Age-related changes in upper body grip strength and lower extremity power in healthy adults aged 18-70 years

The client's study focused on the age-related changes in upper body grip strength and lower extremity power in healthy adults aged 18-70 years. Client needed to test for differences in strength and power between the age bands, as well as finding out at what age does strength and power significantly decline from their peak values. Additionally, they wanted to find out how much age predicts strength and power, and check to see if there is a correlation between age and power.

I have recoded variable 'Agedec' into 'Age_bands' and labelled into its categories (mandatory for the comparison analysis). I have computed variable 'Age_squared' (mandatory for curvilinear regression). I have performed 5 hypothesis testing (additional testing included assumption verification before actual testing) which included 2 comparisons, 2 curvilinear regression and 1 correlation.

I have also provided statistical interpretation of results and academic reporting. I have included a peak point in both regression scatterplots, as per client's specific request, after calculating them using formula. As the results concluded, all of them confirmed as being good fit for the models of the design, and all of them were valid.

All of the tables and figures were generated, formatted, named and labeled using APA Style.

Statistical analyst

Nicoleta Gena Oncescu

HYPOTHESIS TESTING

H_1*: *There are differences in power between age bands.

Before performing the comparison test, the assumption of normality was tested using the Kolmogorov-Smirnov test.

Table 1.

Tests of Normality

	Age_bands	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
@1minpower	18-29	.095	73	.168	.965	73	.038
	30-39	.088	49	.200*	.970	49	.250
	40-49	.065	51	.200*	.978	51	.444
	50-59	.117	50	.084	.957	50	.065
	60-70	.110	51	.178	.973	51	.300

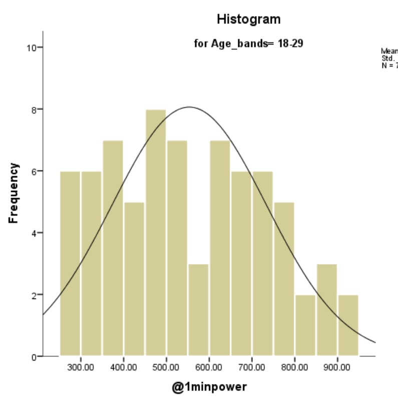
**. This is a lower bound of the true significance.*

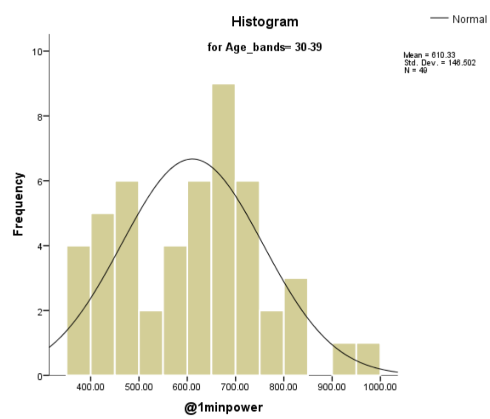
a. Lilliefors Significance Correction

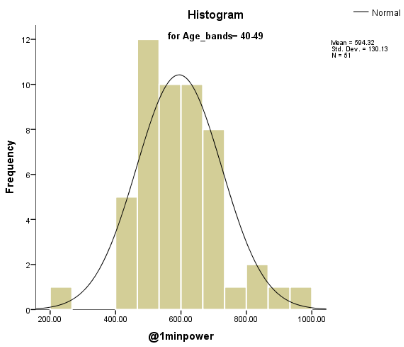
Table above presents the *Kolmogorov-Smirnov* test, which indicates that there is no statistically significant deviation from normality for none of the participants categories, regarding the variable that measures power. The histograms presenting the distribution curve are available below as well. Given the result, *One-Way ANOVA* test was performed.

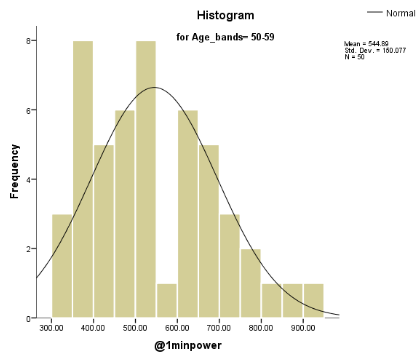
Figure 1.

