survival_analysis

May 15, 2020

[47]:
```
# store start time to get execution time of entire script
import time
start_time = time.time()
```

[48]:
```
# helper functions for displaying table data

import numpy as np
from IPython.display import display_html

# n is the number of columns to display data in
def display_side_by_side(series_obj, n):
    df = pd.DataFrame(series_obj)
    partition = int(round(len(df) / n))
    lower_bound = 0
    upper_bound = partition
    args = []
    for i in range(n):
        args.append(df[lower_bound:upper_bound])
        lower_bound += partition
        upper_bound += partition
    helper(args)

def helper(args):
    html_str=''
    for df in args:
        html_str+=df.to_html()
    display_html(html_str.replace('table','table style="display:
 ↪inline"'),raw=True)
```

[49]:
```
# helper function for plotting out ground truth curves

import matplotlib.pyplot as plt
plt.rcParams["font.weight"] = "bold"

def get_ground_truth(data):
    relapsed = data[data.Illicit_Cens5 == 1]
    counts = relapsed['Illicit_Days5'].value_counts()
    counts = counts.to_dict()
    temp = [len(data)] * 365
    labels = list(range(365))
    for i in range(365):
        labels[i] += 1
    total = 0
    errors = []
    for i in range(365):
        try:
            temp[i] = temp[i] - counts[i+1] - total
            total = total + counts[i+1]
        except KeyError:
            errors.append(i)

    for ele in sorted(errors, reverse = False):
        if ele != 0:
            temp[ele] = temp[ele-1]
        else:
             temp[0] = len(data)
    temp = [x / len(data) for x in temp]
    return labels, temp
```

[50]:

```
from sklearn.model_selection import cross_validate
from sksurv.ensemble import GradientBoostingSurvivalAnalysis
from sksurv.ensemble import RandomSurvivalForest
from sksurv.linear_model import CoxnetSurvivalAnalysis

def run_models(X, y, label):
    rsf = RandomSurvivalForest()
    scores = cross_validate(rsf, X, y, cv=5)
    rsf_score = scores['test_score'].mean()
    print('RF score:', rsf_score)

    rsf = RandomSurvivalForest()
    rsf.fit(X, y)

    # l1_ratio = 1 adjusts model to implement LASSO method for penalties
    rcr = CoxnetSurvivalAnalysis(l1_ratio=1)
    # one-hot encode all variables (except primsev) to get hazards across␣
 ↪groups, drop highest reference group
    lasso_X = get_lasso_features(X)

    scores = cross_validate(rcr, lasso_X, y, cv=5)
    rcr_score = scores['test_score'].mean()
    print('Lasso score:', rcr_score)
    # fit_baseline_model = True allows us to create survival/hazard plots after␣
↪model is fit
    rcr = CoxnetSurvivalAnalysis(fit_baseline_model=True, l1_ratio=1)
    rcr.fit(lasso_X, y)

    # concordance index
    scores = {'Model': ['Random Forest','Lasso','Dataset Size'],
              label: [rsf_score,rcr_score,int(X.shape[0])]}

    concordance = pd.DataFrame(data=scores)

    # return scores and models
    return concordance, rsf, rcr
```

[51]:

```
def get_survival_graph(rsf, rcr, X, Y, label, filename):
    pred_surv_rsf = rsf.predict_survival_function(X)

    # one-hot encode all variables (except primsev) to get hazards across␣
↪groups, drop highest reference group
    lasso_X = get_lasso_features(X)

    pred_surv_rcr = rcr.predict_survival_function(lasso_X)

    # display survival plot
    plt.suptitle(label)
    plt.plot(np.mean([person for person in pred_surv_rsf], axis=0), label='RF')
    plt.plot(np.mean([person.y for person in pred_surv_rcr], axis=0),␣
↪label='Lasso')
    labels, temp = get_ground_truth(Y)
    plt.plot(labels, temp, label='Ground Truth')
    plt.legend()
    plt.xlim(0, 365)
    plt.xticks(np.arange(0, 365, step=50))
    plt.yticks(np.arange(0, 1.1, step=0.1))
    plt.savefig(filename)

    plt.show()
```

[52]:

```
from tqdm.notebook import tqdm # used to show progress bar

def get_feature_importance(X, y, rsf, rcr, label):
    # feature importances from Random Forest
    feature_importance_rf = pd.DataFrame({'Feature':list(X.columns),})
    feature_importance_rf[label] = 0

    scores = cross_validate(rsf, X, y, cv=5)
    reference = scores['test_score'].mean()
    for i,row in tqdm(feature_importance_rf.iterrows(),␣
↪total=feature_importance_rf.shape[0]):
        feat = row['Feature']
        temp_data = X.copy()
        temp_data[feat] = np.random.permutation(temp_data[feat].values)
        temp_scores = cross_validate(rsf, temp_data, y, cv=5)
        temp_score = temp_scores['test_score'].mean()
        percent_change = (reference - temp_score) / reference * 100 # percent␣
↪change
        if percent_change < 0:
            percent_change = 0 # removing feature helped model, should not be␣
↪reflected in feature importance
        feature_importance_rf.iloc[i, feature_importance_rf.columns.
↪get_loc(label)] = percent_change

    feature_importance_rf = feature_importance_rf.nlargest(10,[label]) # keep␣
↪top 10 features

    # feature importances from Lasso
    lasso_X = get_lasso_features(X)
    feature_importance_lasso = pd.DataFrame({'Feature':list(lasso_X.columns),
                                             label:np.average(rcr.coef_,␣
↪weights=rcr.alphas_, axis = 1),})
    # remove features that were zero-ed out by lasso
    feature_importance_lasso =␣
↪feature_importance_lasso[feature_importance_lasso[label] != 0]
    # convert regression coefficients to hazard ratios
    feature_importance_lasso[label] = np.exp(feature_importance_lasso[label])
    # rank by magnitude of deviation from 1
    feature_importance_lasso[label + '_adjusted'] = np.
↪absolute(feature_importance_lasso[label]-1)
    feature_importance_lasso = feature_importance_lasso.nlargest(10,[label +␣
↪'_adjusted']) # keep top 10 features

    return feature_importance_rf, feature_importance_lasso
```

```
[53]: def get_lasso_features(X):
          features_to_ignore =␣
      ↪['female_cd','nonwhite_cd','unemplmt_cd','SUDSy','primsev_cd_1','primsev_cd_2',
                                    ␣
      ↪'primsev_cd_3','primsev_cd_4','primsev_cd_5','primsev_cd_6']
          lasso_X = X.copy()
          for col in lasso_X.columns:
              if col not in features_to_ignore:
                  one_hot = pd.get_dummies(lasso_X[col], prefix=col)
```

```
            one_hot = one_hot.loc[:, ~one_hot.columns.str.endswith('1')] # drop␣
↪group and use as reference
            lasso_X = lasso_X.drop(col,axis = 1)
            lasso_X = lasso_X.join(one_hot)
    #print(lasso_X.columns)
    return lasso_X
```

Survival Analysis by Severity

[54]:

```
import pandas as pd
pd.set_option('display.max_rows', 500)
pd.set_option('display.max_columns', 500)
import csv

df = pd.read_csv('data/data_superset.csv')
df.head()
```

[54]:

```
   Unnamed: 0  Unnamed: 0.1  Unnamed: 0.1.1    ID State        City  \
0           0             1               2   929    OH   Cleveland
1           1             2               3   951    OH   Cleveland
2           2             3               4  1032    OH   Cleveland
3           3            18              19  1673    KY  Louisville
4           4            21              22  3870    AZ      Tucson

                    agyaddr  xobsyr_0  Illicit_Days5  Illicit_Cens5  \
0  1276 West Third St. #400      2006            354              0
1  1276 West Third St. #400      2006            365              0
2  1276 West Third St. #400      2006            365              0
3         1220 Bardstown Rd      2006            365              0
4      3130 E Broadway Blvd      2006              5              1

   female_cd  nonwhite_cd  unemplmt_cd  prsatx_cd  gvsg_cd  CWSg_0_cd  \
0          0            0            0          0        1          0
1          0            0            0          0        0          0
2          0            0            0          0        2          0
3          0            0            0          0        0          0
4          0            0            0          1        2          1

   srprobg_cd  dssg_0_cd  epsg_0_cd  adhdg_0_cd  cdsg_0_cd  cjsig_0_cd  \
0           1          0          1           0          1           1
1           1          0          0           0          0           1
2           1          1          1           1          1           0
3           0          0          1           1          0           0
4           2          2          2           1          2           1

   lrig_0_cd  srig_0_cd  SESg_0_cd  r4ag_0_cd  primsev_cd_1  primsev_cd_2  \
0          0          1          0          2             1             0
```

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

   primsev_cd_3  primsev_cd_4  primsev_cd_5  primsev_cd_6  B2a_0g  SUDSy_0  \
0             0             0             0             0       0        3
1             1             0             0             0       0        2
2             1             0             0             0       0        2
3             1             0             0             0       0        2
4             1             0             0             0       0       11

