linear_regression_XYZ_MET-standing

January 12, 2021

[1]:
```
from helpers import pandas_helper as pdh
from helpers import math_helper as mth
from sensors.activpal import *
from utils import read_functions

from scipy.stats import linregress
from sklearn.linear_model import LinearRegression
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error
from sklearn.feature_selection import RFE
import seaborn as sns

import math
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import datetime

activpal = Activpal()

activity_focus = 'staan'
respondents = ['BMR002', 'BMR011', 'BMR012', 'BMR014', 'BMR018', 'BMR030',␣
 ↪'BMR031', 'BMR032', 'BMR033', 'BMR034','BMR036', 'BMR040', 'BMR041',␣
 ↪'BMR042', 'BMR043', 'BMR044', 'BMR052', 'BMR053', 'BMR055', 'BMR058',␣
 ↪'BMR064', 'BMR098']
test_respondents = ['BMR004', 'BMR008', 'BMR097']
```

1 Defining functions

1.0.1 Method to retrieve DataFrame containing all information for regression

[2]:
```
def get_regression_df(respondent, activity):
    start, stop = get_timestamps(respondent, activity)

    # read in all dataframes necessary
```

```
    respondents_df = pdh.read_csv_respondents()
    res_number = get_respondent_number(respondent)
    vyntus_df, min_index, max_index = get_vyntus_df(respondent,␣
↪respondents_df['gewicht'][res_number], start, stop)
    raw_df = get_raw_df(respondent, min_index, max_index)

    # add met and mag acc to new dataframe
    new_df = pd.DataFrame(index=raw_df.index)
    new_df['mean_met'] = vyntus_df['met']
    new_df['sum_mag_acc'] = raw_df['sum_mag_acc']

    # add features to new dataframe
    new_df['length_cm'] = respondents_df['lengte'][res_number]
    new_df['weight_kg'] = respondents_df['gewicht'][res_number]
    new_df['mean_speed'] = raw_df['mean_speed']
    new_df['bmi'] = mth.calculate_bmi(new_df['weight_kg'], new_df['length_cm'])
    new_df['gender'] = int(respondents_df['geslacht'][res_number].
↪replace('vrouw',str(0)).replace('man', str(1)))
    new_df['age_category'] = respondents_df['leeftijdscategorie'][res_number]
    convert_age_to_number(new_df, "age_category")
    new_df['is_sporter'] = respondents_df['sporter'][res_number]
    new_df['meets_activity_guidelines'] = int(respondents_df['voldoet aan␣
↪beweegrichtlijn 2nee17'][res_number].replace('ja', '1').replace('nee', '0'))
    new_df['does_muscle_bone_exercises'] = int(respondents_df['voldoet aan␣
↪richtlijn bot en spierversterkende activiteiten'][res_number].replace('ja',␣
↪'1').replace('nee', '0'))
    new_df['meets_balance_guidelines'] = int(respondents_df['voldoet aan␣
↪richtlijn balansoefeningen'][res_number].replace('ja', '1').replace('nee',␣
↪'0'))

    return new_df


def get_regression_dfs(respondents, activity):
    all_df = pd.DataFrame(index=pd.to_datetime([]))

    for cor in respondents:
        df = get_regression_df(cor, activity)
        all_df = pd.concat([all_df, df])


    all_df.sort_index(inplace=True)
    return all_df
```

1.0.2 Helper method, returning start and stop timestamps for an activity

[3]:
```
def get_timestamps(respondent, activity):
    activities_df = read_functions.read_activities(respondent)
    start = activities_df.loc[activity].start
    stop = activities_df.loc[activity].stop

    return (start, stop)
```

1.0.3 Helper method, returning the number of respondent code

[4]:
```
def get_respondent_number(respondent):
    if ('BMR0' in respondent):
        return int(respondent.replace('BMR0', ''))

    if ('BMR' in respondent):
        return int(respondent.replace('BMR', ''))
```

