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

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# 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$^{TM}$, 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$^{TM}$ 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$^{TM}$. Specifically, this analysis will examine whether the 12-week Rock Solid@Work$^{TM}$ functional core strengthening program increases movement competency and/or reduces blood pressure among participants.

# Description of Dataset

Data were measured across five organizations, both before participants began and after they completed the twelve-week program of FMS Correctives. One of the five organizations was divided into control (no FMS Correctives provided) and experimental (FMS Correctives provided) conditions with each condition's participants located at a different site. Trained on-site assessors, with multiple assessors per organization and different assessors at each organization, measured age, systolic blood pressure, diastolic blood pressure, and performance on a four-point scale (0 through 3) in six to twelve movement dimensions (depending on organization), including a total of all distinct FMS scores assessed. Participants who expressed pain during the FMS received scores of zero, were referred for medical consultation, and were removed from the FMS Correctives program or further measurement. Two of the five organizations' observations could be paired unambiguously across each participant's before and after measurements, measures from another two could be paired (in most cases) by a combination of last name and age, and one other organization's data were entirely unpaired. The organization that provided entirely unpaired data was the only to include the participant's work unit but included no blood pressure measurements. Pain self-assessments were available as well but rarely associated with the above measurements by more than organization.

For the purposes of this analysis, completion of the FMS Correctives program (identified below in the 'before' and 'after' conditions of the 'Observation' variable) will serve as the independent variable. Percentage movement competency, calculated as the total FMS score divided by the participant's maximum possible total score will form one dependent variable, comparable across organizations with varying FMS dimensions assessed. Systolic and diastolic blood pressure provide two additional dependent variables. Age and organization offer potential interaction or confounding factors.

Standardizing labels and combining data across multiple organizations, the provided FMS-related data are summarized below. For consistency and completeness, all FMS grand totals and maximum possible scores have been calculated based on provided formulas (the sum of each FMS activity final score and, respectively, the sum of each FMS activity final score if each activity scored by the organization had achieved the maximum score of 3). This particular approach effectively overlooks missing individual movement scores and treats missing summary ('Final') test scores as zero, as if pain had been reported and the participant had been removed from participation. One organization had documented dates instead of labeling observations as before or after the 12-week program, labeling one observation from each pair consistently for all pairs and the other with either one consistent date in the year 2012 or the same month and day in 2013. The client reports that this was an entry error, and all dates have been adjusted to reflect the year 2013, which is both more consistent with the order of entry in other provided data files and would represent a 15-week span, closer to the program's 12 weeks than the 37-week span indicated by the 2012 date.

| Observation | Organization | Control | Work_Unit |
|---|---|---|---|
| after :220 | HHS : 82 | FALSE:60 | operations : 94 |
| before:224 | Landfill : 50 | TRUE :22 | admin : 18 |
| | Mine :202 | NA's :362 | maintenance: 16 |
| | NatRes : 12 | | plant : 16 |
| | RoadBridge: 98 | | crusher : 15 |
| | | | (Other) : 25 |
| | | | :260 |

| | Age | BP_Systolic | BP_Diastolic | Deep_Squat | Hurdle_Right | Hurdle_Left |
|---|---|---|---|---|---|---|
| Min.   : | 0.00 | 100.0 | 48.00 | 0.000 | 0.000 | 0.000 |
| 1st Qu.: | 34.00 | 120.0 | 72.00 | 2.000 | 1.000 | 1.000 |
| Median : | 44.00 | 126.5 | 80.00 | 2.000 | 2.000 | 2.000 |
| Mean   : | 42.83 | 127.3 | 78.69 | 1.864 | 1.875 | 1.846 |
| 3rd Qu.: | 52.00 | 134.0 | 84.00 | 2.000 | 2.000 | 2.000 |
| Max.   : | 75.00 | 176.0 | 115.00 | 3.000 | 3.000 | 3.000 |
| NA's   : | 108 | 210 | 210 | 84 | 3 | 3 |