                                    Address        lat         lng state_name  \
0  1276 West Third St. #400, Cleveland, OH  41.501028  -81.697772       Ohio
1  1276 West Third St. #400, Cleveland, OH  41.501028  -81.697772       Ohio
2  1276 West Third St. #400, Cleveland, OH  41.501028  -81.697772       Ohio
3        1220 Bardstown Rd, Louisville, KY  38.236398  -85.717815   Kentucky
4         3130 E Broadway Blvd, Tucson, AZ  32.221465 -110.926070    Arizona

   county_FIPS    block_FIPS  murder_numg  %_dropoutg  %_povertyg  \
0      39035.0  3.903511e+14            0         0.0         0.0
1      39035.0  3.903511e+14            0         0.0         0.0
2      39035.0  3.903511e+14            0         0.0         0.0
3      21111.0  2.111101e+14            0         0.0         0.0
4       4019.0  4.019002e+13            0         0.0         0.0

   %_public_assistanceg  %_unemployedg closest  gran  \
0                   0.0            0.0     NaN   0.0
1                   0.0            0.0     NaN   0.0
2                   0.0            0.0     NaN   0.0
3                   0.0            0.0     NaN   0.0
4                   0.0            0.0     NaN   1.0

                                   point  pop_deng
0   ('41.501028000000005', '-81.697772')       0.0
1   ('41.501028000000005', '-81.697772')       0.0
2   ('41.501028000000005', '-81.697772')       0.0
3  ('38.236397499999995', '-85.7178152')       0.0
4  ('32.2214651', '-110.92607029999999')       0.0
```

[55]:

```
df['r4ag_0_cd'].value_counts()
```

[55]:

```
2    4225
0    4108
1    1735
Name: r4ag_0_cd, dtype: int64
```

```
[56]: # drop unnecessary columns
      cols_to_drop = ['Address','lat','lng','xobsyr_0','Unnamed: 0','Unnamed: 0.
       ↪1','Unnamed: 0.1.1',
                        ␣
       ↪'ID','State','City','agyaddr','state_name','gran','srprobg_cd','county_FIPS','block_FIPS',
                        'point','closest']

      df.drop(columns=cols_to_drop, inplace=True)
      df.dropna(inplace=True) # drops any remaining rows with null values

      # uncomment to get CONTROL statistics
      #cols_to_drop =␣
       ↪['pop_deng','%_dropoutg','%_unemployedg','%_public_assistanceg','%_povertyg','murder_numg']
      #df.drop(columns=cols_to_drop, inplace=True)

      df = df.astype(int)
      df = df.sample(frac=1).reset_index(drop=True) # shuffle rows
      df.shape
```

```
[56]: (10068, 31)
```

```
[57]: df.head()
```

```
[57]:    Illicit_Days5  Illicit_Cens5  female_cd  nonwhite_cd  unemplmt_cd  \
      0            149              1          1            1            1
      1            365              0          1            1            0
      2            135              0          1            0            0
      3            180              0          0            1            1
      4            112              0          0            1            0

         prsatx_cd  gvsg_cd  CWSg_0_cd  dssg_0_cd  epsg_0_cd  adhdg_0_cd  cdsg_0_cd  \
      0          1        0          1          0          0           0          0
      1          0        0          0          1          1           0          2
      2          1        2          1          2          1           0          0
      3          0        2          0          0          1           0          1
      4          0        0          0          1          1           1          2

         cjsig_0_cd  lrig_0_cd  srig_0_cd  SESg_0_cd  r4ag_0_cd  primsev_cd_1  \
      0           2          2          2          1          2             1
      1           2          2          2          0          0             1
      2           0          1          2          0          0             1
      3           1          1          2          0          2             1
      4           2          1          1          2          2             0

         primsev_cd_2  primsev_cd_3  primsev_cd_4  primsev_cd_5  primsev_cd_6  \
      0             0             0             0             0             0
      1             0             0             0             0             0
```

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

   B2a_0g  SUDSy_0  murder_numg  %_dropoutg  %_povertyg  %_public_assistanceg  \
0       2       10            2           0           0                     0
1       1        0            0           0           0                     0
2       2        6            0           0           0                     0
3       1        0            0           0           1                     0
4       1        4            0           0           0                     0

   %_unemployedg  pop_deng
0              0         0
1              0         0
2              0         0
3              0         0
4              0         0
```

Full Population Survival Analysis

[58]:

```
from sklearn.model_selection import train_test_split
from sksurv.util import Surv

predictor_var = 'Illicit_Days5'
censoring_var = 'Illicit_Cens5'

X = df.copy()
Y = X[[censoring_var, predictor_var]]
X.drop(columns=[censoring_var, predictor_var], inplace=True)
y = Surv.from_arrays(Y[censoring_var], Y[predictor_var]) # structured array to␣
 ↪ensure correct censoring

print(X.shape, y.shape)
```

```
(10068, 29) (10068,)
```

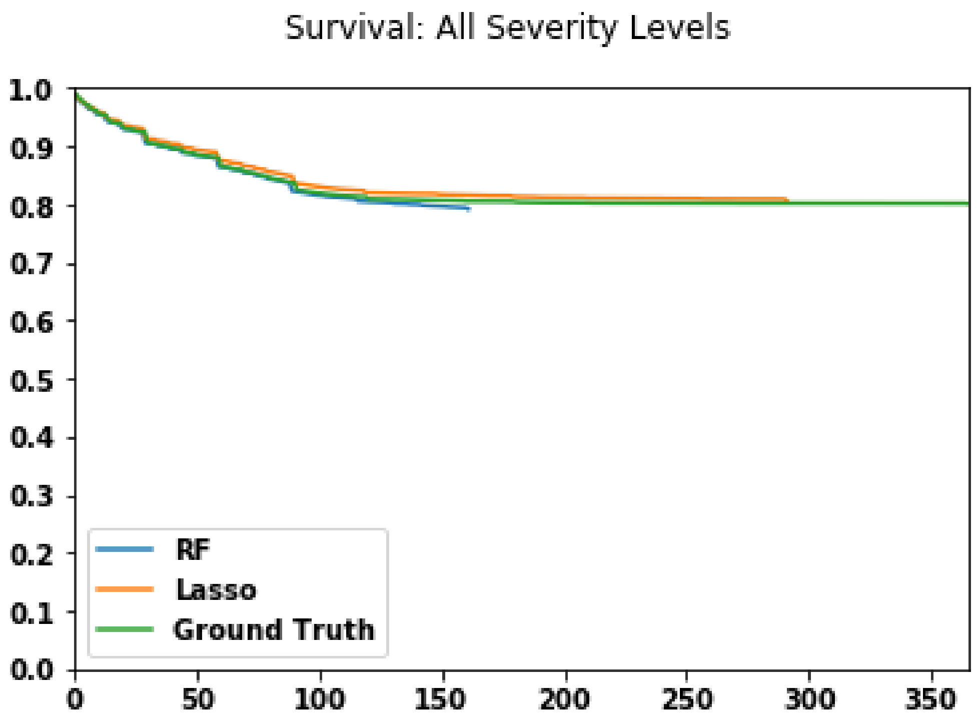
[59]:

```
%%time
full_concordance, rsf, rcr = run_models(X, y, 'ALL')
```

```
RF score: 0.6729187092855099
Lasso score: 0.6818858447762428
CPU times: user 31.3 s, sys: 3.28 s, total: 34.6 s
Wall time: 37.7 s
```

[60]:

```
get_survival_graph(rsf, rcr, X, Y, 'Survival: All Severity Levels','graphs/
 ↪survival_all.png')
```



Subclinical Severity Survival Analysis

[61]:
```
X = df[df.SUDSy_0 < 2]
Y = X[[censoring_var, predictor_var]]
X.drop(columns=[censoring_var, predictor_var, 'SUDSy_0'], inplace=True)

y = Surv.from_arrays(Y[censoring_var], Y[predictor_var]) # structured array to␣
↪ensure correct censoring

print(X.shape, y.shape)
```

```
(3250, 28) (3250,)
```

