Movement Competency and Blood Pressure with Rock Solid@Work^{TM}: Analysis Report

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Executive Summary

This analysis used observational data collected during four pilot programs to assess the confidence with which the 12-week Rock Solid@Work™ functional core strengthening program implemented by 3:1 Corporate Health and Productivity Management Solutions increased movement competency as measured by the Functional Movement Screen (FMS) and reduced blood pressure (BP) among participants. Paired-observation tests of difference with false discovery rate correction showed that an average improvement in movement competency occurred with nearly 100% confidence, in systolic BP with close to 95% confidence, and in diastolic BP with more than 96% confidence. Rank-based correlation tests identified a significant (97% confidence, corrected) weak-to-moderate correlation between systolic and diastolic BP change from before to after FMS Correctives but failed to show relationships between average FMS score change and either BP change metric. Exploratory regression analysis indicated that results varied by organization and initial performance (before-correctives FMS score and BP), suggesting the use of caution in generalizing results to new organizations while identifying value in controlling for these factors if estimating or predicting program impact for known populations.

Introduction

Neither employees nor employers want injuries on the job. For employees, injuries can lead to pain, reduced function and mobility, and reduction or loss of livelihood. Employers, in turn, can experience reduced productivity due to outages, increased healthcare and insurance costs, and increased costs related to employee turnover, such as recruitment and training. Rock Solid@Work™, a solution by 3:1 Corporate Health and Productivity Management Solutions, combines education, assessments, activities, and employee engagement to promote employee health and safety in ways that reduce common employee injuries.

One component of Rock Solid@Work™ centers around the Functional Movement Screen (FMS), a robust evaluation tool that assesses and grades a participant's motor control and competence in performing several fundamental movement patterns[1]. After initial FMS assessment and systolic and diastolic blood pressure (BP) readings, participants engage in a 12-week program of functional core strengthening activities (FMS Correctives). Activities occur four times per week, in 7-to-10-minute sessions at the beginning of the employee's shift, and emphasize the diaphragm--a critical core muscle--and relaxation by timing movements to 10-second breath cycles and by beginning and ending each session with 1 minute of diaphragmatic breathing. Participants are re-assessed according to the FMS and BP measures following the 12-week program. By this point, FMS Correctives are expected to have improved FMS performance while, in agreement with research indicating a positive effect on hypertension[2], paced breathing is hoped to have decreased BP.

While the FMS has been applied to athletes in organizations such as the NFL and NHL, this analysis seeks a better understanding of its health and wellness effects in blue-collar work environments, as applied by Rock Solid@Work™. Specifically, this analysis examines whether the 12-week Rock Solid@Work™ functional core strengthening program increased movement competency and reduced blood pressure among participants.

Data

Data were measured across five organizations of varying sizes, both before participants began and after they completed the twelve-week program of FMS Correctives. Trained on-site assessors, with multiple assessors per organization and different assessors at each organization, measured age, systolic BP, diastolic BP, and FMS score on a four-point integer scale (0 through 3) in six to twelve movement dimensions, including a total of all distinct FMS scores assessed. The selection of measured scores varied from organization to organization because certain assessed motions were considered unsafe in some work environments, such as shop floors, in which assessment occurred. Participants who expressed pain during the FMS received scores of zero, were referred for medical consultation, and were removed from the FMS Correctives program as well as from further measurement.

Because each organization provided data in a distinct format, variable names were standardized, and the 6 separate worksheets were combined, using the browser-based Google

Sheets spreadsheet tool, into one table of relevant variables (columns) and individual measurements (rows) from either before FMS Correctives or after. Variables of particular interest included an independent variable marking observations as either before or after FMS Correctives; independent variables identifying participant age and organization; and the base dependent variables of FMS score, systolic BP, and diastolic BP. A client-verified data entry error (the year 2012 had been entered in place of 2013) that had reversed some before/after pairings was corrected at this stage. A new unique participant identifier was added in order to mark repeated observations of the same individual, and both FMS score grand totals and maximum possible scores were calculated based on provided formulas (the sum of FMS activity final scores and, respectively, the sum of potential FMS activity final scores if each activity scored by the organization had achieved the maximum score of 3). Then a vertical lookup function populated an additional worksheet with one row per participant and one set of columns for each respective set of before and after measurements, leaving missing data as blank.

In this format, data were exported to CSV files and imported to the R statistical software environment[3] by way of the RStudio[4] interface. Blank values and values of zero in the age field (participants--all employees in the United States--were assumed be have been adults) were converted to NA. Percentage movement competency was calculated as the total FMS score divided by the participant's maximum possible total score in order to make FMS scores comparable across organizations with varying quantities of assessed FMS dimensions. Differences in FMS score and BP as measured after versus before FMS Correctives were calculated for use in correlation and regression analyses. Participants without both an identified before and after observation were removed from the data at this stage as detailed below. Because age, measured by the year, should differ by one year or less between before and after measurements of the 12-week program, age was condensed to a single variable taking the lesser of a participant's available ages. Remaining missing age and BP values were imputed according to the process described below.

In order to control for potential confounding variables that tend to remain consistent for one individual over 12 weeks--such as weight or gender--this analysis pairs before and after measurements made on the same individual. Depending on the organization, observations were recorded in pairs, individuals were labeled with a unique identifier, or participants were distinguished by unique combinations of last name and age. One entire organization (*Mine*, with 101 observations before FMS Correctives and 101 after) documented insufficient details for pairing observations and was omitted from analysis. This omission is expected to have introduced minimal bias because removing an entire organization is comparable to the observational choice to collect data from any one organization instead of another. Additional observations (24 participants) were excluded from analysis because their participants were measured either at the beginning or at the end of the 12-week program and not at both times. This exclusion seems similar to program policy that excludes individuals from participation if they report pain during the FMS and, as such, should not introduce a meaningful level of additional systematic bias. Additionally, one organization (Health & Human Services) measured individuals at two separate sites, one of which received no FMS Correctives; this control group (11 participants) was omitted from analysis as well because it would not have demonstrated effects of FMS Correctives. Preliminary power analyses conducted after data had been collected yet before removing records or imputing missing values indicated that retaining the unpaired observations would not have provided a meaningful improvement in power or confidence for the paired-difference tests in this analysis and that controlled tests with this data would not have provided consistent advantages in power or confidence. After the above adjustments, 98 paired records remained available for analysis.

Calculating FMS score grand totals and maximum possible scores as described above effectively overlooked missing individual movement scores and treated missing summary (*Final*) test scores as zero, as if pain had been reported and the participant had been removed from participation. All missing age (7 participants) and BP (6 participants) measurements were imputed using random forests (up to 10 iterations of 150 trees) as implemented in the R package `missForest`[5] in order to maintain variability, avoid increasing bias, and maximize the available data without depending on assumptions about the data's structure. Table 1 reports out of bag (OOB) error for the imputed values in this analysis. Imputed values were rounded to the nearest integer for consistency with significant digits in the provided data, and before/after differences in BP were recalculated.

Variable	OOB Error
Age	138.90
Systolic BP (before)	99.04
Diastolic BP (before)	77.80
Systolic BP (after)	66.41
Diastolic BP (after)	32.39

Table 1: Out of Bag Error for Imputed Values

Finally, the above data were duplicated and transformed for use in regression analysis. FMS score percentages were multiplied by 100, converting the values from decimals to numbers between 0 and 100 in order to make the measurements similar in variance to the BP difference measures. The percent-transformed data were used in regression analysis only, not in analyses of difference or correlation.

Methods

Analysis continued in R and RStudio, using the data prepared as above.

Difference

Because the client expressed interest primarily in identifying the level of confidence with which the Rock Solid@Work™ program of FMS Correctives can be said to improve outcomes rather than the degree to which outcomes improve with the program, analysis began with one-sided tests of difference (positive difference in FMS score or negative difference in BP after FMS Correctives) between paired before and after measurements for each participant for which paired observations had been identified. Quantile-quantile plots (see appendix) suggested that the distributions of FMS score and systolic BP values would be sufficiently normal and similar in variance to support the standard Student's t-test while diastolic BP data would benefit from the nonparametric approximated Wilcoxon signed-rank test. Analysis proceeded with the indicated tests of paired difference, performed using the `t.test` and `wilcox.test` functions available in the base R `stats` package[3]. In order to mitigate the potential for false discoveries due to chance, resulting p-values were adjusted to control the false discovery rate (FDR) by using the `p.adjust` function in the `stats` package[3] to apply the Benjamini–Hochberg procedure.

Correlation

Analysis next evaluated correlation among dependent variables in order to determine the degree to which change in one metric coincided with change in another. The tests specifically assessed differences (after-correctives minus before-correctives) in FMS score percentage, systolic BP, and diastolic BP. A scatterplot of each combination of variable pairs (see appendix) identified at least one participant as a potential outlier; therefore, the pairwise Kendall rank correlation coefficient, which is not sensitive to outliers or deviations from normal distributions, was calculated for each of the relationships between FMS score percentage and systolic BP, FMS score percentage and diastolic BP, and systolic BP and diastolic BP using the `cor.test` function in the `stats` package[3]. This function used an approximate, continuity-corrected method to accommodate tied ranks and provided a two-sided p-value for each association, which was corrected to control FDR by using the Benjamini–Hochberg procedure as implemented in `p.adjust` in the `stats` package[3].

Regression

Because none of the dependent variables were shown to be highly correlated, all three were included in regression analysis, which was used to determine whether age and organization impacted, simultaneously, FMS score and BP change. Data, after the minor transformation described above, met the necessary assumptions for performing a MANCOVA in order to analyze multivariate variance and covariance due to age and organization. Normal quantile-quantile plots and the Anderson-Darling test for multivariate normality, as implemented in the `AD.test` function in the `mvnTest` package[6], indicated sufficient normality among the untransformed continuous variables under consideration (see appendix). The Fligner-Killeen test, applied using the `fligner.test` function in the `stats` package[3], identified non-homogeneous variances (p-value $< 2.2 \times 10^{-16}$) among the untransformed regression data; however, no violation (p-value = 0.894) of the homogeneous variances assumption surfaced when the data were retested (see appendix) after transforming FMS score percentages. Using the `boxM` function in the `biotools` package[7] on either transformed or untransformed data, Box's M-test of covariance matrix homogeneity returned a p-value of 0.044 (see appendix). This result might have been considered indication of nonhomogeneous covariance under a different test, but this analysis had set the functional threshold for significance near or below a p-value of.001 because Box’s M has high sensitivity.