| | Hurdle_Final | Lunge_Right | Lunge_Left | Lunge_Final | Shoulder_Clearing |
|---|---|---|---|---|---|
| Min.   : | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| 1st Qu.: | 1.000 | 2.000 | 2.000 | 1.000 | 1.000 |
| Median : | 2.000 | 2.000 | 2.000 | 2.000 | 1.000 |
| Mean   : | 1.738 | 2.006 | 2.025 | 1.903 | 1.000 |
| 3rd Qu.: | 2.000 | 3.000 | 3.000 | 2.000 | 1.000 |
| Max.   : | 4.000 | 3.000 | 3.000 | 3.000 | 1.000 |
| NA's   : | 1 | 84 | 84 | 84 | 432 |

| | Shoulder_Right | Shoulder_Left | Shoulder_Final | FMS_Total | FMS_Max |
|---|---|---|---|---|---|
| Min.   : | 0.000 | 0.000 | 0.000 | 0.000 | 6.000 |
| 1st Qu.: | 1.000 | 1.000 | 1.000 | 4.000 | 9.000 |
| Median : | 2.000 | 2.000 | 1.000 | 6.000 | 9.000 |
| Mean   : | 1.807 | 1.576 | 1.546 | 5.624 | 9.527 |
| 3rd Qu.: | 3.000 | 2.000 | 2.000 | 7.000 | 12.000 |
| Max.   : | 3.000 | 3.000 | 3.000 | 12.000 | 12.000 |
| NA's   : | 206 | 206 | 204 | | |

Data without an identifiable before and after paired observation (226 records) will be excluded from the study. This should have a minimal impact on bias for two reasons. First, most unpaired observations belong to a single, complete organization that began its pilot, apparently, before a clear need to identify paired observations was identified; this makes their removal largely unsystematic and comparable to the observational choice to collect data from any one organization instead of another. Second, excluding participants who were observed either at the beginning or at the end of the 12-week program--and not at both times--should be little different from the impact of program policy that excludes participants from participation if they report pain during the FMS. As such, the omission should not introduce a meaningful level of additional systematic bias. For paired records missing blood pressure measurements (6 records, paired), blood pressure values will be imputed using random forests in order to minimize bias and maximize the available data. Unless analyzing control-versus-experimental performance specifically, analysis will omit all control-group observations (11 records, paired). Age should differ by one year or less between before and after measurements of the 12-week program; therefore, this analysis will use only the lesser of a participant's available ages for any analyses involving age, treating values of zero as missing and imputing any remaining missing age values using random forests.