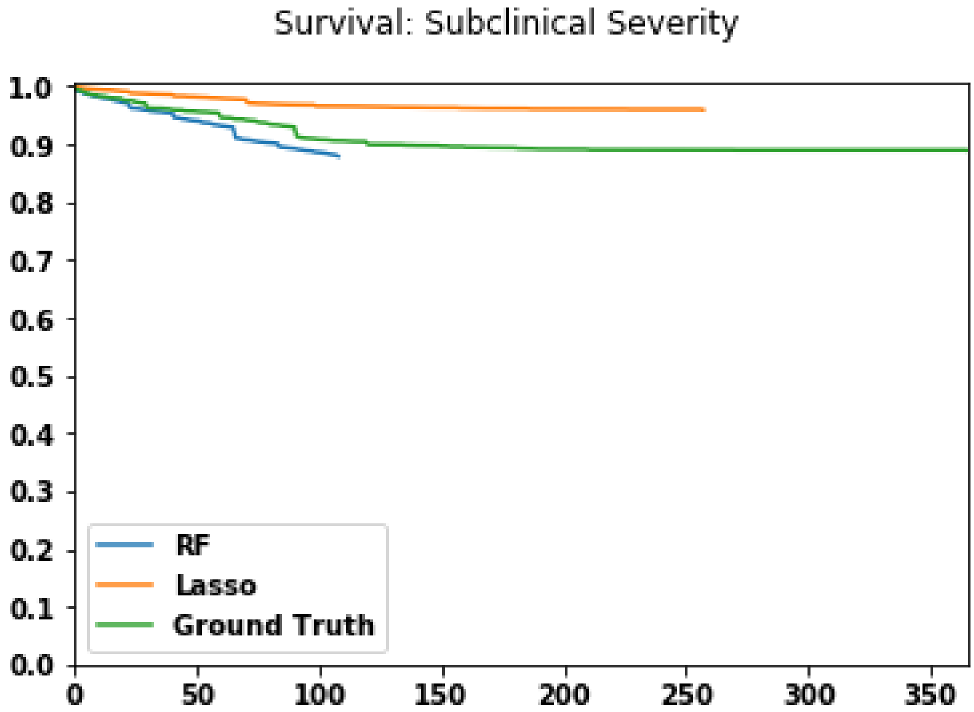
```
//anaconda3/lib/python3.7/site-packages/pandas/core/frame.py:4097:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: http://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  errors=errors,
```

[62]:
```
%%time
subclinical_concordance, rsf, rcr = run_models(X, y, 'SUB')
```

```
RF score: 0.6539875838187909
```

```
Lasso score: 0.6881885648855273
CPU times: user 8.09 s, sys: 664 ms, total: 8.76 s
Wall time: 8.92 s
```

```
[63]: get_survival_graph(rsf, rcr, X, Y, 'Survival: Subclinical Severity', 'graphs/
      ↪survival_subclinical.png')
```



```
[64]: %%time
      subclinical_feature_importance_rf, subclinical_feature_importance_lasso = \
                                                  get_feature_importance(X, y, rsf, rcr,␣
      ↪'SUB')
```

```
HBox(children=(IntProgress(value=0, max=28), HTML(value='')))


CPU times: user 2min 29s, sys: 6.84 s, total: 2min 36s
Wall time: 2min 49s
```

Mild/Moderate Severity Survival Analysis

```
[65]: X = df[df.SUDSy_0 >= 2]
      X = X[X.SUDSy_0 <= 5]
      Y = X[[censoring_var, predictor_var]]
      X.drop(columns=[censoring_var, predictor_var, 'SUDSy_0'], inplace=True)
```

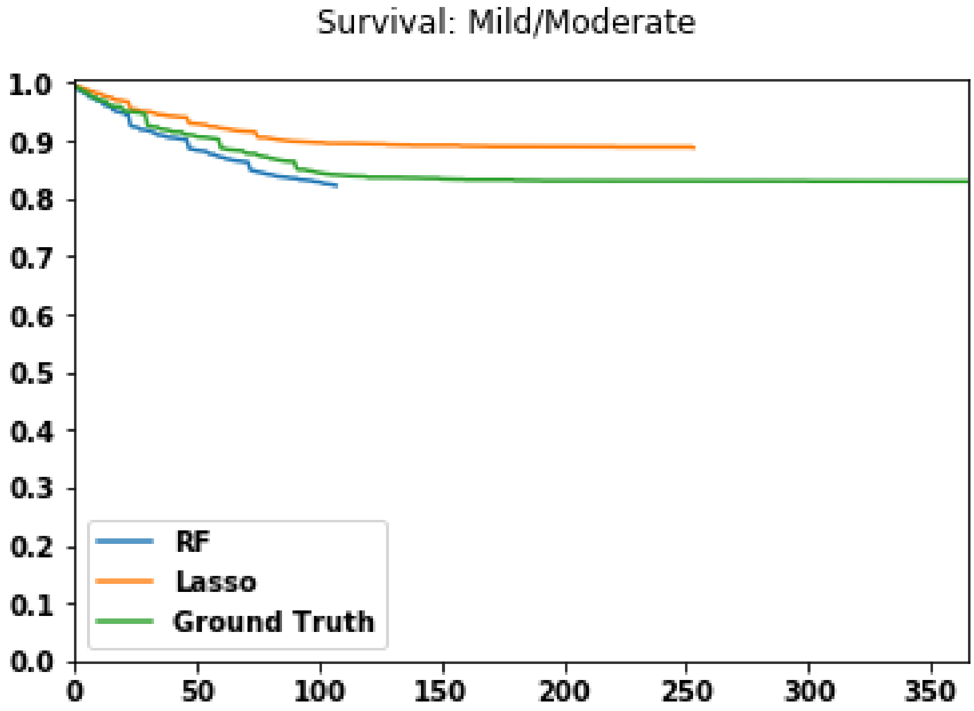
```
y = Surv.from_arrays(Y[censoring_var], Y[predictor_var]) # structured array to␣
 ↪ensure correct censoring

print(X.shape, y.shape)
```

```
(2838, 28) (2838,)
```

[66]:
```
%%time
mild_concordance, rsf, rcr = run_models(X, y, 'MILD')
```

```
RF score: 0.5715619738619677
Lasso score: 0.5985526576573125
CPU times: user 6.99 s, sys: 442 ms, total: 7.43 s
Wall time: 6.97 s
```

[67]:
```
get_survival_graph(rsf, rcr, X, Y, 'Survival: Mild/Moderate', 'graphs/
 ↪survival_mild.png')
```



[68]:
```
%%time
mild_feature_importance_rf, mild_feature_importance_lasso =␣
 ↪get_feature_importance(X, y, rsf, rcr, 'MILD')
```

```
HBox(children=(IntProgress(value=0, max=28), HTML(value='')))
```

```
CPU times: user 2min 19s, sys: 7.1 s, total: 2min 26s
Wall time: 2min 36s
```

Severe Severity Survival Analysis

[69]:

```
X = df[df.SUDSy_0 > 5]
Y = X[[censoring_var, predictor_var]]
X.drop(columns=[censoring_var, predictor_var, 'SUDSy_0'], inplace=True)

y = Surv.from_arrays(Y[censoring_var], Y[predictor_var]) # structured array to␣
 ↪ensure correct censoring

print(X.shape, y.shape)
```

```
(3980, 28) (3980,)
```

```
//anaconda3/lib/python3.7/site-packages/pandas/core/frame.py:4097:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: http://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  errors=errors,
```

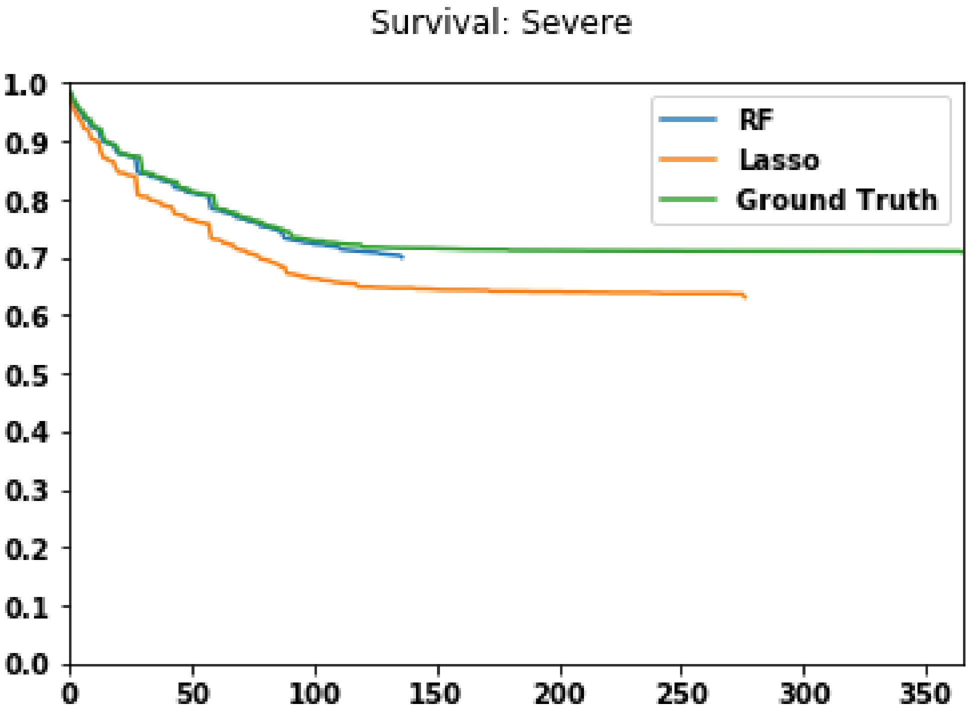
[70]:

```
%%time
severe_concordance, rsf, rcr = run_models(X, y, 'SEVERE')
```

```
RF score: 0.6101425909578948
Lasso score: 0.6177165003984422
CPU times: user 10.5 s, sys: 963 ms, total: 11.4 s
Wall time: 11.3 s
```