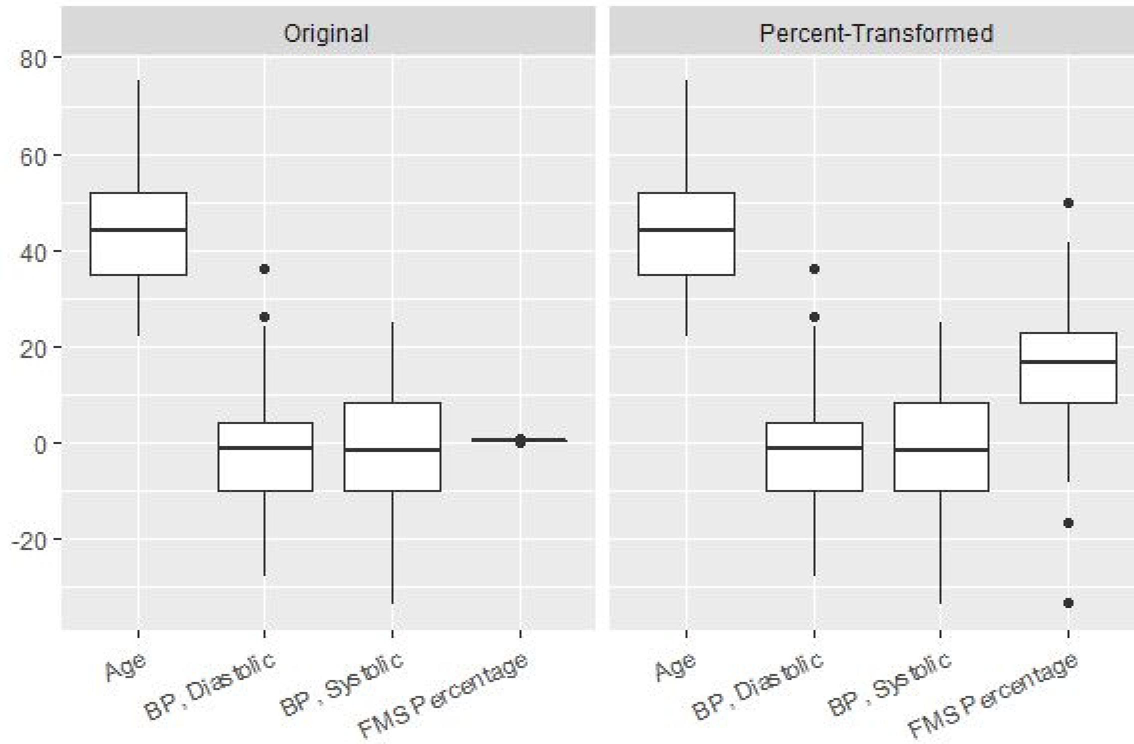

Figure 1: Difference Distributions Before and After Percentage Transformation

MANCOVA proceeded with the transformed data under the following initial linear model:

$$Y = \beta_1 + \beta_2 Organization + \beta_3 Age + \beta_4 (Organization \times Age) + \varepsilon$$

in which each Y represents the matrix of differences in FMS score percentage, diastolic BP, and systolic BP; $Organization$ is a matrix of indicator variables identifying membership in each of four organizations; Age is the participant’s measured age, treated as a continuous variable; $Organization \times Age$ is the matrix of interactions between age and membership in each organization; β_i represent matrices of constants estimating the impact of each independent variable; and ε represents the model’s remaining error. In R, the `lm` function in the base `stats` package[3] fit the model; however, the model was tested using the `Manova` function in the `car` package[8] in order to perform a type II MANCOVA, which tests the incremental effect of each modeled main variable versus all other main variables then the effect of each interaction versus all main effects and other interaction effects. This analysis used Pillai’s trace as the test statistic due to its robustness and comparable sensitivity to other established MANCOVA test statistics.

Because visualizing multivariate data presents dimensional challenges, Mahalanobis distances, calculated with the `mahalanobis` function in the `stats` package[3], were used to identify potential outliers in the transformed continuous data (see appendix). The initial model was re-fit with as many as four outlier candidates removed, resulting in no substantial change to the modeled coefficients. Consequently, all 98 transformed records were retained for regression.

After exploring the initial model, post-hoc analysis fit a model without age and with before-correctives FMS score and BP measurements:

$$Y = \beta_5 + \beta_6 Organization + \beta_7 (Organization \times Age) +$$
$$\beta_8 FMS_{before} + \beta_9 SystolicBP_{before} + \beta_{10} DiastolicBP_{before} + \varepsilon \; .$$

A type II MANCOVA, conducted as above, was performed on this before-correctives model. The two models were compared by explanatory power, based on adjusted R^2 metrics calculated using `lm`'s `summary` function, as well as by stability, based on bias and bootstrap standard error metrics obtained from 150 replicates generated using the `boot` function in the `boot` package[9]. Follow-up ANCOVA tests, using F-tests as applied by `lm`'s `summary` function, assessed the significance of the model for each dependent variable (Y_j) separately. All post-hoc p-values, together, were adjusted using the Holm method.

Results

Difference

Guided by diagnostic quantile-quantile plots (see appendix), Student's t-test assessed confidence in increased FMS score percentage and decreased systolic BP after FMS Correctives while the Wilcoxon signed-rank test assessed confidence in decreased systolic BP. Adjusting for FDR, analysis asserts nearly 100% confidence that FMS score improved in the motions assessed, 94.7% confidence that systolic BP improved, and 96.5% confidence that diastolic BP improved after the 12-week course of FMS Correctives.

Variable	p-value	Adjusted p-value	Confidence	Adjusted Confidence
FMS Percentage	3.448×10^{-18}	1.034×10^{-17}	1.000	1.000
Systolic BP	0.053	0.053	0.947	0.947
Diastolic BP	0.023	0.035	0.977	0.965

Table 2: Confidence in Improvement After FMS Correctives

Correlation

The Kendall rank correlation coefficient, also known as Kendall's tau (τ), described the degree of association among changes in FMS score percentage, systolic BP, and diastolic BP from after versus before FMS Correctives, and a related test assessed the statistical significance of the correlations. Adjusting for FDR, the tests found no significant correlation (adjusted p-value = 0.412) between change in FMS score percentage and change in either BP metric. This might seem to contradict the average improvements supported above; however, rank-based correlation assessed the degree to which measurements for the same participant were ordered alike across two ranked metrics (e.g.: whether the participant with the most-improved FMS score also had the most-improved BP). The non-significant correlations, then, indicate that improvements in FMS score did not relate to the same rank of improvement in either BP (e.g.: the participant with the most-improved FDR score may have had the third-most-improved BP), potentially because the degree of improvement in each metric depended on the participant's initial performance in that metric rather than an uniform effect of FMS Correctives. More intuitively, there was a significant (adjusted p-value = 0.032) positive correlation between changes in systolic and diastolic BP. The correlation was weak-to-moderate in strength but discernible, possibly signifying a more uniform effect for BP metrics or an underlying correlation between a participant's initial systolic and diastolic BP measurements.

Difference Variables	Kendall's tau (τ)	p-value	Adjusted p-value	Confidence	Adjusted Confidence
FMS Percentage & Systolic BP	-0.062	0.412	0.412	0.588	0.588
FMS Percentage & Diastolic BP	-0.068	0.363	0.412	0.637	0.588
Systolic BP & Diastolic BP	0.181	0.011	0.032	0.989	0.968

Table 3: Correlation in Before/After Difference

Regression

The type II MANCOVA procedure identified organization and the interaction of organization and age as significant predictors of change in FMS score and BP after FMS Correctives (see Table 4). Reviewing the regression coefficients or plotting estimates (see appendix, Table A and Figure A) supports the quantitative assessment that age, modeled linearly, was not reliably influential to paired-difference results.

Variable	DF	Pillai's Trace	p-value	Confidence
Organization	3	0.426	3.513×10^{-6}	1.000
Age	1	0.041	0.298	0.702
Org. x Age	3	0.183	0.045	0.955

Table 4: Type II MANCOVA for Before/After Difference -- Initial Model

Plotting residual error for the analyzed multivariate regression model (see Figure 2) shows no clear patterns in FMS percentage or systolic BP. Although the residual error in diastolic BP--like diagnostics for tests of difference--suggested unequal variance in this variable, the pattern appeared weak enough for the MANCOVA to operate effectively.

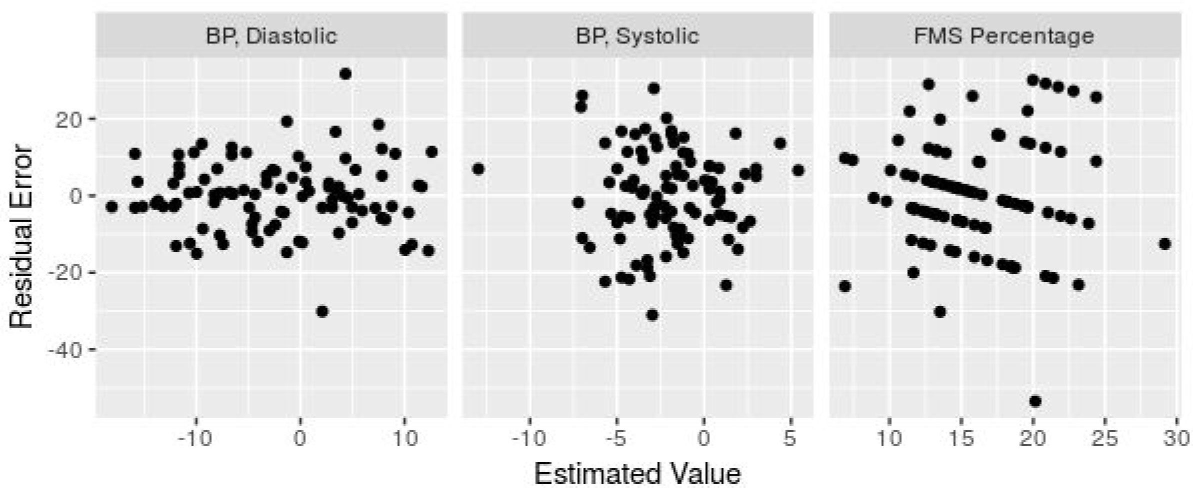

Figure 2: Multivariate Model Residual Error -- Initial Model

Attempting to produce a more effective model, analysis continued by replacing the initial model's non-significant age variable with the last remaining independent variables linked to paired observations: before-correctives FMS score, diastolic BP, and systolic BP. Each new variable had a significant impact while both organization and organization-age interaction effects decreased in significance (see Table 5). Although organization remained highly significant, the organization-age interaction reduced from just above 95% confidence to slightly above 90%.

Variable	DF	Pillai's Trace	p-value	Adjusted p-value	Confidence	Adjusted Confidence
Organization	3	0.339	2.210×10^{-4}	0.001	1.000	0.999
FMS Percentage Before Correctives	1	0.151	0.003	0.009	0.997	0.991
Systolic BP Before Correctives	1	0.647	2.200×10^{-16}	1.760×10^{-15}	1.000	1.000
Diastolic BP Before Correctives	1	0.731	2.200×10^{-16}	1.760×10^{-15}	1.000	1.000
Org. x Age	4	0.206	0.091	0.091	0.909	0.909

Table 5: Type II MANCOVA for Before/After Difference -- Before-Correctives Model

Residual error for this model appeared less disperse, and diastolic BP exhibited less evidence of unequal variance. Without additional patterns evident, the before-correctives model seemed to have improved estimates compared to the initial model.

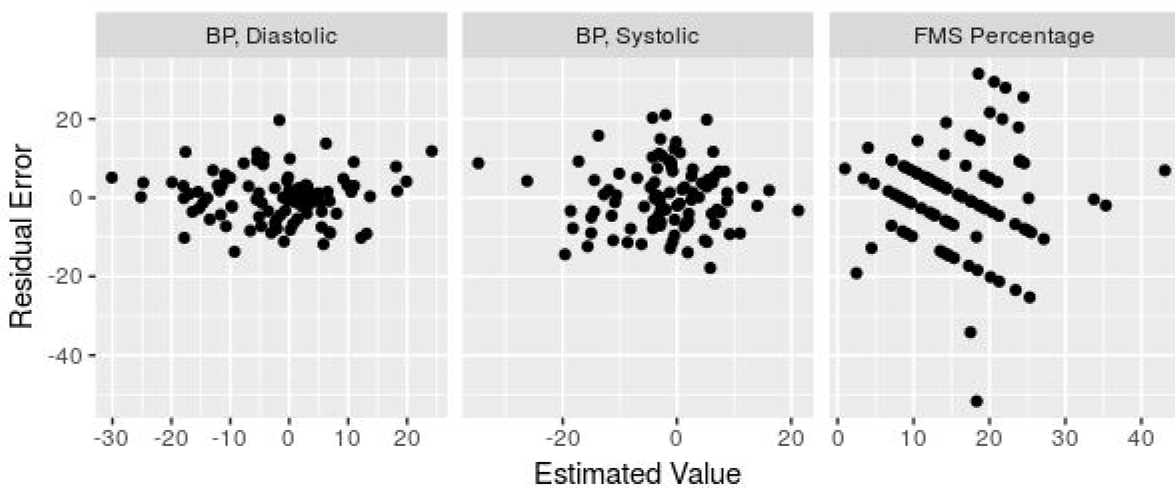

Figure 3: Multivariate Model Residual Error -- Before-Correctives Model

Adjusted R^2 values offered numeric assessments of the models' explanatory power by describing the percentage of total variation in each dependent variable that each model explained, adjusted by a penalty for including more explanatory variables in the model. In this case, the before-correctives model improved adjusted R2 performance for differences in FMS score percentage by 0.137, systolic BP by 0.507, and diastolic BP by 0.312 compared to the initial model, all substantial improvements.

	Initial Model		Before-Correctives Model	
Difference Variable	**Multiple R^2**	**Adjusted R^2**	**Multiple R^2**	**Adjusted R^2**
FMS Percentage	0.080	0.008	0.233	0.145
Systolic BP	0.056	-0.018	0.542	0.489
Diastolic BP	0.432	0.388	0.731	0.700

Table 6: R^2 Comparisons of Multivariate Models

Because incorporating before-correctives values increased the risk of overfitting the model such that the model would describe the specific data collected rather than information about the Rock Solid@Work™ functional core strengthening program as a whole, analysis also compared the two models using bootstrap statistics. Randomly resampling the collected data introduced a degree of variation into the data in order to measure the stability--or resistance to changes in the data--of the coefficients each model generated. Table 7 summarizes coefficients' bootstrap performance for explanatory variables that appeared in both models. While bias was slightly stronger and in the opposite direction under the before-correctives model, it did not indicate an overwhelming performance decrease. Bootstrap standard error, in turn, reduced substantially under the before-correctives model. Taken as a whole, these measurements favored the stability of the before-correctives model.

Model	Total Bias	Median Bias	Total Bootstrap Std. Error	Median Bootstrap Std. Error
Initial Model	-17.797	-0.003	431.050	7.678
Before-Correctives Model	19.931	0.011	134.365	0.283

Table 7: Bootstrap Comparisons of Multivariate Models

While the before-correctives model's multidimensionality made regression lines difficult to visualize effectively, its regression coefficients (see appendix, Table B) suggested additional relationships among variables. For instance, organization coefficients indicated that Health & Human Services experienced some of the greatest average improvements among organizations. Road & Bridge, counter to its counterparts, experienced an average increase in diastolic BP after completing FMS Correctives and generally saw some of the most meager average improvements. The Natural Resources organization, by contrast, was fit by some of the most extreme coefficients, including a substantial decrease in FMS score improvements with age; however, this seems to be a result of the organization's small set of six observations. Before-correctives measurements each had relatively strong negative effects on after-correctives change in the same variable (e.g.: participants with a high starting systolic BP also experienced a relatively large drop in systolic BP). Because tests of difference indicated that improvements were unlikely to have occurred by chance alone, a tendency for repeat measurements to take less extreme values probably does not explain this phenomenon. Room for improvement--in which FMS score cannot improve beyond a maximum score of 3 or where it is easier to reduce a high BP than to reduce an already-low BP--might explain this result better. Of note, before-correctives FMS score percentage and systolic BP had essentially no relation to results in other dependent variables, but higher initial diastolic BP was associated somewhat with less improvement in systolic BP and more weakly with less improvement in FMS score, maybe as a more general indicator of bodily function potential.

Univariate ANCOVAs explored the effectiveness of using the before-correctives model to predict each dependent variable. The model explains a significant (adjusted p-value = 0.015) yet small (adjusted R^2 = 0.145) portion of FMS score percentage change. This implies that organization and initial FMS score influenced improvements in FMS score but that unknown factors or properties intrinsic to the FMS and FMS Correctives caused most of the variation. Changes in BP after FMS Correctives were influenced by organization and initial BP much more strongly and reliably, with the model explaining roughly half or more of the variation in BP improvement. Controlling for these variables in future analyses could provide a substantial advantage in estimating or predicting BP improvements.

Difference Variable	Adjusted R^2	F (DF = 10)	p-value	Adjusted p-value	Confidence	Adjusted Confidence
FMS Percentage	0.145	2.639	0.007	0.015	0.993	0.985
Systolic BP	0.489	10.27	3.216×10^{-11}	1.608×10^{-10}	1.000	1.000
Diastolic BP	0.700	23.61	2.200×10^{-16}	1.760×10^{-15}	1.000	1.000

Table 8: ANCOVA F-tests for Before/After Difference -- Before-Correctives Model

Conclusions

Based on the paired before/after participant performance data collected to date, 3:1 Corporate Health and Productivity Management Solutions can claim that the Rock Solid@Work™ 12-week FMS Correctives program achieved improvements in movement competency with nearly 100% confidence, in systolic BP with close to 95% confidence, and in diastolic BP with more than 96% confidence. Participants did not necessarily experience related degrees of improvement in FMS score and in either BP metric, but systolic and diastolic BP tended to improve together weakly-to-moderately with almost 97% confidence.

Although analyzing paired-observation data may have controlled for some differences among participants, regression analysis indicated that FMS Correctives performed differently for different categories of participants. The average degree of improvement in each outcome metric varied significantly with organization as well as with the participant's FMS score and BP before beginning FMS Correctives. In addition to the analysis's observational nature, regression results give cause for caution in generalizing results to new organizations; however, considering participants' organization and before-correctives performance could improve estimates and predictive performance for known populations.

Appendix

References

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Supplemental Tables and Figures

Variable	Difference in FMS Percentage	Difference in Systolic BP	Difference in Diastolic BP
Intercept	27.04	13.04	-16.34
Org.: Landfill	-32.34	-13.44	14.28
Org.: Natural Resources	3.88	-28.27	-15.00
Org.: Road & Bridge	-7.29	-7.53	36.28
Org.: Health & Human Services	0.00	0.00	0.00
Age	-0.18	-0.35	0.28
Org.: Landfill x Age	0.71	0.27	-0.53
Org.: Natural Resources x Age	-0.26	0.56	0.24
Org.: Road & Bridge x Age	0.04	0.21	-0.60
Org.: Health & Human Services x Age	0.00	0.00	0.00

