CDC Heart Disease Prediction

October 22, 2024

[1]:
```
# Background: A Kaggle data set from the CDC that is a major part of the␣
 ↪Behavioral Risk Factor Surveillance System
# (BRFSS), which conducts annual telephone surveys to collect data on the␣
 ↪health status of U.S. residents.
#  https://www.kaggle.com/datasets/kamilpytlak/
 ↪personal-key-indicators-of-heart-disease
```

[2]:
```
# The goal of the notebook is to construct a logistic regression model to␣
 ↪predict heart attacks
#   (the dependent variable - 'HadHeartAttack') based on the other variables as␣
 ↪independet predictor variables.
```

[3]:
```
# Import libraries
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
from sklearn.preprocessing import StandardScaler, MinMaxScaler
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
from sklearn.svm import SVC
from sklearn.metrics import confusion_matrix
```

[4]:
```
# setup for multiple outputs from single cell
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = 'all'
```

[5]:
```
# silence warnings
import warnings
warnings.filterwarnings('ignore')
import absl.logging as absl_logging
```

[6]:
```
###############################################################################################
# SET AND VERIFY THE CURRENT WORKING DIRECTORY (CHANGE AS␣
 ↪NEEDED)#########################
###############################################################################################
import os
```

```
root_directory = '/media/ijmg/SSD_FOUR_TB/IJMG_DATA_SCIENTIST/data sets/CDC_CHD/
 ↪'
os.chdir(root_directory)
print(os.getcwd() + '/')
print(root_directory)
```

```
/media/ijmg/SSD_FOUR_TB/IJMG_DATA_SCIENTIST/data sets/CDC_CHD/
/media/ijmg/SSD_FOUR_TB/IJMG_DATA_SCIENTIST/data sets/CDC_CHD/
```

[7]:
```
################################################
##    I. EXPLORATORY DATA ANALYSIS (EDA):
################################################
# Data Visualization: As allowed by data, show:
#  -- summary statistics
#  -- histograms
#  -- box plots
#  -- outliers
#  -- scatter plots
#  -- correlation matrices
```

[8]:
```
# Load the dataset from CSV file into a DataFrame and preview
source_df = pd.read_csv('heart_2022_with_nans.csv')
# Display the DataFrame and print dimensions
print("Number of rows:", source_df.shape[0])
print("Number of columns:", source_df.shape[1])
source_df.head()
source_df.tail()
```

```
Number of rows: 445132
Number of columns: 40
```

[8]:
```
     State     Sex GeneralHealth  PhysicalHealthDays  MentalHealthDays  \
0  Alabama  Female     Very good                 0.0               0.0
1  Alabama  Female     Excellent                 0.0               0.0
2  Alabama  Female     Very good                 2.0               3.0
3  Alabama  Female     Excellent                 0.0               0.0
4  Alabama  Female          Fair                 2.0               0.0

                                     LastCheckupTime PhysicalActivities  \
0  Within past year (anytime less than 12 months …                No
1                                                NaN                 No
2  Within past year (anytime less than 12 months …               Yes
3  Within past year (anytime less than 12 months …               Yes
4  Within past year (anytime less than 12 months …               Yes

   SleepHours RemovedTeeth HadHeartAttack  … HeightInMeters  \
0         8.0          NaN             No  …            NaN
1         6.0          NaN             No  …           1.60
```

```
2         5.0          NaN             No  …           1.57
3         7.0          NaN             No  …           1.65
4         9.0          NaN             No  …           1.57

  WeightInKilograms    BMI AlcoholDrinkers HIVTesting FluVaxLast12  \
0               NaN    NaN              No         No          Yes
1             68.04  26.57              No         No           No
2             63.50  25.61              No         No           No
3             63.50  23.30              No         No          Yes
4             53.98  21.77             Yes         No           No

  PneumoVaxEver                                  TetanusLast10Tdap  \
0            No  Yes, received tetanus shot but not sure what type
1            No  No, did not receive any tetanus shot in the pa…
2            No                                                NaN
3           Yes  No, did not receive any tetanus shot in the pa…
4           Yes  No, did not receive any tetanus shot in the pa…

  HighRiskLastYear CovidPos
0               No       No
1               No       No
2               No      Yes
3               No       No
4               No       No

[5 rows x 40 columns]
```

[8]:

```
                 State     Sex GeneralHealth  PhysicalHealthDays   \
445127  Virgin Islands  Female          Good                 0.0
445128  Virgin Islands  Female     Excellent                 2.0
445129  Virgin Islands  Female          Poor                30.0
445130  Virgin Islands    Male     Very good                 0.0
445131  Virgin Islands    Male     Very good                 0.0

        MentalHealthDays                                    LastCheckupTime   \
445127               3.0  Within past 2 years (1 year but less than 2 ye…
445128               2.0  Within past year (anytime less than 12 months …
445129              30.0                                5 or more years ago
445130               0.0  Within past year (anytime less than 12 months …
445131               1.0                                                NaN

       PhysicalActivities  SleepHours  RemovedTeeth HadHeartAttack  …  \
445127                Yes         6.0  None of them             No  …
445128                Yes         7.0  None of them             No  …
445129                 No         5.0        1 to 5             No  …
445130                 No         5.0  None of them            Yes  …
445131                Yes         5.0  None of them             No  …
```

```
       HeightInMeters WeightInKilograms    BMI AlcoholDrinkers HIVTesting  \
445127           1.65             69.85  25.63             NaN        Yes
445128           1.70             83.01  28.66              No        Yes
445129           1.70             49.90  17.23             NaN         No
445130           1.83            108.86  32.55              No        Yes
445131           1.68             63.50  22.60             Yes         No

       FluVaxLast12 PneumoVaxEver  \
445127           No            No
445128          Yes            No
445129           No            No
445130          Yes           Yes
445131           No            No

                                        TetanusLast10Tdap HighRiskLastYear  \
445127  No, did not receive any tetanus shot in the pa…               No
445128  Yes, received tetanus shot but not sure what type               No
445129  No, did not receive any tetanus shot in the pa…               No
445130  No, did not receive any tetanus shot in the pa…               No
445131  Yes, received tetanus shot but not sure what type               No

       CovidPos
445127      Yes
445128       No
445129       No
445130      Yes
445131       No

[5 rows x 40 columns]
```

[9]:

```
# Before any data visualizations, count then remove any missing values or NaNs
```

[10]:

```
# Count missing (NaN) values for each column/variable
missing_values_df = source_df.isna().sum()  # or df.isnull().sum()
print("Missing Values in Each Variable:\n")
print(missing_values_df)
print("\nMissing Values in Entire Dataframe:\n")
print(missing_values_df.sum())
```

```
Missing Values in Each Variable:

State                          0
Sex                            0
GeneralHealth               1198
PhysicalHealthDays         10927
MentalHealthDays            9067
LastCheckupTime             8308
```

```
PhysicalActivities            1093
SleepHours                    5453
RemovedTeeth                 11360
HadHeartAttack                3065
HadAngina                     4405
HadStroke                     1557
HadAsthma                     1773
HadSkinCancer                 3143
HadCOPD                       2219
HadDepressiveDisorder         2812
HadKidneyDisease              1926
HadArthritis                  2633
HadDiabetes                   1087
DeafOrHardOfHearing          20647
BlindOrVisionDifficulty      21564
DifficultyConcentrating      24240
DifficultyWalking            24012
DifficultyDressingBathing    23915
DifficultyErrands            25656
SmokerStatus                 35462
ECigaretteUsage              35660
ChestScan                    56046
RaceEthnicityCategory        14057
AgeCategory                   9079
HeightInMeters               28652
WeightInKilograms            42078
BMI                          48806
AlcoholDrinkers              46574
HIVTesting                   66127
FluVaxLast12                 47121
PneumoVaxEver                77040
TetanusLast10Tdap            82516
HighRiskLastYear             50623
CovidPos                     50764
dtype: int64

Missing Values in Entire Dataframe:

902665
```

[11]:

```
# Remove missing (NaN) values for each column/variable
source_df = source_df.dropna()
```

[12]:

```
# Verify removal of missing (NaN) values with counts for each column/variable
missing_values_df = source_df.isna().sum()  # or df.isnull().sum()
print("Missing Values in Each Variable:\n")
print(missing_values_df)
print("\nMissing Values in Entire Dataframe:\n")
print(missing_values_df.sum())
```

```
Missing Values in Each Variable:

State                        0
Sex                          0
GeneralHealth                0
PhysicalHealthDays           0
MentalHealthDays             0
LastCheckupTime              0
PhysicalActivities           0
SleepHours                   0
RemovedTeeth                 0
HadHeartAttack               0
HadAngina                    0
HadStroke                    0
HadAsthma                    0
HadSkinCancer                0
HadCOPD                      0
HadDepressiveDisorder        0
HadKidneyDisease             0
HadArthritis                 0
HadDiabetes                  0
DeafOrHardOfHearing          0
BlindOrVisionDifficulty      0
DifficultyConcentrating      0
DifficultyWalking            0
DifficultyDressingBathing    0
DifficultyErrands            0
SmokerStatus                 0
ECigaretteUsage              0
ChestScan                    0
RaceEthnicityCategory        0
AgeCategory                  0
HeightInMeters               0
WeightInKilograms            0
BMI                          0
AlcoholDrinkers              0
HIVTesting                   0
FluVaxLast12                 0
PneumoVaxEver                0
TetanusLast10Tdap            0
HighRiskLastYear             0
CovidPos                     0
dtype: int64

Missing Values in Entire Dataframe:
```

```
0
```

[13]:

```python
# Display the DataFrame and print dimensions
print("Number of rows:", source_df.shape[0])
print("Number of columns:", source_df.shape[1])
source_df.head()
source_df.tail()
```

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

[13]:

```
       State     Sex GeneralHealth  PhysicalHealthDays  MentalHealthDays  \
342  Alabama  Female     Very good                 4.0               0.0
343  Alabama    Male     Very good                 0.0               0.0
345  Alabama    Male     Very good                 0.0               0.0
346  Alabama  Female          Fair                 5.0               0.0
347  Alabama  Female          Good                 3.0              15.0

                                       LastCheckupTime PhysicalActivities  \
342  Within past year (anytime less than 12 months …                Yes
343  Within past year (anytime less than 12 months …                Yes
345  Within past year (anytime less than 12 months …                 No
346  Within past year (anytime less than 12 months …                Yes
347  Within past year (anytime less than 12 months …                Yes

     SleepHours           RemovedTeeth HadHeartAttack  … HeightInMeters  \
342         9.0           None of them             No  …           1.60
343         6.0           None of them             No  …           1.78
345         8.0  6 or more, but not all             No  …           1.85
346         9.0           None of them             No  …           1.70
347         5.0                 1 to 5             No  …           1.55

    WeightInKilograms    BMI AlcoholDrinkers HIVTesting FluVaxLast12  \
342             71.67  27.99              No         No          Yes
343             95.25  30.13              No         No          Yes
345            108.86  31.66             Yes         No           No
346             90.72  31.32              No         No          Yes
347             79.38  33.07              No         No          Yes

    PneumoVaxEver                                  TetanusLast10Tdap  \
342           Yes                                 Yes, received Tdap
343           Yes  Yes, received tetanus shot but not sure what type
345           Yes    No, did not receive any tetanus shot in the pa…
346           Yes    No, did not receive any tetanus shot in the pa…
347           Yes    No, did not receive any tetanus shot in the pa…

    HighRiskLastYear CovidPos
```

```
342              No       No
343              No       No
345              No      Yes
346              No      Yes
347              No       No

[5 rows x 40 columns]
```

[13]:

```
                 State     Sex GeneralHealth  PhysicalHealthDays  \
445117  Virgin Islands    Male     Very good                 0.0
445123  Virgin Islands  Female          Fair                 0.0
445124  Virgin Islands    Male          Good                 0.0
445128  Virgin Islands  Female     Excellent                 2.0
445130  Virgin Islands    Male     Very good                 0.0

        MentalHealthDays                                    LastCheckupTime  \
445117               0.0  Within past 2 years (1 year but less than 2 ye…
445123               7.0  Within past year (anytime less than 12 months …
445124              15.0  Within past year (anytime less than 12 months …
445128               2.0  Within past year (anytime less than 12 months …
445130               0.0  Within past year (anytime less than 12 months …

       PhysicalActivities  SleepHours  RemovedTeeth HadHeartAttack  …  \
445117                Yes         6.0  None of them             No  …
445123                Yes         7.0  None of them             No  …
445124                Yes         7.0        1 to 5             No  …
445128                Yes         7.0  None of them             No  …
445130                 No         5.0  None of them            Yes  …

       HeightInMeters WeightInKilograms    BMI AlcoholDrinkers HIVTesting  \
445117           1.78            102.06  32.28             Yes         No
445123           1.93             90.72  24.34              No         No
445124           1.68             83.91  29.86             Yes        Yes
445128           1.70             83.01  28.66              No        Yes
445130           1.83            108.86  32.55              No        Yes

       FluVaxLast12 PneumoVaxEver  \
445117           No            No
445123           No            No
445124          Yes           Yes
445128          Yes            No
445130          Yes           Yes

                                        TetanusLast10Tdap HighRiskLastYear  \
445117  Yes, received tetanus shot but not sure what type               No
445123  No, did not receive any tetanus shot in the pa…               No
445124  Yes, received tetanus shot but not sure what type               No
```

```
445128  Yes, received tetanus shot but not sure what type               No
445130  No, did not receive any tetanus shot in the pa…               No

       CovidPos
445117       No
445123      Yes
445124      Yes
445128       No
445130      Yes

[5 rows x 40 columns]
```

[14]:

```
# COMMENT: At this point, the removal of rows holding 902665 missing values
#    resulted in a decrease in the datarame size
#    from
#    Number of rows: 445132
#    Number of columns: 40
#    to
#    Number of rows: 246022
#    Number of columns: 40
```