Distribution curve for the variable power – all age group









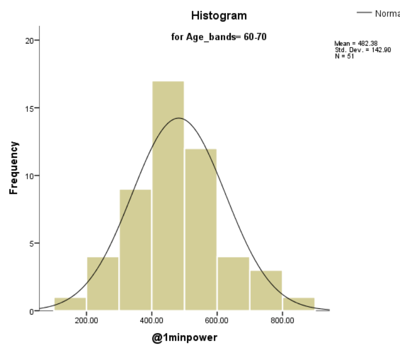


Table 2.

Descriptives statistics – variable power

Age_bands	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
18-29	73	553.1932	180.62393	21.14043	511.0505	595.3358	253.17	940.29
30-39	49	610.3347	146.50227	20.92890	568.2543	652.4151	370.82	982.23
40-49	51	594.3204	130.13004	18.22185	557.7207	630.9201	215.87	944.26
50-59	50	544.8874	150.07719	21.22412	502.2359	587.5389	316.02	947.65
60-70	51	482.3818	142.89962	20.00995	442.1906	522.5729	169.96	867.01
Total	274	556.3711	158.44051	9.57174	537.5273	575.2149	169.96	982.23

Table above presents the mean and standard deviation for the all age-bands of the hypothesis. For the age group of 18-29 the mean of the variable is M = 553.19, and the standard deviation is SD = 180.62. For the age group of 30-39 the mean of the variable is M = 610.33, and the standard deviation is SD = 146.50. For the age group of 40-49 the mean of the variable is M = 594.32, and the standard deviation is SD = 130.13. For the age group of 50-59 the mean of the variable is M = 544.88, and the standard deviation is SD = 150.07. For the age group of 60-70 the mean of the variable is M = 482.38, and the standard deviation is SD = 142.89.

Table 3.

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
3.763	4	269	.005

Table 3 presents the *Levene's test of Homogeneity of Variances* which is statically significant, $p < .05$. This means that we can not assume that there is homogeneity of variances, as this assumption is violated, and we can not interpret the ANOVA overall result, therefor we are going to proceed with *Welch* and *Brown-Forsythe* tests presented below.

Table 4.

Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	6.142	4	131.575	.000
Brown-Forsythe	5.562	4	266.299	.000

a. Asymptotically F distributed.

In *Table 4* both tests, *Welch* and *Brown-Forsythe,* show statistical significance, $p < .05$. Therefor we can translate this to having statistically significant differences between age groups, being able to proceed further and interpret the post-hoc tests.

Table 5.

Multiple Comparisons – Games-Howell

(I) Age_bands	(J) Age_bands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
18-29	30-39	-57.14154	29.74788	.312	-139.5814	25.2983
	40-49	-41.12724	27.90974	.582	-118.4106	36.1561
	50-59	8.30575	29.95632	.999	-74.7027	91.3142
	60-70	70.81139	29.10869	.114	-9.8103	151.4330
30-39	18-29	57.14154	29.74788	.312	-25.2983	139.5814
	40-49	16.01430	27.74986	.978	-61.1448	93.1734
	50-59	65.44729	29.80741	.190	-17.4101	148.3047
	60-70	127.95293*	28.95543	.000	47.4730	208.4328
40-49	18-29	41.12724	27.90974	.582	-36.1561	118.4106

