BTRY4830-Project

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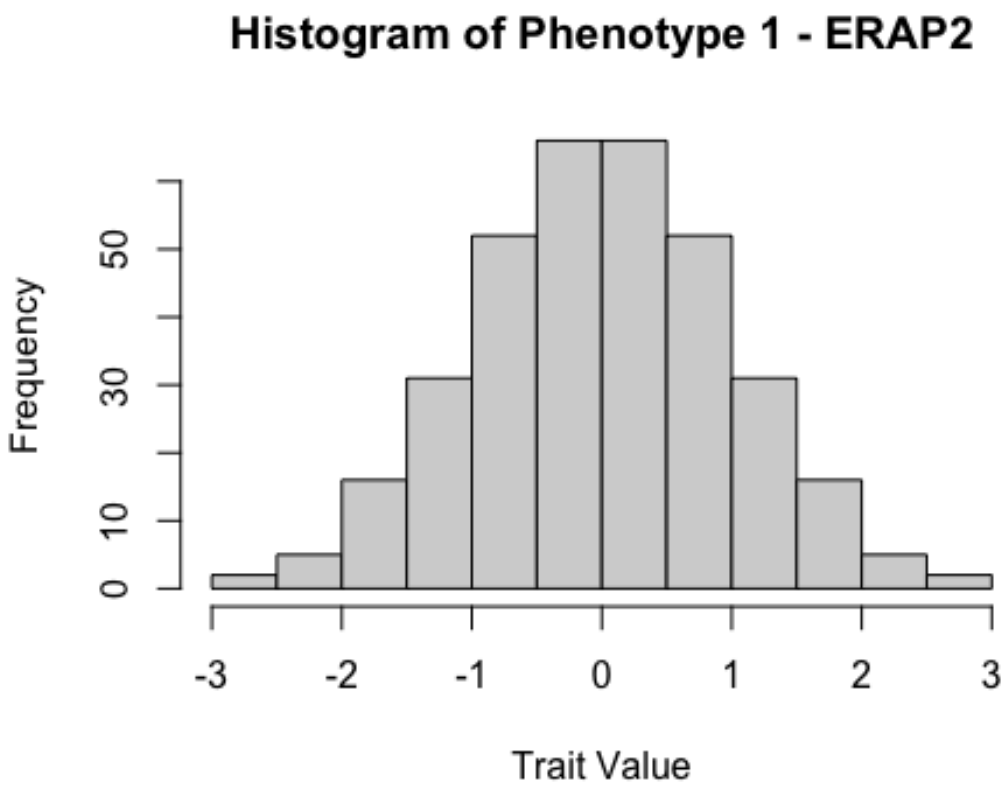
2023-05-05

```
libs = c('tidyverse', 'data.table', 'MASS',
         'ggsci', 'ggthemes', 'ggpubr', 'KEGGREST',
         'rentrez', 'tidyimpute','ggplot','ggfortify')
suppressMessages(
  suppressWarnings(sapply(libs, require, character.only = TRUE))
)

##  tidyverse data.table       MASS      ggsci   ggthemes     ggpubr
KEGGREST
##       TRUE       TRUE       TRUE      FALSE       TRUE      FALSE
FALSE
##    rentrez tidyimpute     ggplot  ggfortify
##      FALSE      FALSE      FALSE       TRUE

rm(libs)
theme_set(theme_few(14))
```

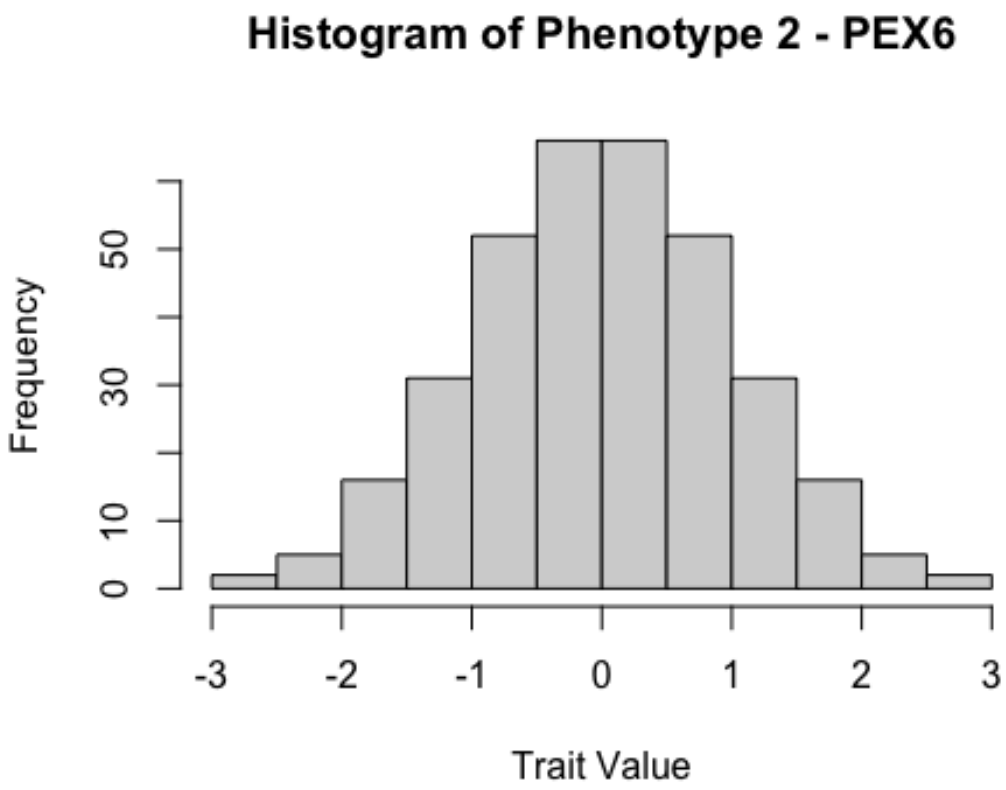
1.

a.

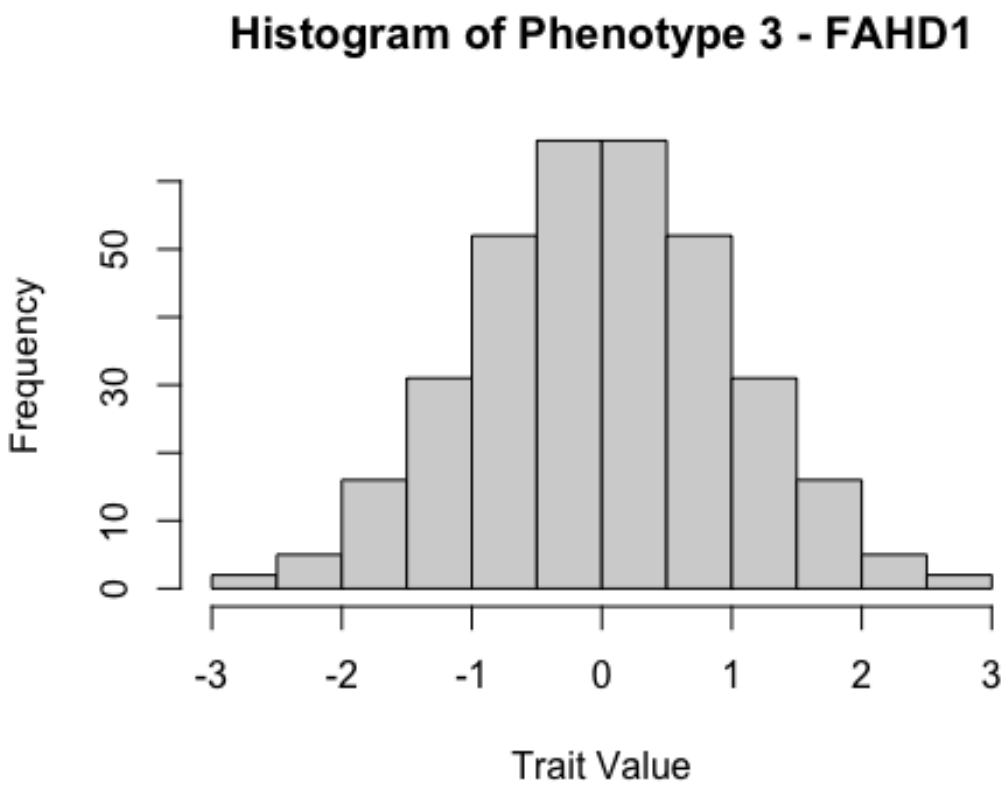
```
pheno_import <- read.csv("projectphenotypes.csv")

pheno1 <- pheno_import$ENSG00000164308.12

hist(pheno1, main = "Histogram of Phenotype 1 - ERAP2", xlab = "Trait Value",
ylab = "Frequency")
```



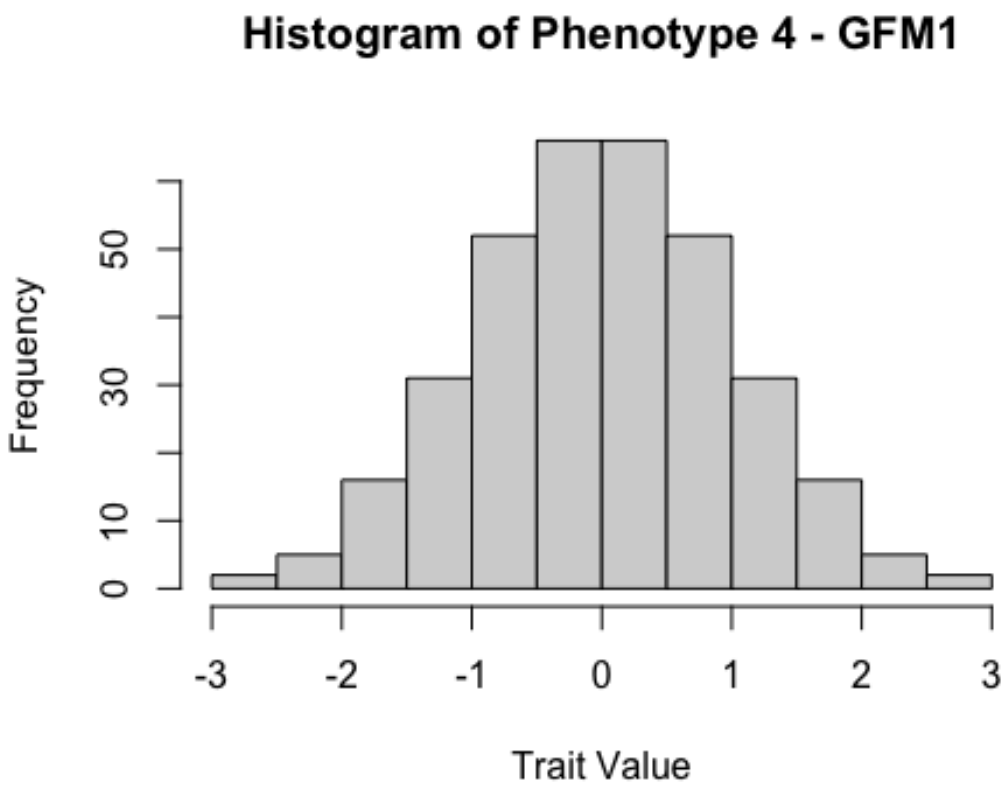

```
pheno_import <- read.csv("projectphenotypes.csv")

pheno2 <- pheno_import$ENSG00000124587.9

hist(pheno2, main = "Histogram of Phenotype 2 - PEX6", xlab = "Trait Value",
ylab = "Frequency")
```



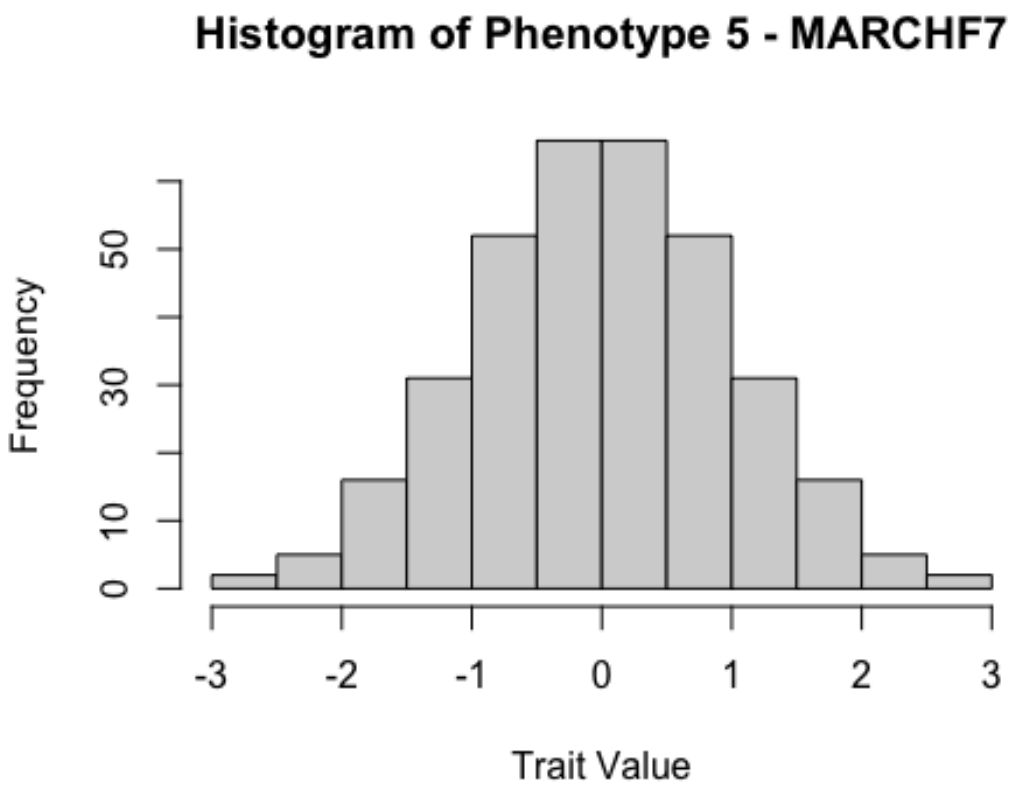

```
pheno_import <- read.csv("projectphenotypes.csv")

pheno3 <- pheno_import$ENSG00000180185.7

hist(pheno3, main = "Histogram of Phenotype 3 - FAHD1", xlab = "Trait Value",
ylab = "Frequency")
```