1.0.4 Helper method, returning Vyntus (lab data)

The DataFrame contains MET and other information necessary for regression

The DataFrame is resampled to minutes by mean

[5]:
```
def get_vyntus_df(respondent, weight, start, stop):
    vyntus_df = pdh.read_csv_vyntus(respondent)
    mask = (vyntus_df.index >= start) & (vyntus_df.index < stop)
    vyntus_df = vyntus_df.loc[mask]

    min_index = vyntus_df.index.min()
    max_index = vyntus_df.index.max()

    vyntus_df['vyn_VO2'] = [float(vo2.replace(',', '.')) if type(vo2) == str␣
 ↪else vo2 for vo2 in vyntus_df['vyn_VO2']]
    vyntus_df['met'] = mth.calculate_met(vyntus_df['vyn_VO2'], weight)

    vyntus_df = vyntus_df.resample('60s').mean()[:-1]

    return (vyntus_df, min_index, max_index)
```

1.0.5 Helper method, returning Activpal20

The DataFrame contains sumation of magnitude of acceleration

The DataFrame is resampled to minutes by sumation

[6]:
```
def get_raw_df(respondent, start, stop):
    df = activpal.read_data(respondent, start, stop)

    mask = (df.index >= start) & (df.index < stop)
    df = df.loc[mask]

    df = df[['pal_accX', 'pal_accY', 'pal_accZ']].apply(mth.convert_value_to_g)
    df['sum_mag_acc'] = mth.to_mag_acceleration(df['pal_accX'], df['pal_accY'],␣
↪df['pal_accZ'])
    df['mean_speed'] = get_speed(df['pal_accX'], df['pal_accY'], df['pal_accZ'])

    df = df.resample('60s').agg({'sum_mag_acc':'sum', 'mean_speed':'mean'})[:-1]

    return df
```

1.0.6 Helper method, from Colin

[7]:
```
def convert_age_to_number(dataframe, age_category):
    age_convertion = {
        age_category: {
            "15-19": 0, "20-24": 1, "25-29": 2, "30-34": 3,
            "35-39": 4,  "40-44": 5, "45-49": 6, "50-54": 7,
            "55-59": 8,  "60-64": 9, "65-69": 10,  "70-74": 11, "75-79": 12
        }
    }
    return dataframe.replace(age_convertion, inplace=True)
```

1.0.7 Helper method, returns speed, from Adnan

[8]:
```
import scipy.integrate as it

def get_speed(x_acc, y_acc, z_acc):
    activpal_time = 0.05

    x_vel = np.array([sum(x_acc[:i]) * activpal_time for i in␣
↪range(len(x_acc))])
    y_vel = np.array([sum(y_acc[:i]) * activpal_time for i in␣
↪range(len(y_acc))])
    z_vel = np.array([sum(z_acc[:i]) * activpal_time for i in␣
↪range(len(z_acc))])


    return np.sqrt(x_vel ** 2 + y_vel **2 + z_vel ** 2)
```

1.0.8 Helper method, returns best features out of all features

[9]:
```
def get_best_features(df, feature_columns, n_features_to_select):
    x_train, x_valid, y_train, y_valid = train_test_split(df[feature_columns],␣
 ↪df['mean_met'], test_size=0.2, random_state=0)

    estimator = LinearRegression()
    selector = RFE(estimator, n_features_to_select=n_features_to_select)
    selector = selector.fit(x_train, y_train)

    return x_train.columns[selector.support_]
```