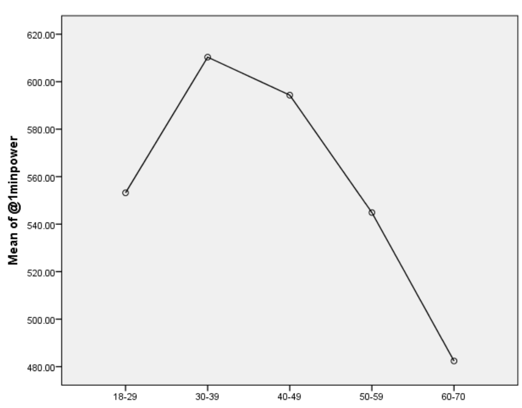
	30-39	-16.01430	27.74986	.978	-93.1734	61.1448
	50-59	49.43299	27.97319	.399	-28.3335	127.1995
	60-70	111.93863*	27.06352	.001	36.7393	187.1379
50-59	18-29	-8.30575	29.95632	.999	-91.3142	74.7027
	30-39	-65.44729	29.80741	.190	-148.3047	17.4101
	40-49	-49.43299	27.97319	.399	-127.1995	28.3335
	60-70	62.50564	29.16953	.211	-18.5547	143.5660
60-70	18-29	-70.81139	29.10869	.114	-151.4330	9.8103
	30-39	-127.95293*	28.95543	.000	-208.4328	-47.4730
	40-49	-111.93863*	27.06352	.001	-187.1379	-36.7393
	50-59	-62.50564	29.16953	.211	-143.5660	18.5547

**. The mean difference is significant at the 0.05 level.*

Table above shows the results of the analysis, and it can be concluded that *power* differs among the participants, based on age. The *Games-Howell post-hoc* additional testing, has shown that there are statistically significant differences between participants in the age group of 30-39 and participants in the age group of 60-70, when it comes to power, p = .00, the first group manifesting more power the second group. Another statistically significant difference has been observed between participants in the age group of 40-49 and participants in the age group of 60-70, p = .00, once again the first group manifesting more power the second group. There are no other differences that are statistically significant between age groups regarding power.

Figure 2.

Power mean values (M) – all age group



To conclude, the obtained results reject the null hypothesis. *Hypothesis* $\boldsymbol{H_1}$ **is accepted and valid.**

$\boldsymbol{H_2}$**:** *There are differences in strenght between age bands.*

Before performing the comparison test, the assumption of normality was tested using the Kolmogorov-Smirnov test.

Table 6.

Tests of Normality – variable strength

	Age_bands	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Mean Grip strength	18-29	.087	73	.200*	.975	73	.157
	30-39	.121	49	.072	.947	49	.029
	40-49	.089	51	.200*	.962	51	.098
	50-59	.154	50	.005	.915	50	.002
	60-70	.152	51	.005	.902	51	.000

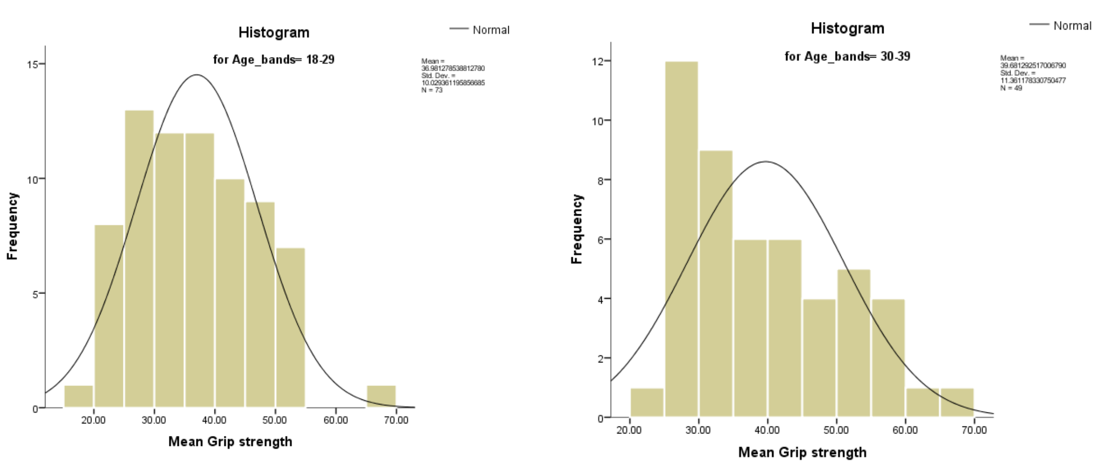
**. This is a lower bound of the true significance.*

