LAB REPORT

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Introduction:

Powerlifting is a sport that involves three attempts to lift the maximum weight over three kinds of lifts squats, bench and deadlift. So, competitors try to lift as maximum weight as possible. In powerlifting competitions, equipped or unequipped (refers to raw or classic) lifts maybe performed. Equipment can be supportive suits, shirts and knee or wrist wraps made of materials that store elastic potential energy and thus provide help with the lifts. This supportive equipment can be made from different types of materials. Single-ply equipment made of one layer of material while muti-ply made of two or more layers. Comparison of lifters can be made using different world federations such as wilks score which is set by international powerlifting federation. Three variables are used to calculate wilks score: Body weight, weight lifted, and gender.

In powerlifting challenge, three attempts on each of the squat, bench press and deadlift are given for each competitor. The best valid attempt on each lift counts toward the competition total. The competitor with the highest total wins. If two or more competitors have the same total, the lifter with less weight ranks above the lifter with more weight. Powerlifting data set has 17 variables and 4900 observations. These variables can be described below:

1. ID: Participant ID.
2. Sex: is a categorical (2 levels) Sex: M = Male, F = Female.
3. AverageTime: Assume to be continuous and it represents average time (minutes) per training session.
4. Equipment: is a categorical (4 levels) that represents hand covering type which can be raw, single-ply, multi-ply and wrap.
5. Age: Assume to be continuous and it represents competitors age in years.
6. Schedule: is a categorical (2 levels) that means Whether someone trains in the morning or at night.
7. LiquidConsumed: Assume to be continuous and it represents the average liquid consumed (ml) by each competitor per training session.
8. GymCost: Assume to be continuous and it represents the monthly amount paid (£) by each competitor for all gym costs (including membership, products etc).
9. BodyweightKg: Assume to be continuous and it represents the bodyweight in kilograms.
10. BestSquatKg: Assume to continuous A competitor's best squat in kilograms
11. BestBenchKg Assume to be continuous and it represents the competitor's best bench press in kilograms.
12. BestDeadliftKg: Assume to be continuous and it represents the competitor's best deadlift in kilograms.
13. TotalKg: Assume to be continuous and it represents the total amount for a competitor's combined squat, bench and deadlift in kilograms.
14. Wilks: Assume to be continuous and it represents Wilks score (strength adjusted for body mass).
15. Winner: is a categorical (2 levels) and it means Whether a competitor won their last event: Y = Yes, N = No.
16. Displacement: Assume to be continuous and it represents the Distance (cm) during an additional challenge that a competitor was able to push a weighted object from
17. its starting location (can be positive or negative depending which direction it was pushed).
18. Group : is a categorical (10 levels) and it means Which group of judges a competitor was assigned (ranges from A-J).

In this report, the main questions were addressed:

- Whether there is a difference between the average total amount a competitor lifts and their sex.
- Whether there is a difference between the average total amount a competitor lifts and their choice of equipment.
- Regression model to predict the Wilks variable using all the given variables except the participant ID and the winner.
- Regression model to predict the Winner variable using all the given variables except the participant ID and the Wilks.
- Regression model to predict the Winner variable using only Wilks variable.
- Compare the above two last models and decide which one is better to predict the powerlifiting competition winner.

Exploratory Analysis

Univariate Exploration

- Table 1 shows the first 5 observations of powerlifting data. From these observations, many missing values for different variables can be noticed.
- Table 2 shows that the exact number of missing values and more descriptive statistics. 62.6% of Age is missing values. The missing values of other variables range from 0.05% to 22.89%. Also*, bestsquatkg, bestdeadliftkg* and *bestbenchkg* have negative minimum values which is not realistic and most probably the negative sign was incorrectly typed. By exploring the data more, 18 of the *bestbenchKg*, 13 of the *bestsquatKg* and 4 of the *bestdeadliftKg* are negative values. *Displacement* can be positive or negative depending on the pushing direction. As the direction is not important in our analysis, the absolute value of the displacement will be used instead.
- Table 3 shows categorical variables frequency table. *Schedule* frequency table. 64.8% of the competitors train in the morning while 35.18% of them in the evening. 6.4% of the *winner* variable are missing values. Given the available *winner* data, 53.79% of the competitor's won their last event while 46.2% didn't win. Female competitors represent less than a quarter of all competitors, so most competitors are male. 3.87% of the *group* variable are missing values. About 48% of the competitors were assigned to group J of judges given the available group variable. Less the 40% of the competitors were assigned to group B and C. The rest of the competitors were distributed between the 6 groups A, E, F, G, H and I. Most of competitors didn't use any hand cover, while 38% used single-ply, 11.5% used wraps and just 2.24% used multi-ply.

Multivariate Exploration

Table 4 shows the correlation between numerical variables. High correlation between *bestsquatkg*, *bestbecnhkg* and *bestdeadliftkg*. Also, high correlation between *totalkg* and *bestsquatkg*, *bestdeadliftkg* and *wilks* score. Moreover, the correlation between the bodyweightkg and best lift (squat, bench and deadlift) is moderately high. The relationship between *wilks* score and all numerical variables can be seen in Figure 1. Most of the variables have normal distribution except the AverageTime, LiquidConsumed and Gymcost.

Figure 2 and Figure 3 shows the distribution of the total amount of competitors lifts by sex and equipment respectively. From the two figures it can be noticed that totalkg has some outliers. Also, the distribution of *wilks* score by *sex, winner, schedule, equipment* and *group* is represented in Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8. It can be noticed that *wilks* score has some outliers.

Data Manipulation:

- To maximise the use of available information, and minimize the bias, the missing values for the variable *age* which comprises more than 60% of the total observations, are imputed. The missing values for *age* variable are replaced with its overall estimated mean. This imputing method is very simple and easily implemented. But it artificially reduces the variability and changes the correlations between the imputed variables and other variables.
- The *group* variable has too many levels, so the number of levels can be reduced. As most of the competitors are assigned to groups J, B, and C of judges, the rest of the levels are grouped together using thresholding method as shown in Table 5.
- As Female competitors represent less than a quarter of all competitors, oversampling is used to adjust data such that certain ratio between the levels of *sex* variable.
- Transforming the *age* variable from continuous to categorical variable as shown in Table 5 with three levels less than 30, from 30 to 40 and more than 40.
- Hoeffding's D and Spearman Statistics are applied to check for non-linearities and possible irrelevant variables for the variable wilks score. There is no evidence of non-linearities as there is no low Spearman and high Hoeffding for same coefficient as presented in Figure 9. From Table 6, AverageTime, GymCost and LiquidConsumed have small coefficients so they are irrelevant.

Formal Analysis

1- Whether there is a difference between the average total amount a competitor lifts and their sex.

Oversampling is used to adjust the imbalanced data and have equal ratio between males and females. A two-sample t-test is used to Compare the average total amount competitor lifts based on whether competitor is male or female. The null hypothesis states that the difference between the average total amount competitor lifts for male and female is zero. From the results in Figure 10, two methods are used to get the difference between the male and female average *totalkg*, Pooled and Satterthwaite. First the validity of the modelling assumptions is checked:

- From our study design and since the dataset contains records for different competitors, the independence assumption between all the observations is valid. The independence between male and female groups assumption is also valid.
- Based on the histogram and the Q-Q plot, the normality assumption appears reasonable.
- From the equality of variances table and the result of the F-test, the groups equal variances assumption can be checked. The null hypothesis states that the variance is the same for both male and female groups. With 5% significance level, the null hypothesis of equal variances is rejected (p-value < 0.001).

The Pooled method conclusion can't be used because it compares the mean for populations in which the variance should be the same for each group. In this case, Satterthwaite method can be used as it compares the mean for populations with different groups variances. With 5% significance level, there is enough evidence to reject the null hypothesis (p-value <0.001) that the difference between the average total amount competitor lifts for males and females is zero.

In other words, there is difference between the total amount competitor lifts for male and female. For Pooled and Satterthwaite methods, the confidence interval plot for the difference between the two population means confirms our result as it doesn't contain zero. Also, from the result plot, the average total amount competitor lifts for males is higher than female.

2- Whether there is a difference between the average total amount a competitor lifts and their choice of equipment.

One-way Analysis of variance (ANOVA) is used to compare the average total amount competitors lift based on their choice of equipment. The null hypothesis states that the average total amount competitor lifts are equal depending on the competitor's choice of equipment.
From the results Figure 11, with a significance level of 5%, there is enough evidence to reject the null hypothesis that the average total amount competitor lifts are the same across different competitor's equipment choices (p-value <0.0001).
For our conclusion to be valid, modelling assumptions must be checked:

- From our study design and since the dataset contains records for different competitors, the independence assumption between all the observations is valid.

- From diagnostics plots in Figure 11, the assumption of the normally distributed errors seems valid as the residual histogram shows a bell-shaped distribution and most of the points of the residuals QQ plot lie in a diagonal line.

- Levene's test is conducted to check if Equipment groups have equal variances. By looking at the result in Figure 11, with a significance level of 5%, the null hypothesis of equal variances is rejected (F=31.24, p-value < 0.0001).

