Table of Contents

Rice University - 148/263

Introduction

As an avid golfer and an enthusiast of the game of golf, my choice of area of interest for the *Math Studies Project* came easily. I have played golf since the age of five years old and have during that time, gradually lowered my handicap by acquiring a deeper and greater understanding of the complex relationship between body, golf club, and ball. For this project, I will be investigating the relationship between the club face angle or *loft* and the distance traveled by the ball after impact.

The game of golf is played with a series of clubs comprising generally of 11 *irons* and 3 *woods*. Irons are as their name indicates clubs with an iron/steel/chrome club face and are used on every surface of the golf course excepting the green where only a putter is used. Different irons, with different club length and different *lofts* are used depending on the distance from the hole and/or depending on the surface your ball is placed on, e.g.: the short and large lofted sand wedge for the sand bunker or other tricky situations or the slightly longer and 'squarer' lofted 4 iron for fairway use. Woods on the other hand are mostly used off the tee (beginning of course) as they are considerably larger and make the ball travel a longer distance. They are know as woods because is older times they were made of wood, however nowadays they are made of a combination of metals and graphite's. As irons, woods also have different lofts and different numbers e.g.: 5 wood, 3 wood or 1 wood which is known as the driver.

In this investigation, I will not be using woods in view of the differences labeled above, and the fact that these clubs would not bring relevant data. My investigation will, however consist of the use of a series of 11 irons including the Sand Wedge (SW), the Lob Wedge (LW), the Pitching Wedge (P), and irons 2,3,4,5,6,7,8 and 9. As my research question states, I will be observing two factors, the first being the loft of the club face, and the second being the distance traveled by the ball. To obtain the most accurate results possible, and in view of the fact that the different lofts of clubs is meant for a different swing and setup, i.e. a chip shot with a wedge uses a half swing, and a fairway shot with a 4 iron uses a wide bodied stance and a full swing; I will attempt to keep a constant swing equal in force throughout the range of clubs I will be using. I have spent a considerable amount of time working on a swing and a stance that I am confident will act as a constant throughout the gathering of results. This swing will comprise of a full bodied golf swing with a setup whereby my feet remain exactly 60cm apart. Furthermore, I will be taking a total of 8 trials in two different driving ranges in order for my investigation to be the most accurate possible. To determine whether a correlation exist between the club angle and the distance traveled by the ball, I will be using a series of mathematical tests and processes, including frequency tables, scatter diagrams, and correlation coefficients.

It is my hypothesis that I will discover a negative correlation between the loft of the club and the distance traveled by the ball, i.e. that the larger the angle, the shorter the distance traveled by the ball, and inversely, the smaller the angle, the larger the distance traveled by the ball.

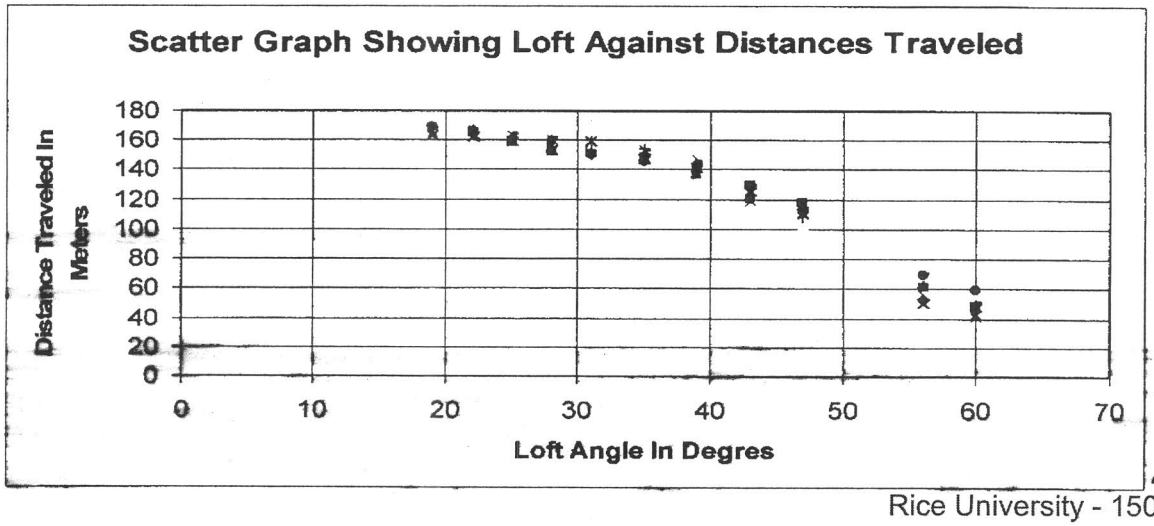
Rice University - 149/263

Is their a relationship between the club face angle and the distance traveled by the ball?