[71]:

```
get_survival_graph(rsf, rcr, X, Y, 'Survival: Severe', 'graphs/survival_severe.
 ↪png')
```



```
[72]: %%time
      severe_feature_importance_rf, severe_feature_importance_lasso =␣
       ↪get_feature_importance(X, y, rsf, rcr, 'SEVERE')
```

```
HBox(children=(IntProgress(value=0, max=28), HTML(value='')))
```

```
CPU times: user 3min 29s, sys: 19.9 s, total: 3min 49s
Wall time: 4min 5s
```

Overall Statistics

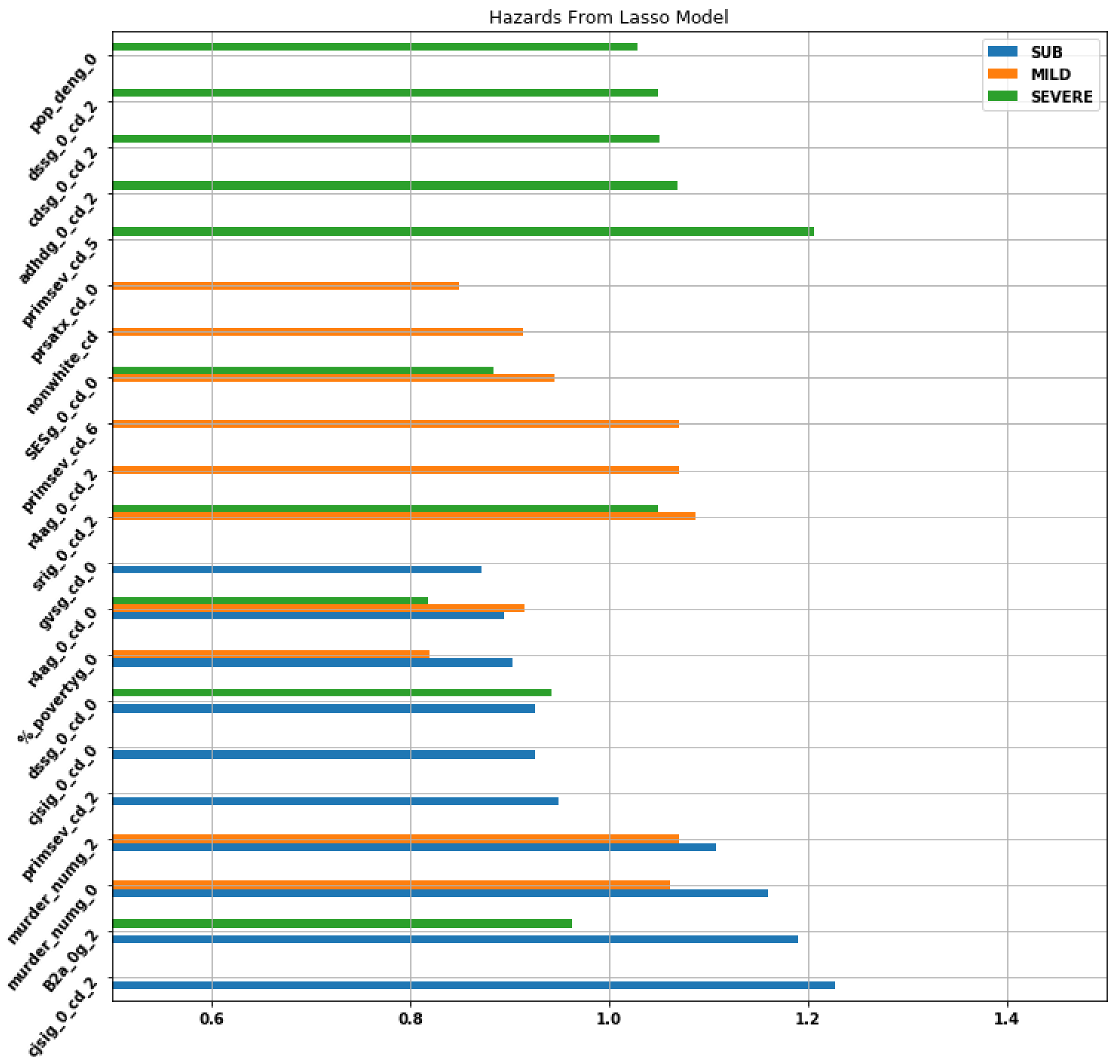
```
[73]: overall_concordance = pd.concat([subclinical_concordance,␣
       ↪mild_concordance['MILD'], severe_concordance['SEVERE'],
                                          full_concordance['ALL']], axis=1)
      pd.DataFrame(data=overall_concordance).round(4)
```

```
[73]:            Model        SUB        MILD      SEVERE         ALL
      0  Random Forest     0.6540      0.5716      0.6101      0.6729
      1          Lasso     0.6882      0.5986      0.6177      0.6819
      2   Dataset Size  3250.0000   2838.0000   3980.0000  10068.0000
```

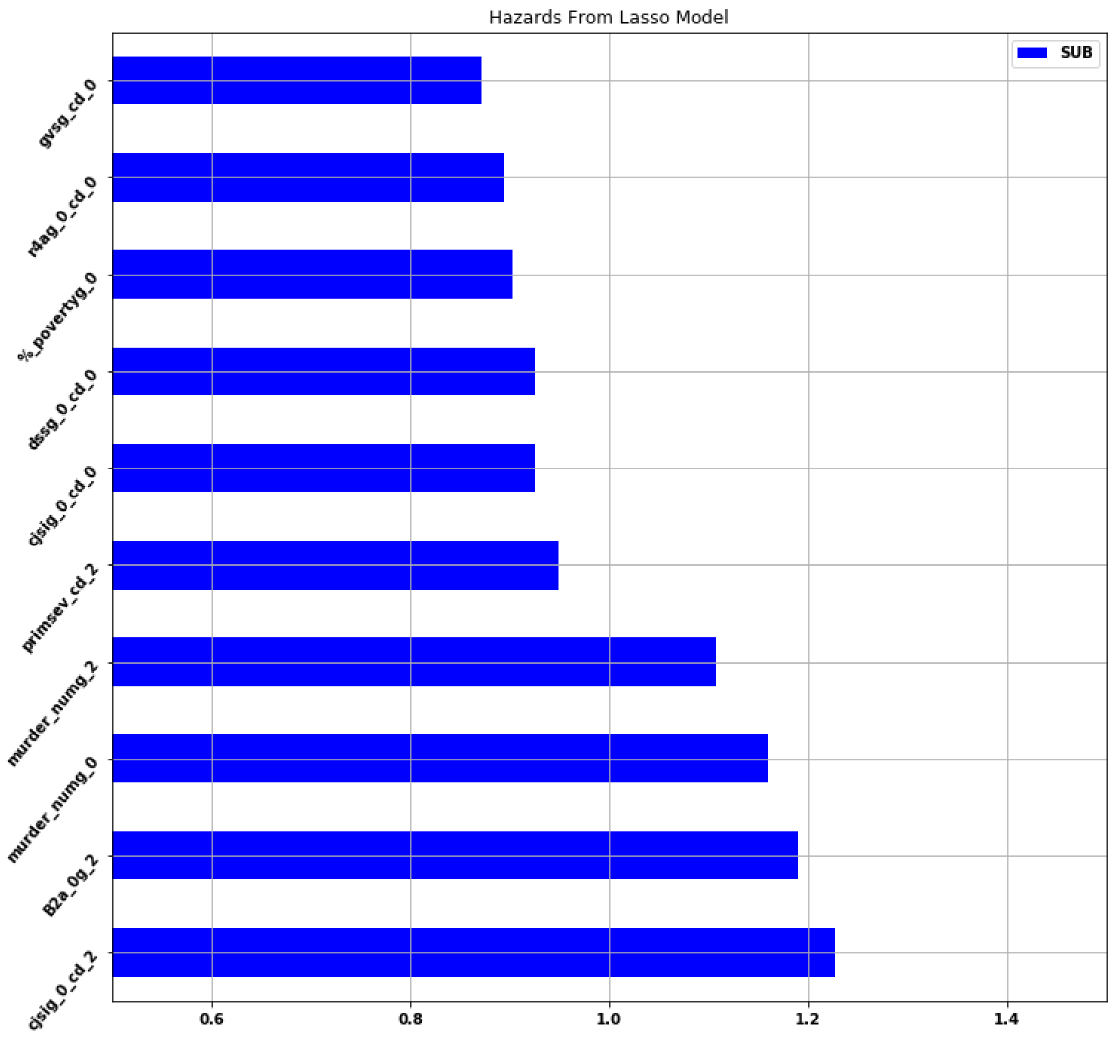
```
[74]: overall_feature_importance_lasso = pd.
       ↪merge(subclinical_feature_importance_lasso, \
                                            mild_feature_importance_lasso,␣
 ↪on='Feature', how='outer')
overall_feature_importance_lasso = pd.merge(overall_feature_importance_lasso, \
                                            severe_feature_importance_lasso,␣
 ↪on='Feature', how='outer')
overall_feature_importance_lasso.fillna(0, inplace=True)
display_side_by_side(overall_feature_importance_lasso, 2)
```