Table A: Multivariate Model Regression Coefficient Estimates -- Initial Model

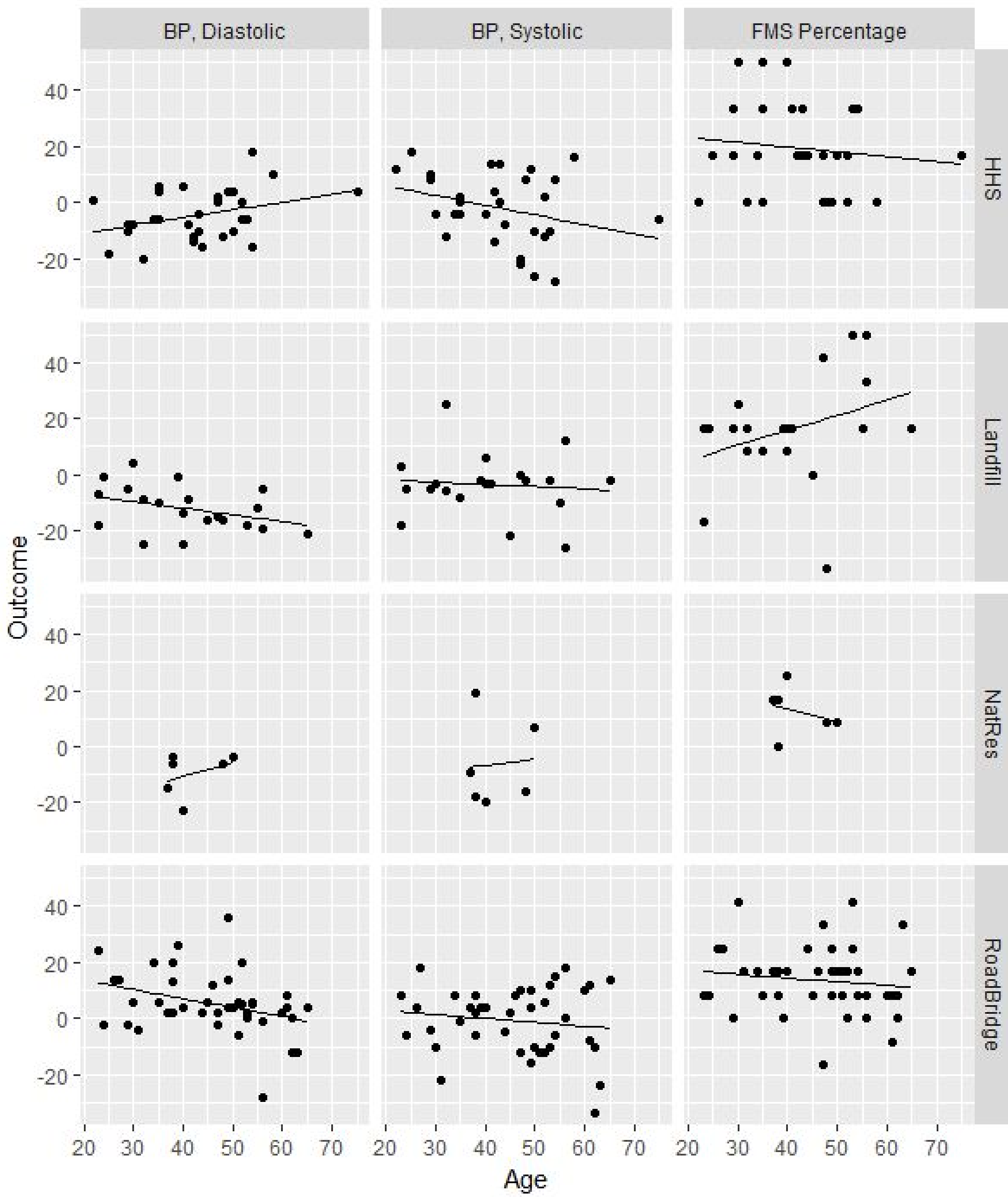


Figure A: Observed Outcomes and Modeled Multivariate Regression Lines -- Initial Model

Variable	Difference in FMS Percentage	Difference in Systolic BP	Difference in Diastolic BP
Intercept	76.18	77.11	29.00
Org.: Landfill	-10.78	0.41	10.55
Org.: Natural Resources	37.37	3.57	-7.57
Org.: Road & Bridge	-3.04	9.44	24.98
Org.: Health & Human Services	0.00	0.00	0.00
FMS Percentage Before Correctives	-0.46	0.03	0.03
Systolic BP Before Correctives	-0.02	-0.94	0.07
Diastolic BP Before Correctives	-0.25	0.50	-0.68
Org.: Health & Human Services x Age	-0.30	-0.06	0.25
Org.: Landfill x Age	0.06	-0.10	-0.09
Org.: Natural Resources x Age	-1.14	-0.10	0.40
Org.: Road & Bridge x Age	-0.28	-0.15	-0.15

Table B: Multivariate Model Regression Coefficient Estimates -- Before-Correctives Model

Code: R Output

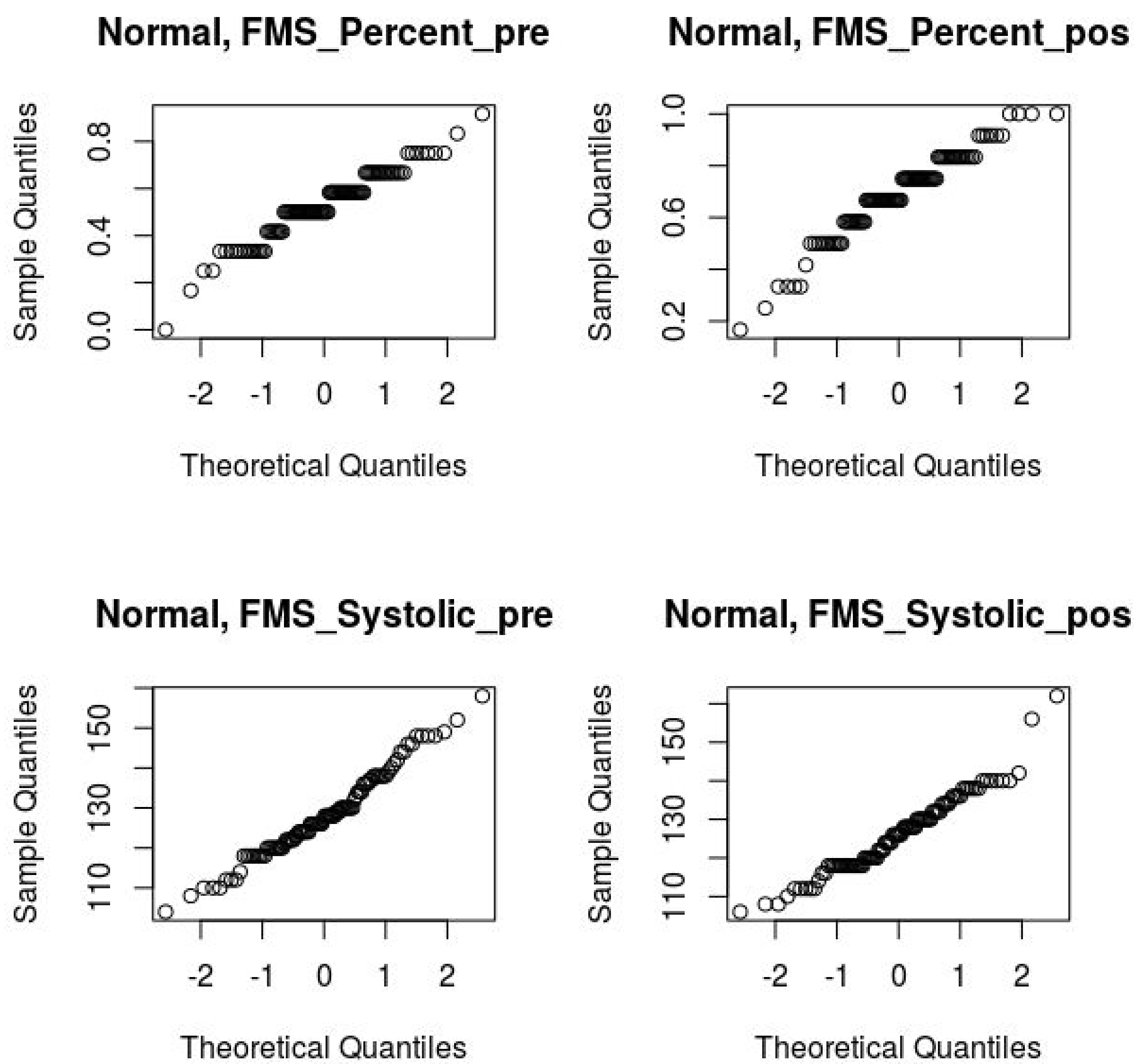
Imputation using Random Forests

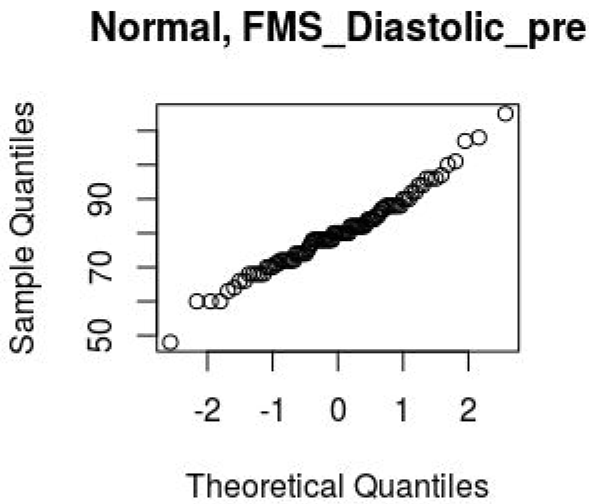
```
> imp <- missForest(dat, maxiter = 10, ntree = 150,
+                       variablewise = TRUE, parallelize = "no")
  missForest iteration 1 in progress...done!
  missForest iteration 2 in progress...done!
  missForest iteration 3 in progress...done!
> data.frame(Factor = colnames(imp$ximp),
+              OOB_Error = imp$OOBerror)[c(2,3,4,6,7),]
       Variable OOB_Error
2           Age    138.90
3  BP_Systolic_pre    99.04
4 BP_Diastolic_pre    77.80
6  BP_Systolic_pos    66.41
7 BP_Diastolic_pos    32.39
> dat <- imp$ximp
> dat[,2:8] <- round(dat[,2:8], 0)
```

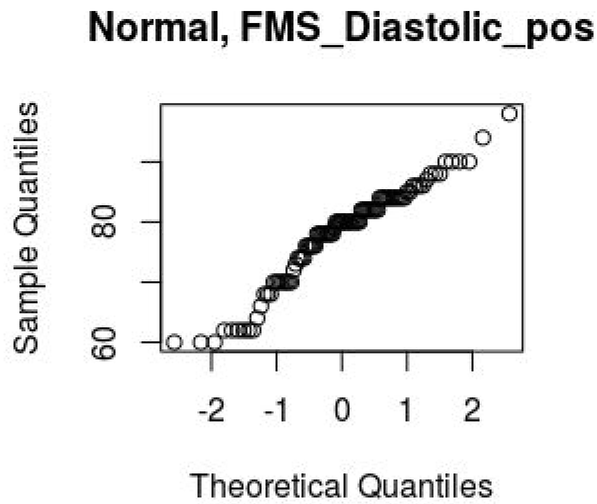
```
> dat$BP_Systolic_dif <- dat$BP_Systolic_pos - dat$BP_Systolic_pre
> dat$BP_Diastolic_dif <- dat$BP_Diastolic_pos - dat$BP_Diastolic_pre
```

Quantile-Quantile Plots

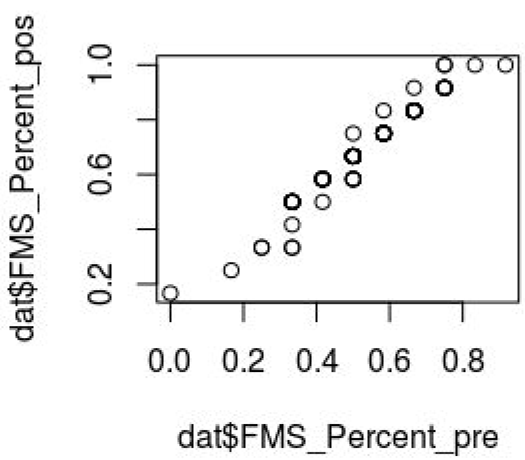
```
> qqnorm(dat$FMS_Percent_pre, main = "Normal, FMS_Percent_pre")
> qqnorm(dat$FMS_Percent_pos, main = "Normal, FMS_Percent_pos")
> qqnorm(dat$BP_Systolic_pre, main = "Normal, FMS_Systolic_pre")
> qqnorm(dat$BP_Systolic_pos, main = "Normal, FMS_Systolic_pos")
> qqnorm(dat$BP_Diastolic_pre, main = "Normal, FMS_Diastolic_pre")
> qqnorm(dat$BP_Diastolic_pos, main = "Normal, FMS_Diastolic_pos")
```

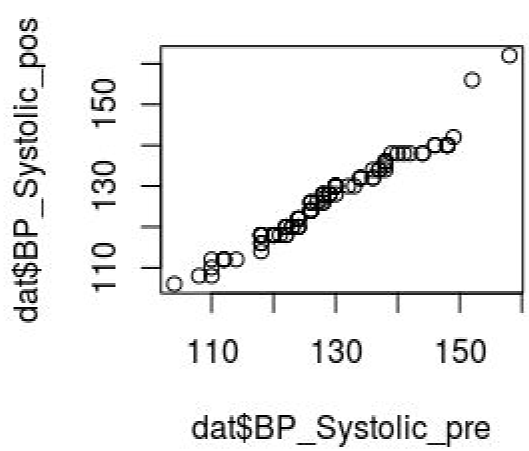


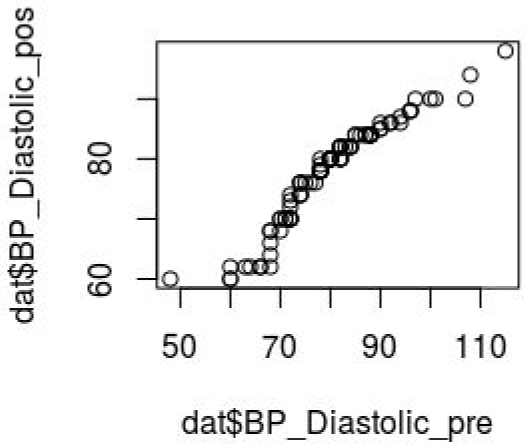




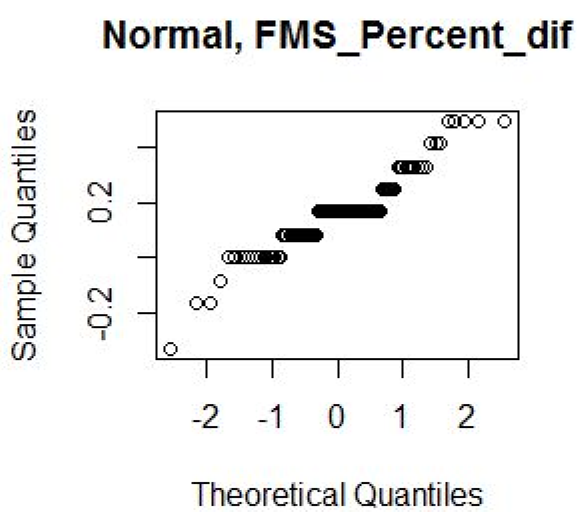

```
qqplot(dat$FMS_Percent_pre, dat$FMS_Percent_pos) #not normal
qqplot(dat$BP_Systolic_pre, dat$BP_Systolic_pos) #maybe normal
qqplot(dat$BP_Diastolic_pre, dat$BP_Diastolic_pos) #not normal
qqplot(dat$FMS_Percent_dif, dat$BP_Systolic_dif) #not normal
```

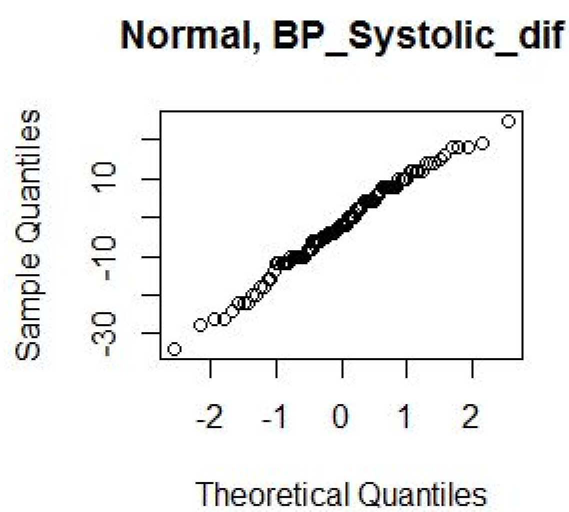


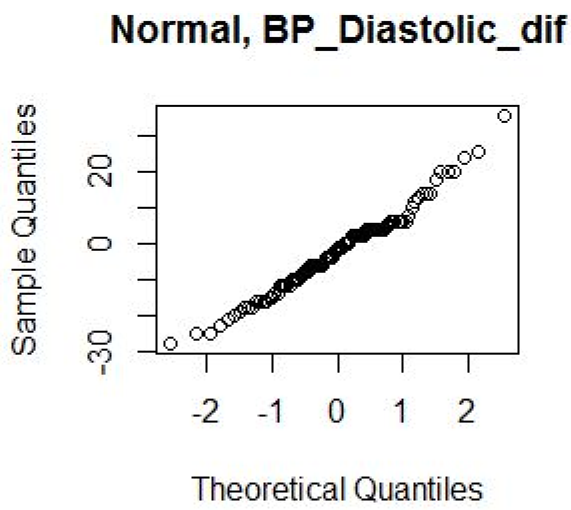


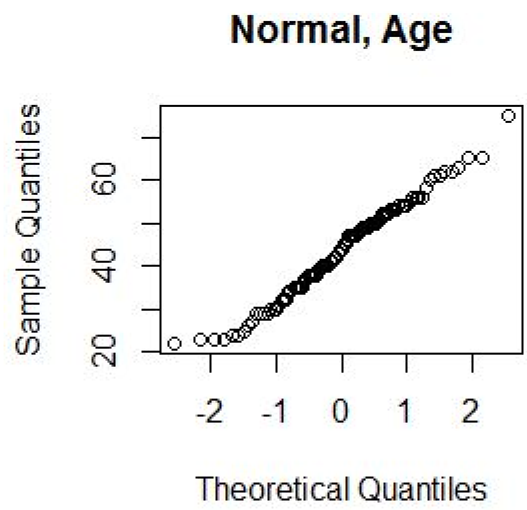



```
> qqnorm(dat$FMS_Percent_dif, main = "Normal, FMS_Percent_dif")
> qqnorm(dat$BP_Systolic_dif, main = "Normal, BP_Systolic_dif")
> qqnorm(dat$BP_Diastolic_dif, main = "Normal, BP_Diastolic_dif")
> qqnorm(dat$Age, main = "Normal, Age")
```

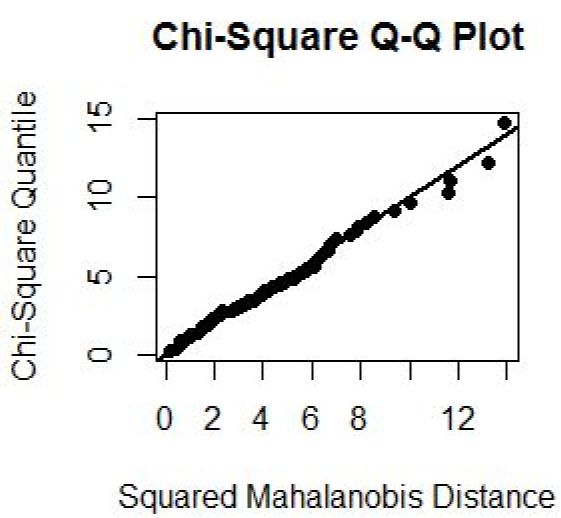






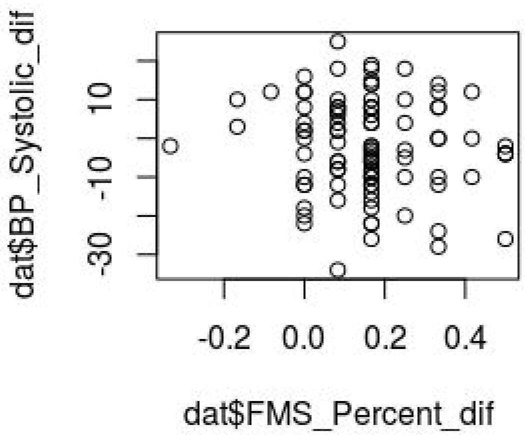


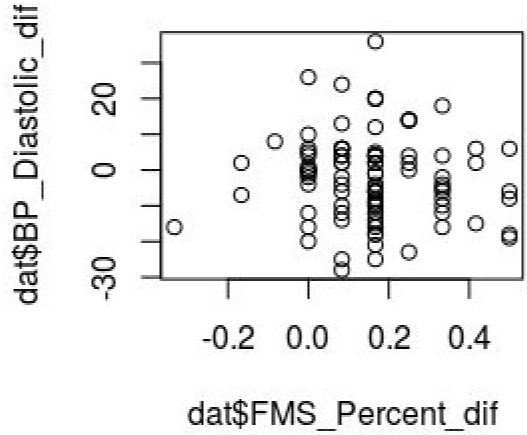

```
> AD.test(dat[,c(3,12,13,14)], qqplot = TRUE)
           Anderson-Darling test for Multivariate Normality

  data : dat[, c(3, 12, 13, 14)]

  AD                : 0.442545
  p-value           : 0.5517448

  Result  : Data are multivariate normal (sig.level = 0.05)
```

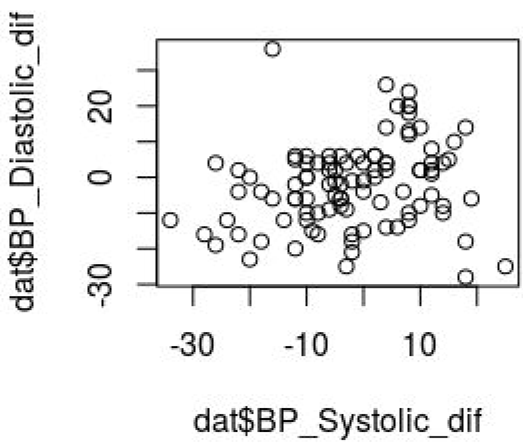


Scatterplots

```
> plot(dat$FMS_Percent_dif, dat$BP_Systolic_dif) #no outliers
> plot(dat$FMS_Percent_dif, dat$BP_Diastolic_dif) #no outliers
> plot(dat$BP_Systolic_dif, dat$BP_Diastolic_dif) #outlier
```







Fligner-Killeen Test of Homogeneity of Variances

```
> #untransformed
> fligner.test(x = dat[,c(3,12,13,14)], g = dat$Org)

	Fligner-Killeen test of homogeneity of variances

data:  dat[, c(3, 12, 13, 14)]
Fligner-Killeen:med chi-squared = 141.91, df = 3, p-value <
2.2e-16

> #transformed
> fligner.test(x = dat_reg[,c(3,12,13,14)], g = dat_reg$Org)

	Fligner-Killeen test of homogeneity of variances
```

```
data:  dat_reg[, c(3, 12, 13, 14)]
Fligner-Killeen:med chi-squared = 0.61195, df = 3, p-value =
0.8937
```

Box's M-test for Homogeneity of Covariance Matrices

```
> boxM(data = dat[,c(3,12,13,14)], grouping = dat[,2])

       Box's M-test for Homogeneity of Covariance Matrices

data:  dat[, c(3, 12, 13, 14)]
Chi-Sq (approx.) = 44.421, df = 30, p-value = 0.04366
```

Mahalanobis Distances

```
> m_out <- mahalanobis(x = dat_reg[,c(3,12,13,14)],
+                      center = colMeans(dat_reg[,c(3,12,13,14)]),
+                      cov = cov(dat_reg[,c(3,12,13,14)]))
> summary(m_out)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.1784  1.7381  3.3714  3.9592  5.6908 13.7832
```

Bootstrap Comparison of Regression Coefficients

```
> lab <- rbind(expand.grid("mod", rownames(mod$coefficients),
+                          colnames(mod$coefficients)),
+              expand.grid("mod2", rownames(mod2$coefficients),
+                          colnames(mod2$coefficients)))
> func <- function(d, i){
+  mod <- lm(cbind(FMS_Percent_dif, BP_Systolic_dif, BP_Diastolic_dif) ~
+               Org*Age, data = d[i,])
+  mod2 <- lm(cbind(FMS_Percent_dif, BP_Systolic_dif, BP_Diastolic_dif) ~
+                Org + Org:Age + I(FMS_Percent_pre*100) + BP_Systolic_pre + BP_Diastolic_pre,
+              data = d[i,])
+  return(rbind(mod$coefficients, mod2$coefficients))
+ }
> boot_out <- boot(dat_reg, statistic = func, R = 150)
> boot_out

ORDINARY NONPARAMETRIC BOOTSTRAP


Call:
boot(data = dat_reg, statistic = func, R = 150)


Bootstrap Statistics :
        original        bias     std. error
t1*   27.03955314  1.255974e+00  12.96726707
t2*  -32.34385023 -7.353688e-01  17.97842815
t3*    3.88445377 -1.667335e+01 100.17913253
t4*   -7.28978033 -1.663938e+00  13.60917461
t5*   -0.17663043 -3.139648e-02   0.27007034
t6*    0.70687145  1.977884e-02   0.45861011
t7*   -0.26378407  4.360340e-01   2.61456569
```

```
t8*    0.04401425  4.033292e-02   0.28626813
t9*   76.17801361  1.894639e+00  18.96513269
t10* -10.77758502 -2.711141e+00  17.55878407
t11*  37.36893145 -1.336992e+01 118.06539194
t12*  -3.04335698 -3.186580e+00  13.72315936
t13*  -0.46109909  9.007128e-03   0.10993697
t14*  -0.02399971 -3.468827e-03   0.15973913
t15*  -0.24696460  1.321998e-02   0.15660158
t16*  -0.29726903 -6.984636e-02   0.28722570
t17*   0.05732608 -7.147741e-03   0.35536611
t18*  -1.13681339  2.276760e-01   3.09435660
t19*  -0.28073771  4.122620e-03   0.12655510
t20*  13.04311594  1.750419e+00   7.67830014
t21* -13.43732611 -1.897195e+00  11.12493667
t22* -28.27005895  1.647532e+01  91.54540213
t23*  -7.53072082 -1.449151e+00  11.03668281
t24*  -0.34673913 -4.474481e-02   0.20363126
t25*   0.26910592  3.794624e-02   0.28272618
t26*   0.56331944 -4.400501e-01   2.31030235
t27*   0.20993840  3.707062e-02   0.28237191
t28*  77.11435341  6.243156e-01  12.13798373
t29*   0.41342171 -4.145535e-01  10.87902989
t30*   3.56996035  1.456296e+01  76.82353931
t31*   9.43963079 -2.980083e-01   9.47956151
t32*   0.02629555  2.795145e-03   0.08154574
t33*  -0.93601083 -2.615248e-04   0.09658517
t34*   0.49966338 -1.432204e-02   0.11718117
t35*  -0.05667657  1.076776e-02   0.18107579
t36*  -0.10269208  1.109294e-02   0.17609632
t37*  -0.10386782 -3.885811e-01   1.93765734
t38*  -0.15133051  1.079407e-02   0.14410816
t39* -16.34356884  6.690203e-01   6.94139445
t40*  14.27950446 -8.336371e-01   9.52115008
t41* -14.99840007  1.509433e+01  84.97401725
t42*  36.27648936 -6.971184e-01   8.62092095
t43*   0.27853261 -1.540147e-02   0.16549958
t44*  -0.52541909  1.690365e-02   0.21352179
t45*   0.23960211 -4.027122e-01   2.22278613
t46*  -0.59702279  1.323490e-02   0.19447211
t47*  28.99786498 -1.567042e+00   9.83486872
t48*  10.55224227  1.020637e+00   8.77021280
t49*  -7.57114239  2.015405e+01  78.76327632
t50*  24.98049506  6.337855e-01   7.48555808
t51*   0.03442713  1.349716e-02   0.06371282
t52*   0.06598362 -1.811211e-03   0.08079778
t53*  -0.67814815 -3.153174e-03   0.08018818
t54*   0.25084313  3.463356e-02   0.18246485
t55*  -0.09384778 -2.782065e-04   0.13828713
t56*   0.39544984 -5.097573e-01   2.05355635
t57*  -0.15155088  1.438116e-02   0.08112672
> lab
   Var1                   Var2             Var3
1   mod            (Intercept)  FMS_Percent_dif
2   mod            OrgLandfill  FMS_Percent_dif
3   mod              OrgNatRes  FMS_Percent_dif
4   mod           OrgRoadBridge  FMS_Percent_dif
5   mod                    Age  FMS_Percent_dif
```

```
6    mod           OrgLandfill:Age   FMS_Percent_dif
7    mod             OrgNatRes:Age   FMS_Percent_dif
8    mod         OrgRoadBridge:Age   FMS_Percent_dif
9    mod               (Intercept)   BP_Systolic_dif
10   mod               OrgLandfill   BP_Systolic_dif
11   mod                 OrgNatRes   BP_Systolic_dif
12   mod             OrgRoadBridge   BP_Systolic_dif
13   mod                       Age   BP_Systolic_dif
14   mod           OrgLandfill:Age   BP_Systolic_dif
15   mod             OrgNatRes:Age   BP_Systolic_dif
16   mod         OrgRoadBridge:Age   BP_Systolic_dif
17   mod               (Intercept) BP_Diastolic_dif
18   mod               OrgLandfill BP_Diastolic_dif
19   mod                 OrgNatRes BP_Diastolic_dif
20   mod             OrgRoadBridge BP_Diastolic_dif
21   mod                       Age BP_Diastolic_dif
22   mod           OrgLandfill:Age BP_Diastolic_dif
23   mod             OrgNatRes:Age BP_Diastolic_dif
24   mod         OrgRoadBridge:Age BP_Diastolic_dif
25 mod2               (Intercept)   FMS_Percent_dif
26 mod2               OrgLandfill   FMS_Percent_dif
27 mod2                 OrgNatRes   FMS_Percent_dif
28 mod2             OrgRoadBridge   FMS_Percent_dif
29 mod2 I(FMS_Percent_pre * 100)   FMS_Percent_dif
30 mod2            BP_Systolic_pre   FMS_Percent_dif
31 mod2           BP_Diastolic_pre   FMS_Percent_dif
32 mod2                OrgHHS:Age   FMS_Percent_dif
33 mod2           OrgLandfill:Age   FMS_Percent_dif
34 mod2             OrgNatRes:Age   FMS_Percent_dif
35 mod2         OrgRoadBridge:Age   FMS_Percent_dif
36 mod2               (Intercept)   BP_Systolic_dif
37 mod2               OrgLandfill   BP_Systolic_dif
38 mod2                 OrgNatRes   BP_Systolic_dif
39 mod2             OrgRoadBridge   BP_Systolic_dif
40 mod2 I(FMS_Percent_pre * 100)   BP_Systolic_dif
41 mod2            BP_Systolic_pre   BP_Systolic_dif
42 mod2           BP_Diastolic_pre   BP_Systolic_dif
43 mod2                OrgHHS:Age   BP_Systolic_dif
44 mod2           OrgLandfill:Age   BP_Systolic_dif
45 mod2             OrgNatRes:Age   BP_Systolic_dif
46 mod2         OrgRoadBridge:Age   BP_Systolic_dif
47 mod2               (Intercept) BP_Diastolic_dif
48 mod2               OrgLandfill BP_Diastolic_dif
49 mod2                 OrgNatRes BP_Diastolic_dif
50 mod2             OrgRoadBridge BP_Diastolic_dif
51 mod2 I(FMS_Percent_pre * 100) BP_Diastolic_dif
52 mod2            BP_Systolic_pre BP_Diastolic_dif
53 mod2           BP_Diastolic_pre BP_Diastolic_dif
54 mod2                OrgHHS:Age BP_Diastolic_dif
55 mod2           OrgLandfill:Age BP_Diastolic_dif
56 mod2             OrgNatRes:Age BP_Diastolic_dif
57 mod2         OrgRoadBridge:Age BP_Diastolic_dif
```

Difference

```
> dif_FMS <- t.test(x = dat$FMS_Percent_pos, y = dat$FMS_Percent_pre,
+                  alternative = "greater", paired = TRUE, var.equal = TRUE)
```

```
> dif_FMS

	Paired t-test

data:  dat$FMS_Percent_pos and dat$FMS_Percent_pre
t = 10.598, df = 97, p-value < 2.2e-16
alternative hypothesis: true difference in means is greater than 0
95 percent confidence interval:
 0.1340956       Inf
sample estimates:
mean of the differences 
              0.1590136 

> dif_BPs <- t.test(x = dat$BP_Systolic_pos, y = dat$BP_Systolic_pre,
+                  alternative = "less", paired = TRUE, var.equal = TRUE)
> dif_BPs

	Paired t-test

data:  dat$BP_Systolic_pos and dat$BP_Systolic_pre
t = -1.6277, df = 97, p-value = 0.05341
alternative hypothesis: true difference in means is less than 0
95 percent confidence interval:
       -Inf 0.04030003
sample estimates:
mean of the differences 
              -1.989796 

> dif_BPd <- wilcox.test(x = dat$BP_Diastolic_pos, y = dat$BP_Diastolic_pre,
+                       alternative = "less", mu = 0, paired = TRUE,
+                       exact = FALSE, correct = TRUE)
> dif_BPd

	Wilcoxon signed rank test with continuity correction

data:  dat$BP_Diastolic_pos and dat$BP_Diastolic_pre
V = 1705, p-value = 0.02332
alternative hypothesis: true location shift is less than 0

> data.frame(vbl = c("FMS Percentage", "Systolic BP", "Diastolic BP"),
+           p = c(dif_FMS$p.value, dif_BPs$p.value, dif_BPd$p.value),
+           p.adj = p.adjust(p = c(dif_FMS$p.value, dif_BPs$p.value,
+                                  dif_BPd$p.value), method = "BH"),
+           conf = round(1 - c(dif_FMS$p.value, dif_BPs$p.value, dif_BPd$p.value), 3),
+           c.adj = round(1 - p.adjust(p = c(dif_FMS$p.value, dif_BPs$p.value,
+                                          dif_BPd$p.value), method = "BH"), 3))
             vbl            p        p.adj  conf c.adj
1 FMS Percentage 3.448226e-18 1.034468e-17 1.000 1.000
2    Systolic BP 5.341125e-02 5.341125e-02 0.947 0.947
3   Diastolic BP 2.332160e-02 3.498240e-02 0.977 0.965
```

Correlation

```
> cor_FMS.BPs <- cor.test(dat$FMS_Percent_dif, dat$BP_Systolic_dif,
+                        alternative = "two.sided", use = "pairwise.complete.obs",
+                        method = "kendall", exact = FALSE, continuity = TRUE)
> cor_FMS.BPs
```

```
	Kendall's rank correlation tau

data:  dat$FMS_Percent_dif and dat$BP_Systolic_dif
z = -0.82014, p-value = 0.4121
alternative hypothesis: true tau is not equal to 0
sample estimates:
        tau 
-0.06168241 

> cor_FMS.BPd <- cor.test(dat$FMS_Percent_dif, dat$BP_Diastolic_dif,
+                        alternative = "two.sided", use = "pairwise.complete.obs",
+                        method = "kendall", exact = FALSE, continuity = TRUE)
> cor_FMS.BPd

	Kendall's rank correlation tau

data:  dat$FMS_Percent_dif and dat$BP_Diastolic_dif
z = -0.90914, p-value = 0.3633
alternative hypothesis: true tau is not equal to 0
sample estimates:
        tau 
-0.06845182 

> cor_BPs.BPd <- cor.test(dat$BP_Systolic_dif, dat$BP_Diastolic_dif,
+                        alternative = "two.sided", use = "pairwise.complete.obs",
+                        method = "kendall", exact = FALSE, continuity = TRUE)
> cor_BPs.BPd

	Kendall's rank correlation tau

data:  dat$BP_Systolic_dif and dat$BP_Diastolic_dif
z = 2.5551, p-value = 0.01062
alternative hypothesis: true tau is not equal to 0
sample estimates:
      tau 
0.1811052 

> data.frame(vbl = c("FMS Percentage & Systolic BP",
+                   "FMS Percentage & Diastolic BP",
+                   "Systolic BP & Diastolic BP"),
+           tau = round(c(cor_FMS.BPs$estimate, cor_FMS.BPd$estimate,
+                         cor_BPs.BPd$estimate), 3),
+           p = round(c(cor_FMS.BPs$p.value, cor_FMS.BPd$p.value,
+                       cor_BPs.BPd$p.value), 3),
+           p.adj = round(p.adjust(p = c(cor_FMS.BPs$p.value, cor_FMS.BPd$p.value,
+                                        cor_BPs.BPd$p.value), method = "BH"), 3),
+           conf = round(1 - c(cor_FMS.BPs$p.value, cor_FMS.BPd$p.value,
+                              cor_BPs.BPd$p.value), 3),
+           c.adj = round(1 - p.adjust(p = c(cor_FMS.BPs$p.value,
+                                            cor_FMS.BPd$p.value,
+                                            cor_BPs.BPd$p.value),
+                                      method = "BH"), 3))
                            vbl    tau     p p.adj  conf c.adj
1  FMS Percentage & Systolic BP -0.062 0.412 0.412 0.588 0.588
2 FMS Percentage & Diastolic BP -0.068 0.363 0.412 0.637 0.588
3    Systolic BP & Diastolic BP  0.181 0.011 0.032 0.989 0.968
```

Regression

```
> # MANCOVA (Organization and Age)
> mod <- lm(cbind(FMS_Percent_dif, BP_Systolic_dif, BP_Diastolic_dif) ~
+           Org*Age, data = dat_reg)
> mod_mancova <- Manova(mod = mod,
+                      type = 2, test.statistic = "Pillai", digits = 3,
+                      multivariate = TRUE, univariate = TRUE,
+                      p.adjust.method = c("none", "Holm"))
> mod_mancova

Type II MANOVA Tests: Pillai test statistic
        Df test stat approx F num Df den Df    Pr(>F)
Org      3   0.42565   4.9603      9    270 3.513e-06 ***
Age      1   0.04076   1.2463      3     88   0.29789
Org:Age  3   0.18332   1.9525      9    270   0.04505 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> mod

Call:
lm(formula = cbind(FMS_Percent_dif, BP_Systolic_dif, BP_Diastolic_dif) ~
    Org * Age, data = dat_reg)

Coefficients:
                   FMS_Percent_dif  BP_Systolic_dif  BP_Diastolic_dif
(Intercept)         27.03955         13.04312        -16.34357
OrgLandfill        -32.34385        -13.43733         14.27950
OrgNatRes            3.88445        -28.27006        -14.99840
OrgRoadBridge       -7.28978         -7.53072         36.27649
Age                 -0.17663         -0.34674          0.27853
OrgLandfill:Age      0.70687          0.26911         -0.52542
OrgNatRes:Age       -0.26378          0.56332          0.23960
OrgRoadBridge:Age    0.04401          0.20994         -0.59702

> # MANCOVA (Organization and ‘Before’ Measurements)
> mod2 <- lm(cbind(FMS_Percent_dif, BP_Systolic_dif, BP_Diastolic_dif) ~
+           Org + Org:Age + I(FMS_Percent_pre*100) + BP_Systolic_pre + BP_Diastolic_pre,
+         data = dat_reg)
> mod2_mancova <- Manova(mod = mod2,
+                      type = 2, test.statistic = "Pillai", digits = 3,
+                      multivariate = TRUE, univariate = TRUE,
+                      p.adjust.method = c("none", "Holm"))
> mod2_mancova

Type II MANOVA Tests: Pillai test statistic
                         Df test stat approx F num Df den Df    Pr(>F)
Org                       3   0.33928    3.698      9    261  0.000221 ***
I(FMS_Percent_pre * 100)  1   0.15084    5.033      3     85  0.002935 **
BP_Systolic_pre           1   0.64705   51.942      3     85 < 2.2e-16 ***
BP_Diastolic_pre          1   0.73115   77.056      3     85 < 2.2e-16 ***
Org:Age                   4   0.20573    1.601     12    261  0.091132 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> mod2
```

```
Call:
lm(formula = cbind(FMS_Percent_dif, BP_Systolic_dif, BP_Diastolic_dif) ~
    Org + Org:Age + I(FMS_Percent_pre * 100) + BP_Systolic_pre +
        BP_Diastolic_pre, data = dat_reg)

Coefficients:
                          FMS_Percent_dif  BP_Systolic_dif  BP_Diastolic_dif
(Intercept)                76.17801         77.11435         28.99786
OrgLandfill               -10.77759          0.41342         10.55224
OrgNatRes                  37.36893          3.56996         -7.57114
OrgRoadBridge              -3.04336          9.43963         24.98050
I(FMS_Percent_pre * 100)   -0.46110          0.02630          0.03443
BP_Systolic_pre            -0.02400         -0.93601          0.06598
BP_Diastolic_pre           -0.24696          0.49966         -0.67815
OrgHHS:Age                 -0.29727         -0.05668          0.25084
OrgLandfill:Age             0.05733         -0.10269         -0.09385
OrgNatRes:Age              -1.13681         -0.10387          0.39545
OrgRoadBridge:Age          -0.28074         -0.15133         -0.15155

> # ANOVAs
> summary(mod) # Initial model, for R-squared values
Response FMS_Percent_dif :

Call:
lm(formula = FMS_Percent_dif ~ Org * Age, data = dat_reg)

Residuals:
    Min      1Q  Median      3Q     Max
-53.481  -6.675  -0.879   8.916  30.026

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       27.03955   10.82805   2.497   0.0143 *
OrgLandfill      -32.34385   15.94237  -2.029   0.0454 *
OrgNatRes          3.88445   50.34730   0.077   0.9387
OrgRoadBridge     -7.28978   14.26738  -0.511   0.6106
Age               -0.17663    0.24386  -0.724   0.4707
OrgLandfill:Age    0.70687    0.36837   1.919   0.0582 .
OrgNatRes:Age     -0.26378    1.19168  -0.221   0.8253
OrgRoadBridge:Age  0.04401    0.31355   0.140   0.8887
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.79 on 90 degrees of freedom
Multiple R-squared:  0.07971,Adjusted R-squared:  0.008133
F-statistic: 1.114 on 7 and 90 DF,  p-value: 0.3616


Response BP_Systolic_dif :

Call:
lm(formula = BP_Systolic_dif ~ Org * Age, data = dat_reg)

Residuals:
    Min      1Q  Median      3Q     Max
-31.031  -7.026   0.835   7.486  27.878
```

```
Coefficients:
                  Estimate Std. Error t value Pr(>|t|)  
(Intercept)        13.0431     8.9357   1.460   0.1479  
OrgLandfill       -13.4373    13.1562  -1.021   0.3098  
OrgNatRes         -28.2701    41.5485  -0.680   0.4980  
OrgRoadBridge      -7.5307    11.7740  -0.640   0.5241  
Age                -0.3467     0.2012  -1.723   0.0883 .
OrgLandfill:Age     0.2691     0.3040   0.885   0.3784  
OrgNatRes:Age       0.5633     0.9834   0.573   0.5682  
OrgRoadBridge:Age   0.2099     0.2588   0.811   0.4193  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 12.21 on 90 degrees of freedom
Multiple R-squared:  0.05578,Adjusted R-squared:  -0.01766 
F-statistic: 0.7595 on 7 and 90 DF,  p-value: 0.6225


Response BP_Diastolic_dif :

Call:
lm(formula = BP_Diastolic_dif ~ Org * Age, data = dat_reg)

Residuals:
    Min      1Q  Median      3Q     Max 
-30.097  -4.409   0.129   5.070  31.673 

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)       -16.3436     6.8086  -2.400 0.018434 *  
OrgLandfill        14.2795    10.0244   1.424 0.157768    
OrgNatRes         -14.9984    31.6579  -0.474 0.636815    
OrgRoadBridge      36.2765     8.9712   4.044 0.000111 ***
Age                 0.2785     0.1533   1.817 0.072622 .  
OrgLandfill:Age    -0.5254     0.2316  -2.268 0.025700 *  
OrgNatRes:Age       0.2396     0.7493   0.320 0.749890    
OrgRoadBridge:Age  -0.5970     0.1972  -3.028 0.003210 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.302 on 90 degrees of freedom
Multiple R-squared:  0.432,	Adjusted R-squared:  0.3879 
F-statistic:  9.78 on 7 and 90 DF,  p-value: 5.217e-09



> summary(mod2) # Before-correctives model
Response FMS_Percent_dif :

Call:
lm(formula = FMS_Percent_dif ~ Org + Org:Age + I(FMS_Percent_pre * 
    100) + BP_Systolic_pre + BP_Diastolic_pre, data = dat_reg)

Residuals:
    Min      1Q  Median      3Q     Max 
-51.650  -6.884   0.347   7.019  31.453 
```

```
Coefficients:
                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)             76.17801   20.38400   3.737 0.000332 ***
OrgLandfill            -10.77759   15.95923  -0.675 0.501263    
OrgNatRes               37.36893   47.70430   0.783 0.435552    
OrgRoadBridge           -3.04336   13.78633  -0.221 0.825803    
I(FMS_Percent_pre * 100)  -0.46110    0.11905  -3.873 0.000208 ***
BP_Systolic_pre         -0.02400    0.15513  -0.155 0.877408    
BP_Diastolic_pre        -0.24696    0.15970  -1.546 0.125623    
OrgHHS:Age              -0.29727    0.23379  -1.272 0.206925    
OrgLandfill:Age          0.05733    0.28889   0.198 0.843166    
OrgNatRes:Age           -1.13681    1.09723  -1.036 0.303039    
OrgRoadBridge:Age       -0.28074    0.19270  -1.457 0.148764    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 13.74 on 87 degrees of freedom
Multiple R-squared:  0.2327, Adjusted R-squared:  0.1445 
F-statistic: 2.639 on 10 and 87 DF,  p-value: 0.007417


Response BP_Systolic_dif :

Call:
lm(formula = BP_Systolic_dif ~ Org + Org:Age + I(FMS_Percent_pre * 
    100) + BP_Systolic_pre + BP_Diastolic_pre, data = dat_reg)

Residuals:
     Min       1Q   Median       3Q      Max 
-17.8445  -5.9644  -0.2914   5.3061  20.9946 

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)    
(Intercept)            77.11435   12.83782   6.007 4.29e-08 ***
OrgLandfill             0.41342   10.05110   0.041    0.967    
OrgNatRes               3.56996   30.04411   0.119    0.906    
OrgRoadBridge           9.43963    8.68261   1.087    0.280    
I(FMS_Percent_pre * 100)  0.02630    0.07498   0.351    0.727    
BP_Systolic_pre        -0.93601    0.09770  -9.581 2.91e-15 ***
BP_Diastolic_pre        0.49966    0.10058   4.968 3.35e-06 ***
OrgHHS:Age             -0.05668    0.14724  -0.385    0.701    
OrgLandfill:Age        -0.10269    0.18194  -0.564    0.574    
OrgNatRes:Age          -0.10387    0.69104  -0.150    0.881    
OrgRoadBridge:Age      -0.15133    0.12137  -1.247    0.216    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 8.652 on 87 degrees of freedom
Multiple R-squared:  0.5415, Adjusted R-squared:  0.4888 
F-statistic: 10.27 on 10 and 87 DF,  p-value: 3.216e-11


Response BP_Diastolic_dif :

Call:
lm(formula = BP_Diastolic_dif ~ Org + Org:Age + I(FMS_Percent_pre * 
    100) + BP_Systolic_pre + BP_Diastolic_pre, data = dat_reg)
```

```
Residuals:
     Min       1Q   Median       3Q      Max 
-13.7161  -4.0172   0.2243   3.1472  19.6732 

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)    
(Intercept)              28.99786    9.66534   3.000 0.003519 ** 
OrgLandfill              10.55224    7.56728   1.394 0.166730    
OrgNatRes                -7.57114   22.61962  -0.335 0.738645    
OrgRoadBridge            24.98050    6.53697   3.821 0.000249 ***
I(FMS_Percent_pre * 100)  0.03443    0.05645   0.610 0.543541    
BP_Systolic_pre           0.06598    0.07356   0.897 0.372162    
BP_Diastolic_pre         -0.67815    0.07572  -8.956 5.53e-14 ***
OrgHHS:Age                0.25084    0.11085   2.263 0.026135 *  
OrgLandfill:Age          -0.09385    0.13698  -0.685 0.495090    
OrgNatRes:Age             0.39545    0.52027   0.760 0.449256    
OrgRoadBridge:Age        -0.15155    0.09137  -1.659 0.100801    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.514 on 87 degrees of freedom
Multiple R-squared:  0.7307,	Adjusted R-squared:  0.6998 
F-statistic: 23.61 on 10 and 87 DF,  p-value: < 2.2e-16
```

```
> # post-hoc Holm corrections
> p <- c(0.000221, 0.002935, 2.2*10^-16, 2.2*10^-16, 0.091132,
+       0.007417, 3.216*10^-11, 2.2*10^-16)
> data.frame(vbl = c("Org", "FMS_Percent_pre", "BP_Systolic_pre",
+                    "BP_Diastolic_pre", "Org:Age", "FMS_Percent_dif",
+                    "BP_Systolic_dif", "BP_Diastolic_dif"),
+           p = p,
+           p.round = round(p, 3),
+           conf = round(1 - p, 3),
+           p.adj = p.adjust(p, method = "holm"),
+           p.adj.round = round(p.adjust(p, method = "holm"), 3),
+           c.adj = round(1 - p.adjust(p, method = "holm"), 3))
               vbl          p p.round  conf      p.adj p.adj.round c.adj
1              Org 2.2100e-04   0.000 1.000 8.8400e-04       0.001 0.999
2  FMS_Percent_pre 2.9350e-03   0.003 0.997 8.8050e-03       0.009 0.991
3  BP_Systolic_pre 2.2000e-16   0.000 1.000 1.7600e-15       0.000 1.000
4 BP_Diastolic_pre 2.2000e-16   0.000 1.000 1.7600e-15       0.000 1.000
5          Org:Age 9.1132e-02   0.091 0.909 9.1132e-02       0.091 0.909
6  FMS_Percent_dif 7.4170e-03   0.007 0.993 1.4834e-02       0.015 0.985
7  BP_Systolic_dif 3.2160e-11   0.000 1.000 1.6080e-10       0.000 1.000
8 BP_Diastolic_dif 2.2000e-16   0.000 1.000 1.7600e-15       0.000 1.000
```