In gathering my results I attached a particular importance on keeping my variables and my constants exact and precise. My swing was developed over a series of weeks prior to beginning my research. I developed a swing that would remain constant throughout the proceedings. In all honesty, it is difficult, and even impossible to give with exact certitude the affirmation that this swing remained constant. To combat this, or rather to incorporate this uncertain constant, I undertook many trials, in not one, but two different driving ranges, the first being the Domaine Imperial Club of Gland Switzerland and the second being the Bonita Bay Golf Club of Bonita Springs, Florida. I was able to measure the distances traveled using pins placed at 50 meter intervals on the driving range and measuring the difference between these pins with measuring tape. Therefore, my results are as exact as possible. My results are as follows:

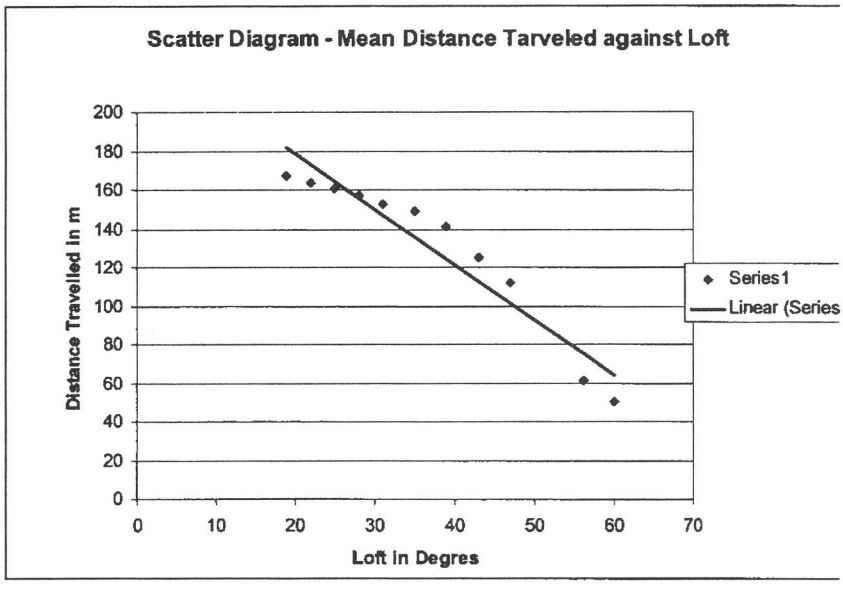
Club Number	Loft	Distance Traveled in m							
		trial 1	trial 2	trial 3	trial 4	trial 5	trial 6	trial 7	trial 8
2	19°	166	168	167	165	163	169	166	168
3	22°	164	165	160	167	162	166	167	160
4	25°	161	158	162	163	159	160	161	164
5	28°	156	152	158	160	153	159	160	161
6	31°	150	153	156	151	159	150	153	152
7	35°	149	148	145	153	147	145	154	153
8	39°	142	136	139	147	141	138	137	145
9	43°	128	130	122	119	126	120	121	130
P	47°	112	118	102	110	111	117	108	114
SW	26°	52	61	68	56	50	69	62	70
LW	60°	52	48	55	41	43	59	49	50

It is clear by observing these results that as the loft of the club increases the distance traveled by the ball decreases. This does not altogether prove that there is a correlation. However by observing the scatter diagram hereunder, which is based on the average distance traveled against the loft of the club, it becomes clear that the relationship between these two variables is strong.



To further determine the extent of this correlation, I have graphed a scatter graph of the average distance traveled by the ball against the loft of the club. It is clear by observing this graph that there exists a strong negative correlation.