[75]:

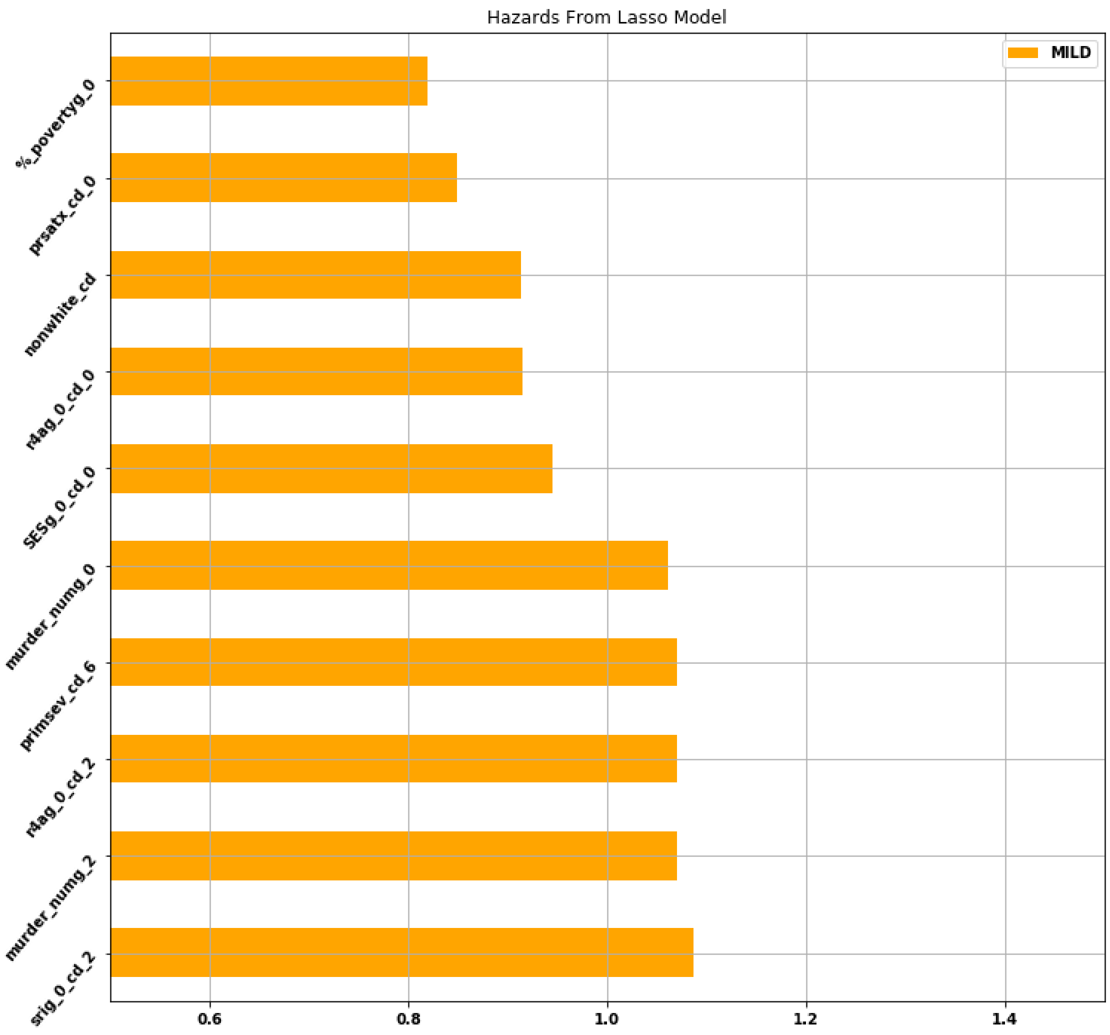
```
haz_df = pd.DataFrame({'SUB': overall_feature_importance_lasso['SUB'].tolist(),
                   'MILD': overall_feature_importance_lasso['MILD'].tolist(),
                   'SEVERE': overall_feature_importance_lasso['SEVERE'].
 ↪tolist()},
                  index=overall_feature_importance_lasso['Feature'].tolist())
haz_df = haz_df.replace(1, 0)
haz_df.sort_values(by=['SUB','MILD','SEVERE'], ascending=False, inplace=True)
ax = haz_df.plot.barh(rot=50, figsize=(12, 12))
ax.set_xlim([0.5,1.5])
ax.grid()
ax.set_title('Hazards From Lasso Model')
fig = ax.get_figure()

fig.savefig('graphs/hazards_lasso.png', bbox_inches='tight')
```



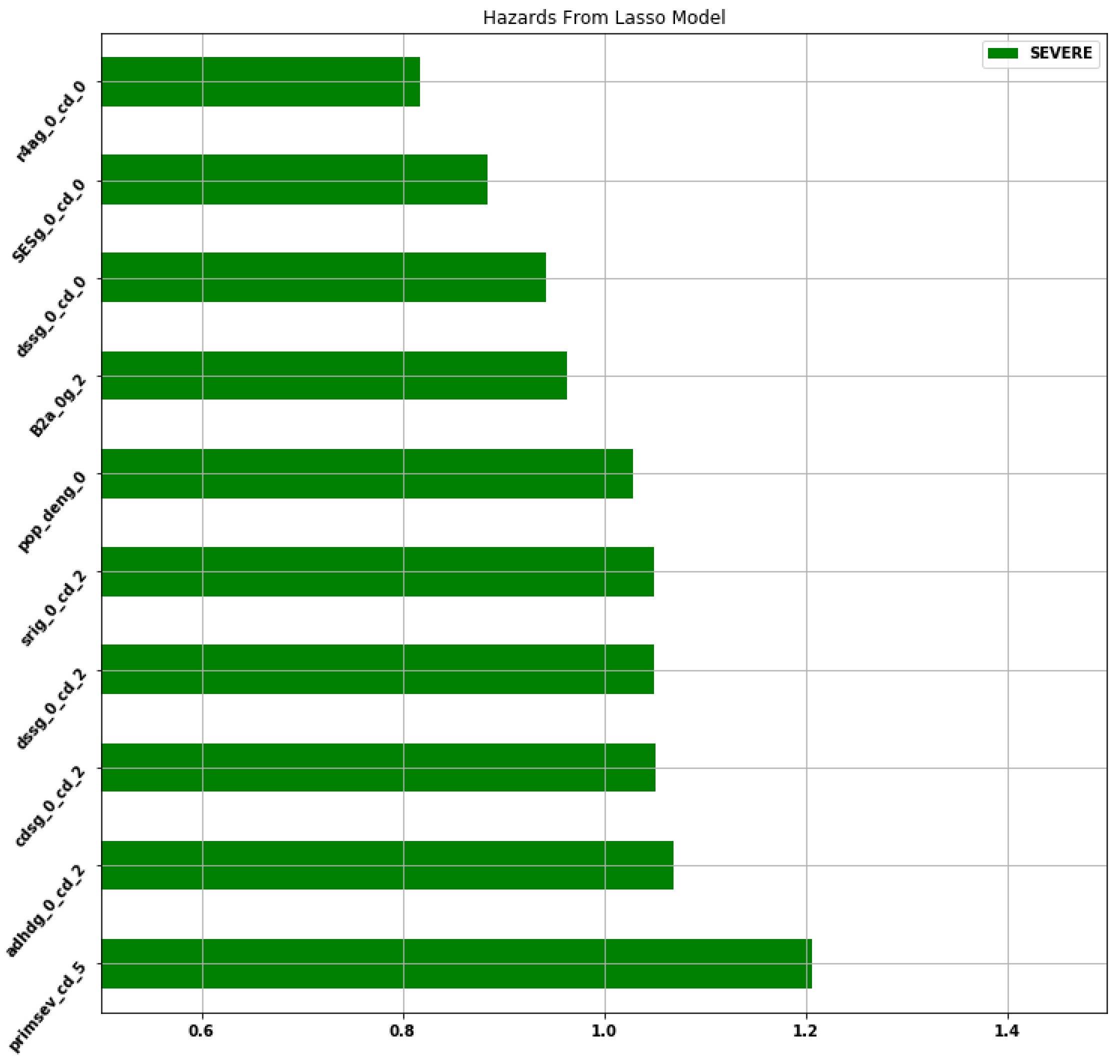
[76]:
```
haz_sub = pd.DataFrame({'SUB': overall_feature_importance_lasso['SUB'].
 ↪tolist()},
                  index=overall_feature_importance_lasso['Feature'].tolist())
haz_sub = haz_sub[haz_sub.SUB != 0]
haz_sub.sort_values(by=['SUB'], ascending=False, inplace=True)

ax = haz_sub.plot.barh(rot=50, figsize=(12, 12), color='blue')
ax.set_xlim([0.5,1.5])
ax.grid()
ax.set_title('Hazards From Lasso Model')
fig = ax.get_figure()

fig.savefig('graphs/hazards_lasso_sub.png', bbox_inches='tight')
```



```
[77]: haz_mild = pd.DataFrame({'MILD': overall_feature_importance_lasso['MILD'].
       ↪tolist()},
                          index=overall_feature_importance_lasso['Feature'].tolist())
      haz_mild = haz_mild[haz_mild.MILD != 0]
      haz_mild.sort_values(by=['MILD'], ascending=False, inplace=True)

      ax = haz_mild.plot.barh(rot=50, figsize=(12, 12), color='orange')
      ax.set_xlim([0.5,1.5])
      ax.grid()
      ax.set_title('Hazards From Lasso Model')
      fig = ax.get_figure()

      fig.savefig('graphs/hazards_lasso_mild.png', bbox_inches='tight')
```