As the assumption of groups equal variances is rejected, Welch's variance-weighted one-way ANOVA test can be used instead of Levene's test. With a significance level of 5%, there is enough evidence to reject the null hypothesis that the average total amount competitor lifts are the same across different competitor's equipment choices (p-value <0.0001). T-tests is used between pairs of levels to check for statistical difference without adjusted p-values and with Tukey's HSD adjusted p-values. From Figure 12 results, the average total amount competitor lifts is statistically different between all equipment levels, with the exception of multi-ply and wraps, for both adjusted and not adjusted p-value.

3- Regression model to predict the Wilks variable using all the given variables except the participant ID and the winner.

As there are number of categorical variables as well as continuous variables, linear model Analysis of covariance (ANCOVA) is used. As there is high correlation between many variables, multicollinearity must be checked. To check multicollinearity, variance inflation factor (VIF), tolerance and condition index (CI) are calculated as shown in Figure 13. For VIF more than 10, tolerance less than 0.1 are indicators for multicollinearity. To avoid multicollinearity, increase of computation time and chance of overfitting, competitor's best squat and Competitor's best deadlift are deleted from the explanatory variables.
Also, Average time, Gym cost, body weight and Liquid consumed are excluded because they are irrelevant as stated before. *Age* is used as a categorical variable with three

levels as mentioned before. Also, the number of levels of equipment variable is reduced to two levels Raw and Equipped (Multi-ply, Single-ply and Wraps).
To select which predictors are significant, forward selection method and Schwarz's Bayesian Information criterion (SBC) are used. As shown in Figure 14, *wilks* score is significantly different depending on whether the *sex* is male or female, the group of *age* the competitor in, the *group* of judges competitor was assigned to, the total amount the competitor lifts (squat and deadlift) and competitor's weight. For our conclusion to be valid, modelling assumptions must be checked:

- From diagnostics plot, Hence the normality assumption seems to hold as the residual histogram shows a bell-shaped distribution and the QQ plot points lie in a diagonal line except from some outliers.
- From our study design and since the dataset contains records for different competitors, the independence assumption between all the observations is valid.
- The residuals vs fitted values plot shows a pattern, so the assumption of constant variance (Homoscedasticity) is not valid.

By transforming the dependent variable *wilks* score and the independent variables *bodyweightkg, bestsquatkg, bestdeadliftkg, bestbenchkg* and *totalkg* to their natural log, the error variance variability can be solved.

By using forward selection method and Schwarz's Bayesian Information criterion (SBC), the natural log of *Wilks* score is significantly different depending on whether the sex is male or female, competitor using hand cover or no, the *group* of judges competitor was assigned to, the natural log of the total amount the competitor lifts, natural log of competitor's weight and the natural log of competitor best bench press (Figure 15). In Figure 15, several plots show the behaviour of different criteria and the progression of average squared errors throughout the selection process. The averaged squared error is lowest for the final iteration of the process, which means it's the best model.
For our conclusion to be valid, modelling assumptions must be checked. By looking at the diagnostics plot, the residual histogram shows slightly skewed bell-shaped distribution and the QQ plot points lie in a diagonal line except from some outliers. Hence the normality assumption is dubiously hold. Moreover, from our study design and since the dataset contains records for different competitors, the independence assumption between all the observations is valid. The assumption of constant variance (Homoscedasticity) is almost valid.

4- Regression model to predict the Winner variable using all the given variables except the participant ID and the Wilks.

As the dependent variable winner is a binary categorical variable, logistic regression model is used. Forward selection method with significance level of 0.1 is used. All predictors are included in the selection process except for Competitor's best squat and Competitor's best deadlift as they are highly correlated with the total amount competitor lifts.

From the results in Figure 16, the final model has converged. From the analysis of maximum likelihood estimates, with significance level of 10%, the odds of being a winner or not is affected by competitor sex, using hand cover or not, the judges group the competitor was assigned to, competitor's best bench press, competitor's age and the total amount competitor lifts. The first plot shows the odds ratio estimates with a

95% confidence interval. The confidence interval for the odds of being assigned to one of the other groups (combined by thresholding A, E, F, G, H and I) vs assigned to group C contains 1, which indicates that there is no significance difference for that ratio. The second plot compares the predicted probabilities for being winning based on different levels of our explanatory variables. It shows the probability of winning changes by best competitor's bench press and different combinations of sex variable levels and equipment variable levels.

For our conclusion to be valid, modelling assumptions must be checked. From our study design and since the dataset contains records for different competitors, the independence assumption between all the observations is valid. There is no high correlation between independent variables to avoid collinearity. The assumption of large sample size is valid. The assumption of Linear relationships between independent variables and their log odds (Box-Tidwell) can be checked by adding interaction term, cross product of each independent variable times its natural logarithm to the logistic model. If the interaction terms are significant then there is nonlinearity in the logit. The total amount competitor lifts interaction term is significant, so the linear relationship assumption is dubious. To meet the linearity assumption, the total amount competitor lift variable must be replaced by its natural log. By dividing the data to training data 70% and test data 30%, the model performance can be assessed. From Figure 17, it shows the ROC curve which scored using the test data. The area under the curve is 0.7353 indicating that the model generalizes to the test data just fine (acceptable).

5- Regression model to predict the Winner variable using only Wilks variable and compare with previous model.

As the dependent variable winner is a binary categorical variable, logistic regression model is used. From the results in Figure 18, the final model has converged. From the analysis of maximum likelihood estimates, with significance level of 5%, the odds of being a *winner* or not is affected by *wilks* score. The first plot shows the odds ratio estimates with a 95% confidence interval. The second plot shows the probability of winning changes by *wilks* score, which indicates a negative relationship between the probability of winning and *wilks* score value.
For our conclusion to be valid, modelling assumptions must be checked. From our study design and since the dataset contains records for different competitors, the independence assumption between all the observations is valid. The assumption of large sample size is valid. By checking the assumption of Linear relationships between independent variables and their log odds, the wilks interaction term is significant so the assumption is dubious. To meet the linearity assumption, the wilks score variable must be replaced by its natural log.
By comparing the two models in Figure 19, there is difference between the area under the curves (AUROCs). In addition, the chi-squared test rejects the null hypothesis that the two ROC curves are the same. There is evidence that the complex model is a better fit to the data than the simple model. When AUC is 0.5, model can't distinguish between 1's and 0's (no discrimination), while when it is 0.7, it means there is 70% chance that model will distinguish between 1's and 0's. Comparing the two models AIC, the complex model has better AIC than the simple mode. Although, there is high cost for having all the independent variables, but the complex model is more preferable.

Conclusion

Oversampling results in balanced data which doesn't have any benefit for our models. So, imbalanced data is not a problem for regression models.

By Using a two-sample t-test, there is enough evidence that the difference between the total amount competitor lifts for male and female is not zero. Also, the average total amount competitor lifts for males is higher than female.

The total amount competitor lifts is statistically different between all equipment levels, with the exception of multi-ply and wraps.

The natural log of wilks score is significantly different depending on whether the sex is male or female, competitor using hand cover or no, the group of judges competitor was assigned to, the natural log of the total amount competitor lifts, the natural log of competitor's weight and the natural log of competitor best bench press.

The odds of being a winner or not is affected by competitor sex, using hand cover or not, the judges group the competitor was assigned to, competitor's best bench press, competitor's age and the total amount competitor lifts.

Comparing the resulted complex model with a simple model(only wilks as explanatory), the complex model is better as it has 70% change to distinguish between being a winner or not. While the simple model has no discriminatory ability to distinguish between being winner or not.

Table 1:First 5 Observations of Data

Obs	ID	Sex	AverageTime	Equipment	Age	Schedule	LiquidConsumed	GymCost	BodyweightKg	BestSquatKg	BestBenchKg	BestDeadliftKg	TotalKg	Wilks	Winner	Displacement	Group
1	1	M	69	Single-ply	31	Morning	2200	12.74	105	280	.	.	.	.		.	J
2	2	M	29	Multi-ply	57	Morning	500	55.05	109.1	.	.	.	.	.		.	J
3	3	M	55	Multi-ply	50	Morning	2300	39.25	88	272.5	.	.	.	.		.	J
4	4	M	89	Raw	45	Morning	560	12.27	96.5	.	.	.	.	.		.	J
5	5	M	80	Wraps	23	Night	3700	23.42	86.6	.	.	.	.	.		.	J

Table 2:Numerical variables Statistical Summary

Variable	N Miss	N	Minimum	Maximum	Mean	Std Dev
ID	0	4900	1.0000000	4900.00	2450.50	1414.65
AverageTime	0	4900	18.0000000	90.0000000	54.5002041	20.7597431
Age	3068	1832	9.5000000	84.5000000	31.8084061	12.9877321
LiquidConsumed	0	4900	200.0000000	4000.00	2106.09	1088.37
GymCost	0	4900	6.0100000	60.0000000	33.1867367	15.6885170
BodyweightKg	25	4875	25.4000000	197.6300000	86.9895881	23.1940769
BestSquatKg	1122	3778	-375.0000000	444.5200000	175.3020487	67.9675116
BestBenchKg	357	4543	-327.5000000	381.0200000	118.2484768	53.9556623
BestDeadliftKg	863	4037	-327.5000000	410.0000000	194.2284989	60.3751090
TotalKg	296	4604	27.2200000	1077.50	423.1623132	194.1788582
Wilks	306	4594	21.5200000	629.3500000	300.6032490	114.6128358
Displacement	306	4594	-1005.73	923.6086849	1.9028938	327.9368216

Table 3:Categorical Variables Frequency Table

The FREQ Procedure

Schedule	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Morning	3176	64.82	3176	64.82
Night	1724	35.18	4900	100.00

Winner	Frequency	Percent	Cumulative Frequency	Cumulative Percent
N	2119	46.21	2119	46.21
Y	2467	53.79	4586	100.00
Frequency Missing = 314				

Sex	Frequency	Percent	Cumulative Frequency	Cumulative Percent
F	1127	23.00	1127	23.00
M	3773	77.00	4900	100.00

Group	Frequency	Percent	Cumulative Frequency	Cumulative Percent
A	366	7.77	366	7.77
B	776	16.48	1142	24.25
C	882	18.73	2024	42.97
E	70	1.49	2094	44.46
F	94	2.00	2188	46.45
G	80	1.70	2268	48.15
H	64	1.36	2332	49.51
I	98	2.08	2430	51.59
J	2280	48.41	4710	100.00
Frequency Missing = 190				

Equipment	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Multi-ply	110	2.24	110	2.24
Raw	2331	47.57	2441	49.82
Single-ply	1894	38.65	4335	88.47
Wraps	565	11.53	4900	100.00

Table 4:Correlation

11 Variables:	AverageTime Age LiquidConsumed GymCost BodyweightKg BestSquatKg BestBenchKg BestDeadliftKg TotalKg Wilks Displacement

Pearson Correlation Coefficients Number of Observations											
	AverageTime	**Age**	**LiquidConsumed**	**GymCost**	**BodyweightKg**	**BestSquatKg**	**BestBenchKg**	**BestDeadliftKg**	**TotalKg**	**Wilks**	**Displacement**
AverageTime	1.00000 4900	-0.00731 1832	-0.00977 4900	-0.02540 4900	0.00647 4875	-0.00235 3778	0.00651 4543	0.00641 4037	-0.00489 4604	-0.00818 4594	0.00800 4594
Age	-0.00731 1832	1.00000 1832	0.03214 1832	-0.00095 1832	0.12880 1832	-0.02438 1407	0.07194 1669	-0.03645 1551	-0.16813 1737	-0.23460 1737	0.01878 1737
LiquidConsumed	-0.00977 4900	0.03214 1832	1.00000 4900	-0.00553 4900	-0.00346 4875	0.01957 3778	0.01957 4543	0.02392 4037	0.01970 4604	0.01631 4594	0.00017 4594
GymCost	-0.02540 4900	-0.00095 1832	-0.00553 4900	1.00000 4900	-0.02425 4875	-0.03384 3778	-0.01795 4543	-0.02881 4037	-0.01309 4604	0.00059 4594	0.01456 4594
BodyweightKg	0.00647 4875	0.12880 1832	-0.00346 4875	-0.02425 4875	1.00000 4875	0.63214 3773	0.63372 4534	0.59381 4031	0.41835 4594	0.03654 4594	0.00444 4594
BestSquatKg	-0.00235 3778	-0.02438 1407	0.01957 3778	-0.03384 3778	0.63214 3773	1.00000 3778	0.89107 3709	0.90076 3685	0.96842 3651	0.76603 3646	0.01391 3646
BestBenchKg	0.00651 4543	0.07194 1669	0.01957 4543	-0.01795 4543	0.63372 4534	0.89107 3709	1.00000 4543	0.86392 3847	0.53637 4437	0.23204 4428	0.01601 4428
BestDeadliftKg	0.00641 4037	-0.03645 1551	0.02392 4037	-0.02881 4037	0.59381 4031	0.90076 3685	0.86392 3847	1.00000 4037	0.87563 3960	0.62574 3954	0.00598 3954
TotalKg	-0.00489 4604	-0.16813 1737	0.01970 4604	-0.01309 4604	0.41835 4594	0.96842 3651	0.53637 4437	0.87563 3960	1.00000 4604	0.87326 4594	0.00508 4594
Wilks	-0.00818 4594	-0.23460 1737	0.01631 4594	0.00059 4594	0.03654 4594	0.76603 3646	0.23204 4428	0.62574 3954	0.87326 4594	1.00000 4594	-0.00205 4594
Displacement	0.00800 4594	0.01878 1737	0.00017 4594	0.01456 4594	0.00444 4594	0.01391 3646	0.01601 4428	0.00598 3954	0.00508 4594	-0.00205 4594	1.00000 4594

Table 5:Groupthresh and age_comb frequency Table

groupthresh	Frequency	Percent	Cumulative Frequency	Cumulative Percent
B	776	16.48	776	16.48
C	882	18.73	1658	35.20
J	2280	48.41	3938	83.61
others	772	16.39	4710	100.00
Frequency Missing = 190				

age_comb	Frequency	Percent	Cumulative Frequency	Cumulative Percent
30-40	3486	71.14	3486	71.14
<30	992	20.24	4478	91.39
>40	422	8.61	4900	100.00

Table 6: Hoeffding's D and Spearman Statistics

Obs	Variable	ranksp	rankho	scoef	spvalue	hcoef	hpvalue
1	Age	5	5	-0.15910	<.0001	0.01354	<.0001
2	AverageTime	2	3	-0.00829	0.5744	-0.00006	0.6834
3	BestBenchKg	6	6	0.35036	<.0001	0.07479	<.0001
4	BestDeadliftKg	8	8	0.64582	<.0001	0.18519	<.0001
5	BestSquatKg	9	9	0.74136	<.0001	0.22669	<.0001
6	BodyweightKg	4	4	0.05810	<.0001	0.00229	<.0001
7	GymCost	1	1	-0.00038	0.9794	-0.00001	0.4293
8	LiquidConsumed	3	2	0.01626	0.2706	0.00002	0.2795
9	TotalKg	10	10	0.86104	<.0001	0.37818	<.0001
10	abs_displacement	7	7	0.54104	<.0001	0.11092	<.0001

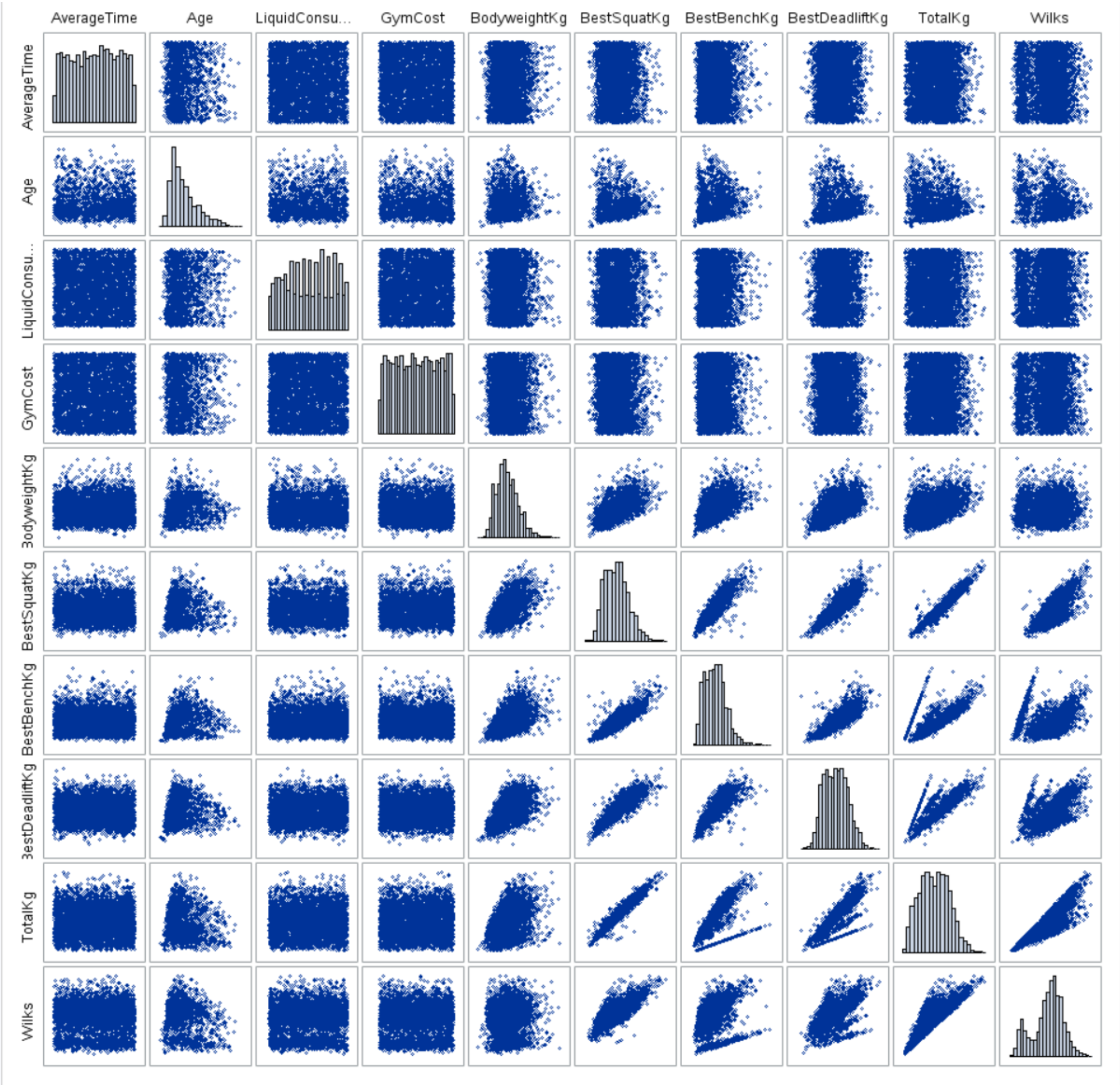


Figure 1:Scatter Plot Matrix

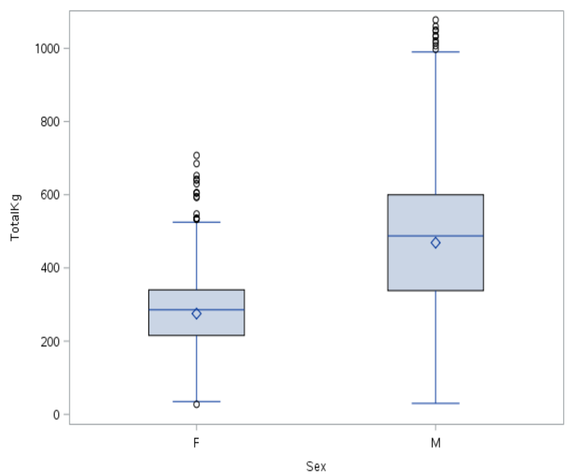


Figure 2:Total amount competitor lifts distribution by sex

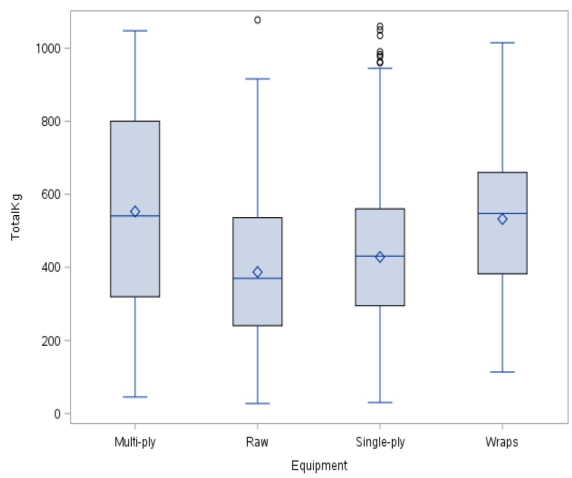


Figure 3:Total amount competitor lifts distribution by equipment

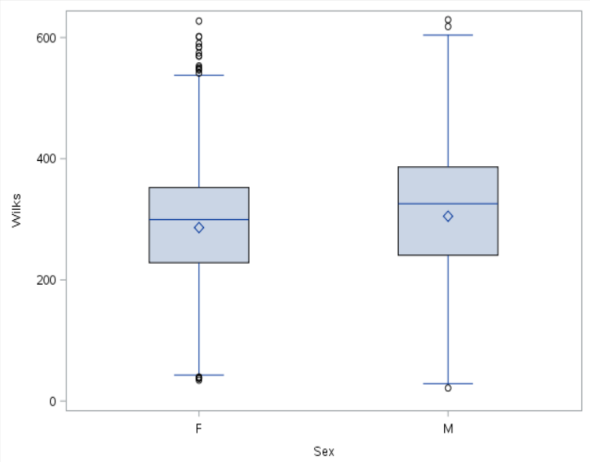


Figure 4:Wilks Score Distribution by Sex

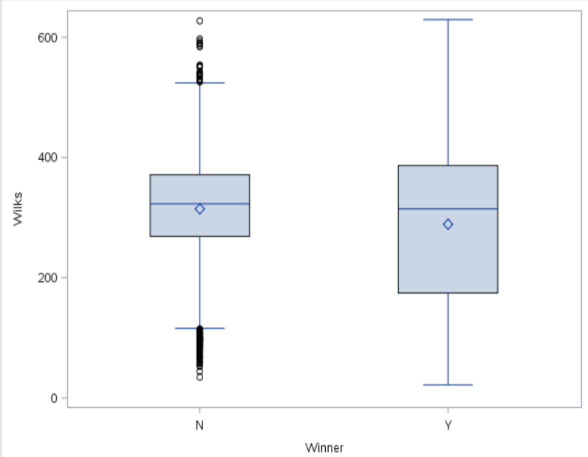


Figure 5:Wilks Score Distribution by Winner

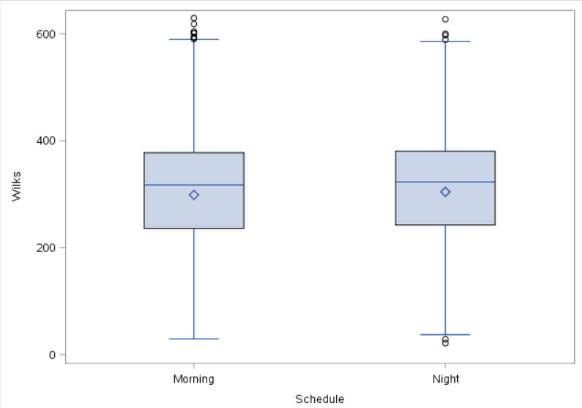


Figure 6:Wilks Score Distribution by Schedule

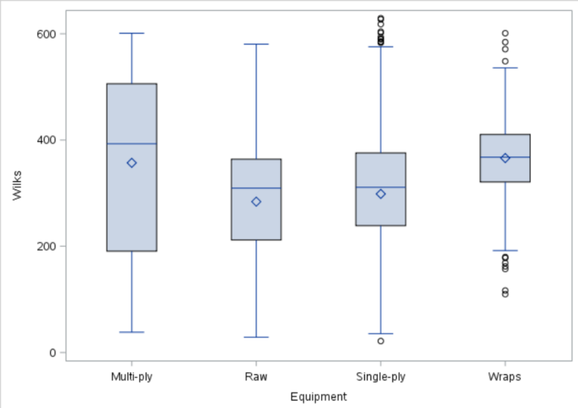


Figure 7:Wilks Score Distribution by Equipment

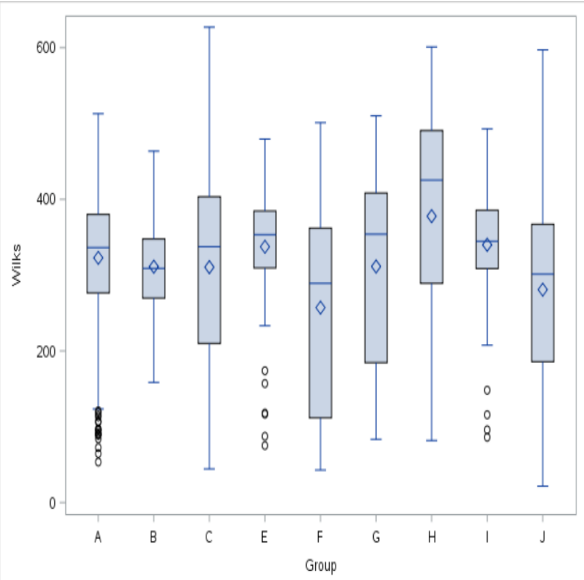


Figure 8:Wilks Score Distribution by Group

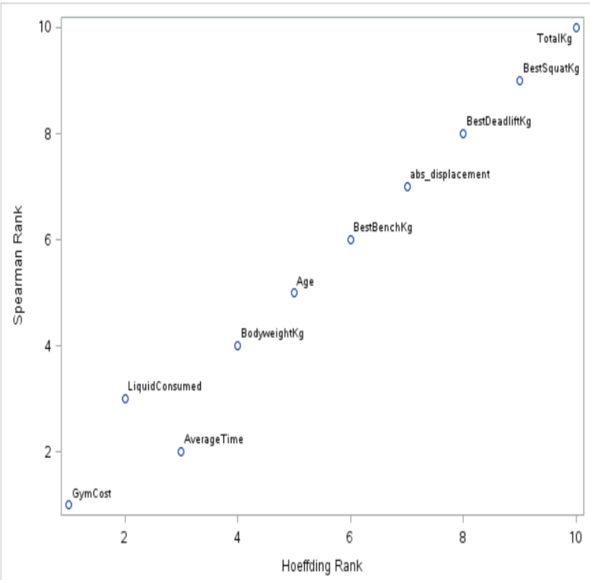


Figure 9:Hoeffding Ranks vs Spearman Ranks run

Figure 10: Two Sample T-Test Comparing Sex (Male/Female)

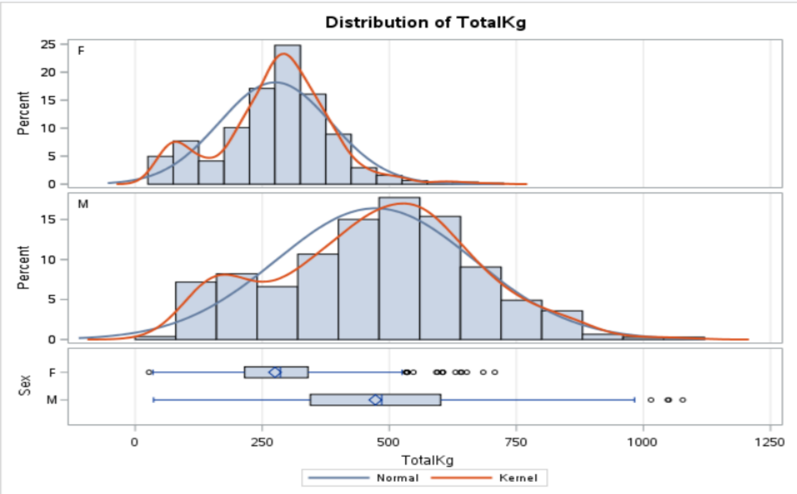
Variable: TotalKg

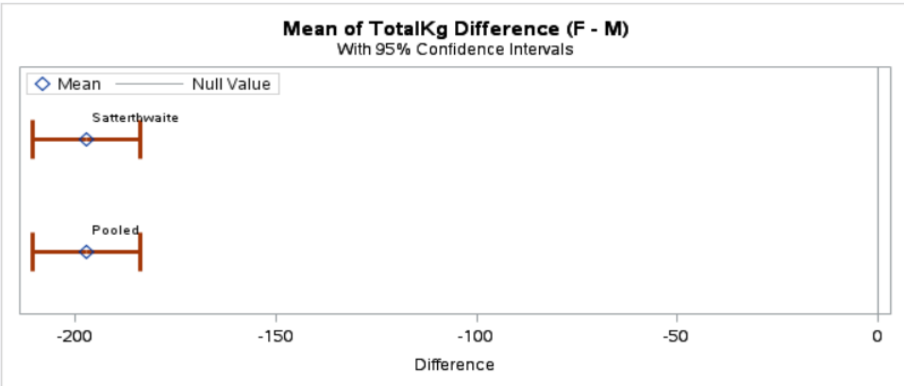
Sex	Method	N	Mean	Std Dev	Std Err	Minimum	Maximum
F		1088	275.3	109.7	3.3258	27.2200	707.5
M		1059	472.6	194.6	5.9787	36.2900	1077.5
Diff (1-2)	Pooled		-197.3	157.4	6.7938		
Diff (1-2)	Satterthwaite		-197.3		6.8414		

Sex	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
F		275.3	268.7	281.8	109.7	105.3	114.5
M		472.6	460.9	484.3	194.6	186.6	203.2
Diff (1-2)	Pooled	-197.3	-210.6	-184.0	157.4	152.8	162.2
Diff (1-2)	Satterthwaite	-197.3	-210.7	-183.9			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	2145	-29.05	<.0001
Satterthwaite	Unequal	1659.4	-28.84	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	1058	1087	3.15	<.0001





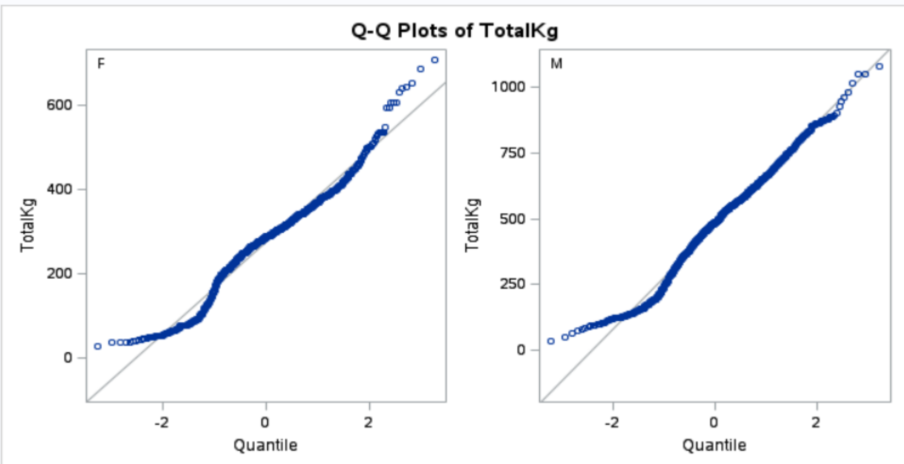


Figure 11: One-Way ANOVA with Equipment as Explanatory

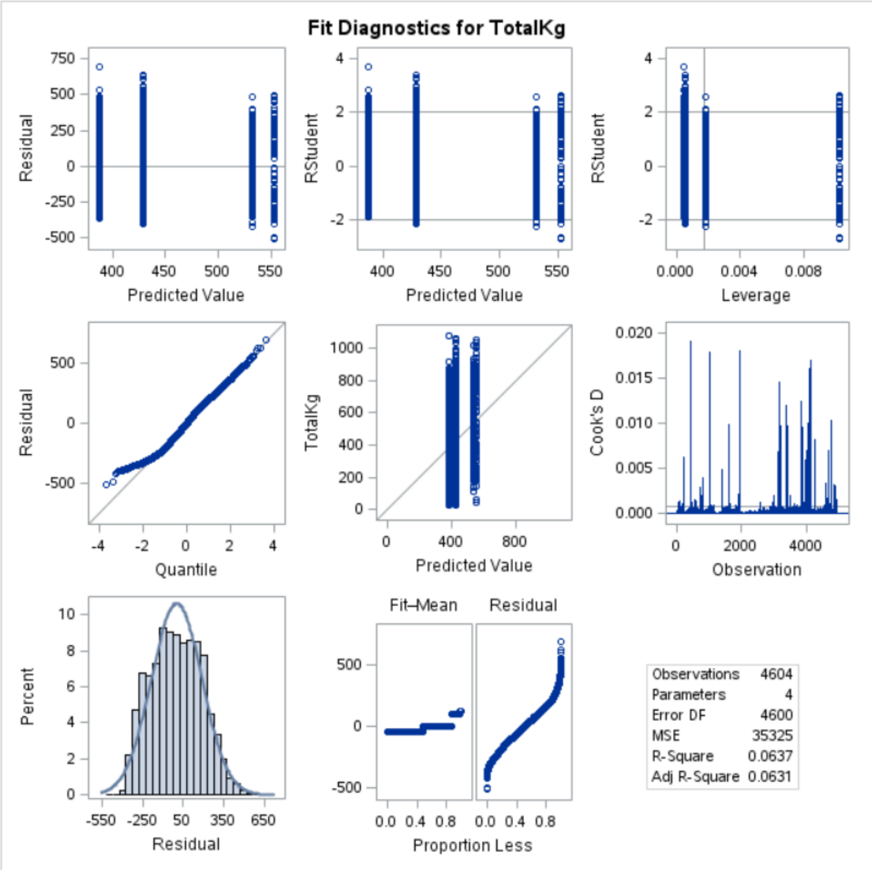
Dependent Variable: TotalKg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	11062986.4	3687662.1	104.39	<.0001
Error	4600	162495103.1	35325.0		
Corrected Total	4603	173558089.5			

R-Square	Coeff Var	Root MSE	TotalKg Mean
0.063742	44.41547	187.9495	423.1623

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Equipment	3	11062986.36	3687662.12	104.39	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Equipment	3	11062986.36	3687662.12	104.39	<.0001



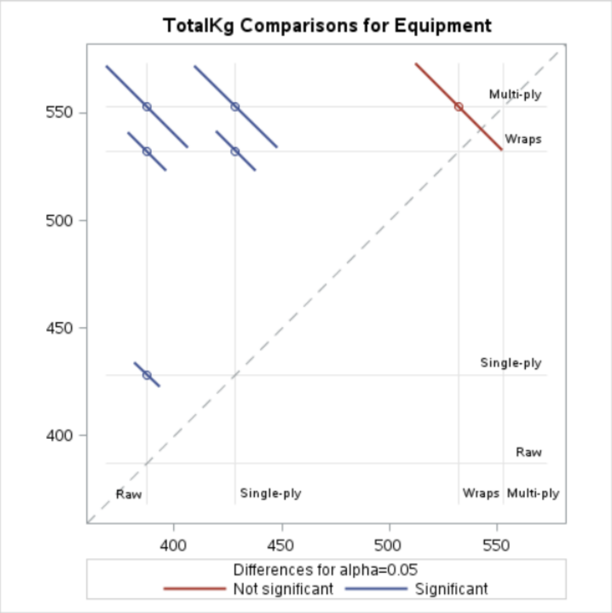
Levene's Test for Homogeneity of TotalKg Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Equipment	3	1.616E11	5.388E10	31.24	<.0001
Error	4600	7.933E12	1.7245E9		

Welch's ANOVA for TotalKg			
Source	DF	F Value	Pr > F
Equipment	3.0000	106.28	<.0001
Error	422.0		

Figure 12:Post-Hoc analysis of ANOVA-Equipment as Explanatory run

Least Squares Means

Least Squares Means for effect Equipment Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: TotalKg				
i/j	1	2	3	4
1		<.0001	<.0001	0.3175
2	<.0001		<.0001	<.0001
3	<.0001	<.0001		<.0001
4	0.3175	<.0001	<.0001	



Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Least Squares Means for effect Equipment Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: TotalKg				
i/j	1	2	3	4
1		<.0001	<.0001	0.7495
2	<.0001		<.0001	<.0001
3	<.0001	<.0001		<.0001
4	0.7495	<.0001	<.0001	

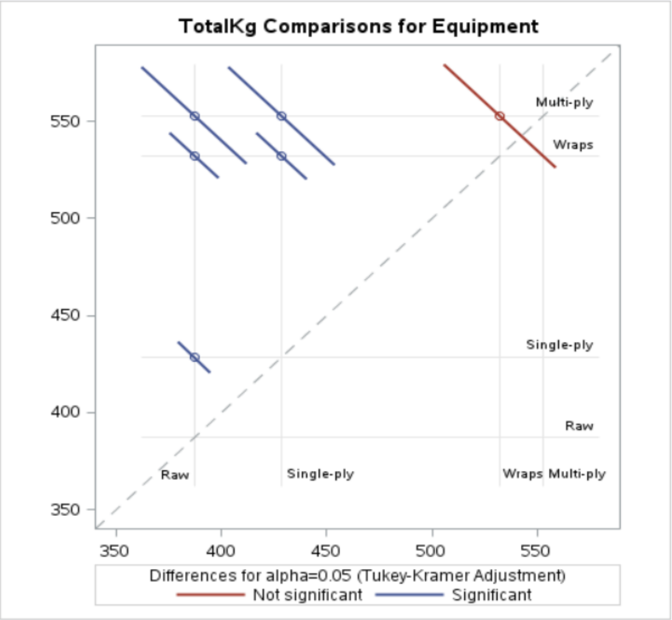


Figure 13:Collinearity Diagnostics

Model: MODEL1
Dependent Variable: Wilks

Parameter Estimates							
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Tolerance	Variance Inflation
Intercept	1	252.06776	2.51665	100.16	<.0001	.	0
BodyweightKg	1	-1.91651	0.03216	-59.59	<.0001	0.57776	1.73082
BestBenchKg	1	15.88120	30.76199	0.52	0.6057	1.478036E-7	6765735
TotalKg	1	-15.59825	30.76122	-0.51	0.6121	1.237918E-8	80780777
abs_displacement	1	0.00267	0.00354	0.75	0.4512	0.69977	1.42904
BestSquatKg	1	16.41704	30.76090	0.53	0.5936	7.967332E-8	12551253
BestDeadliftKg	1	16.01415	30.76082	0.52	0.6027	9.783877E-8	10220897

Collinearity Diagnostics										
			Proportion of Variation							
Number	Eigenvalue	Condition Index	Intercept	BodyweightKg	BestBenchKg	TotalKg	abs_displacement	BestSquatKg	BestDeadliftKg
1	6.67086	1.00000	0.00103	0.00082632	4.7265E-10	2.80615E-11	0.00366	2.06394E-10	1.77624E-10
2	0.17887	6.10699	0.02944	0.01308	9.12125E-11	3.80431E-11	0.86873	2.13186E-10	5.36247E-10
3	0.09574	8.34719	0.23571	0.03196	4.759174E-8	9.92388E-10	0.12460	9.869063E-9	1.193398E-9
4	0.02985	14.94875	0.31840	0.88794	6.2979E-9	6.66563E-10	0.00270	2.860276E-9	2.17639E-8
5	0.01554	20.72072	0.21369	0.04113	8.257809E-7	9.82676E-10	0.00002313	1.247558E-7	5.398296E-8
6	0.00915	27.00493	0.20144	0.02506	2.1884E-13	2.907E-10	0.00028620	4.410909E-7	4.576791E-7
7	9.33079E-10	84554	0.00028684	0.00000173	1.00000	1.00000	0.00001045	1.00000	1.00000

Figure 14: Forward Selection with SBC Summary

Selected Model

The selected model is the model at the last step (Step 5).

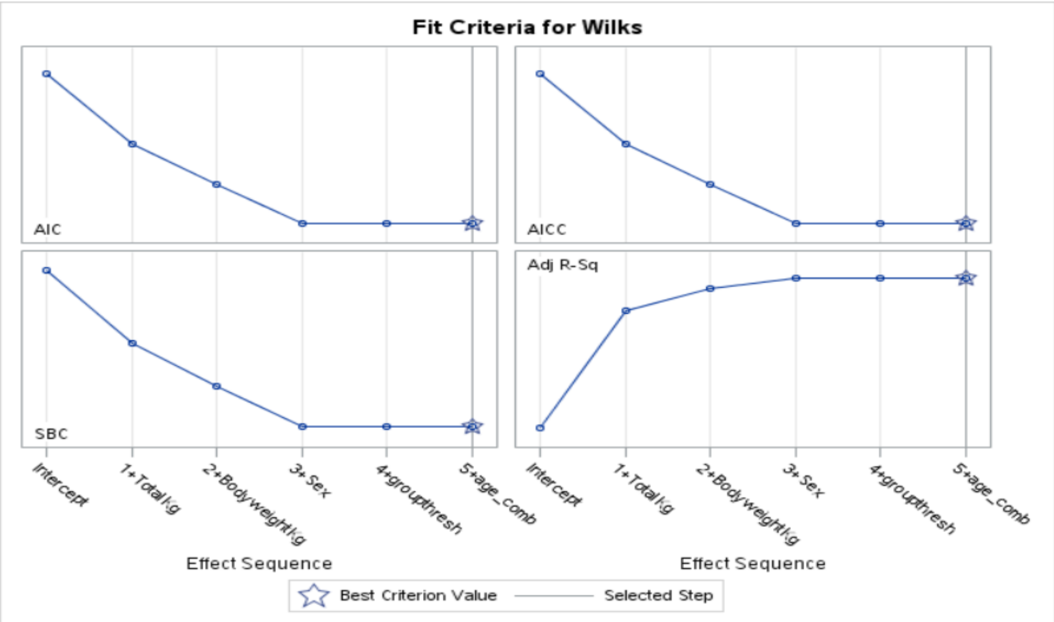
Effects:	Intercept Sex groupthresh BodyweightKg TotalKg age_comb

Note: The p-values for parameters and effects are not adjusted for the fact that the terms in the model have been selected and so are generally liberal.

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	49546118	6193265	9654.63	<.0001
Error	4245	2723087	641.48108		
Corrected Total	4253	52269205			

Root MSE	25.32748
Dependent Mean	303.90854
R-Square	0.9479
Adj R-Sq	0.9478
AIC	31762
AICC	31762
SBC	27563

Parameter Estimates					
Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	137.363498	2.550968	53.85	<.0001
Sex F	1	76.247740	1.104792	69.02	<.0001
Sex M	0	0	.	.	.
groupthresh B	1	10.083821	1.441352	7.00	<.0001
groupthresh C	1	0.467909	1.310797	0.36	0.7211
groupthresh J	1	1.393745	1.118536	1.25	0.2128
groupthresh others	0	0	.	.	.
BodyweightKg	1	-1.543056	0.019666	-78.46	<.0001
TotalKg	1	0.657693	0.002430	270.68	<.0001
age_comb 30-40	1	-2.129174	1.462613	-1.46	0.1455
age_comb <30	1	2.662168	1.659733	1.60	0.1088
age_comb >40	0	0	.	.	.



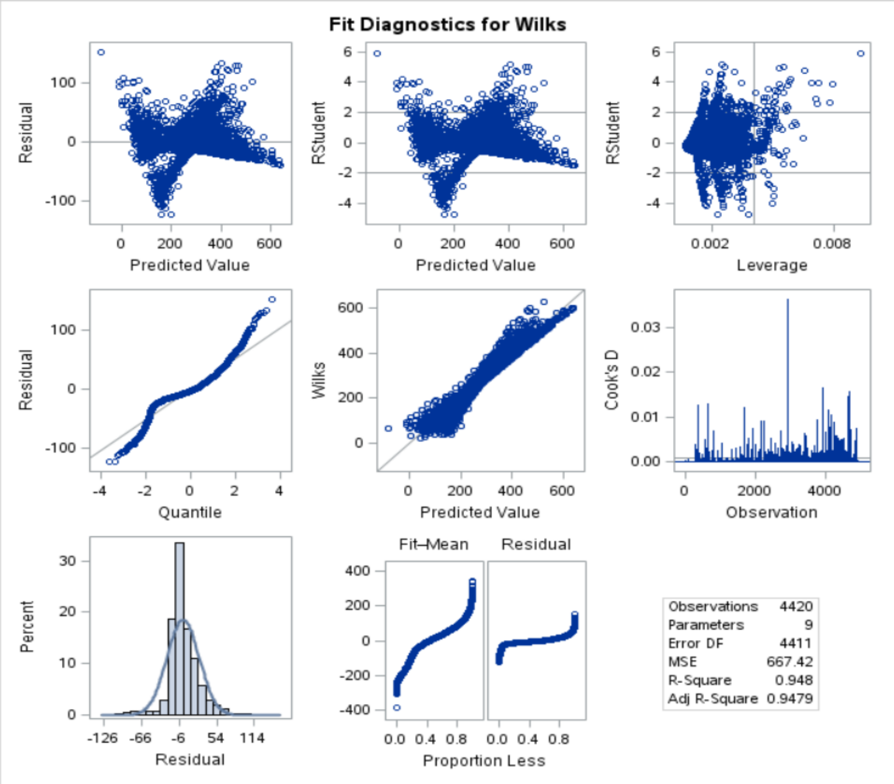


Figure 15: Forward Selection with SBC Summary for log(wilks)

Selected Model

The selected model is the model at the last step (Step 6).