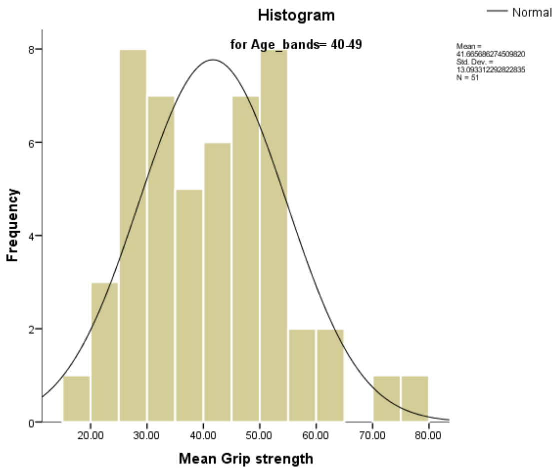
a. Lilliefors Significance Correction

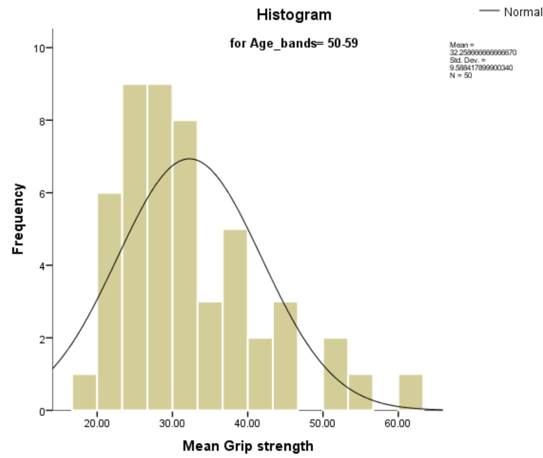
Table above presents the *Kolmogorov-Smirnov* test, which indicates that there are statistically significant deviations from normality for some of the participants categories, regarding the variable that measures strength. The histograms presenting the distribution curve are available below as well.

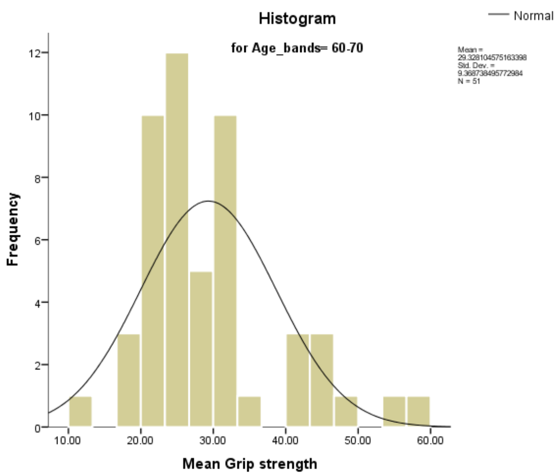
Figure 3.

Distribution curve for variable strength – all age group









As the assumption of normality of distribution was not met, the non-parametric *Kruskal Wallis* test was performed.

Table 7.
Ranks

	Age_bands	N	Mean Rank
Mean Grip strength	18-29	73	148.71
	30-39	49	164.65
	40-49	51	172.41
	50-59	50	110.53
	60-70	51	86.90
	Total	274	

Table 8.

Test Statistics[a,b]

	Mean Grip strength
Chi-Square	43.699
df	4
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Age_bands

Table 7 and *Table 8* present the results of the *Kruskal Wallis test* which shows statistical significance, $p < .05$. We can translate this to having statistically significant differences between age groups.

Figure 4.