[15]:

```
# Begin Exploratory Data Analysis and Visualizations
```

[16]:

```
# Visualize unique categories for each column/variable
for column in source_df.columns:
    unique_categories = source_df[column].unique()
    print(f"Unique categories for column '{column}':")
    print(unique_categories)
    print()
```

```
Unique categories for column 'State':
['Alabama' 'Alaska' 'Arizona' 'Arkansas' 'California' 'Colorado'
 'Connecticut' 'Delaware' 'District of Columbia' 'Florida' 'Georgia'
 'Hawaii' 'Idaho' 'Illinois' 'Indiana' 'Iowa' 'Kansas' 'Kentucky'
 'Louisiana' 'Maine' 'Maryland' 'Massachusetts' 'Michigan' 'Minnesota'
 'Mississippi' 'Missouri' 'Montana' 'Nebraska' 'Nevada' 'New Hampshire'
 'New Jersey' 'New Mexico' 'New York' 'North Carolina' 'North Dakota'
 'Ohio' 'Oklahoma' 'Oregon' 'Pennsylvania' 'Rhode Island' 'South Carolina'
 'South Dakota' 'Tennessee' 'Texas' 'Utah' 'Vermont' 'Virginia'
 'Washington' 'West Virginia' 'Wisconsin' 'Wyoming' 'Guam' 'Puerto Rico'
 'Virgin Islands']

Unique categories for column 'Sex':
['Female' 'Male']

Unique categories for column 'GeneralHealth':
['Very good' 'Fair' 'Good' 'Excellent' 'Poor']
```

```
Unique categories for column 'PhysicalHealthDays':
[ 4.  0.  5.  3.  2. 25. 30. 15. 29.  8. 16. 20. 10.  9.  7.  1. 21.  6.
 27. 14. 12. 11. 13. 28. 17. 23. 24. 26. 18. 22. 19.]

Unique categories for column 'MentalHealthDays':
[ 0. 15.  4. 25.  5. 30. 27.  3.  2.  1. 10. 20. 21.  6.  7.  8. 14.  9.
 12. 18. 29. 28. 17. 11. 16. 13. 26. 22. 24. 19. 23.]

Unique categories for column 'LastCheckupTime':
['Within past year (anytime less than 12 months ago)'
 '5 or more years ago'
 'Within past 2 years (1 year but less than 2 years ago)'
 'Within past 5 years (2 years but less than 5 years ago)']

Unique categories for column 'PhysicalActivities':
['Yes' 'No']

Unique categories for column 'SleepHours':
[ 9.  6.  8.  5.  7. 10.  4. 12.  3. 18. 11.  2.  1. 16. 14. 15. 13. 20.
 24. 23. 19. 17. 22.]

Unique categories for column 'RemovedTeeth':
['None of them' '6 or more, but not all' '1 to 5' 'All']

Unique categories for column 'HadHeartAttack':
['No' 'Yes']

Unique categories for column 'HadAngina':
['No' 'Yes']

Unique categories for column 'HadStroke':
['No' 'Yes']

Unique categories for column 'HadAsthma':
['No' 'Yes']

Unique categories for column 'HadSkinCancer':
['No' 'Yes']

Unique categories for column 'HadCOPD':
['No' 'Yes']

Unique categories for column 'HadDepressiveDisorder':
['No' 'Yes']

Unique categories for column 'HadKidneyDisease':
['No' 'Yes']
```

```
Unique categories for column 'HadArthritis':
['Yes' 'No']

Unique categories for column 'HadDiabetes':
['No' 'Yes' 'Yes, but only during pregnancy (female)'
 'No, pre-diabetes or borderline diabetes']

Unique categories for column 'DeafOrHardOfHearing':
['No' 'Yes']

Unique categories for column 'BlindOrVisionDifficulty':
['No' 'Yes']

Unique categories for column 'DifficultyConcentrating':
['No' 'Yes']

Unique categories for column 'DifficultyWalking':
['No' 'Yes']

Unique categories for column 'DifficultyDressingBathing':
['No' 'Yes']

Unique categories for column 'DifficultyErrands':
['No' 'Yes']

Unique categories for column 'SmokerStatus':
['Former smoker' 'Never smoked' 'Current smoker - now smokes every day'
 'Current smoker - now smokes some days']

Unique categories for column 'ECigaretteUsage':
['Never used e-cigarettes in my entire life' 'Use them some days'
 'Not at all (right now)' 'Use them every day']

Unique categories for column 'ChestScan':
['No' 'Yes']

Unique categories for column 'RaceEthnicityCategory':
['White only, Non-Hispanic' 'Black only, Non-Hispanic'
 'Other race only, Non-Hispanic' 'Multiracial, Non-Hispanic' 'Hispanic']

Unique categories for column 'AgeCategory':
['Age 65 to 69' 'Age 70 to 74' 'Age 75 to 79' 'Age 80 or older'
 'Age 50 to 54' 'Age 40 to 44' 'Age 60 to 64' 'Age 55 to 59'
 'Age 45 to 49' 'Age 35 to 39' 'Age 25 to 29' 'Age 30 to 34'
 'Age 18 to 24']

Unique categories for column 'HeightInMeters':
[1.6  1.78 1.85 1.7  1.55 1.63 1.75 1.68 1.83 1.52 1.88 1.5  1.73 1.65
```

```
 1.8  1.57 1.91 1.47 1.42 1.22 1.93 2.01 1.96 1.98 1.45 1.35 1.76 2.03
 2.16 1.51 1.53 1.69 1.56 1.84 1.9  1.54 1.72 1.87 1.74 1.4  1.64 1.58
 1.62 1.79 1.67 1.46 1.89 1.61 1.3  1.37 2.13 2.06 2.11 0.91 2.26 2.18
 1.77 2.36 1.59 1.86 1.82 1.66 1.71 1.95 1.05 2.08 1.49 1.38 1.81 1.44
 1.48 1.19 1.32 1.24 1.07 1.04 1.27 1.1  1.92 1.2  2.24 1.12 1.03 0.97
 1.25 2.29 1.16 1.18 1.09 2.41 1.   1.17 1.08 1.43 1.14 1.02 2.   2.02
 0.95 2.34 2.21]

Unique categories for column 'WeightInKilograms':
[ 71.67  95.25 108.86  90.72  79.38 120.2   88.    74.84  78.02  63.5
 122.47 115.67  81.65  86.18  76.2   54.88  72.57  88.45 104.33  52.16
  68.04  65.77  56.7   94.8  123.83  50.8   68.95 113.4   83.91  77.56
  68.49  82.1   80.74 106.14  58.06  61.69  57.61  84.82  70.76  70.31
  91.63 102.06  48.08  61.23 109.77  99.79  58.97 110.68  64.86 111.13
  45.36  79.83  98.88  55.34 101.6   77.11  93.89  71.21  49.9   96.16
 163.29 120.66  97.52  88.9   44.91  85.73  83.46  92.99 132.    67.59
  92.08  73.48 107.5  107.95  91.17  74.39  64.41  62.6   46.72 103.42
  87.09  89.81  83.01 100.7   56.25  96.62  66.68  67.13  69.4   58.51
  78.93  95.71  63.05  49.44 127.01 145.15 122.02 107.05 126.55 117.03
  47.17 181.44  65.32 117.93 136.08  78.47  52.62 121.56  73.94  82.55
 106.59  59.87 110.22  62.14  51.71  93.44  54.43  85.28  59.42  66.22
  76.66  55.79  75.3   97.07  87.54  69.85 124.74  63.96  47.63  94.35
  97.98  89.36  92.53 101.15 149.69 129.27  84.37 195.04  99.34 114.31
  53.07  81.19  75.75 124.28 112.94  80.29 114.76  45.81  53.52 133.81
  51.26 158.76  60.78  46.27  72.12 131.54 127.91  53.98  98.43 130.63
 143.34 102.51 115.21  90.26 166.92 109.32  40.37 135.62 204.12 129.73
 127.46 138.35 105.69 119.75  48.53 140.61 105.23 139.25 126.1  135.17
 102.97 122.92  57.15  38.56  60.33 131.09 148.78 116.57 112.49  86.64
 112.04 172.37 133.36 118.84  50.35 103.87 111.58 121.11 113.85  73.03
 142.88 134.26 123.38  37.19 119.29  36.29  48.99  43.09  41.73  35.38
 104.78 144.24 167.83 149.23  37.65  86.   147.42 165.56 154.22 136.98
 108.41 155.58 206.38 148.32  42.18  44.45  90.   191.87 249.48  67.
  44.    40.82 156.49  53.   139.71 130.18 118.39 100.   151.95 165.11
  43.54 134.72 141.52 125.19  75.   250.   116.12  73.   100.24  74.
 200.    80.    82.    54.    66.   152.41  39.46  41.28 190.51 188.24
  59.    70.   170.1   46.   265.   168.74 190.    55.    93.   159.66
  78.    38.1  185.07 104.   183.7  125.65  68.   134.   130.    32.21
 143.79 137.89 179.17 105.    65.    32.   292.57  85.    72.   174.63
  50.   128.37  62.    87.   176.9   39.92  76.   128.82  58.   156.04
 121.    42.64  89.   146.96 146.06 171.46 227.25  29.48 190.06 161.03
 226.8  132.45 137.44  64.    56.   141.07  52.    63.   120.    83.
  57.    31.75  77.    96.    60.   115.    41.   150.59 272.16  48.
  39.01  95.   197.31 158.3   45.    94.   240.4   49.   157.85 108.
 185.    61.    34.02 132.9   84.   229.97 138.8   81.    79.    92.
 107.   155.13 208.65  69.   111.   110.   151.05 210.   140.16  35.83
 146.51 117.48 102.   125.   151.5   36.74  38.   135.    71.   147.87
 153.77 170.    91.    98.   192.32 186.88 118.   160.12 160.   170.55
 201.85 184.16 175.09 142.43 169.   166.01 180.53 196.41 162.39  40.
 171.91 195.95 136.53 153.31 159.21 164.2  219.99 141.97 173.27  34.47
 213.19 276.24 199.58 215.46 217.72 175.99 200.03 230.88  33.57 185.52
 103.   152.86 101.   160.57 150.14 157.4  145.   150.   163.75 191.42
 174.18 164.65 256.28 205.48 192.78 161.48 178.26 179.62 144.7  205.02
 178.72 154.68 166.47 177.81 200.49 231.79 238.14 227.7  273.52 211.83
 223.62 197.77 189.15 185.97 250.38 183.25 181.89 222.26 231.33 180.08
 202.76 180.   164.   156.94 114.   122.   161.93 137.   162.84 188.69
 234.51 199.13 203.21 145.6  173.73 263.08 154.   239.04 177.35 224.98
 117.    37.    97.   210.92 273.06 203.66 238.59 113.   224.53 169.64
 146.   201.4  220.    34.93 254.01 212.73 176.45 184.61 124.   152.
 233.6  193.23 205.   244.94 229.06  47.   167.38  99.    28.12 235.87
 171.   212.28 180.98 169.19 175.54  30.84 116.   168.28 123.   186.43
 172.82 182.8  217.27 182.34 246.3   30.39]

Unique categories for column 'BMI':
[27.99 30.13 31.66 … 38.8  58.95 45.28]

Unique categories for column 'AlcoholDrinkers':
['No' 'Yes']

Unique categories for column 'HIVTesting':
['No' 'Yes']

Unique categories for column 'FluVaxLast12':
['Yes' 'No']

Unique categories for column 'PneumoVaxEver':
['Yes' 'No']

Unique categories for column 'TetanusLast10Tdap':
['Yes, received Tdap' 'Yes, received tetanus shot but not sure what type'
 'No, did not receive any tetanus shot in the past 10 years'
 'Yes, received tetanus shot, but not Tdap']

Unique categories for column 'HighRiskLastYear':
['No' 'Yes']

Unique categories for column 'CovidPos':
['No' 'Yes'
 'Tested positive using home test without a health professional']
```

[17]:

```
# Visualize data types of each column/variable
column_types = source_df.dtypes

# Find columns with data type 'object' (strings), 'int' (integers), 'float'␣
 ↪(float numbers)
```

```python
string_columns = column_types[column_types == 'object'].index.tolist()
integer_columns = column_types[column_types == 'int'].index.tolist()
float_columns = column_types[column_types == 'float'].index.tolist()

# Display remaining categorical string variables for one-hot encoding
print("Columns holding data as strings:")
print(string_columns)
# Display numeric integer value (binary) variables
print("\nColumns holding data as numeric integers:")
print(integer_columns)
# Display numeric floating value variables
print("\nColumns holding data as numeric floats:")
print(float_columns)
```

```
Columns holding data as strings:
['State', 'Sex', 'GeneralHealth', 'LastCheckupTime', 'PhysicalActivities',
'RemovedTeeth', 'HadHeartAttack', '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']

Columns holding data as numeric integers:
[]

Columns holding data as numeric floats:
['PhysicalHealthDays', 'MentalHealthDays', 'SleepHours', 'HeightInMeters',
'WeightInKilograms', 'BMI']
```

[18]:

```python
# Visualize summary statistics of numeric float variables
summary_statistics_df = source_df[float_columns].describe()
print(summary_statistics_df)
```

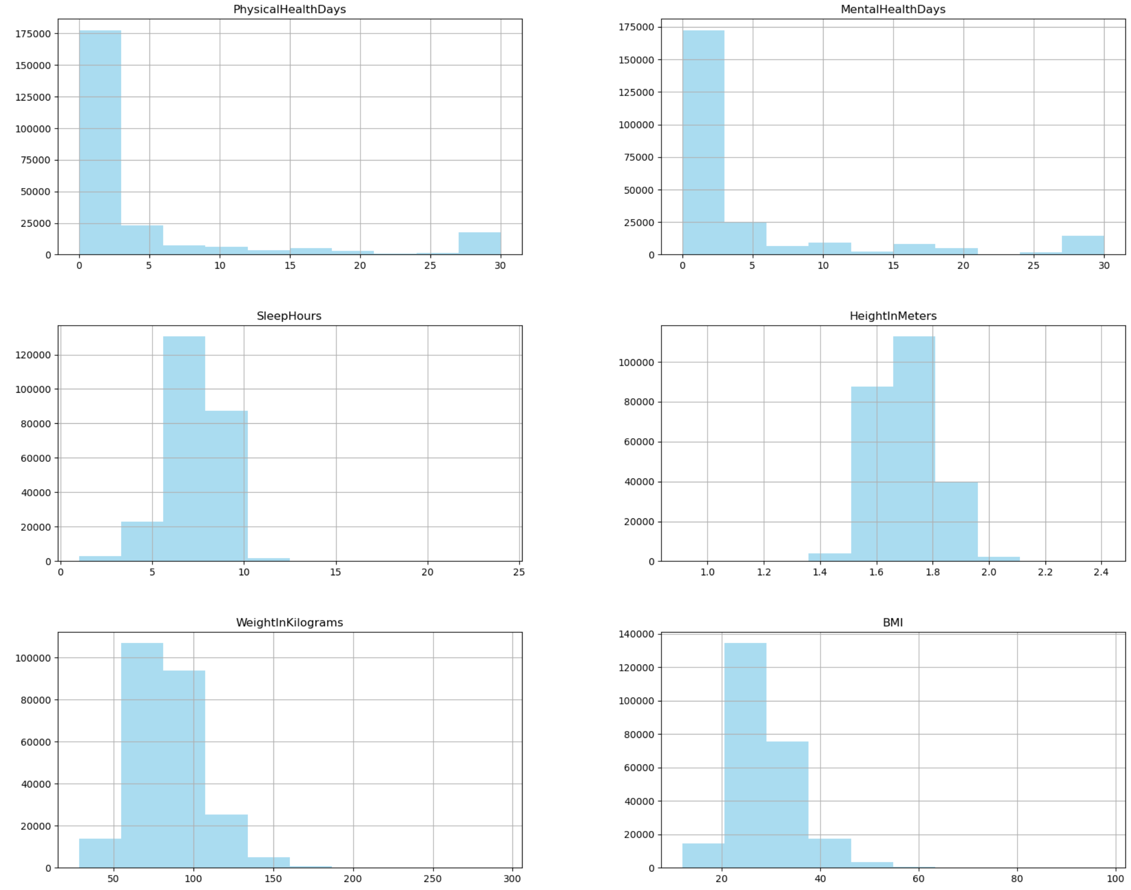
```
       PhysicalHealthDays  MentalHealthDays     SleepHours  HeightInMeters  \
count       246022.000000     246022.000000  246022.000000   246022.000000
mean             4.119026          4.167140       7.021331        1.705150
std              8.405844          8.102687       1.440681        0.106654
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
```

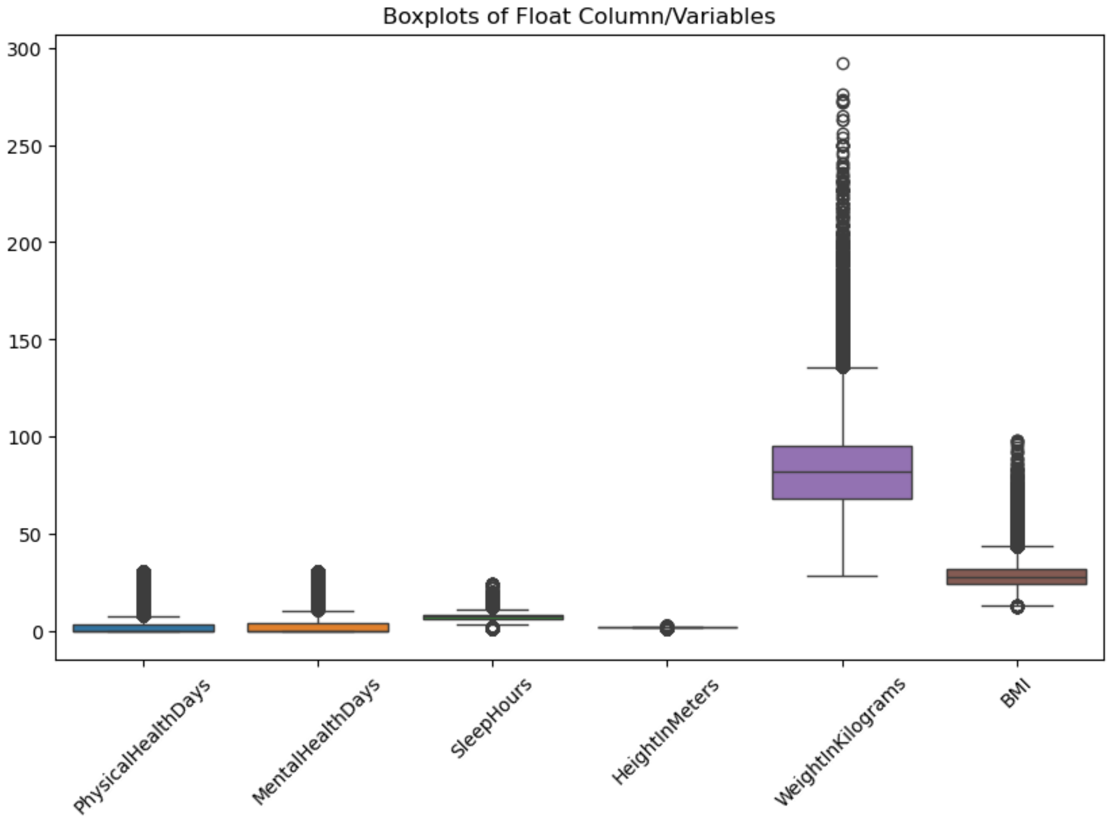
[19]:

```
# Visualize histograms of numeric float variables
source_df[float_columns].hist(figsize=(20, 16) , color='skyblue', alpha=0.7)
plt.show();
```



[20]:

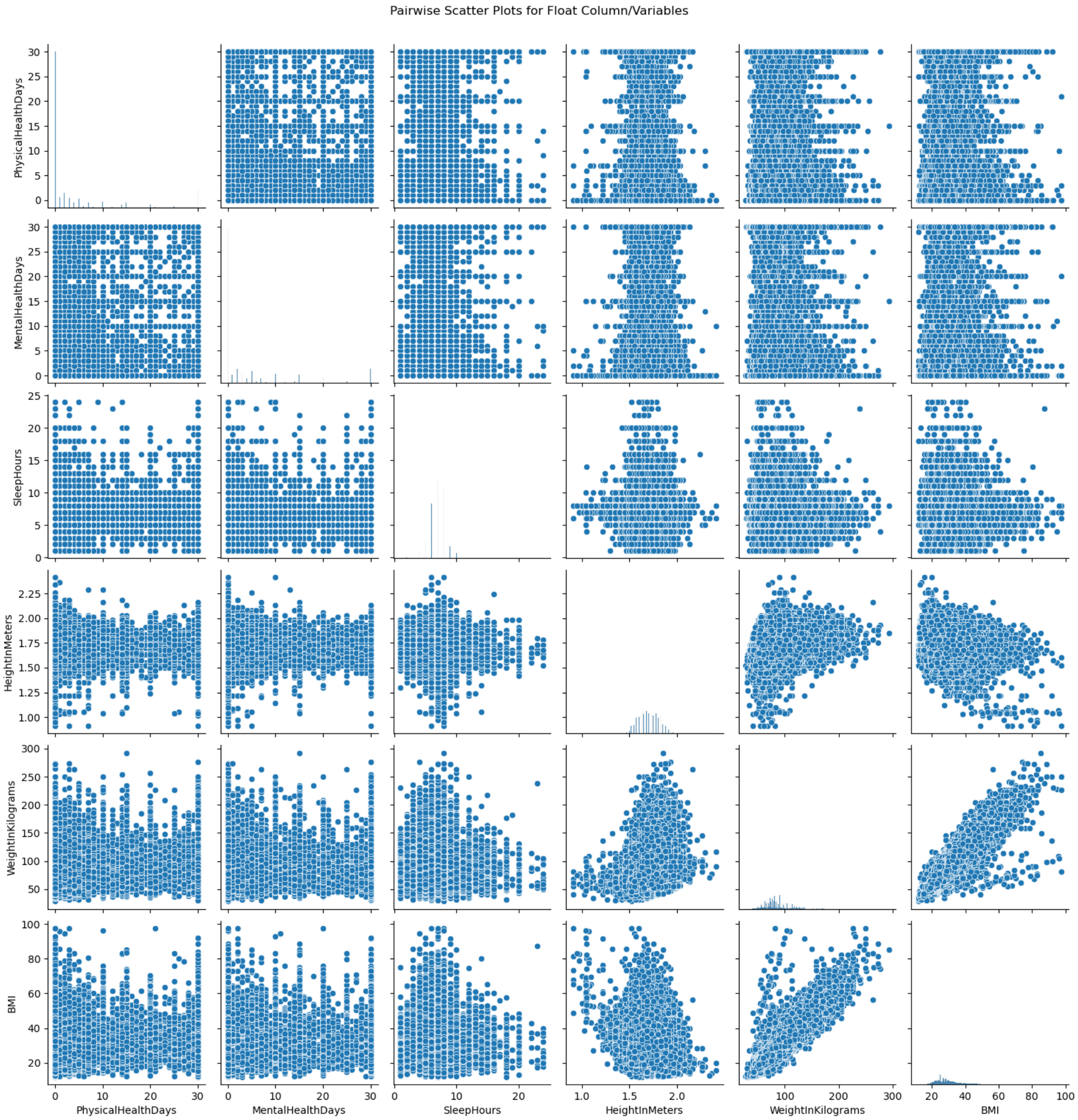
```
# Visualize boxplots of numeric float variables
plt.figure(figsize=(10, 6));
sns.boxplot(data=source_df[float_columns]);
plt.title('Boxplots of Float Column/Variables');
plt.xticks(rotation=45);  # Rotate x-axis labels for better readability
plt.show;
```



[21]:
```
# COMMENT:
#   Summary statistics, histograms, and boxplots all indicate the presence of
#   outliers for the numeric float variables:
#   'PhysicalHealthDays', 'MentalHealthDays', 'SleepHours', 'HeightInMeters',␣
 ↪'WeightInKilograms', 'BMI'.
#   No effort will be made to remove these outliers since they may be relevant␣
 ↪in
#   predicting the dependent variable, 'HadHeartAttack'.
```

[22]:
```
# Visualize scatter plots of numeric float variables
plt.figure(figsize=(12, 8));
sns.pairplot(source_df[float_columns]);
plt.suptitle('Pairwise Scatter Plots for Float Column/Variables', y=1.02);
plt.show();
```

```
<Figure size 1200x800 with 0 Axes>
```



[23]:
```
# COMMENT:
#   Scatter plots suggest positive correlations between:
#   'HeightInMeters' and 'BMI'
#   'WeightInKilograms' and 'BMI'
#   'WeightInKilograms' and 'HeightInMeters'
#   No other positive or negative correlations seem present
```

[24]:
```
# Visualize correlation matrix

# COMMENT:
#   Given the large number of variables and anticipated difficulty in viewing them
#   all in the same correlation matrix, the attempt to visualize a correlation
#   matrix will be made after the most relevant variables have been selected␣
 ↪using
#   feature engineering.
```

[25]:

```
#################################################
##    II.    FEATURE ENGINEERING:
#################################################
# Begin the process of
#  -- making all variables numeric,
#  -- normalize/scale all numeric float variables,
#  -- selecting the best variables based on correlation matrix values
#  -- adding any variable-to-variable interation terms
```