1.0.9 Helper methods to plot various graphs

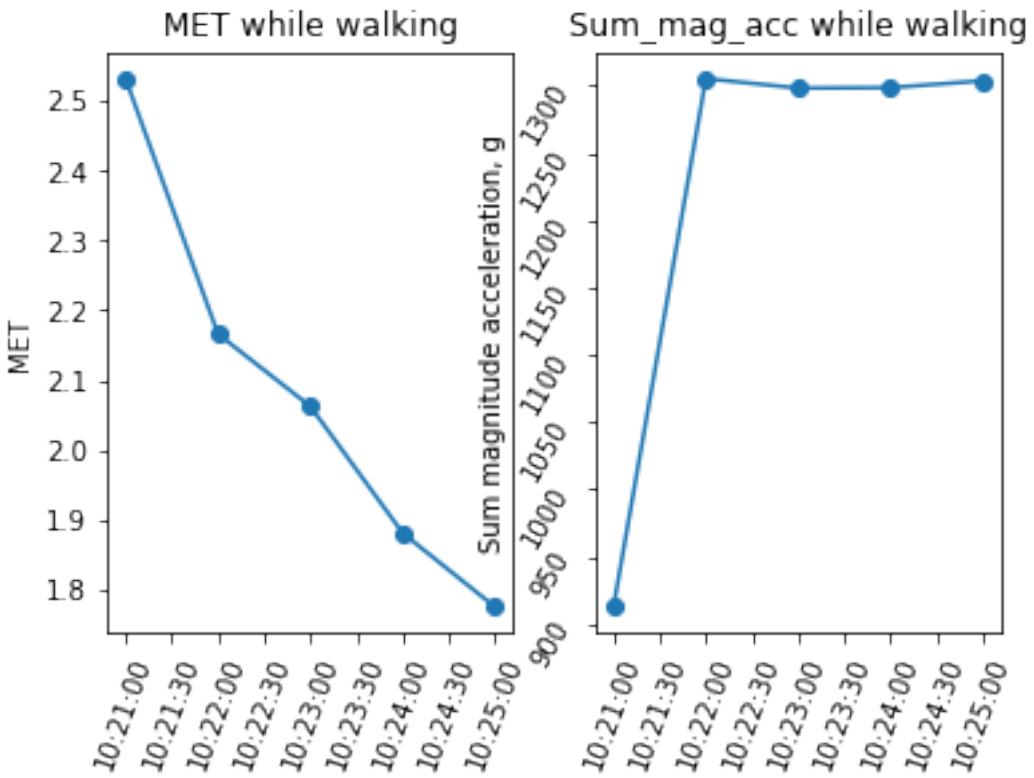
[10]:
```
def plot_met(met, title = 'MET while standing'):
    plt.ylabel('MET')
    plt.plot(met, marker = 'o')
    plt.title(title)
    plt.xticks(rotation=70)

def plot_mag_acc(mag_acc, title = 'Sum_mag_acc while standing'):
    plt.ylabel('Sum magnitude acceleration, g')
    plt.plot(mag_acc, marker = 'o')
    plt.title(title)
    plt.xticks(rotation=70)
    plt.yticks(rotation=60)

def plot_lin_reg(x, y, xlabel = 'acceleration, g', ylabel = 'MET'):
    linreg = linregress(x, y)
    fx = np.array([x.min(), x.max()])
    fy = linreg.intercept + linreg.slope * fx

    plt.xlabel(xlabel)
    plt.ylabel(ylabel)
    plt.plot(x, y, 'o')
    plt.plot(fx, fy, '-')

def plot_heatmap(df):
    plt.figure(figsize=(15,10))
    sns.heatmap(df.corr(), annot=True, cmap=plt.cm.Reds)
    plt.show()

def plot_pred_truth(pred_y, valid_y, title):
    plt.plot(range(len(pred_y)), pred_y, label='prediction', marker='o')
    plt.plot(range(len(valid_y)),valid_y,label='ground_truth', marker='o')
```

```
    plt.title(title)
    plt.ylabel('met')
    plt.xlabel('Prediction Number')
    plt.legend()

def plot_ground_truth_vs_prediction(pred_y, valid_y, title='Predictions on␣
 ↪validation dataset'):
    plt.figure(figsize=(20,10))
    bar_width = 0.35

    pred_index = np.arange(len(pred_y))
    y_index = np.arange(len(valid_y)) + bar_width
    plt.bar(pred_index, pred_y, bar_width, label='Prediction')
    plt.bar(y_index, valid_y, bar_width, label='Ground Truth')

    plt.xlabel('Prediction Number')
    plt.ylabel("MET")
    plt.title(title)
    plt.xticks(pred_index + 0.15, pred_index)
    plt.legend()
    plt.grid()
    plt.show()
```

