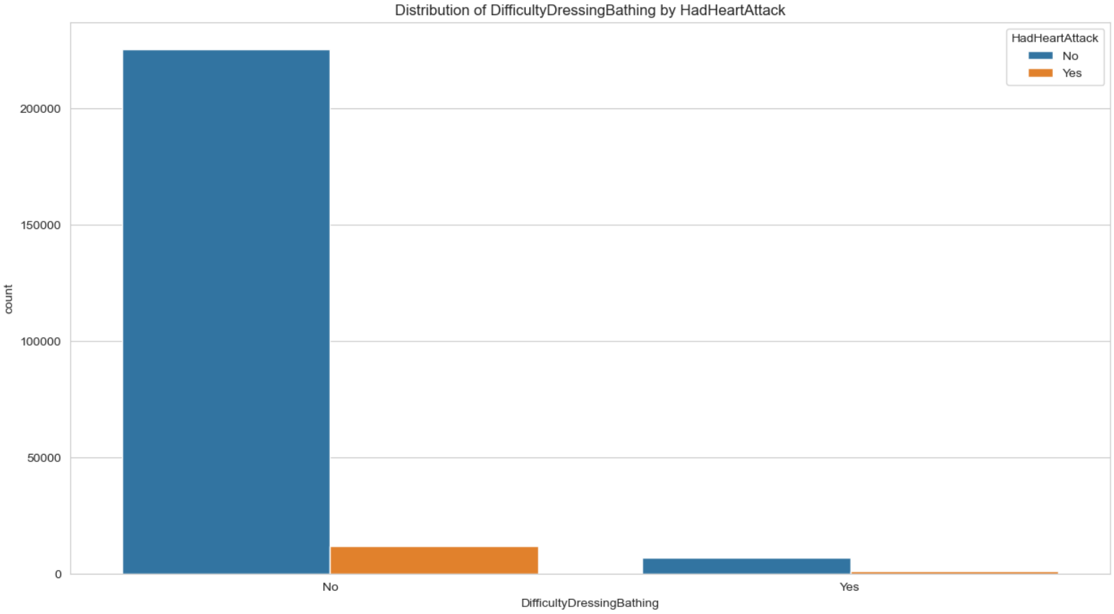
```
HadHeartAttack               No    Yes
DifficultyConcentrating
No                       208681  11112
Yes                       23897   2323
Chi-Squared Test for DifficultyConcentrating and HadHeartAttack
Chi2 value = 655.8249785059869, p-value = 1.2086533205176142e-144
```



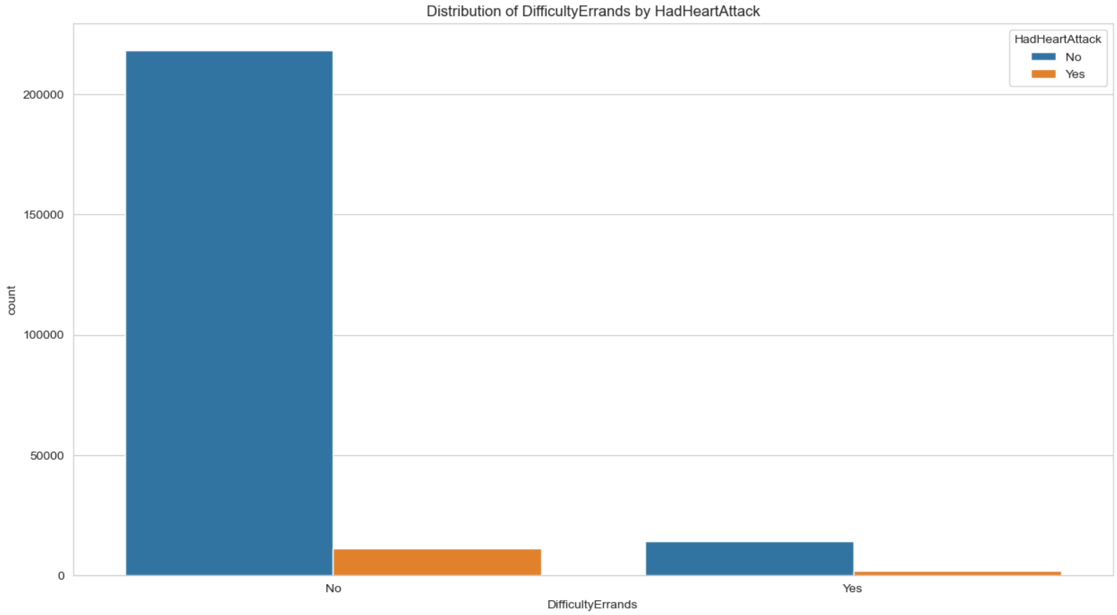
```
HadHeartAttack         No   Yes
DifficultyWalking
No                 201641  8304
Yes                 30937  5131
Chi-Squared Test for DifficultyWalking and HadHeartAttack
Chi2 value = 6286.838781453804, p-value = 0.0
```



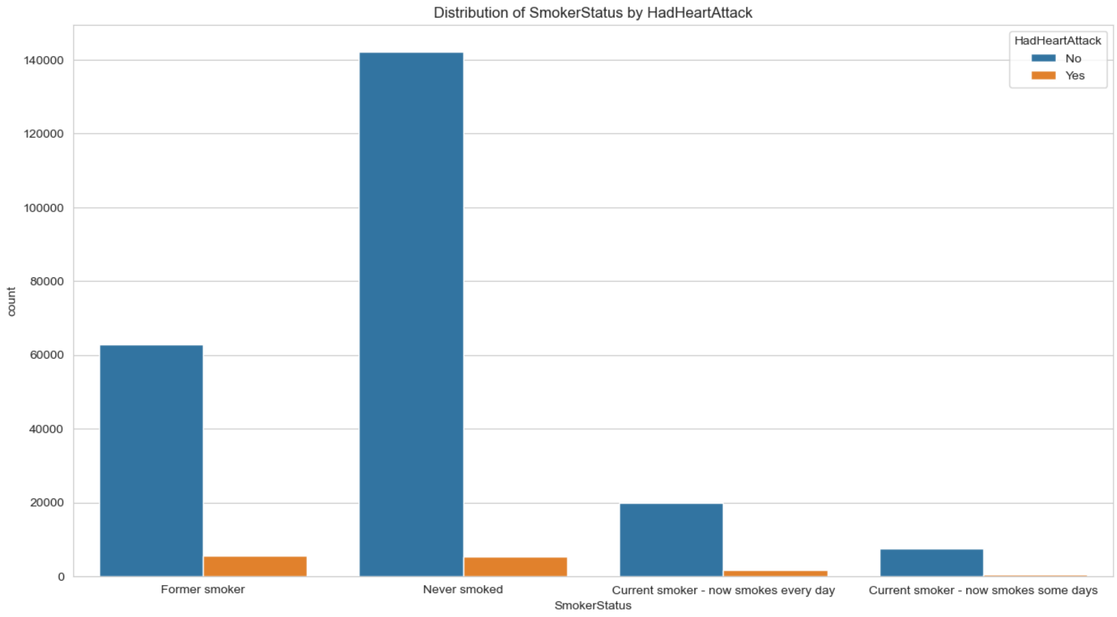
```
HadHeartAttack                No    Yes
DifficultyDressingBathing
No                        225534  12139
Yes                         7044   1296
Chi-Squared Test for DifficultyDressingBathing and HadHeartAttack
Chi2 value = 1696.394540678655, p-value = 0.0
```