Loft	Mean	Median
19	167	167
22	164	165
25	161	161
28	157	159
[illegible]	153	153
35	149	149
39	141	140
43	125	124
47	112	112
56	61	62
60	50	50



If this line correlation is in fact linear, we can calculate the equation of this line by taking two points off this graph using the following calculation:

E.g.: points (60; 50) and (25; 161)

$$\frac{y-b}{x-a} = m \qquad \frac{50-161}{60-25} = -3.17 \qquad \frac{y-161}{x-25} = -3.17$$

$$\therefore \; y-161 = -3.17(x-25)$$

$$\therefore \; y-161 = -3.17x+79.25$$

$$i.e., \; y = -3.17x+240.25$$

Assuming this correlation is in fact linear; we can determine the extent of the correlation between loft and distance traveled by using **Pearson's Correlation Coefficient**:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2}\sqrt{\sum(y-\bar{y})^2}}$$

Club Number	Angle X (degrees)	Distance Y (meters)
2	19	167
3	22	164
4	25	161
5	28	157
6	31	153
7	35	149
8	39	141
9	43	125
P	47	112
SW	56	61
LW	60	50

X	Y	XY	X^2	Y^2
19	167	3173	361	27889
22	164	3608	484	26896
25	161	4025	625	25921
28	157	4396	784	24649
31	153	4743	961	23409
35	149	5215	1225	22201
39	141	5499	1521	19881
43	125	5375	1849	15625
47	112	5264	2209	12544
56	61	3416	3136	3721
60	50	3000	3600	2500
Total = 405	Total = 1438	Total = 47'714	Total = 16'755	Total = 205'236

n=11 $\sum x = 405$ $\sum y = 1'438$ $\sum xy = 47'714$ $\sum x^2 = 16'755$ $\sum y^2 = 205'236$

$$r = \frac{47714 - 11(405/11)(1438/11)}{\sqrt{16755 - 11\times(\frac{405}{11})^2}\ \sqrt{205236 - 11\times(\frac{1438}{11})^2}} = \frac{-5304.181}{42.937\times 131.339} = \frac{-5304.181}{5639.420} = -0.940$$

Clearly we have a strong negative association between the angle of the club head and the distance the ball travels. This says that generally, the smaller the club face loft, the greater the distance traveled.

We can use the **Coefficient of Determination** to describe the strength of association between these two variables by doing:

r^2

Therefore $r^2 = 0.883$

This result confirms the previous notion that in fact there is a strong correlation.

We can also use the Least Squares Regression technique in order to further determine the relationship between club face angle and distance traveled:

$$y - \bar{y} = \frac{s_{xy}}{s_x 2}(x - \bar{x})$$

X	Y	XY	X^2
19	167	3173	361
22	164	3608	484
25	161	4025	625
28	157	4396	784
31	153	4743	961
35	149	5215	1225
39	141	5499	1521
43	125	5375	1849
47	112	5264	2209
56	61	3416	3136
60	50	3000	3600
Total = 405	Total = 1438	Total = 47'714	Total = 16'755

So,

$$\sum x = 405 \quad , \quad \sum y = 1438 \quad ,$$

$$\sum xy = 47714 \quad , \quad \sum x^2 ,$$

$$n = 11$$

$$\bar{x} = \frac{\sum x}{n} = \frac{405}{11} = 36.8 \quad \textit{and} \quad \bar{y} = \frac{\sum 1438}{11} = 130.7$$

$$s_{xy} = \frac{\sum xy}{n} - \overline{xy} = \frac{47714}{11} - (36.8 \times 130.7) \cong -472.1$$