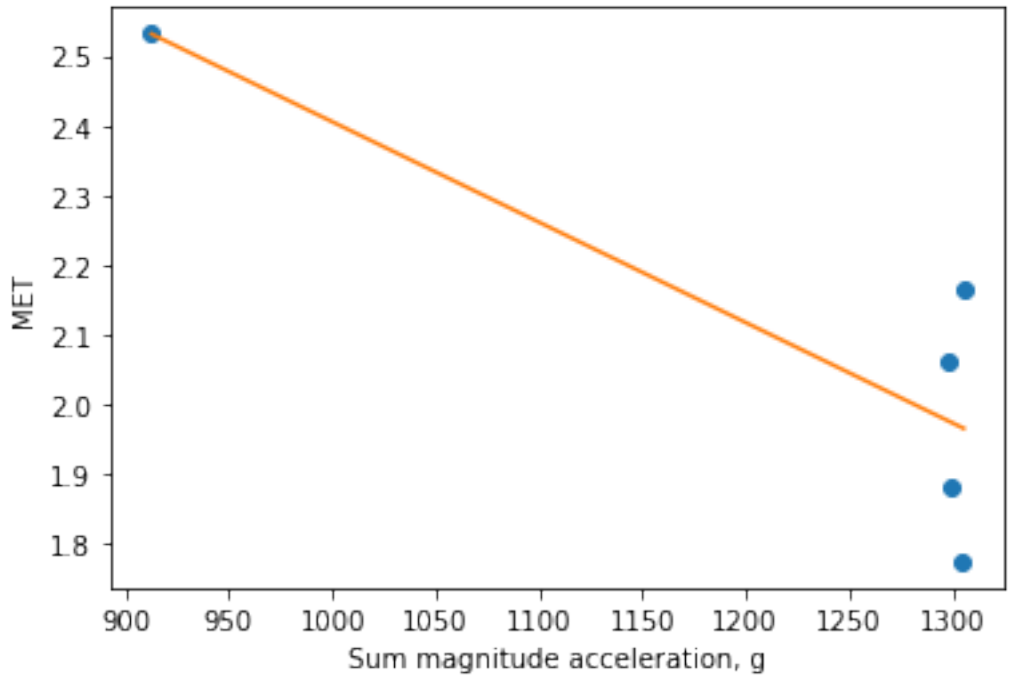
2 Univariate linear regression

2.0.1 One respondent

[11]:
```
res30 = 'BMR030'
df30 = get_regression_df(res30, activity_focus)

plt.subplot(1, 2, 1)
plot_met(df30['mean_met'])

plt.subplot(1, 2, 2)
plot_mag_acc(df30['sum_mag_acc'])
plt.show()

print('r = ' + str(df30['sum_mag_acc'].corr(df30['mean_met'])))
plot_lin_reg(df30['sum_mag_acc'], df30['mean_met'], xlabel='Sum magnitude␣
 ↪acceleration, g')
```

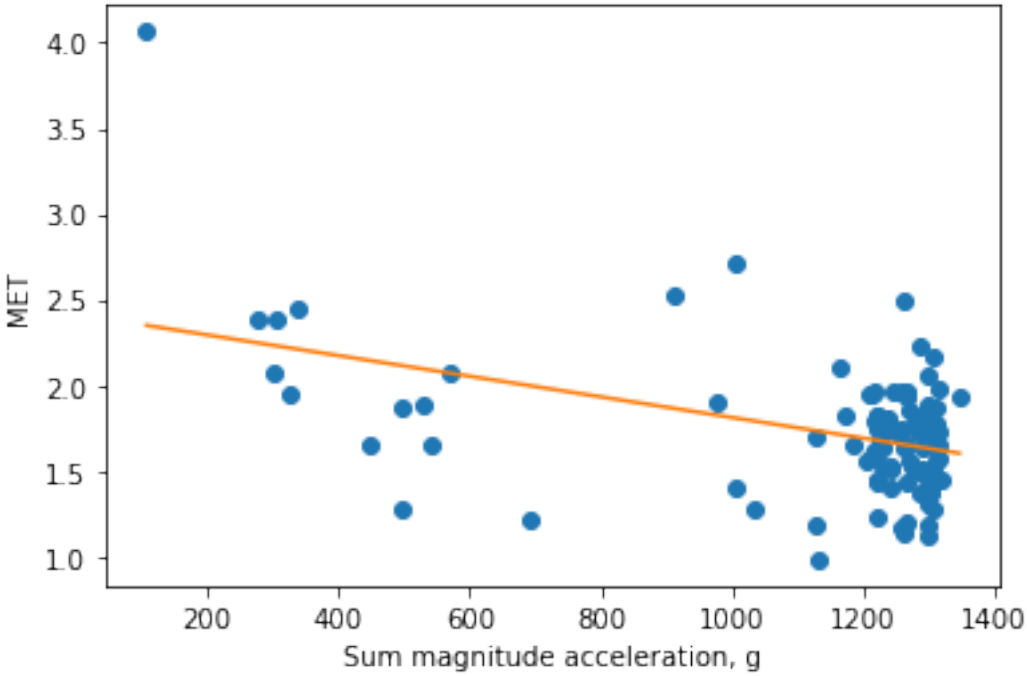


r = -0.8529609304931086



2.0.2 All respondents

[12]:
```
all_df = get_regression_dfs(respondents, activity_focus)
test_df = get_regression_dfs(test_respondents, activity_focus)

plot_lin_reg(all_df['sum_mag_acc'], all_df['mean_met'], xlabel='Sum magnitude␣
↪acceleration, g')
```

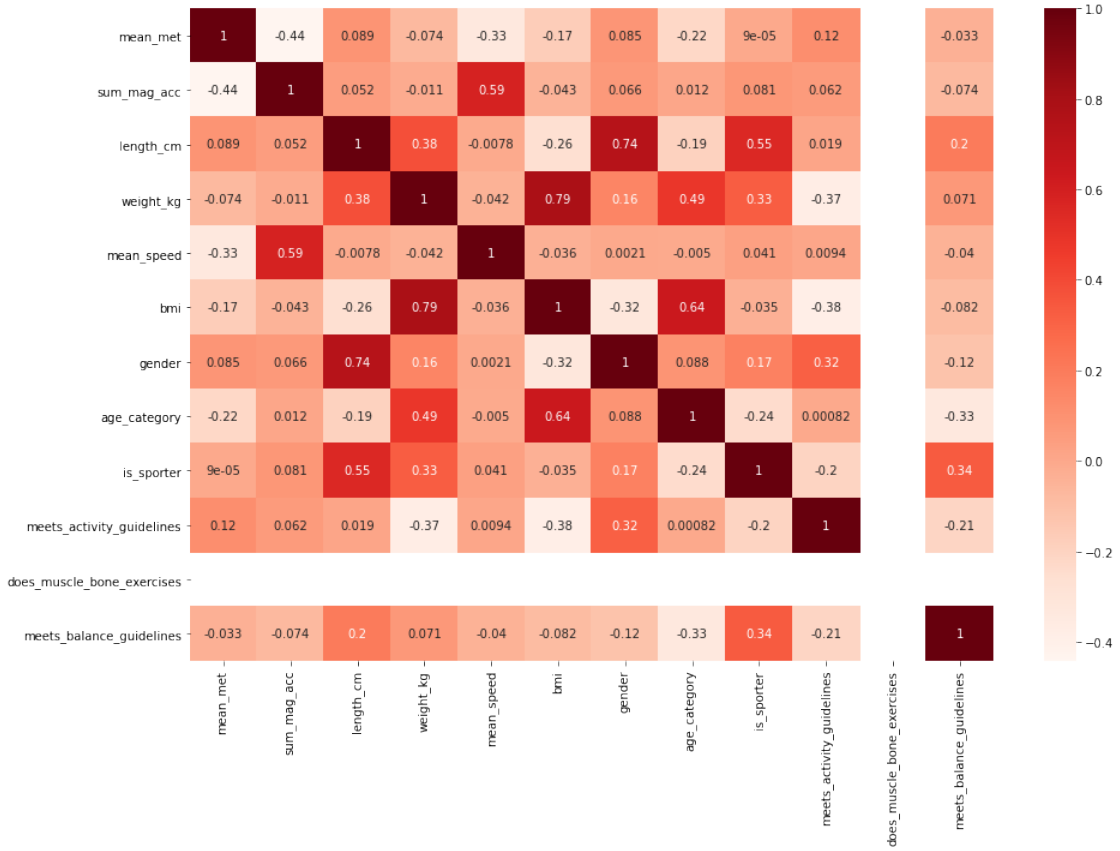


3 Multivariate Linear regression model training

3.1 Dimensionality reduction

3.1.1 Pearson Correlation confusion matrix

[13]:
```
plot_heatmap(all_df)
```



3.1.2 Drop missing values

[14]:
```
all_df = all_df.dropna(how='any')
test_df = test_df.dropna(how='any')
```