Power mean (M) – all age group

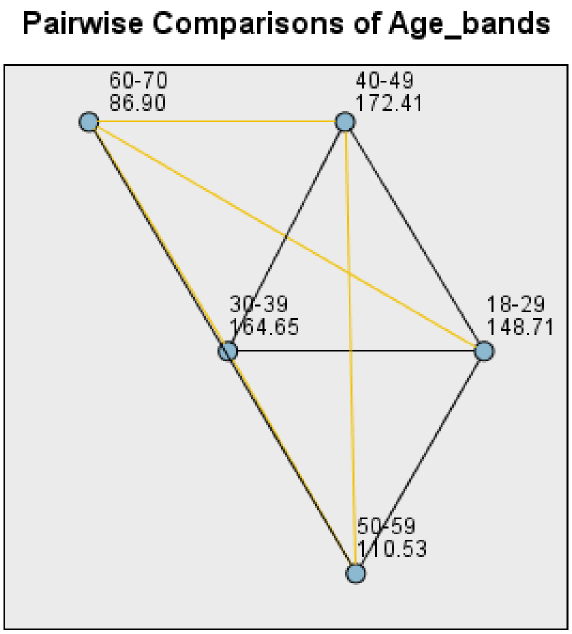


Table 9.
Kruskal Walls – group differences

Each node shows the sample average rank of Age_bands.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
60-70-50-59	23.628	15.770	1.498	.134	1.000
60-70-18-29	61.804	14.462	4.274	.000	.000
60-70-30-39	77.751	15.851	4.905	.000	.000
60-70-40-49	85.510	15.692	5.449	.000	.000
50-59-18-29	38.175	14.546	2.624	.009	.087
50-59-30-39	54.123	15.929	3.398	.001	.007
50-59-40-49	61.882	15.770	3.924	.000	.001
18-29-30-39	-15.948	14.634	-1.090	.276	1.000
18-29-40-49	-23.706	14.462	-1.639	.101	1.000
30-39-40-49	-7.759	15.851	-.489	.625	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Table above shows the results of the analysis, and it can be concluded that strength differs among the participants, based on age group, and the significant differences are between the following groups:

- participants in the age group of 50-59, have statistically significant lower power compared to participants in the age group of 30-39 (p = 00), and participants in the age group of 40-49 (p = 00).
- participants in the age group of 60-70, have statistically significant lower power compared to participants in the age group of 18-29 (p = 00), and participants in the age group of 30-39 (p = 00), and participants in the age group of 40-49 (p = 00).

To conclude, the obtained results reject the null hypothesis. *Hypothesis* $\boldsymbol{H_2}$ **is accepted and valid.**

$\boldsymbol{H_3}$**:** *There is a statistically significant correlation between age and power.*

Before performing the correlation test, the assumption of normality was tested using the Kolmogorov-Smirnov test.

Table 10.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
@1minpower	.064	274	.009	.990	274	.055
Age	.130	274	.000	.923	274	.000

a. Lilliefors Significance Correction

Table above presents the Kolmogorov-Smirnov test, which indicates that there is a statistically significant deviation from normality for both power, *D*(274) = .064, *p* =.009 and age *D*(274) = .130, *p* =.000.

Figure 5.

Distribution curve for the variable power

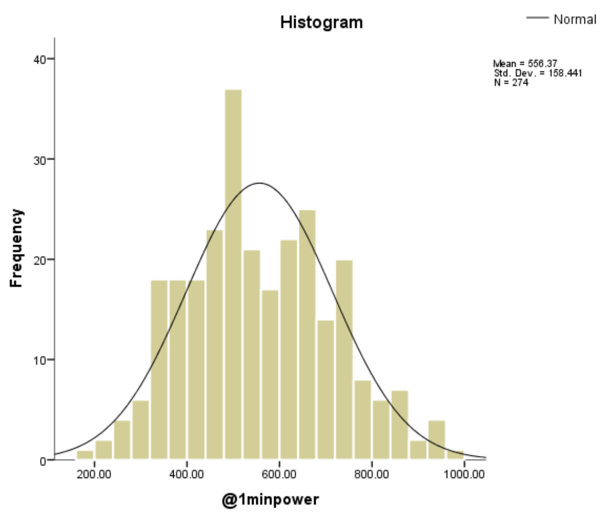
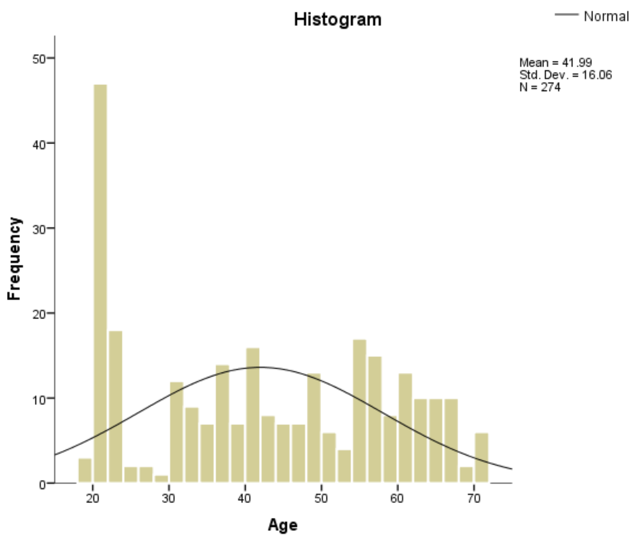