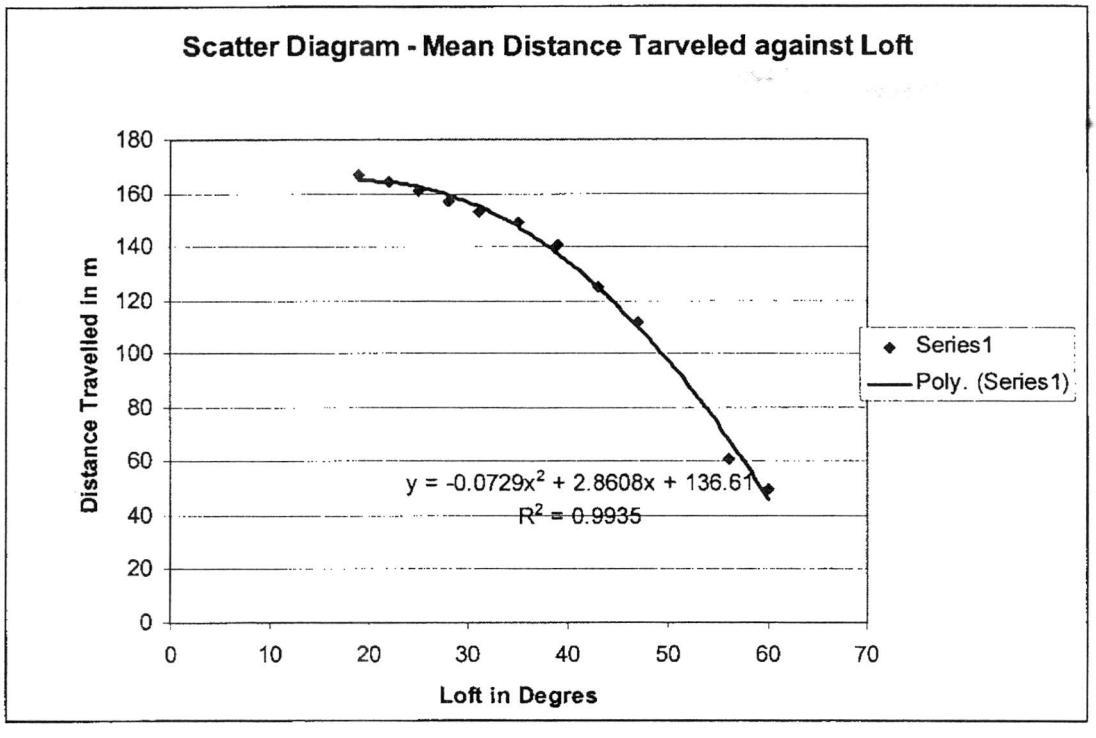
$$s_x^2 = \frac{\sum x^2}{n} - \bar{x}^2 = \frac{16755}{11} - (36.8)^2 = 168.9$$

$$\therefore y - \bar{y} = \frac{s_{xy}}{s_x^2}(x - \bar{x}) = \quad y - 130.7 = -2.8(x - 36.8)$$

$$y = -2.8x + 103 + 130.7$$

$$y = -2.8x + 233.7$$

By observing these results, we can see that the Coefficient of determination has provided a result very similar to that found by calculating the Coefficient of the Line on page 5. However the fact that they are not the same confirm the visibly noticeable fact that the correlation between the loft and the mean distance traveled is not linear but rather like a parabola as shown in the graph hereunder:



It is clear by observing this graph that the correlation is very similar to that previously calculated when we assumed the line to be linear. In fact, all of the previous calculations such as the Pearson's correlation and the Correlation of determination are nonetheless relevant in this investigation. What we can observe now is that the real values of this correlation are in fact stronger. The excel program registers this best fit line to have a regression of 0.99, similar, but stronger than the previously calculated 0.94. The equation of the line however is logically different as it is a parabola and not a straight line.

By observing this parabola equation ($-0.0729x+2.8608x+136.61$), we can easily and confidently predict the distance traveled by inputting the loft desired. E.g., a club loft of 55° would make the ball travel approximately 73.4 meters. This result could be assumed to be very accurate considering that it is within the range of loft and distances actually measured. Predicting outside this range would result in a value that could be considered to be relatively correct but not exact, i.e. a loft of 0° would supposedly result in a distance of 136.61 meters. Though in my personal opinion this result is quite probable, I cannot confirm it to be exact since no data near that loft was investigated.

What is most interesting about this equation is if you calculate the maximum point of the line, (which equals 19.62° at a distance of 164.67meters), it becomes apparent that the beyond this specific loft, as suggested above the ball actually travels a shorter distance.