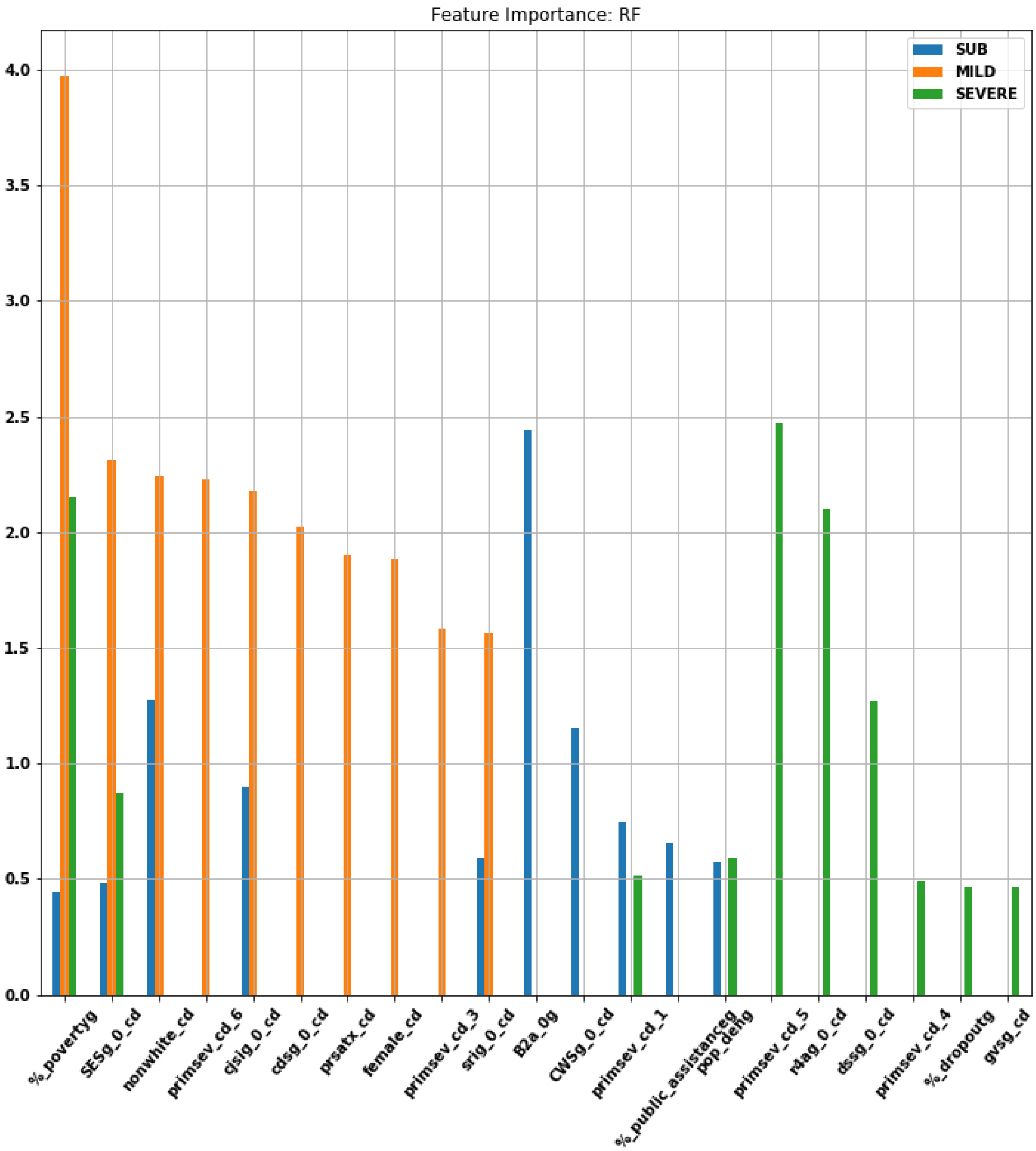
[78]:
```
haz_severe = pd.DataFrame({'SEVERE': overall_feature_importance_lasso['SEVERE'].
 ↪tolist()},
                  index=overall_feature_importance_lasso['Feature'].tolist())
haz_severe = haz_severe[haz_severe.SEVERE != 0]
haz_severe.sort_values(by=['SEVERE'], ascending=False, inplace=True)

ax = haz_severe.plot.barh(rot=50, figsize=(12, 12), color='green')
ax.set_xlim([0.5,1.5])
ax.grid()
ax.set_title('Hazards From Lasso Model')
fig = ax.get_figure()

fig.savefig('graphs/hazards_lasso_severe.png', bbox_inches='tight')
```



[79]:
```
overall_feature_importance_rf = pd.merge(subclinical_feature_importance_rf,␣
 ↪mild_feature_importance_rf, on='Feature', how='outer')
overall_feature_importance_rf = pd.merge(overall_feature_importance_rf,␣
 ↪severe_feature_importance_rf, on='Feature', how='outer')
overall_feature_importance_rf.fillna(0, inplace=True)
display_side_by_side(overall_feature_importance_rf, 4)
```

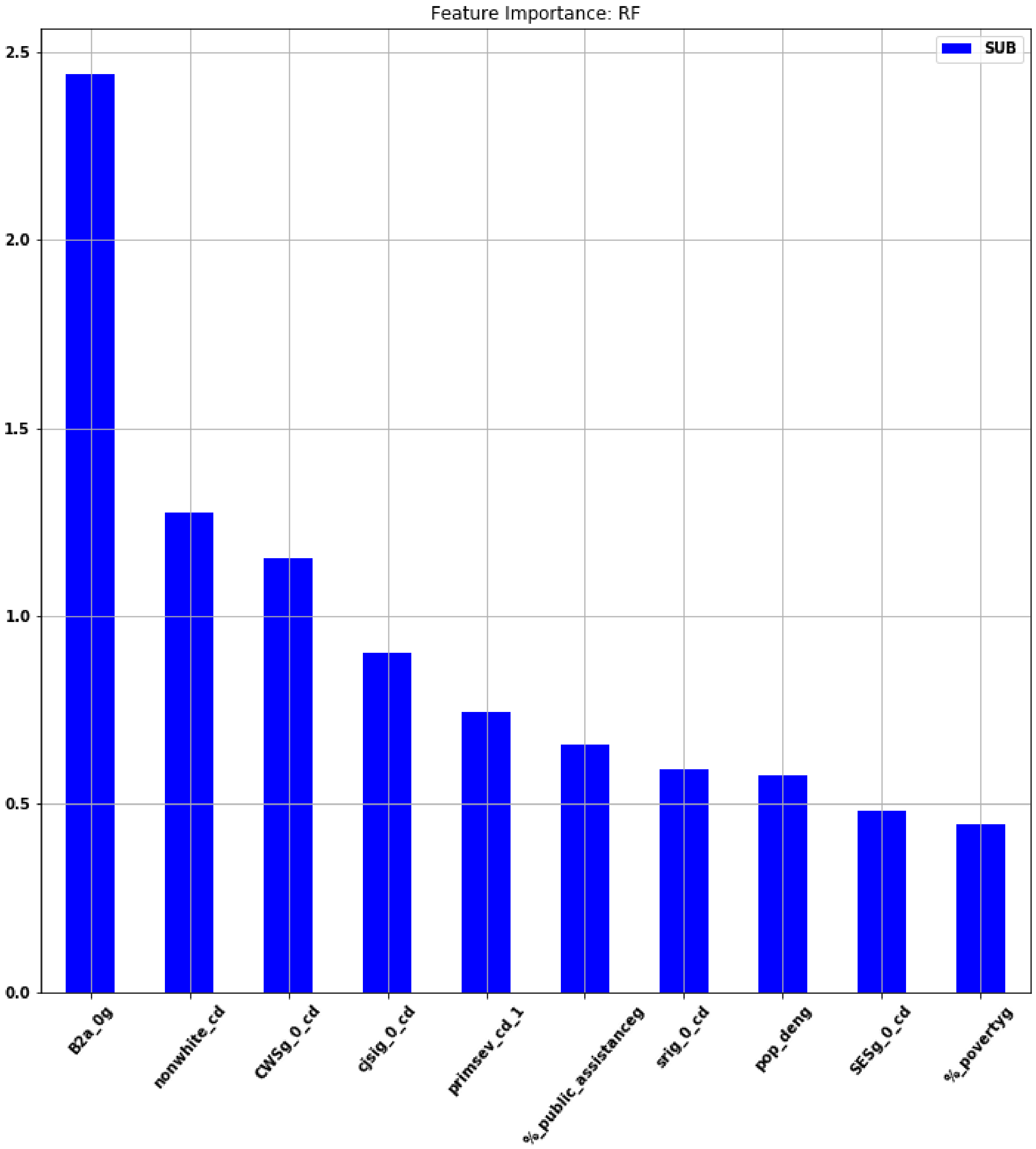
[80]:
```
# feature importance for rf across all ages
feature_importance = pd.DataFrame({'SUB': overall_feature_importance_rf['SUB'].
 ↪tolist(),
                   'MILD': overall_feature_importance_rf['MILD'].tolist(),
                   'SEVERE': overall_feature_importance_rf['SEVERE'].tolist()},
                  index=overall_feature_importance_rf['Feature'].tolist())
# John asked to sort this graph by MILD
```

```
feature_importance.sort_values(by=['MILD','SUB','SEVERE'], ascending=False,␣
 ↪inplace=True)
ax = feature_importance.plot.bar(rot=50, figsize=(12, 12))
ax.grid()
ax.set_title('Feature Importance: RF')
fig = ax.get_figure()

fig.savefig('graphs/feature_importance.png', bbox_inches='tight')
```



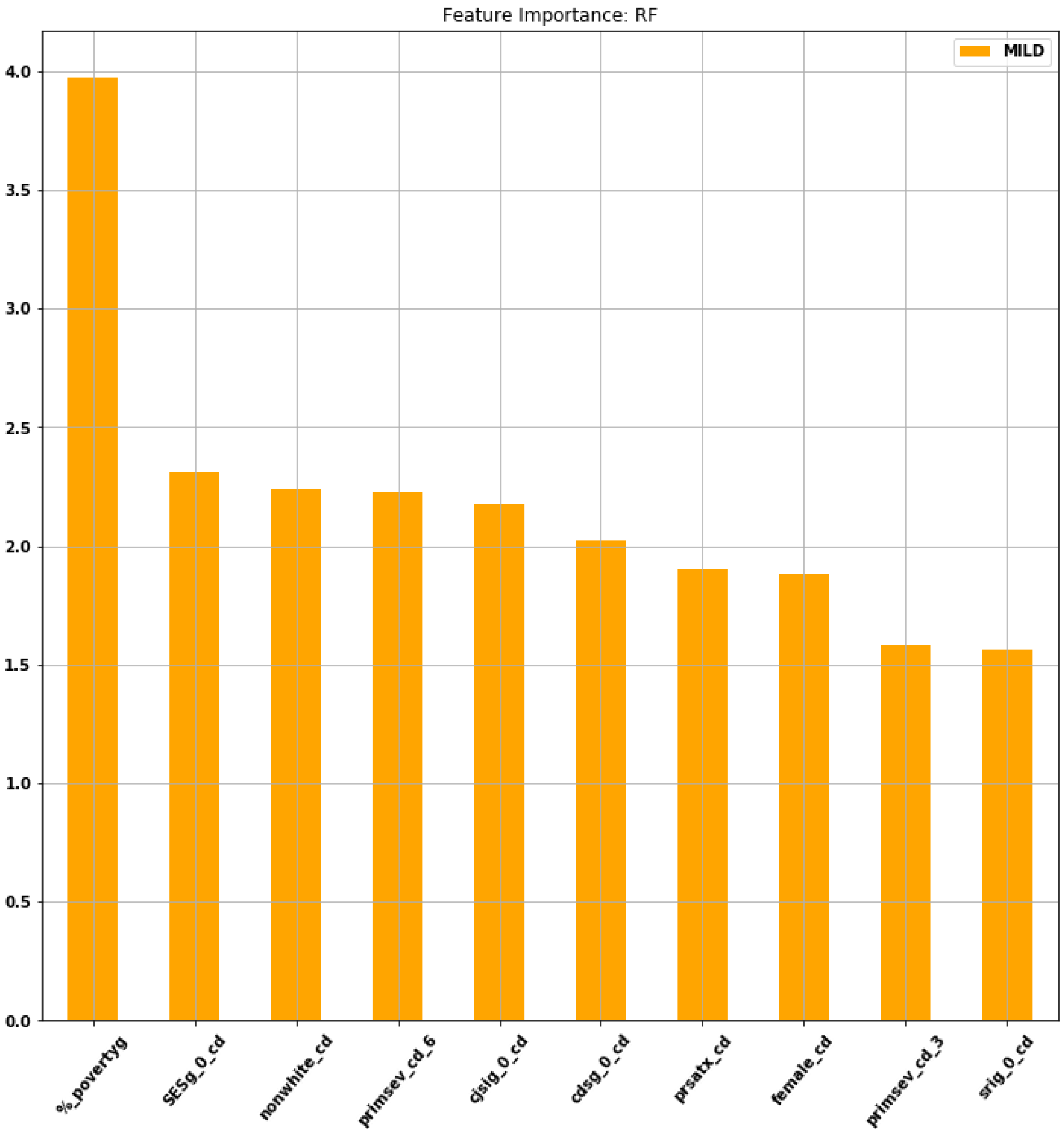
[81]:

```
# feature importance for rf across all ages
feature_importance_sub = pd.DataFrame({'SUB':␣
 ↪overall_feature_importance_rf['SUB'].tolist()},
                  index=overall_feature_importance_rf['Feature'].tolist())
feature_importance_sub = feature_importance_sub[feature_importance_sub.SUB != 0]
# John asked to sort this graph by MILD
feature_importance_sub.sort_values(by=['SUB'], ascending=False, inplace=True)
ax = feature_importance_sub.plot.bar(rot=50, figsize=(12, 12), color='blue')
ax.grid()
ax.set_title('Feature Importance: RF')
fig = ax.get_figure()

fig.savefig('graphs/feature_importance_sub.png', bbox_inches='tight')
```



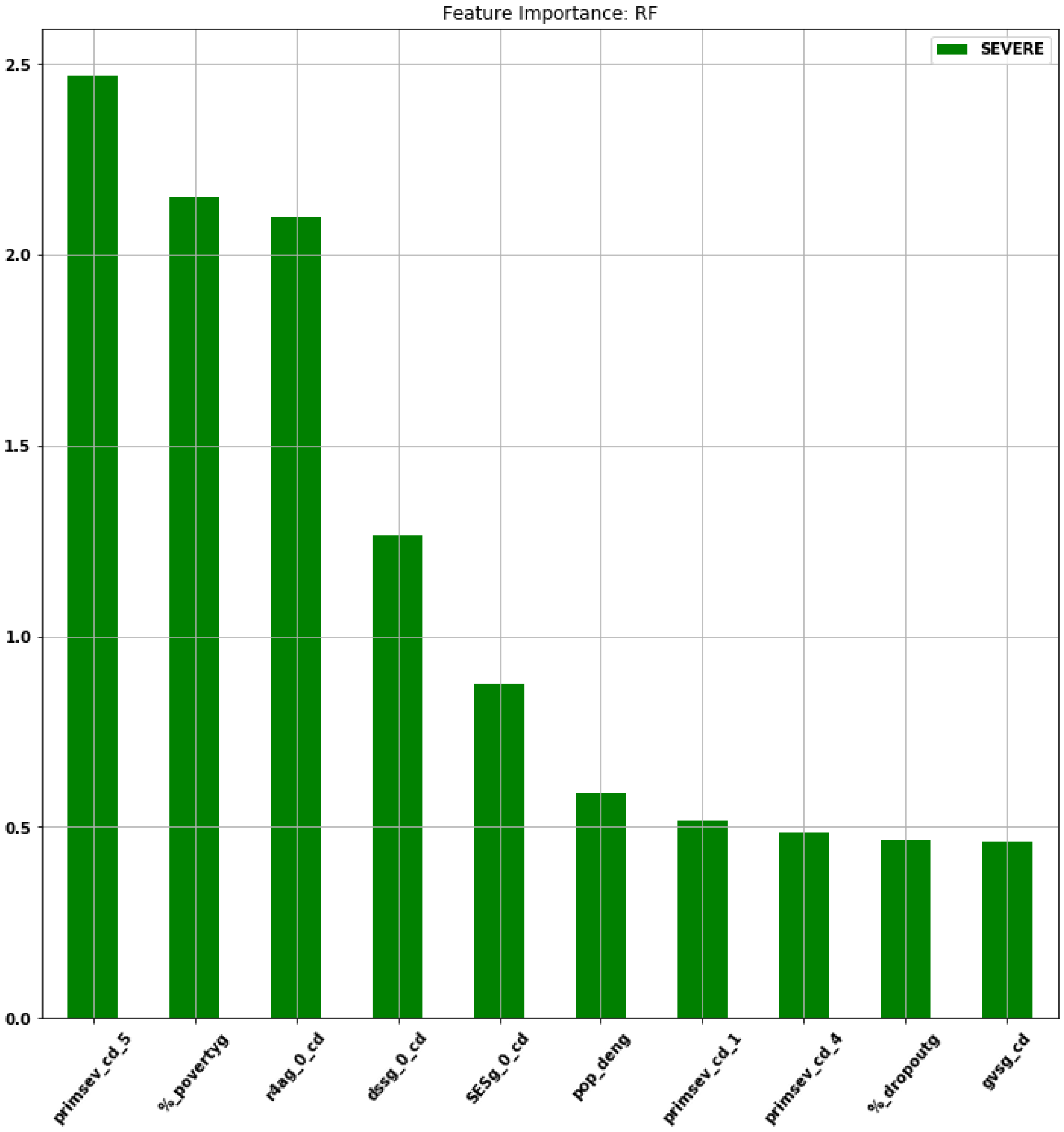
```
[82]: # feature importance for rf across all ages
      feature_importance_mild = pd.DataFrame({'MILD':␣
       ↪overall_feature_importance_rf['MILD'].tolist()},
                          index=overall_feature_importance_rf['Feature'].tolist())
      feature_importance_mild = feature_importance_mild[feature_importance_mild.MILD !
       ↪= 0]
      # John asked to sort this graph by MILD
      feature_importance_mild.sort_values(by=['MILD'], ascending=False, inplace=True)
      ax = feature_importance_mild.plot.bar(rot=50, figsize=(12, 12), color='orange')
```

```
ax.grid()
ax.set_title('Feature Importance: RF')
fig = ax.get_figure()

fig.savefig('graphs/feature_importance_mild.png', bbox_inches='tight')
```