Effects:	Intercept Sex equip_group groupthresh ln_bodyweightkg ln_bestbenchkg ln_totalkg

Note: The p-values for parameters and effects are not adjusted for the fact that the terms in the model have been selected and so are generally liberal.

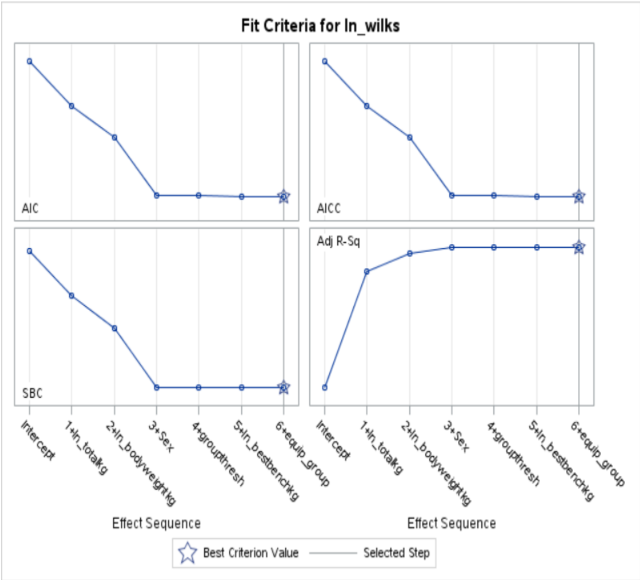
Analysis of Variance

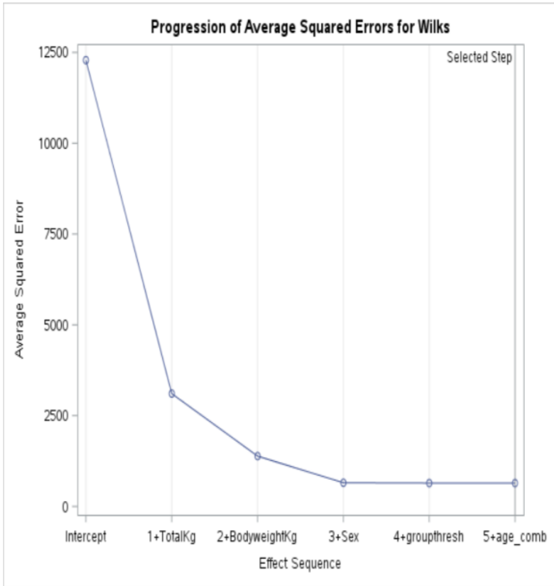
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1066.31213	133.28902	99921.3	<.0001
Error	4245	5.66257	0.00133		
Corrected Total	4253	1071.97470			

Root MSE	0.03652
Dependent Mean	5.61776
R-Square	0.9947
Adj R-Sq	0.9947
AIC	-23895
AICC	-23895
SBC	-28094

Parameter Estimates

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	2.046836	0.012159	168.34	<.0001
Sex F	1	0.300553	0.002007	149.76	<.0001
Sex M	0	0	.	.	.
equip_group Multi_ Single_Wraps	1	0.004017	0.001300	3.09	0.0020
equip_group Raw	0	0	.	.	.
groupthresh B	1	0.011823	0.002368	4.99	<.0001
groupthresh C	1	0.001951	0.001920	1.02	0.3095
groupthresh J	1	0.001006	0.001653	0.61	0.5426
groupthresh others	0	0	.	.	.
ln_bodyweightkg	1	-0.531314	0.002878	-184.64	<.0001
ln_bestbenchkg	1	-0.011017	0.002251	-4.89	<.0001
ln_totalkg	1	0.995153	0.001156	861.18	<.0001


Fit Criteria for ln_wilks
AIC
AICC
SBC
Adj R-Sq
Intercept
1+ln_totalkg
2+ln_bodyweightkg
3+Sex
4+groupthresh
5+ln_bestbenchkg
6+equip_group
Effect Sequence
Best Criterion Value
Selected Step


Progression of Average Squared Errors for Wilks
Selected Step
Average Squared Error
12500
10000
7500
5000
2500
0
Intercept
1+TotalKg
2+BodyweightKg
3+Sex
4+groupthresh
5+age_comb
Effect Sequence

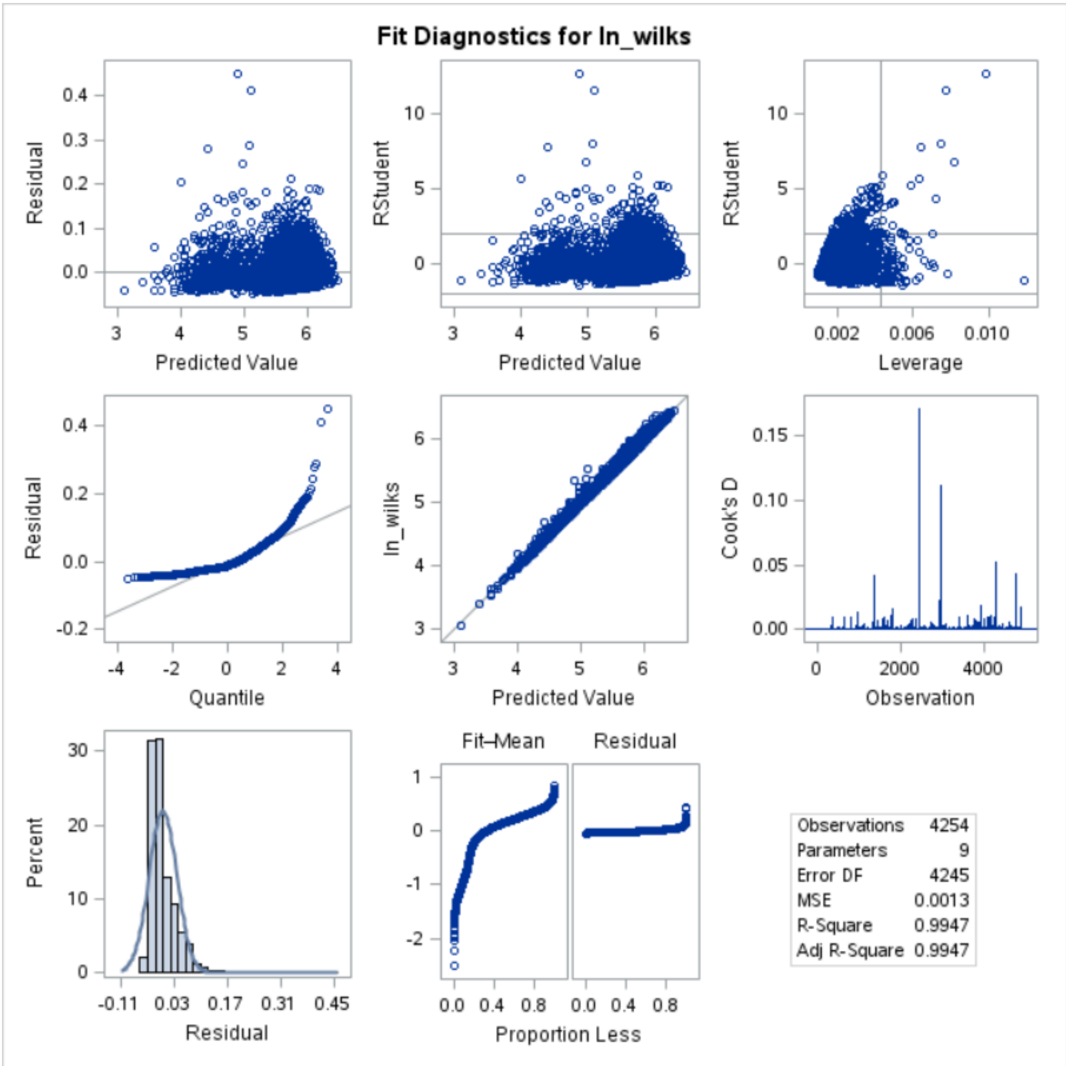

Fit Diagnostics for ln_wilks
Residual
RStudent
Predicted Value
Leverage
Quantile
ln_wilks
Cook's D
Observation
Percent
Fit–Mean
Residual
Proportion Less
Observations 4254
Parameters 9
Error DF 4245
MSE 0.0013
R-Square 0.9947
Adj R-Square 0.9947

Figure 16: Forward Selection Summary For Winner

Model Convergence Status
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	5856.002	5041.498
SC	5862.353	5105.014
-2 Log L	5854.002	5021.498

Testing Global Null Hypothesis: BETA=0

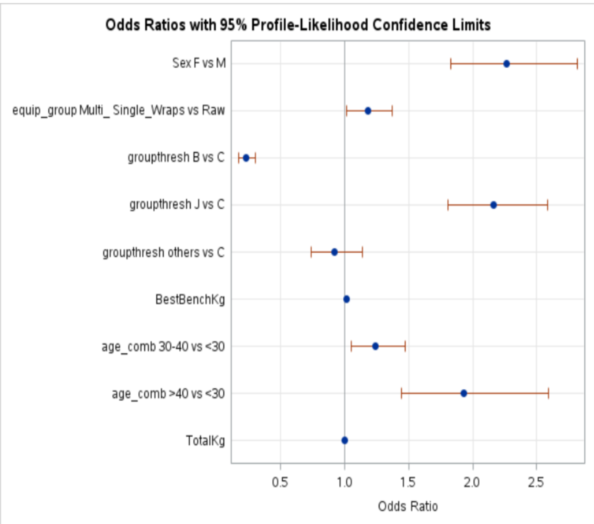
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	832.5039	9	<.0001
Score	765.3164	9	<.0001
Wald	617.3530	9	<.0001

Analysis of Maximum Likelihood Estimates

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	-0.7974	0.1232	41.9207	<.0001
Sex	F	1	0.4094	0.0551	55.1204	<.0001
equip_group	Multi_ Single_Wraps	1	0.0824	0.0386	4.5612	0.0327
groupthresh	B	1	-1.2888	0.1015	161.0930	<.0001
groupthresh	J	1	0.9723	0.0540	324.6645	<.0001
groupthresh	others	1	0.1146	0.0744	2.3740	0.1234
BestBenchKg		1	0.0114	0.00110	107.8147	<.0001
age_comb	30-40	1	-0.0754	0.0573	1.7347	0.1878
age_comb	>40	1	0.3664	0.0904	16.4106	<.0001
TotalKg		1	-0.00110	0.000229	23.0689	<.0001

Association of Predicted Probabilities and Observed Responses

Percent Concordant	74.0	Somers' D	0.480
Percent Discordant	26.0	Gamma	0.480
Percent Tied	0.0	Tau-a	0.239
Pairs	4467162	c	0.740



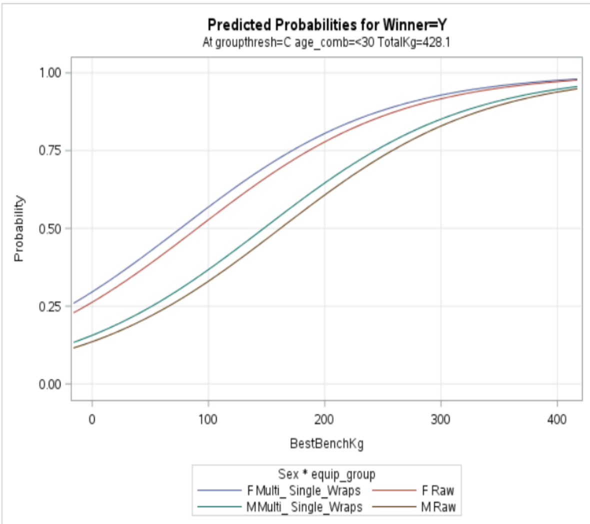


Figure 17: Roc Curve for Winner

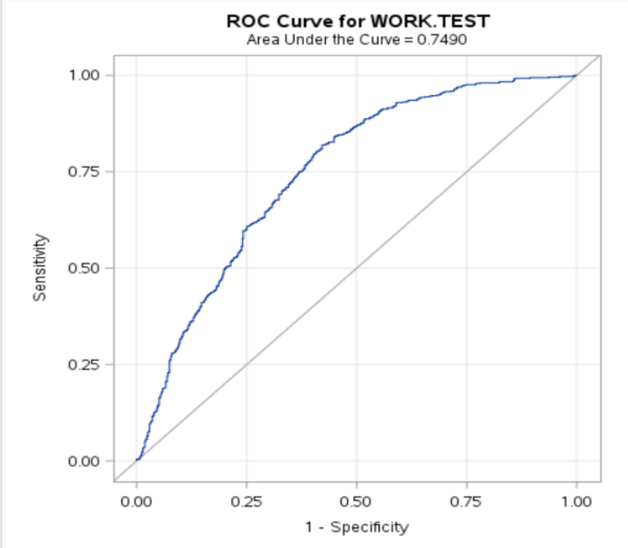


Figure 18: Model Summary for winner

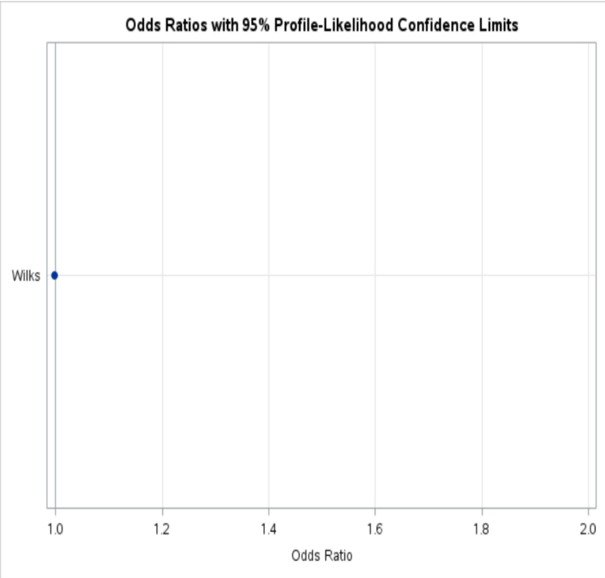
Model Convergence Status
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	6320.737	6265.734
SC	6327.165	6278.591
-2 Log L	6318.737	6261.734

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	57.0029	1	<.0001
Score	56.5711	1	<.0001
Wald	55.9425	1	<.0001

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.7479	0.0854	76.6857	<.0001
Wilks	1	-0.00197	0.000264	55.9425	<.0001

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	54.0	Somers' D	0.080
Percent Discordant	46.0	Gamma	0.080
Percent Tied	0.0	Tau-a	0.040
Pairs	5207130	c	0.540



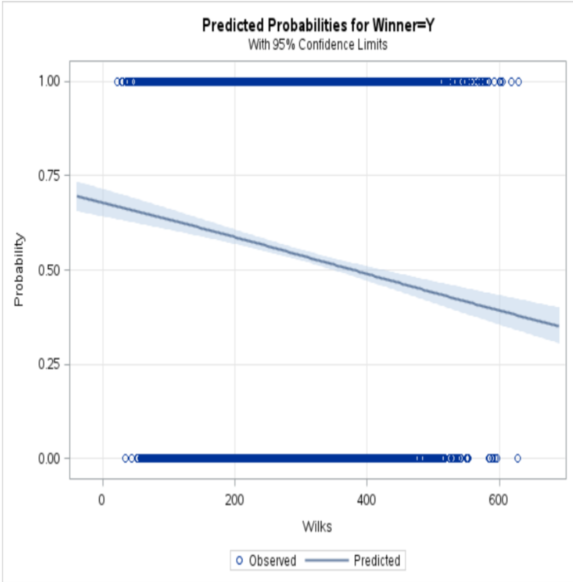
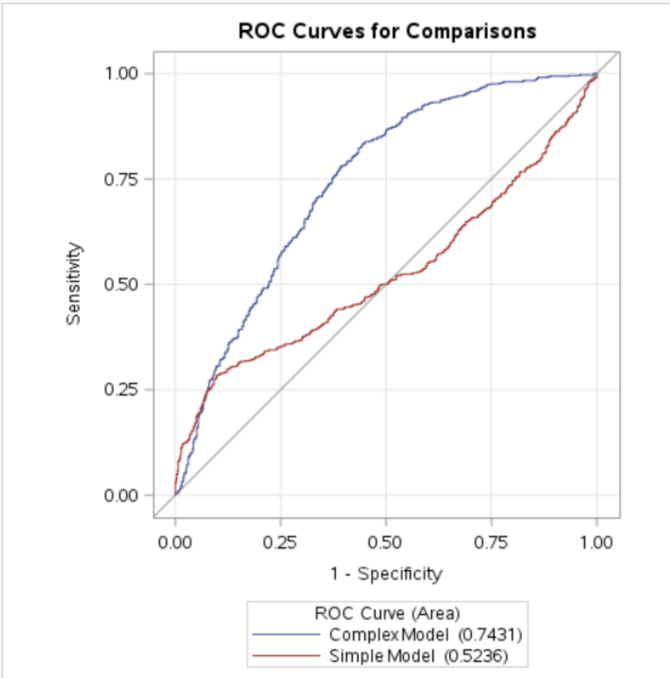


Figure 19:Models Comparison



ROC Association Statistics

ROC Model	Mann-Whitney Area	Mann-Whitney Standard Error	Mann-Whitney 95% Wald Confidence Limits		Somers' D	Gamma	Tau-a
Complex Model	0.7431	0.0140	0.7156	0.7706	0.4863	0.4863	0.2425
Simple Model	0.5236	0.0164	0.4914	0.5558	0.0472	0.0472	0.0235

ROC Contrast Test Results

Contrast	DF	Chi-Square	Pr > ChiSq
Comparing Models	1	113.8597	<.0001