Figure 6.

Distribution curve for the variable age



As the assumption of normality of distribution was not met, the *Spearman's Rank Order* correlation test was performed.

Table 11.

Correlations

			Age	@1minpower
Spearman's rho	Age	Correlation Coefficient	1.000	-.155*
		Sig. (2-tailed)	.	.010
		N	274	274
	@1minpower	Correlation Coefficient	-.155*	1.000
		Sig. (2-tailed)	.010	.
		N	274	274

**. Correlation is significant at the 0.05 level (2-tailed).*

A *Spearman's Rank-order* correlation was run to determine the relationship between age and power. There is a negative correlation between the two variables, which is statistically significant, $r_s(274) = -.15$, $p = .0101$, yet the resulted effect size coefficient is weak.

The obtained results reject the null hypothesis. *Hypothesis* $\boldsymbol{H_3}$ **is accepted and valid, as there is a negative correlation that is statistically significant between Age and Power.** This means that as *Age* increases, *Power* decreases, and the relatioship between the two is available in reverse as well.

H_4*: *Age-related changes influences strength in healthy adults.

The hypothesis above is intended to be verified through a *Curvilinear Regression*, testing a quadratic effect, having *Age* as the predictor variable and *Strength* as the outcome variable.

Before performing the *Curvilinear Regression*, the data needs to meet the required assumptions that qualifies the data as being proper for the design.

The approach used is through a hierarchical multiple regression technique which requires the squaring of the predictor variable, being the first step taken in the analysis.

Table 12.
Descriptive Statistics

	Mean	Std. Deviation	N
Mean Grip strength	36.049756690997555	11.522270641601190	274
Age	41.99	16.060	274
Age_Squared	2019.74	1367.004	274

Table above presents the mean and standard deviation for the both variables of the hypothesis. For variable *Strength*, the mean is *M* = 36.04, and the standard deviation is *SD* = 11.52. For variable *Age*, the mean is *M* = 41.99, and the standard deviation is *SD* = 16.06.

Table 13.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.241[a]	.058	.055	11.202500561696842	.058	16.808	1	272	.000
2	.348[b]	.121	.115	10.840935973709874	.063	19.446	1	271	.000

a. Predictors: (Constant), Age

b. Predictors: (Constant), Age, Age_Squared

Table 13 presents the Model 1's *R Square*, showing a value of .058 which is a good fit. This means that our linear model explains 5.8% of the variance of the dependent variable, which is statistically significant $p = .00$. The Model 2's *R Square,* which is the curvilinear model, shows a value of .121 cumulated with Model 1's, which is also statistically significant, $p = .00$. The same table confirms that the curvilinear model contributes to the whole percentage of the variance with 6.3%, which is even more than the linear model. This implies that, there is indeed a non-linear trend in our regression.

Table 14.
ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2109.306	1	2109.306	16.808	.000[b]
	Residual	34134.917	272	125.496		
	Total	36244.223	273			
2	Regression	4394.706	2	2197.353	18.697	.000[c]
	Residual	31849.517	271	117.526		
	Total	36244.223	273			

a. Dependent Variable: Mean Grip strength

b. Predictors: (Constant), Age

c. Predictors: (Constant), Age, Age_Squared

The ANOVA tests the null hypothesis that the slope of the line is 0. We do have a significant finding here, $p < .05$, so **we reject the null hypothesis, for both models**.