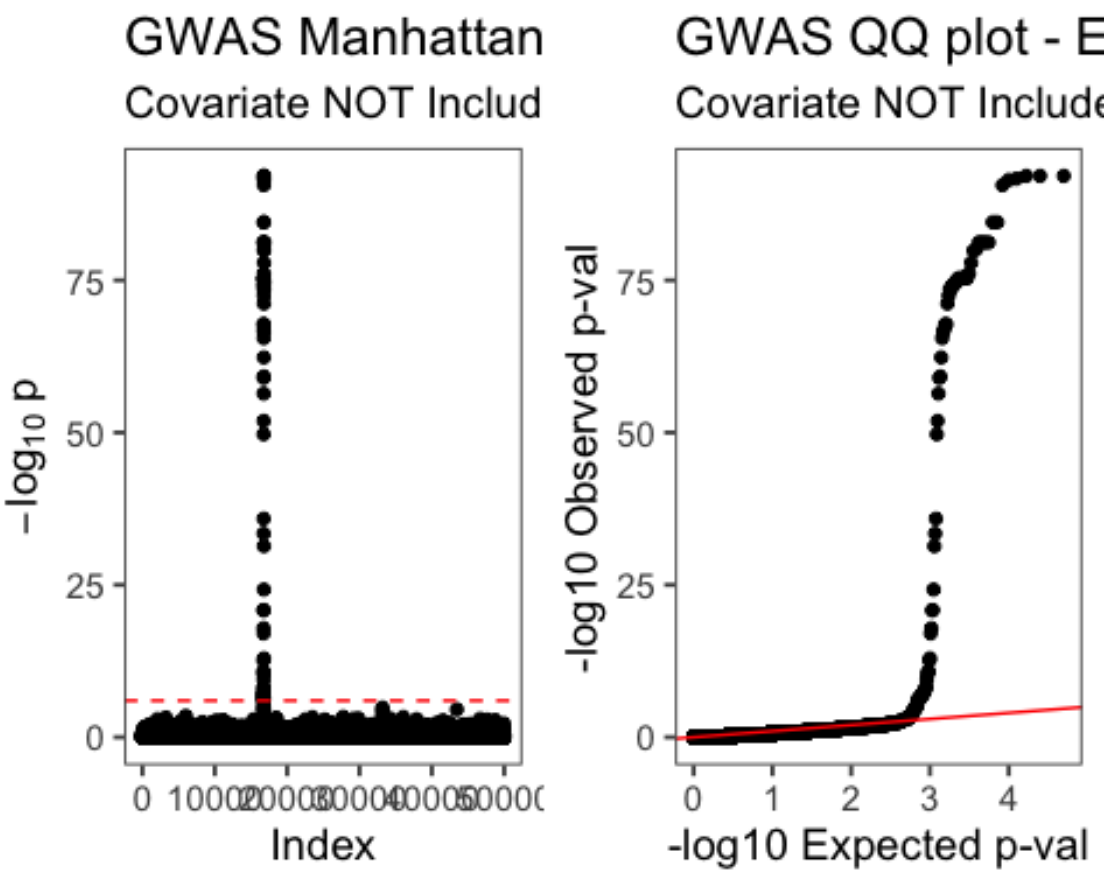

```
pheno_import <- read.csv("projectphenotypes.csv")

pheno4 <- pheno_import$ENSG00000168827.9

hist(pheno4, main = "Histogram of Phenotype 4 - GFM1", xlab = "Trait Value",
ylab = "Frequency")
```

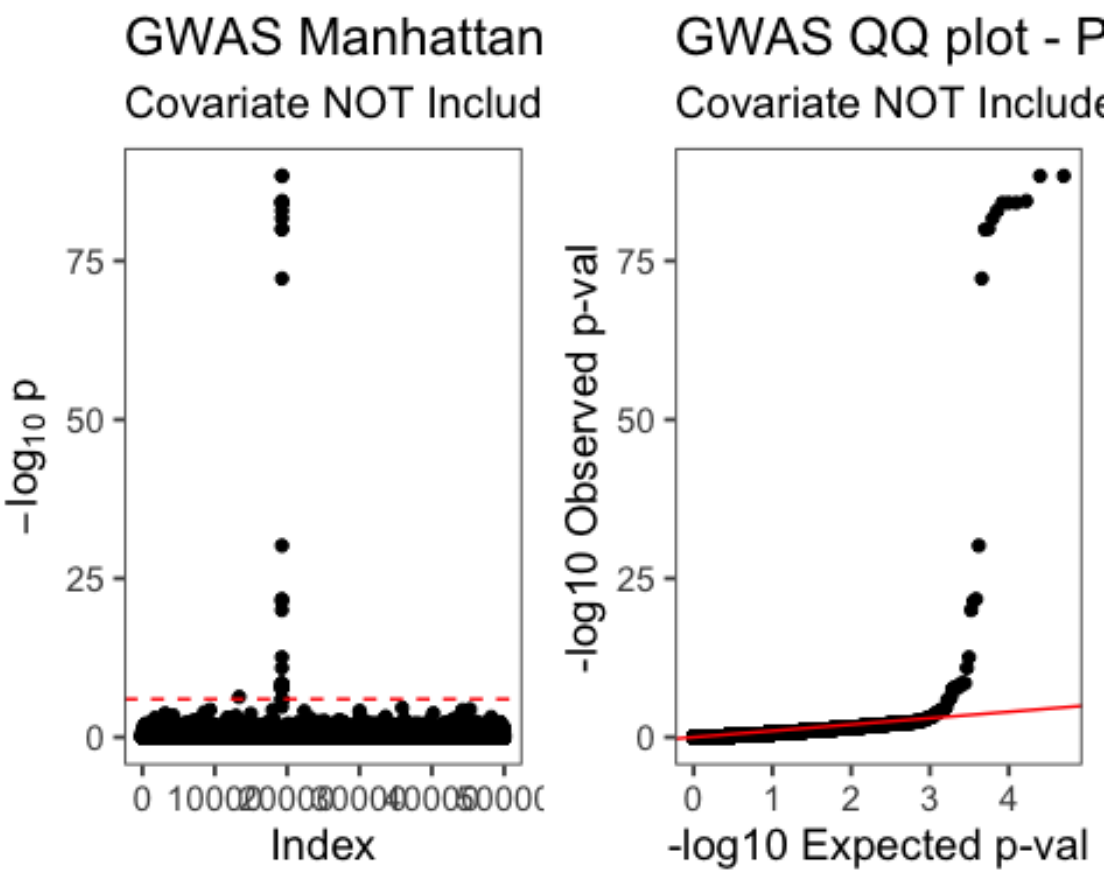


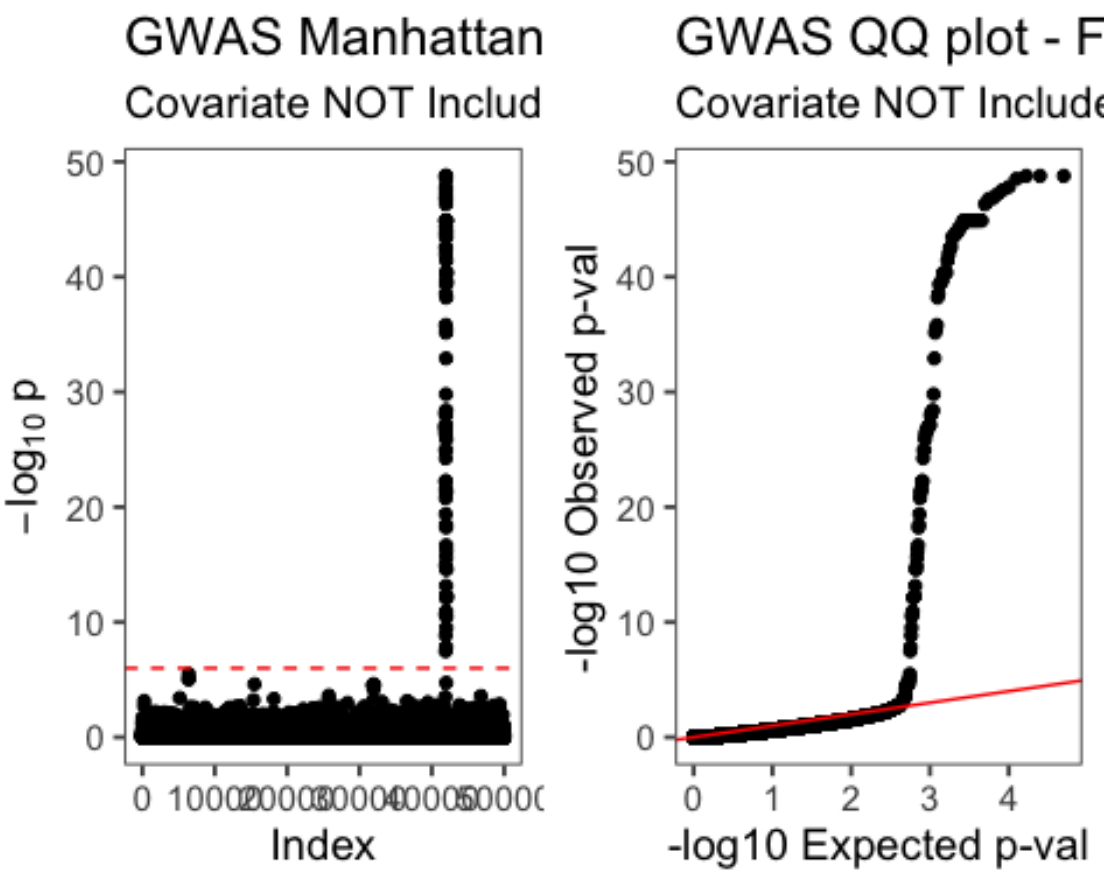

```
pheno_import <- read.csv("projectphenotypes.csv")

pheno5 <- pheno_import$ENSG00000136536.9

hist(pheno5, main = "Histogram of Phenotype 5 - MARCHF7", xlab = "Trait
Value", ylab = "Frequency")
```

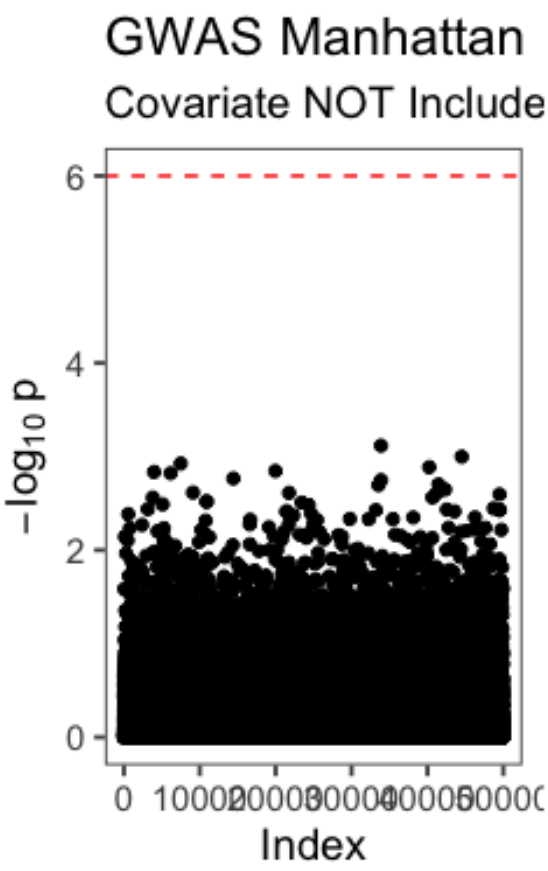


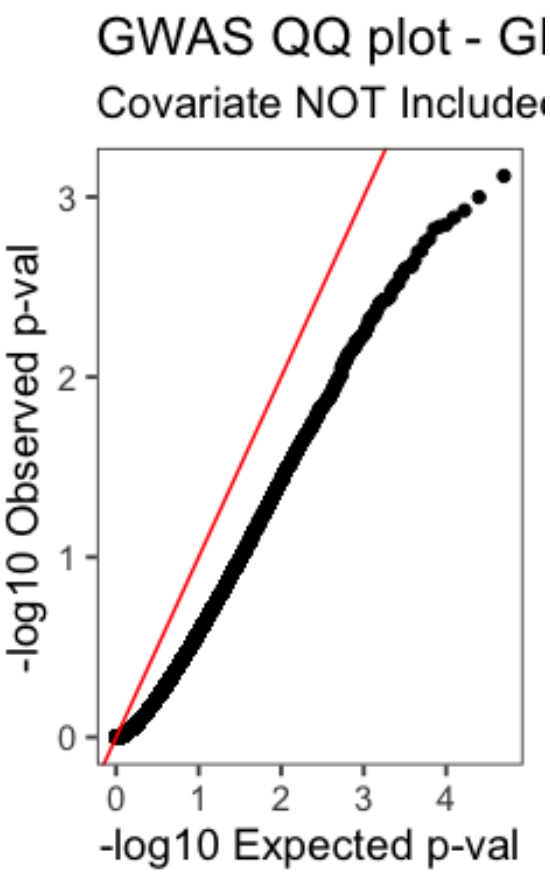

```
geno_import <- read.csv("projectgenotypes.csv")

N <- ncol(geno_import) - 1

cat("Number of SNPs (N):", N, "\n")

## Number of SNPs (N): 50000

gen_import <- read.csv("projectgenotypes.csv")
gen_import<- gen_import[,-1]
colnames(gen_import) <- NULL
rownames(gen_import) <- NULL
```

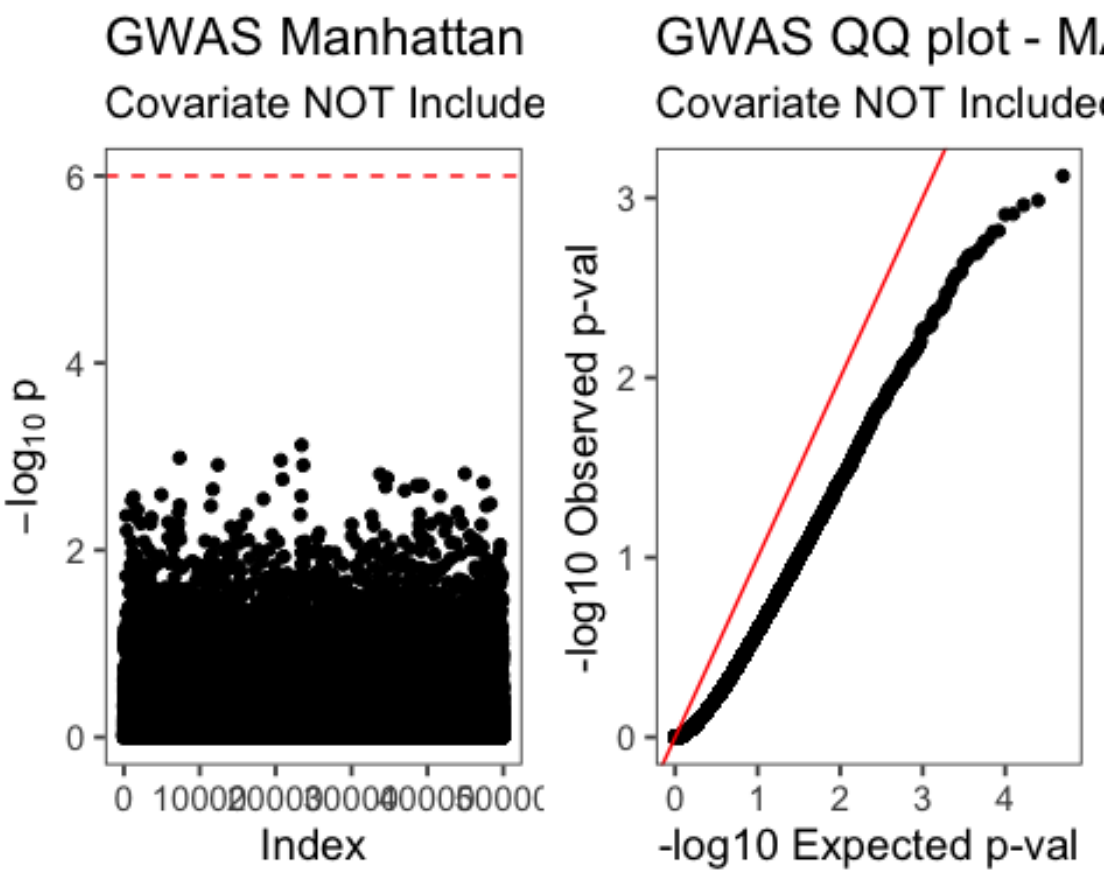

GWAS Manhattan
Covariate NOT Includ
−log10 p
75
50
25
0
0
Index
GWAS QQ plot - E
Covariate NOT Include
-log10 Observed p-val
75
50
25
0
0
1
2
3
4
-log10 Expected p-val


GWAS Manhattan
Covariate NOT Includ
−log10 p
75
50
25
0
0
Index
GWAS QQ plot - P
Covariate NOT Include
-log10 Observed p-val
75
50
25
0
0
1
2
3
4
-log10 Expected p-val


GWAS Manhattan
Covariate NOT Includ
−log10 p
50
40
30
20
10
0
0
Index
GWAS QQ plot - F
Covariate NOT Include
-log10 Observed p-val
50
40
30
20
10
0
0
1
2
3
4
-log10 Expected p-val


GWAS Manhattan
Covariate NOT Include
6
4
2
0
−log10 p
0
Index


GWAS QQ plot - Gl
Covariate NOT Include
3
2
1
0
-log10 Observed p-val
0
1
2
3
4
-log10 Expected p-val




```
# Convert genotypes to Xa & Xd
# # Details can be found in lab 6
gen_import <- read.csv("projectgenotypes.csv")
gen_import<- gen_import[,-1]
colnames(gen_import) <- NULL
rownames(gen_import) <- NULL

xa_mat <- as.matrix(gen_import )
xd_mat <- ((2*xa_mat) - 1)


# Load in phenotype data and run GWAS
sim_pheno_mx <- read.csv("projectphenotypes.csv",
                         header = TRUE, row.names = 1)

# Read-in our covariate data
xc_mat = read.csv('projectcovars.csv')
Xc <- model.matrix(~Population + Sex, data=xc_mat)
xc_mat1 <- Xc[,-1]

xc.pca<- prcomp(xa_mat %*% t(xa_mat))
```

```
xc.pca$sdev
```

```
##   [1] 6.427237e+03 3.116876e+03 1.626246e+03 1.393769e+03 1.348115e+03
##   [6] 1.262807e+03 1.209274e+03 1.203364e+03 1.196482e+03 1.189354e+03
##  [11] 1.183723e+03 1.176994e+03 1.169424e+03 1.163703e+03 1.159626e+03
##  [16] 1.154370e+03 1.152850e+03 1.148883e+03 1.141628e+03 1.138455e+03
##  [21] 1.135365e+03 1.131426e+03 1.129800e+03 1.124041e+03 1.121787e+03
##  [26] 1.119182e+03 1.117536e+03 1.113179e+03 1.111885e+03 1.109252e+03
##  [31] 1.104816e+03 1.103658e+03 1.101757e+03 1.100419e+03 1.098486e+03
##  [36] 1.096698e+03 1.095543e+03 1.095326e+03 1.089676e+03 1.088675e+03
##  [41] 1.087383e+03 1.086510e+03 1.082802e+03 1.081972e+03 1.079094e+03
##  [46] 1.077650e+03 1.076481e+03 1.073658e+03 1.073091e+03 1.070557e+03
##  [51] 1.067799e+03 1.067384e+03 1.064559e+03 1.063028e+03 1.061835e+03
##  [56] 1.059029e+03 1.057953e+03 1.055338e+03 1.054601e+03 1.052785e+03
##  [61] 1.052125e+03 1.050047e+03 1.049038e+03 1.048526e+03 1.046296e+03
##  [66] 1.043911e+03 1.042524e+03 1.041937e+03 1.038166e+03 1.036866e+03
##  [71] 1.035134e+03 1.033292e+03 1.031230e+03 1.030714e+03 1.029552e+03
##  [76] 1.027296e+03 1.026493e+03 1.026187e+03 1.023989e+03 1.022830e+03
##  [81] 1.020409e+03 1.018483e+03 1.018153e+03 1.017024e+03 1.015774e+03
##  [86] 1.015339e+03 1.013081e+03 1.011066e+03 1.010345e+03 1.009144e+03
##  [91] 1.007144e+03 1.004131e+03 1.003394e+03 1.002108e+03 1.001168e+03
##  [96] 1.000130e+03 9.990847e+02 9.977815e+02 9.966950e+02 9.953574e+02
## [101] 9.934285e+02 9.928147e+02 9.921263e+02 9.889116e+02 9.878715e+02
## [106] 9.870330e+02 9.858830e+02 9.844095e+02 9.828766e+02 9.817144e+02
## [111] 9.815441e+02 9.801736e+02 9.794226e+02 9.773364e+02 9.762718e+02
## [116] 9.747273e+02 9.743429e+02 9.733624e+02 9.721300e+02 9.694334e+02
## [121] 9.690543e+02 9.665108e+02 9.659888e+02 9.651578e+02 9.646666e+02
## [126] 9.628692e+02 9.617965e+02 9.606342e+02 9.589537e+02 9.579263e+02
## [131] 9.576399e+02 9.565771e+02 9.551647e+02 9.534546e+02 9.527577e+02
## [136] 9.513468e+02 9.510565e+02 9.497074e+02 9.475445e+02 9.472500e+02
## [141] 9.452895e+02 9.447093e+02 9.439998e+02 9.431473e+02 9.419851e+02
## [146] 9.413799e+02 9.396646e+02 9.373141e+02 9.370022e+02 9.351853e+02
## [151] 9.336451e+02 9.327803e+02 9.318289e+02 9.309163e+02 9.301936e+02
## [156] 9.289218e+02 9.275203e+02 9.272192e+02 9.248979e+02 9.237018e+02
## [161] 9.223170e+02 9.212970e+02 9.207484e+02 9.190583e+02 9.175964e+02
## [166] 9.168758e+02 9.155734e+02 9.144915e+02 9.139177e+02 9.115838e+02
## [171] 9.100090e+02 9.089549e+02 9.082701e+02 9.075609e+02 9.070621e+02
## [176] 9.061834e+02 9.037305e+02 9.031297e+02 9.026705e+02 9.015705e+02
## [181] 9.006897e+02 8.995660e+02 8.988972e+02 8.969267e+02 8.967292e+02
## [186] 8.947837e+02 8.945184e+02 8.930036e+02 8.923525e+02 8.912859e+02
## [191] 8.905865e+02 8.886448e+02 8.882295e+02 8.867257e+02 8.855461e+02
## [196] 8.846877e+02 8.830573e+02 8.825466e+02 8.818479e+02 8.814751e+02
## [201] 8.794259e+02 8.777186e+02 8.767972e+02 8.758468e+02 8.757262e+02
## [206] 8.744545e+02 8.736686e+02 8.721873e+02 8.717075e+02 8.697694e+02
## [211] 8.692546e+02 8.677861e+02 8.661287e+02 8.652436e+02 8.642717e+02
## [216] 8.633542e+02 8.617654e+02 8.611184e+02 8.597113e+02 8.594240e+02
## [221] 8.587240e+02 8.581504e+02 8.569184e+02 8.564457e+02 8.553471e+02
## [226] 8.539759e+02 8.532587e+02 8.521061e+02 8.513172e+02 8.493478e+02
## [231] 8.485337e+02 8.477899e+02 8.466858e+02 8.455183e+02 8.446625e+02
```

```
## [236] 8.424588e+02 8.415318e+02 8.411388e+02 8.405069e+02 8.389686e+02
## [241] 8.382553e+02 8.380126e+02 8.361499e+02 8.351868e+02 8.348635e+02
## [246] 8.329343e+02 8.322722e+02 8.314363e+02 8.306184e+02 8.290522e+02
## [251] 8.274878e+02 8.267802e+02 8.260722e+02 8.250299e+02 8.235588e+02
## [256] 8.224138e+02 8.219797e+02 8.203458e+02 8.194079e+02 8.182833e+02
## [261] 8.171338e+02 8.157413e+02 8.156224e+02 8.139621e+02 8.137759e+02
## [266] 8.123691e+02 8.112856e+02 8.101449e+02 8.091977e+02 8.087009e+02
## [271] 8.077159e+02 8.062131e+02 8.055174e+02 8.031145e+02 8.023779e+02
## [276] 8.010343e+02 8.007215e+02 7.984976e+02 7.981396e+02 7.966775e+02
## [281] 7.958301e+02 7.954928e+02 7.941076e+02 7.935662e+02 7.911468e+02
## [286] 7.908311e+02 7.903589e+02 7.891410e+02 7.869310e+02 7.858087e+02
## [291] 7.855454e+02 7.849577e+02 7.820512e+02 7.811003e+02 7.802921e+02
## [296] 7.796162e+02 7.790589e+02 7.770834e+02 7.754008e+02 7.753526e+02
## [301] 7.728763e+02 7.726947e+02 7.705890e+02 7.701995e+02 7.693325e+02
## [306] 7.686392e+02 7.667707e+02 7.665011e+02 7.648718e+02 7.640755e+02
## [311] 7.615802e+02 7.614540e+02 7.589987e+02 7.568496e+02 7.560320e+02
## [316] 7.550266e+02 7.538642e+02 7.529631e+02 7.526921e+02 7.492002e+02
## [321] 7.486189e+02 7.473058e+02 7.456907e+02 7.421292e+02 7.408742e+02
## [326] 7.401063e+02 7.387272e+02 7.382018e+02 7.359075e+02 7.341505e+02
## [331] 7.326539e+02 7.291693e+02 7.283385e+02 7.257851e+02 7.224219e+02
## [336] 7.202882e+02 7.180573e+02 7.160515e+02 7.140979e+02 7.082242e+02
## [341] 7.067593e+02 6.938449e+02 5.987201e+02 2.584256e-12
```

```
(xc.pca$sdev / sum(xc.pca$sdev))*100
```

```
##   [1] 1.982205e+00 9.612662e-01 5.015456e-01 4.298480e-01 4.157681e-01
##   [6] 3.894586e-01 3.729485e-01 3.711259e-01 3.690034e-01 3.668051e-01
##  [11] 3.650685e-01 3.629930e-01 3.606586e-01 3.588940e-01 3.576369e-01
##  [16] 3.560158e-01 3.555470e-01 3.543236e-01 3.520862e-01 3.511074e-01
##  [21] 3.501545e-01 3.489397e-01 3.484383e-01 3.466620e-01 3.459669e-01
##  [26] 3.451635e-01 3.446559e-01 3.433122e-01 3.429130e-01 3.421011e-01
##  [31] 3.407328e-01 3.403757e-01 3.397894e-01 3.393770e-01 3.387808e-01
##  [36] 3.382295e-01 3.378732e-01 3.378061e-01 3.360637e-01 3.357549e-01
##  [41] 3.353566e-01 3.350872e-01 3.339438e-01 3.336879e-01 3.328002e-01
##  [46] 3.323548e-01 3.319942e-01 3.311237e-01 3.309487e-01 3.301672e-01
##  [51] 3.293167e-01 3.291886e-01 3.283173e-01 3.278452e-01 3.274773e-01
##  [56] 3.266120e-01 3.262802e-01 3.254735e-01 3.252462e-01 3.246862e-01
##  [61] 3.244827e-01 3.238418e-01 3.235307e-01 3.233727e-01 3.226850e-01
##  [66] 3.219494e-01 3.215217e-01 3.213407e-01 3.201777e-01 3.197768e-01
##  [71] 3.192426e-01 3.186745e-01 3.180386e-01 3.178795e-01 3.175211e-01
##  [76] 3.168254e-01 3.165776e-01 3.164833e-01 3.158052e-01 3.154480e-01
##  [81] 3.147013e-01 3.141074e-01 3.140056e-01 3.136574e-01 3.132717e-01
##  [86] 3.131377e-01 3.124413e-01 3.118198e-01 3.115973e-01 3.112271e-01
##  [91] 3.106101e-01 3.096809e-01 3.094538e-01 3.090570e-01 3.087671e-01
##  [96] 3.084471e-01 3.081247e-01 3.077228e-01 3.073877e-01 3.069752e-01
## [101] 3.063803e-01 3.061910e-01 3.059787e-01 3.049872e-01 3.046665e-01
## [106] 3.044079e-01 3.040532e-01 3.035988e-01 3.031260e-01 3.027676e-01
## [111] 3.027150e-01 3.022924e-01 3.020608e-01 3.014174e-01 3.010890e-01
## [116] 3.006127e-01 3.004942e-01 3.001918e-01 2.998117e-01 2.989800e-01
## [121] 2.988631e-01 2.980787e-01 2.979177e-01 2.976614e-01 2.975099e-01
```

```
## [126] 2.969556e-01 2.966247e-01 2.962663e-01 2.957480e-01 2.954312e-01
## [131] 2.953428e-01 2.950151e-01 2.945795e-01 2.940521e-01 2.938371e-01
## [136] 2.934020e-01 2.933125e-01 2.928964e-01 2.922293e-01 2.921385e-01
## [141] 2.915339e-01 2.913549e-01 2.911361e-01 2.908732e-01 2.905148e-01
## [146] 2.903281e-01 2.897991e-01 2.890742e-01 2.889780e-01 2.884177e-01
## [151] 2.879427e-01 2.876760e-01 2.873825e-01 2.871011e-01 2.868782e-01
## [156] 2.864860e-01 2.860537e-01 2.859609e-01 2.852450e-01 2.848761e-01
## [161] 2.844490e-01 2.841344e-01 2.839653e-01 2.834440e-01 2.829931e-01
## [166] 2.827709e-01 2.823692e-01 2.820356e-01 2.818586e-01 2.811388e-01
## [171] 2.806531e-01 2.803280e-01 2.801168e-01 2.798981e-01 2.797443e-01
## [176] 2.794733e-01 2.787168e-01 2.785315e-01 2.783899e-01 2.780506e-01
## [181] 2.777790e-01 2.774324e-01 2.772262e-01 2.766185e-01 2.765575e-01
## [186] 2.759575e-01 2.758757e-01 2.754086e-01 2.752078e-01 2.748788e-01
## [191] 2.746631e-01 2.740643e-01 2.739362e-01 2.734724e-01 2.731086e-01
## [196] 2.728439e-01 2.723410e-01 2.721835e-01 2.719680e-01 2.718531e-01
## [201] 2.712211e-01 2.706945e-01 2.704104e-01 2.701173e-01 2.700801e-01
## [206] 2.696879e-01 2.694455e-01 2.689887e-01 2.688407e-01 2.682429e-01
## [211] 2.680842e-01 2.676313e-01 2.671201e-01 2.668472e-01 2.665474e-01
## [216] 2.662644e-01 2.657745e-01 2.655749e-01 2.651410e-01 2.650523e-01
## [221] 2.648365e-01 2.646596e-01 2.642796e-01 2.641338e-01 2.637950e-01
## [226] 2.633721e-01 2.631509e-01 2.627955e-01 2.625522e-01 2.619448e-01
## [231] 2.616937e-01 2.614643e-01 2.611238e-01 2.607637e-01 2.604998e-01
## [236] 2.598202e-01 2.595343e-01 2.594131e-01 2.592182e-01 2.587438e-01
## [241] 2.585238e-01 2.584489e-01 2.578745e-01 2.575774e-01 2.574777e-01
## [246] 2.568828e-01 2.566786e-01 2.564208e-01 2.561685e-01 2.556855e-01
## [251] 2.552030e-01 2.549848e-01 2.547664e-01 2.544450e-01 2.539913e-01
## [256] 2.536382e-01 2.535043e-01 2.530004e-01 2.527111e-01 2.523643e-01
## [261] 2.520098e-01 2.515803e-01 2.515437e-01 2.510316e-01 2.509742e-01
## [266] 2.505403e-01 2.502062e-01 2.498543e-01 2.495622e-01 2.494090e-01
## [271] 2.491052e-01 2.486418e-01 2.484272e-01 2.476861e-01 2.474589e-01
## [276] 2.470446e-01 2.469481e-01 2.462622e-01 2.461518e-01 2.457009e-01
## [281] 2.454396e-01 2.453355e-01 2.449083e-01 2.447414e-01 2.439952e-01
## [286] 2.438978e-01 2.437522e-01 2.433766e-01 2.426950e-01 2.423489e-01
## [291] 2.422677e-01 2.420864e-01 2.411901e-01 2.408968e-01 2.406475e-01
## [296] 2.404391e-01 2.402672e-01 2.396579e-01 2.391390e-01 2.391241e-01
## [301] 2.383604e-01 2.383045e-01 2.376550e-01 2.375349e-01 2.372675e-01
## [306] 2.370537e-01 2.364774e-01 2.363943e-01 2.358918e-01 2.356462e-01
## [311] 2.348766e-01 2.348377e-01 2.340805e-01 2.334177e-01 2.331655e-01
## [316] 2.328555e-01 2.324970e-01 2.322191e-01 2.321355e-01 2.310586e-01
## [321] 2.308793e-01 2.304743e-01 2.299762e-01 2.288778e-01 2.284908e-01
## [326] 2.282540e-01 2.278286e-01 2.276666e-01 2.269590e-01 2.264172e-01
## [331] 2.259556e-01 2.248809e-01 2.246247e-01 2.238372e-01 2.228000e-01
## [336] 2.221419e-01 2.214539e-01 2.208353e-01 2.202328e-01 2.184213e-01
## [341] 2.179695e-01 2.139866e-01 1.846495e-01 7.970027e-16

summary(xc.pca)

## Importance of components:
##                             PC1       PC2       PC3       PC4       PC5
## Standard deviation     6427.2371 3.117e+03 1.626e+03 1.394e+03 1.348e+03
```

```
## Proportion of Variance    0.1189 2.796e-02 7.610e-03 5.590e-03 5.230e-03
## Cumulative Proportion     0.1189 1.469e-01 1.545e-01 1.601e-01 1.653e-01
##                              PC6       PC7       PC8       PC9      PC10
## Standard deviation     1.263e+03 1.209e+03 1.203e+03 1.196e+03 1.189e+03
## Proportion of Variance 4.590e-03 4.210e-03 4.170e-03 4.120e-03 4.070e-03
## Cumulative Proportion  1.699e-01 1.741e-01 1.782e-01 1.824e-01 1.864e-01
##                             PC11      PC12      PC13      PC14      PC15
## Standard deviation     1.184e+03 1.177e+03 1.169e+03 1163.7026 1.160e+03
## Proportion of Variance 4.030e-03 3.990e-03 3.940e-03    0.0039 3.870e-03
## Cumulative Proportion  1.905e-01 1.945e-01 1.984e-01    0.2023 2.062e-01
##                             PC16      PC17      PC18      PC19      PC20
## Standard deviation     1.154e+03 1.153e+03 1148.8830 1.142e+03 1.138e+03
## Proportion of Variance 3.840e-03 3.830e-03    0.0038 3.750e-03 3.730e-03
## Cumulative Proportion  2.100e-01 2.138e-01    0.2176 2.214e-01 2.251e-01
##                             PC21      PC22      PC23      PC24      PC25
## Standard deviation     1.135e+03 1.131e+03 1.130e+03 1.124e+03 1.122e+03
## Proportion of Variance 3.710e-03 3.680e-03 3.670e-03 3.640e-03 3.620e-03
## Cumulative Proportion  2.288e-01 2.325e-01 2.362e-01 2.398e-01 2.434e-01
##                             PC26      PC27      PC28      PC29      PC30
## Standard deviation     1.119e+03 1.118e+03 1.113e+03 1.112e+03 1.109e+03
## Proportion of Variance 3.610e-03 3.590e-03 3.570e-03 3.560e-03 3.540e-03
## Cumulative Proportion  2.470e-01 2.506e-01 2.542e-01 2.578e-01 2.613e-01
##                             PC31      PC32      PC33      PC34      PC35
## Standard deviation     1.105e+03 1.104e+03 1.102e+03 1.100e+03 1.098e+03
## Proportion of Variance 3.510e-03 3.510e-03 3.490e-03 3.490e-03 3.470e-03
## Cumulative Proportion  2.648e-01 2.683e-01 2.718e-01 2.753e-01 2.788e-01
##                             PC36      PC37      PC38      PC39      PC40
## Standard deviation     1.097e+03 1.096e+03 1.095e+03 1.090e+03 1.089e+03
## Proportion of Variance 3.460e-03 3.450e-03 3.450e-03 3.420e-03 3.410e-03
## Cumulative Proportion  2.822e-01 2.857e-01 2.891e-01 2.926e-01 2.960e-01
##                             PC41      PC42      PC43      PC44      PC45
## Standard deviation     1087.3834 1086.5098 1.083e+03 1.082e+03 1.079e+03
## Proportion of Variance    0.0034    0.0034 3.370e-03 3.370e-03 3.350e-03
## Cumulative Proportion     0.2994    0.3028 3.061e-01 3.095e-01 3.129e-01
##                             PC46      PC47      PC48      PC49      PC50
## Standard deviation     1.078e+03 1.076e+03 1.074e+03 1.073e+03 1070.5568
## Proportion of Variance 3.340e-03 3.340e-03 3.320e-03 3.310e-03    0.0033
## Cumulative Proportion  3.162e-01 3.195e-01 3.229e-01 3.262e-01    0.3295
##                             PC51      PC52      PC53      PC54      PC55
## Standard deviation     1.068e+03 1.067e+03 1.065e+03 1.063e+03 1.062e+03
## Proportion of Variance 3.280e-03 3.280e-03 3.260e-03 3.250e-03 3.250e-03
## Cumulative Proportion  3.327e-01 3.360e-01 3.393e-01 3.426e-01 3.458e-01
##                             PC56      PC57      PC58      PC59      PC60
## Standard deviation     1.059e+03 1.058e+03 1.055e+03 1054.6006 1.053e+03
## Proportion of Variance 3.230e-03 3.220e-03 3.210e-03    0.0032 3.190e-03
## Cumulative Proportion  3.490e-01 3.522e-01 3.554e-01    0.3587 3.618e-01
##                             PC61      PC62      PC63      PC64      PC65
## Standard deviation     1.052e+03 1.050e+03 1.049e+03 1.049e+03 1.046e+03
## Proportion of Variance 3.190e-03 3.170e-03 3.170e-03 3.160e-03 3.150e-03
## Cumulative Proportion  3.650e-01 3.682e-01 3.714e-01 3.745e-01 3.777e-01
```

```
##                             PC66      PC67      PC68      PC69      PC70
## Standard deviation     1.044e+03 1.043e+03 1.042e+03 1038.1663 1.037e+03
## Proportion of Variance 3.140e-03 3.130e-03 3.120e-03    0.0031 3.090e-03
## Cumulative Proportion  3.808e-01 3.840e-01 3.871e-01    0.3902 3.933e-01
##                             PC71      PC72      PC73      PC74      PC75
## Standard deviation     1.035e+03 1.033e+03 1.031e+03 1.031e+03 1.030e+03
## Proportion of Variance 3.080e-03 3.070e-03 3.060e-03 3.060e-03 3.050e-03
## Cumulative Proportion  3.963e-01 3.994e-01 4.025e-01 4.055e-01 4.086e-01
##                             PC76      PC77      PC78      PC79      PC80
## Standard deviation     1.027e+03 1.026e+03 1.026e+03 1.024e+03 1.023e+03
## Proportion of Variance 3.040e-03 3.030e-03 3.030e-03 3.020e-03 3.010e-03
## Cumulative Proportion  4.116e-01 4.147e-01 4.177e-01 4.207e-01 4.237e-01
##                             PC81      PC82      PC83      PC84      PC85
## Standard deviation     1020.4091 1.018e+03 1.018e+03 1.017e+03 1.016e+03
## Proportion of Variance    0.0030 2.990e-03 2.980e-03 2.980e-03 2.970e-03
## Cumulative Proportion     0.4267 4.297e-01 4.327e-01 4.357e-01 4.386e-01
##                             PC86      PC87      PC88      PC89      PC90
## Standard deviation     1.015e+03 1.013e+03 1.011e+03 1.010e+03 1.009e+03
## Proportion of Variance 2.970e-03 2.950e-03 2.940e-03 2.940e-03 2.930e-03
## Cumulative Proportion  4.416e-01 4.446e-01 4.475e-01 4.504e-01 4.534e-01
##                             PC91      PC92      PC93      PC94      PC95
## Standard deviation     1.007e+03 1004.1305 1003.3942 1.002e+03 1.001e+03
## Proportion of Variance 2.920e-03    0.0029    0.0029 2.890e-03 2.880e-03
## Cumulative Proportion  4.563e-01    0.4592    0.4621 4.650e-01 4.679e-01
##                             PC96      PC97      PC98      PC99     PC100
## Standard deviation     1.000e+03 999.08472 997.78146 996.69503 995.35740
## Proportion of Variance 2.880e-03   0.00287   0.00287   0.00286   0.00285
## Cumulative Proportion  4.707e-01   0.47361   0.47648   0.47934   0.48219
##                            PC101     PC102     PC103     PC104     PC105
## Standard deviation     993.42854 992.81470 992.12632 988.91157 987.87151
## Proportion of Variance   0.00284   0.00284   0.00283   0.00281   0.00281
## Cumulative Proportion    0.48503   0.48787   0.49070   0.49351   0.49632
##                            PC106    PC107     PC108     PC109     PC110
## Standard deviation     987.0330 985.8830 984.40946 982.87657 981.71439
## Proportion of Variance   0.0028   0.0028   0.00279   0.00278   0.00277
## Cumulative Proportion    0.4991   0.5019   0.50471   0.50749   0.51027
##                            PC111     PC112     PC113     PC114     PC115
## Standard deviation     981.54406 980.17362 979.42257 977.33637 976.27183
## Proportion of Variance   0.00277   0.00277   0.00276   0.00275   0.00274
## Cumulative Proportion    0.51304   0.51580   0.51856   0.52131   0.52406
##                            PC116     PC117     PC118     PC119    PC120
## Standard deviation     974.72735 974.34291 973.36240 972.13000 969.4334
## Proportion of Variance   0.00273   0.00273   0.00273   0.00272   0.0027
## Cumulative Proportion    0.52679   0.52952   0.53225   0.53497   0.5377
##                            PC121     PC122     PC123     PC124     PC125
## Standard deviation     969.0543 966.51082 965.98879 965.15780 964.66663
## Proportion of Variance   0.0027   0.00269   0.00269   0.00268   0.00268
## Cumulative Proportion    0.5404   0.54307   0.54575   0.54843   0.55111
##                            PC126     PC127     PC128     PC129     PC130
## Standard deviation     962.86922 961.79648 960.63423 958.95375 957.92629
```

```
## Proportion of Variance   0.00267   0.00266   0.00266   0.00265   0.00264
## Cumulative Proportion    0.55378   0.55644   0.55910   0.56175   0.56439
##                            PC131     PC132     PC133     PC134     PC135
## Standard deviation     957.63992 956.57709 955.16471 953.45459 952.75773
## Proportion of Variance   0.00264   0.00263   0.00263   0.00262   0.00261
## Cumulative Proportion    0.56703   0.56966   0.57229   0.57490   0.57751
##                            PC136    PC137    PC138     PC139     PC140
PC141
## Standard deviation     951.3468 951.0565 949.7074 947.54449 947.25003
945.28954
## Proportion of Variance   0.0026   0.0026   0.0026   0.00258   0.00258
0.00257
## Cumulative Proportion    0.5801   0.5827   0.5853   0.58790   0.59048
0.59306
##                            PC142     PC143     PC144     PC145     PC146
## Standard deviation     944.70931 943.99979 943.14729 941.98509 941.37995
## Proportion of Variance   0.00257   0.00256   0.00256   0.00255   0.00255
## Cumulative Proportion    0.59563   0.59819   0.60075   0.60330   0.60585
##                            PC147     PC148     PC149     PC150     PC151
## Standard deviation     939.66465 937.31413 937.00220 935.18535 933.64506
## Proportion of Variance   0.00254   0.00253   0.00253   0.00252   0.00251
## Cumulative Proportion    0.60840   0.61092   0.61345   0.61597   0.61848
##                            PC152    PC153     PC154     PC155     PC156
## Standard deviation     932.7803 931.8289 930.91633 930.19361 928.92185
## Proportion of Variance   0.0025   0.0025   0.00249   0.00249   0.00248
## Cumulative Proportion    0.6210   0.6235   0.62597   0.62847   0.63095
##                            PC157     PC158     PC159     PC160     PC161
## Standard deviation     927.52026 927.21918 924.89786 923.70176 922.31703
## Proportion of Variance   0.00248   0.00247   0.00246   0.00246   0.00245
## Cumulative Proportion    0.63342   0.63590   0.63836   0.64082   0.64327
##                            PC162     PC163     PC164     PC165     PC166
## Standard deviation     921.29699 920.74845 919.05833 917.59636 916.87582
## Proportion of Variance   0.00244   0.00244   0.00243   0.00242   0.00242
## Cumulative Proportion    0.64571   0.64815   0.65058   0.65300   0.65542
##                            PC167     PC168    PC169     PC170     PC171
## Standard deviation     915.57335 914.49148 913.9177 911.58384 910.00905
## Proportion of Variance   0.00241   0.00241   0.0024   0.00239   0.00238
## Cumulative Proportion    0.65783   0.66024   0.6626   0.66504   0.66742
##                            PC172     PC173     PC174     PC175     PC176
## Standard deviation     908.95494 908.27011 907.56094 907.06211 906.18340
## Proportion of Variance   0.00238   0.00237   0.00237   0.00237   0.00236
## Cumulative Proportion    0.66980   0.67217   0.67454   0.67691   0.67927
##                            PC177     PC178     PC179     PC180     PC181
## Standard deviation     903.73049 903.12970 902.67053 901.57053 900.68965
## Proportion of Variance   0.00235   0.00235   0.00235   0.00234   0.00233
## Cumulative Proportion    0.68163   0.68397   0.68632   0.68866   0.69099
##                            PC182     PC183     PC184     PC185    PC186
## Standard deviation     899.56596 898.89720 896.92670 896.72921 894.7837
## Proportion of Variance   0.00233   0.00233   0.00232   0.00231   0.0023
## Cumulative Proportion    0.69332   0.69565   0.69796   0.70028   0.7026
```

```
##                            PC187    PC188     PC189     PC190     PC191
## Standard deviation     894.5184 893.0036 892.35254 891.28595 890.58649
## Proportion of Variance   0.0023   0.0023   0.00229   0.00229   0.00228
## Cumulative Proportion    0.7049   0.7072   0.70947   0.71176   0.71404
##                            PC192     PC193     PC194     PC195     PC196
## Standard deviation     888.64477 888.22955 886.72565 885.54610 884.68771
## Proportion of Variance   0.00227   0.00227   0.00226   0.00226   0.00225
## Cumulative Proportion    0.71631   0.71858   0.72085   0.72310   0.72536
##                            PC197     PC198     PC199     PC200     PC201
## Standard deviation     883.05731 882.54659 881.84786 881.47513 879.42589
## Proportion of Variance   0.00224   0.00224   0.00224   0.00224   0.00223
## Cumulative Proportion    0.72760   0.72984   0.73208   0.73432   0.73654
##                            PC202     PC203     PC204     PC205    PC206
## Standard deviation     877.71856 876.79720 875.84678 875.72619 874.4545
## Proportion of Variance   0.00222   0.00221   0.00221   0.00221   0.0022
## Cumulative Proportion    0.73876   0.74097   0.74318   0.74539   0.7476
##                           PC207     PC208     PC209     PC210     PC211
## Standard deviation     873.6686 872.18734 871.70746 869.76936 869.25465
## Proportion of Variance   0.0022   0.00219   0.00219   0.00218   0.00217
## Cumulative Proportion    0.7498   0.75197   0.75416   0.75634   0.75851
##                            PC212     PC213     PC214     PC215     PC216
## Standard deviation     867.78609 866.12867 865.24357 864.27167 863.35416
## Proportion of Variance   0.00217   0.00216   0.00215   0.00215   0.00215
## Cumulative Proportion    0.76068   0.76284   0.76499   0.76714   0.76929
##                            PC217     PC218     PC219     PC220     PC221
## Standard deviation     861.76538 861.11841 859.71126 859.42395 858.72401
## Proportion of Variance   0.00214   0.00213   0.00213   0.00213   0.00212
## Cumulative Proportion    0.77143   0.77356   0.77569   0.77781   0.77994
##                            PC222     PC223     PC224     PC225    PC226
## Standard deviation     858.15042 856.91837 856.44571 855.34707 853.9759
## Proportion of Variance   0.00212   0.00211   0.00211   0.00211   0.0021
## Cumulative Proportion    0.78206   0.78417   0.78628   0.78839   0.7905
##                           PC227     PC228     PC229     PC230     PC231
## Standard deviation     853.2587 852.10611 851.31720 849.34779 848.53370
## Proportion of Variance   0.0021   0.00209   0.00209   0.00208   0.00207
## Cumulative Proportion    0.7926   0.79467   0.79676   0.79883   0.80091
##                            PC232     PC233     PC234     PC235     PC236
## Standard deviation     847.78987 846.68578 845.51827 844.66254 842.45881
## Proportion of Variance   0.00207   0.00206   0.00206   0.00205   0.00204
## Cumulative Proportion    0.80297   0.80504   0.80709   0.80915   0.81119
##                            PC237     PC238     PC239     PC240     PC241
## Standard deviation     841.53183 841.13881 840.50695 838.96856 838.25535
## Proportion of Variance   0.00204   0.00204   0.00203   0.00203   0.00202
## Cumulative Proportion    0.81323   0.81527   0.81730   0.81932   0.82135
##                            PC242     PC243     PC244     PC245    PC246
## Standard deviation     838.01260 836.14987 835.18682 834.86347 832.9343
## Proportion of Variance   0.00202   0.00201   0.00201   0.00201   0.0020
## Cumulative Proportion    0.82337   0.82538   0.82739   0.82939   0.8314
##                            PC247     PC248     PC249     PC250     PC251
## Standard deviation     832.27220 831.43634 830.61835 829.05215 827.48778
```

```
## Proportion of Variance   0.00199   0.00199   0.00199   0.00198   0.00197
## Cumulative Proportion    0.83338   0.83537   0.83736   0.83934   0.84131
##                            PC252     PC253     PC254     PC255     PC256
## Standard deviation     826.78021 826.07222 825.02992 823.55881 822.41380
## Proportion of Variance   0.00197   0.00196   0.00196   0.00195   0.00195
## Cumulative Proportion    0.84328   0.84524   0.84720   0.84915   0.85110
##                            PC257     PC258     PC259     PC260     PC261
## Standard deviation     8.22e+02 820.34579 819.40790 818.28326 817.13380
## Proportion of Variance 1.94e-03   0.00194   0.00193   0.00193   0.00192
## Cumulative Proportion  8.53e-01   0.85498   0.85691   0.85884   0.86076
##                            PC262     PC263     PC264     PC265    PC266
## Standard deviation     815.74132 815.62244 813.96213 813.77593 812.3691
## Proportion of Variance   0.00192   0.00191   0.00191   0.00191   0.0019
## Cumulative Proportion    0.86268   0.86459   0.86650   0.86840   0.8703
##                            PC267     PC268     PC269     PC270     PC271
## Standard deviation     811.28565 810.14490 809.19772 808.70092 807.71591
## Proportion of Variance   0.00189   0.00189   0.00188   0.00188   0.00188
## Cumulative Proportion    0.87220   0.87409   0.87597   0.87785   0.87973
##                            PC272     PC273     PC274     PC275    PC276
## Standard deviation     806.21314 805.51739 803.11445 802.37787 8.01e+02
## Proportion of Variance   0.00187   0.00187   0.00186   0.00185 1.85e-03
## Cumulative Proportion    0.88160   0.88347   0.88532   0.88718 8.89e-01
##                            PC277     PC278     PC279     PC280     PC281
## Standard deviation     800.72148 798.49763 798.13957 796.67753 795.83013
## Proportion of Variance   0.00185   0.00184   0.00183   0.00183   0.00182
## Cumulative Proportion    0.89087   0.89270   0.89454   0.89637   0.89819
##                            PC282     PC283     PC284    PC285    PC286
PC287
## Standard deviation     795.49283 794.10760 793.56622 791.1468 790.8311
790.3589
## Proportion of Variance   0.00182   0.00181   0.00181   0.0018   0.0018
0.0018
## Cumulative Proportion    0.90001   0.90182   0.90364   0.9054   0.9072
0.9090
##                            PC288     PC289     PC290     PC291     PC292
## Standard deviation     789.14105 786.93102 785.80873 785.54538 784.95766
## Proportion of Variance   0.00179   0.00178   0.00178   0.00178   0.00177
## Cumulative Proportion    0.91083   0.91261   0.91439   0.91616   0.91794
##                            PC293     PC294     PC295     PC296     PC297
## Standard deviation     782.05124 781.10025 780.29212 779.61622 779.05885
## Proportion of Variance   0.00176   0.00176   0.00175   0.00175   0.00175
## Cumulative Proportion    0.91970   0.92145   0.92321   0.92496   0.92670
##                            PC298     PC299     PC300     PC301     PC302
## Standard deviation     777.08340 775.40078 775.35255 772.87626 772.69474
## Proportion of Variance   0.00174   0.00173   0.00173   0.00172   0.00172
## Cumulative Proportion    0.92844   0.93017   0.93190   0.93362   0.93534
##                            PC303     PC304    PC305    PC306     PC307
## Standard deviation     770.58903 770.19950 769.3325 768.6392 766.77070
## Proportion of Variance   0.00171   0.00171   0.0017   0.0017   0.00169
## Cumulative Proportion    0.93705   0.93875   0.9405   0.9422   0.94385
```

```
##                            PC308     PC309     PC310     PC311     PC312
## Standard deviation     766.50114 764.87184 764.07549 761.58017 761.45398
## Proportion of Variance   0.00169   0.00168   0.00168   0.00167   0.00167
## Cumulative Proportion    0.94554   0.94723   0.94891   0.95058   0.95224
##                            PC313     PC314     PC315     PC316     PC317
## Standard deviation     758.99870 756.84958 756.03198 755.02663 753.86420
## Proportion of Variance   0.00166   0.00165   0.00165   0.00164   0.00164
## Cumulative Proportion    0.95390   0.95555   0.95720   0.95884   0.96047
##                            PC318     PC319     PC320     PC321     PC322
## Standard deviation     752.96305 752.69211 749.20016 748.61892 747.30583
## Proportion of Variance   0.00163   0.00163   0.00162   0.00161   0.00161
## Cumulative Proportion    0.96210   0.96373   0.96535   0.96696   0.96857
##                            PC323     PC324     PC325     PC326     PC327
## Standard deviation     745.6907 742.12923 740.87419 740.10633 738.72716
## Proportion of Variance   0.0016   0.00159   0.00158   0.00158   0.00157
## Cumulative Proportion    0.9702   0.97176   0.97334   0.97491   0.97648
##                            PC328     PC329     PC330     PC331     PC332
## Standard deviation     738.20175 735.90746 734.15054 732.65389 729.16925
## Proportion of Variance   0.00157   0.00156   0.00155   0.00154   0.00153
## Cumulative Proportion    0.97805   0.97961   0.98116   0.98271   0.98424
##                            PC333     PC334    PC335     PC336     PC337
## Standard deviation     728.33855 725.78514 722.4219 720.28823 718.05731
## Proportion of Variance   0.00153   0.00152   0.0015   0.00149   0.00148
## Cumulative Proportion    0.98576   0.98728   0.9888   0.99027   0.99176
##                            PC338     PC339     PC340     PC341     PC342
## Standard deviation     716.05153 714.09795 708.22422 706.75925 693.84489
## Proportion of Variance   0.00148   0.00147   0.00144   0.00144   0.00139
## Cumulative Proportion    0.99323   0.99470   0.99615   0.99758   0.99897
##                            PC343     PC344
## Standard deviation     598.72011 2.584e-12
## Proportion of Variance   0.00103 0.000e+00
## Cumulative Proportion    1.00000 1.000e+00

Xc.just.sex <- model.matrix(~ Sex, data=xc_mat)

xc.pca.and.sex <- cbind(xc.pca, Xc.just.sex)

## Warning in cbind(xc.pca, Xc.just.sex): number of rows of result is not a
## multiple of vector length (arg 1)

gene_info <- read.csv('gene_info.csv')
SNP_info <- read.csv('SNP_info.csv')

# Define our function to run GWAS and get p-values
pval_calculator_w_covars <- function(pheno_input, xa_input, xd_input,
xz_input){
  n_samples <- length(xa_input) # calculate your number of samples
  X_mx <- cbind(rep(1,length(xa_input)),xa_input, xd_input, xz_input) #create
your X matrix under H1
```

```
  MLE_beta <- ginv(t(X_mx) %*% X_mx) %*% t(X_mx) %*% pheno_input #calculate
your MLE of the betas

  x_h0 =  cbind(rep(1,length(xa_input)), xz_input) #calculate your x under H0
  MLE_h0 = ginv(t(x_h0) %*% x_h0) %*% t(x_h0) %*% pheno_input #calculate your
MLE under h0
  y_hat_0 = x_h0 %*% MLE_h0 #calculate y_hat under the null hypothesis
  y_hat_1 = X_mx%*% MLE_beta #calculate y_hat under H1

  SSE_theta_0 = sum((pheno_input-y_hat_0)^2) #calculate SSE under null
  SSE_theta_1 = sum((pheno_input-y_hat_1)^2) #calculate SSE under H1

  df_M <- 2
  df_E <- n_samples - 4

  numerator <- (SSE_theta_0-SSE_theta_1) / df_M #calculate your F statistic
  denom <- SSE_theta_1 / df_E
  Fstatistic <-numerator / denom

  # to check if it is correct
  pval <- pf(Fstatistic, df_M, df_E,lower.tail = FALSE) #calculate your p
value and return it
  return(pval)
}

# Run the functions

results.1 <- lapply(1:ncol(xa_mat), function(column.counter){
  data.table(pval_calculator_w_covars(pheno_input = sim_pheno_mx[,1],
                                      xa_input = as.matrix(xa_mat[,
column.counter]),
                                      xd_input = as.matrix(xd_mat[,
column.counter]),
                                      xz_input = as.matrix(xc_mat1)))
              }) %>% rbindlist() %>% mutate(p=V1, index = 1:ncol(xa_mat))

indices1 <- which(p.adjust(results.1$p, method = "bonferroni") <= 0.05)
hits1 <- sort(SNP_info$position[indices1])
length(hits1)

## [1] 71

results.2 <- lapply(1:ncol(xa_mat), function(column.counter){
  data.table(pval_calculator_w_covars(pheno_input = sim_pheno_mx[,2],
                                      xa_input = as.matrix(xa_mat[,
column.counter]),
                                      xd_input = as.matrix(xd_mat[,
column.counter]),
                                      xz_input = as.matrix(xc_mat1)))
              }) %>% rbindlist() %>% mutate(p=V1, index = 1:ncol(xa_mat))
```

```r
indices2 <- which(p.adjust(results.2$p, method = "bonferroni") <= 0.05)
hits2 <- sort(SNP_info$position[indices2])
hits2
```

```
##  [1] 42889467 42893842 42896182 42903013 42904736 42907726 42911587
42916172
##  [9] 42919954 42924756 42938645 42942927 42946612 42949278 42952810
42953822
## [17] 42954621 42956454 42957216 42962100 42964461 42969161 42972496
42973585
## [25] 42977844 43108015 98486048
```

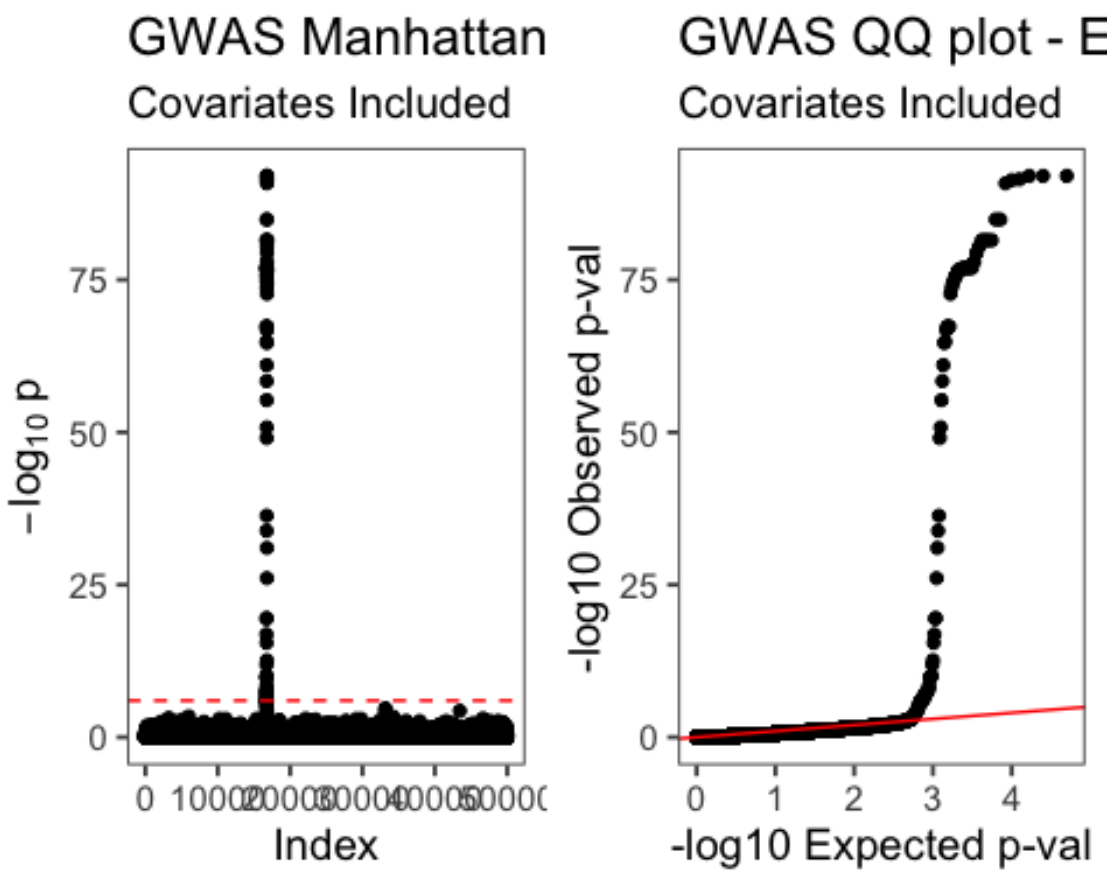
```r
results.3 <- lapply(1:ncol(xa_mat), function(column.counter){
  data.table(pval_calculator_w_covars(pheno_input = sim_pheno_mx[,3],
                                      xa_input = as.matrix(xa_mat[,
column.counter]),
                                      xd_input = as.matrix(xd_mat[,
column.counter]),
                                      xz_input = as.matrix(xc_mat1)))
             }) %>% rbindlist() %>% mutate(p=V1, index = 1:ncol(xa_mat))

indices3 <- which(p.adjust(results.3$p, method = "bonferroni") <= 0.05)
hits3 <- sort(SNP_info$position[indices3])
hits3
```

```
##  [1] 1524250 1604317 1614929 1780619 1785391 1789021 1792207 1794224
1798982
## [10] 1804934 1806080 1806559 1807707 1808392 1809480 1810194 1810803
1811984
## [19] 1812168 1813518 1816100 1819604 1820639 1824144 1825190 1826990
1828065
## [28] 1829958 1831143 1831554 1832328 1832761 1835286 1836231 1837572
1839643
## [37] 1842605 1842970 1845028 1845980 1846938 1848043 1849190 1850033
1852576
## [46] 1854320 1854638 1855229 1856231 1857300 1858216 1858666 1859725
1860371
## [55] 1861583 1862683 1862993 1864524 1864887 1865581 1866730 1867504
1868123
## [64] 1868857 1869663 1870120 1871282 1872310 1873062 1873933 1874763
1883987
## [73] 1892929 1895185 1897411 1898338 1899224 1901135 1902367 1904506
1911549
## [82] 1916400 1919081 1921599 1923514 1926150 1926998 1928485 1929366
```

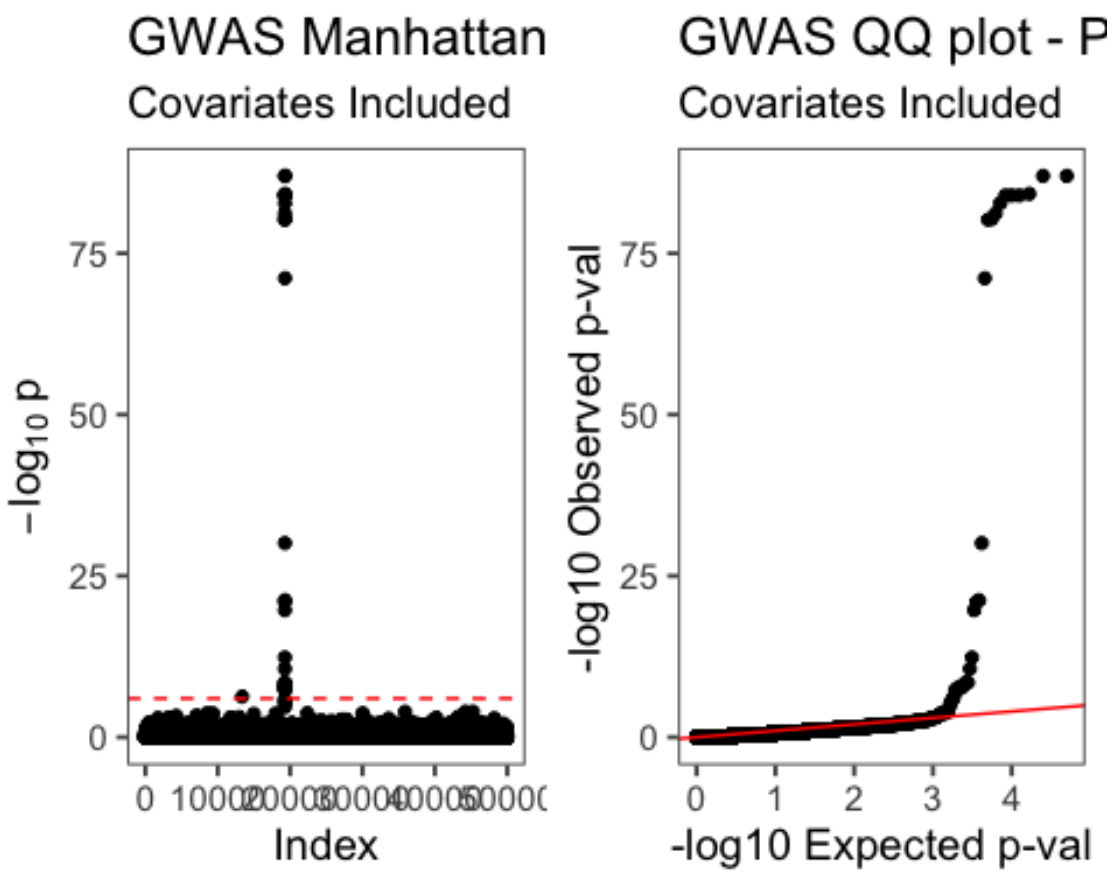
```r
results.4 <- lapply(1:ncol(xa_mat), function(column.counter){
  data.table(pval_calculator_w_covars(pheno_input = sim_pheno_mx[,4],
                                      xa_input = as.matrix(xa_mat[,
column.counter]),
                                      xd_input = as.matrix(xd_mat[,
```

```
column.counter]),
                                        xz_input = as.matrix(xc_mat1)))
              }) %>% rbindlist() %>% mutate(p=V1, index = 1:ncol(xa_mat))

indices4 <- which(p.adjust(results.4$p, method = "bonferroni") <= 0.05)
hits4 <- sort(SNP_info$position[indices4])


results.5 <- lapply(1:ncol(xa_mat), function(column.counter){
  data.table(pval_calculator_w_covars(pheno_input = sim_pheno_mx[,5],
                                        xa_input = as.matrix(xa_mat[,
column.counter]),
                                        xd_input = as.matrix(xd_mat[,
column.counter]),
                                        xz_input = as.matrix(xc_mat1)))
              }) %>% rbindlist() %>% mutate(p=V1, index = 1:ncol(xa_mat))

indices5 <- which(p.adjust(results.5$p, method = "bonferroni") <= 0.05)
hits5 <- sort(SNP_info$position[indices5])


# Manhattan Plot

## phenotype 1 - ERAP2
my.alpha = 0.05/ncol(xa_mat)
man1 <- ggplot(results.1, aes(x = index, y = -log10(p))) +
  geom_point() +
  geom_hline(yintercept = -log10(my.alpha), color = 'red', lty = 2) +
  labs(x = 'Index', y = expression(-log[10]~p),
       title = 'GWAS Manhattan Plot- ERAP2', subtitle='Covariates Included')

## phenotype 2 - PEX6
my.alpha = 0.05/ncol(xa_mat)
man2 <- ggplot(results.2, aes(x = index, y = -log10(p))) +
  geom_point() +
  geom_hline(yintercept = -log10(my.alpha), color = 'red', lty = 2) +
  labs(x = 'Index', y = expression(-log[10]~p),
       title = 'GWAS Manhattan Plot - PEX6', subtitle='Covariates Included')

## phenotype 3 - FAHD1
my.alpha = 0.05/ncol(xa_mat)
man3 <- ggplot(results.3, aes(x = index, y = -log10(p))) +
  geom_point() +
  geom_hline(yintercept = -log10(my.alpha), color = 'red', lty = 2) +
  labs(x = 'Index', y = expression(-log[10]~p),
       title = 'GWAS Manhattan Plot - FAHD1', subtitle='Covariates Included')

## phenotype 4 - GFM1
my.alpha = 0.05/ncol(xa_mat)
```

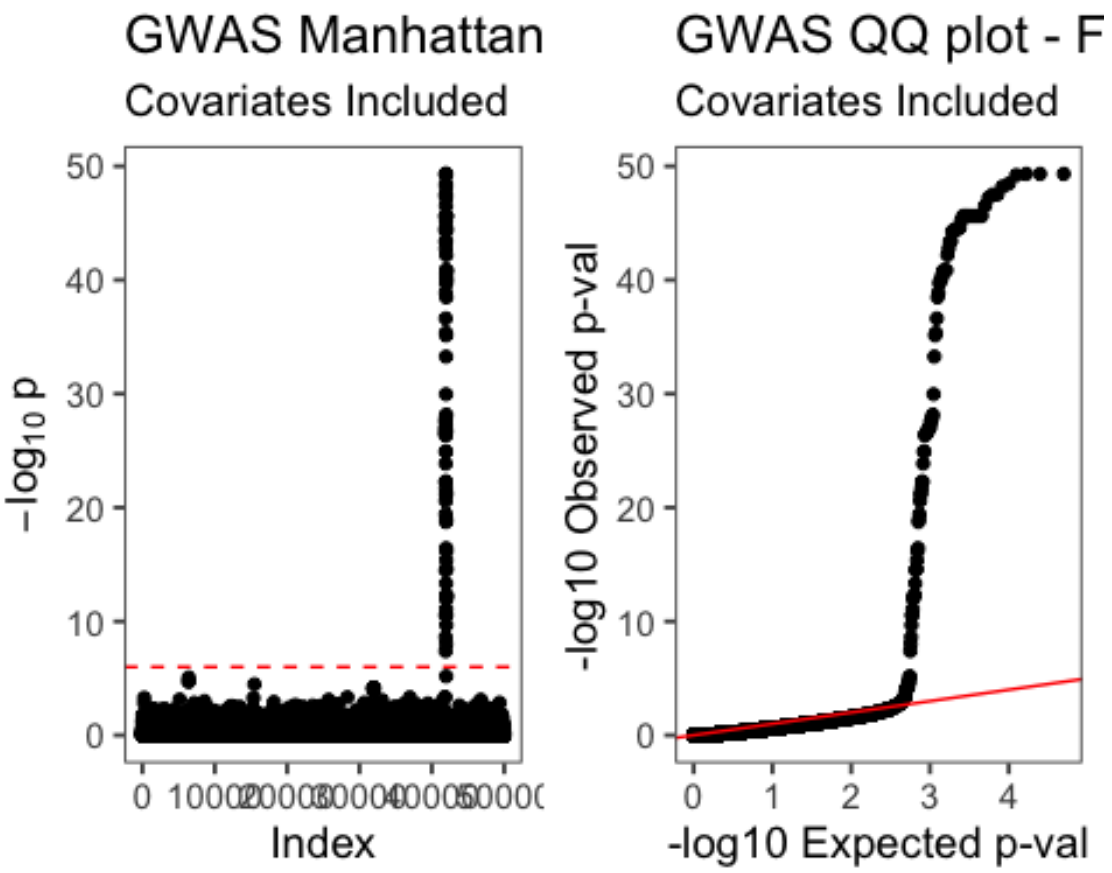
```r
man4 <- ggplot(results.4, aes(x = index, y = -log10(p))) +
  geom_point() +
  geom_hline(yintercept = -log10(my.alpha), color = 'red', lty = 2) +
  labs(x = 'Index', y = expression(-log[10]~p),
       title = 'GWAS Manhattan Plot - GFM1', subtitle='Covariates Included')

## phenotype 5 - MARCHF7
my.alpha = 0.05/ncol(xa_mat)
man5 <- ggplot(results.5, aes(x = index, y = -log10(p))) +
  geom_point() +
  geom_hline(yintercept = -log10(my.alpha), color = 'red', lty = 2) +
  labs(x = 'Index', y = expression(-log[10]~p),
       title = 'GWAS Manhattan Plot - MARCHF7', subtitle='Covariates
Included')


# QQ plot
## phenotype 1 - ERAP2
observed_pvals = sort(results.1$p)
expected_pvals = qunif(seq(0, 1, length.out = length(observed_pvals) + 2),
min = 0, max = 1)  ## Generate expected values. Note that we are using
length+2
expected_pvals = expected_pvals[expected_pvals != 0 & expected_pvals != 1]
## Remove the two extra values since they are 0 and 1

p_df = data.frame(observed = -log10(observed_pvals),
                  expected = -log10(expected_pvals))

qq <- ggplot(p_df, aes(x = expected, y = observed)) +
  geom_point() +
  geom_abline(intercept = 0, slope = 1, color = 'red') +
  labs(x = '-log10 Expected p-val',
       y = '-log10 Observed p-val',
       title = 'GWAS QQ plot - ERAP2',
       subtitle = 'Covariates Included')
grid.arrange(man1,qq, ncol=2)
```



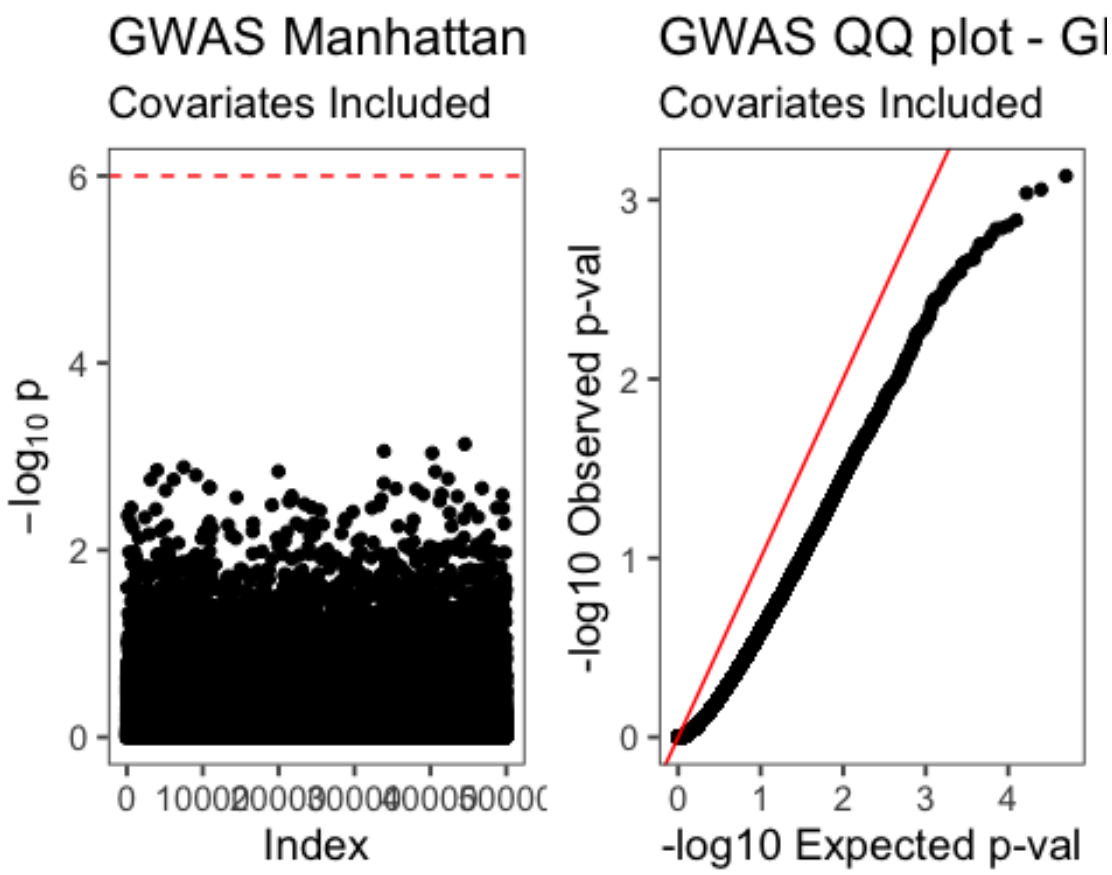

```
## phenotype 2 - PEX6
observed_pvals = sort(results.2$p)
expected_pvals = qunif(seq(0, 1, length.out = length(observed_pvals) + 2),
min = 0, max = 1)  ## Generate expected values. Note that we are using
length+2
expected_pvals = expected_pvals[expected_pvals != 0 & expected_pvals != 1]
## Remove the two extra values since they are 0 and 1

p_df = data.frame(observed = -log10(observed_pvals),
                  expected = -log10(expected_pvals))

qq <- ggplot(p_df, aes(x = expected, y = observed)) +
  geom_point() +
  geom_abline(intercept = 0, slope = 1, color = 'red') +
  labs(x = '-log10 Expected p-val',
       y = '-log10 Observed p-val',
       title = 'GWAS QQ plot - PEX6',
       subtitle = 'Covariates Included')
grid.arrange(man2,qq, ncol=2)
```



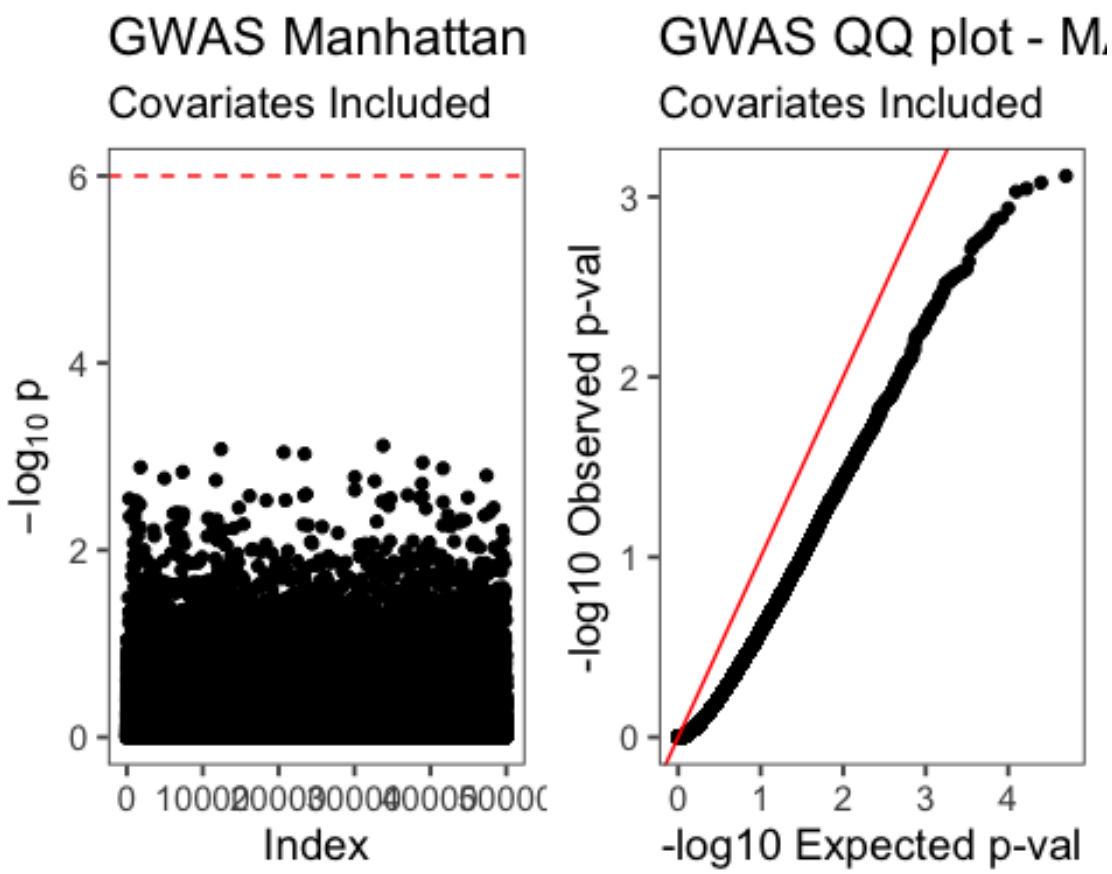

```r
## phenotype 3 - FAHD1
observed_pvals = sort(results.3$p)
expected_pvals = qunif(seq(0, 1, length.out = length(observed_pvals) + 2),
min = 0, max = 1)  ## Generate expected values. Note that we are using
length+2
expected_pvals = expected_pvals[expected_pvals != 0 & expected_pvals != 1]
## Remove the two extra values since they are 0 and 1

p_df = data.frame(observed = -log10(observed_pvals),
                  expected = -log10(expected_pvals))

qq <- ggplot(p_df, aes(x = expected, y = observed)) +
  geom_point() +
  geom_abline(intercept = 0, slope = 1, color = 'red') +
  labs(x = '-log10 Expected p-val',
       y = '-log10 Observed p-val',
       title = 'GWAS QQ plot - FAHD1',
       subtitle = 'Covariates Included')
grid.arrange(man3,qq, ncol=2)
```



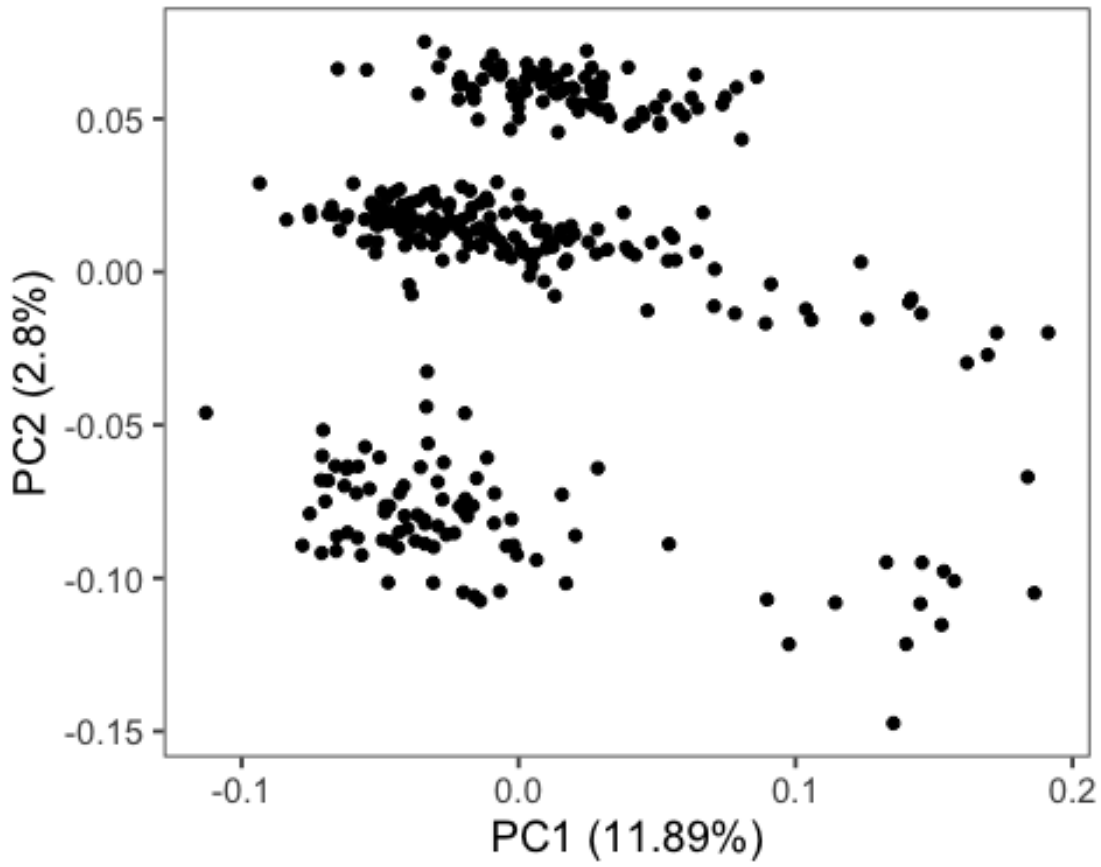

```
## phenotype 4 - GFM1
observed_pvals = sort(results.4$p)
expected_pvals = qunif(seq(0, 1, length.out = length(observed_pvals) + 2),
min = 0, max = 1)  ## Generate expected values. Note that we are using
length+2
expected_pvals = expected_pvals[expected_pvals != 0 & expected_pvals != 1]
## Remove the two extra values since they are 0 and 1

p_df = data.frame(observed = -log10(observed_pvals),
                  expected = -log10(expected_pvals))

qq <- ggplot(p_df, aes(x = expected, y = observed)) +
  geom_point() +
  geom_abline(intercept = 0, slope = 1, color = 'red') +
  labs(x = '-log10 Expected p-val',
       y = '-log10 Observed p-val',
       title = 'GWAS QQ plot - GFM1',
       subtitle = 'Covariates Included')
grid.arrange(man4,qq, ncol=2)
```



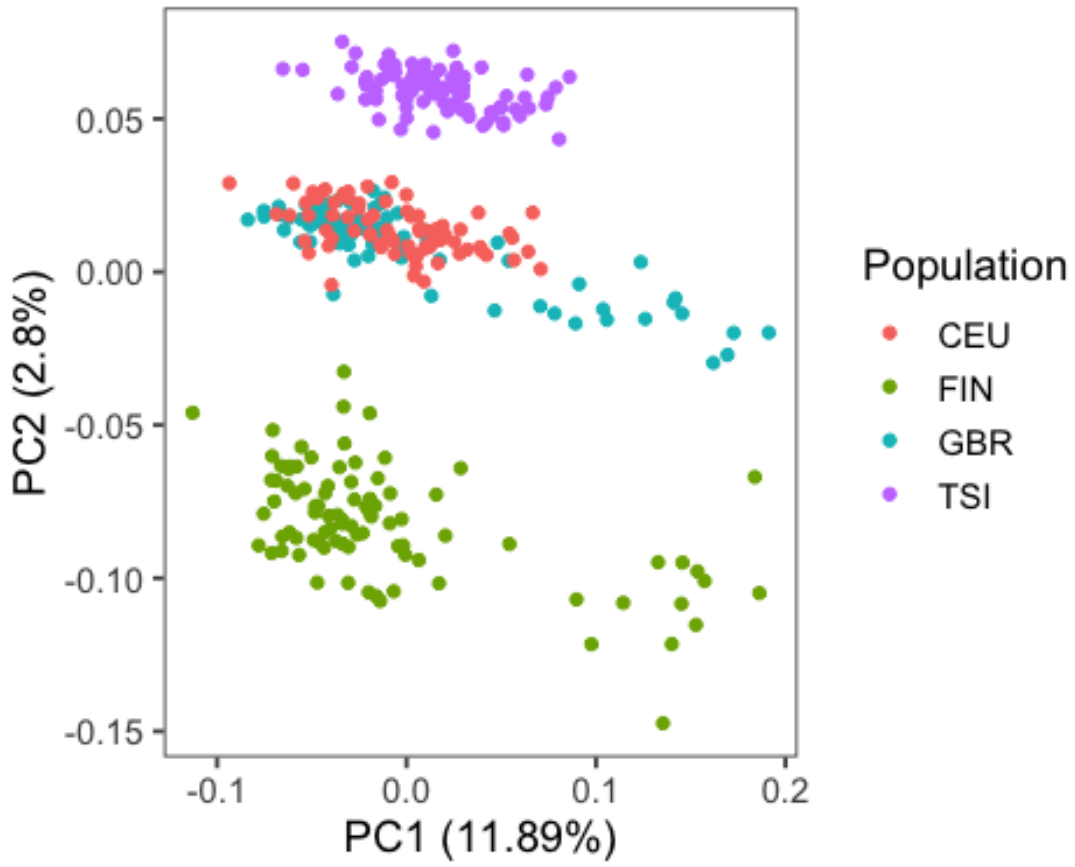

```
## phenotype 5 - MARCHF7
observed_pvals = sort(results.5$p)
expected_pvals = qunif(seq(0, 1, length.out = length(observed_pvals) + 2),
min = 0, max = 1)  ## Generate expected values. Note that we are using
length+2
expected_pvals = expected_pvals[expected_pvals != 0 & expected_pvals != 1]
## Remove the two extra values since they are 0 and 1

p_df = data.frame(observed = -log10(observed_pvals),
                  expected = -log10(expected_pvals))

qq <- ggplot(p_df, aes(x = expected, y = observed)) +
  geom_point() +
  geom_abline(intercept = 0, slope = 1, color = 'red') +
  labs(x = '-log10 Expected p-val',
       y = '-log10 Observed p-val',
       title = 'GWAS QQ plot - MARCHF7',
       subtitle = 'Covariates Included')
grid.arrange(man5,qq, ncol=2)
```



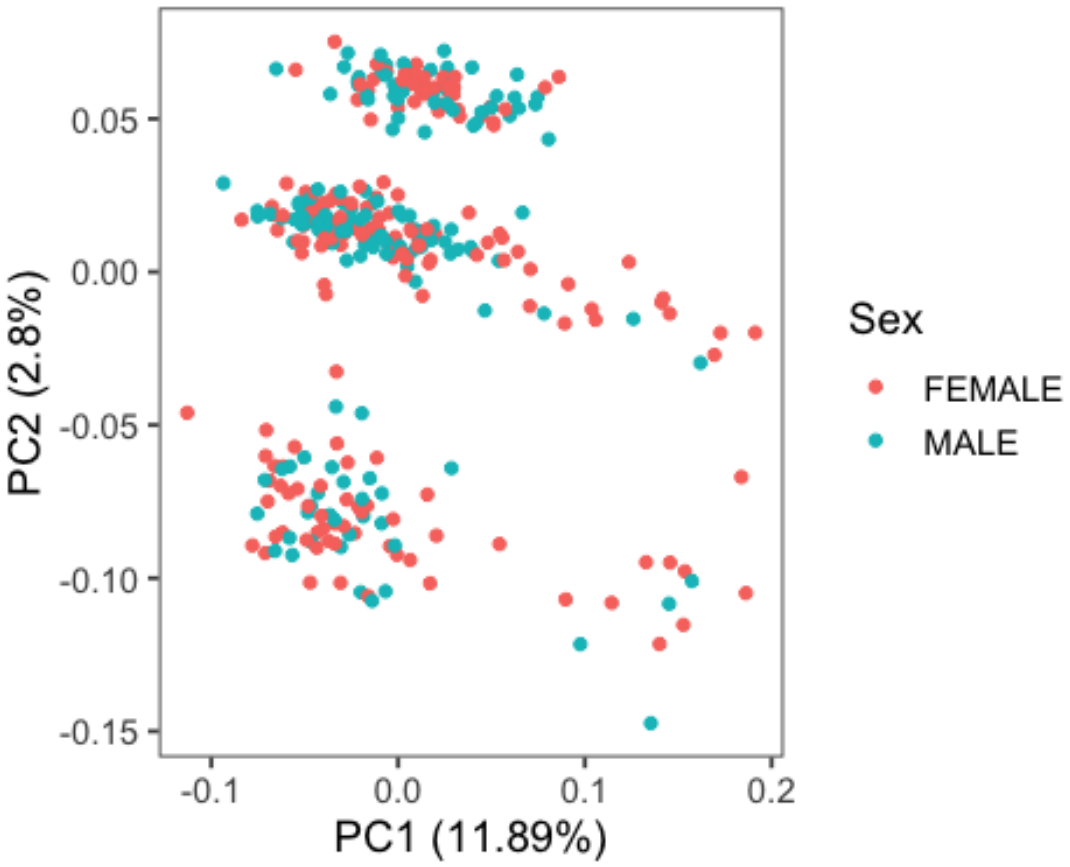

```
library(ggfortify)
xc.pca<- prcomp(xa_mat %*% t(xa_mat))

autoplot(xc.pca)
```




```
autoplot(xc.pca, data = xc_mat, colour = "Population")
```




```
autoplot(xc.pca, data = xc_mat, colour = "Sex")
```


0.05
0.00
-0.05
-0.10
-0.15
PC2 (2.8%)
-0.1
0.0
0.1
0.2
PC1 (11.89%)
Sex
FEMALE
MALE