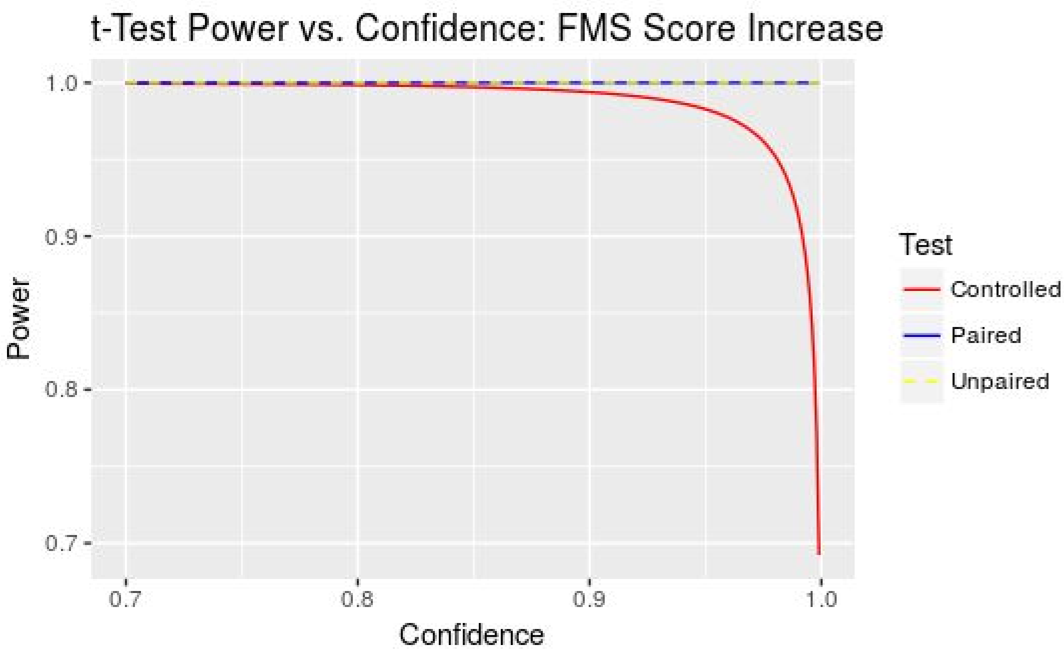
# Proposed Analyses

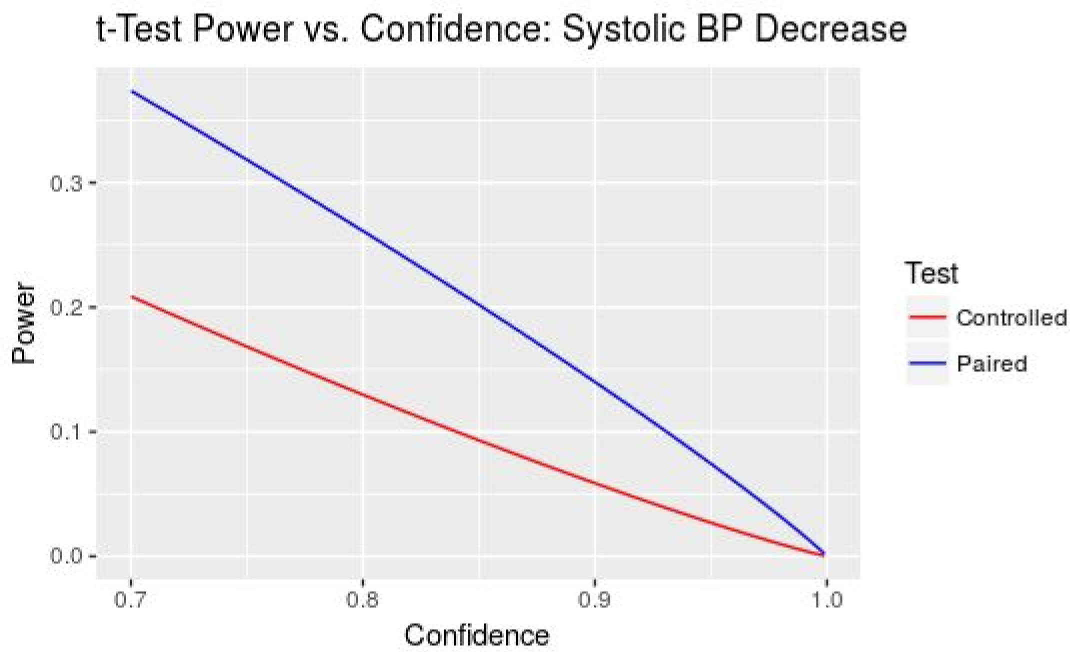
Analysis will use all paired and readily pairable treatment data, discarding unpaired and control observations, to address the research questions. Tools such as quantile-quantile plots and F-tests will help determine whether the available data meet the standard assumptions of normality and equal variance required for parametric tests. Depending on the assumptions met, analysis will continue with one-sided, paired-difference t-tests (for normal, equal-variance data), Welch's t-tests (for normal, unequal-variance data), or Wilcoxon signed-rank tests (for non-normal data) as appropriate. Both uncorrected p-values and significance values corrected to mitigate false discovery rate (FDR) will be provided.

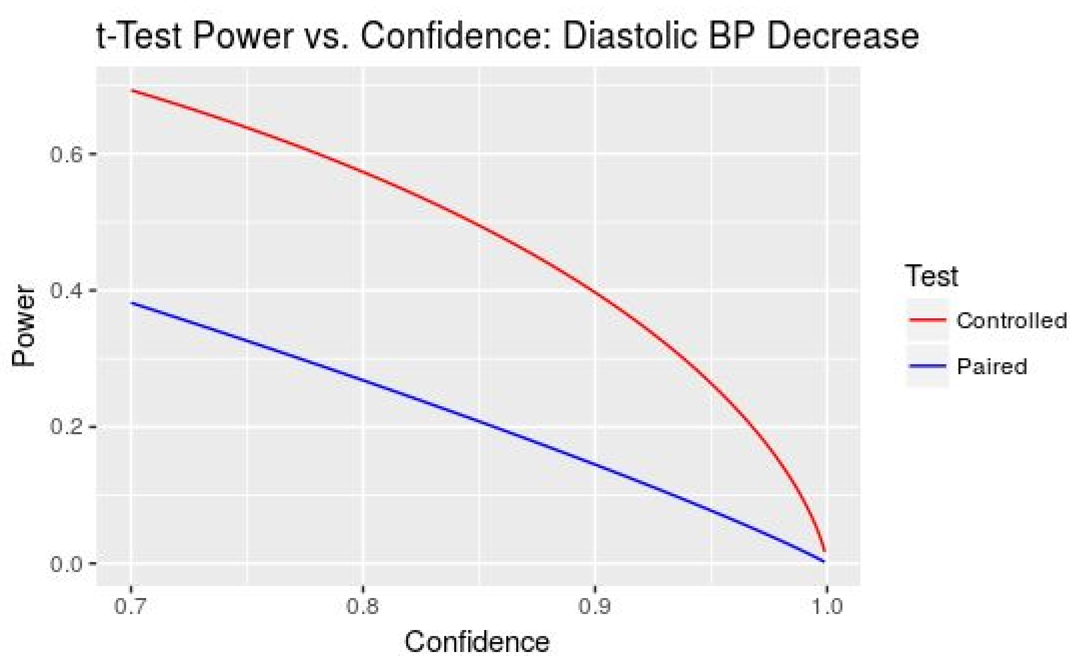
Analysis will continue by assessing potential interrelationships among available variables. Pearson (for normal data without outliers apparent in scatterplots) or Kendall (otherwise) correlation coefficients will assess the strength of any relationships among differences between before and after FMS score percentages, before and after systolic BP, and before and after diastolic BP with FDR-corrected significance tested using two-tailed t or tau tests, respectively. Regression will follow, and the type of regression used will depend on the results of several potential tests of assumptions: scatterplots by factor (for parallelism); adjusted quantile plots using Mahalanobis distances (for absence of outliers); quantile-quantile plots and multiple Shapiro-Wilk test (for univariate and multivariate normality), Bartlett or Fligner tests (for variance homogeneity); Box's M (for variance-covariance homogeneity). Met assumptions will dictate whether multivariate linear regression and multivariate analysis of covariance (MANCOVA with Wilks' test of significance), multiple linear regression and analysis of variance (ANOVA with F-test), or spline regression attempts to determine whether the participant's organization or age impacts how dependent variables change with FMS correctives.

# Justification

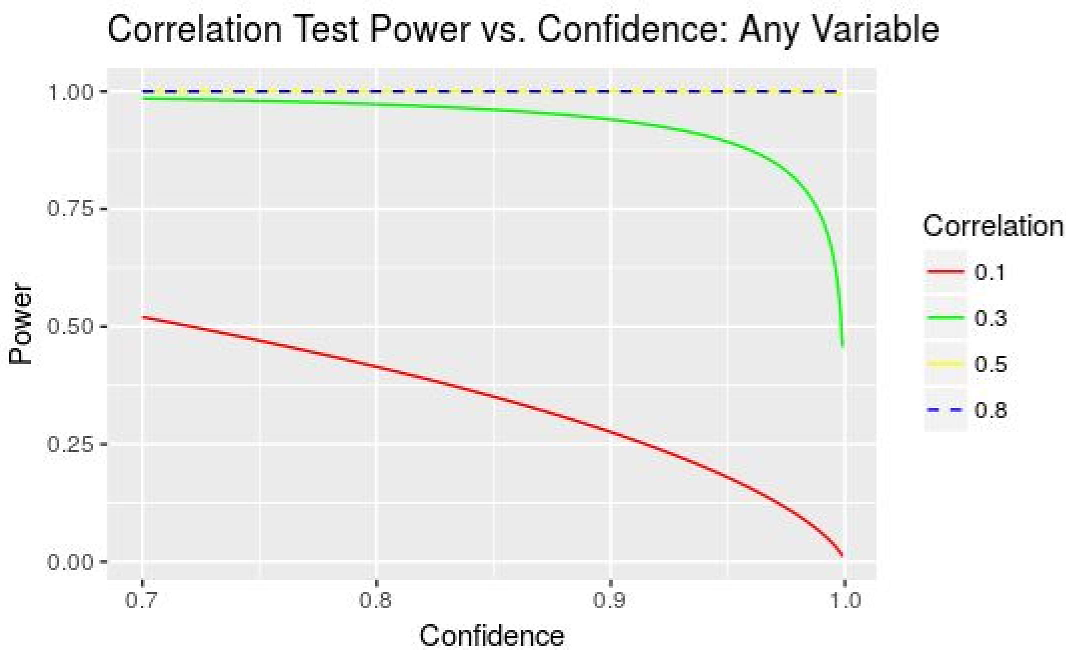
Using only paired observations, while reducing the test's sample size, effectively controls for most impact from any confounding factors--such as weight or gender--that tend to remain consistent for one individual over 12 weeks, including the captured variables of age and work unit. This approach should not hurt the power of the analysis because, as indicated by the power calculations graphed below, the FMS data's properties should enable the planned tests to reach near-100% power and confidence with either paired or unpaired data and because blood pressure data only exist for paired data sets. Comparative power analyses do not show consistent advantages for testing performance against the small set of control-group data, so controlled tests will not be applied. Because the client expressed interest primarily in identifying the level of confidence with which Rock Solid@Work™'s program of FMS correctives can be said to improve outcomes rather than the degree to which outcomes improve with the program, tests of difference will serve the primary analysis goals effectively without necessitating more-complex models. All tests can apply confidence efficiently using one-sided alternative hypotheses because the client is concerned only with demonstrating improvements in performance (positive difference in FMS or negative difference in BP after FMS Correctives). Because analysis will involve three pairwise tests, significance adjustments will mitigate the potential for false discoveries due to chance; however, raw p-values will be made available due to the client's specific interest in confidence.