3.1.3 Drop variables with zero variation (unary)

[16]:
```
print(all_df.var())

if 'does_muscle_bone_exercises' in all_df.columns:
    all_df = all_df.drop('does_muscle_bone_exercises', axis=1)

if 'does_muscle_bone_exercises' in test_df.columns:
    test_df = test_df.drop('does_muscle_bone_exercises', axis=1)

all_df.columns
```

```
mean_met                          0.155380
sum_mag_acc                   83581.706408
length_cm                       102.542176
weight_kg                       169.440562
mean_speed                     6841.273388
bmi                              16.014773
gender                            0.252198
age_category                     14.509524
is_sporter                        0.201832
meets_activity_guidelines         0.086996
meets_balance_guidelines          0.178022
dtype: float64
```

[16]:
```
Index(['mean_met', 'sum_mag_acc', 'length_cm', 'weight_kg', 'mean_speed',
       'bmi', 'gender', 'age_category', 'is_sporter',
       'meets_activity_guidelines', 'meets_balance_guidelines'],
      dtype='object')
```

3.1.4 Drop very low correlation variables

[17]:
```
if 'length_cm' in all_df.columns:
    all_df = all_df.drop('length_cm', axis=1)

if 'length_cm' in test_df.columns:
    test_df = test_df.drop('length_cm', axis=1)

if 'weight_kg' in all_df.columns:
    all_df = all_df.drop('weight_kg', axis=1)

if 'weight_kg' in test_df.columns:
    test_df = test_df.drop('weight_kg', axis=1)

if 'gender' in all_df.columns:
    all_df = all_df.drop('gender', axis=1)

if 'gender' in test_df.columns:
    test_df = test_df.drop('gender', axis=1)

if 'is_sporter' in all_df.columns:
    all_df = all_df.drop('is_sporter', axis=1)

if 'is_sporter' in test_df.columns:
    test_df = test_df.drop('is_sporter', axis=1)

if 'meets_balance_guidelines' in all_df.columns:
    all_df = all_df.drop('meets_balance_guidelines', axis=1)
```

```
if 'meets_balance_guidelines' in test_df.columns:
    test_df = test_df.drop('meets_balance_guidelines', axis=1)
```

3.1.5 Define remaining features

[18]:
```
remaining_features = ['sum_mag_acc', 'mean_speed', 'bmi', 'age_category',␣
↪'meets_activity_guidelines']
```

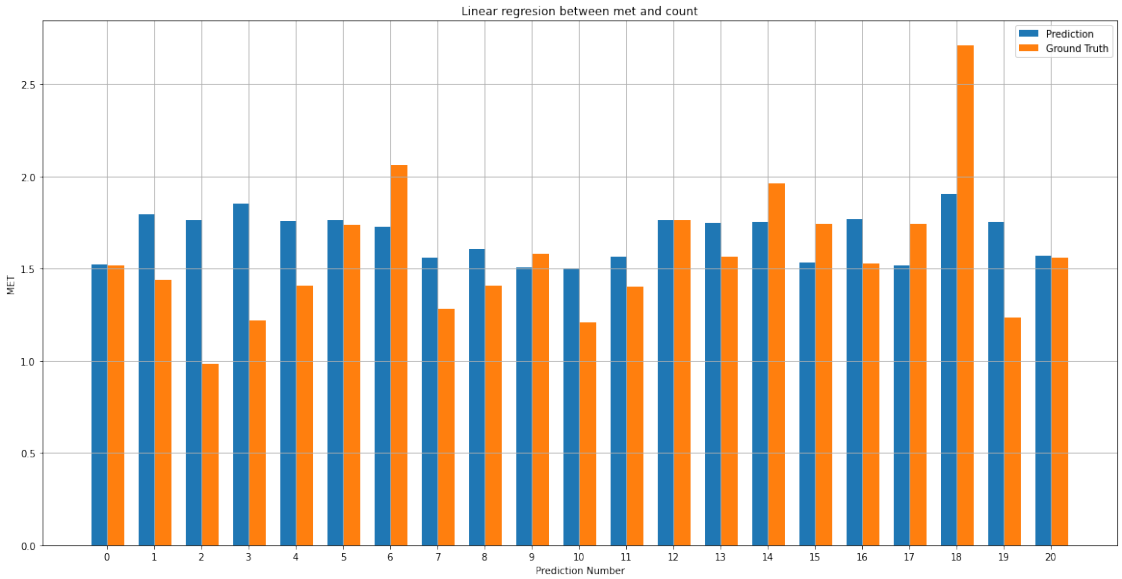
3.1.6 Recursive Feature Elimination (RFE)