[83]:
```
# feature importance for rf across all ages
feature_importance_severe = pd.DataFrame({'SEVERE':␣
 ↪overall_feature_importance_rf['SEVERE'].tolist()},
                    index=overall_feature_importance_rf['Feature'].tolist())
```

```
feature_importance_severe = feature_importance_severe[feature_importance_severe.SEVERE != 0]
# John asked to sort this graph by MILD
feature_importance_severe.sort_values(by=['SEVERE'], ascending=False, inplace=True)
ax = feature_importance_severe.plot.bar(rot=50, figsize=(12, 12), color='green')
ax.grid()
ax.set_title('Feature Importance: RF')
fig = ax.get_figure()

fig.savefig('graphs/feature_importance_severe.png', bbox_inches='tight')
```



[84]:

```
# top features in both models across all severity groups
rf = overall_feature_importance_rf['Feature'].tolist()
lasso = overall_feature_importance_lasso['Feature'].tolist()

common_features = []
lasso_common_features = []

for elem_rf in rf:
    for elem_lasso in lasso:
        if elem_lasso.startswith(elem_rf):
            common_features.append(elem_rf)
            lasso_common_features.append(elem_lasso)

common_features = list(set(common_features))
lasso_common_features = list(set(lasso_common_features))
```

[85]:

```
def analyze_common_features(subgroup):
    global common_features
    global lasso_common_features

    data = []

    for feat in common_features:
        temp = []
        temp.append(feat)
        temp.append(float(overall_feature_importance_rf.
 ↪loc[overall_feature_importance_rf['Feature'] == feat, subgroup]))
        for i,row in overall_feature_importance_lasso.iterrows():
            if row['Feature'].startswith(feat):
                temp.append((row['Feature'], row[subgroup]))
        data.append(temp)

    df = pd.DataFrame(data=data, columns=['Feature', 'RF', 'Lasso', 'Lasso_'])
    df = df.fillna(0)

    """for i,row in df.iterrows():
        if row['Lasso'][1] == 0:
            df.iloc[i, df.columns.get_loc('Lasso')] = np.nan
    df = df.dropna()


    df = df[df.RF != 0]"""
    return df
```

[86]:

```
analyze_common_features('SUB')
```

```
[86]:          Feature        RF                                  Lasso  \
      0       pop_deng  0.573440                     (pop_deng_0, 0.0)
      1   primsev_cd_6  0.000000                   (primsev_cd_6, 0.0)
      2      prsatx_cd  0.000000                     (prsatx_cd_0, 0.0)
      3   primsev_cd_5  0.000000                   (primsev_cd_5, 0.0)
      4      r4ag_0_cd  0.000000    (r4ag_0_cd_0, 0.8943756250236367)
      5      srig_0_cd  0.592309                     (srig_0_cd_2, 0.0)
      6        B2a_0g  2.439656        (B2a_0g_2, 1.190314278250104)
      7     cjsig_0_cd  0.899658   (cjsig_0_cd_2, 1.2276726576437922)
      8      cdsg_0_cd  0.000000                     (cdsg_0_cd_2, 0.0)
      9        gvsg_cd  0.000000      (gvsg_cd_0, 0.8719665245021884)
      10     SESg_0_cd  0.480806                     (SESg_0_cd_0, 0.0)
      11     dssg_0_cd  0.000000    (dssg_0_cd_0, 0.9256993213006859)
      12     %_povertyg  0.444665   (%_povertyg_0, 0.9034016255204161)
      13    nonwhite_cd  1.274638                     (nonwhite_cd, 0.0)

                                      Lasso_
      0                                    0
      1                                    0
      2                                    0
      3                                    0
      4                  (r4ag_0_cd_2, 0.0)
      5                                    0
      6                                    0
      7   (cjsig_0_cd_0, 0.9258371119040572)
      8                                    0
      9                                    0
      10                                   0
      11                 (dssg_0_cd_2, 0.0)
      12                                   0
      13                                   0
```

```
[87]: analyze_common_features('MILD')
```

```
[87]:          Feature        RF                                  Lasso  \
      0       pop_deng  0.000000                     (pop_deng_0, 0.0)
      1   primsev_cd_6  2.226833   (primsev_cd_6, 1.0700582678355541)
      2      prsatx_cd  1.900921    (prsatx_cd_0, 0.8493564319288581)
      3   primsev_cd_5  0.000000                   (primsev_cd_5, 0.0)
      4      r4ag_0_cd  0.000000     (r4ag_0_cd_0, 0.914863462824036)
      5      srig_0_cd  1.560394    (srig_0_cd_2, 1.0859730943172983)
      6        B2a_0g  0.000000                        (B2a_0g_2, 0.0)
      7     cjsig_0_cd  2.176948                   (cjsig_0_cd_2, 0.0)
      8      cdsg_0_cd  2.025326                     (cdsg_0_cd_2, 0.0)
      9        gvsg_cd  0.000000                       (gvsg_cd_0, 0.0)
      10     SESg_0_cd  2.312789     (SESg_0_cd_0, 0.9451013277176767)
      11     dssg_0_cd  0.000000                     (dssg_0_cd_0, 0.0)
```

```
12    %_povertyg  3.972744  (%_povertyg_0, 0.8195578460391757)
13   nonwhite_cd  2.242264   (nonwhite_cd, 0.9136070915315466)

                               Lasso_
0                                   0
1                                   0
2                                   0
3                                   0
4   (r4ag_0_cd_2, 1.0706710621496862)
5                                   0
6                                   0
7                 (cjsig_0_cd_0, 0.0)
8                                   0
9                                   0
10                                  0
11                 (dssg_0_cd_2, 0.0)
12                                  0
13                                  0
```

[88]:
```
analyze_common_features('SEVERE')
```

[88]:
```
         Feature        RF                              Lasso  \
0       pop_deng  0.589556   (pop_deng_0, 1.0287385555084427)
1   primsev_cd_6  0.000000                (primsev_cd_6, 0.0)
2      prsatx_cd  0.000000                 (prsatx_cd_0, 0.0)
3   primsev_cd_5  2.469815  (primsev_cd_5, 1.206089393203066)
4      r4ag_0_cd  2.099218  (r4ag_0_cd_0, 0.8173748295251714)
5      srig_0_cd  0.000000  (srig_0_cd_2, 1.0494541105644781)
6         B2a_0g  0.000000     (B2a_0g_2, 0.9630940196453059)
7     cjsig_0_cd  0.000000                (cjsig_0_cd_2, 0.0)
8      cdsg_0_cd  0.000000  (cdsg_0_cd_2, 1.0509071441402698)
9        gvsg_cd  0.462539                   (gvsg_cd_0, 0.0)
10     SESg_0_cd  0.875159  (SESg_0_cd_0, 0.8836409928869089)
11     dssg_0_cd  1.266258  (dssg_0_cd_0, 0.9422487596626504)
12    %_povertyg  2.151659                (%_povertyg_0, 0.0)
13   nonwhite_cd  0.000000                 (nonwhite_cd, 0.0)

                               Lasso_
0                                   0
1                                   0
2                                   0
3                                   0
4                  (r4ag_0_cd_2, 0.0)
5                                   0
6                                   0
7                 (cjsig_0_cd_0, 0.0)
8                                   0
```

```
9                                   0
10                                  0
11  (dssg_0_cd_2, 1.0499228872371273)
12                                  0
13                                  0
```

[89]:

```
# print out total notebook execution time
total_seconds = int(time.time() - start_time)
minutes = total_seconds // 60
seconds = total_seconds % 60
print("--- " + str(minutes) + " minutes " + str(seconds) + " seconds ---")
```

```
--- 10 minutes 52 seconds ---
```

[ ]: