PH Paper Models

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Load Packages and Data

Summary Statistics

```
##    Study #              Date                Age            Sex
##  Length:100         Length:100         Min.   :19.00   Length:100
##  Class :character   Class :character   1st Qu.:24.00   Class :character
##  Mode  :character   Mode  :character   Median :31.00   Mode  :character
##                                        Mean   :32.27
##                                        3rd Qu.:37.25
##                                        Max.   :54.00
##  Race/Ethnicity      Height (cm)     Weight (kg)          BMI
##  Length:100         Min.   :148.0   Min.   : 49.20   Min.   :19.21
##  Class :character   1st Qu.:164.0   1st Qu.: 64.72   1st Qu.:22.96
##  Mode  :character   Median :170.0   Median : 74.70   Median :25.27
##                     Mean   :170.6   Mean   : 74.38   Mean   :25.50
##                     3rd Qu.:177.2   3rd Qu.: 83.45   3rd Qu.:28.01
##                     Max.   :194.0   Max.   :105.20   Max.   :33.38

## # A tibble: 2 × 13
##   Sex   Age_mean Age_median Age_sd Height_mean Height_median Height_sd
##   <chr>    <dbl>      <dbl>  <dbl>       <dbl>         <dbl>     <dbl>
## 1 F         33.4       33     9.25        164.           164      6.22
## 2 M         31.1       27.5   9.03        177.           177      7.46
## # ℹ 6 more variables: Weight_mean <dbl>, Weight_median <dbl>, Weight_sd
<dbl>,
## #   BMI_mean <dbl>, BMI_median <dbl>, BMI_sd <dbl>

##
##  Two Sample t-test
##
## data:  demographics$Age[which(demographics$Sex == "F")] and
demographics$Age[which(demographics$Sex == "M")]
## t = 1.258, df = 98, p-value = 0.2114
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -1.328178  5.928178
## sample estimates:
```

```
## mean of x mean of y
##     33.42     31.12

##
##  Two Sample t-test
##
## data:  demographics$Height[which(demographics$Sex == "F")] and
demographics$Height[which(demographics$Sex == "M")]
## t = -9.8771, df = 98, p-value = 2.237e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -16.29644 -10.84356
## sample estimates:
## mean of x mean of y
##    163.84    177.41

##
##  Two Sample t-test
##
## data:  demographics$Weight[which(demographics$Sex == "F")] and
demographics$Weight[which(demographics$Sex == "M")]
## t = -4.5064, df = 98, p-value = 1.826e-05
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -14.838698  -5.765302
## sample estimates:
## mean of x mean of y
##    69.226    79.528

##
##  Two Sample t-test
##
## data:  demographics$BMI[which(demographics$Sex == "F")] and
demographics$BMI[which(demographics$Sex == "M")]
## t = 0.81901, df = 98, p-value = 0.4148
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.7923331  1.9059331
## sample estimates:
## mean of x mean of y
##   25.7790   25.2222

##       N95             KN95          Surgical          KF94
##  Min.   :83.10   Min.   :44.80   Min.   :36.20   Min.   :18.70
##  1st Qu.:97.67   1st Qu.:60.50   1st Qu.:49.58   1st Qu.:43.02
##  Median :99.20   Median :70.20   Median :57.65   Median :52.80
##  Mean   :97.83   Mean   :69.39   Mean   :57.46   Mean   :55.20
##  3rd Qu.:99.60   3rd Qu.:78.62   3rd Qu.:63.55   3rd Qu.:67.30
##  Max.   :99.90   Max.   :91.80   Max.   :83.20   Max.   :89.60
##
##      MKF94
```

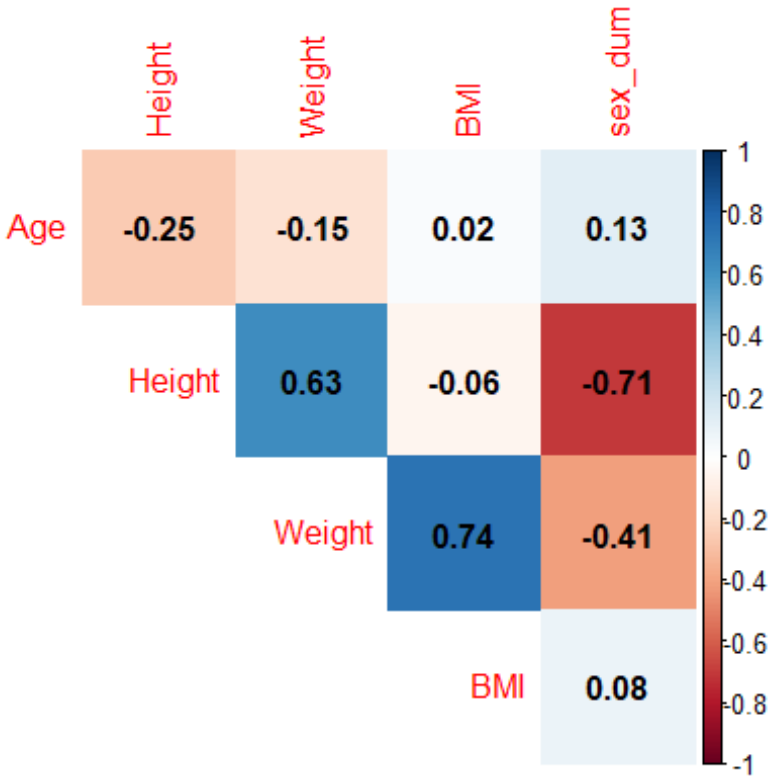
```
##  Min.   :33.30
##  1st Qu.:56.25
##  Median :66.90
##  Mean   :66.85
##  3rd Qu.:76.10
##  Max.   :95.90
##  NA's   :9

## # A tibble: 2 × 16
##   Sex   N95_mean N95_median N95_sd KN95_mean KN95_median KN95_sd
Surgical_mean
##   <chr>    <dbl>      <dbl>  <dbl>     <dbl>       <dbl>   <dbl>
<dbl>
## 1 F         97.4       98.8   3.35      65.7        64.2    12.0
52.4
## 2 M         98.2       99.5   2.91      73.1        74.8    11.5
62.5
## # ℹ 8 more variables: Surgical_median <dbl>, Surgical_sd <dbl>,
## #   KF94_mean <dbl>, KF94_median <dbl>, KF94_sd <dbl>, MKF94_mean <dbl>,
## #   MKF94_median <dbl>, MKF94_sd <dbl>

## # A tibble: 2 × 21
##   Sex   KN95_mean KN95_median KN95_sd KN95_diff_mean KN95_diff_median
##   <chr>     <dbl>       <dbl>   <dbl>          <dbl>             <dbl>
## 1 F          84.5        87.0    10.1          18.8               19.1
## 2 M          77.1        75.6    12.6           3.98               5.3
## # ℹ 15 more variables: Surgical_mean <dbl>, Surgical_median <dbl>,
## #   Surgical_sd <dbl>, Surgical_diff_mean <dbl>, Surgical_diff_median
<dbl>,
## #   KF94_mean <dbl>, KF94_median <dbl>, KF94_sd <dbl>, KF94_diff_mean
<dbl>,
## #   KF94_diff_median <dbl>, MKF94_mean <dbl>, MKF94_median <dbl>,
## #   MKF94_sd <dbl>, MKF94_diff_mean <dbl>, MKF94_diff_median <dbl>

##    Subject             Date               Sex                 Age
##  Length:100         Length:100         Length:100         Min.   :19.00
##  Class :character   Class :character   Class :character   1st Qu.:24.00
##  Mode  :character   Mode  :character   Mode  :character   Median :31.00
##                                                           Mean   :32.27
##                                                           3rd Qu.:37.25
##                                                           Max.   :54.00
##
##       BMI             N95             KN95         KN95_clip
##  Min.   :19.21   Min.   :83.10   Min.   :44.80   Min.   :51.00
##  1st Qu.:22.96   1st Qu.:97.67   1st Qu.:60.50   1st Qu.:72.30
##  Median :25.27   Median :99.20   Median :70.20   Median :82.10
##  Mean   :25.58   Mean   :97.83   Mean   :69.39   Mean   :80.78
##  3rd Qu.:28.01   3rd Qu.:99.60   3rd Qu.:78.62   3rd Qu.:90.72
##  Max.   :39.15   Max.   :99.90   Max.   :91.80   Max.   :98.60
##
```

```
##     Surgical     Surgical_clip        KF94         KF94_clip
##  Min.   :36.20   Min.   :40.90   Min.   :18.70   Min.   :28.90
##  1st Qu.:49.58   1st Qu.:61.70   1st Qu.:43.02   1st Qu.:62.42
##  Median :57.65   Median :67.85   Median :52.80   Median :75.55
##  Mean   :57.46   Mean   :66.36   Mean   :55.20   Mean   :73.10
##  3rd Qu.:63.55   3rd Qu.:71.58   3rd Qu.:67.30   3rd Qu.:81.45
##  Max.   :83.20   Max.   :90.60   Max.   :89.60   Max.   :97.50
##
##      MKF94         MKF94_clip      KN95_diff      Surgical_diff
##  Min.   :33.30   Min.   :46.70   Min.   :-10.20   Min.   :-13.000
##  1st Qu.:56.25   1st Qu.:68.95   1st Qu.:  4.60   1st Qu.:  2.425
##  Median :66.90   Median :78.90   Median :  9.95   Median :  8.800
##  Mean   :66.85   Mean   :76.47   Mean   : 11.38   Mean   :  8.901
##  3rd Qu.:76.10   3rd Qu.:87.90   3rd Qu.: 20.52   3rd Qu.: 14.925
##  Max.   :95.90   Max.   :99.70   Max.   : 43.20   Max.   : 31.500
##  NA's   :9       NA's   :9
##    KF94_diff        MKF94_diff
##  Min.   :-15.90   Min.   :-22.500
##  1st Qu.:  9.15   1st Qu.:  1.200
##  Median : 15.65   Median :  9.600
##  Mean   : 17.90   Mean   :  9.622
##  3rd Qu.: 26.73   3rd Qu.: 15.750
##  Max.   : 52.50   Max.   : 46.800
##                   NA's   :9

##    Subject              Date               Sex                 Age
##  Length:50          Length:50          Length:50          Min.   :19.00
##  Class :character   Class :character   Class :character   1st Qu.:24.00
##  Mode  :character   Mode  :character   Mode  :character   Median :27.50
##                                                           Mean   :31.12
##                                                           3rd Qu.:36.50
##                                                           Max.   :52.00
##
##       BMI              N95              KN95         KN95_clip
##  Min.   :19.29   Min.   :83.40   Min.   :44.80   Min.   :51.00
##  1st Qu.:23.73   1st Qu.:98.12   1st Qu.:65.08   1st Qu.:68.25
##  Median :25.18   Median :99.50   Median :74.75   Median :75.60
##  Mean   :25.22   Mean   :98.25   Mean   :73.07   Mean   :77.06
##  3rd Qu.:27.24   3rd Qu.:99.60   3rd Qu.:80.70   3rd Qu.:85.25
##  Max.   :31.56   Max.   :99.80   Max.   :91.30   Max.   :98.40
##
##     Surgical     Surgical_clip        KF94         KF94_clip
##  Min.   :43.40   Min.   :40.90   Min.   :30.40   Min.   :35.70
##  1st Qu.:55.58   1st Qu.:61.70   1st Qu.:51.25   1st Qu.:61.83
##  Median :62.30   Median :68.45   Median :62.00   Median :71.40
##  Mean   :62.49   Mean   :66.59   Mean   :62.81   Mean   :72.54
##  3rd Qu.:68.42   3rd Qu.:73.85   3rd Qu.:73.47   3rd Qu.:83.72
##  Max.   :83.20   Max.   :90.60   Max.   :89.60   Max.   :96.00
##
##      MKF94         MKF94_clip      KN95_diff       Surgical_diff
```

```
##  Min.   :33.30   Min.   :48.40   Min.   :-10.200   Min.   :-13.000
##  1st Qu.:55.65   1st Qu.:59.80   1st Qu.: -3.250   1st Qu.:  0.350
##  Median :68.90   Median :71.40   Median :  5.300   Median :  3.900
##  Mean   :67.38   Mean   :72.27   Mean   :  3.982   Mean   :  4.106
##  3rd Qu.:77.10   3rd Qu.:81.50   3rd Qu.:  8.675   3rd Qu.:  7.550
##  Max.   :95.90   Max.   :99.70   Max.   : 24.300   Max.   : 20.500
##  NA's   :3       NA's   :3
##    KF94_diff         MKF94_diff
##  Min.   :-15.900   Min.   :-22.500
##  1st Qu.:  5.475   1st Qu.: -0.800
##  Median : 10.300   Median :  3.700
##  Mean   :  9.728   Mean   :  4.889
##  3rd Qu.: 14.175   3rd Qu.: 11.150
##  Max.   : 37.500   Max.   : 36.200
##                    NA's   :3

##    Subject              Date               Sex                 Age
##  Length:50          Length:50          Length:50          Min.   :21.00
##  Class :character   Class :character   Class :character   1st Qu.:25.25
##  Mode  :character   Mode  :character   Mode  :character   Median :33.00
##                                                           Mean   :33.42
##                                                           3rd Qu.:39.50
##                                                           Max.   :54.00
##
##       BMI             N95             KN95          KN95_clip
##  Min.   :19.21   Min.   :83.10   Min.   :46.10   Min.   :57.40
##  1st Qu.:22.75   1st Qu.:96.67   1st Qu.:58.50   1st Qu.:77.50
##  Median :25.57   Median :98.80   Median :64.25   Median :86.95
##  Mean   :25.94   Mean   :97.40   Mean   :65.72   Mean   :84.50
##  3rd Qu.:28.75   3rd Qu.:99.40   3rd Qu.:73.08   3rd Qu.:91.90
##  Max.   :39.15   Max.   :99.90   Max.   :91.80   Max.   :98.60
##
##     Surgical     Surgical_clip        KF94          KF94_clip
##  Min.   :36.20   Min.   :46.90   Min.   :18.70   Min.   :28.90
##  1st Qu.:47.35   1st Qu.:62.15   1st Qu.:39.75   1st Qu.:67.25
##  Median :52.35   Median :67.60   Median :45.00   Median :77.05
##  Mean   :52.43   Mean   :66.12   Mean   :47.60   Mean   :73.66
##  3rd Qu.:59.10   3rd Qu.:70.65   3rd Qu.:54.62   3rd Qu.:81.25
##  Max.   :66.60   Max.   :82.60   Max.   :87.60   Max.   :97.50
##
##      MKF94          MKF94_clip      KN95_diff     Surgical_diff
##  Min.   :33.30   Min.   :46.70   Min.   :-7.50   Min.   :-7.70
##  1st Qu.:56.40   1st Qu.:73.60   1st Qu.:12.57   1st Qu.:10.38
##  Median :65.80   Median :81.25   Median :19.05   Median :14.40
##  Mean   :66.28   Mean   :80.96   Mean   :18.79   Mean   :13.70
##  3rd Qu.:74.42   3rd Qu.:90.90   3rd Qu.:23.88   3rd Qu.:17.00
##  Max.   :95.00   Max.   :99.50   Max.   :43.20   Max.   :31.50
##  NA's   :6       NA's   :6
##    KF94_diff       MKF94_diff
##  Min.   : 8.40   Min.   :-12.300
```

```
##  1st Qu.:17.10   1st Qu.:  6.775
##  Median :26.45   Median : 13.550
##  Mean   :26.07   Mean   : 14.677
##  3rd Qu.:34.95   3rd Qu.: 21.600
##  Max.   :52.50   Max.   : 46.800
##                  NA's   :6

## [1] 87

## [1] 45

## [1] 42
```

Correlation of Demographic Information



Experiment 1: Explore the variance in FFE of commonly worn masks

Linear Regression Models

In this section we look at different models to explain the variation for the baseline (overall) FFE for each mask. We chose Condition (mask) and sex as the predictor variables. The referent is N95. We also look at Age and BMI as covariates or confounders. Linear regression is the method used in all the models in this section. The models are also subset to exclude MKF94 that will not be included in the analysis.

```
## Linear mixed-effects model fit by REML
##   Data: FFE_base
##        AIC      BIC    logLik
##   2935.486 2975.198 -1457.743
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    5.506446 8.466227
##
## Fixed effects:  Overall_FFE ~ Condition * Sex
##                           Value Std.Error  DF   t-value p-value
## (Intercept)             97.404  1.428271 294  68.19712  0.0000
## ConditionKN95          -31.688  1.693245 294 -18.71436  0.0000
## ConditionSurgical      -44.978  1.693245 294 -26.56319  0.0000
## ConditionKF94          -49.806  1.693245 294 -29.41452  0.0000
## SexM                     0.842  2.019881  98   0.41686  0.6777
## ConditionKN95:SexM       6.516  2.394611 294   2.72111  0.0069
## ConditionSurgical:SexM   9.218  2.394611 294   3.84948  0.0001
## ConditionKF94:SexM      14.370  2.394611 294   6.00098  0.0000
##  Correlation:
##                         (Intr) CnKN95 CndtnS CnKF94 SexM   CKN95: CnS:SM
## ConditionKN95           -0.593
## ConditionSurgical       -0.593  0.500
## ConditionKF94           -0.593  0.500  0.500
## SexM                    -0.707  0.419  0.419  0.419
## ConditionKN95:SexM       0.419 -0.707 -0.354 -0.354 -0.593
## ConditionSurgical:SexM   0.419 -0.354 -0.707 -0.354 -0.593  0.500
## ConditionKF94:SexM       0.419 -0.354 -0.354 -0.707 -0.593  0.500  0.500
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.35457594 -0.57955538 -0.04891315  0.58237664  3.35308253
##
## Number of Observations: 400
## Number of Groups: 100

## Approximate 95% confidence intervals
##
##  Fixed effects:
##                              lower    est.      upper
## (Intercept)             94.593068  97.404 100.214932
## ConditionKN95          -35.020418 -31.688 -28.355582
## ConditionSurgical      -48.310418 -44.978 -41.645582
## ConditionKF94          -53.138418 -49.806 -46.473582
## SexM                    -3.166388   0.842   4.850388
## ConditionKN95:SexM       1.803249   6.516  11.228751
## ConditionSurgical:SexM   4.505249   9.218  13.930751
## ConditionKF94:SexM       9.657249  14.370  19.082751
##
```

```
##  Random Effects:
##   Level: Subject
##                    lower     est.    upper
## sd((Intercept)) 4.384703 5.506446 6.915166
##
##  Within-group standard error:
##    lower     est.    upper
## 7.808849 8.466227 9.178947
```

```
## Linear mixed-effects model fit by REML
##   Data: FFE_base
##        AIC      BIC    logLik
##   2935.486 2975.198 -1457.743
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    5.506446 8.466227
##
## Fixed effects:  Overall_FFE ~ Condition * Sex - 1
##                          Value Std.Error  DF  t-value p-value
## ConditionN95           97.404  1.428271 294 68.19712  0.0000
## ConditionKN95          65.716  1.428271 294 46.01086  0.0000
## ConditionSurgical      52.426  1.428271 294 36.70591  0.0000
## ConditionKF94          47.598  1.428271 294 33.32560  0.0000
## SexM                    0.842  2.019881  99  0.41686  0.6777
## ConditionKN95:SexM      6.516  2.394611 294  2.72111  0.0069
## ConditionSurgical:SexM  9.218  2.394611 294  3.84948  0.0001
## ConditionKF94:SexM     14.370  2.394611 294  6.00098  0.0000
##  Correlation:
##                        CndN95 CnKN95 CndtnS CnKF94 SexM   CKN95: CnS:SM
## ConditionKN95           0.297
## ConditionSurgical       0.297  0.297
## ConditionKF94           0.297  0.297  0.297
## SexM                   -0.707 -0.210 -0.210 -0.210
## ConditionKN95:SexM      0.419 -0.419  0.000  0.000 -0.593
## ConditionSurgical:SexM  0.419  0.000 -0.419  0.000 -0.593  0.500
## ConditionKF94:SexM      0.419  0.000  0.000 -0.419 -0.593  0.500  0.500
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.35457594 -0.57955538 -0.04891315  0.58237664  3.35308253
##
## Number of Observations: 400
## Number of Groups: 100
```

```
##               numDF denDF   F-value p-value
## Condition         4   294 2938.6069  <.0001
## Sex               1    99   36.2889  <.0001
## Condition:Sex     3   294   12.4824  <.0001
```

The above models only include the overall FFE for masks without the clip. This models shows that there is a statistically significant difference between male and females for the masks. When we change the referent mask to N95 because it is considered the most effective mask sex is not significant in the regression model because males and females are not different for that mask. The interaction between mask and sex does show a significance, with the exception of the KF94(M). This makes sense when you look at the box plots of the raw data without a clip. When you look at the ANOVA, you can see that sex is a significant variable.

Contrasts

In this section the same models are performed as above, but the contrasts are changed to compare the means to the overall group mean.

```
## $lsmeans
##  Condition lsmean   SE df lower.CL upper.CL
##  N95         97.8 1.12 99     95.6    100.0
##  KN95        69.4 1.12 99     67.2     71.6
##  Surgical    57.5 1.12 99     55.2     59.7
##  KF94        55.2 1.12 99     53.0     57.4
##
## Degrees-of-freedom method: containment
## Confidence level used: 0.95
##
## $contrasts
##  contrast        estimate   SE  df t.ratio p.value
##  N95 - KN95         28.43 1.26 297  22.477  <.0001
##  N95 - Surgical     40.37 1.26 297  31.916  <.0001
##  N95 - KF94         42.62 1.26 297  33.697  <.0001
##  KN95 - Surgical    11.94 1.26 297   9.439  <.0001
##  KN95 - KF94        14.19 1.26 297  11.220  <.0001
##  Surgical - KF94     2.25 1.26 297   1.780  0.2848
##
## Degrees-of-freedom method: containment
## P value adjustment: tukey method for comparing a family of 4 estimates

## Full coefficients are
##
## (Intercept):        69.97
## Condition:            N95    KN95   Surgical    KF94
##                     27.855  -0.575    -12.514 -14.766
## Sex:                     F       M
##                     -4.184   4.184
## Condition:Sex:      N95:F  KN95:F Surgical:F  KF94:F  N95:M KN95:M
Surgical:M
##                      3.763   0.505     -0.846  -3.422 -3.763 -0.505
0.846
##
## (Intercept):
## Condition:
```

```
##
## Sex:
##
## Condition:Sex:    KF94:M
##                    3.422

## Linear mixed-effects model fit by REML
##   Data: FFE_base
##        AIC      BIC    logLik
##   2946.576 2986.289 -1463.288
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    5.506446 8.466228
##
## Fixed effects:  Overall_FFE ~ Condition * Sex
##                   Value Std.Error  DF   t-value p-value
## (Intercept)      69.970 0.6945516 294 100.74125  0.0000
## Condition1       27.855 0.7331968 294  37.99116  0.0000
## Condition2       -0.575 0.7331968 294  -0.78424  0.4335
## Condition3      -12.514 0.7331968 294 -17.06772  0.0000
## Sex1             -4.184 0.6945516  98  -6.02403  0.0000
## Condition1:Sex1   3.763 0.7331968 294   5.13232  0.0000
## Condition2:Sex1   0.505 0.7331968 294   0.68876  0.4915
## Condition3:Sex1  -0.846 0.7331968 294  -1.15385  0.2495
##  Correlation:
##                 (Intr) Cndtn1 Cndtn2 Cndtn3 Sex1   Cn1:S1 Cn2:S1
## Condition1       0.000
## Condition2       0.000 -0.333
## Condition3       0.000 -0.333 -0.333
## Sex1             0.000  0.000  0.000  0.000
## Condition1:Sex1  0.000  0.000  0.000  0.000  0.000
## Condition2:Sex1  0.000  0.000  0.000  0.000  0.000 -0.333
## Condition3:Sex1  0.000  0.000  0.000  0.000  0.000 -0.333 -0.333
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.35457596 -0.57955539 -0.04891314  0.58237663  3.35308254
##
## Number of Observations: 400
## Number of Groups: 100

##               numDF denDF   F-value p-value
## (Intercept)       1   294 10148.799  <.0001
## Condition         3   294   535.210  <.0001
## Sex               1    98    36.289  <.0001
## Condition:Sex     3   294    12.482  <.0001
```

```
## Approximate 95% confidence intervals
##
##  Fixed effects:
##                       lower    est.       upper
## (Intercept)      68.6030768  69.970  71.3369232
## Condition1       26.4120205  27.855  29.2979795
## Condition2       -2.0179795  -0.575   0.8679795
## Condition3      -13.9569795 -12.514 -11.0710205
## Sex1             -5.5623151  -4.184  -2.8056849
## Condition1:Sex1   2.3200205   3.763   5.2059795
## Condition2:Sex1  -0.9379795   0.505   1.9479795
## Condition3:Sex1  -2.2889795  -0.846   0.5969795
##
##  Random Effects:
##   Level: Subject
##                     lower     est.    upper
## sd((Intercept)) 4.384674 5.506446 6.915211
##
##  Within-group standard error:
##    lower     est.    upper
## 7.808849 8.466228 9.178947
```

```
##  contrast        estimate  SE  df t.ratio p.value
##  N95 - KN95         28.43 1.2 294  23.745  <.0001
##  N95 - Surgical     40.37 1.2 294  33.717  <.0001
##  N95 - KF94         42.62 1.2 294  35.597  <.0001
##  KN95 - Surgical    11.94 1.2 294   9.972  <.0001
##  KN95 - KF94        14.19 1.2 294  11.852  <.0001
##  Surgical - KF94     2.25 1.2 294   1.881  0.2385
##
## Results are averaged over the levels of: Sex
## Degrees-of-freedom method: containment
## P value adjustment: tukey method for comparing a family of 4 estimates
```

```
## Condition = N95:
##  contrast estimate   SE df t.ratio p.value
##  F - M      -0.842 2.02 98  -0.417  0.6777
##
## Condition = KN95:
##  contrast estimate   SE df t.ratio p.value
##  F - M      -7.358 2.02 98  -3.643  0.0004
##
## Condition = Surgical:
##  contrast estimate   SE df t.ratio p.value
##  F - M     -10.060 2.02 98  -4.980  <.0001
##
## Condition = KF94:
##  contrast estimate   SE df t.ratio p.value
##  F - M     -15.212 2.02 98  -7.531  <.0001
```

```
##
## Degrees-of-freedom method: containment

## Condition = N95:
##  contrast estimate   SE df lower.CL upper.CL
##  F - M      -0.842 2.02 98    -4.85     3.17
##
## Condition = KN95:
##  contrast estimate   SE df lower.CL upper.CL
##  F - M      -7.358 2.02 98   -11.37    -3.35
##
## Condition = Surgical:
##  contrast estimate   SE df lower.CL upper.CL
##  F - M     -10.060 2.02 98   -14.07    -6.05
##
## Condition = KF94:
##  contrast estimate   SE df lower.CL upper.CL
##  F - M     -15.212 2.02 98   -19.22   -11.20
##
## Degrees-of-freedom method: containment
## Confidence level used: 0.95

##  contrast                estimate   SE  df t.ratio p.value
##  F N95 - M N95             -0.842 2.02  98  -0.417  0.9999
##  F N95 - F KN95            31.688 1.69 294  18.714  <.0001
##  F N95 - M KN95            24.330 2.02  98  12.045  <.0001
##  F N95 - F Surgical        44.978 1.69 294  26.563  <.0001
##  F N95 - M Surgical        34.918 2.02  98  17.287  <.0001
##  F N95 - F KF94            49.806 1.69 294  29.415  <.0001
##  F N95 - M KF94            34.594 2.02  98  17.127  <.0001
##  M N95 - F KN95            32.530 2.02  98  16.105  <.0001
##  M N95 - M KN95            25.172 1.69 294  14.866  <.0001
##  M N95 - F Surgical        45.820 2.02  98  22.685  <.0001
##  M N95 - M Surgical        35.760 1.69 294  21.119  <.0001
##  M N95 - F KF94            50.648 2.02  98  25.075  <.0001
##  M N95 - M KF94            35.436 1.69 294  20.928  <.0001
##  F KN95 - M KN95           -7.358 2.02  98  -3.643  0.0099
##  F KN95 - F Surgical       13.290 1.69 294   7.849  <.0001
##  F KN95 - M Surgical        3.230 2.02  98   1.599  0.7497
##  F KN95 - F KF94           18.118 1.69 294  10.700  <.0001
##  F KN95 - M KF94            2.906 2.02  98   1.439  0.8369
##  M KN95 - F Surgical       20.648 2.02  98  10.222  <.0001
##  M KN95 - M Surgical       10.588 1.69 294   6.253  <.0001
##  M KN95 - F KF94           25.476 2.02  98  12.613  <.0001
##  M KN95 - M KF94           10.264 1.69 294   6.062  <.0001
##  F Surgical - M Surgical  -10.060 2.02  98  -4.980  0.0001
##  F Surgical - F KF94        4.828 1.69 294   2.851  0.0867
##  F Surgical - M KF94      -10.384 2.02  98  -5.141  <.0001
##  M Surgical - F KF94       14.888 2.02  98   7.371  <.0001
##  M Surgical - M KF94       -0.324 1.69 294  -0.191  1.0000
```

```
##  F KF94 - M KF94          -15.212 2.02  98  -7.531  <.0001
##
## Degrees-of-freedom method: containment
## P value adjustment: tukey method for comparing a family of 8 estimates

##  contrast                estimate   SE  df lower.CL upper.CL
##  F N95 - M N95             -0.842 2.02  98   -7.098     5.41
##  F N95 - F KN95            31.688 1.69 294   26.519    36.86
##  F N95 - M KN95            24.330 2.02  98   18.074    30.59
##  F N95 - F Surgical        44.978 1.69 294   39.809    50.15
##  F N95 - M Surgical        34.918 2.02  98   28.662    41.17
##  F N95 - F KF94            49.806 1.69 294   44.637    54.98
##  F N95 - M KF94            34.594 2.02  98   28.338    40.85
##  M N95 - F KN95            32.530 2.02  98   26.274    38.79
##  M N95 - M KN95            25.172 1.69 294   20.003    30.34
##  M N95 - F Surgical        45.820 2.02  98   39.564    52.08
##  M N95 - M Surgical        35.760 1.69 294   30.591    40.93
##  M N95 - F KF94            50.648 2.02  98   44.392    56.90
##  M N95 - M KF94            35.436 1.69 294   30.267    40.61
##  F KN95 - M KN95           -7.358 2.02  98  -13.614    -1.10
##  F KN95 - F Surgical       13.290 1.69 294    8.121    18.46
##  F KN95 - M Surgical        3.230 2.02  98   -3.026     9.49
##  F KN95 - F KF94           18.118 1.69 294   12.949    23.29
##  F KN95 - M KF94            2.906 2.02  98   -3.350     9.16
##  M KN95 - F Surgical       20.648 2.02  98   14.392    26.90
##  M KN95 - M Surgical       10.588 1.69 294    5.419    15.76
##  M KN95 - F KF94           25.476 2.02  98   19.220    31.73
##  M KN95 - M KF94           10.264 1.69 294    5.095    15.43
##  F Surgical - M Surgical  -10.060 2.02  98  -16.316    -3.80
##  F Surgical - F KF94        4.828 1.69 294   -0.341    10.00
##  F Surgical - M KF94      -10.384 2.02  98  -16.640    -4.13
##  M Surgical - F KF94       14.888 2.02  98    8.632    21.14
##  M Surgical - M KF94       -0.324 1.69 294   -5.493     4.85
##  F KF94 - M KF94          -15.212 2.02  98  -21.468    -8.96
##
## Degrees-of-freedom method: containment
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 8 estimates

##  Sex Condition emmean   SE df lower.CL upper.CL .group
##  F   KF94        47.6 1.43 98     44.8     50.4  a
##  F   Surgical    52.4 1.43 98     49.6     55.3  a
##  M   Surgical    62.5 1.43 98     59.7     65.3   b
##  M   KF94        62.8 1.43 98     60.0     65.6   b
##  F   KN95        65.7 1.43 98     62.9     68.6   b
##  M   KN95        73.1 1.43 98     70.2     75.9    c
##  F   N95         97.4 1.43 98     94.6    100.2     d
##  M   N95         98.2 1.43 98     95.4    101.1     d
##
## Degrees-of-freedom method: containment
```

```
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 8 estimates
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
##       then we cannot show them to be different.
##       But we also did not show them to be the same.
```

Sensitivity Analysis

In this section we look at whether demographic variables change the interpretation or conclusions of the final model from the section above.

```
## Linear mixed-effects model fit by REML
##   Data: FFE_base
##        AIC      BIC    logLik
##   2930.102 2993.395 -1449.051
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    4.961273 8.466228
##
## Fixed effects:  Overall_FFE ~ Condition * Sex + Race_Ethnicity + Age + BMI
##                                            Value Std.Error  DF   t-value
## (Intercept)                             54.98314  5.349393 294  10.27839
## Condition1                              27.85500  0.733197 294  37.99116
## Condition2                              -0.57500  0.733197 294  -0.78424
## Condition3                             -12.51400  0.733197 294 -17.06772
## Sex1                                    -4.33923  0.709307  92  -6.11756
## Race_EthnicityHispanic/Latino           -3.58601  3.322273  92  -1.07938
## Race_EthnicityNon-Hispanic Black         2.30556  2.352730  92   0.97995
## Race_EthnicityNon-Hispanic White        -1.27099  1.851677  92  -0.68640
## Race_EthnicityOther including Multi-Race  7.71563  4.910332  92   1.57130
## Age                                      0.16897  0.073542  92   2.29757
## BMI                                      0.38807  0.186866  92   2.07671
## Condition1:Sex1                          3.76300  0.733197 294   5.13232
## Condition2:Sex1                          0.50500  0.733197 294   0.68876
## Condition3:Sex1                         -0.84600  0.733197 294  -1.15385
##                                        p-value
## (Intercept)                             0.0000
## Condition1                              0.0000
## Condition2                              0.4335
## Condition3                              0.0000
## Sex1                                    0.0000
## Race_EthnicityHispanic/Latino           0.2832
## Race_EthnicityNon-Hispanic Black        0.3297
## Race_EthnicityNon-Hispanic White        0.4942
## Race_EthnicityOther including Multi-Race  0.1195
## Age                                     0.0239
## BMI                                     0.0406
```

```
## Condition1:Sex1                              0.0000
## Condition2:Sex1                              0.4915
## Condition3:Sex1                              0.2495
##  Correlation:
##                                             (Intr) Cndtn1 Cndtn2 Cndtn3 Sex1
## Condition1                                   0.000
## Condition2                                   0.000 -0.333
## Condition3                                   0.000 -0.333 -0.333
## Sex1                                         0.187  0.000  0.000  0.000
## Race_EthnicityHispanic/Latino               -0.025  0.000  0.000  0.000 -
0.091
## Race_EthnicityNon-Hispanic Black            -0.028  0.000  0.000  0.000 -
0.260
## Race_EthnicityNon-Hispanic White            -0.182  0.000  0.000  0.000 -
0.329
## Race_EthnicityOther including Multi-Race -0.009  0.000  0.000  0.000
0.052
## Age                                         -0.392  0.000  0.000  0.000 -
0.047
## BMI                                         -0.864  0.000  0.000  0.000 -
0.089
## Condition1:Sex1                              0.000  0.000  0.000  0.000
0.000
## Condition2:Sex1                              0.000  0.000  0.000  0.000
0.000
## Condition3:Sex1                              0.000  0.000  0.000  0.000
0.000
##                                             R_EH/L R_EN-B R_EN-W R_EOiM Age
## Condition1
## Condition2
## Condition3
## Sex1
## Race_EthnicityHispanic/Latino
## Race_EthnicityNon-Hispanic Black             0.333
## Race_EthnicityNon-Hispanic White             0.402  0.629
## Race_EthnicityOther including Multi-Race     0.148  0.187  0.222
## Age                                          0.000 -0.127 -0.131  0.090
## BMI                                         -0.126 -0.141 -0.024 -0.124 -
0.020
## Condition1:Sex1                              0.000  0.000  0.000  0.000
0.000
## Condition2:Sex1                              0.000  0.000  0.000  0.000
0.000
## Condition3:Sex1                              0.000  0.000  0.000  0.000
0.000
##                                             BMI    Cn1:S1 Cn2:S1
## Condition1
## Condition2
## Condition3
## Sex1
```

```
## Race_EthnicityHispanic/Latino
## Race_EthnicityNon-Hispanic Black
## Race_EthnicityNon-Hispanic White
## Race_EthnicityOther including Multi-Race
## Age
## BMI
## Condition1:Sex1                            0.000
## Condition2:Sex1                            0.000 -0.333
## Condition3:Sex1                            0.000 -0.333 -0.333
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.36653838 -0.62053102 -0.00874441  0.58111595  3.22887051
##
## Number of Observations: 400
## Number of Groups: 100
```

Experiment 2

Clip Modification

In experiment 2, the ear loop mask are modified with a clip to evaluate performance. Expected to improve performance. N95 is removed from the analysis because it is not an ear loop mask and it is not modifiable.

```
## Linear mixed-effects model fit by REML
##   Data: FFE_clip_subset
##        AIC      BIC    logLik
##   4496.553 4531.648 -2240.276
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    7.902941 8.875643
##
## Fixed effects:  Overall_FFE ~ Condition + Clip * Sex
##                   Value Std.Error  DF  t-value p-value
## (Intercept)    50.10433 1.4272000 496 35.10674  0.0000
## ConditionKF94   2.24600 0.8875643 496  2.53052  0.0117
## ConditionKN95  13.18100 0.8875643 496 14.85076  0.0000
## Clip1          19.51667 1.0248709 496 19.04305  0.0000
## SexM           10.87667 1.8837779  98  5.77386  0.0000
## Clip1:SexM    -13.57800 1.4493864 496 -9.36810  0.0000
##  Correlation:
##               (Intr) CnKF94 CnKN95 Clip1  SexM
## ConditionKF94 -0.311
## ConditionKN95 -0.311  0.500
## Clip1         -0.359  0.000  0.000
## SexM          -0.660  0.000  0.000  0.272
```

```
## Clip1:SexM     0.254  0.000  0.000 -0.707 -0.385
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.65740780 -0.67103702  0.06357832  0.66793099  2.26519016
##
## Number of Observations: 600
## Number of Groups: 100

## Approximate 95% confidence intervals
##
##  Fixed effects:
##                     lower      est.      upper
## (Intercept)    47.3002304  50.10433  52.908436
## ConditionKF94   0.5021507   2.24600   3.989849
## ConditionKN95  11.4371507  13.18100  14.924849
## Clip1          17.5030430  19.51667  21.530290
## SexM            7.1383707  10.87667  14.614963
## Clip1:SexM    -16.4256939 -13.57800 -10.730306
##
##  Random Effects:
##   Level: Subject
##                    lower     est.    upper
## sd((Intercept)) 6.667915 7.902941 9.366716
##
##  Within-group standard error:
##    lower     est.    upper
## 8.340156 8.875643 9.445510

## Linear mixed-effects model fit by REML
##   Data: FFE_clip_subset
##        AIC      BIC    logLik
##   4477.297 4538.571 -2224.649
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:     7.31109 8.875643
##
## Fixed effects:  Overall_FFE ~ Condition + Clip * Sex + BMI + Age +
Race_Ethnicity
##                                            Value Std.Error  DF   t-value
## (Intercept)                             32.88363  6.951743 496  4.730271
## ConditionKF94                            2.24600  0.887564 496  2.530521
## ConditionKN95                           13.18100  0.887564 496 14.850756
## Clip1                                   19.51667  1.024871 496 19.043048
## SexM                                    11.04662  1.917153  92  5.761988
## BMI                                      0.43396  0.233798  92  1.856138
## Age                                      0.22203  0.092012  92  2.413006
## Race_EthnicityHispanic/Latino           -5.60036  4.156681  92 -1.347316
```

```
## Race_EthnicityNon-Hispanic Black           2.22512  2.943632  92  0.755910
## Race_EthnicityNon-Hispanic White          -2.39751  2.316737  92 -1.034864
## Race_EthnicityOther including Multi-Race   9.19231  6.143591  92  1.496244
## Clip1:SexM                               -13.57800  1.449386 496 -9.368102
##                                          p-value
## (Intercept)                               0.0000
## ConditionKF94                             0.0117
## ConditionKN95                             0.0000
## Clip1                                     0.0000
## SexM                                      0.0000
## BMI                                       0.0666
## Age                                       0.0178
## Race_EthnicityHispanic/Latino             0.1812
## Race_EthnicityNon-Hispanic Black          0.4516
## Race_EthnicityNon-Hispanic White          0.3034
## Race_EthnicityOther including Multi-Race  0.1380
## Clip1:SexM                                0.0000
##  Correlation:
##                                          (Intr) CnKF94 CnKN95 Clip1  SexM
## ConditionKF94                            -0.064
## ConditionKN95                            -0.064  0.500
## Clip1                                    -0.074  0.000  0.000
## SexM                                     -0.304  0.000  0.000  0.267
## BMI                                      -0.843  0.000  0.000  0.000
0.083
## Age                                      -0.383  0.000  0.000  0.000
0.044
## Race_EthnicityHispanic/Latino            -0.036  0.000  0.000  0.000
0.084
## Race_EthnicityNon-Hispanic Black         -0.060  0.000  0.000  0.000
0.241
## Race_EthnicityNon-Hispanic White         -0.217  0.000  0.000  0.000
0.305
## Race_EthnicityOther including Multi-Race -0.002  0.000  0.000  0.000 -
0.048
## Clip1:SexM                                0.052  0.000  0.000 -0.707 -
0.378
##                                          BMI    Age    R_EH/L R_EN-B R_EN-
W
## ConditionKF94
## ConditionKN95
## Clip1
## SexM
## BMI
## Age                                      -0.020
## Race_EthnicityHispanic/Latino            -0.126  0.000
## Race_EthnicityNon-Hispanic Black         -0.141 -0.127  0.333
## Race_EthnicityNon-Hispanic White         -0.024 -0.131  0.402  0.629
## Race_EthnicityOther including Multi-Race -0.124  0.090  0.148  0.187
0.222
```

```
## Clip1:SexM                                  0.000  0.000  0.000  0.000
0.000
##                                          R_EOiM
## ConditionKF94
## ConditionKN95
## Clip1
## SexM
## BMI
## Age
## Race_EthnicityHispanic/Latino
## Race_EthnicityNon-Hispanic Black
## Race_EthnicityNon-Hispanic White
## Race_EthnicityOther including Multi-Race
## Clip1:SexM                                  0.000
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.65173830 -0.66347518  0.06047191  0.69189103  2.16512469
##
## Number of Observations: 600
## Number of Groups: 100

## Linear mixed-effects model fit by REML
##   Data: FFE_clip_subset
##        AIC      BIC    logLik
##   4496.553 4531.648 -2240.276
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    7.902941 8.875643
##
## Fixed effects:  Overall_FFE ~ Condition + Clip * Sex - 1
##                       Value Std.Error  DF  t-value p-value
## ConditionSurgical  50.10433  1.427200 496 35.10674       0
## ConditionKF94      52.35033  1.427200 496 36.68045       0
## ConditionKN95      63.28533  1.427200 496 44.34230       0
## Clip1              19.51667  1.024871 496 19.04305       0
## SexM               10.87667  1.883778  99  5.77386       0
## Clip1:SexM        -13.57800  1.449386 496 -9.36810       0
##  Correlation:
##               CndtnS CnKF94 CnKN95 Clip1  SexM
## ConditionKF94  0.807
## ConditionKN95  0.807  0.807
## Clip1         -0.359 -0.359 -0.359
## SexM          -0.660 -0.660 -0.660  0.272
## Clip1:SexM     0.254  0.254  0.254 -0.707 -0.385
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
```

```
## -2.65740780 -0.67103702  0.06357832  0.66793099  2.26519016
##
## Number of Observations: 600
## Number of Groups: 100
```

When you look at all the masks, with and without the clip, males are statistically different from females. However, when you look at clip as a treatment as opposed to an independent variable, sex is no longer significant. We can see that males and females show a difference in the performance with the clip, but the difference is not statistically significant (> 2 standard deviations different). This could be due to a small sample size.

Experiment 2 Contrasts

```
## Linear mixed-effects model fit by REML
##   Data: FFE_clip_subset
##        AIC     BIC    logLik
##   4504.295 4539.39 -2244.148
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    7.902941 8.875643
##
## Fixed effects:  Overall_FFE ~ Condition + Clip * Sex
##                Value Std.Error  DF   t-value p-value
## (Intercept) 67.04883 0.8694020 496  77.12064  0.0000
## Condition1  -5.14233 0.5124355 496 -10.03508  0.0000
## Condition2  -2.89633 0.5124355 496  -5.65209  0.0000
## Clip1       -6.36383 0.3623466 496 -17.56283  0.0000
## Sex1        -2.04383 0.8694020  98  -2.35085  0.0207
## Clip1:Sex1  -3.39450 0.3623466 496  -9.36810  0.0000
##  Correlation:
##            (Intr) Cndtn1 Cndtn2 Clip1 Sex1
## Condition1  0.0
## Condition2  0.0   -0.5
## Clip1       0.0    0.0    0.0
## Sex1        0.0    0.0    0.0    0.0
## Clip1:Sex1  0.0    0.0    0.0    0.0   0.0
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.65740780 -0.67103702  0.06357832  0.66793099  2.26519016
##
## Number of Observations: 600
## Number of Groups: 100

## Approximate 95% confidence intervals
##
##  Fixed effects:
##                 lower      est.      upper
## (Intercept) 65.340669 67.048833 68.7569980
```

```
## Condition1  -6.149145 -5.142333 -4.1355215
## Condition2  -3.903145 -2.896333 -1.8895215
## Clip1       -7.075757 -6.363833 -5.6519099
## Sex1        -3.769133 -2.043833 -0.3185334
## Clip1:Sex1  -4.106423 -3.394500 -2.6825765
##
##  Random Effects:
##   Level: Subject
##                    lower     est.    upper
## sd((Intercept)) 6.667915 7.902941 9.366716
##
##  Within-group standard error:
##    lower     est.    upper
## 8.340156 8.875643 9.445511
```

```
## Full coefficients are
##
## (Intercept):     67.04883
## Condition:       Surgical      KF94      KN95
##                 -5.142333 -2.896333  8.038667
## Clip:                   0         1
##                 -6.363833  6.363833
## Sex:                    F         M
##                 -2.043833  2.043833
## Clip:Sex:             0:F       1:F       0:M     1:M
##                   -3.3945    3.3945    3.3945 -3.3945
```

```
##  contrast          estimate   SE  df t.ratio p.value
##  Clip0 F - Clip1 F   -19.52 1.02 496 -19.043  <.0001
##  Clip0 F - Clip0 M   -10.88 1.88  98  -5.774  <.0001
##  Clip0 F - Clip1 M   -16.82 1.88  98  -8.926  <.0001
##  Clip1 F - Clip0 M     8.64 1.88  98   4.587  0.0001
##  Clip1 F - Clip1 M     2.70 1.88  98   1.434  0.4814
##  Clip0 M - Clip1 M    -5.94 1.02 496  -5.795  <.0001
##
## Results are averaged over the levels of: Condition
## Degrees-of-freedom method: containment
## P value adjustment: tukey method for comparing a family of 4 estimates
```

```
##  contrast          estimate   SE  df lower.CL upper.CL
##  Clip0 F - Clip1 F   -19.52 1.02 496   -22.16   -16.87
##  Clip0 F - Clip0 M   -10.88 1.88  98   -15.80    -5.95
##  Clip0 F - Clip1 M   -16.82 1.88  98   -21.74   -11.89
##  Clip1 F - Clip0 M     8.64 1.88  98     3.72    13.56
##  Clip1 F - Clip1 M     2.70 1.88  98    -2.22     7.62
##  Clip0 M - Clip1 M    -5.94 1.02 496    -8.58    -3.30
##
## Results are averaged over the levels of: Condition
## Degrees-of-freedom method: containment
```

```
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 4 estimates

##  Clip Sex emmean   SE df lower.CL upper.CL .group
##  0    F     55.2 1.33 98     52.6     57.9  1
##  0    M     66.1 1.33 98     63.5     68.8   2
##  1    M     72.1 1.33 98     69.4     74.7    3
##  1    F     74.8 1.33 98     72.1     77.4    3
##
## Results are averaged over the levels of: Condition
## Degrees-of-freedom method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
##       then we cannot show them to be different.
##       But we also did not show them to be the same.

## Linear mixed-effects model fit by REML
##   Data: FFE_clip_subset
##       AIC      BIC   logLik
##   4485.04 4546.314 -2228.52
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:     7.31109 8.875643
##
## Fixed effects:  Overall_FFE ~ Condition + Clip * Sex + Race_Ethnicity +
BMI +      Age
##                                            Value Std.Error  DF    t-value
## (Intercept)                                49.91310  6.692924 496   7.457593
## Condition1                                 -5.14233  0.512435 496 -10.035085
## Condition2                                 -2.89633  0.512435 496  -5.652094
## Clip1                                      -6.36383  0.362347 496 -17.562835
## Sex1                                       -2.12881  0.887454  92  -2.398781
## Race_EthnicityHispanic/Latino              -5.60036  4.156681  92  -1.347316
## Race_EthnicityNon-Hispanic Black            2.22512  2.943632  92   0.755910
## Race_EthnicityNon-Hispanic White           -2.39751  2.316737  92  -1.034864
## Race_EthnicityOther including Multi-Race    9.19231  6.143591  92   1.496244
## BMI                                         0.43396  0.233798  92   1.856138
## Age                                         0.22203  0.092012  92   2.413006
## Clip1:Sex1                                 -3.39450  0.362347 496  -9.368102
##                                           p-value
## (Intercept)                                0.0000
## Condition1                                 0.0000
## Condition2                                 0.0000
## Clip1                                      0.0000
## Sex1                                       0.0185
## Race_EthnicityHispanic/Latino              0.1812
```

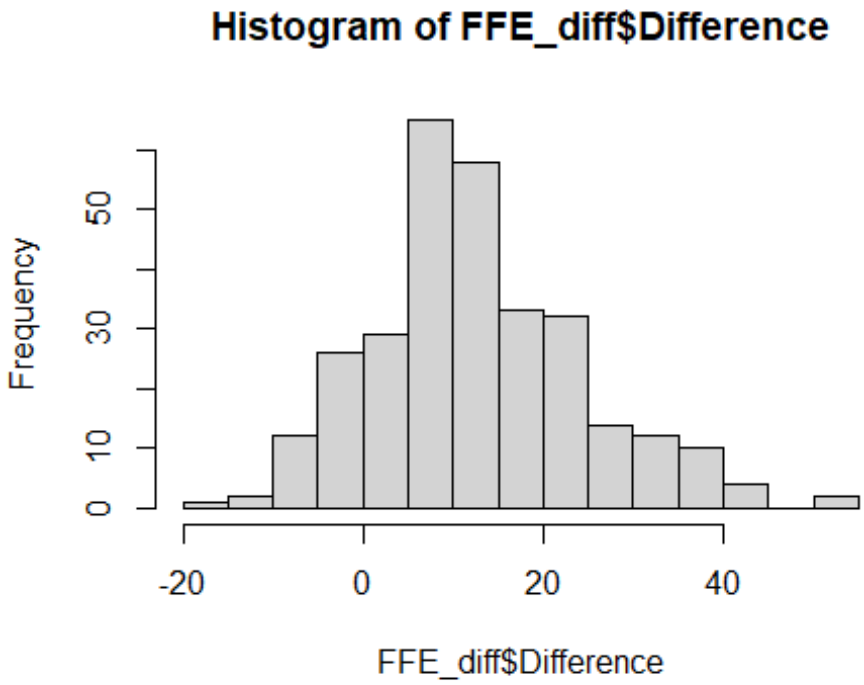
```
## Race_EthnicityNon-Hispanic Black          0.4516
## Race_EthnicityNon-Hispanic White          0.3034
## Race_EthnicityOther including Multi-Race  0.1380
## BMI                                       0.0666
## Age                                       0.0178
## Clip1:Sex1                                0.0000
##  Correlation:
##                                          (Intr) Cndtn1 Cndtn2 Clip1  Sex1
## Condition1                                0.000
## Condition2                                0.000 -0.500
## Clip1                                     0.000  0.000  0.000
## Sex1                                      0.187  0.000  0.000  0.000
## Race_EthnicityHispanic/Latino            -0.025  0.000  0.000  0.000 -
0.091
## Race_EthnicityNon-Hispanic Black         -0.028  0.000  0.000  0.000 -
0.260
## Race_EthnicityNon-Hispanic White         -0.182  0.000  0.000  0.000 -
0.329
## Race_EthnicityOther including Multi-Race -0.009  0.000  0.000  0.000
0.052
## BMI                                      -0.864  0.000  0.000  0.000 -
0.089
## Age                                      -0.392  0.000  0.000  0.000 -
0.047
## Clip1:Sex1                                0.000  0.000  0.000  0.000
0.000
##                                          R_EH/L R_EN-B R_EN-W R_EOiM BMI
## Condition1
## Condition2
## Clip1
## Sex1
## Race_EthnicityHispanic/Latino
## Race_EthnicityNon-Hispanic Black          0.333
## Race_EthnicityNon-Hispanic White          0.402  0.629
## Race_EthnicityOther including Multi-Race  0.148  0.187  0.222
## BMI                                      -0.126 -0.141 -0.024 -0.124
## Age                                       0.000 -0.127 -0.131  0.090 -
0.020
## Clip1:Sex1                                0.000  0.000  0.000  0.000
0.000
##                                          Age
## Condition1
## Condition2
## Clip1
## Sex1
## Race_EthnicityHispanic/Latino
## Race_EthnicityNon-Hispanic Black
## Race_EthnicityNon-Hispanic White
## Race_EthnicityOther including Multi-Race
## BMI
```

```
## Age
## Clip1:Sex1                                0.000
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.65173830 -0.66347518  0.06047191  0.69189103  2.16512469
##
## Number of Observations: 600
## Number of Groups: 100

## Linear mixed-effects model fit by REML
##   Data: FFE_clip_subset
##       AIC      BIC    logLik
##   4463.55 4524.824 -2217.775
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    7.974888 8.480732
##
## Fixed effects:  Overall_FFE ~ Condition + Clip * Sex * Condition
##                           Value Std.Error  DF   t-value p-value
## (Intercept)           67.04883 0.8694020 490  77.12064  0.0000
## Condition1            -5.14233 0.4896353 490 -10.50238  0.0000
## Condition2            -2.89633 0.4896353 490  -5.91529  0.0000
## Clip1                 -6.36383 0.3462244 490 -18.38066  0.0000
## Sex1                  -2.04383 0.8694020  98  -2.35085  0.0207
## Clip1:Sex1            -3.39450 0.3462244 490  -9.80433  0.0000
## Condition1:Clip1       1.91333 0.4896353 490   3.90767  0.0001
## Condition2:Clip1      -2.58467 0.4896353 490  -5.27876  0.0000
## Condition1:Sex1       -0.58867 0.4896353 490  -1.20226  0.2298
## Condition2:Sex1       -1.47767 0.4896353 490  -3.01789  0.0027
## Condition1:Clip1:Sex1  0.99700 0.4896353 490   2.03621  0.0423
## Condition2:Clip1:Sex1 -0.69000 0.4896353 490  -1.40921  0.1594
##  Correlation:
##                       (Intr) Cndtn1 Cndtn2 Clip1 Sex1 Cl1:S1 Cn1:C1 Cn2:C1
## Condition1             0.0
## Condition2             0.0   -0.5
## Clip1                  0.0    0.0    0.0
## Sex1                   0.0    0.0    0.0    0.0
## Clip1:Sex1             0.0    0.0    0.0    0.0   0.0
## Condition1:Clip1       0.0    0.0    0.0    0.0   0.0  0.0
## Condition2:Clip1       0.0    0.0    0.0    0.0   0.0  0.0   -0.5
## Condition1:Sex1        0.0    0.0    0.0    0.0   0.0  0.0    0.0    0.0
## Condition2:Sex1        0.0    0.0    0.0    0.0   0.0  0.0    0.0    0.0
## Condition1:Clip1:Sex1  0.0    0.0    0.0    0.0   0.0  0.0    0.0    0.0
## Condition2:Clip1:Sex1  0.0    0.0    0.0    0.0   0.0  0.0    0.0    0.0
##                       Cn1:S1 Cn2:S1 C1:C1:
## Condition1
## Condition2
```

```
## Clip1
## Sex1
## Clip1:Sex1
## Condition1:Clip1
## Condition2:Clip1
## Condition1:Sex1
## Condition2:Sex1       -0.5
## Condition1:Clip1:Sex1  0.0    0.0
## Condition2:Clip1:Sex1  0.0    0.0   -0.5
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.95124467 -0.62122845  0.05108128  0.65421683  2.89837560
##
## Number of Observations: 600
## Number of Groups: 100

##  contrast                              estimate   SE  df t.ratio p.value
##  Clip0 F Surgical - Clip1 F Surgical  -13.696 1.70 490  -8.075  <.0001
##  Clip0 F Surgical - Clip0 M Surgical  -10.060 2.33  98  -4.321  0.0021
##  Clip0 F Surgical - Clip1 M Surgical  -14.166 2.33  98  -6.084  <.0001
##  Clip0 F Surgical - Clip0 F KF94        4.828 1.70 490   2.846  0.1642
##  Clip0 F Surgical - Clip1 F KF94      -21.238 1.70 490 -12.521  <.0001
##  Clip0 F Surgical - Clip0 M KF94      -10.384 2.33  98  -4.460  0.0013
##  Clip0 F Surgical - Clip1 M KF94      -20.112 2.33  98  -8.638  <.0001
##  Clip0 F Surgical - Clip0 F KN95      -13.290 1.70 490  -7.835  <.0001
##  Clip0 F Surgical - Clip1 F KN95      -32.078 1.70 490 -18.912  <.0001
##  Clip0 F Surgical - Clip0 M KN95      -20.648 2.33  98  -8.868  <.0001
##  Clip0 F Surgical - Clip1 M KN95      -24.630 2.33  98 -10.579  <.0001
##  Clip1 F Surgical - Clip0 M Surgical    3.636 2.33  98   1.562  0.9184
##  Clip1 F Surgical - Clip1 M Surgical   -0.470 2.33  98  -0.202  1.0000
##  Clip1 F Surgical - Clip0 F KF94       18.524 1.70 490  10.921  <.0001
##  Clip1 F Surgical - Clip1 F KF94       -7.542 1.70 490  -4.447  0.0007
##  Clip1 F Surgical - Clip0 M KF94        3.312 2.33  98   1.423  0.9562
##  Clip1 F Surgical - Clip1 M KF94       -6.416 2.33  98  -2.756  0.2159
##  Clip1 F Surgical - Clip0 F KN95        0.406 1.70 490   0.239  1.0000
##  Clip1 F Surgical - Clip1 F KN95      -18.382 1.70 490 -10.838  <.0001
##  Clip1 F Surgical - Clip0 M KN95       -6.952 2.33  98  -2.986  0.1287
##  Clip1 F Surgical - Clip1 M KN95      -10.934 2.33  98  -4.696  0.0005
##  Clip0 M Surgical - Clip1 M Surgical   -4.106 1.70 490  -2.421  0.3939
##  Clip0 M Surgical - Clip0 F KF94       14.888 2.33  98   6.394  <.0001
##  Clip0 M Surgical - Clip1 F KF94      -11.178 2.33  98  -4.801  0.0003
##  Clip0 M Surgical - Clip0 M KF94       -0.324 1.70 490  -0.191  1.0000
##  Clip0 M Surgical - Clip1 M KF94      -10.052 1.70 490  -5.926  <.0001
##  Clip0 M Surgical - Clip0 F KN95       -3.230 2.33  98  -1.387  0.9634
##  Clip0 M Surgical - Clip1 F KN95      -22.018 2.33  98  -9.457  <.0001
##  Clip0 M Surgical - Clip0 M KN95      -10.588 1.70 490  -6.242  <.0001
##  Clip0 M Surgical - Clip1 M KN95      -14.570 1.70 490  -8.590  <.0001
##  Clip1 M Surgical - Clip0 F KF94       18.994 2.33  98   8.158  <.0001
##  Clip1 M Surgical - Clip1 F KF94       -7.072 2.33  98  -3.037  0.1136
```

```
##  Clip1 M Surgical - Clip0 M KF94        3.782 1.70 490   2.230  0.5287
##  Clip1 M Surgical - Clip1 M KF94       -5.946 1.70 490  -3.506  0.0248
##  Clip1 M Surgical - Clip0 F KN95        0.876 2.33  98   0.376  1.0000
##  Clip1 M Surgical - Clip1 F KN95      -17.912 2.33  98  -7.693  <.0001
##  Clip1 M Surgical - Clip0 M KN95       -6.482 1.70 490  -3.822  0.0082
##  Clip1 M Surgical - Clip1 M KN95      -10.464 1.70 490  -6.169  <.0001
##  Clip0 F KF94 - Clip1 F KF94          -26.066 1.70 490 -15.368  <.0001
##  Clip0 F KF94 - Clip0 M KF94          -15.212 2.33  98  -6.534  <.0001
##  Clip0 F KF94 - Clip1 M KF94          -24.940 2.33  98 -10.712  <.0001
##  Clip0 F KF94 - Clip0 F KN95          -18.118 1.70 490 -10.682  <.0001
##  Clip0 F KF94 - Clip1 F KN95          -36.906 1.70 490 -21.759  <.0001
##  Clip0 F KF94 - Clip0 M KN95          -25.476 2.33  98 -10.942  <.0001
##  Clip0 F KF94 - Clip1 M KN95          -29.458 2.33  98 -12.652  <.0001
##  Clip1 F KF94 - Clip0 M KF94           10.854 2.33  98   4.662  0.0006
##  Clip1 F KF94 - Clip1 M KF94            1.126 2.33  98   0.484  1.0000
##  Clip1 F KF94 - Clip0 F KN95            7.948 1.70 490   4.686  0.0002
##  Clip1 F KF94 - Clip1 F KN95          -10.840 1.70 490  -6.391  <.0001
##  Clip1 F KF94 - Clip0 M KN95            0.590 2.33  98   0.253  1.0000
##  Clip1 F KF94 - Clip1 M KN95           -3.392 2.33  98  -1.457  0.9484
##  Clip0 M KF94 - Clip1 M KF94           -9.728 1.70 490  -5.735  <.0001
##  Clip0 M KF94 - Clip0 F KN95           -2.906 2.33  98  -1.248  0.9834
##  Clip0 M KF94 - Clip1 F KN95          -21.694 2.33  98  -9.318  <.0001
##  Clip0 M KF94 - Clip0 M KN95          -10.264 1.70 490  -6.051  <.0001
##  Clip0 M KF94 - Clip1 M KN95          -14.246 1.70 490  -8.399  <.0001
##  Clip1 M KF94 - Clip0 F KN95            6.822 2.33  98   2.930  0.1468
##  Clip1 M KF94 - Clip1 F KN95          -11.966 2.33  98  -5.139  0.0001
##  Clip1 M KF94 - Clip0 M KN95           -0.536 1.70 490  -0.316  1.0000
##  Clip1 M KF94 - Clip1 M KN95           -4.518 1.70 490  -2.664  0.2478
##  Clip0 F KN95 - Clip1 F KN95          -18.788 1.70 490 -11.077  <.0001
##  Clip0 F KN95 - Clip0 M KN95           -7.358 2.33  98  -3.160  0.0832
##  Clip0 F KN95 - Clip1 M KN95          -11.340 2.33  98  -4.871  0.0003
##  Clip1 F KN95 - Clip0 M KN95           11.430 2.33  98   4.909  0.0002
##  Clip1 F KN95 - Clip1 M KN95            7.448 2.33  98   3.199  0.0752
##  Clip0 M KN95 - Clip1 M KN95           -3.982 1.70 490  -2.348  0.4442
##
## Degrees-of-freedom method: containment
## P value adjustment: tukey method for comparing a family of 12 estimates
```

T-tests on Difference between sex by mask




```
##          statistic parameter      p.value           conf.int estimate
## KF94      7.872721        49 2.991971e-10 12.16759, 20.50841   16.338
## KN95      8.589431        49 2.432515e-11     11.342, 18.270   14.806
## Surgical  9.494024        49 1.096171e-12  7.56011, 11.61989     9.59
##          null.value   stderr alternative        method
## KF94              0 2.075267   two.sided Paired t-test
## KN95              0 1.723746   two.sided Paired t-test
## Surgical          0 1.010109   two.sided Paired t-test
##
data.name
## KF94     x$Difference[which(x$Sex == "F")] and x$Difference[which(x$Sex ==
"M")]
## KN95     x$Difference[which(x$Sex == "F")] and x$Difference[which(x$Sex ==
"M")]
## Surgical x$Difference[which(x$Sex == "F")] and x$Difference[which(x$Sex ==
"M")]

## # A tibble: 3 × 8
## # Groups:   Condition [3]
##   Condition     F     M estimate CI_lower CI_upper t_statistic  p.value
##   <chr>     <dbl> <dbl>    <dbl>    <dbl>    <dbl>       <dbl>    <dbl>
## 1 KF94       26.1  9.73    16.3     12.2      20.5        7.87 2.99e-10
## 2 KN95       18.8  3.98    14.8     11.3      18.3        8.59 2.43e-11
## 3 Surgical   13.7  4.11     9.59     7.56     11.6        9.49 1.10e-12
```

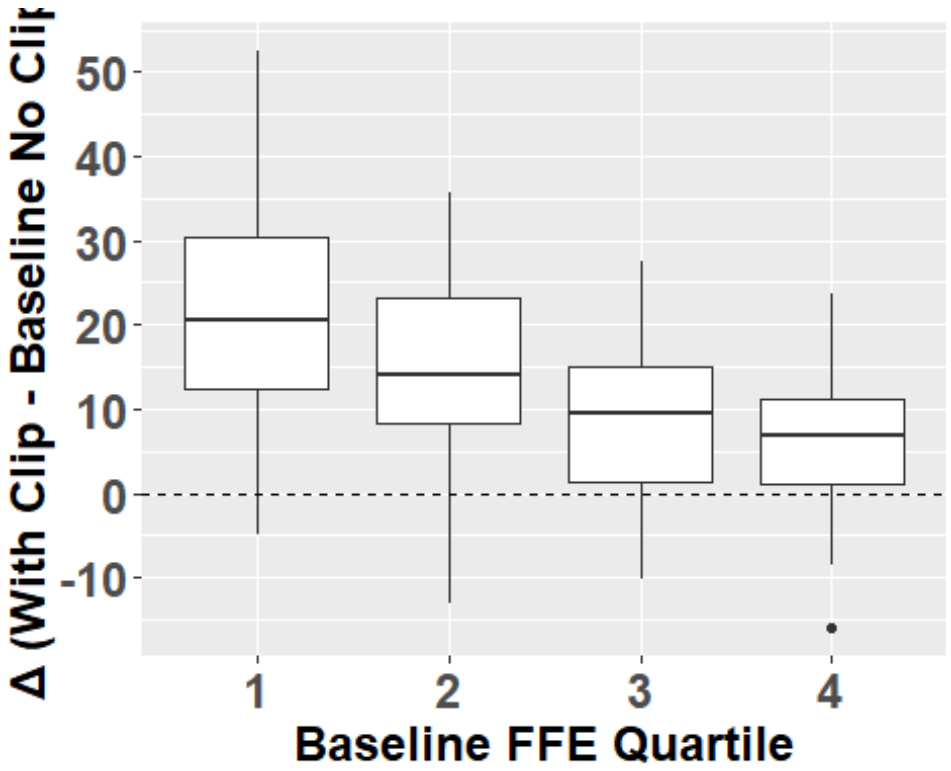
```
##
##  Welch Two Sample t-test
##
## data:  FFE_diff$Difference[which(FFE_diff$Sex == "M" & FFE_diff$Condition
== "KN95")] and FFE_diff$Difference[which(FFE_diff$Sex == "F" &
FFE_diff$Condition == "KN95")]
## t = -8.1737, df = 92.049, p-value = 1.561e-12
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -18.40362 -11.20838
## sample estimates:
## mean of x mean of y
##     3.982    18.788
```

Improvement Analysis

```
##     0%    25%    50%    75%   100%
## 83.100 97.675 99.200 99.600 99.900

##     0%    25%    50%    75%   100%
## 44.800 60.500 70.200 78.625 91.800

##     0%    25%    50%    75%   100%
## 36.200 49.575 57.650 63.550 83.200

##     0%    25%    50%    75%   100%
## 18.700 43.025 52.800 67.300 89.600

##
## Call:
## lm(formula = diff ~ FFE * Sex + quantile, data = FFE_quant_long)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -24.5192  -6.3295  -0.0135   5.1525  27.5286
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  36.00290    3.66668   9.819  < 2e-16 ***
## FFE          -0.27171    0.07620  -3.566 0.000424 ***
## SexM        -20.54211    5.27797  -3.892 0.000123 ***
## quantile2    -1.34959    1.68903  -0.799 0.424917
## quantile3    -3.71502    2.05899  -1.804 0.072212 .
## quantile4    -3.13946    2.66681  -1.177 0.240058
## FFE:SexM      0.16751    0.08405   1.993 0.047184 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.97 on 293 degrees of freedom
## Multiple R-squared:  0.4357, Adjusted R-squared:  0.4241
## F-statistic:  37.7 on 6 and 293 DF,  p-value: < 2.2e-16
```

```
## Linear mixed-effects model fit by REML
##   Data: FFE_quant_long
##        AIC      BIC    logLik
##   2217.897 2243.706 -1101.948
##
## Random effects:
##  Formula: ~1 | Subject
##         (Intercept) Residual
## StdDev:    5.773388 8.357928
##
## Fixed effects:  diff ~ FFE + quantile
##                 Value Std.Error  DF   t-value p-value
## (Intercept) 31.581207  3.195600 196  9.882716  0.0000
## FFE         -0.241812  0.064567 196 -3.745128  0.0002
## quantile2   -3.379661  1.705619 196 -1.981486  0.0489
## quantile3   -6.403687  2.025779 196 -3.161098  0.0018
## quantile4   -6.882007  2.634816 196 -2.611950  0.0097
##  Correlation:
##           (Intr) FFE    quntl2 quntl3
## FFE       -0.918
## quantile2  0.123 -0.394
## quantile3  0.358 -0.618  0.631
## quantile4  0.519 -0.757  0.604  0.758
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.31682788 -0.62119389 -0.01485066  0.56234614  2.67128268
##
## Number of Observations: 300
## Number of Groups: 100

##             numDF denDF   F-value p-value
## (Intercept)     1   196 286.12167  <.0001
## FFE             1   196  83.52543  <.0001
## quantile        3   196   3.37125  0.0196

## Approximate 95% confidence intervals
##
##  Fixed effects:
##                    lower       est.       upper
## (Intercept)  25.2790324 31.5812071 37.88338182
## FFE          -0.3691469 -0.2418117 -0.11447643
## quantile2    -6.7433828 -3.3796607 -0.01593872
## quantile3   -10.3988103 -6.4036871 -2.40856387
## quantile4   -12.0782362 -6.8820070 -1.68577776
##
##  Random Effects:
##   Level: Subject
##                     lower     est.    upper
## sd((Intercept)) 4.502852 5.773388 7.402422
```

```
##
##  Within-group standard error:
##    lower     est.    upper
## 7.570489 8.357928 9.227272
```




```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   -5.00   12.50   20.55   21.32   30.48   52.50

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  -13.00    8.35   14.15   14.94   23.30   35.80

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## -10.200   1.450   9.550   8.726  14.975  27.600

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## -15.900   1.150   6.750   6.046  11.225  23.700
```

R Markdown

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