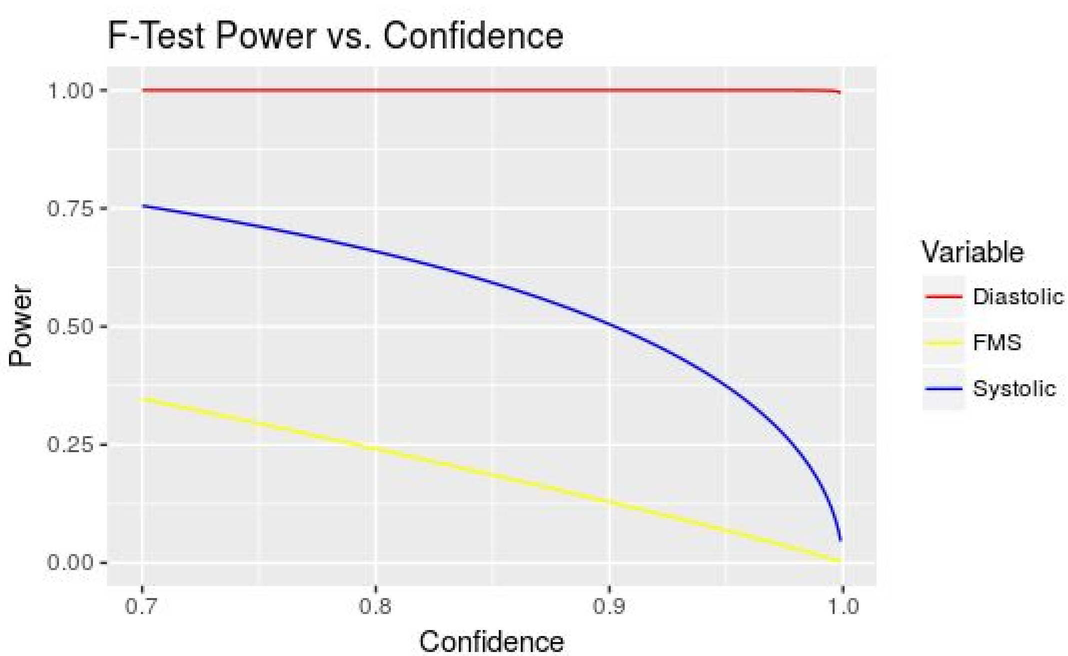





Follow-up testing has value because it can identify potential relationships among dependent variables, such as if people who experience FMS improvements also tend to improve their BP, and helps determine, specifically, if different ages or organizations experienced different outcomes after FMS correctives. Tests of correlation that use paired-difference metrics have many advantages and disadvantages in common with the tests of difference described above; however, this analysis will test simultaneously for positive or negative correlation. In this case, correlation tests should be very effective at identifying strong correlations yet largely ineffective at identifying weak correlations with high confidence. Assessing correlation has the advantage of helping prepare for the planned regression analysis, which increases complexity in order to explore multiple potential interrelationships among variables. Regression, additionally, may identify post-hoc inquiries to explore during this or future analysis.



# Expected Outcomes

Based on theory behind the FMS and the diaphragmatic breath exercises that Rock Solid@Work™ incorporates in its program of FMS Correctives, the client anticipates improvements in both movement competency and blood pressure after participants complete the 12-week functional core strengthening program. Preliminary power analyses suggest that the study stands a substantial chance of detecting a significant increase in FMS if it is present; however, it is unlikely that this analysis will detect a decrease in either systolic or diastolic BP with reasonable confidence. Because theory suggests that all dependent variables will improve, it seems reasonable to expect at least weak negative correlation between change in FMS and change in each BP metric as well as at least weak positive correlation between changes in systolic and diastolic BP, and this analysis is highly likely to detect such associations if they are strong. Regression outcomes have not been predicted; however, any covariate relationships related to changes in diastolic BP are likely to be identified. Although the observational nature of the data collected will limit the ability to generalize results to organizations unlike those observed, paired tests supported by regression analysis will reduce the influence of potential confounding factors and provide reasonable estimates of the confidence with which 3:1 Corporate Health and Productivity Management Solutions can claim Rock Solid@Work™ achieves improvements in movement competency and blood pressure.

# References


1. Perry, Fraser T. and Michael S. Koehle. Normative Data for the Functional Movement Screen in Middle-Aged Adults. *The Journal of Strength and Conditioning Research* 27 (2): 458-462, 2013.
2. Sharma, M., WH Frishman, KL Gandhi. RESPeRATE: Nonpharmacological Treatment of Hypertension. *Cardiol Review* 19 (2): 47-51, 2011.