[26]:

```
 # Make all column/variables binary with replacements of "1" or "0"
replacements = {
    'PhysicalActivities': {'Yes': 1, 'No': 0},
    'HadHeartAttack': {'Yes': 1, 'No': 0},
    'HadAngina': {'Yes': 1, 'No': 0},
    'HadStroke': {'Yes': 1, 'No': 0},
    'HadAsthma': {'Yes': 1, 'No': 0},
    'HadSkinCancer': {'Yes': 1, 'No': 0},
    'HadCOPD': {'Yes': 1, 'No': 0},
    'HadDepressiveDisorder': {'Yes': 1, 'No': 0},
    'HadKidneyDisease': {'Yes': 1, 'No': 0},
    'HadArthritis': {'Yes': 1, 'No': 0},
    'DeafOrHardOfHearing': {'Yes': 1, 'No': 0},
    'BlindOrVisionDifficulty': {'Yes': 1, 'No': 0},
    'DifficultyConcentrating': {'Yes': 1, 'No': 0},
    'DifficultyWalking': {'Yes': 1, 'No': 0},
    'DifficultyDressingBathing': {'Yes': 1, 'No': 0},
    'DifficultyErrands': {'Yes': 1, 'No': 0},
    'ChestScan': {'Yes': 1, 'No': 0},
    'gender': {'Yes': 1, 'No': 0},
    'AlcoholDrinkers': {'Yes': 1, 'No': 0},
    'HIVTesting': {'Yes': 1, 'No': 0},
    'FluVaxLast12': {'Yes': 1, 'No': 0},
    'PneumoVaxEver': {'Yes': 1, 'No': 0},
    'HighRiskLastYear': {'Yes': 1, 'No': 0}
}

# Apply replacements to multiple columns at once
source_df.replace(replacements, inplace=True)
```

[27]:

```
# Verify changes. Print unique categories for each column/variable
for column in source_df.columns:
    unique_categories = source_df[column].unique()
    print(f"Unique categories for column '{column}':")
    print(unique_categories)
    print()
```

```
Unique categories for column 'State':
['Alabama' 'Alaska' 'Arizona' 'Arkansas' 'California' 'Colorado'
 'Connecticut' 'Delaware' 'District of Columbia' 'Florida' 'Georgia'
 'Hawaii' 'Idaho' 'Illinois' 'Indiana' 'Iowa' 'Kansas' 'Kentucky'
 'Louisiana' 'Maine' 'Maryland' 'Massachusetts' 'Michigan' 'Minnesota'
 'Mississippi' 'Missouri' 'Montana' 'Nebraska' 'Nevada' 'New Hampshire'
 'New Jersey' 'New Mexico' 'New York' 'North Carolina' 'North Dakota'
 'Ohio' 'Oklahoma' 'Oregon' 'Pennsylvania' 'Rhode Island' 'South Carolina'
 'South Dakota' 'Tennessee' 'Texas' 'Utah' 'Vermont' 'Virginia'
 'Washington' 'West Virginia' 'Wisconsin' 'Wyoming' 'Guam' 'Puerto Rico'
 'Virgin Islands']

Unique categories for column 'Sex':
['Female' 'Male']

Unique categories for column 'GeneralHealth':
['Very good' 'Fair' 'Good' 'Excellent' 'Poor']

Unique categories for column 'PhysicalHealthDays':
[ 4.  0.  5.  3.  2. 25. 30. 15. 29.  8. 16. 20. 10.  9.  7.  1. 21.  6.
 27. 14. 12. 11. 13. 28. 17. 23. 24. 26. 18. 22. 19.]

Unique categories for column 'MentalHealthDays':
[ 0. 15.  4. 25.  5. 30. 27.  3.  2.  1. 10. 20. 21.  6.  7.  8. 14.  9.
 12. 18. 29. 28. 17. 11. 16. 13. 26. 22. 24. 19. 23.]

Unique categories for column 'LastCheckupTime':
['Within past year (anytime less than 12 months ago)'
 '5 or more years ago'
 'Within past 2 years (1 year but less than 2 years ago)'
 'Within past 5 years (2 years but less than 5 years ago)']

Unique categories for column 'PhysicalActivities':
[1 0]

Unique categories for column 'SleepHours':
[ 9.  6.  8.  5.  7. 10.  4. 12.  3. 18. 11.  2.  1. 16. 14. 15. 13. 20.
 24. 23. 19. 17. 22.]

Unique categories for column 'RemovedTeeth':
['None of them' '6 or more, but not all' '1 to 5' 'All']

Unique categories for column 'HadHeartAttack':
[0 1]
```

```
Unique categories for column 'HadAngina':
[0 1]

Unique categories for column 'HadStroke':
[0 1]

Unique categories for column 'HadAsthma':
[0 1]

Unique categories for column 'HadSkinCancer':
[0 1]

Unique categories for column 'HadCOPD':
[0 1]

Unique categories for column 'HadDepressiveDisorder':
[0 1]

Unique categories for column 'HadKidneyDisease':
[0 1]

Unique categories for column 'HadArthritis':
[1 0]

Unique categories for column 'HadDiabetes':
['No' 'Yes' 'Yes, but only during pregnancy (female)'
 'No, pre-diabetes or borderline diabetes']

Unique categories for column 'DeafOrHardOfHearing':
[0 1]

Unique categories for column 'BlindOrVisionDifficulty':
[0 1]

Unique categories for column 'DifficultyConcentrating':
[0 1]

Unique categories for column 'DifficultyWalking':
[0 1]

Unique categories for column 'DifficultyDressingBathing':
[0 1]

Unique categories for column 'DifficultyErrands':
[0 1]

Unique categories for column 'SmokerStatus':
```

```
['Former smoker' 'Never smoked' 'Current smoker - now smokes every day'
 'Current smoker - now smokes some days']

Unique categories for column 'ECigaretteUsage':
['Never used e-cigarettes in my entire life' 'Use them some days'
 'Not at all (right now)' 'Use them every day']

Unique categories for column 'ChestScan':
[0 1]

Unique categories for column 'RaceEthnicityCategory':
['White only, Non-Hispanic' 'Black only, Non-Hispanic'
 'Other race only, Non-Hispanic' 'Multiracial, Non-Hispanic' 'Hispanic']

Unique categories for column 'AgeCategory':
['Age 65 to 69' 'Age 70 to 74' 'Age 75 to 79' 'Age 80 or older'
 'Age 50 to 54' 'Age 40 to 44' 'Age 60 to 64' 'Age 55 to 59'
 'Age 45 to 49' 'Age 35 to 39' 'Age 25 to 29' 'Age 30 to 34'
 'Age 18 to 24']

Unique categories for column 'HeightInMeters':
[1.6  1.78 1.85 1.7  1.55 1.63 1.75 1.68 1.83 1.52 1.88 1.5  1.73 1.65
 1.8  1.57 1.91 1.47 1.42 1.22 1.93 2.01 1.96 1.98 1.45 1.35 1.76 2.03
 2.16 1.51 1.53 1.69 1.56 1.84 1.9  1.54 1.72 1.87 1.74 1.4  1.64 1.58
 1.62 1.79 1.67 1.46 1.89 1.61 1.3  1.37 2.13 2.06 2.11 0.91 2.26 2.18
 1.77 2.36 1.59 1.86 1.82 1.66 1.71 1.95 1.05 2.08 1.49 1.38 1.81 1.44
 1.48 1.19 1.32 1.24 1.07 1.04 1.27 1.1  1.92 1.2  2.24 1.12 1.03 0.97
 1.25 2.29 1.16 1.18 1.09 2.41 1.   1.17 1.08 1.43 1.14 1.02 2.   2.02
 0.95 2.34 2.21]

Unique categories for column 'WeightInKilograms':
[ 71.67  95.25 108.86  90.72  79.38 120.2   88.    74.84  78.02  63.5
 122.47 115.67  81.65  86.18  76.2   54.88  72.57  88.45 104.33  52.16
  68.04  65.77  56.7   94.8  123.83  50.8   68.95 113.4   83.91  77.56
  68.49  82.1   80.74 106.14  58.06  61.69  57.61  84.82  70.76  70.31
  91.63 102.06  48.08  61.23 109.77  99.79  58.97 110.68  64.86 111.13
  45.36  79.83  98.88  55.34 101.6   77.11  93.89  71.21  49.9   96.16
 163.29 120.66  97.52  88.9   44.91  85.73  83.46  92.99 132.    67.59
  92.08  73.48 107.5  107.95  91.17  74.39  64.41  62.6   46.72 103.42
  87.09  89.81  83.01 100.7   56.25  96.62  66.68  67.13  69.4   58.51
  78.93  95.71  63.05  49.44 127.01 145.15 122.02 107.05 126.55 117.03
  47.17 181.44  65.32 117.93 136.08  78.47  52.62 121.56  73.94  82.55
 106.59  59.87 110.22  62.14  51.71  93.44  54.43  85.28  59.42  66.22
  76.66  55.79  75.3   97.07  87.54  69.85 124.74  63.96  47.63  94.35
  97.98  89.36  92.53 101.15 149.69 129.27  84.37 195.04  99.34 114.31
  53.07  81.19  75.75 124.28 112.94  80.29 114.76  45.81  53.52 133.81
  51.26 158.76  60.78  46.27  72.12 131.54 127.91  53.98  98.43 130.63
 143.34 102.51 115.21  90.26 166.92 109.32  40.37 135.62 204.12 129.73
 127.46 138.35 105.69 119.75  48.53 140.61 105.23 139.25 126.1  135.17
 102.97 122.92  57.15  38.56  60.33 131.09 148.78 116.57 112.49  86.64
 112.04 172.37 133.36 118.84  50.35 103.87 111.58 121.11 113.85  73.03
 142.88 134.26 123.38  37.19 119.29  36.29  48.99  43.09  41.73  35.38
 104.78 144.24 167.83 149.23  37.65  86.   147.42 165.56 154.22 136.98
 108.41 155.58 206.38 148.32  42.18  44.45  90.   191.87 249.48  67.
  44.    40.82 156.49  53.   139.71 130.18 118.39 100.   151.95 165.11
  43.54 134.72 141.52 125.19  75.   250.   116.12  73.   100.24  74.
 200.    80.    82.    54.    66.   152.41  39.46  41.28 190.51 188.24
  59.    70.   170.1   46.   265.   168.74 190.    55.    93.   159.66
  78.    38.1  185.07 104.   183.7  125.65  68.   134.   130.    32.21
 143.79 137.89 179.17 105.    65.    32.   292.57  85.    72.   174.63
  50.   128.37  62.    87.   176.9   39.92  76.   128.82  58.   156.04
 121.    42.64  89.   146.96 146.06 171.46 227.25  29.48 190.06 161.03
 226.8  132.45 137.44  64.    56.   141.07  52.    63.   120.    83.
  57.    31.75  77.    96.    60.   115.    41.   150.59 272.16  48.
  39.01  95.   197.31 158.3   45.    94.   240.4   49.   157.85 108.
 185.    61.    34.02 132.9   84.   229.97 138.8   81.    79.    92.
 107.   155.13 208.65  69.   111.   110.   151.05 210.   140.16  35.83
 146.51 117.48 102.   125.   151.5   36.74  38.   135.    71.   147.87
 153.77 170.    91.    98.   192.32 186.88 118.   160.12 160.   170.55
 201.85 184.16 175.09 142.43 169.   166.01 180.53 196.41 162.39  40.
 171.91 195.95 136.53 153.31 159.21 164.2  219.99 141.97 173.27  34.47
 213.19 276.24 199.58 215.46 217.72 175.99 200.03 230.88  33.57 185.52
 103.   152.86 101.   160.57 150.14 157.4  145.   150.   163.75 191.42
 174.18 164.65 256.28 205.48 192.78 161.48 178.26 179.62 144.7  205.02
 178.72 154.68 166.47 177.81 200.49 231.79 238.14 227.7  273.52 211.83
 223.62 197.77 189.15 185.97 250.38 183.25 181.89 222.26 231.33 180.08
 202.76 180.   164.   156.94 114.   122.   161.93 137.   162.84 188.69
 234.51 199.13 203.21 145.6  173.73 263.08 154.   239.04 177.35 224.98
 117.    37.    97.   210.92 273.06 203.66 238.59 113.   224.53 169.64
 146.   201.4  220.    34.93 254.01 212.73 176.45 184.61 124.   152.
 233.6  193.23 205.   244.94 229.06  47.   167.38  99.    28.12 235.87
 171.   212.28 180.98 169.19 175.54  30.84 116.   168.28 123.   186.43
 172.82 182.8  217.27 182.34 246.3   30.39]

Unique categories for column 'BMI':
[27.99 30.13 31.66 … 38.8  58.95 45.28]

Unique categories for column 'AlcoholDrinkers':
[0 1]

Unique categories for column 'HIVTesting':
[0 1]

Unique categories for column 'FluVaxLast12':
[1 0]
```

```
Unique categories for column 'PneumoVaxEver':
[1 0]

Unique categories for column 'TetanusLast10Tdap':
['Yes, received Tdap' 'Yes, received tetanus shot but not sure what type'
 'No, did not receive any tetanus shot in the past 10 years'
 'Yes, received tetanus shot, but not Tdap']

Unique categories for column 'HighRiskLastYear':
[0 1]

Unique categories for column 'CovidPos':
['No' 'Yes'
 'Tested positive using home test without a health professional']
```

[28]:

```python
# In anticipation of one-hot encoding for remaining categorical string␣
 ↪variables,
#   check data types of each column.
column_types = source_df.dtypes

# Find columns with data type 'object' (strings), 'int' (integers), 'float'␣
 ↪(float numbers)
string_columns = column_types[column_types == 'object'].index.tolist()
integer_columns = column_types[column_types == 'int'].index.tolist()
float_columns = column_types[column_types == 'float'].index.tolist()

# Display remaining categorical string variables for one-hot encoding
print("Columns holding values as strings:")
print(string_columns)
# Display numeric integer value (binary) variables
print("\nColumns holding values as integers:")
print(integer_columns)
# Display numeric floating value variables
print("\nColumns holding values as floats:")
print(float_columns)
```

```
Columns holding values as strings:
['State', 'Sex', 'GeneralHealth', 'LastCheckupTime', 'RemovedTeeth',
'HadDiabetes', 'SmokerStatus', 'ECigaretteUsage', 'RaceEthnicityCategory',
'AgeCategory', 'TetanusLast10Tdap', 'CovidPos']

Columns holding values as integers:
['PhysicalActivities', 'HadHeartAttack', 'HadAngina', 'HadStroke', 'HadAsthma',
'HadSkinCancer', 'HadCOPD', 'HadDepressiveDisorder', 'HadKidneyDisease',
'HadArthritis', 'DeafOrHardOfHearing', 'BlindOrVisionDifficulty',
'DifficultyConcentrating', 'DifficultyWalking', 'DifficultyDressingBathing',
'DifficultyErrands', 'ChestScan', 'AlcoholDrinkers', 'HIVTesting',
'FluVaxLast12', 'PneumoVaxEver', 'HighRiskLastYear']

Columns holding values as floats:
['PhysicalHealthDays', 'MentalHealthDays', 'SleepHours', 'HeightInMeters',
'WeightInKilograms', 'BMI']
```

[29]:

```
# Apply one-hot encoding to categorical column/variables holding values
#   as strings
encoded_df = pd.get_dummies(source_df, columns=string_columns)
```

[30]:

```
# Verify changes. Check data types of each column
column_types = encoded_df.dtypes

# Find columns with data type 'object' (strings)
string_columns = column_types[column_types == 'object'].index.tolist()
integer_columns = column_types[column_types == 'int'].index.tolist()
float_columns = column_types[column_types == 'float'].index.tolist()
boolean_columns = column_types[column_types == 'bool'].index.tolist()

print("Columns holding values as strings:")
print(string_columns)
print("\nColumns holding values as integers:")
print(integer_columns)
print("\nColumns holding values as floats:")
print(float_columns)
print("\nColumns holding values as booleans (True/False):")
print(boolean_columns)
```

```
Columns holding values as strings:
[]

Columns holding values as integers:
['PhysicalActivities', 'HadHeartAttack', 'HadAngina', 'HadStroke', 'HadAsthma',
'HadSkinCancer', 'HadCOPD', 'HadDepressiveDisorder', 'HadKidneyDisease',
'HadArthritis', 'DeafOrHardOfHearing', 'BlindOrVisionDifficulty',
'DifficultyConcentrating', 'DifficultyWalking', 'DifficultyDressingBathing',
'DifficultyErrands', 'ChestScan', 'AlcoholDrinkers', 'HIVTesting',
'FluVaxLast12', 'PneumoVaxEver', 'HighRiskLastYear']

Columns holding values as floats:
['PhysicalHealthDays', 'MentalHealthDays', 'SleepHours', 'HeightInMeters',
'WeightInKilograms', 'BMI']

Columns holding values as booleans (True/False):
['State_Alabama', 'State_Alaska', 'State_Arizona', 'State_Arkansas',
'State_California', 'State_Colorado', 'State_Connecticut', 'State_Delaware',
'State_District of Columbia', 'State_Florida', 'State_Georgia', 'State_Guam',
'State_Hawaii', 'State_Idaho', 'State_Illinois', 'State_Indiana', 'State_Iowa',
'State_Kansas', 'State_Kentucky', 'State_Louisiana', 'State_Maine',
'State_Maryland', 'State_Massachusetts', 'State_Michigan', 'State_Minnesota',
'State_Mississippi', 'State_Missouri', 'State_Montana', 'State_Nebraska',
'State_Nevada', 'State_New Hampshire', 'State_New Jersey', 'State_New Mexico',
'State_New York', 'State_North Carolina', 'State_North Dakota', 'State_Ohio',
'State_Oklahoma', 'State_Oregon', 'State_Pennsylvania', 'State_Puerto Rico',
'State_Rhode Island', 'State_South Carolina', 'State_South Dakota',
'State_Tennessee', 'State_Texas', 'State_Utah', 'State_Vermont', 'State_Virgin
Islands', 'State_Virginia', 'State_Washington', 'State_West Virginia',
'State_Wisconsin', 'State_Wyoming', 'Sex_Female', 'Sex_Male',
'GeneralHealth_Excellent', 'GeneralHealth_Fair', 'GeneralHealth_Good',
'GeneralHealth_Poor', 'GeneralHealth_Very good', 'LastCheckupTime_5 or more
years ago', 'LastCheckupTime_Within past 2 years (1 year but less than 2 years
ago)', 'LastCheckupTime_Within past 5 years (2 years but less than 5 years
ago)', 'LastCheckupTime_Within past year (anytime less than 12 months ago)',
'RemovedTeeth_1 to 5', 'RemovedTeeth_6 or more, but not all',
'RemovedTeeth_All', 'RemovedTeeth_None of them', 'HadDiabetes_No',
'HadDiabetes_No, pre-diabetes or borderline diabetes', 'HadDiabetes_Yes',
'HadDiabetes_Yes, but only during pregnancy (female)', 'SmokerStatus_Current
smoker - now smokes every day', 'SmokerStatus_Current smoker - now smokes some
days', 'SmokerStatus_Former smoker', 'SmokerStatus_Never smoked',
'ECigaretteUsage_Never used e-cigarettes in my entire life',
'ECigaretteUsage_Not at all (right now)', 'ECigaretteUsage_Use them every day',
'ECigaretteUsage_Use them some days', 'RaceEthnicityCategory_Black only, Non-
Hispanic', 'RaceEthnicityCategory_Hispanic', 'RaceEthnicityCategory_Multiracial,
Non-Hispanic', 'RaceEthnicityCategory_Other race only, Non-Hispanic',
'RaceEthnicityCategory_White only, Non-Hispanic', 'AgeCategory_Age 18 to 24',
'AgeCategory_Age 25 to 29', 'AgeCategory_Age 30 to 34', 'AgeCategory_Age 35 to
39', 'AgeCategory_Age 40 to 44', 'AgeCategory_Age 45 to 49', 'AgeCategory_Age 50
to 54', 'AgeCategory_Age 55 to 59', 'AgeCategory_Age 60 to 64', 'AgeCategory_Age
65 to 69', 'AgeCategory_Age 70 to 74', 'AgeCategory_Age 75 to 79',
'AgeCategory_Age 80 or older', 'TetanusLast10Tdap_No, did not receive any
tetanus shot in the past 10 years', 'TetanusLast10Tdap_Yes, received Tdap',
'TetanusLast10Tdap_Yes, received tetanus shot but not sure what type',
'TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap', 'CovidPos_No',
'CovidPos_Tested positive using home test without a health professional',
'CovidPos_Yes']
```

[31]:

```python
# Verify that all variables are now some form of numeric:
#  -- integer, binary 0 or 1
#  -- float
#  -- boolean, True "1"/False "0" (after one-hot encoding)
# Print unique catagories for each column/variable
for column in encoded_df.columns:
    unique_categories = encoded_df[column].unique()
    print(f"Unique categories for column '{column}':")
    print(unique_categories)
    print()
```

```
Unique categories for column 'PhysicalHealthDays':
[ 4.  0.  5.  3.  2. 25. 30. 15. 29.  8. 16. 20. 10.  9.  7.  1. 21.  6.
 27. 14. 12. 11. 13. 28. 17. 23. 24. 26. 18. 22. 19.]

Unique categories for column 'MentalHealthDays':
[ 0. 15.  4. 25.  5. 30. 27.  3.  2.  1. 10. 20. 21.  6.  7.  8. 14.  9.
 12. 18. 29. 28. 17. 11. 16. 13. 26. 22. 24. 19. 23.]

Unique categories for column 'PhysicalActivities':
[1 0]

Unique categories for column 'SleepHours':
[ 9.  6.  8.  5.  7. 10.  4. 12.  3. 18. 11.  2.  1. 16. 14. 15. 13. 20.
 24. 23. 19. 17. 22.]

Unique categories for column 'HadHeartAttack':
[0 1]

Unique categories for column 'HadAngina':
[0 1]

Unique categories for column 'HadStroke':
[0 1]

Unique categories for column 'HadAsthma':
[0 1]

Unique categories for column 'HadSkinCancer':
[0 1]

Unique categories for column 'HadCOPD':
[0 1]

Unique categories for column 'HadDepressiveDisorder':
[0 1]

Unique categories for column 'HadKidneyDisease':
[0 1]

Unique categories for column 'HadArthritis':
[1 0]

Unique categories for column 'DeafOrHardOfHearing':
[0 1]

Unique categories for column 'BlindOrVisionDifficulty':
```

```
[0 1]

Unique categories for column 'DifficultyConcentrating':
[0 1]

Unique categories for column 'DifficultyWalking':
[0 1]

Unique categories for column 'DifficultyDressingBathing':
[0 1]

Unique categories for column 'DifficultyErrands':
[0 1]

Unique categories for column 'ChestScan':
[0 1]

Unique categories for column 'HeightInMeters':
[1.6  1.78 1.85 1.7  1.55 1.63 1.75 1.68 1.83 1.52 1.88 1.5  1.73 1.65
 1.8  1.57 1.91 1.47 1.42 1.22 1.93 2.01 1.96 1.98 1.45 1.35 1.76 2.03
 2.16 1.51 1.53 1.69 1.56 1.84 1.9  1.54 1.72 1.87 1.74 1.4  1.64 1.58
 1.62 1.79 1.67 1.46 1.89 1.61 1.3  1.37 2.13 2.06 2.11 0.91 2.26 2.18
 1.77 2.36 1.59 1.86 1.82 1.66 1.71 1.95 1.05 2.08 1.49 1.38 1.81 1.44
 1.48 1.19 1.32 1.24 1.07 1.04 1.27 1.1  1.92 1.2  2.24 1.12 1.03 0.97
 1.25 2.29 1.16 1.18 1.09 2.41 1.   1.17 1.08 1.43 1.14 1.02 2.   2.02
 0.95 2.34 2.21]

Unique categories for column 'WeightInKilograms':
[ 71.67  95.25 108.86  90.72  79.38 120.2   88.    74.84  78.02  63.5
 122.47 115.67  81.65  86.18  76.2   54.88  72.57  88.45 104.33  52.16
  68.04  65.77  56.7   94.8  123.83  50.8   68.95 113.4   83.91  77.56
  68.49  82.1   80.74 106.14  58.06  61.69  57.61  84.82  70.76  70.31
  91.63 102.06  48.08  61.23 109.77  99.79  58.97 110.68  64.86 111.13
  45.36  79.83  98.88  55.34 101.6   77.11  93.89  71.21  49.9   96.16
 163.29 120.66  97.52  88.9   44.91  85.73  83.46  92.99 132.    67.59
  92.08  73.48 107.5  107.95  91.17  74.39  64.41  62.6   46.72 103.42
  87.09  89.81  83.01 100.7   56.25  96.62  66.68  67.13  69.4   58.51
  78.93  95.71  63.05  49.44 127.01 145.15 122.02 107.05 126.55 117.03
  47.17 181.44  65.32 117.93 136.08  78.47  52.62 121.56  73.94  82.55
 106.59  59.87 110.22  62.14  51.71  93.44  54.43  85.28  59.42  66.22
  76.66  55.79  75.3   97.07  87.54  69.85 124.74  63.96  47.63  94.35
  97.98  89.36  92.53 101.15 149.69 129.27  84.37 195.04  99.34 114.31
  53.07  81.19  75.75 124.28 112.94  80.29 114.76  45.81  53.52 133.81
  51.26 158.76  60.78  46.27  72.12 131.54 127.91  53.98  98.43 130.63
 143.34 102.51 115.21  90.26 166.92 109.32  40.37 135.62 204.12 129.73
 127.46 138.35 105.69 119.75  48.53 140.61 105.23 139.25 126.1  135.17
 102.97 122.92  57.15  38.56  60.33 131.09 148.78 116.57 112.49  86.64
 112.04 172.37 133.36 118.84  50.35 103.87 111.58 121.11 113.85  73.03
 142.88 134.26 123.38  37.19 119.29  36.29  48.99  43.09  41.73  35.38
 104.78 144.24 167.83 149.23  37.65  86.   147.42 165.56 154.22 136.98
 108.41 155.58 206.38 148.32  42.18  44.45  90.   191.87 249.48  67.
  44.    40.82 156.49  53.   139.71 130.18 118.39 100.   151.95 165.11
  43.54 134.72 141.52 125.19  75.   250.   116.12  73.   100.24  74.
 200.    80.    82.    54.    66.   152.41  39.46  41.28 190.51 188.24
  59.    70.   170.1   46.   265.   168.74 190.    55.    93.   159.66
  78.    38.1  185.07 104.   183.7  125.65  68.   134.   130.    32.21
 143.79 137.89 179.17 105.    65.    32.   292.57  85.    72.   174.63
  50.   128.37  62.    87.   176.9   39.92  76.   128.82  58.   156.04
 121.    42.64  89.   146.96 146.06 171.46 227.25  29.48 190.06 161.03
 226.8  132.45 137.44  64.    56.   141.07  52.    63.   120.    83.
  57.    31.75  77.    96.    60.   115.    41.   150.59 272.16  48.
  39.01  95.   197.31 158.3   45.    94.   240.4   49.   157.85 108.
 185.    61.    34.02 132.9   84.   229.97 138.8   81.    79.    92.
 107.   155.13 208.65  69.   111.   110.   151.05 210.   140.16  35.83
 146.51 117.48 102.   125.   151.5   36.74  38.   135.    71.   147.87
 153.77 170.    91.    98.   192.32 186.88 118.   160.12 160.   170.55
 201.85 184.16 175.09 142.43 169.   166.01 180.53 196.41 162.39  40.
 171.91 195.95 136.53 153.31 159.21 164.2  219.99 141.97 173.27  34.47
 213.19 276.24 199.58 215.46 217.72 175.99 200.03 230.88  33.57 185.52
 103.   152.86 101.   160.57 150.14 157.4  145.   150.   163.75 191.42
 174.18 164.65 256.28 205.48 192.78 161.48 178.26 179.62 144.7  205.02
 178.72 154.68 166.47 177.81 200.49 231.79 238.14 227.7  273.52 211.83
 223.62 197.77 189.15 185.97 250.38 183.25 181.89 222.26 231.33 180.08
 202.76 180.   164.   156.94 114.   122.   161.93 137.   162.84 188.69
 234.51 199.13 203.21 145.6  173.73 263.08 154.   239.04 177.35 224.98
 117.    37.    97.   210.92 273.06 203.66 238.59 113.   224.53 169.64
 146.   201.4  220.    34.93 254.01 212.73 176.45 184.61 124.   152.
 233.6  193.23 205.   244.94 229.06  47.   167.38  99.    28.12 235.87
 171.   212.28 180.98 169.19 175.54  30.84 116.   168.28 123.   186.43
 172.82 182.8  217.27 182.34 246.3   30.39]

Unique categories for column 'BMI':
[27.99 30.13 31.66 … 38.8  58.95 45.28]

Unique categories for column 'AlcoholDrinkers':
[0 1]

Unique categories for column 'HIVTesting':
[0 1]

Unique categories for column 'FluVaxLast12':
[1 0]

Unique categories for column 'PneumoVaxEver':
[1 0]
```

```
Unique categories for column 'HighRiskLastYear':
[0 1]

Unique categories for column 'State_Alabama':
[ True False]

Unique categories for column 'State_Alaska':
[False  True]

Unique categories for column 'State_Arizona':
[False  True]

Unique categories for column 'State_Arkansas':
[False  True]

Unique categories for column 'State_California':
[False  True]

Unique categories for column 'State_Colorado':
[False  True]

Unique categories for column 'State_Connecticut':
[False  True]

Unique categories for column 'State_Delaware':
[False  True]

Unique categories for column 'State_District of Columbia':
[False  True]

Unique categories for column 'State_Florida':
[False  True]

Unique categories for column 'State_Georgia':
[False  True]

Unique categories for column 'State_Guam':
[False  True]

Unique categories for column 'State_Hawaii':
[False  True]

Unique categories for column 'State_Idaho':
[False  True]

Unique categories for column 'State_Illinois':
[False  True]
```

```
Unique categories for column 'State_Indiana':
[False  True]

Unique categories for column 'State_Iowa':
[False  True]

Unique categories for column 'State_Kansas':
[False  True]

Unique categories for column 'State_Kentucky':
[False  True]

Unique categories for column 'State_Louisiana':
[False  True]

Unique categories for column 'State_Maine':
[False  True]

Unique categories for column 'State_Maryland':
[False  True]

Unique categories for column 'State_Massachusetts':
[False  True]

Unique categories for column 'State_Michigan':
[False  True]

Unique categories for column 'State_Minnesota':
[False  True]

Unique categories for column 'State_Mississippi':
[False  True]

Unique categories for column 'State_Missouri':
[False  True]

Unique categories for column 'State_Montana':
[False  True]

Unique categories for column 'State_Nebraska':
[False  True]

Unique categories for column 'State_Nevada':
[False  True]

Unique categories for column 'State_New Hampshire':
[False  True]
```

```
Unique categories for column 'State_New Jersey':
[False  True]

Unique categories for column 'State_New Mexico':
[False  True]

Unique categories for column 'State_New York':
[False  True]

Unique categories for column 'State_North Carolina':
[False  True]

Unique categories for column 'State_North Dakota':
[False  True]

Unique categories for column 'State_Ohio':
[False  True]

Unique categories for column 'State_Oklahoma':
[False  True]

Unique categories for column 'State_Oregon':
[False  True]

Unique categories for column 'State_Pennsylvania':
[False  True]

Unique categories for column 'State_Puerto Rico':
[False  True]

Unique categories for column 'State_Rhode Island':
[False  True]

Unique categories for column 'State_South Carolina':
[False  True]

Unique categories for column 'State_South Dakota':
[False  True]

Unique categories for column 'State_Tennessee':
[False  True]

Unique categories for column 'State_Texas':
[False  True]

Unique categories for column 'State_Utah':
[False  True]
```

```
Unique categories for column 'State_Vermont':
[False  True]

Unique categories for column 'State_Virgin Islands':
[False  True]

Unique categories for column 'State_Virginia':
[False  True]

Unique categories for column 'State_Washington':
[False  True]

Unique categories for column 'State_West Virginia':
[False  True]

Unique categories for column 'State_Wisconsin':
[False  True]

Unique categories for column 'State_Wyoming':
[False  True]

Unique categories for column 'Sex_Female':
[ True False]

Unique categories for column 'Sex_Male':
[False  True]

Unique categories for column 'GeneralHealth_Excellent':
[False  True]

Unique categories for column 'GeneralHealth_Fair':
[False  True]

Unique categories for column 'GeneralHealth_Good':
[False  True]

Unique categories for column 'GeneralHealth_Poor':
[False  True]

Unique categories for column 'GeneralHealth_Very good':
[ True False]

Unique categories for column 'LastCheckupTime_5 or more years ago':
[False  True]

Unique categories for column 'LastCheckupTime_Within past 2 years (1 year but
less than 2 years ago)':
[False  True]
```

```
Unique categories for column 'LastCheckupTime_Within past 5 years (2 years but
less than 5 years ago)':
[False  True]

Unique categories for column 'LastCheckupTime_Within past year (anytime less
than 12 months ago)':
[ True False]

Unique categories for column 'RemovedTeeth_1 to 5':
[False  True]

Unique categories for column 'RemovedTeeth_6 or more, but not all':
[False  True]

Unique categories for column 'RemovedTeeth_All':
[False  True]

Unique categories for column 'RemovedTeeth_None of them':
[ True False]

Unique categories for column 'HadDiabetes_No':
[ True False]

Unique categories for column 'HadDiabetes_No, pre-diabetes or borderline
diabetes':
[False  True]

Unique categories for column 'HadDiabetes_Yes':
[False  True]

Unique categories for column 'HadDiabetes_Yes, but only during pregnancy
(female)':
[False  True]

Unique categories for column 'SmokerStatus_Current smoker - now smokes every
day':
[False  True]

Unique categories for column 'SmokerStatus_Current smoker - now smokes some
days':
[False  True]

Unique categories for column 'SmokerStatus_Former smoker':
[ True False]

Unique categories for column 'SmokerStatus_Never smoked':
[False  True]
```

```
Unique categories for column 'ECigaretteUsage_Never used e-cigarettes in my
entire life':
[ True False]

Unique categories for column 'ECigaretteUsage_Not at all (right now)':
[False  True]

Unique categories for column 'ECigaretteUsage_Use them every day':
[False  True]

Unique categories for column 'ECigaretteUsage_Use them some days':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Black only, Non-Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Multiracial, Non-Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Other race only, Non-
Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_White only, Non-Hispanic':
[ True False]

Unique categories for column 'AgeCategory_Age 18 to 24':
[False  True]

Unique categories for column 'AgeCategory_Age 25 to 29':
[False  True]

Unique categories for column 'AgeCategory_Age 30 to 34':
[False  True]

Unique categories for column 'AgeCategory_Age 35 to 39':
[False  True]

Unique categories for column 'AgeCategory_Age 40 to 44':
[False  True]

Unique categories for column 'AgeCategory_Age 45 to 49':
[False  True]
```

```
Unique categories for column 'AgeCategory_Age 50 to 54':
[False  True]

Unique categories for column 'AgeCategory_Age 55 to 59':
[False  True]

Unique categories for column 'AgeCategory_Age 60 to 64':
[False  True]

Unique categories for column 'AgeCategory_Age 65 to 69':
[ True False]

Unique categories for column 'AgeCategory_Age 70 to 74':
[False  True]

Unique categories for column 'AgeCategory_Age 75 to 79':
[False  True]

Unique categories for column 'AgeCategory_Age 80 or older':
[False  True]

Unique categories for column 'TetanusLast10Tdap_No, did not receive any tetanus
shot in the past 10 years':
[False  True]

Unique categories for column 'TetanusLast10Tdap_Yes, received Tdap':
[ True False]

Unique categories for column 'TetanusLast10Tdap_Yes, received tetanus shot but
not sure what type':
[False  True]

Unique categories for column 'TetanusLast10Tdap_Yes, received tetanus shot, but
not Tdap':
[False  True]

Unique categories for column 'CovidPos_No':
[ True False]

Unique categories for column 'CovidPos_Tested positive using home test without a
health professional':
[False  True]

Unique categories for column 'CovidPos_Yes':
[False  True]
```

[32]:

```
# Normalize/scale all numeric float variables
# Initialize scaler objects
standard_scaler = StandardScaler()
min_max_scaler = MinMaxScaler()

# Fit and transform selected columns using standard scaler
encoded_df[float_columns] = standard_scaler.
 ↪fit_transform(encoded_df[float_columns])

# Fit and transform selected columns using min-max scaler
encoded_df[float_columns] = min_max_scaler.
 ↪fit_transform(encoded_df[float_columns])
```

[33]:

```
# Verify that all variables are now some form of numeric:
#   -- integer, binary 0 or 1
#   -- float (normalized/scaled between 0 and 1)
#   -- boolean, True "1"/False "0" (after one-hot encoding)
# Print unique catagories for each column/variable
for column in encoded_df.columns:
    unique_categories = encoded_df[column].unique()
    print(f"Unique categories for column '{column}':")
    print(unique_categories)
    print()
```

```
Unique categories for column 'PhysicalHealthDays':
[0.13333333 0.         0.16666667 0.1        0.06666667 0.83333333
 1.         0.5        0.96666667 0.26666667 0.53333333 0.66666667
 0.33333333 0.3        0.23333333 0.03333333 0.7        0.2
 0.9        0.46666667 0.4        0.36666667 0.43333333 0.93333333
 0.56666667 0.76666667 0.8        0.86666667 0.6        0.73333333
 0.63333333]

Unique categories for column 'MentalHealthDays':
[0.         0.5        0.13333333 0.83333333 0.16666667 1.
 0.9        0.1        0.06666667 0.03333333 0.33333333 0.66666667
 0.7        0.2        0.23333333 0.26666667 0.46666667 0.3
 0.4        0.6        0.96666667 0.93333333 0.56666667 0.36666667
 0.53333333 0.43333333 0.86666667 0.73333333 0.8        0.63333333
 0.76666667]

Unique categories for column 'PhysicalActivities':
[1 0]

Unique categories for column 'SleepHours':
[0.34782609 0.2173913  0.30434783 0.17391304 0.26086957 0.39130435
 0.13043478 0.47826087 0.08695652 0.73913043 0.43478261 0.04347826
 0.         0.65217391 0.56521739 0.60869565 0.52173913 0.82608696
 1.         0.95652174 0.7826087  0.69565217 0.91304348]
```

```
Unique categories for column 'HadHeartAttack':
[0 1]

Unique categories for column 'HadAngina':
[0 1]

Unique categories for column 'HadStroke':
[0 1]

Unique categories for column 'HadAsthma':
[0 1]

Unique categories for column 'HadSkinCancer':
[0 1]

Unique categories for column 'HadCOPD':
[0 1]

Unique categories for column 'HadDepressiveDisorder':
[0 1]

Unique categories for column 'HadKidneyDisease':
[0 1]

Unique categories for column 'HadArthritis':
[1 0]

Unique categories for column 'DeafOrHardOfHearing':
[0 1]

Unique categories for column 'BlindOrVisionDifficulty':
[0 1]

Unique categories for column 'DifficultyConcentrating':
[0 1]

Unique categories for column 'DifficultyWalking':
[0 1]

Unique categories for column 'DifficultyDressingBathing':
[0 1]

Unique categories for column 'DifficultyErrands':
[0 1]

Unique categories for column 'ChestScan':
[0 1]
```

```
Unique categories for column 'HeightInMeters':
[0.46       0.58       0.62666667 0.52666667 0.42666667 0.48
 0.56       0.51333333 0.61333333 0.40666667 0.64666667 0.39333333
 0.54666667 0.49333333 0.59333333 0.44       0.66666667 0.37333333
 0.34       0.20666667 0.68       0.73333333 0.7        0.71333333
 0.36       0.29333333 0.56666667 0.74666667 0.83333333 0.4
 0.41333333 0.52       0.43333333 0.62       0.66       0.42
 0.54       0.64       0.55333333 0.32666667 0.48666667 0.44666667
 0.47333333 0.58666667 0.50666667 0.36666667 0.65333333 0.46666667
 0.26       0.30666667 0.81333333 0.76666667 0.8        0.
 0.9        0.84666667 0.57333333 0.96666667 0.45333333 0.63333333
 0.60666667 0.5        0.53333333 0.69333333 0.09333333 0.78
 0.38666667 0.31333333 0.6        0.35333333 0.38       0.18666667
 0.27333333 0.22       0.10666667 0.08666667 0.24       0.12666667
 0.67333333 0.19333333 0.88666667 0.14       0.08       0.04
 0.22666667 0.92       0.16666667 0.18       0.12       1.
 0.06       0.17333333 0.11333333 0.34666667 0.15333333 0.07333333
 0.72666667 0.74       0.02666667 0.95333333 0.86666667]

Unique categories for column 'WeightInKilograms':
[0.16468141 0.25384761 0.30531291 0.23671772 0.19383626 0.34819437
 0.22643222 0.17666856 0.18869351 0.13378711 0.35677822 0.33106447
 0.20242012 0.21955001 0.18181131 0.10119115 0.1680847  0.22813386
 0.28818302 0.09090565 0.15095481 0.14237096 0.10807336 0.25214596
 0.36192097 0.0857629  0.15439592 0.32248062 0.21096616 0.18695406
 0.15265646 0.20412176 0.19897901 0.29502742 0.11321611 0.12694271
 0.11151446 0.21440726 0.16124031 0.15953867 0.24015882 0.27959917
 0.07547741 0.12520325 0.30875402 0.27101531 0.11665721 0.31219512
 0.13892985 0.31389677 0.06519191 0.19553791 0.26757421 0.10293061
 0.27785971 0.18525241 0.24870486 0.16294196 0.08235961 0.25728871
 0.51113632 0.34993382 0.26243146 0.22983551 0.06349026 0.21784836
 0.20926451 0.24530157 0.39281528 0.14925317 0.24186047 0.17152581
 0.30017016 0.30187181 0.23841936 0.17496691 0.13722821 0.13038382
 0.07033466 0.28474192 0.22299111 0.23327661 0.20756287 0.27445642
 0.10637171 0.25902817 0.14581206 0.14751371 0.15609756 0.11491775
 0.19213462 0.25558707 0.13208546 0.08062016 0.37394593 0.44254112
 0.35507657 0.29846852 0.37220647 0.33620722 0.0720363  0.57976933
 0.14066931 0.33961051 0.40824352 0.19039516 0.09264511 0.35333711
 0.17326527 0.20582341 0.29672906 0.1200605  0.31045566 0.12864436
 0.08920401 0.24700321 0.09948951 0.21614672 0.11835886 0.1440726
 0.18355077 0.10463226 0.17840802 0.26072982 0.22469276 0.15779921
 0.36536207 0.13552656 0.07377576 0.25044432 0.26417092 0.23157497
 0.24356211 0.27615806 0.45970883 0.38249196 0.21270562 0.63119682
 0.26931367 0.32592172 0.09434676 0.20068066 0.18010966 0.36362261
 0.32074116 0.19727737 0.32762337 0.06689355 0.0960484  0.39965967
 0.08750236 0.49400643 0.12350161 0.06863301 0.16638306 0.39107582
 0.37734922 0.09778786 0.26587257 0.38763471 0.43569673 0.28130081
```

```
0.32932501 0.23497826 0.52486292 0.30705237 0.04632256 0.40650407
0.66553224 0.38423142 0.37564757 0.41682738 0.29332577 0.34649272
0.07717905 0.42537342 0.29158631 0.42023067 0.37050482 0.40480242
0.28304027 0.35847986 0.109775   0.03947816 0.12179996 0.38937417
0.45626773 0.33446776 0.31903952 0.22128947 0.31733787 0.54547173
0.39795803 0.34305162 0.08406126 0.28644356 0.31559841 0.35163547
0.32418227 0.16982416 0.43395727 0.40136132 0.36021932 0.0342976
0.34475326 0.03089431 0.07891851 0.05660805 0.05146531 0.0274532
0.28988467 0.43910002 0.52830403 0.45796937 0.03603706 0.21886935
0.45112498 0.51972017 0.47683872 0.41164681 0.30361127 0.48198147
0.67407828 0.45452827 0.05316695 0.0617508  0.23399508 0.61920968
0.83705804 0.14702212 0.06004916 0.0480242  0.48542258 0.09408206
0.42197013 0.38593307 0.34134997 0.27180942 0.46825487 0.51801853
0.0583097  0.40310078 0.42881452 0.36706372 0.17727359 0.83902439
0.33276612 0.16971072 0.27271696 0.17349215 0.64995273 0.19618075
0.20374362 0.09786349 0.14324069 0.46999433 0.04288145 0.04976366
0.61406693 0.60548308 0.11677066 0.15836642 0.53688788 0.06761202
0.89574589 0.53174513 0.6121384  0.10164492 0.24533938 0.49740972
0.18861789 0.0377387  0.59349593 0.28693515 0.58831537 0.36880318
0.15080355 0.40037814 0.38525241 0.01546606 0.43739837 0.41508792
0.57118548 0.29071658 0.13945926 0.01467196 1.         0.21508792
0.16592929 0.55401777 0.08273776 0.37908867 0.12811496 0.22265078
0.56260163 0.04462091 0.18105502 0.38079032 0.11298922 0.48372093
0.35121951 0.05490641 0.23021365 0.44938552 0.44598223 0.54203063
0.75299679 0.00514275 0.61236529 0.50259028 0.75129514 0.39451692
0.41338627 0.13567782 0.10542636 0.42711288 0.09030062 0.13189639
0.34743808 0.20752505 0.10920779 0.0137266  0.18483645 0.25668368
0.12055209 0.32853091 0.04870486 0.46311212 0.92282095 0.07517489
0.04117981 0.25290225 0.63978068 0.49226697 0.06383059 0.24912082
0.80272263 0.07895632 0.49056532 0.30206088 0.59323123 0.12433352
0.02231046 0.39621857 0.21130649 0.76328228 0.41852902 0.19996219
0.19239932 0.24155795 0.29827945 0.48027983 0.68266213 0.15458499
0.31340518 0.30962375 0.46485158 0.68776706 0.42367177 0.02915485
0.44768387 0.33790887 0.27937228 0.36634524 0.46655322 0.03259595
0.03736056 0.40415958 0.16214785 0.45282662 0.47513708 0.53650974
0.23777652 0.26424655 0.62091133 0.60034033 0.33987521 0.49914918
0.49869541 0.53858953 0.65694838 0.59005483 0.55575723 0.43225562
0.5327283  0.52142182 0.57632823 0.63637739 0.50773303 0.04492343
0.54373227 0.63463793 0.40994517 0.47339762 0.49570807 0.51457742
0.72554358 0.43051617 0.54887502 0.0240121  0.69982984 0.9382492
0.64836453 0.70841369 0.71695973 0.55916052 0.65006618 0.76672339
0.02060881 0.59519758 0.28315372 0.47169597 0.27559085 0.50085082
0.46141047 0.48886368 0.44197391 0.46088107 0.51287578 0.61750804
0.55231613 0.51627907 0.86277179 0.67067499 0.62265078 0.50429193
0.56774438 0.57288712 0.44083948 0.66893553 0.56948383 0.47857818
0.52316128 0.56604273 0.65180563 0.77016449 0.79417659 0.75469843
0.9279637  0.69468709 0.73927018 0.64152014 0.60892418 0.59689922
0.84046133 0.58661373 0.58147098 0.73412743 0.76842503 0.57462658
```

```
 0.66038949 0.57432407 0.51382114 0.48712422 0.32474948 0.35500095
 0.50599357 0.41172244 0.50943468 0.60718472 0.78044999 0.64666289
 0.66209113 0.44424277 0.55061448 0.88848554 0.47600681 0.79757988
 0.56430327 0.74441293 0.33609378 0.03357913 0.26046512 0.69124598
 0.92622424 0.66379278 0.79587824 0.32096805 0.74271129 0.53514842
 0.44575534 0.65524674 0.7255814  0.02575156 0.85418794 0.69809038
 0.56089998 0.59175648 0.36256381 0.46844394 0.77700889 0.62435243
 0.6688599  0.81989034 0.75984118 0.07139346 0.52660238 0.26802798
 0.         0.78559274 0.54029117 0.69638873 0.57802987 0.53344678
 0.55745888 0.0102855  0.33231235 0.53000567 0.35878238 0.59863868
 0.54717338 0.58491208 0.71525808 0.58317262 0.82503309 0.00858385]

Unique categories for column 'BMI':
[0.18650006 0.2114913  0.22935887 … 0.31274086 0.54805559 0.38841528]

Unique categories for column 'AlcoholDrinkers':
[0 1]

Unique categories for column 'HIVTesting':
[0 1]

Unique categories for column 'FluVaxLast12':
[1 0]

Unique categories for column 'PneumoVaxEver':
[1 0]

Unique categories for column 'HighRiskLastYear':
[0 1]

Unique categories for column 'State_Alabama':
[ True False]

Unique categories for column 'State_Alaska':
[False  True]

Unique categories for column 'State_Arizona':
[False  True]

Unique categories for column 'State_Arkansas':
[False  True]

Unique categories for column 'State_California':
[False  True]

Unique categories for column 'State_Colorado':
[False  True]
```

```
Unique categories for column 'State_Connecticut':
[False  True]

Unique categories for column 'State_Delaware':
[False  True]

Unique categories for column 'State_District of Columbia':
[False  True]

Unique categories for column 'State_Florida':
[False  True]

Unique categories for column 'State_Georgia':
[False  True]

Unique categories for column 'State_Guam':
[False  True]

Unique categories for column 'State_Hawaii':
[False  True]

Unique categories for column 'State_Idaho':
[False  True]

Unique categories for column 'State_Illinois':
[False  True]

Unique categories for column 'State_Indiana':
[False  True]

Unique categories for column 'State_Iowa':
[False  True]

Unique categories for column 'State_Kansas':
[False  True]

Unique categories for column 'State_Kentucky':
[False  True]

Unique categories for column 'State_Louisiana':
[False  True]

Unique categories for column 'State_Maine':
[False  True]

Unique categories for column 'State_Maryland':
[False  True]
```

```
Unique categories for column 'State_Massachusetts':
[False  True]

Unique categories for column 'State_Michigan':
[False  True]

Unique categories for column 'State_Minnesota':
[False  True]

Unique categories for column 'State_Mississippi':
[False  True]

Unique categories for column 'State_Missouri':
[False  True]

Unique categories for column 'State_Montana':
[False  True]

Unique categories for column 'State_Nebraska':
[False  True]

Unique categories for column 'State_Nevada':
[False  True]

Unique categories for column 'State_New Hampshire':
[False  True]

Unique categories for column 'State_New Jersey':
[False  True]

Unique categories for column 'State_New Mexico':
[False  True]

Unique categories for column 'State_New York':
[False  True]

Unique categories for column 'State_North Carolina':
[False  True]

Unique categories for column 'State_North Dakota':
[False  True]

Unique categories for column 'State_Ohio':
[False  True]

Unique categories for column 'State_Oklahoma':
[False  True]
```

```
Unique categories for column 'State_Oregon':
[False  True]

Unique categories for column 'State_Pennsylvania':
[False  True]

Unique categories for column 'State_Puerto Rico':
[False  True]

Unique categories for column 'State_Rhode Island':
[False  True]

Unique categories for column 'State_South Carolina':
[False  True]

Unique categories for column 'State_South Dakota':
[False  True]

Unique categories for column 'State_Tennessee':
[False  True]

Unique categories for column 'State_Texas':
[False  True]

Unique categories for column 'State_Utah':
[False  True]

Unique categories for column 'State_Vermont':
[False  True]

Unique categories for column 'State_Virgin Islands':
[False  True]

Unique categories for column 'State_Virginia':
[False  True]

Unique categories for column 'State_Washington':
[False  True]

Unique categories for column 'State_West Virginia':
[False  True]

Unique categories for column 'State_Wisconsin':
[False  True]

Unique categories for column 'State_Wyoming':
[False  True]
```

```
Unique categories for column 'Sex_Female':
[ True False]

Unique categories for column 'Sex_Male':
[False  True]

Unique categories for column 'GeneralHealth_Excellent':
[False  True]

Unique categories for column 'GeneralHealth_Fair':
[False  True]

Unique categories for column 'GeneralHealth_Good':
[False  True]

Unique categories for column 'GeneralHealth_Poor':
[False  True]

Unique categories for column 'GeneralHealth_Very good':
[ True False]

Unique categories for column 'LastCheckupTime_5 or more years ago':
[False  True]

Unique categories for column 'LastCheckupTime_Within past 2 years (1 year but
less than 2 years ago)':
[False  True]

Unique categories for column 'LastCheckupTime_Within past 5 years (2 years but
less than 5 years ago)':
[False  True]

Unique categories for column 'LastCheckupTime_Within past year (anytime less
than 12 months ago)':
[ True False]

Unique categories for column 'RemovedTeeth_1 to 5':
[False  True]

Unique categories for column 'RemovedTeeth_6 or more, but not all':
[False  True]

Unique categories for column 'RemovedTeeth_All':
[False  True]

Unique categories for column 'RemovedTeeth_None of them':
[ True False]
```

```
Unique categories for column 'HadDiabetes_No':
[ True False]

Unique categories for column 'HadDiabetes_No, pre-diabetes or borderline
diabetes':
[False  True]

Unique categories for column 'HadDiabetes_Yes':
[False  True]

Unique categories for column 'HadDiabetes_Yes, but only during pregnancy
(female)':
[False  True]

Unique categories for column 'SmokerStatus_Current smoker - now smokes every
day':
[False  True]

Unique categories for column 'SmokerStatus_Current smoker - now smokes some
days':
[False  True]

Unique categories for column 'SmokerStatus_Former smoker':
[ True False]

Unique categories for column 'SmokerStatus_Never smoked':
[False  True]

Unique categories for column 'ECigaretteUsage_Never used e-cigarettes in my
entire life':
[ True False]

Unique categories for column 'ECigaretteUsage_Not at all (right now)':
[False  True]

Unique categories for column 'ECigaretteUsage_Use them every day':
[False  True]

Unique categories for column 'ECigaretteUsage_Use them some days':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Black only, Non-Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_Multiracial, Non-Hispanic':
```

```
[False  True]

Unique categories for column 'RaceEthnicityCategory_Other race only, Non-
Hispanic':
[False  True]

Unique categories for column 'RaceEthnicityCategory_White only, Non-Hispanic':
[ True False]

Unique categories for column 'AgeCategory_Age 18 to 24':
[False  True]

Unique categories for column 'AgeCategory_Age 25 to 29':
[False  True]

Unique categories for column 'AgeCategory_Age 30 to 34':
[False  True]

Unique categories for column 'AgeCategory_Age 35 to 39':
[False  True]

Unique categories for column 'AgeCategory_Age 40 to 44':
[False  True]

Unique categories for column 'AgeCategory_Age 45 to 49':
[False  True]

Unique categories for column 'AgeCategory_Age 50 to 54':
[False  True]

Unique categories for column 'AgeCategory_Age 55 to 59':
[False  True]

Unique categories for column 'AgeCategory_Age 60 to 64':
[False  True]

Unique categories for column 'AgeCategory_Age 65 to 69':
[ True False]

Unique categories for column 'AgeCategory_Age 70 to 74':
[False  True]

Unique categories for column 'AgeCategory_Age 75 to 79':
[False  True]

Unique categories for column 'AgeCategory_Age 80 or older':
[False  True]
```

```
Unique categories for column 'TetanusLast10Tdap_No, did not receive any tetanus
shot in the past 10 years':
[False  True]

Unique categories for column 'TetanusLast10Tdap_Yes, received Tdap':
[ True False]

Unique categories for column 'TetanusLast10Tdap_Yes, received tetanus shot but
not sure what type':
[False  True]

Unique categories for column 'TetanusLast10Tdap_Yes, received tetanus shot, but
not Tdap':
[False  True]

Unique categories for column 'CovidPos_No':
[ True False]

Unique categories for column 'CovidPos_Tested positive using home test without a
health professional':
[False  True]

Unique categories for column 'CovidPos_Yes':
[False  True]
```

[34]:

```python
# Display the DataFrame and print dimensions
# Note increase in total column/variable count due to one-hot encoding
# Note that all column/variables are normalized, binary, or boolean
print("Number of rows:", encoded_df.shape[0])
print("Number of columns:", encoded_df.shape[1])
encoded_df.head()
encoded_df.tail()
```

```
Number of rows: 246022
Number of columns: 134
```

[34]:

```
     PhysicalHealthDays  MentalHealthDays  PhysicalActivities  SleepHours  \
342            0.133333               0.0                   1    0.347826
343            0.000000               0.0                   1    0.217391
345            0.000000               0.0                   0    0.304348
346            0.166667               0.0                   1    0.347826
347            0.100000               0.5                   1    0.173913

     HadHeartAttack  HadAngina  HadStroke  HadAsthma  HadSkinCancer  HadCOPD  \
342               0          0          0          0              0        0
343               0          0          0          0              0        0
345               0          0          0          0              0        0
```

```
346               0          0          0          0              1        0
347               0          0          0          0              0        0

     …  AgeCategory_Age 70 to 74  AgeCategory_Age 75 to 79  \
342  …                     False                     False   
343  …                      True                     False   
345  …                     False                      True   
346  …                     False                     False   
347  …                     False                     False   

     AgeCategory_Age 80 or older  \
342                        False   
343                        False   
345                        False   
346                         True   
347                         True   

     TetanusLast10Tdap_No, did not receive any tetanus shot in the past 10 years 
\
342                                              False                            
343                                              False                            
345                                               True                            
346                                               True                            
347                                               True                            

     TetanusLast10Tdap_Yes, received Tdap  \
342                                  True   
343                                 False   
345                                 False   
346                                 False   
347                                 False   

     TetanusLast10Tdap_Yes, received tetanus shot but not sure what type  \
342                                              False                      
343                                               True                      
345                                              False                      
346                                              False                      
347                                              False                      

     TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap  CovidPos_No  \
342                                              False                  True   
343                                              False                  True   
345                                              False                 False   
346                                              False                 False   
347                                              False                  True   

     CovidPos_Tested positive using home test without a health professional  \
342                                              False
343                                              False
345                                              False
346                                              False
347                                              False

     CovidPos_Yes
342         False
343         False
345          True
346          True
347         False

[5 rows x 134 columns]
```

[34]:

```
        PhysicalHealthDays  MentalHealthDays  PhysicalActivities  SleepHours  \
445117            0.000000          0.000000                   1    0.217391
445123            0.000000          0.233333                   1    0.260870
445124            0.000000          0.500000                   1    0.260870
445128            0.066667          0.066667                   1    0.260870
445130            0.000000          0.000000                   0    0.173913

        HadHeartAttack  HadAngina  HadStroke  HadAsthma  HadSkinCancer  \
445117               0          0          0          0              0
445123               0          0          0          0              0
445124               0          0          1          0              0
445128               0          0          0          0              0
445130               1          0          0          1              0

        HadCOPD  …  AgeCategory_Age 70 to 74  AgeCategory_Age 75 to 79  \
445117        0  …                     False                     False
445123        0  …                     False                     False
445124        0  …                     False                     False
445128        0  …                     False                     False
445130        0  …                      True                     False

        AgeCategory_Age 80 or older  \
445117                        False
445123                        False
445124                        False
445128                        False
445130                        False

        TetanusLast10Tdap_No, did not receive any tetanus shot in the past 10
years  \
445117                                              False
445123                                               True
```

```
445124                                              False
445128                                              False
445130                                               True

        TetanusLast10Tdap_Yes, received Tdap  \
445117                                 False
445123                                 False
445124                                 False
445128                                 False
445130                                 False

        TetanusLast10Tdap_Yes, received tetanus shot but not sure what type  \
445117                                               True
445123                                              False
445124                                               True
445128                                               True
445130                                              False

        TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap  \
445117                                              False
445123                                              False
445124                                              False
445128                                              False
445130                                              False

        CovidPos_No  \
445117         True
445123        False
445124        False
445128         True
445130        False

        CovidPos_Tested positive using home test without a health professional
\
445117                                              False
445123                                              False
445124                                              False
445128                                              False
445130                                              False

        CovidPos_Yes
445117         False
445123          True
445124          True
445128         False
445130          True
```

```
[5 rows x 134 columns]
```

[35]:

```python
# Begin analysis of correlation values to select best predictor variables
```

[36]:

```python
# Determine correlation matrix
# Set pandas display options to show all columns
pd.set_option('display.max_rows', None)

# Calculate correlation between the selected variable and all other variables
correlation_with_HadHeartAttack_variable = encoded_df.corr()['HadHeartAttack'].
 ↪sort_values(ascending=False)

# Print all correlation values
print("Correlation with selected variable:")
print(correlation_with_HadHeartAttack_variable)
```

```
Correlation with selected variable:
HadHeartAttack
1.000000
HadAngina
0.445903
HadStroke
0.177137
ChestScan
0.167760
DifficultyWalking
0.159878
HadDiabetes_Yes
0.145868
GeneralHealth_Poor
0.140607
PhysicalHealthDays
0.133420
HadCOPD
0.133223
RemovedTeeth_All
0.120564
PneumoVaxEver
0.119955
HadArthritis
0.117773
GeneralHealth_Fair
0.112319
HadKidneyDisease
0.109355
AgeCategory_Age 80 or older
0.100296
DeafOrHardOfHearing
```

```
0.097662
RemovedTeeth_6 or more, but not all
0.092477
DifficultyErrands
0.089495
DifficultyDressingBathing
0.083090
SmokerStatus_Former smoker
0.074537
AgeCategory_Age 75 to 79
0.073567
Sex_Male
0.073316
BlindOrVisionDifficulty
0.072964
LastCheckupTime_Within past year (anytime less than 12 months ago)
0.070725
AgeCategory_Age 70 to 74
0.058590
DifficultyConcentrating
0.051663
HadSkinCancer
0.049408
FluVaxLast12
0.045235
SmokerStatus_Current smoker - now smokes every day
0.039031
WeightInKilograms
0.038436
AgeCategory_Age 65 to 69
0.033260
BMI
0.030413
MentalHealthDays
0.025892
CovidPos_No
0.024529
RaceEthnicityCategory_White only, Non-Hispanic
0.024221
HadAsthma
0.023756
HadDepressiveDisorder
0.023706
HeightInMeters
0.023059
TetanusLast10Tdap_Yes, received tetanus shot but not sure what type
0.021735
State_Florida
```

```
0.016592
GeneralHealth_Good
0.014322
State_Arkansas
0.013738
State_West Virginia
0.013684
HadDiabetes_No, pre-diabetes or borderline diabetes
0.011919
TetanusLast10Tdap_No, did not receive any tetanus shot in the past 10 years
0.011883
State_Maine
0.011196
SmokerStatus_Current smoker - now smokes some days
0.011101
RemovedTeeth_1 to 5
0.010878
TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap
0.009777
State_Ohio
0.009321
State_Nebraska
0.008170
ECigaretteUsage_Never used e-cigarettes in my entire life
0.008082
State_Arizona
0.007373
State_South Dakota
0.007210
AgeCategory_Age 60 to 64
0.006661
State_New Hampshire
0.006257
State_Tennessee
0.004819
State_Kentucky
0.004761
State_Indiana
0.004663
State_Oklahoma
0.004509
State_New Mexico
0.004247
RaceEthnicityCategory_Multiracial, Non-Hispanic
0.004232
State_Alabama
0.004112
SleepHours
```

```
0.003631
ECigaretteUsage_Not at all (right now)
0.003358
State_Nevada
0.003048
State_Louisiana
0.002380
State_Texas
0.002246
State_Missouri
0.001923
State_Michigan
0.000949
State_Montana
0.000843
State_Virginia
0.000614
State_Georgia
0.000528
State_North Dakota
0.000283
State_Mississippi
-0.000025
State_South Carolina
-0.000093
State_Maryland
-0.000424
State_Kansas
-0.000524
State_Rhode Island
-0.000631
State_Wisconsin
-0.000865
State_Guam
-0.001264
State_Alaska
-0.001581
State_Vermont
-0.001748
State_Delaware
-0.001859
State_Wyoming
-0.001927
State_Pennsylvania
-0.002054
State_North Carolina
-0.002173
State_Idaho
```

```
-0.003548
State_Oregon
-0.003800
State_Puerto Rico
-0.003878
State_Iowa
-0.004618
State_Virgin Islands
-0.005078
State_Connecticut
-0.005794
State_Illinois
-0.006004
RaceEthnicityCategory_Other race only, Non-Hispanic
-0.006220
State_Massachusetts
-0.006244
AgeCategory_Age 55 to 59
-0.006342
State_Hawaii
-0.006790
State_New York
-0.006820
State_District of Columbia
-0.007547
State_New Jersey
-0.007760
State_California
-0.008075
State_Utah
-0.008129
State_Washington
-0.008832
State_Colorado
-0.008955
State_Minnesota
-0.009852
HadDiabetes_Yes, but only during pregnancy (female)
-0.010461
RaceEthnicityCategory_Black only, Non-Hispanic
-0.011076
ECigaretteUsage_Use them some days
-0.012412
HIVTesting
-0.014563
CovidPos_Yes
-0.016444
ECigaretteUsage_Use them every day
```

```
-0.017250
HighRiskLastYear
-0.021127
CovidPos_Tested positive using home test without a health professional
-0.022104
RaceEthnicityCategory_Hispanic
-0.023148
AgeCategory_Age 50 to 54
-0.025214
LastCheckupTime_5 or more years ago
-0.035137
AgeCategory_Age 45 to 49
-0.035142
LastCheckupTime_Within past 5 years (2 years but less than 5 years ago)
-0.037198
TetanusLast10Tdap_Yes, received Tdap
-0.040362
LastCheckupTime_Within past 2 years (1 year but less than 2 years ago)
-0.041811
AgeCategory_Age 25 to 29
-0.048216
AgeCategory_Age 40 to 44
-0.049331
AgeCategory_Age 30 to 34
-0.050453
AgeCategory_Age 35 to 39
-0.051119
AgeCategory_Age 18 to 24
-0.053068
Sex_Female
-0.073316
AlcoholDrinkers
-0.074181
GeneralHealth_Excellent
-0.079933
PhysicalActivities
-0.083187
GeneralHealth_Very good
-0.085347
SmokerStatus_Never smoked
-0.094843
RemovedTeeth_None of them
-0.122556
HadDiabetes_No
-0.136692
Name: HadHeartAttack, dtype: float64
```

[37]:

```python
# Find high correlation values based on the threshold of > +0.07 or < -0.07
correlations_above_threshold = correlation_with_HadHeartAttack_variable > +0.07
correlations_below_threshold = correlation_with_HadHeartAttack_variable < -0.07
high_correlation_variables =␣
 ↪correlation_with_HadHeartAttack_variable[(correlations_above_threshold) |␣
 ↪(correlations_below_threshold)]

# Sort the high correlation values
high_correlation_variables = high_correlation_variables.
 ↪sort_values(ascending=False)

# Print high correlation values
print("Variables with correlation greater than +0.7 or less than -0.7:")
print(high_correlation_variables)
```

```
Variables with correlation greater than +0.7 or less than -0.7:
HadHeartAttack                                                        1.000000
HadAngina                                                             0.445903
HadStroke                                                             0.177137
ChestScan                                                             0.167760
DifficultyWalking                                                     0.159878
HadDiabetes_Yes                                                       0.145868
GeneralHealth_Poor                                                    0.140607
PhysicalHealthDays                                                    0.133420
HadCOPD                                                               0.133223
RemovedTeeth_All                                                      0.120564
PneumoVaxEver                                                         0.119955
HadArthritis                                                          0.117773
GeneralHealth_Fair                                                    0.112319
HadKidneyDisease                                                      0.109355
AgeCategory_Age 80 or older                                           0.100296
DeafOrHardOfHearing                                                   0.097662
RemovedTeeth_6 or more, but not all                                   0.092477
DifficultyErrands                                                     0.089495
DifficultyDressingBathing                                             0.083090
SmokerStatus_Former smoker                                            0.074537
AgeCategory_Age 75 to 79                                              0.073567
Sex_Male                                                              0.073316
BlindOrVisionDifficulty                                               0.072964
LastCheckupTime_Within past year (anytime less than 12 months ago)    0.070725
Sex_Female                                                           -0.073316
AlcoholDrinkers                                                      -0.074181
GeneralHealth_Excellent                                              -0.079933
PhysicalActivities                                                   -0.083187
GeneralHealth_Very good                                              -0.085347
SmokerStatus_Never smoked                                            -0.094843
RemovedTeeth_None of them                                            -0.122556
HadDiabetes_No                                                       -0.136692
```

```
Name: HadHeartAttack, dtype: float64
```

[38]:

```
# Create empty list
high_correlation_variable_list = []
# Convert first column from 'high_correlation_variables' series into a list
for i in range(0, len(high_correlation_variables)):
    high_correlation_variable_list.append(high_correlation_variables.index[i])

print(high_correlation_variable_list)
```

```
['HadHeartAttack', 'HadAngina', 'HadStroke', 'ChestScan', 'DifficultyWalking',
'HadDiabetes_Yes', 'GeneralHealth_Poor', 'PhysicalHealthDays', 'HadCOPD',
'RemovedTeeth_All', 'PneumoVaxEver', 'HadArthritis', 'GeneralHealth_Fair',
'HadKidneyDisease', 'AgeCategory_Age 80 or older', 'DeafOrHardOfHearing',
'RemovedTeeth_6 or more, but not all', 'DifficultyErrands',
'DifficultyDressingBathing', 'SmokerStatus_Former smoker', 'AgeCategory_Age 75
to 79', 'Sex_Male', 'BlindOrVisionDifficulty', 'LastCheckupTime_Within past year
(anytime less than 12 months ago)', 'Sex_Female', 'AlcoholDrinkers',
'GeneralHealth_Excellent', 'PhysicalActivities', 'GeneralHealth_Very good',
'SmokerStatus_Never smoked', 'RemovedTeeth_None of them', 'HadDiabetes_No']
```

[39]:

```
# Create smaller data frame consisting only of high correlation variables from
#   original larger data frame
high_corr_encoded_df = encoded_df[high_correlation_variable_list]

# Display original larger data frame with its dimensions
print("LARGER DATA FRAME CONSISTING OF ALL VARIABLES\n")
print("Number of rows:", encoded_df.shape[0])
print("Number of columns:", encoded_df.shape[1])
encoded_df.head()
encoded_df.tail()

# Display new data smaller frame with its dimensions
print("\n\nSMALLER DATA FRAME CONSISTING OF ONLY HIGH CORRELATION VARIABLES\n")
print("Number of rows:", high_corr_encoded_df.shape[0])
print("Number of columns:", high_corr_encoded_df.shape[1])
high_corr_encoded_df.head()
high_corr_encoded_df.tail()
```

```
LARGER DATA FRAME CONSISTING OF ALL VARIABLES

Number of rows: 246022
Number of columns: 134
```

[39]:

```
     PhysicalHealthDays  MentalHealthDays  PhysicalActivities  SleepHours  \
342            0.133333               0.0                   1    0.347826
343            0.000000               0.0                   1    0.217391
345            0.000000               0.0                   0    0.304348
```

```
346            0.166667               0.0                     1    0.347826
347            0.100000               0.5                     1    0.173913

     HadHeartAttack  HadAngina  HadStroke  HadAsthma  HadSkinCancer  HadCOPD  \
342               0          0          0          0              0        0
343               0          0          0          0              0        0
345               0          0          0          0              0        0
346               0          0          0          0              1        0
347               0          0          0          0              0        0

     …  AgeCategory_Age 70 to 74  AgeCategory_Age 75 to 79  \
342  …                     False                     False
343  …                      True                     False
345  …                     False                      True
346  …                     False                     False
347  …                     False                     False

     AgeCategory_Age 80 or older  \
342                        False
343                        False
345                        False
346                         True
347                         True

     TetanusLast10Tdap_No, did not receive any tetanus shot in the past 10 years
\
342                                              False
343                                              False
345                                               True
346                                               True
347                                               True

     TetanusLast10Tdap_Yes, received Tdap  \
342                                  True
343                                 False
345                                 False
346                                 False
347                                 False

     TetanusLast10Tdap_Yes, received tetanus shot but not sure what type  \
342                                              False
343                                               True
345                                              False
346                                              False
347                                              False

     TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap  CovidPos_No  \
342                                              False                 True
343                                              False                 True
345                                              False                False
346                                              False                False
347                                              False                 True

     CovidPos_Tested positive using home test without a health professional  \
342                                              False
343                                              False
345                                              False
346                                              False
347                                              False

     CovidPos_Yes
342         False
343         False
345          True
346          True
347         False

[5 rows x 134 columns]
```

[39]:

```
        PhysicalHealthDays  MentalHealthDays  PhysicalActivities  SleepHours  \
445117            0.000000          0.000000                   1    0.217391
445123            0.000000          0.233333                   1    0.260870
445124            0.000000          0.500000                   1    0.260870
445128            0.066667          0.066667                   1    0.260870
445130            0.000000          0.000000                   0    0.173913

        HadHeartAttack  HadAngina  HadStroke  HadAsthma  HadSkinCancer  \
445117               0          0          0          0              0
445123               0          0          0          0              0
445124               0          0          1          0              0
445128               0          0          0          0              0
445130               1          0          0          1              0

        HadCOPD  …  AgeCategory_Age 70 to 74  AgeCategory_Age 75 to 79  \
445117        0  …                     False                     False
445123        0  …                     False                     False
445124        0  …                     False                     False
445128        0  …                     False                     False
445130        0  …                      True                     False

        AgeCategory_Age 80 or older  \
445117                        False
445123                        False
445124                        False
```

```
445128                        False
445130                        False

        TetanusLast10Tdap_No, did not receive any tetanus shot in the past 10
years  \
445117                                              False
445123                                               True
445124                                              False
445128                                              False
445130                                               True

        TetanusLast10Tdap_Yes, received Tdap  \
445117                                 False
445123                                 False
445124                                 False
445128                                 False
445130                                 False

        TetanusLast10Tdap_Yes, received tetanus shot but not sure what type  \
445117                                               True
445123                                              False
445124                                               True
445128                                               True
445130                                              False

        TetanusLast10Tdap_Yes, received tetanus shot, but not Tdap  \
445117                                              False
445123                                              False
445124                                              False
445128                                              False
445130                                              False

        CovidPos_No  \
445117         True
445123        False
445124        False
445128         True
445130        False

        CovidPos_Tested positive using home test without a health professional
\
445117                                              False
445123                                              False
445124                                              False
445128                                              False
445130                                              False
```

```
        CovidPos_Yes
445117         False
445123          True
445124          True
445128         False
445130          True

[5 rows x 134 columns]



SMALLER DATA FRAME CONSISTING OF ONLY HIGH CORRELATION VARIABLES

Number of rows: 246022
Number of columns: 32
```

[39]:

```
     HadHeartAttack  HadAngina  HadStroke  ChestScan  DifficultyWalking  \
342               0          0          0          0                  0
343               0          0          0          0                  0
345               0          0          0          1                  1
346               0          0          0          0                  1
347               0          0          0          0                  0

     HadDiabetes_Yes  GeneralHealth_Poor  PhysicalHealthDays  HadCOPD  \
342            False               False            0.133333        0
343             True               False            0.000000        0
345            False               False            0.000000        0
346            False               False            0.166667        0
347            False               False            0.100000        0

     RemovedTeeth_All  …  BlindOrVisionDifficulty  \
342             False  …                        0
343             False  …                        0
345             False  …                        1
346             False  …                        0
347             False  …                        0

     LastCheckupTime_Within past year (anytime less than 12 months ago)  \
342                                               True
343                                               True
345                                               True
346                                               True
347                                               True

     Sex_Female  AlcoholDrinkers  GeneralHealth_Excellent  PhysicalActivities  \
342        True                0                    False                   1
343       False                0                    False                   1
345       False                1                    False                   0
```

```
346        True                0                    False                  1
347        True                0                    False                  1

     GeneralHealth_Very good  SmokerStatus_Never smoked  \
342                     True                      False
343                     True                      False
345                     True                      False
346                    False                       True
347                    False                       True

     RemovedTeeth_None of them  HadDiabetes_No
342                       True            True
343                       True           False
345                      False            True
346                       True            True
347                      False            True

[5 rows x 32 columns]
```

[39]:

```
        HadHeartAttack  HadAngina  HadStroke  ChestScan  DifficultyWalking  \
445117               0          0          0          0                  0
445123               0          0          0          0                  0
445124               0          0          1          0                  0
445128               0          0          0          0                  0
445130               1          0          0          1                  0

        HadDiabetes_Yes  GeneralHealth_Poor  PhysicalHealthDays  HadCOPD  \
445117            False               False            0.000000        0
445123            False               False            0.000000        0
445124             True               False            0.000000        0
445128            False               False            0.066667        0
445130            False               False            0.000000        0

        RemovedTeeth_All  …  BlindOrVisionDifficulty  \
445117             False  …                        0
445123             False  …                        0
445124             False  …                        0
445128             False  …                        0
445130             False  …                        0

        LastCheckupTime_Within past year (anytime less than 12 months ago)  \
445117                                              False
445123                                               True
445124                                               True
445128                                               True
445130                                               True
```

```
        Sex_Female  AlcoholDrinkers  GeneralHealth_Excellent  \
445117       False                1                    False
445123        True                0                    False
445124       False                1                    False
445128        True                0                     True
445130       False                0                    False

        PhysicalActivities  GeneralHealth_Very good  \
445117                   1                     True
445123                   1                    False
445124                   1                    False
445128                   1                    False
445130                   0                     True

        SmokerStatus_Never smoked  RemovedTeeth_None of them  HadDiabetes_No
445117                       True                       True            True
445123                       True                       True            True
445124                       True                      False           False
445128                       True                       True            True
445130                       True                       True            True

[5 rows x 32 columns]
```

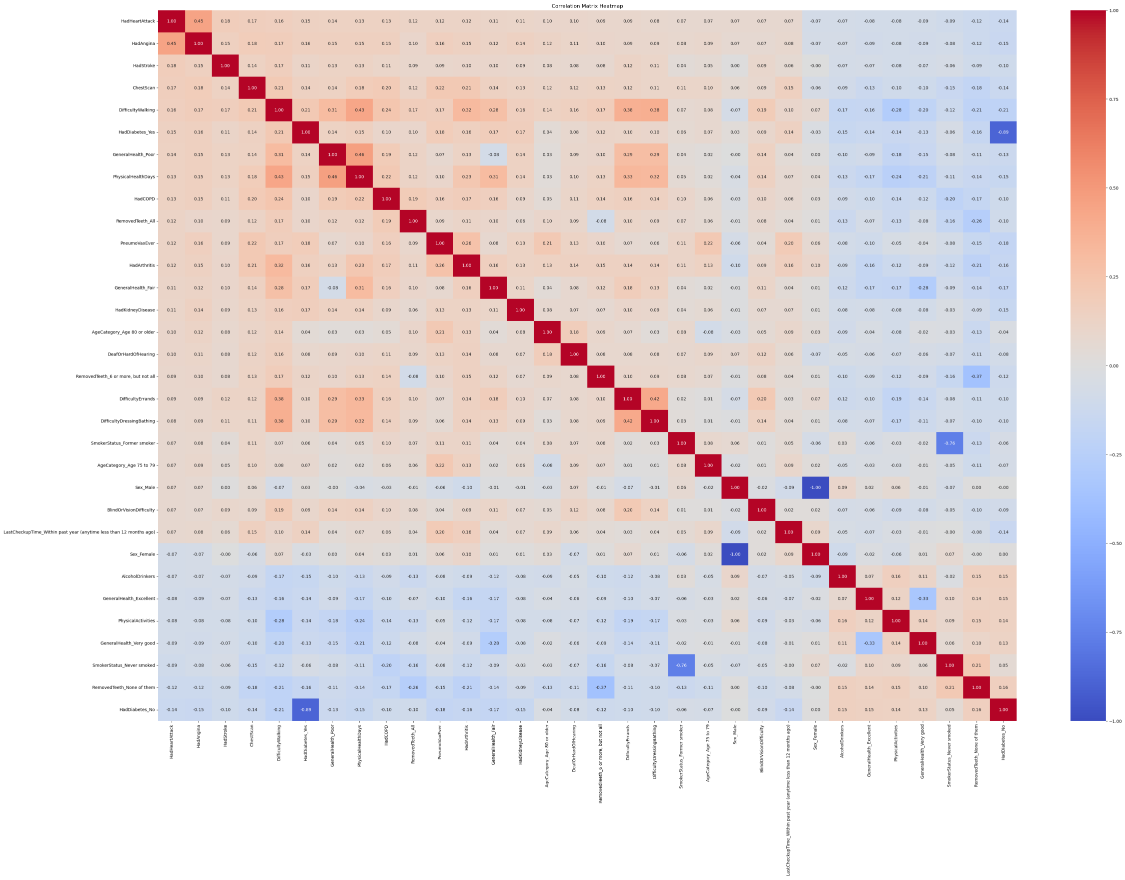
[40]:

```
# COMMENT:
#   Focusing only on high correlaton variables, drops the total
#   variable count from 134 to 32
```

[41]:

```
# Correlation matrix of only high correlaton variables and
#    dependent variables 'HadHeartAttack' using smaller data frame,␣
 ↪'high_corr_encoded_df'
correlation_matrix = high_corr_encoded_df[high_correlation_variable_list].corr()
# Create heatmap
plt.figure(figsize=(45, 30))
sns.heatmap(correlation_matrix, annot=True, cmap='coolwarm', fmt=".2f");
plt.title('Correlation Matrix Heatmap');
plt.show();

# NOTE: Double click on image to zoom or right click to open in new tab (better)
```



[42]:
```
###############################################
##    III.    MODEL BUILDING AND EVALUATION:
###############################################
```

[43]:
```
# LOGISTIC REGRESSION

# Isolate independent variables
independent_variables_list = [x for x in high_correlation_variable_list if x !=␣
↪'HadHeartAttack']
independent_variables = high_corr_encoded_df[independent_variables_list]
# Isolate dependent variables
dependent_variable = high_corr_encoded_df['HadHeartAttack']

# Split data into train and test sets
X_train1, X_test1, y_train1, y_test1 = train_test_split(independent_variables,␣
↪dependent_variable, test_size=0.2, random_state=42)

# Initialize logistic regression model
log_reg = LogisticRegression()
```

```python
# Fit logistic regression model
log_reg.fit(X_train1, y_train1)

# Create a list of tuples containing coefficients and variables
coefficients_with_variables = [(coefficient, variable) for coefficient,␣
 ↪variable in zip(log_reg.coef_[0], independent_variables)]
# Sort the list based on the absolute value of coefficients in descending order
coefficients_with_variables.sort(key=lambda x: x[0], reverse=True)

# Evaluate and print model accuracy
accuracy_lr1 = log_reg.score(X_test1, y_test1)
print(f"\nACCURACY:\t{accuracy_lr1:.5f}")

# Print model coefficients for each independent variable in descending order
print("\nMODEL INTERCEPT AND COEFFICIENTS IN DESCENDING ORDER:\n")

# Print model coefficients
print(f"INTERCEPT:\t{log_reg.intercept_[0]}")
print("\nCOEFFICIENT:\tVARIABLE:\n")
for coefficient, variable in coefficients_with_variables:
    print(f"{coefficient:.5f}:\t{variable}")
```

[43]:
```
LogisticRegression()
```

```

ACCURACY:       0.94899

MODEL INTERCEPT AND COEFFICIENTS IN DESCENDING ORDER:

INTERCEPT:      -3.850075594149293

COEFFICIENT:    VARIABLE:

2.50148:        HadAngina
0.90330:        HadStroke
0.61369:        ChestScan
0.47206:        AgeCategory_Age 80 or older
0.42342:        RemovedTeeth_All
0.35085:        LastCheckupTime_Within past year (anytime less than 12 months
ago)
0.33718:        GeneralHealth_Poor
0.32893:        Sex_Male
0.32789:        AgeCategory_Age 75 to 79
0.21815:        GeneralHealth_Fair
0.18364:        HadDiabetes_Yes
0.17069:        RemovedTeeth_6 or more, but not all
```

```
0.16947:        PneumoVaxEver
0.16527:        BlindOrVisionDifficulty
0.13044:        HadArthritis
0.09380:        DifficultyWalking
0.07365:        DeafOrHardOfHearing
0.06801:        HadCOPD
0.04120:        HadKidneyDisease
0.03421:        DifficultyErrands
-0.02655:       PhysicalHealthDays
-0.07039:       DifficultyDressingBathing
-0.07605:       PhysicalActivities
-0.13161:       SmokerStatus_Former smoker
-0.15674:       HadDiabetes_No
-0.19865:       AlcoholDrinkers
-0.21184:       RemovedTeeth_None of them
-0.29520:       GeneralHealth_Very good
-0.30845:       Sex_Female
-0.39795:       SmokerStatus_Never smoked
-0.63267:       GeneralHealth_Excellent
```

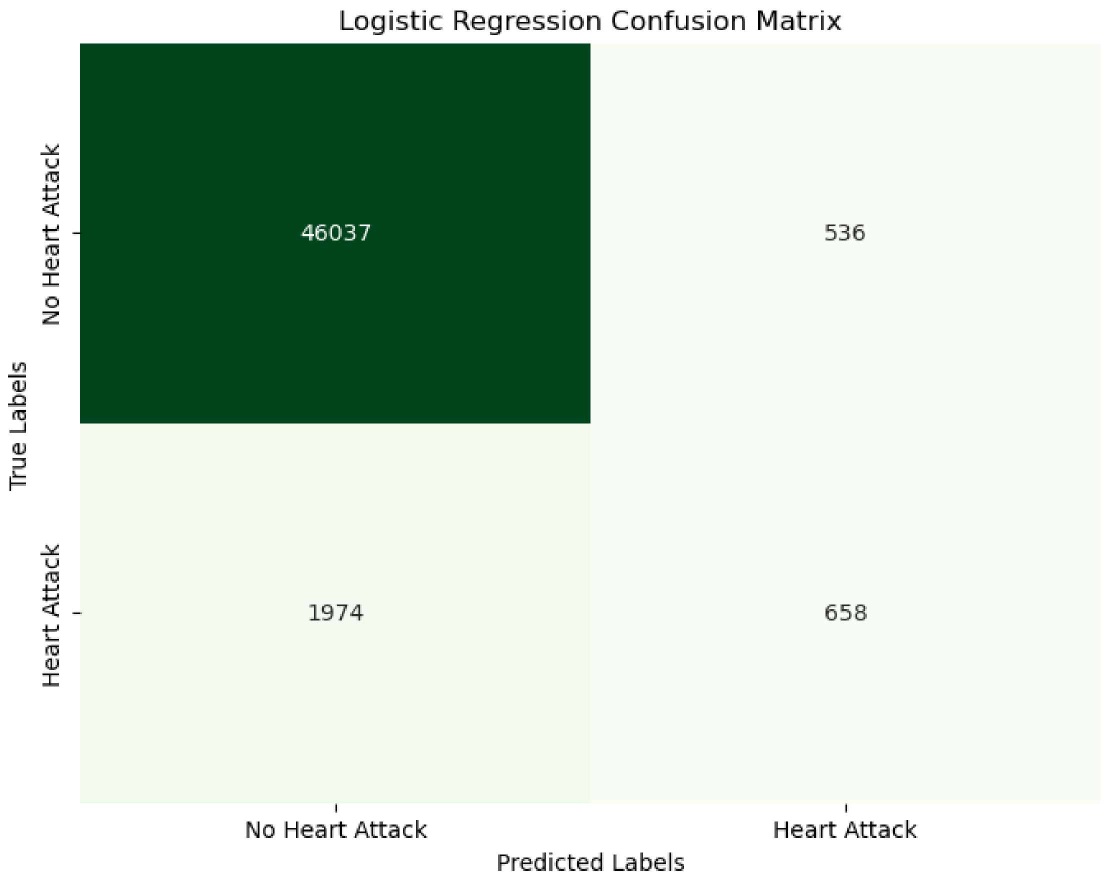
[44]:

```python
# Define custom labels
label_names = ['No Heart Attack', 'Heart Attack'];

# Calculate the confusion matrix
# Predict the labels for the test set
y_pred1 = log_reg.predict(X_test1)
conf_matrix1 = confusion_matrix(y_test1, y_pred1);

# Create a heatmap of the confusion matrix
plt.figure(figsize=(8, 6));
sns.heatmap(conf_matrix1, annot=True, fmt='d', cmap='Greens', cbar=False);
plt.title('Logistic Regression Confusion Matrix');
plt.xlabel('Predicted Labels');
plt.ylabel('True Labels');

# Set custom labels for ticks
plt.xticks(ticks=[0.5, 1.5], labels=label_names);
plt.yticks(ticks=[0.5, 1.5], labels=label_names);
plt.show();
```



[45]:

```python
# SUPPORT VECTOR MACHINE
# Using the same dependent_variable and independent_variables defined above

# Split data into train and test sets
X_train2, X_test2, y_train2, y_test2 = train_test_split(independent_variables, dependent_variable, test_size=0.2, random_state=42)

# Initialize SVM classifier
svm_classifier = SVC(kernel='linear')  # Linear kernel for binary classification

# Fit SVM classifier
svm_classifier.fit(X_train2, y_train2)

# Evaluate model performance (optional)
accuracy_svm = svm_classifier.score(X_test2, y_test2)
print(f"\nACCURACY:\t{accuracy_svm:.5f}")
```

[45]:

```
SVC(kernel='linear')
```

```
ACCURACY:       0.94651
```

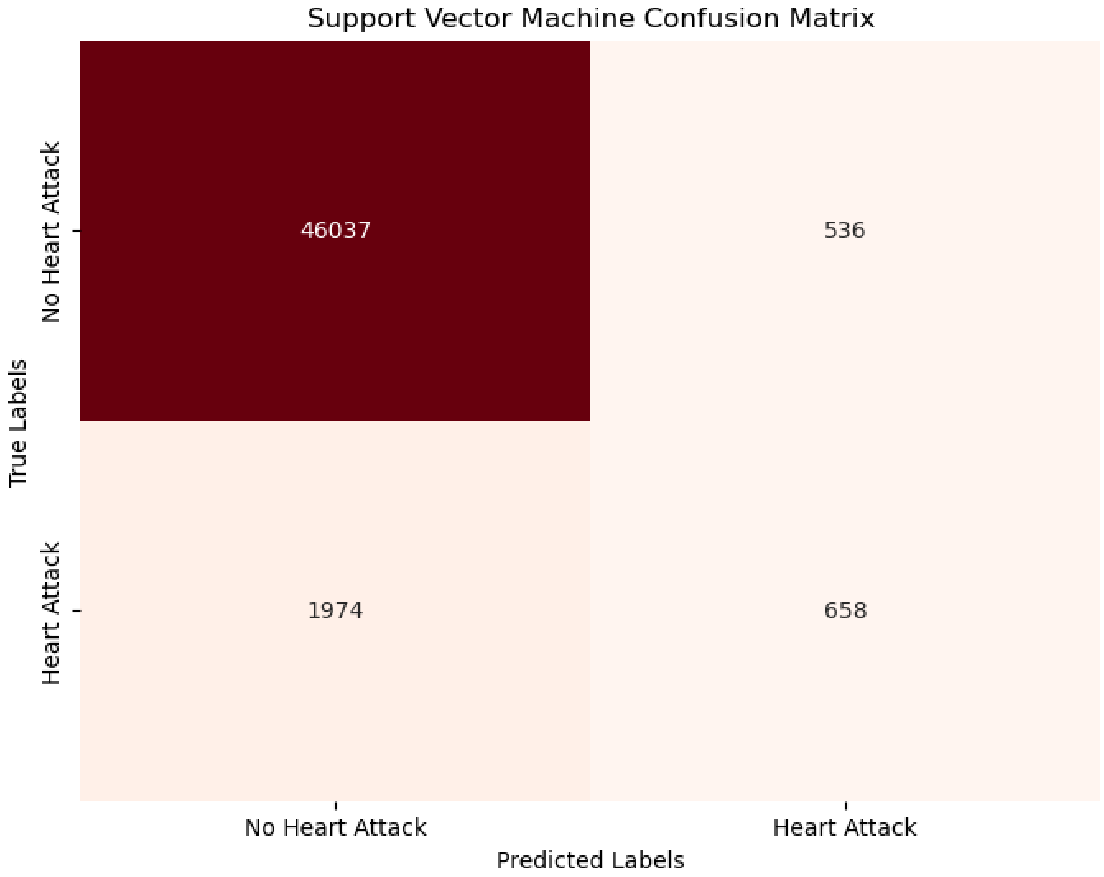
[46]:

```python
# Define custom labels
label_names = ['No Heart Attack', 'Heart Attack'];

# Calculate the confusion matrix
# Predict the labels for the test set
y_pred2 = log_reg.predict(X_test2)
conf_matrix2 = confusion_matrix(y_test2, y_pred2);

# Create a heatmap of the confusion matrix
plt.figure(figsize=(8, 6));
sns.heatmap(conf_matrix2, annot=True, fmt='d', cmap='Reds', cbar=False);
plt.title('Support Vector Machine Confusion Matrix');
plt.xlabel('Predicted Labels');
plt.ylabel('True Labels');

# Set custom labels for ticks
plt.xticks(ticks=[0.5, 1.5], labels=label_names);
plt.yticks(ticks=[0.5, 1.5], labels=label_names);
plt.show();
```



[47]:
```
# COMMENT:
#   As shown above, the accuracy of the SVM model is slightly less than the
#   accuracy of the logistic regression (LR) model. The LR model took about 10␣
 ↪seconds
#   to run. The SVM model took about 4 minutes to run. These ratios between␣
 ↪runtime
#   and accuracy suggest that the LR model is the better choice. As a result,␣
 ↪for
#   this simple classification problem, only the LR model will be used going␣
 ↪forward.
```

[48]:
```
################################################
##    IV.    ITERATIVE PROCESS:
################################################
# A possible interaction term will be considered to capture the interaction␣
 ↪between
#   diabetes (DM) and kidney disease (CKD),
#   ('HadDiabetes_Yes' * 'HadKidneyDisease') = 'Had_DM_+_CKD'.
#   This is meant to capture diabetic nephropathy or diabetic kidney disease␣
 ↪which is associated
#      with increased risk of cardiovascular disease:
#   https://en.wikipedia.org/wiki/Diabetic_nephropathy
#   https://www.sciencedirect.com/science/article/pii/S1548559514000512
#   https://www.sciencedirect.com/science/article/abs/pii/S027092951830024X
#
```

[49]:
```
# Display new data smaller frame with its dimensions
print("\n\nSMALLER DATA FRAME CONSISTING OF ONLY HIGH CORRELATION VARIABLES\n")
print("Number of rows:", high_corr_encoded_df.shape[0])
print("Number of columns:", high_corr_encoded_df.shape[1])
high_corr_encoded_df.head()
high_corr_encoded_df.tail()
```

```


SMALLER DATA FRAME CONSISTING OF ONLY HIGH CORRELATION VARIABLES

Number of rows: 246022
Number of columns: 32
```

[49]:
```
     HadHeartAttack  HadAngina  HadStroke  ChestScan  DifficultyWalking  \
342               0          0          0          0                  0
343               0          0          0          0                  0
345               0          0          0          1                  1
346               0          0          0          0                  1
```

```
347               0          0          0          0                  0

     HadDiabetes_Yes  GeneralHealth_Poor  PhysicalHealthDays  HadCOPD  \
342            False               False            0.133333        0
343             True               False            0.000000        0
345            False               False            0.000000        0
346            False               False            0.166667        0
347            False               False            0.100000        0

     RemovedTeeth_All  …  BlindOrVisionDifficulty  \
342             False  …                        0
343             False  …                        0
345             False  …                        1
346             False  …                        0
347             False  …                        0

     LastCheckupTime_Within past year (anytime less than 12 months ago)  \
342                                               True
343                                               True
345                                               True
346                                               True
347                                               True

     Sex_Female  AlcoholDrinkers  GeneralHealth_Excellent  PhysicalActivities  \
342        True                0                    False                   1
343       False                0                    False                   1
345       False                1                    False                   0
346        True                0                    False                   1
347        True                0                    False                   1

     GeneralHealth_Very good  SmokerStatus_Never smoked  \
342                     True                      False
343                     True                      False
345                     True                      False
346                    False                       True
347                    False                       True

     RemovedTeeth_None of them  HadDiabetes_No
342                       True            True
343                       True           False
345                      False            True
346                       True            True
347                      False            True

[5 rows x 32 columns]
```

```
[49]:         HadHeartAttack  HadAngina  HadStroke  ChestScan  DifficultyWalking  \
      445117               0          0          0          0                  0
      445123               0          0          0          0                  0
      445124               0          0          1          0                  0
      445128               0          0          0          0                  0
      445130               1          0          0          1                  0

              HadDiabetes_Yes  GeneralHealth_Poor  PhysicalHealthDays  HadCOPD  \
      445117            False               False            0.000000        0
      445123            False               False            0.000000        0
      445124             True               False            0.000000        0
      445128            False               False            0.066667        0
      445130            False               False            0.000000        0

              RemovedTeeth_All  …  BlindOrVisionDifficulty  \
      445117             False  …                        0
      445123             False  …                        0
      445124             False  …                        0
      445128             False  …                        0
      445130             False  …                        0

              LastCheckupTime_Within past year (anytime less than 12 months ago)  \
      445117                                              False
      445123                                               True
      445124                                               True
      445128                                               True
      445130                                               True

              Sex_Female  AlcoholDrinkers  GeneralHealth_Excellent  \
      445117       False                1                    False
      445123        True                0                    False
      445124       False                1                    False
      445128        True                0                     True
      445130       False                0                    False

              PhysicalActivities  GeneralHealth_Very good  \
      445117                   1                     True
      445123                   1                    False
      445124                   1                    False
      445128                   1                    False
      445130                   0                     True

              SmokerStatus_Never smoked  RemovedTeeth_None of them  HadDiabetes_No
      445117                       True                       True            True
      445123                       True                       True            True
      445124                       True                      False           False
      445128                       True                       True            True
```

```
445130                         True                       True             True

[5 rows x 32 columns]
```

[50]:
```
# Construction of the interaction term, 'Had_DM_CKD'.
# Insert column 'Had_DM_CKD' at head of high_corr_encoded_df dataframe
high_corr_encoded_df.insert(0, 'Had_DM_+_CKD', value=np.nan)
# Define the new column,Had_DM_CKD,as the product of columns 'HadDiabetes' and␣
 ↪'HadKidneyDisease'
high_corr_encoded_df['Had_DM_+_CKD'] = high_corr_encoded_df['HadDiabetes_Yes']␣
 ↪* high_corr_encoded_df['HadKidneyDisease']
```

[51]:
```
# Reorder the columns to allow for easier viewing of relevant column/variables
reordered_columns = ['HadHeartAttack'] + ['Had_DM_+_CKD'] + ['HadDiabetes_Yes']␣
 ↪+ ['HadKidneyDisease'] + \
[col for col in high_corr_encoded_df.columns if col != 'HadHeartAttack' and col␣
 ↪!= 'Had_DM_+_CKD' \
 and col != 'HadDiabetes_Yes' and col != 'HadKidneyDisease']
high_corr_encoded_df = high_corr_encoded_df[reordered_columns]



# Display new data smaller frame with its dimensions
print("\n\nSMALLER DATA FRAME CONSISTING OF ONLY HIGH CORRELATION VARIABLES\n")
print("Number of rows:", high_corr_encoded_df.shape[0])
print("Number of columns:", high_corr_encoded_df.shape[1])
high_corr_encoded_df.head()
high_corr_encoded_df.tail()
```

```


SMALLER DATA FRAME CONSISTING OF ONLY HIGH CORRELATION VARIABLES

Number of rows: 246022
Number of columns: 33
```

[51]:
```
     HadHeartAttack  Had_DM_+_CKD  HadDiabetes_Yes  HadKidneyDisease  \
342               0             0            False                 0
343               0             0             True                 0
345               0             0            False                 0
346               0             0            False                 0
347               0             0            False                 0

     HadAngina  HadStroke  ChestScan  DifficultyWalking  GeneralHealth_Poor  \
342          0          0          0                  0               False
343          0          0          0                  0               False
345          0          0          1                  1               False
```

```
      346          0          0          0                  1               False
      347          0          0          0                  0               False

           PhysicalHealthDays  …  BlindOrVisionDifficulty  \
      342            0.133333  …                        0
      343            0.000000  …                        0
      345            0.000000  …                        1
      346            0.166667  …                        0
      347            0.100000  …                        0

           LastCheckupTime_Within past year (anytime less than 12 months ago)  \
      342                                               True
      343                                               True
      345                                               True
      346                                               True
      347                                               True

           Sex_Female  AlcoholDrinkers  GeneralHealth_Excellent  PhysicalActivities  \
      342        True                0                    False                   1
      343       False                0                    False                   1
      345       False                1                    False                   0
      346        True                0                    False                   1
      347        True                0                    False                   1

           GeneralHealth_Very good  SmokerStatus_Never smoked  \
      342                     True                      False
      343                     True                      False
      345                     True                      False
      346                    False                       True
      347                    False                       True

           RemovedTeeth_None of them  HadDiabetes_No
      342                       True            True
      343                       True           False
      345                      False            True
      346                       True            True
      347                      False            True

      [5 rows x 33 columns]

[51]:         HadHeartAttack  Had_DM_+_CKD  HadDiabetes_Yes  HadKidneyDisease  \
      445117               0             0            False                 0
      445123               0             0            False                 0
      445124               0             0             True                 0
      445128               0             0            False                 0
      445130               1             0            False                 0
```

```
        HadAngina  HadStroke  ChestScan  DifficultyWalking  \
445117          0          0          0                  0
445123          0          0          0                  0
445124          0          1          0                  0
445128          0          0          0                  0
445130          0          0          1                  0

        GeneralHealth_Poor  PhysicalHealthDays  ...  BlindOrVisionDifficulty  \
445117               False            0.000000  ...                        0
445123               False            0.000000  ...                        0
445124               False            0.000000  ...                        0
445128               False            0.066667  ...                        0
445130               False            0.000000  ...                        0

        LastCheckupTime_Within past year (anytime less than 12 months ago)  \
445117                                              False
445123                                               True
445124                                               True
445128                                               True
445130                                               True

        Sex_Female  AlcoholDrinkers  GeneralHealth_Excellent  \
445117       False                1                    False
445123        True                0                    False
445124       False                1                    False
445128        True                0                     True
445130       False                0                    False

        PhysicalActivities  GeneralHealth_Very good  \
445117                   1                     True
445123                   1                    False
445124                   1                    False
445128                   1                    False
445130                   0                     True

        SmokerStatus_Never smoked  RemovedTeeth_None of them  HadDiabetes_No
445117                       True                       True            True
445123                       True                       True            True
445124                       True                      False           False
445128                       True                       True            True
445130                       True                       True            True

[5 rows x 33 columns]
```

```
[52]: # RE-Verify that all variables (including 'Had_DM_+_CKD') are now some form of␣
       ↪numeric:
      #  -- integer, binary 0 or 1
      #  -- float (normalized/scaled between 0 and 1)
      #  -- boolean, True "1"/False "0" (after one-hot encoding)
      # Print unique catagories for each column/variable
      for column in high_corr_encoded_df.columns:
          unique_categories = high_corr_encoded_df[column].unique()
          print(f"Unique categories for column '{column}':")
          print(unique_categories)
          print()
```

```
Unique categories for column 'HadHeartAttack':
[0 1]

Unique categories for column 'Had_DM_+_CKD':
[0 1]

Unique categories for column 'HadDiabetes_Yes':
[False  True]

Unique categories for column 'HadKidneyDisease':
[0 1]

Unique categories for column 'HadAngina':
[0 1]

Unique categories for column 'HadStroke':
[0 1]

Unique categories for column 'ChestScan':
[0 1]

Unique categories for column 'DifficultyWalking':
[0 1]

Unique categories for column 'GeneralHealth_Poor':
[False  True]

Unique categories for column 'PhysicalHealthDays':
[0.13333333 0.         0.16666667 0.1        0.06666667 0.83333333
 1.         0.5        0.96666667 0.26666667 0.53333333 0.66666667
 0.33333333 0.3        0.23333333 0.03333333 0.7        0.2
 0.9        0.46666667 0.4        0.36666667 0.43333333 0.93333333
 0.56666667 0.76666667 0.8        0.86666667 0.6        0.73333333
 0.63333333]

Unique categories for column 'HadCOPD':
[0 1]

Unique categories for column 'RemovedTeeth_All':
```

```
[False  True]

Unique categories for column 'PneumoVaxEver':
[1 0]

Unique categories for column 'HadArthritis':
[1 0]

Unique categories for column 'GeneralHealth_Fair':
[False  True]

Unique categories for column 'AgeCategory_Age 80 or older':
[False  True]

Unique categories for column 'DeafOrHardOfHearing':
[0 1]

Unique categories for column 'RemovedTeeth_6 or more, but not all':
[False  True]

Unique categories for column 'DifficultyErrands':
[0 1]

Unique categories for column 'DifficultyDressingBathing':
[0 1]

Unique categories for column 'SmokerStatus_Former smoker':
[ True False]

Unique categories for column 'AgeCategory_Age 75 to 79':
[False  True]

Unique categories for column 'Sex_Male':
[False  True]

Unique categories for column 'BlindOrVisionDifficulty':
[0 1]

Unique categories for column 'LastCheckupTime_Within past year (anytime less
than 12 months ago)':
[ True False]

Unique categories for column 'Sex_Female':
[ True False]

Unique categories for column 'AlcoholDrinkers':
[0 1]
```

```
Unique categories for column 'GeneralHealth_Excellent':
[False  True]

Unique categories for column 'PhysicalActivities':
[1 0]

Unique categories for column 'GeneralHealth_Very good':
[ True False]

Unique categories for column 'SmokerStatus_Never smoked':
[False  True]

Unique categories for column 'RemovedTeeth_None of them':
[ True False]

Unique categories for column 'HadDiabetes_No':
[ True False]
```

[53]:
```
# Determine correlation matrix
# Set pandas display options to show all columns
pd.set_option('display.max_rows', None)

# Calculate correlation between the selected variable and all other variables
correlation_with_HadHeartAttack_variable = high_corr_encoded_df.
  ↪corr()['HadHeartAttack'].sort_values(ascending=False)

# Print all correlation values
print("Correlation with selected variable:")
print(correlation_with_HadHeartAttack_variable)
```

```
Correlation with selected variable:
HadHeartAttack                                                        1.000000
HadAngina                                                             0.445903
HadStroke                                                             0.177137
ChestScan                                                             0.167760
DifficultyWalking                                                     0.159878
HadDiabetes_Yes                                                       0.145868
GeneralHealth_Poor                                                    0.140607
PhysicalHealthDays                                                    0.133420
HadCOPD                                                               0.133223
RemovedTeeth_All                                                      0.120564
PneumoVaxEver                                                         0.119955
HadArthritis                                                          0.117773
GeneralHealth_Fair                                                    0.112319
HadKidneyDisease                                                      0.109355
Had_DM_+_CKD                                                          0.106030
AgeCategory_Age 80 or older                                           0.100296
```

```
DeafOrHardOfHearing                                                   0.097662
RemovedTeeth_6 or more, but not all                                   0.092477
DifficultyErrands                                                     0.089495
DifficultyDressingBathing                                             0.083090
SmokerStatus_Former smoker                                            0.074537
AgeCategory_Age 75 to 79                                              0.073567
Sex_Male                                                              0.073316
BlindOrVisionDifficulty                                               0.072964
LastCheckupTime_Within past year (anytime less than 12 months ago)    0.070725
Sex_Female                                                           -0.073316
AlcoholDrinkers                                                      -0.074181
GeneralHealth_Excellent                                              -0.079933
PhysicalActivities                                                   -0.083187
GeneralHealth_Very good                                              -0.085347
SmokerStatus_Never smoked                                            -0.094843
RemovedTeeth_None of them                                            -0.122556
HadDiabetes_No                                                       -0.136692
Name: HadHeartAttack, dtype: float64
```

[54]:

```
# LOGISTIC REGRESSION AGAIN

# Isolate independent variables
column_names_with_interaction_list = high_corr_encoded_df.columns.tolist()
independent_variables_list = [x for x in column_names_with_interaction_list if␣
 ↪x != 'HadHeartAttack']
independent_variables = high_corr_encoded_df[independent_variables_list]
# Isolate dependent variables
dependent_variable = high_corr_encoded_df['HadHeartAttack']

# Split data into train and test sets
X_train3, X_test3, y_train3, y_test3 = train_test_split(independent_variables,␣
 ↪dependent_variable, test_size=0.2, random_state=42)

# Initialize logistic regression model
log_reg = LogisticRegression()

# Fit logistic regression model
log_reg.fit(X_train3, y_train3)

# Create a list of tuples containing coefficients and variables
coefficients_with_variables = [(coefficient, variable) for coefficient,␣
 ↪variable in zip(log_reg.coef_[0], independent_variables)]
# Sort the list based on the absolute value of coefficients in descending order
coefficients_with_variables.sort(key=lambda x: x[0], reverse=True)

# Evaluate and print model accuracy
accuracy_lr_3 = log_reg.score(X_test3, y_test3)
```

```python
print(f"\nACCURACY:\t{accuracy_lr_3:.5f}")

# Print model coefficients for each independent variable in descending order
print("\nMODEL INTERCEPT AND COEFFICIENTS IN DESCENDING ORDER:\n")

# Print model coefficients
print(f"INTERCEPT:\t{log_reg.intercept_[0]}")
print("\nCOEFFICIENT:\tVARIABLE:\n")
for coefficient, variable in coefficients_with_variables:
    print(f"{coefficient:.5f}:\t{variable}")
```

[54]: LogisticRegression()

```
ACCURACY:       0.94899

MODEL INTERCEPT AND COEFFICIENTS IN DESCENDING ORDER:

INTERCEPT:      -3.8379177682053203

COEFFICIENT:    VARIABLE:

2.50163:        HadAngina
0.90367:        HadStroke
0.61366:        ChestScan
0.47199:        AgeCategory_Age 80 or older
0.42350:        RemovedTeeth_All
0.35063:        LastCheckupTime_Within past year (anytime less than 12 months
ago)
0.33744:        GeneralHealth_Poor
0.32790:        AgeCategory_Age 75 to 79
0.31744:        Sex_Male
0.21822:        GeneralHealth_Fair
0.18307:        HadDiabetes_Yes
0.17065:        RemovedTeeth_6 or more, but not all
0.16948:        PneumoVaxEver
0.16498:        BlindOrVisionDifficulty
0.13041:        HadArthritis
0.09381:        DifficultyWalking
0.07362:        DeafOrHardOfHearing
0.06793:        HadCOPD
0.04023:        HadKidneyDisease
0.03432:        DifficultyErrands
0.00121:        Had_DM_+_CKD
-0.02692:       PhysicalHealthDays
-0.07036:       DifficultyDressingBathing
-0.07598:       PhysicalActivities
-0.13149:       SmokerStatus_Former smoker
```

```
-0.15720:       HadDiabetes_No
-0.19864:       AlcoholDrinkers
-0.21189:       RemovedTeeth_None of them
-0.29525:       GeneralHealth_Very good
-0.31989:       Sex_Female
-0.39783:       SmokerStatus_Never smoked
-0.63300:       GeneralHealth_Excellent
```

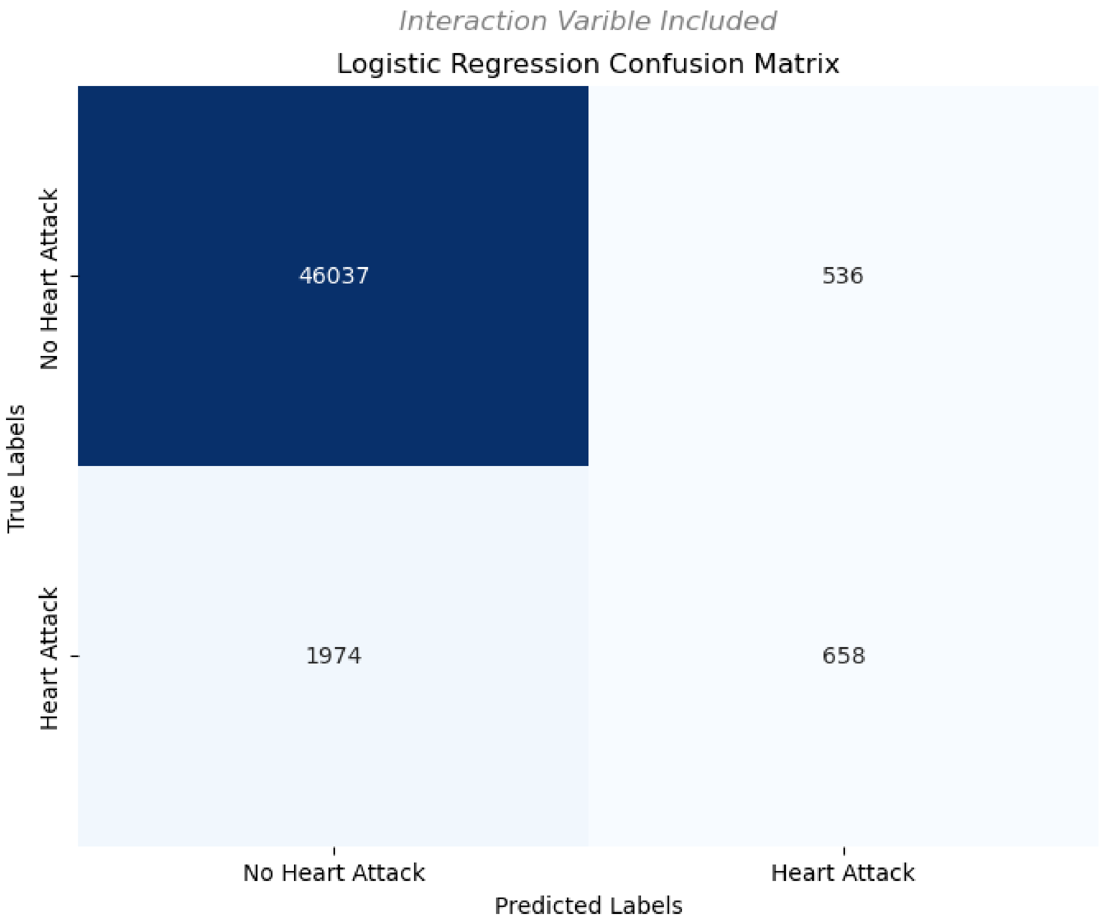
[55]:

```
# Define custom labels
label_names = ['No Heart Attack', 'Heart Attack'];

# Calculate the confusion matrix
# Predict the labels for the test set
y_pred3 = log_reg.predict(X_test3)
conf_matrix3 = confusion_matrix(y_test3, y_pred3);

# Create a heatmap of the confusion matrix
plt.figure(figsize=(8, 6));
sns.heatmap(conf_matrix3, annot=True, fmt='d', cmap='Blues', cbar=False);
plt.title('Logistic Regression Confusion Matrix');
plt.text(1, -0.15, 'Interaction Varible Included',␣
 ↪horizontalalignment='center', \
         fontsize=12, fontstyle='italic', color='gray');
plt.xlabel('Predicted Labels');
plt.ylabel('True Labels');

# Set custom labels for ticks
plt.xticks(ticks=[0.5, 1.5], labels=label_names);
plt.yticks(ticks=[0.5, 1.5], labels=label_names);
plt.show();
```



[56]:

```
##########################################################
##    V.    CONCLUSION:
##########################################################
# Based on the the results of the above logisic regression,
# the top 7 variables or factors most associated with having a heart attack are:
#   1.) HadAngina
#   2.) HadStroke
#   3.) ChestScan
#   4.) AgeCategory_Age 80 or older
#   5.) RemovedTeeth_All
#   6.) LastCheckupTime_Within past year (anytime less than 12 months ago)
#   7.) GeneralHealth_Poor

# Surprisingly, the variables HadDiabetes_Yes, HadCOPD, HadKidneyDisease, and
# the interaction term, Had_DM_+_CKD, hoping to capture diabetic kidney disease,
# were not present in the top 7 risk factors.

# Based on the the results of the above logisic regression,
# the top 7 variables or factors most protective against with having a heart attack are:
#   1.) GeneralHealth_Excellent
#   2.) SmokerStatus_Never smoked
#   3.) Sex_Female
#   4.) GeneralHealth_Very good
#   5.) RemovedTeeth_None of them
#   6.) AlcoholDrinkers
#   7.) HadDiabetes_No

# Surprising among top 7 protective factors is AlcoholDrinkers.
# This most likely indicates light, moderate or social drinking, rather than heavy drinking**.
# However, this distinction is not clear in the data available**.
# Also surprising is the factor of diabetes. When absent it is protective fector,
# HadDiabetes_No, but when present it is a risk factor, but not a top 7 risk factor.

# Public Health Policy Recommendations:
#   1.) Maintain excellent health through diet and exercise.
#   2.) Don't smoke - ever.
#   3.) Practice good daily oral hygiene and see your dentist regularly.
#   4.) Drink alcohol sparingly (?**).
#   5.) Screen routinely for diabetes and prevent it, if possible, through recommendation 1.).
```