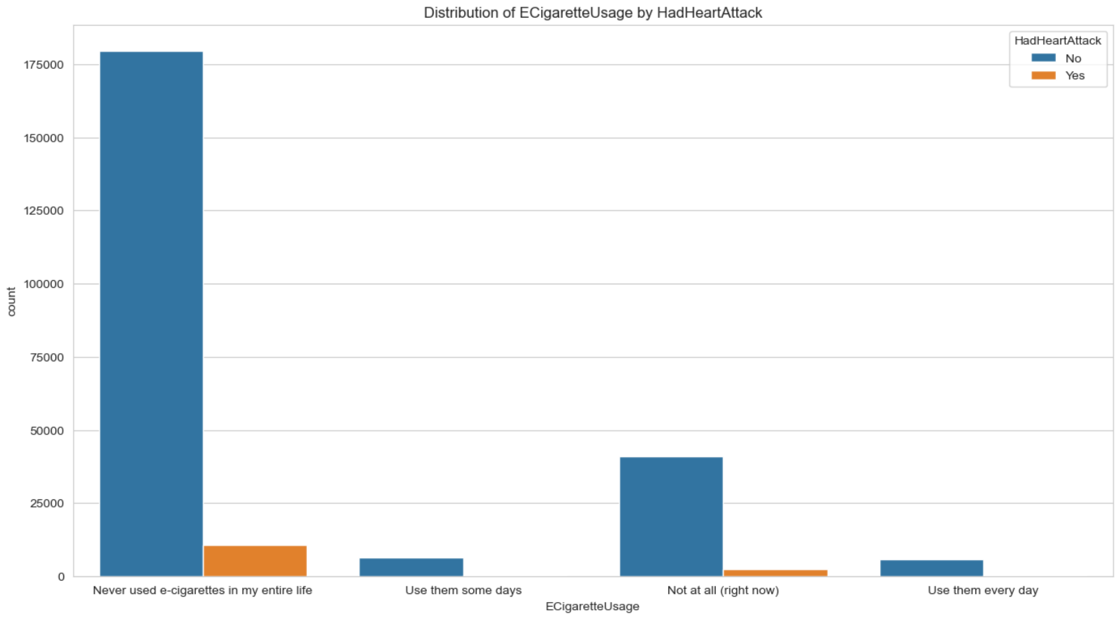
```
HadHeartAttack         No    Yes
DifficultyErrands
No                 218336  11293
Yes                 14242   2142
Chi-Squared Test for DifficultyErrands and HadHeartAttack
Chi2 value = 1968.7158617259954, p-value = 0.0
```



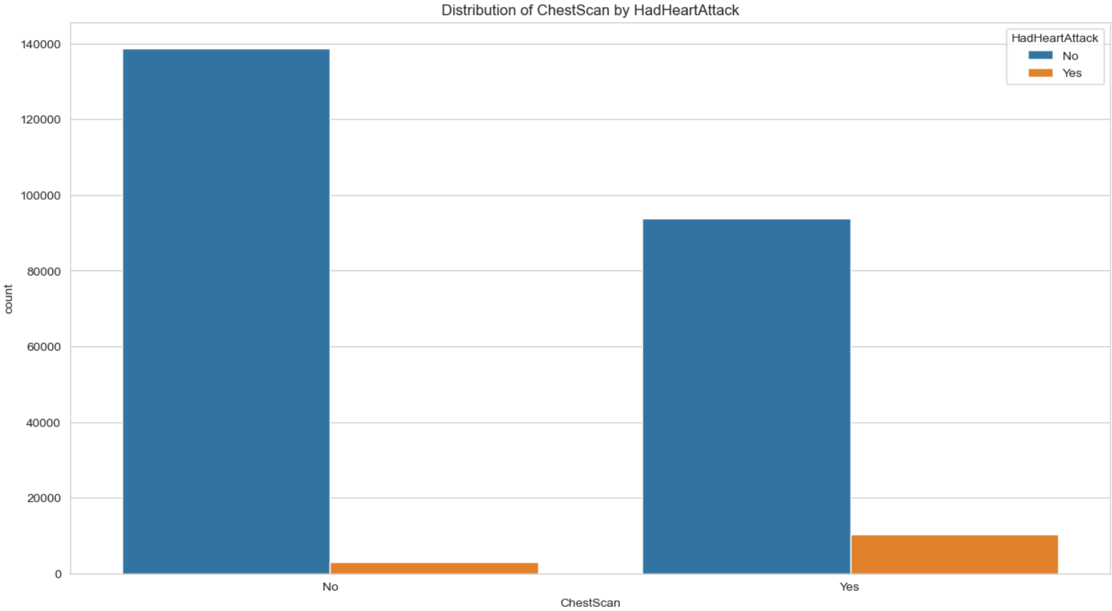
```
HadHeartAttack                               No   Yes
SmokerStatus
Current smoker - now smokes every day    19858  1801
Current smoker - now smokes some days     7546   553
Former smoker                            62914  5610
Never smoked                            142260  5471
Chi-Squared Test for SmokerStatus and HadHeartAttack
Chi2 value = 2241.293874288016, p-value = 0.0
```



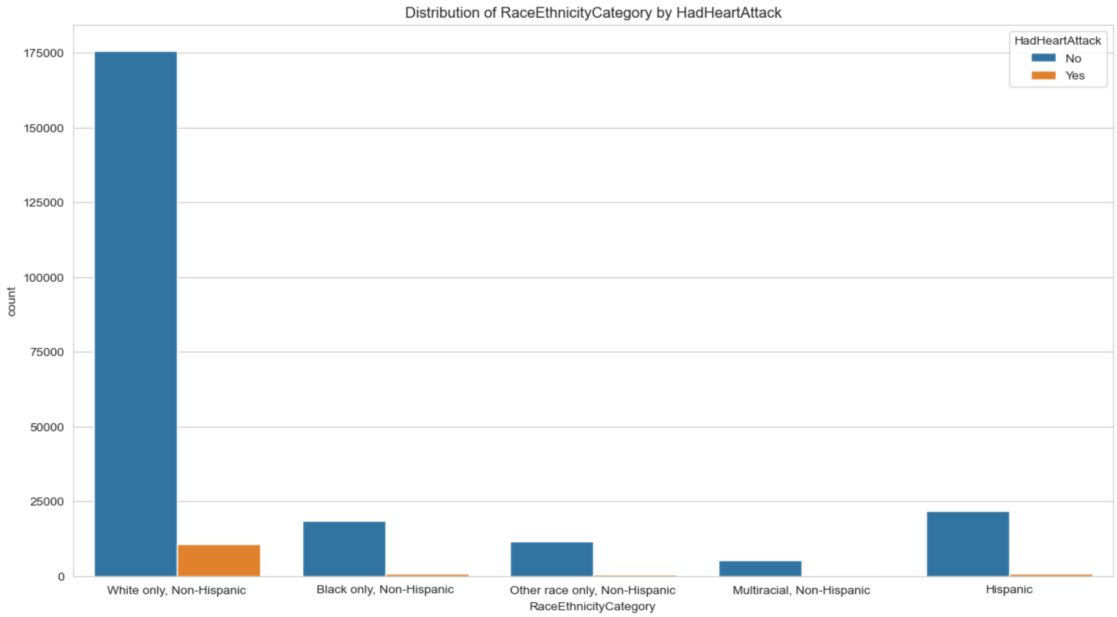
```
HadHeartAttack                                 No    Yes
ECigaretteUsage
Never used e-cigarettes in my entire life  179547  10572
Not at all (right now)                      40846   2435
Use them every day                           5778    177
Use them some days                           6407    251
Chi-Squared Test for ECigaretteUsage and HadHeartAttack
Chi2 value = 114.26515381908608, p-value = 1.3252144336233886e-24
```



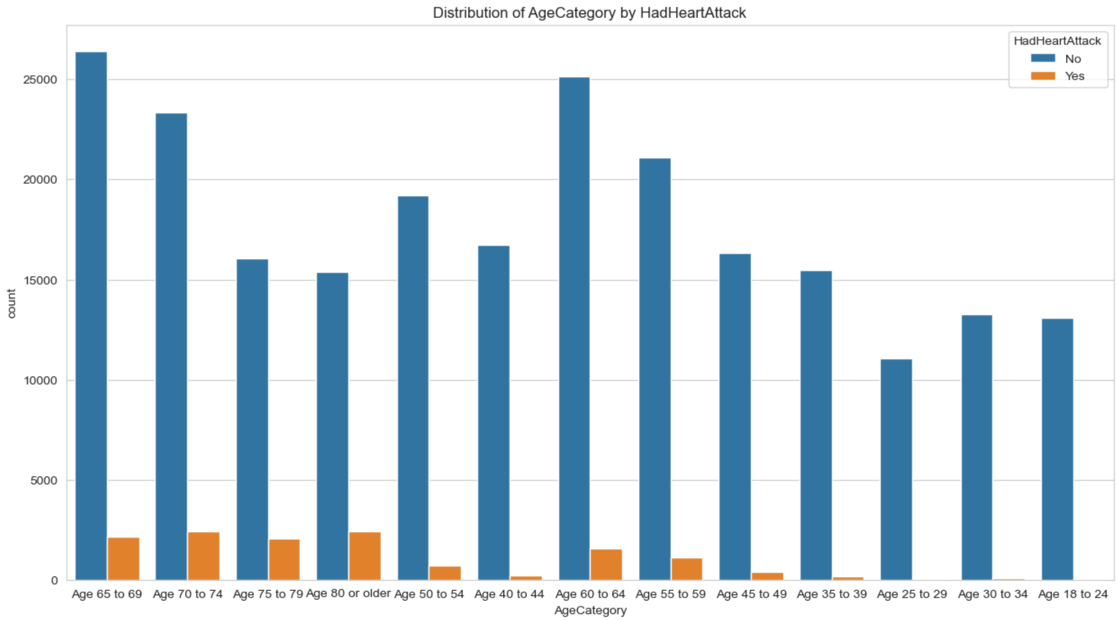
```
HadHeartAttack      No    Yes
ChestScan
No              138707   3111
Yes              93871  10324
Chi-Squared Test for ChestScan and HadHeartAttack
Chi2 value = 6922.660386789881, p-value = 0.0
```



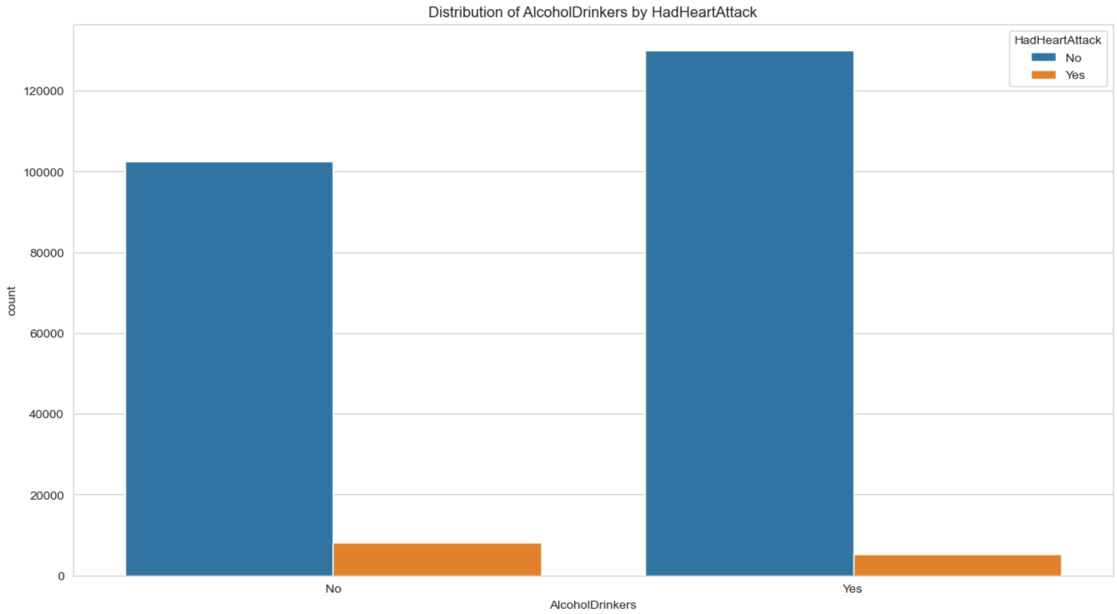
```
HadHeartAttack                      No    Yes
RaceEthnicityCategory
Black only, Non-Hispanic         18441    889
Hispanic                         21711    859
Multiracial, Non-Hispanic         5241    340
Other race only, Non-Hispanic    11614    591
White only, Non-Hispanic        175571  10756
Chi-Squared Test for RaceEthnicityCategory and HadHeartAttack
Chi2 value = 195.9712006643616, p-value = 2.760364866338809e-41
```



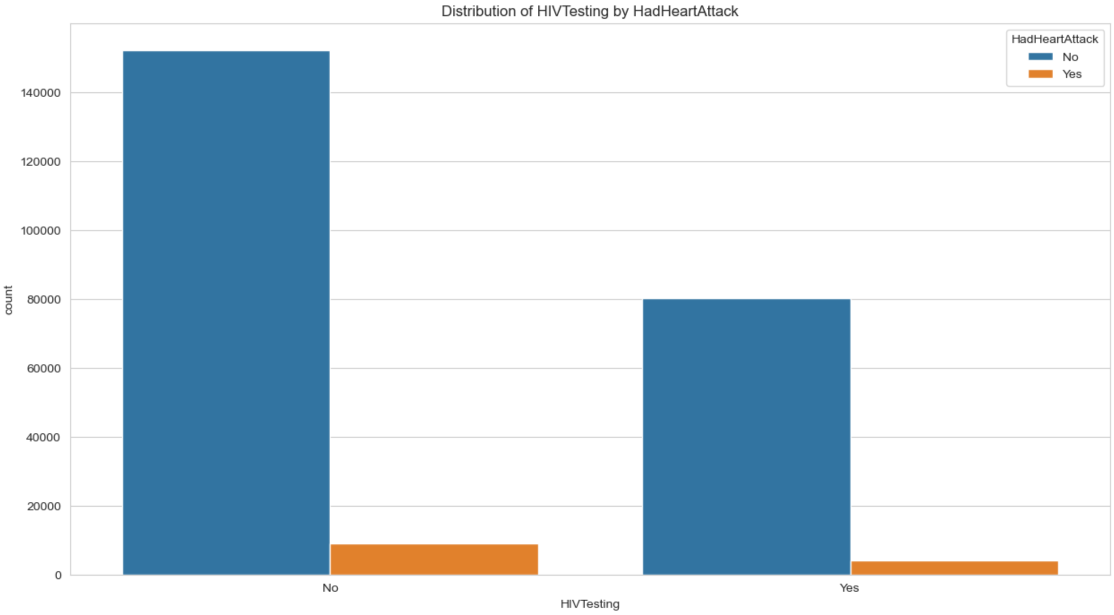
```
HadHeartAttack       No   Yes
AgeCategory
Age 18 to 24      13072    50
Age 25 to 29      11062    47
Age 30 to 34      13256    90
Age 35 to 39      15458   156
Age 40 to 44      16745   228
Age 45 to 49      16333   420
Age 50 to 54      19209   703
Age 55 to 59      21112  1112
Age 60 to 64      25144  1575
Age 65 to 69      26400  2155
Age 70 to 74      23329  2408
Age 75 to 79      16068  2065
Age 80 or older   15390  2426
Chi-Squared Test for AgeCategory and HadHeartAttack
Chi2 value = 7925.704390290559, p-value = 0.0
```



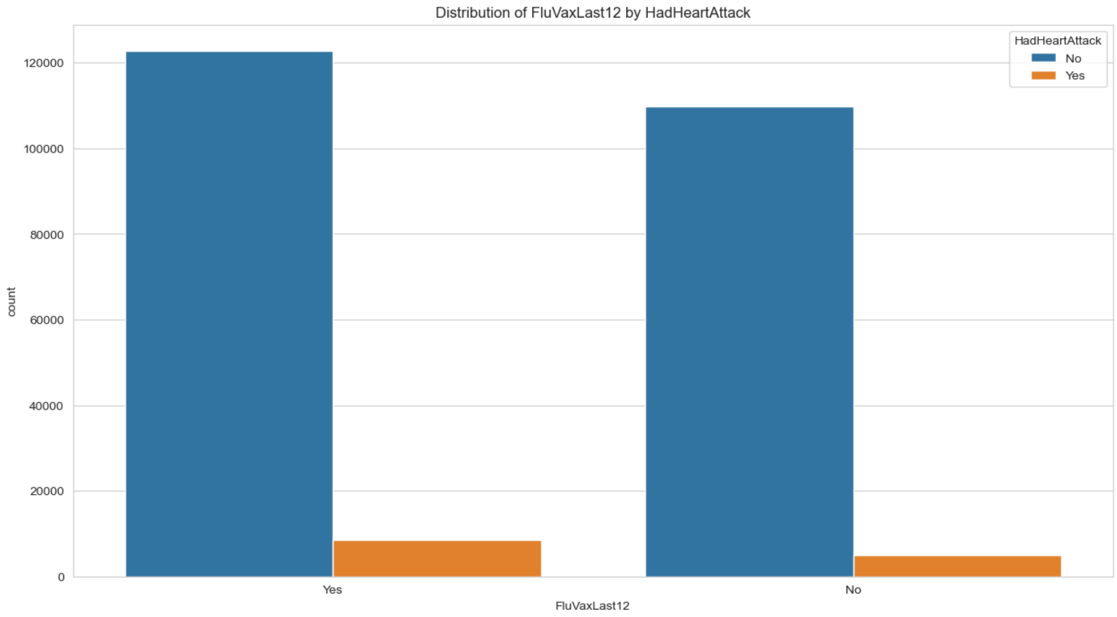
```
HadHeartAttack       No   Yes
AlcoholDrinkers
No               102605  8109
Yes              129973  5326
Chi-Squared Test for AlcoholDrinkers and HadHeartAttack
Chi2 value = 1352.9336428746574, p-value = 3.5495529688639013e-296
```



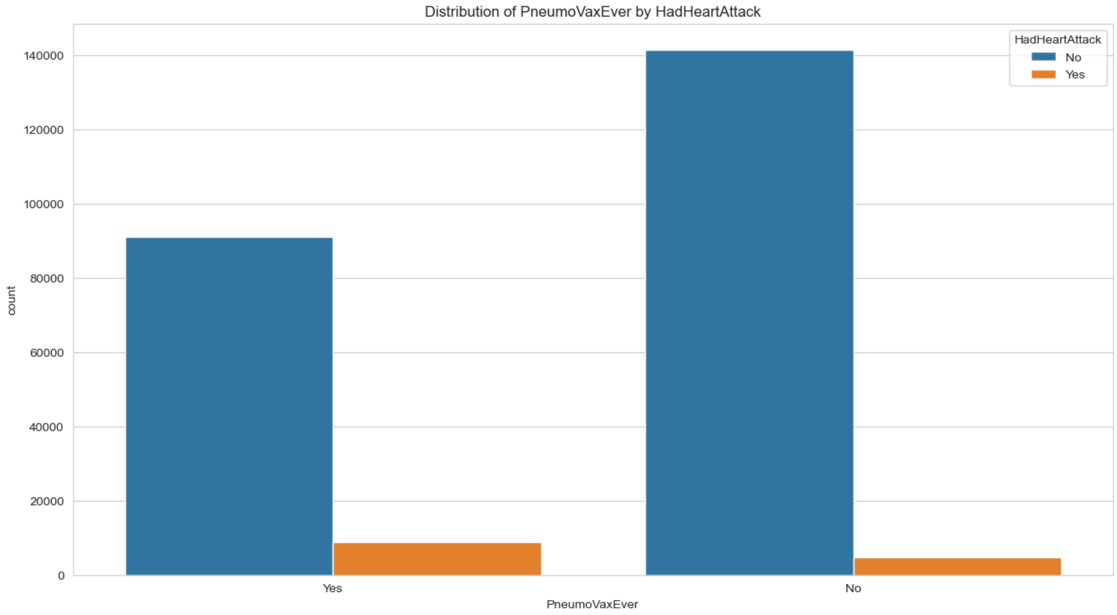
```
HadHeartAttack      No   Yes
HIVTesting
No                152306  9207
Yes                80272  4228
Chi-Squared Test for HIVTesting and HadHeartAttack
Chi2 value = 52.054385349053376, p-value = 5.398452954756739e-13
```



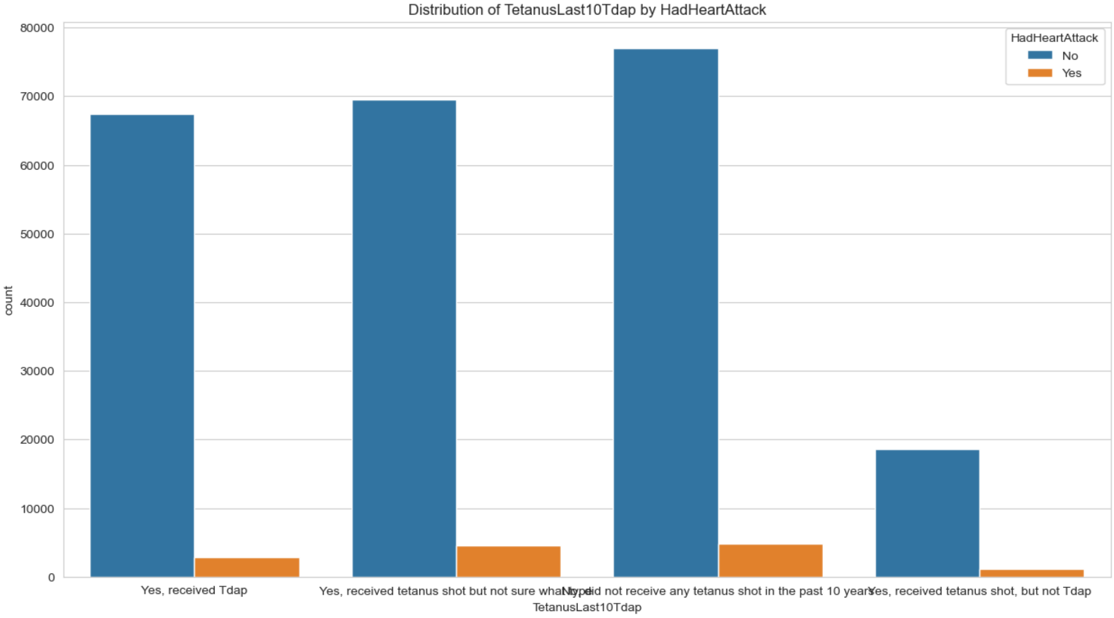
```
HadHeartAttack      No   Yes
FluVaxLast12
No                109816  5009
Yes               122762  8426
Chi-Squared Test for FluVaxLast12 and HadHeartAttack
Chi2 value = 503.1594851068325, p-value = 1.952245327911882e-111
```



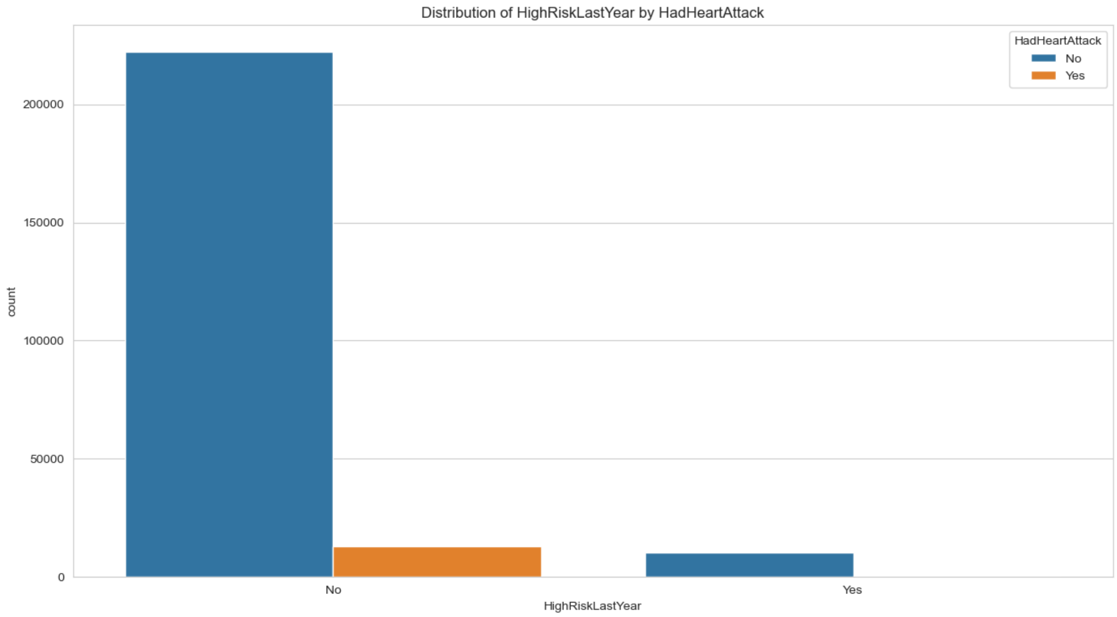
```
HadHeartAttack      No   Yes
PneumoVaxEver
No              141441  4687
Yes              91137  8748
Chi-Squared Test for PneumoVaxEver and HadHeartAttack
Chi2 value = 3539.4434942388366, p-value = 0.0
```



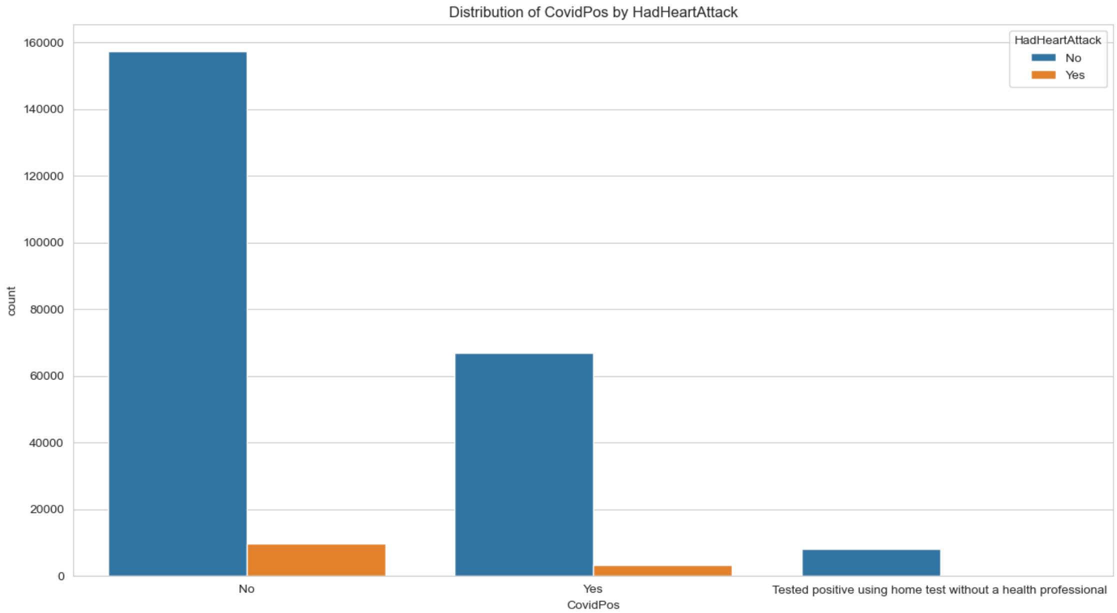
```
HadHeartAttack                                        No   Yes
TetanusLast10Tdap
No, did not receive any tetanus shot in the pas…  76966  4777
Yes, received Tdap                                  67463  2819
Yes, received tetanus shot but not sure what type   69513  4605
Yes, received tetanus shot, but not Tdap            18636  1234
Chi-Squared Test for TetanusLast10Tdap and HadHeartAttack
Chi2 value = 412.2456977489708, p-value = 4.9266526646514085e-89
```



```
HadHeartAttack        No    Yes
HighRiskLastYear
No                222340  13097
Yes                10238    338
Chi-Squared Test for HighRiskLastYear and HadHeartAttack
Chi2 value = 109.3716134286175, p-value = 1.3454258258489073e-25
```



```
HadHeartAttack                                              No   Yes
CovidPos
No                                                      157521  9776
Tested positive using home test without a healt…    8158   234
Yes                                                      66899  3425
Chi-Squared Test for CovidPos and HadHeartAttack
Chi2 value = 211.03994555450967, p-value = 1.490246437343113e-46
```



[ ]:

```
# Perform t-tests for numerical data
results_df_nums = pd.DataFrame(columns=['Feature', 'Statistic', 'P-Value'])

for var in numerical_vars:
  # Statistical Test (e.g., t-test) for significance
  for category in df[target].unique():
    group1 = df[df[target] == category][var]
    group2 = df[df[target] != category][var]

  stat, p = ttest_ind(group1, group2)

  # Add the results to the DataFrame
  new_row = {'Feature': var, 'Statistic': stat, 'P-Value': p}
  results_df_nums = pd.concat([results_df_nums, pd.DataFrame(new_row,␣
 ↪index=[0])], ignore_index=True)
```

[ ]:

```
# Sort the DataFrame by p-values in ascending order and then by chi2 values in␣
 ↪descending order
results_df_cat = results_df_cat.sort_values(by=['P-Value', 'Chi2'],␣
 ↪ascending=[True, False])

# Display the sorted DataFrame
display(results_df_cat)
```

```
                      Feature          Chi2        P-Value
4                   HadAngina  48906.220749   0.000000e+00
1               GeneralHealth   9893.539444   0.000000e+00
23                AgeCategory   7925.704390   0.000000e+00
5                   HadStroke   7716.361887   0.000000e+00
3                RemovedTeeth   6996.544849   0.000000e+00
21                  ChestScan   6922.660387   0.000000e+00
16          DifficultyWalking   6286.838781   0.000000e+00
12                HadDiabetes   5345.991257   0.000000e+00
8                     HadCOPD   4363.963228   0.000000e+00
27              PneumoVaxEver   3539.443494   0.000000e+00
11               HadArthritis   3411.190094   0.000000e+00
10           HadKidneyDisease   2939.567089   0.000000e+00
13        DeafOrHardOfHearing   2344.804201   0.000000e+00
19               SmokerStatus   2241.293874   0.000000e+00
18          DifficultyErrands   1968.715862   0.000000e+00
2          PhysicalActivities   1701.515021   0.000000e+00
17  DifficultyDressingBathing   1696.394541   0.000000e+00
24            AlcoholDrinkers   1352.933643  3.549553e-296
0                         Sex   1321.763475  2.107383e-289
14    BlindOrVisionDifficulty   1308.159375  1.905809e-286
```

```
15    DifficultyConcentrating    655.824979  1.208653e-144
7               HadSkinCancer    599.937749  1.727186e-132
26               FluVaxLast12    503.159485  1.952245e-111
28          TetanusLast10Tdap    412.245698   4.926653e-89
30                   CovidPos    211.039946   1.490246e-46
22      RaceEthnicityCategory    195.971201   2.760365e-41
6                  HadAsthma     138.573175   5.460575e-32
9       HadDepressiveDisorder    137.942355   7.502330e-32
29             HighRiskLastYear  109.371613   1.345426e-25
20             ECigaretteUsage   114.265154   1.325214e-24
25                  HIVTesting    52.054385   5.398453e-13
```

[ ]:

```
# Sort the DataFrame by p-values in ascending order
results_df_nums = results_df_nums.sort_values(by='P-Value', ascending=True)

# Display the sorted DataFrame
display(results_df_nums)
```

```
              Feature  Statistic       P-Value
0  PhysicalHealthDays  66.773602  0.000000e+00
4   WeightInKilograms  19.076335  4.546370e-81
1    MentalHealthDays  12.844421  9.506448e-38
3      HeightInMeters  11.440249  2.678179e-30
2          SleepHours   1.802562  7.145820e-02
```

0.3.1 Null Hypothesis Testing

We're intersted to test the following *null* hypothesis:

H_0: General health and Smoker status don't have effect on the possibility of a heart attack

H_A: General health and Smoker have effect on the possibility of a heart attack

[ ]:

```
hypothesis_df = results_df_cat[results_df_cat['Feature'].isin(['GeneralHealth',␣
 ↪'SmokerStatus'])]

# Define the significance level (alpha)
alpha = 0.05  # You can choose a different alpha value if needed

# Verify the null hypothesis for each feature
for index, row in hypothesis_df.iterrows():
    feature = row['Feature']
    chi2 = row['Chi2']
    p_value = row['P-Value']

    print(f"Feature: {feature}")
    print(f"Chi-Squared Value: {chi2}")
    print(f"P-Value: {p_value}")
    if p_value < alpha:
        print("Reject the null hypothesis ( 0)")
        print(f"{feature} has an effect on the possibility of a heart attack.")
    else:
        print("Fail to reject the null hypothesis ( 0)")
        print(f"{feature} does not have an effect on the possibility of a heart␣
 ↪attack.")

    print("\n")
```

```
Feature: GeneralHealth
Chi-Squared Value: 9893.539444125969
P-Value: 0.0
Reject the null hypothesis ( 0)
GeneralHealth has an effect on the possibility of a heart attack.


Feature: SmokerStatus
Chi-Squared Value: 2241.293874288016
P-Value: 0.0
Reject the null hypothesis ( 0)
SmokerStatus has an effect on the possibility of a heart attack.
```

0.3.2 Conclusion

- We have complted chi square test and we able to reject the *null* hypothesis.

0.4 Model Selection

[ ]:

```
# TESTING FOR MULTICOLLINEARITY
# Add a constant term to the predictor variables
X = add_constant(df[['PhysicalHealthDays', 'MentalHealthDays', 'SleepHours',␣
 ↪'HeightInMeters', 'WeightInKilograms']])

vif_data = pd.DataFrame()
vif_data["Variable"] = X.columns
vif_data["VIF"] = [variance_inflation_factor(X.values, i) for i in range(X.
 ↪shape[1])]

print(vif_data)
```

```
             Variable         VIF
0               const  304.683975
1  PhysicalHealthDays    1.115540
2    MentalHealthDays    1.123823
3          SleepHours    1.019942
```

```
4      HeightInMeters    1.306575
5   WeightInKilograms    1.311968
```

[ ]:

```
# HERE WE ADD DUMMIES TO THE CATEGORICAL VARIABLES
heart_df = pd.get_dummies(df, columns=categorical_includes_taget,␣
 ↪drop_first=True, dtype='int32')
heart_df.head(5)
```

[ ]:

```
   PhysicalHealthDays  MentalHealthDays  SleepHours  HeightInMeters  \
0                 4.0               0.0         9.0            1.60
1                 0.0               0.0         6.0            1.78
2                 0.0               0.0         8.0            1.85
3                 5.0               0.0         9.0            1.70
4                 3.0              15.0         5.0            1.55

   WeightInKilograms  Sex_Male  GeneralHealth_Fair  GeneralHealth_Good  \
0              71.67         0                   0                   0
1              95.25         1                   0                   0
2             108.86         1                   0                   0
3              90.72         0                   1                   0
4              79.38         0                   0                   1

   GeneralHealth_Poor  GeneralHealth_Very good  …  HIVTesting_Yes  \
0                   0                        1  …               0
1                   0                        1  …               0
2                   0                        1  …               0
3                   0                        0  …               0
4                   0                        0  …               0

   FluVaxLast12_Yes  PneumoVaxEver_Yes  TetanusLast10Tdap_Yes, received Tdap  \
0                 1                  1                                     1
1                 1                  1                                     0
2                 0                  1                                     0
3                 1                  1                                     0
4                 1                  1                                     0

   TetanusLast10Tdap_Yes, received tetanus shot but not sure what type  \
0                                                  0
1                                                  1
2                                                  0
3                                                  0
4                                                  0

   TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap  \
0                                                  0
1                                                  0
2                                                  0
```

```
3                                                  0
4                                                  0

   HighRiskLastYear_Yes  \
0                     0
1                     0
2                     0
3                     0
4                     0

   CovidPos_Tested positive using home test without a health professional  \
0                                                  0
1                                                  0
2                                                  0
3                                                  0
4                                                  0

   CovidPos_Yes  HadHeartAttack_Yes
0             0                   0
1             0                   0
2             1                   0
3             1                   0
4             0                   0

[5 rows x 65 columns]
```

[ ]:

```python
# REMOVE OUR DEPENDENT VARIABLE
target = 'HadHeartAttack_Yes'
X = heart_df.drop(target, axis=1)
y = heart_df[target]
```

Since, the dataset description suggested unbalanced data, we are going to perform model training:

- On the oriignal data
- Training data with oversamling with SMOTE
- Traning data with undersampling

[ ]:

```python
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
 ↪random_state=42)

# GENERATING THE OVERSAMPLE:
smote = SMOTE(random_state=42)
X_ovsampled, y_ovsampled = smote.fit_resample(X_train, y_train)

# GENERATING THE UNDERSAMPLE:
undersampler = RandomUnderSampler(random_state=42)
X_undersampled, y_undersampled = undersampler.fit_resample(X_train, y_train)
```

[ ]:

```
# LOGISTIC REGRESSION
def train_and_evaluate_logit(X_train, X_test, y_train, y_test, random_state=42):
    X_train_ = X_train.copy()
    X_test_ = X_test.copy()

    X_train_ = sm.add_constant(X_train_)
    X_test_ = sm.add_constant(X_test_)
    result = sm.Logit(y_train, X_train_).fit()

    y_pred = result.predict(X_test_)
    y_pred = np.where(y_pred > 0.5, 1, 0)

    report_df = pd.DataFrame(classification_report(y_test, y_pred,␣
  ↪output_dict=True)).transpose()
    return (result, report_df)
```

[ ]:

```
# DECISION TREE MODEL
def train_and_evaluate_decision_tree(X_train, X_test, y_train, y_test,␣
  ↪random_state=42):
    # Create and fit a DecisionTreeClassifier
    classifier = DecisionTreeClassifier(random_state=random_state)
    classifier.fit(X_train, y_train)

    y_pred = classifier.predict(X_test)

    report_df = pd.DataFrame(classification_report(y_test, y_pred,␣
  ↪output_dict=True)).transpose()
    return (classifier, report_df)
```

[ ]:

```
# RESULTS FOR LOGISTIC REGRESSION WITH ORIGINAL DATA
result_log, report_df_log = train_and_evaluate_logit(X_train, X_test, y_train,␣
  ↪y_test)
display(report_df_log)
```

```
Optimization terminated successfully.
         Current function value: 0.145333
         Iterations 10

              precision    recall  f1-score      support
0              0.958957  0.988616  0.973561  46558.00000
1              0.560166  0.255198  0.350649   2645.00000
accuracy       0.949190  0.949190  0.949190      0.94919
macro avg      0.759561  0.621907  0.662105  49203.00000
weighted avg   0.937519  0.949190  0.940075  49203.00000
```

[ ]:

```
# RESULTS FOR LOGISTIC REGRESSION WITH OVERSAMPLE WITH SMOTE
result_log_ov, report_df_log_ov = train_and_evaluate_logit(X_ovsampled, X_test,␣
  ↪y_ovsampled, y_test)
```

```
display(report_df_log_ov)
```

```
Optimization terminated successfully.
         Current function value: 0.210823
         Iterations 9

              precision    recall  f1-score      support
0              0.962747  0.926436  0.944243  46558.00000
1              0.221768  0.368998  0.277037   2645.00000
accuracy       0.896470  0.896470  0.896470      0.89647
macro avg      0.592257  0.647717  0.610640  49203.00000
weighted avg   0.922914  0.896470  0.908376  49203.00000
```

[ ]:

```
# RESULTS FOR LOGISTIC REGRESSION WITH UNDERSAMPLE
result_log_un, report_df_log_un = train_and_evaluate_logit(X_undersampled,␣
 ↪X_test, y_undersampled, y_test)
display(report_df_log_un)
```

```
Optimization terminated successfully.
         Current function value: 0.421748
         Iterations 7

              precision    recall  f1-score       support
0              0.984156  0.836505  0.904343  46558.000000
1              0.209553  0.762949  0.328798   2645.000000
accuracy       0.832551  0.832551  0.832551      0.832551
macro avg      0.596855  0.799727  0.616571  49203.000000
weighted avg   0.942516  0.832551  0.873404  49203.000000
```

[ ]:

```
# RESULTS FOR DECISION TREE (ORIGINAL DATA)
result_tree, report_df_tree = train_and_evaluate_decision_tree(X_train, X_test,␣
 ↪y_train, y_test)
display(report_df_tree)
```

```
              precision    recall  f1-score       support
0              0.959465  0.949697  0.954556  46558.000000
1              0.249118  0.293762  0.269604   2645.000000
accuracy       0.914436  0.914436  0.914436      0.914436
macro avg      0.604292  0.621729  0.612080  49203.000000
weighted avg   0.921279  0.914436  0.917735  49203.000000
```

[ ]:

```
# RESULTS FOR DECISION TREE WITH OVERSAMPLE
result_tree_ov, report_df_tree_ov =␣
 ↪train_and_evaluate_decision_tree(X_ovsampled, X_test, y_ovsampled, y_test)
display(report_df_tree_ov)
```

```
              precision    recall  f1-score       support
0              0.960106  0.922162  0.940751  46558.000000
1              0.191973  0.325520  0.241515   2645.000000
accuracy       0.890088  0.890088  0.890088      0.890088
```

```
macro avg      0.576039  0.623841  0.591133  49203.000000
weighted avg   0.918813  0.890088  0.903162  49203.000000
```

```
[ ]: # RESULTS FOR DECISION TREE WITH UNDERSAMPLE
     result_tree_un, report_df_tree_un =␣
      ↪train_and_evaluate_decision_tree(X_undersampled, X_test, y_undersampled,␣
      ↪y_test)
     display(report_df_tree_un)
```

```
              precision    recall  f1-score       support
0              0.978397  0.721788  0.830727  46558.000000
1              0.128096  0.719471  0.217473   2645.000000
accuracy       0.721663  0.721663  0.721663      0.721663
macro avg      0.553247  0.720629  0.524100  49203.000000
weighted avg   0.932687  0.721663  0.797761  49203.000000
```

0.4.1 Conclusion

- Neither oversampling, nor undersampling produced desired results improving precision, i.e. the accuracy of the positive predictions made by the model
- Compared by the accuracy of the model on the entire dataset, and by mimizing the poor precision performance, **Logistic Regression** trained on the original data performed the best.
- Selected model has recall for **0** class of ≈ 98%, meaning low probability of false negatives, which is very important for the health data.

0.5 Model Analysis

```
[ ]: result_log_sum = result_log.summary()
```

```
[ ]: result_log_sum_df = pd.DataFrame(result_log_sum.tables[1].data[1:],␣
      ↪columns=result_log_sum.tables[1].data[0])
     result_log_sum_sorted = result_log_sum_df.sort_values(by="P>|z|",␣
      ↪ascending=True)
     display(result_log_sum_sorted)
```

```
                                                      coef    std err  \
0                                           const    -5.6427     0.321
63  CovidPos_Tested positive using home test witho…  -0.3420    0.084
33                         SmokerStatus_Former smoker  -0.1972     0.040
34                         SmokerStatus_Never smoked  -0.4333     0.042
57                                  FluVaxLast12_Yes  -0.1404     0.026
..                                              …       …        …
37                   ECigaretteUsage_Use them some days  0.0449     0.085
60  TetanusLast10Tdap_Yes, received tetanus shot b…  -0.0143    0.029
17                                     HadAsthma_Yes   0.0138     0.033
36                   ECigaretteUsage_Use them every day -0.0210     0.103
32  SmokerStatus_Current smoker - now smokes some …  -0.0045    0.067
```

```
             z    P>|z|     [0.025     0.975]
0      -17.585    0.000     -6.272     -5.014
63      -4.068    0.000     -0.507     -0.177
33      -4.924    0.000     -0.276     -0.119
34     -10.428    0.000     -0.515     -0.352
57      -5.370    0.000     -0.192     -0.089
..         …        …          …         …
37       0.528    0.598     -0.122      0.212
60      -0.502    0.616     -0.070      0.042
17       0.422    0.673     -0.050      0.078
36      -0.204    0.838     -0.222      0.180
32      -0.068    0.946     -0.135      0.126

[65 rows x 7 columns]
```

```
[ ]: result_log_sum_df_feature_of_interest =␣
       ↪result_log_sum_sorted[result_log_sum_sorted[''].isin(['SmokerStatus_Former␣
       ↪smoker', 'SmokerStatus_Never smoked', 'GeneralHealth_Fair',␣
       ↪'GeneralHealth_Poor', 'GeneralHealth_Good', 'GeneralHealth_Very good',␣
       ↪'SmokerStatus_Current smoker - now smokes some days'])]
```

```
[ ]: display(result_log_sum_df_feature_of_interest)
```

```
                                                        coef    std err  \
33                          SmokerStatus_Former smoker     -0.1972      0.040
34                           SmokerStatus_Never smoked     -0.4333      0.042
7                                   GeneralHealth_Fair      0.8915      0.058
8                                   GeneralHealth_Good      0.6649      0.053
9                                   GeneralHealth_Poor      1.0154      0.071
10                             GeneralHealth_Very good      0.3281      0.054
32  SmokerStatus_Current smoker - now smokes some …      -0.0045      0.067

             z    P>|z|     [0.025     0.975]
33      -4.924    0.000     -0.276     -0.119
34     -10.428    0.000     -0.515     -0.352
7       15.372    0.000      0.778      1.005
8       12.550    0.000      0.561      0.769
9       14.360    0.000      0.877      1.154
10       6.054    0.000      0.222      0.434
32      -0.068    0.946     -0.135      0.126
```

0.5.1 Conclusion

- Smoker status related features have the folloiwing results:
  - `SmokerStatus_Former smoker` has coefficient `-0.1972`,`SmokerStatus_Never smoked` has coefficient `-0.4333`, suggesting negative diraction of the effect on the probability of the a heart attack. In other words, quiting smoking is associated with reduce probability of having a heart attack.

- SmokerStatus_Current smoker - now smokes some days has a small negative coefficient of -0.0045, however the $p - value$ for this feature indicates, that the effect is not statistically significant.

- All features for GeneralHealth have $p - values$ indicating that the effect is statistically significant
- GeneralHealth_Poor has the highest magnitude of the coefficient, suggesting an increase in the corresponding independent variable is associated with an increased probability a heart attack