Table 15.
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	43.317	1.897		22.830	.000			
	Age	-.173	.042	-.241	-4.100	.000	-.241	-.241	-.241
2	(Constant)	22.619	5.040		4.488	.000			
	Age	.979	.264	1.364	3.702	.000	-.241	.219	.211
	Age_Squared	-.014	.003	-1.625	-4.410	.000	-.277	-.259	-.251

a. Dependent Variable: Mean Grip strength

Table 15 further confirms that the independent variable *age* did make a significant contribution to the dependent variable *strength*, $p = .00$. The negative $\beta = -1.625$, along with the quadratic semi-partial correlation equal to -.251, of *Model 2*, implies that the bend in the regression line is going downward after a certain point.

Table 16.

Model Summary and Parameter Estimates

Equation	Model Summary					Parameter Estimates		
	R Square	F	df1	df2	Sig.	Constant	b1	b2
Quadratic	.121	18.697	2	271	.000	22.619	.979	-.014

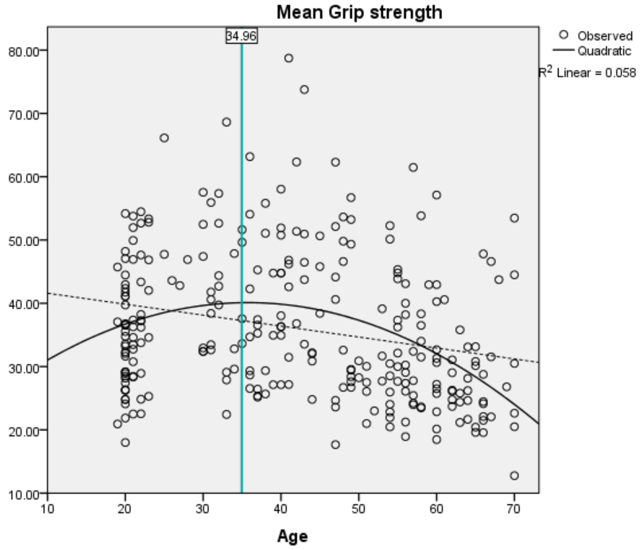
The independent variable is Age.

Table 16 confirms the contribution of the quadratic model significance. Also, the negative *b2* confirms once again, that past certain point, increased age would actually decrease strength.

Based on the *Law of diminishing returns*, the **saturation point** was calculated using the *saturation effect formula*: *b1 / (2 x b2)* = .979 / (2 x .014) = 34.96.

Figure 7.

Quadratic and linear line for regression where the blue line represents the point where strength peaks



A *Curvilinear Regression* was run to identify if *Age-related changes* influences *strength* in healthy adults. This variable **did** statistically significantly influence the level of *Strenght*, *F*(2,271) = 18.697, *p* = .00, R^2 = .121. We accept the alternative hypothesis. $Hypothesis\ \boldsymbol{H_4}$ **is valid.**

$\boldsymbol{H_5}$**:** *Age-related changes influences power in healthy adults.*

The hypothesis above is intended to be verified through a *Curvilinear Regression*, testing a quadratic effect, having *Age* as the predictor variable and *Power* as the outcome variable.

Before performing the *Curvilinear Regression*, the data needs to meet the required assumptions that qualifies the data as being proper for the design.

The approach used is through a hierarchical multiple regression technique which requires the squaring of the predictor variable, which was a step already performed earlier.

Table 17.

Descriptive Statistics

	Mean	Std. Deviation	N
@1minpower	556.3711	158.44051	274
Age	41.99	16.060	274
Age_Squared	2019.74	1367.004	274

Table above presents the mean and standard deviation for the both variables of the hypothesis. For variable *Power,* the mean is *M* = 556.37, and the standard deviation is *SD* = 158.44. For variable *Age,* the mean is *M* = 41.99, and the standard deviation is *SD* = 16.06.

Table 18

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.146[a]	.021	.018	157.04074	.021	5.888	1	272	.016

2	.225[b]	.051	.044	154.94505	.029	8.408	1	271	.004

a. Predictors: (Constant), Age

b. Predictors: (Constant), Age, Age_Squared

Table 18 presents the Model 1's *R Square*, showing a value of .021 which is a good fit. This means that our linear model explains 2.1% of the variance of the dependent variable, which is statistically significant $p = .01$. The Model 2's *R Square,* which is the curvilinear model, shows a value of .051 cumulated with Model 1's, which is also statistically significant, $p = .00$. The same table confirms that the curvilinear model contributes to the whole percentage of the variance with 2.9%, which is more than the linear model's contribution itself. This implies that, there is indeed a non-linear trend in our regression.

Table 19

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	145219.170	1	145219.170	5.888	.016[b]
	Residual	6708007.928	272	24661.794		
	Total	6853227.098	273			
2	Regression	347067.300	2	173533.650	7.228	.001[c]
	Residual	6506159.799	271	24007.970		
	Total	6853227.098	273			

a. Dependent Variable: @1minpower

b. Predictors: (Constant), Age

c. Predictors: (Constant), Age, Age_Squared

The ANOVA tests the null hypothesis that the slope of the line is 0. We do have a significant finding here, $p < .05$, so **we reject the null hypothesis, for both models**.

Table 20

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	616.668	26.598		23.185	.000			

	Age	-1.436	.592	-.146	-2.427	.016	-.146	-.146	-.146
2	(Constant)	422.150	72.035		5.860	.000			
	Age	9.389	3.779	.952	2.485	.014	-.146	.149	.147
	Age_Squared	-.129	.044	-1.111	-2.900	.004	-.170	-.173	-.172

a. Dependent Variable: @1minpower

Table 20 further confirms that the independent variable *age* did make a significant contribution to the dependent variable *strength*, $p = .00$. The negative $\beta = -1.111$, along with the quadratic semi-partial correlation equal to -.172, of *Model 2*, implies that the bend in the regression line is going downward after a certain point, once again.

Table 21.

Model Summary and Parameter Estimates - Dependent Variable

Equation	Model Summary					Parameter Estimates		
	R Square	F	df1	df2	Sig.	Constant	b1	b2
Quadratic	.051	7.228	2	271	.001	422.150	9.389	-.129

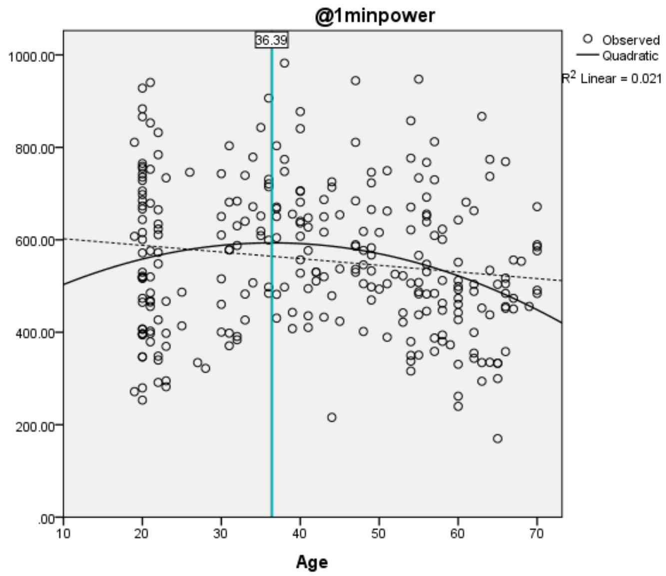
The independent variable is Age.

Table 21 confirms the contribution of the quadratic model significance. Also, the negative *b2* confirms once again, that past certain point, increased age would actually decrease strength.

Based on the *Law of diminishing returns,* the **saturation point** was calculated using the saturation effect formula of *b1 / (2 x b2)* = 9.389 / (2 x .129) = 36.39.

Figure 8.

Quadratic and linear line for regression where the blue line represents the point where power peaks



A *Curvilinear Regression* was run to identify if *Age-related changes* influences *power* in healthy adults. This variable **did** statistically significantly influence the level of *Power*, $F(2,271) = 7.228$, $p = .00$, $R^2 = .051$. We accept the alternative hypothesis. $Hypothesis\ \boldsymbol{H_5}$ **is valid.**