[28]:
```
best_features = get_best_features(all_df, remaining_features, 4)
print(best_features)
```

```
Index(['sum_mag_acc', 'bmi', 'age_category', 'meets_activity_guidelines'],
dtype='object')
```

3.2 Multivariate regression best features

[29]:
```
cleaned_df = all_df.dropna(how='any')

x = all_df[best_features]
y = all_df['mean_met']

train_x, valid_x, train_y, valid_y = train_test_split(x,y, test_size=0.2,␣
↪random_state=0)

mlr = LinearRegression()
mlr.fit(train_x,train_y)

pred_y = mlr.predict(valid_x)

plot_ground_truth_vs_prediction(pred_y, valid_y, 'Linear regresion between met␣
↪and count')

print('mean squared error = ' + str(mean_squared_error(valid_y, pred_y)))
print('r squared = ' + str(mlr.score(train_x,train_y)))
```



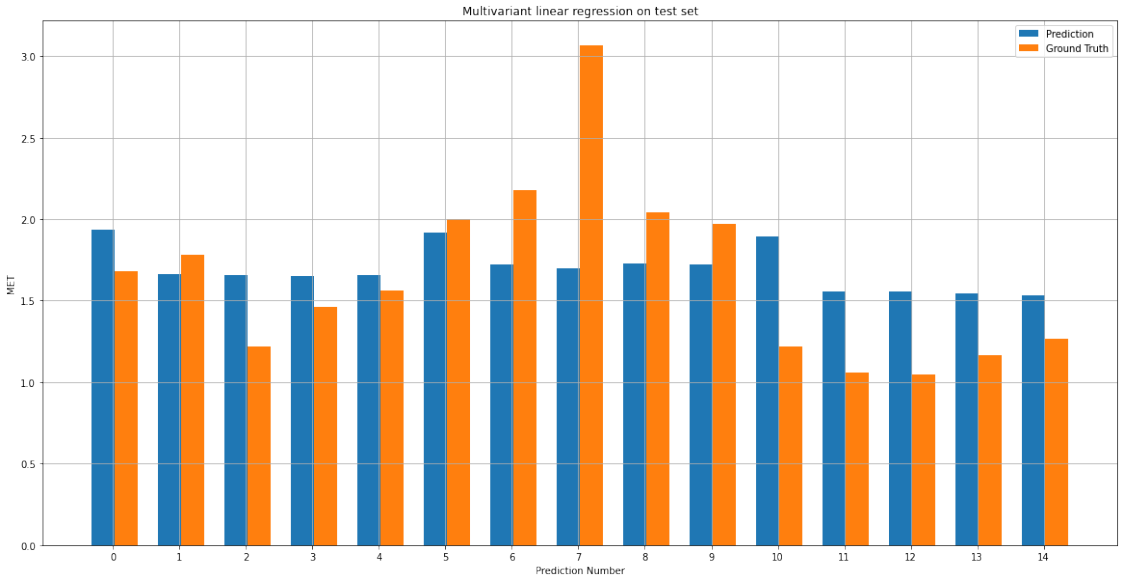

```
mean squared error = 0.13098671154473568
r squared = 0.27798578772772076
```

3.3 Hyperparameter tuning

[ ]:

3.4 Multivariate Linear Regression model on Test set

[30]:
```
test_x = test_df[best_features]
test_y = test_df['mean_met']
pred_y = mlr.predict(test_x)

plot_ground_truth_vs_prediction(pred_y, test_y, 'Multivariant linear regression␣
 ↪on test set')
print('mean squared error = ' + str(mean_squared_error(test_y, pred_y)))
print('r squared = ' + str(mlr.score(test_x,test_y)))
```




```
mean squared error = 0.24916634885802985
r squared = 0.10946194779376106
```

[ ]: