Cardiovascular Disease Modeling

December 29, 2019

0.1 Data source

https://www.kaggle.com/sulianova/cardiovascular-disease-dataset#cardio_train.csv

0.2 Import packages

[40]:
```
import numpy as np
import pandas as pd
from sklearn.metrics import accuracy_score
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeClassifier
from sklearn.preprocessing import StandardScaler
from sklearn.cluster import KMeans
from itertools import cycle, islice
import matplotlib.pyplot as plt
import matplotlib as mpl
from pandas.plotting import parallel_coordinates

%matplotlib inline
```

0.3 Data acquisition and prep

[3]:
```
data = pd.read_table('/Users/ericabadger/Downloads/cardio_train.csv', sep = ';')
```

[4]:
```
data.head()
```

[4]:

	id	age	gender	height	weight	ap_hi	ap_lo	cholesterol	gluc	smoke	alco	active	cardio
0	0	18393	2	168	62.0	110	80	1	1	0	0	1	0
1	1	20228	1	156	85.0	140	90	3	1	0	0	1	1
2	2	18857	1	165	64.0	130	70	3	1	0	0	0	1
3	3	17623	2	169	82.0	150	100	1	1	0	0	1	1
4	4	17474	1	156	56.0	100	60	1	1	0	0	0	0

1	0	1	1
2	0	0	1
3	0	1	1
4	0	0	0

Columns

- id ID number
- age in days
- gender 1 - women, 2 - men
- height cm
- weight kg
- ap_hi Systolic blood pressure
- ap_lo Diastolic blood pressure
- cholesterol 1: normal, 2: above normal, 3: well above normal
- gluc 1: normal, 2: above normal, 3: well above normal
- smoke whether patient smokes or not
- alco Binary feature
- active Binary feature
- cardio Target variable

0.3.1 Check for nulls

[5]:
```
# check for nulls
data[data.isnull().any(axis=1)]
```

[5]:
```
Empty DataFrame
Columns: [id, age, gender, height, weight, ap_hi, ap_lo, cholesterol, gluc,
smoke, alco, active, cardio]
Index: []
```

0.3.2 Convert from metric to imperial

[58]:
```
# add variable to make age in years
data['age_yrs'] = data['age']/365

# add variable to make height in inches
data['height_in'] = data['height'] / 2.54

# add variable to convert weight to pounds
data['weight_lb'] = data['weight'] * 2.2
```

[59]:
```
# summary stats
data.describe()
```

[59]:
```
                id           age        gender        height        weight  \
count  69588.000000  69588.000000  69588.000000  69588.000000  69588.000000
mean   49969.893243  19470.150026      1.349845    164.452463     74.253697
std    28854.199371   2466.191542      0.476924      7.858600     14.314437
min        0.000000  10798.000000      1.000000    122.000000     41.000000
25%    24996.750000  17666.750000      1.000000    159.000000     65.000000
50%    49997.500000  19703.000000      1.000000    165.000000     72.000000
75%    74889.250000  21327.000000      2.000000    170.000000     82.000000
max    99999.000000  23713.000000      2.000000    250.000000    200.000000

              ap_hi         ap_lo   cholesterol          gluc         smoke  \
count  69588.000000  69588.000000  69588.000000  69588.000000  69588.000000
mean     129.101727     96.680635      1.367492      1.226821      0.088334
std      154.164119    188.678257      0.680783      0.572679      0.283782
min       60.000000     30.000000      1.000000      1.000000      0.000000
25%      120.000000     80.000000      1.000000      1.000000      0.000000
50%      120.000000     80.000000      1.000000      1.000000      0.000000
75%      140.000000     90.000000      2.000000      1.000000      0.000000
max    16020.000000  11000.000000      3.000000      3.000000      1.000000

               alco        active        cardio       age_yrs     height_in  \
count  69588.000000  69588.000000  69588.000000  69588.000000  69588.000000
mean       0.053860      0.803817      0.500014     53.342877     64.745064
std        0.225743      0.397112      0.500004      6.756689      3.093937
min        0.000000      0.000000      0.000000     29.583562     48.031496
25%        0.000000      1.000000      0.000000     48.402055     62.598425
50%        0.000000      1.000000      1.000000     53.980822     64.960630
75%        0.000000      1.000000      1.000000     58.430137     66.929134
max        1.000000      1.000000      1.000000     64.967123     98.425197

          weight_lb
count  69588.000000
mean     163.358133
std       31.491761
min       90.200000
25%      143.000000
50%      158.400000
75%      180.400000
max      440.000000
```

0.3.3 Filtering

[60]:
```
# filter data for illogical values
height_filter = data['height_in'] >= 48

weight_filter = data['weight_lb'] >= 90
```

```
ap_hi_filter = data['ap_hi'] >= 50

ap_lo_filter = data['ap_lo'] >= 30

before_filter = data.shape[0]

data = data[height_filter & weight_filter & ap_hi_filter & ap_lo_filter]

after_filter = data.shape[0]

print(before_filter)
print(after_filter)
print(before_filter - after_filter)
```

```
69588
69588
0
```

[61]:
```
data.describe()
```

[61]:

	id	age	gender	height	weight
count	69588.000000	69588.000000	69588.000000	69588.000000	69588.000000
mean	49969.893243	19470.150026	1.349845	164.452463	74.253697
std	28854.199371	2466.191542	0.476924	7.858600	14.314437
min	0.000000	10798.000000	1.000000	122.000000	41.000000
25%	24996.750000	17666.750000	1.000000	159.000000	65.000000
50%	49997.500000	19703.000000	1.000000	165.000000	72.000000
75%	74889.250000	21327.000000	2.000000	170.000000	82.000000
max	99999.000000	23713.000000	2.000000	250.000000	200.000000

	ap_hi	ap_lo	cholesterol	gluc	smoke
count	69588.000000	69588.000000	69588.000000	69588.000000	69588.000000
mean	129.101727	96.680635	1.367492	1.226821	0.088334
std	154.164119	188.678257	0.680783	0.572679	0.283782
min	60.000000	30.000000	1.000000	1.000000	0.000000
25%	120.000000	80.000000	1.000000	1.000000	0.000000
50%	120.000000	80.000000	1.000000	1.000000	0.000000
75%	140.000000	90.000000	2.000000	1.000000	0.000000
max	16020.000000	11000.000000	3.000000	3.000000	1.000000

	alco	active	cardio	age_yrs	height_in
count	69588.000000	69588.000000	69588.000000	69588.000000	69588.000000
mean	0.053860	0.803817	0.500014	53.342877	64.745064
std	0.225743	0.397112	0.500004	6.756689	3.093937
min	0.000000	0.000000	0.000000	29.583562	48.031496
25%	0.000000	1.000000	0.000000	48.402055	62.598425

```
50%        0.000000      1.000000      1.000000     53.980822     64.960630
75%        0.000000      1.000000      1.000000     58.430137     66.929134
max        1.000000      1.000000      1.000000     64.967123     98.425197

          weight_lb
count  69588.000000
mean     163.358133
std       31.491761
min       90.200000
25%      143.000000
50%      158.400000
75%      180.400000
max      440.000000
```

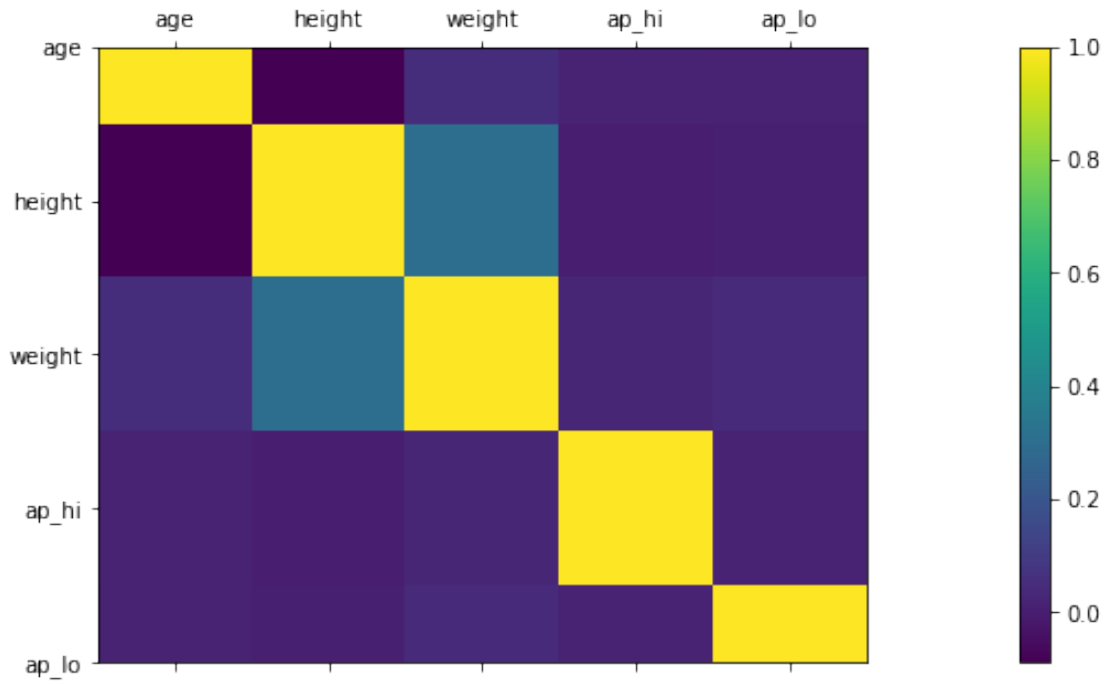
0.3.4 Look for and address highly correlated features

[62]:
```
# Look at correlations between continuous variables
data_cont = data[['age','height','weight','ap_hi','ap_lo']].copy()
```

[63]:
```
data_cont.corr()

plt.matshow(data_cont.corr())
plt.xticks(range(len(data_cont.columns)), data_cont.columns)
plt.yticks(range(len(data_cont.columns)), data_cont.columns)
plt.colorbar()
plt.gcf().set_size_inches(25, 5)

plt.show()
```



[64]:
```
# add clinical variables for highly correlated measures

# BMI : Weight (LBS) x 703 ÷ Height (Inches²)
data['bmi'] = (data['weight_lb'] * 703) / (data['height_in']**2)

# Mean Arterial Pressure (MAP): ((2 * DP) + SP) / 3
data['map'] = ((2 * data['ap_lo']) + data['ap_hi']) / 3

data.head()
```

[64]:

	id	age	gender	height	weight	ap_hi	ap_lo	cholesterol	gluc	smoke	alco	active	cardio	age_yrs	height_in	weight_lb	bmi	map
0	0	18393	2	168	62.0	110	80	1	1	0	0	1	0	50.391781	66.141732	136.4	21.918890	
1	1	20228	1	156	85.0	140	90	3	1	0	0	1	1	55.419178	61.417323	187.0	34.850994	
2	2	18857	1	165	64.0	130	70	3	1	0	0	0	1	51.663014	64.960630	140.8	23.456193	
3	3	17623	2	169	82.0	150	100	1	1	0	0	1	1	48.282192	66.535433	180.4	28.647444	
4	4	17474	1	156	56.0	100	60	1	1	0	0	0	0	47.873973	61.417323	123.2	22.960655	

```
0    90.000000
1   106.666667
2    90.000000
3   116.666667
4    73.333333
```

0.3.5 Final data set

[146]:
```
data2 =␣
↪data[['age','gender','cholesterol','gluc','smoke','alco','active','cardio','bmi','map']].
↪copy()
#data2.head()
```

0.4 Classification

[147]:
```
# make the heart disease label
y = data2[['cardio']].copy()
```

[67]:
```
# specify the features to use
cardio_features = ['age','gender','cholesterol','gluc','smoke',
        'alco','active','bmi','map']
```

[68]:
```
x = data[cardio_features].copy()
```

[69]:
```
# Check the column names
y.columns
```

[69]:
```
Index(['cardio'], dtype='object')
```

[70]:
```
x.columns
```

[70]:
```
Index(['age', 'gender', 'cholesterol', 'gluc', 'smoke', 'alco', 'active',
       'bmi', 'map'],
      dtype='object')
```

[80]:
```
# create the test and train datasets
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.33,␣
↪random_state=777)
```

[81]:
```
# fit the model on the train set
cardio_classifier = DecisionTreeClassifier(max_leaf_nodes=10, random_state=0)
cardio_classifier.fit(x_train, y_train)
```

[81]:
```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=None,
                       max_features=None, max_leaf_nodes=10,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=1, min_samples_split=2,
                       min_weight_fraction_leaf=0.0, presort=False,
                       random_state=0, splitter='best')
```

[82]:
```
# predict on the test set
predictions = cardio_classifier.predict(x_test)
```

[83]:
```
# check predicted vs. actual for 100 values
predictions[:100]
```

[83]:
```
array([1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 1, 0,
       0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 0, 0, 1, 1, 1, 1, 0,
       1, 1, 1, 0, 1, 1, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1,
       1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0,
       0, 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 0])
```

[84]:
```
y_test['cardio'][:100]
```

[84]:
```
2046     0
15141    1
14535    0
55832    1
61032    1
        ..
16625    1
30421    0
6411     1
27639    1
38023    0
Name: cardio, Length: 100, dtype: int64
```

[85]:
```
# Check the accuracy of the model
accuracy_score(y_true = y_test, y_pred = predictions)
```

[85]:
```
0.7250163291966035
```

0.5 Clustering

For the people with heart disease, try to cluster them into groups to see how they are related. This could help with designing programs to target each cluster's specific needs when it comes to health promotion.

[89]:
```
# First, limit data to only people with heart disease.
patients = data2.copy()

before_filter = patients.shape[0]

heart_disease = patients['cardio'] == 1

patients = patients[heart_disease]

after_filter = patients.shape[0]

print(before_filter)
print(after_filter)
print(before_filter - after_filter)
```

```
69588
34795
34793
```

For features, use cardio_features already established above. Create a new dataframe containing only these features.

[90]:
```
select_df = patients[cardio_features]
select_df.head()
```

[90]:

	age	gender	cholesterol	gluc	smoke	alco	active	bmi	map
1	20228	1	3	1	0	0	1	34.850994	106.666667
2	18857	1	3	1	0	0	0	23.456193	90.000000
3	17623	2	1	1	0	0	1	28.647444	116.666667
7	22584	2	3	3	0	0	1	29.917758	103.333333
15	16782	2	1	1	0	0	0	37.775182	93.333333

[91]:
```
# scale the features so they are on normalized scales
X = StandardScaler().fit_transform(select_df)
X
```

[91]:
```
array([[ 0.07390164, -0.73931179,  1.90789673, …,  0.51607348,
         1.16919562, -0.07450624],
       [-0.51810583, -0.73931179,  1.90789673, …, -1.93770854,
        -0.90910928, -0.17895935],
       [-1.05095573,  1.3526093 , -0.66692211, …,  0.51607348,
```

```
         0.0377263 , -0.01183438],
       …,
       [ 1.09857977, -0.73931179,  0.62048731, …,  0.51607348,
         3.99823325, -0.07450624],
       [-0.42785815,  1.3526093 ,  1.90789673, …, -1.93770854,
         0.51874445,  0.00905625],
       [ 1.02517257, -0.73931179, -0.66692211, …, -1.93770854,
        -0.25550143, -0.1267328 ]])
```

[92]:
```
# Set up the K means clustering
kmeans = KMeans(n_clusters= 5) # create a k means object with 5 clusters
model = kmeans.fit(X) # scaled dataframe we are fitting
print("model\n", model) # will be a k means object
```

```
model
 KMeans(algorithm='auto', copy_x=True, init='k-means++', max_iter=300,
       n_clusters=5, n_init=10, n_jobs=None, precompute_distances='auto',
       random_state=None, tol=0.0001, verbose=0)
```

[93]:
```
# Centers of the clusters
centers = model.cluster_centers_
```

[94]:
```
# Plot different pairs of dimensions
labels = kmeans.labels_
```

[102]:
```
select_df2 = select_df.copy()
# select_df2.head()
```

[103]:
```
select_df2['clusters'] = labels
# select_df2.head()
```

[103]:

	age	gender	cholesterol	gluc	smoke	alco	active	bmi	map	clusters
1	20228	1	3	1	0	0	1	34.850994	106.666667	4
2	18857	1	3	1	0	0	0	23.456193	90.000000	2
3	17623	2	1	1	0	0	1	28.647444	116.666667	1
7	22584	2	3	3	0	0	1	29.917758	103.333333	4
15	16782	2	1	1	0	0	0	37.775182	93.333333	2

[104]:
```
# add the cluster column to the feature list
# cardio_features.extend(['clusters'])
```

```
# cardio_features
```

[104]:
```
['age',
 'gender',
 'cholesterol',
 'gluc',
 'smoke',
 'alco',
 'active',
 'bmi',
 'map',
 'clusters']
```

[131]:
```
print(select_df2[cardio_features].groupby(['clusters']).mean())
```

```
                  age    gender  cholesterol      gluc     smoke  alco  \
clusters
0         20564.242993  1.235307     2.449141  2.706826  0.047468  0.00
1         19873.791891  1.999601     1.344717  1.077392  0.164270  0.00
2         19735.732084  1.683021     1.675303  1.326351  0.452591  1.00
3         20066.934352  1.000000     1.374021  1.040382  0.013119  0.00
4         19273.100000  1.350000     1.450000  1.400000  0.050000  0.15

            active        bmi          map
clusters
0         0.789557  30.056903   116.413954
1         0.779708  27.262022   117.424373
2         0.828556  28.995670   122.444322
3         0.791179  28.638399   113.648041
4         0.900000  27.493610  5350.033333
```

[117]:
```
output_n = select_df2[['age','clusters']].groupby(['clusters'], as_index =␣
 ↪False).count()

output_n
```

[117]:

	clusters	age
0	0	2092
1	1	18247
2	2	6063
3	3	1817
4	4	6576

[138]:
```
# percent in cluster 1
18247/ 34795
```

[138]:
```
0.5244144273602529
```

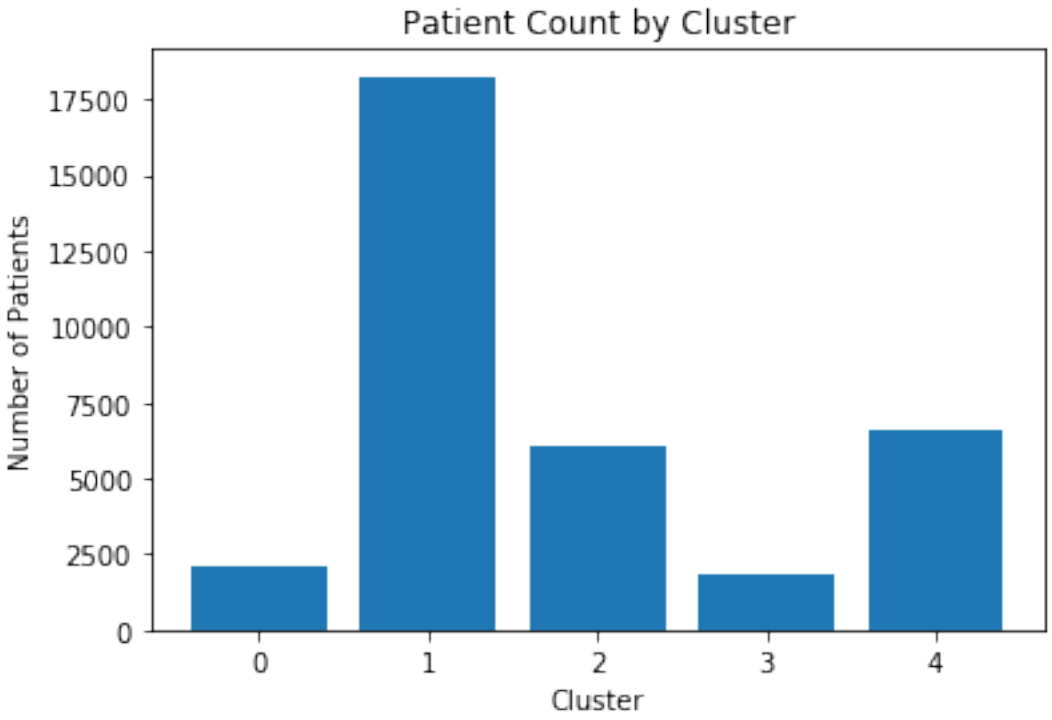
0.5.1 Plots

[118]:
```
# Get the plot variables
clusters = output_n['clusters'].values
# get the values
n = output_n['age'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('Number of Patients')

#label the figure
plt.title('Patient Count by Cluster')


# create
plt.bar(clusters,n)
plt.show()
```



[109]:
```
output = select_df2[cardio_features].groupby(['clusters'], as_index = False).
↪mean()
output['age_yrs'] = output['age']/365
output
```

[109]:

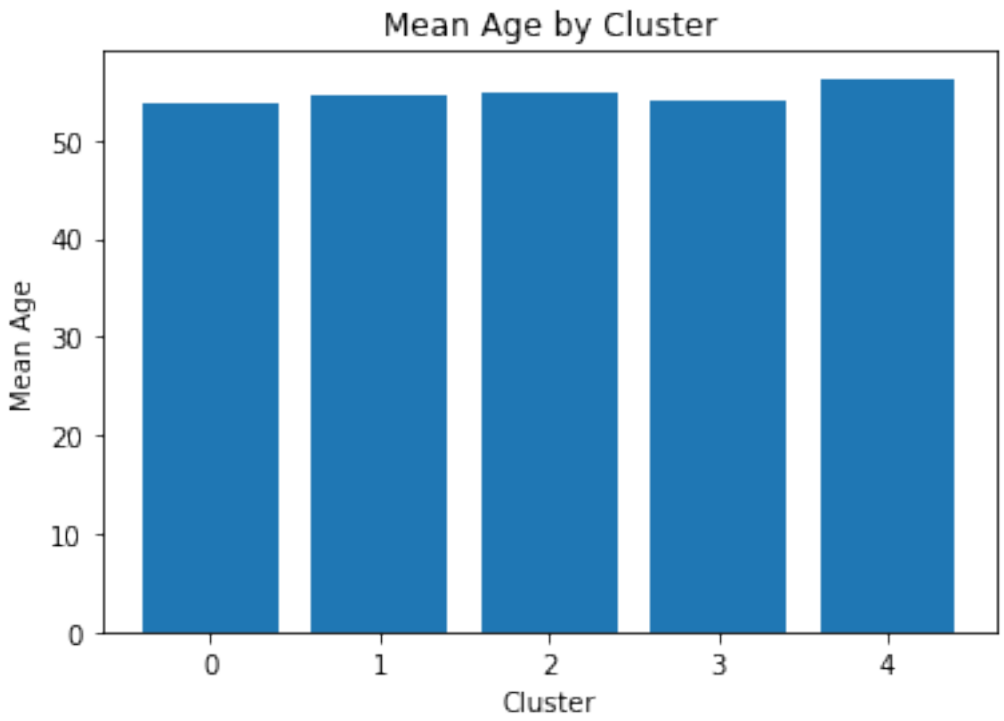
	clusters	age	gender	cholesterol	gluc	smoke	alco	active	bmi	map	age_yrs
0	0	19649.539197	1.851338	1.567400	1.269120	1.000000	0.0	0.808317	27.978445	122.277725	53.834354
1	1	19957.920480	1.308599	1.147038	1.042308	0.000000	0.0	1.000000	27.967330	118.555945	54.679234
2	2	20060.004783	1.320798	1.319809	1.126505	0.000000	0.0	0.000000	28.289592	111.908296	54.958917
3	3	19735.039626	1.682994	1.674739	1.326362	0.452394	1.0	0.828839	28.994345	131.903137	54.068602
4	4	20546.970955	1.258364	2.671229	2.061283	0.000912	0.0	0.917427	29.887076	119.807938	56.293071

[111]:
```
# Get the plot variables
clusters = output['clusters'].values
# get the values
age = output['age_yrs'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('Mean Age')

#label the figure
plt.title('Mean Age by Cluster')


# create
plt.bar(clusters,age)
plt.show()
```

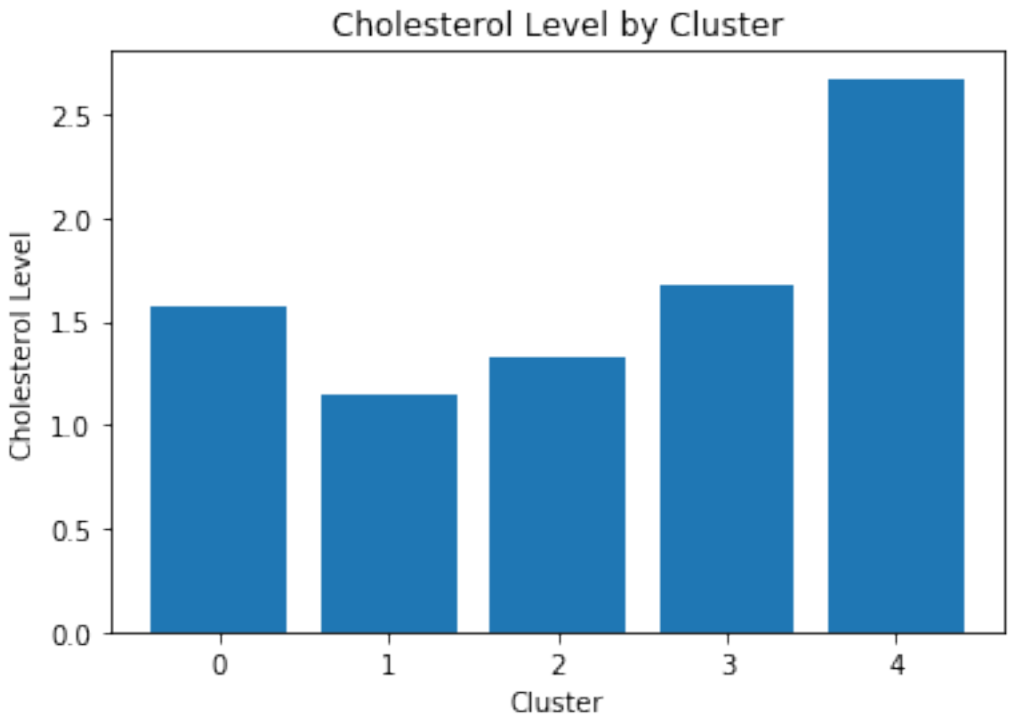


[112]:
```
# Get the plot variables
clusters = output['clusters'].values
# get the values
chol = output['cholesterol'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('Cholesterol Level')

#label the figure
plt.title('Cholesterol Level by Cluster')


# create
plt.bar(clusters,chol)
plt.show()
```

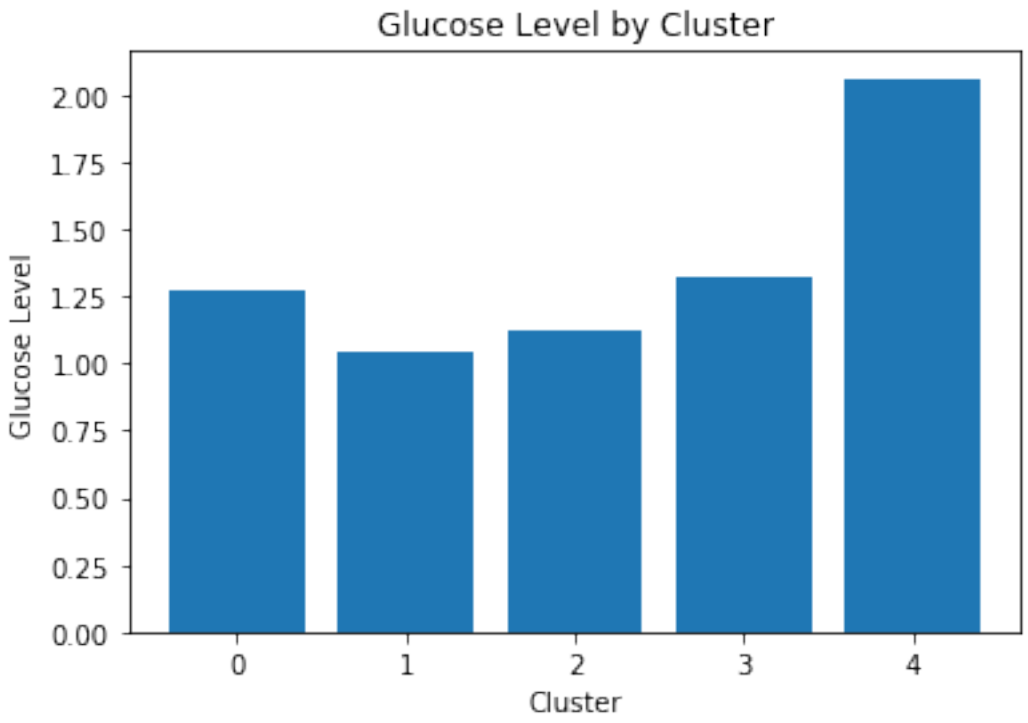


[113]:
```
# Get the plot variables
clusters = output['clusters'].values
# get the values
gluc = output['gluc'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('Glucose Level')

#label the figure
plt.title('Glucose Level by Cluster')


# create
plt.bar(clusters,gluc)
plt.show()
```

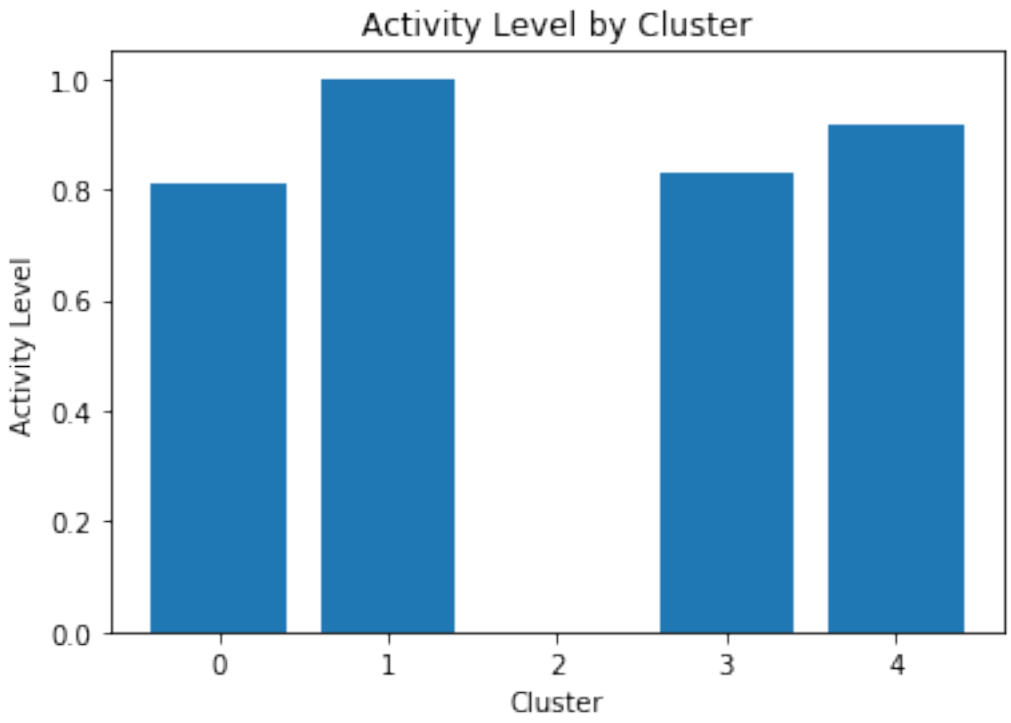


[119]:
```
# Get the plot variables
clusters = output['clusters'].values
# get the values
act = output['active'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('Activity Level')

#label the figure
plt.title('Activity Level by Cluster')


# create
plt.bar(clusters,act)
plt.show()
```

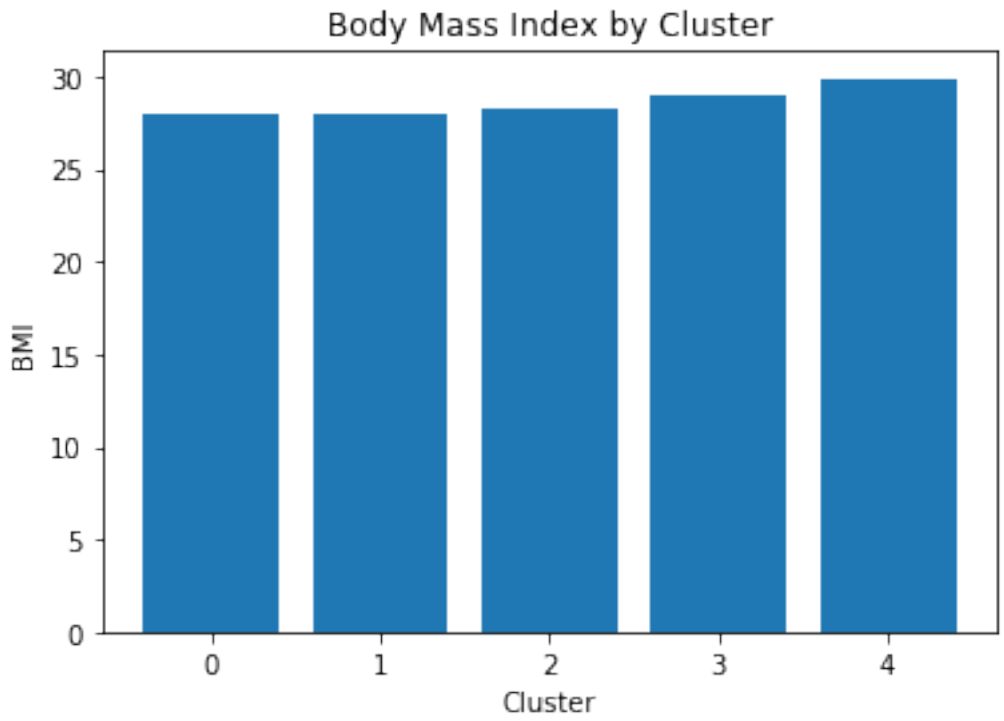


[121]:
```
# Get the plot variables
clusters = output['clusters'].values
# get the values
bmi = output['bmi'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('BMI')

#label the figure
plt.title('Body Mass Index by Cluster')


# create
plt.bar(clusters,bmi)
plt.show()
```

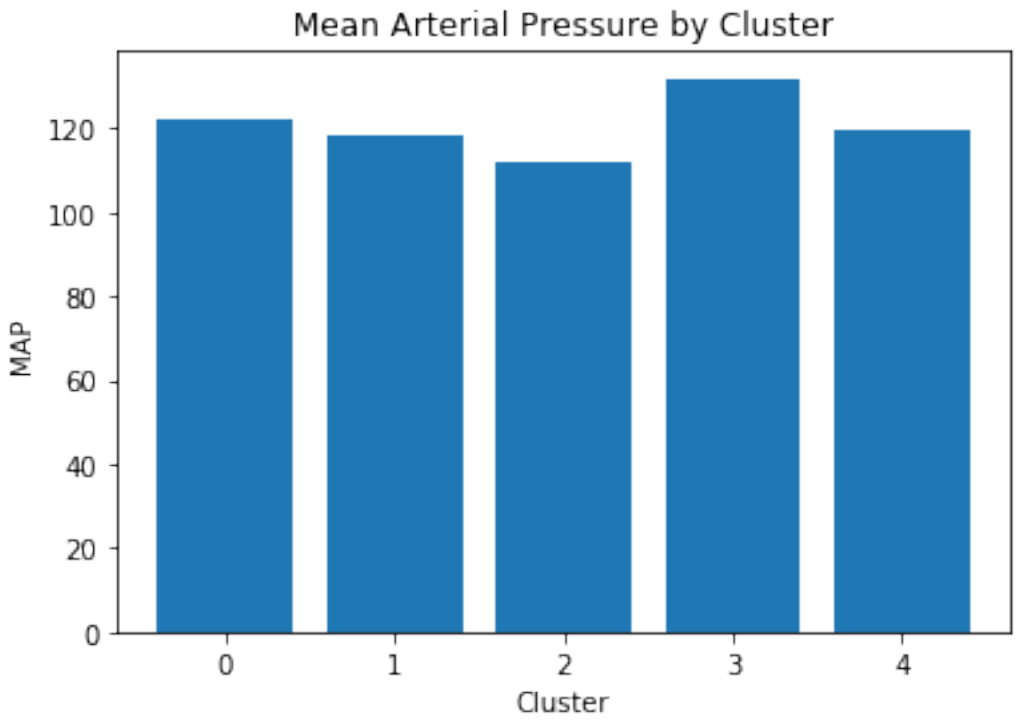


[122]:
```
# Get the plot variables
clusters = output['clusters'].values
# get the values
map = output['map'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('MAP')

#label the figure
plt.title('Mean Arterial Pressure by Cluster')


# create
plt.bar(clusters,map)
plt.show()
```



[135]:
```
output_bin = select_df2[['clusters','smoke','alco']].groupby(['clusters'],␣
↪as_index = False).agg({'smoke': ['sum','count'],
                                                                    ␣
↪                  'alco': ['sum','count']})

output_bin_cols = ['clusters','smoke','smoke_count','alco','total_count']

output_bin.columns = output_bin_cols

del output_bin['smoke_count']

output_bin['percent_smoke'] = output_bin['smoke'] / output_bin['total_count']

output_bin['percent_alco'] = output_bin['alco'] / output_bin['total_count']

output_bin
```

[135]:

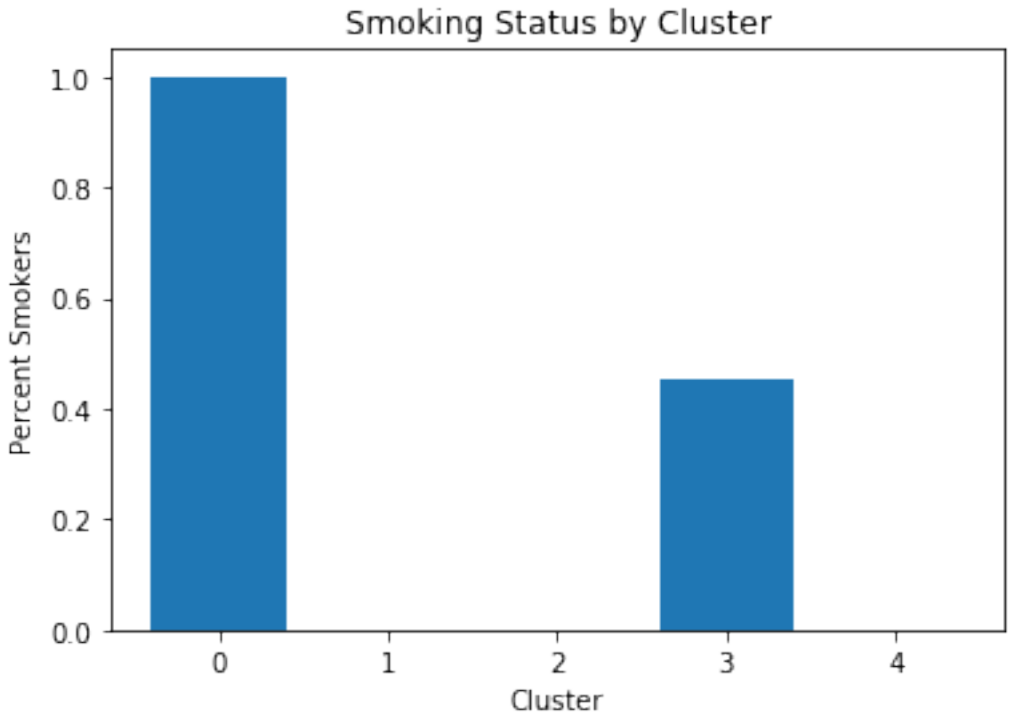
	clusters	smoke	alco	total_count	percent_smoke	percent_alco
0	0	2092	0	2092	1.000000	0.0
1	1	0	0	18247	0.000000	0.0
2	2	0	0	6063	0.000000	0.0
3	3	822	1817	1817	0.452394	1.0
4	4	6	0	6576	0.000912	0.0

[136]:
```
# Get the plot variables
clusters = output_bin['clusters'].values
# get the values
smk = output_bin['percent_smoke'].values

# Label the axes
plt.xlabel('Cluster')
plt.ylabel('Percent Smokers')

#label the figure
plt.title('Smoking Status by Cluster')


# create
plt.bar(clusters,smk)
plt.show()
```



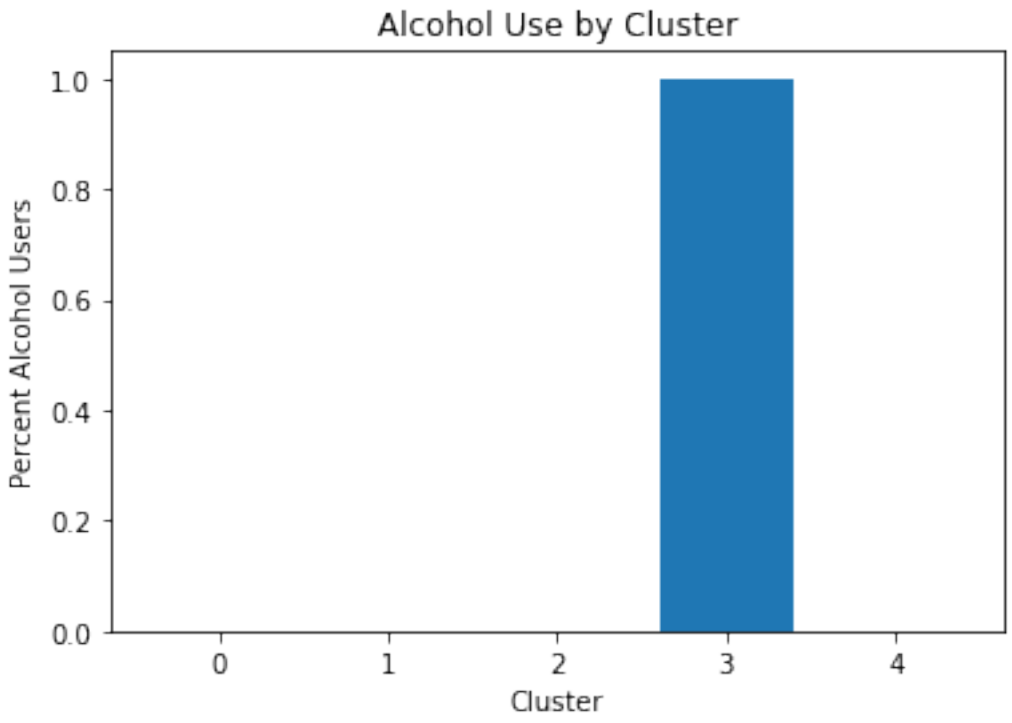
[139]:
```
# Get the plot variables
clusters = output_bin['clusters'].values
# get the values
alc = output_bin['percent_alco'].values

# Label the axes
```

```
plt.xlabel('Cluster')
plt.ylabel('Percent Alcohol Users')

#label the figure
plt.title('Alcohol Use by Cluster')


# create
plt.bar(clusters,alc)
plt.show()
```

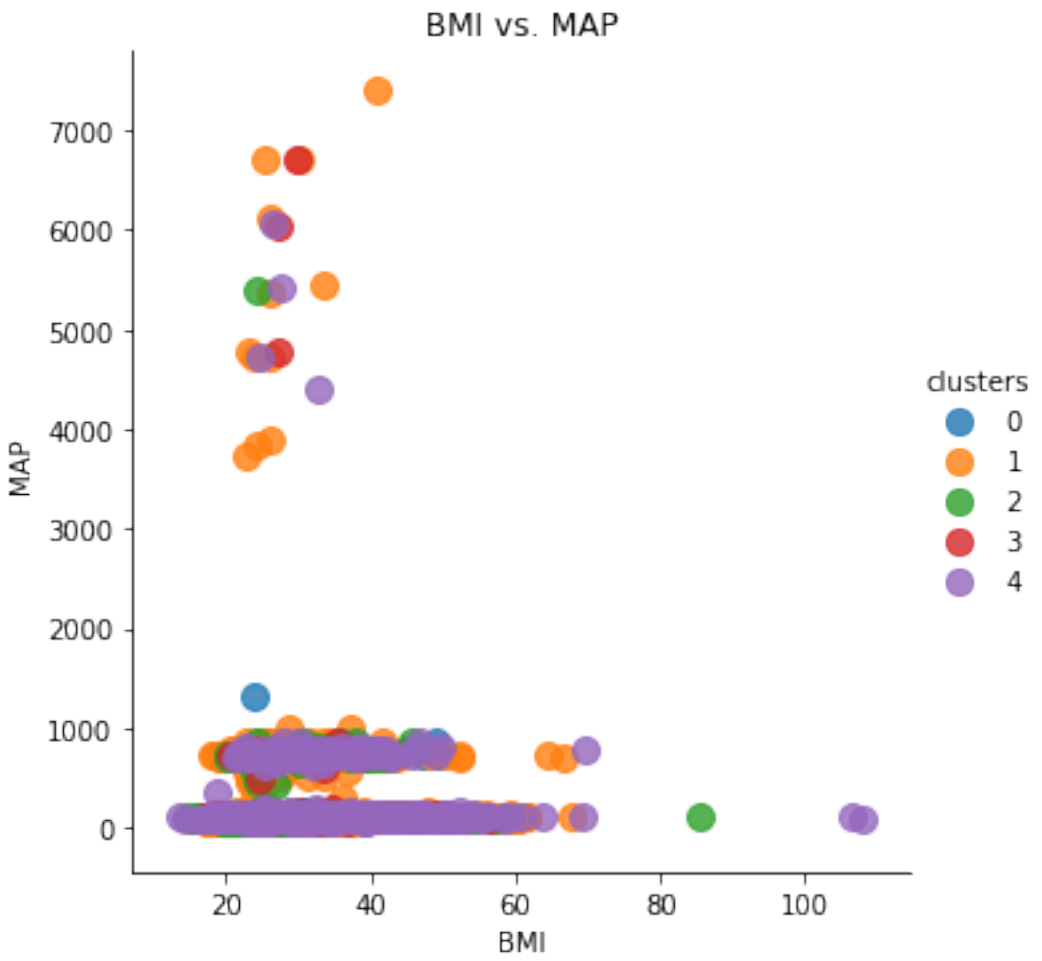


[140]:
```
#Scatter plot
from scipy import stats
import seaborn as sns


sns.lmplot('bmi', 'map',
           data=select_df2,
           fit_reg=False,
           hue="clusters",
           scatter_kws={"marker": "D",
                        "s": 100})
plt.title('BMI vs. MAP')
```

```
plt.xlabel('BMI')
plt.ylabel('MAP')
```

[140]: Text(28.29117187499999, 0.5, 'MAP')

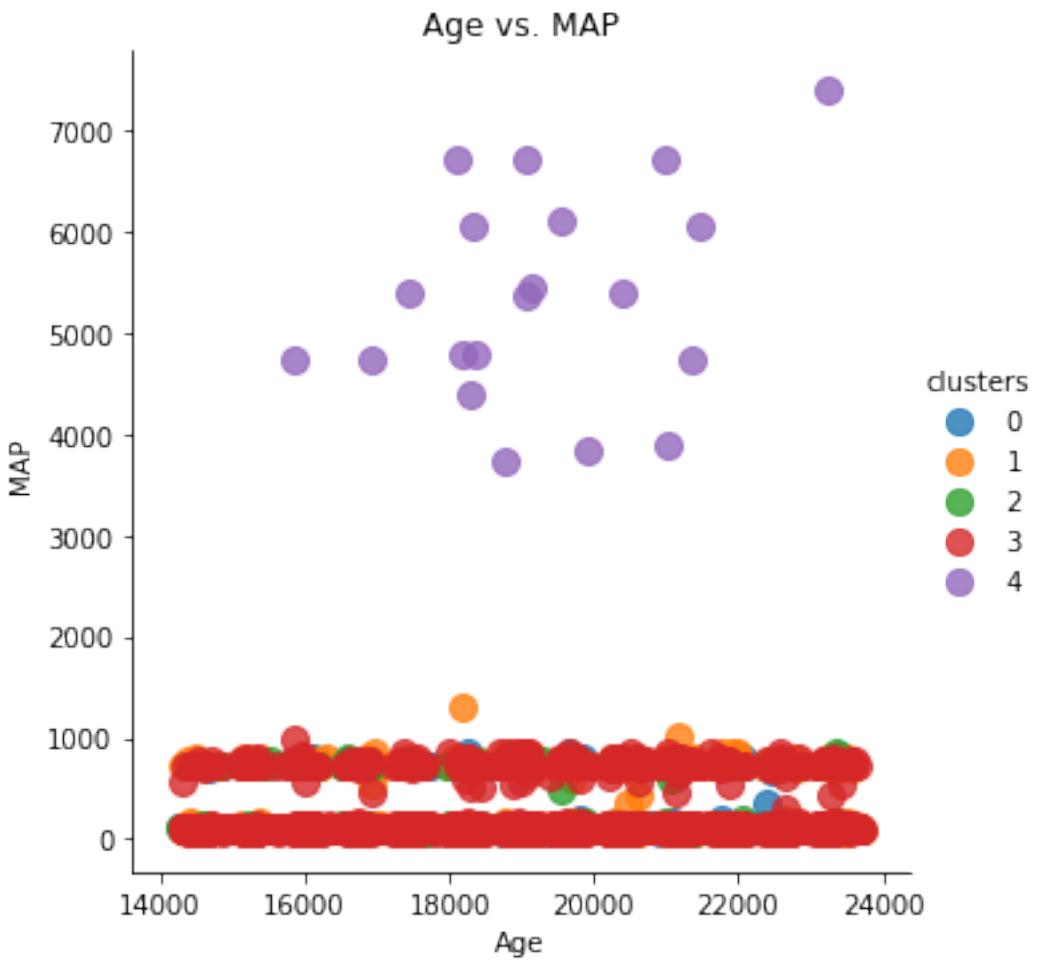


[134]:
```
#Scatter plot
from scipy import stats
import seaborn as sns


sns.lmplot('age', 'map',
           data=select_df2,
           fit_reg=False,
           hue="clusters",
           scatter_kws={"marker": "D",
                        "s": 100})
plt.title('Age vs. MAP')
```

```
plt.xlabel('Age')
plt.ylabel('MAP')
```

[134]: Text(28.29117187499999, 0.5, 'MAP')



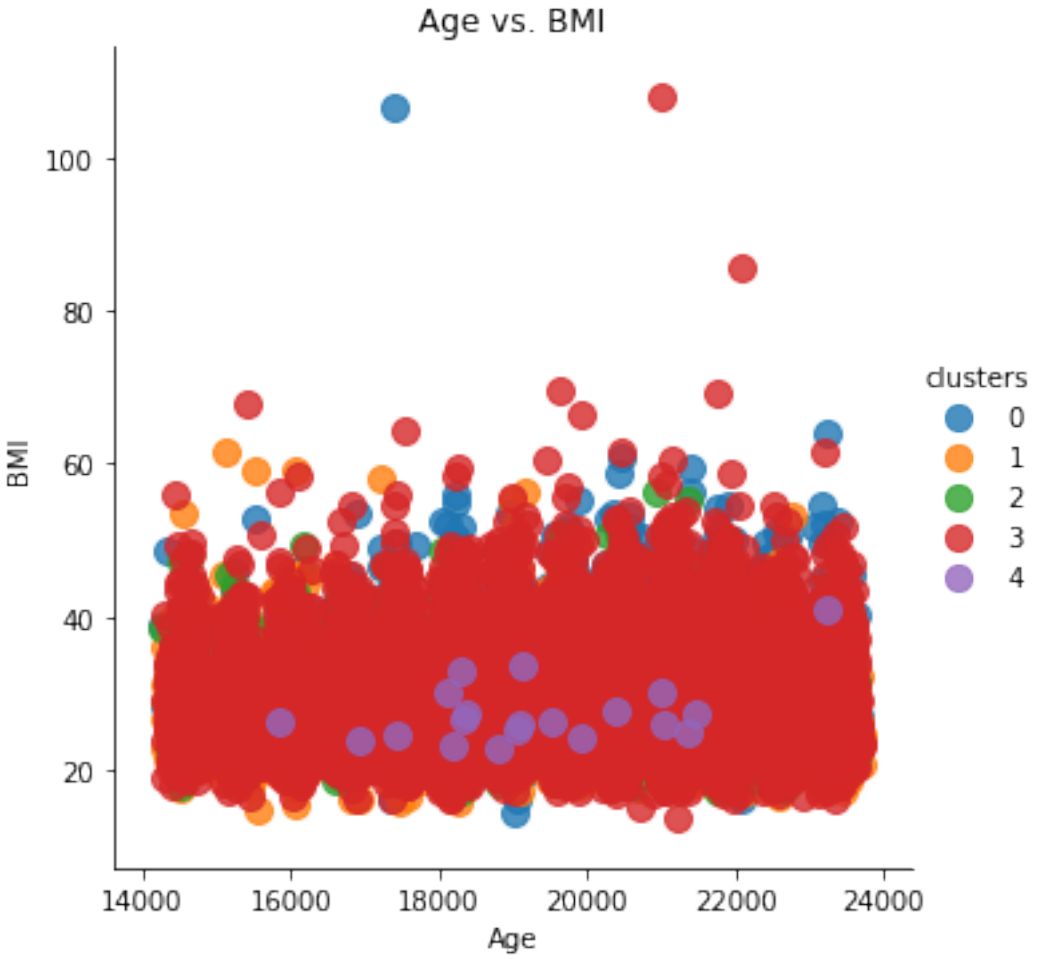
[ ]:

[135]:
```
#Scatter plot
from scipy import stats
import seaborn as sns


sns.lmplot('age', 'bmi',
           data=select_df2,
           fit_reg=False,
           hue="clusters",
           scatter_kws={"marker": "D",
```

```
                          "s": 100})
plt.title('Age vs. BMI')
plt.xlabel('Age')
plt.ylabel('BMI')
```

[135]:
```
Text(27.468689236111118, 0.5, 'BMI')
```



[137]:
```
select_df2['clusters'].describe()
```

[137]:
```
count    34795.000000
mean         1.991407
std          1.153685
min          0.000000
25%          1.000000
50%          3.000000
75%          3.000000
max          4.000000
```

```
Name: clusters, dtype: float64
```

[146]:
```
select_df2['pt_count'] = 1

select_df2[['clusters','pt_count']].groupby(['clusters']).sum()
```

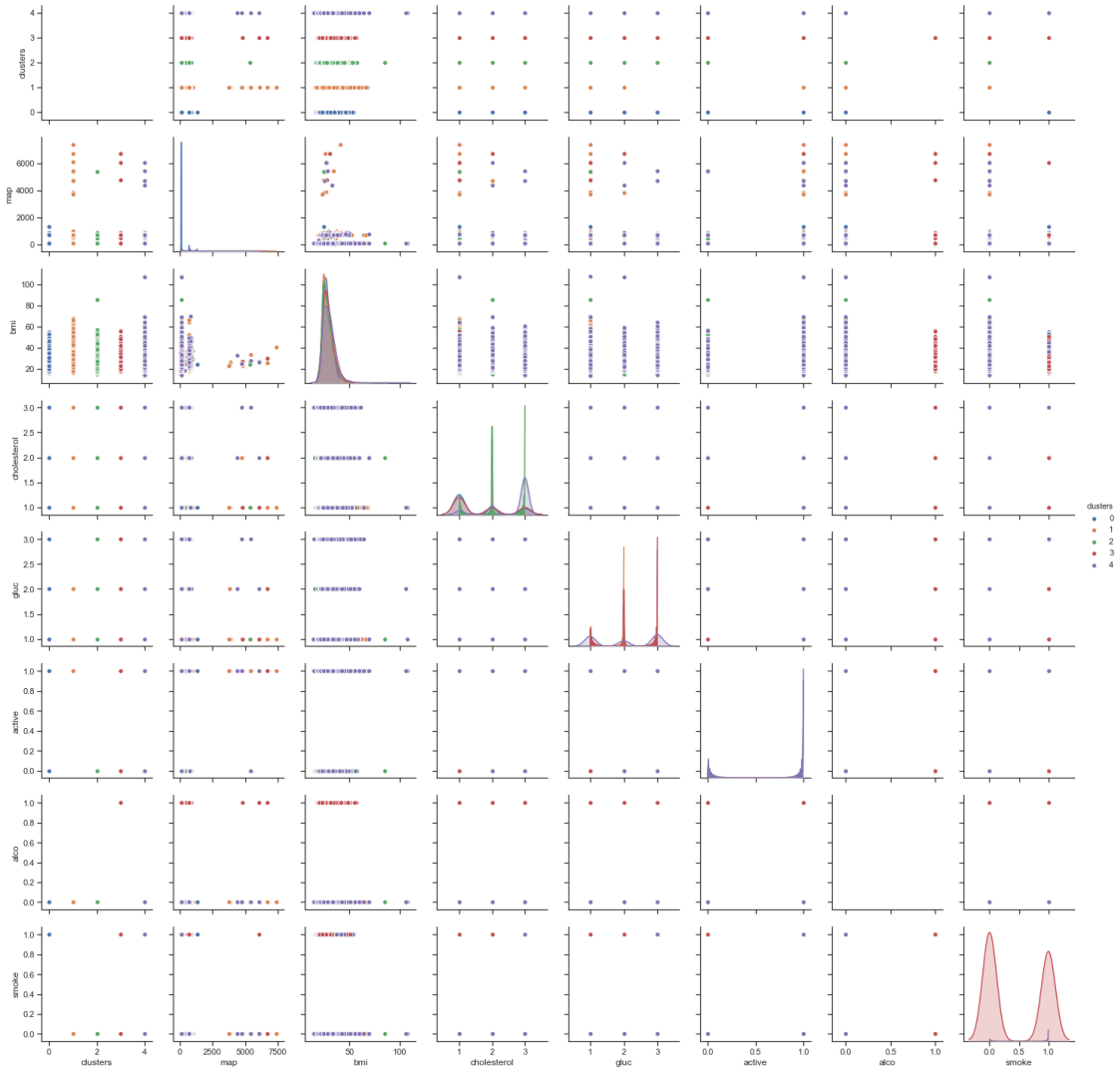
[146]:
```
          pt_count
clusters
0             4424
1            10014
2             1814
3            18523
4               20
```

[145]:
```
matrix = select_df2[['clusters','map','bmi','cholesterol','gluc','active','alco','smoke']].copy()

sns.set(style="ticks")

sns.pairplot(matrix, hue="clusters")
```

[145]:
```
<seaborn.axisgrid.PairGrid at 0x1a45662f90>
```


clusters
map
bmi
cholesterol
gluc
active
alco
smoke
clusters
0
1
2
3
4