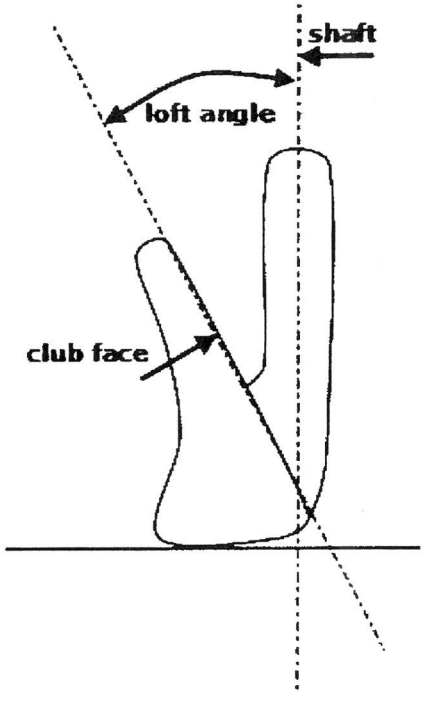
Conclusion

Throughout my research, I attempted to obtain the most accurate results possible by focusing on maintaining the most identical swing possible. In view of the fact that keeping an identical swing, with an identical club speed, is practically impossible to do when using a range of different clubs, I relied on the expert assistance of my two Golf Pros, who kept a constant eye on each swing and those specifically used in the collection of data. This process enabled me to omit many swings that were either too powerful, too wide bodied etc. However there remained two variables that I was unable to control. Those where the length of the club shaft, which differed from club to club, and the weight of the club heads, which also varied from club to club. However to have been able to control these two variables, I would have had to change my golf clubs and modify the shafts. Though I was unable to do this, I am very confident in the accuracy of my results as the actual club weight of my different clubs differs by a barely noticeable amount. The only variable which could have influenced my results would have been the length of the shaft. I am sure, however, that the influence of this variable is minimal, and had I been able to control it, it is my belief that I would have had very similar if not identical results.

To conclude, this investigation has succeeded in proving my hypothesis, which stated that their existed a negative correlation between the loft of the golf club and the distance traveled by the ball after impact, to be true. My investigation has gone even further and shown that beyond 19.62°, the correlation reverses, and the lower the loft, the shorter the distance traveled by the ball.

Rice University - 155/263

Appendix

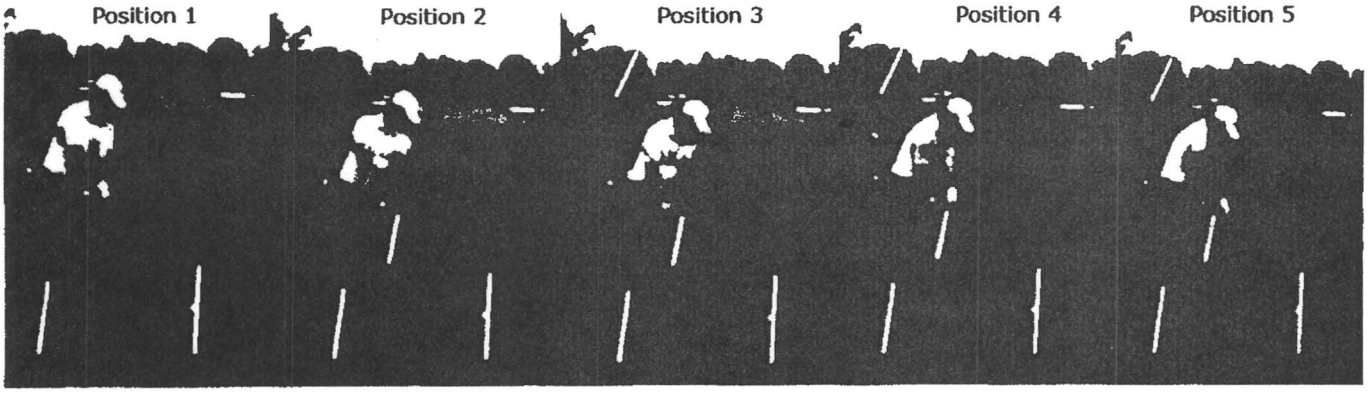


A diagram of a golf club head and the way the loft of the club is measured.

735.CM	2 Iron	3 iron	4 Iron	5 Iron	6 Iron	7 Iron	8 Iron	9 Iron	P	256.14	260.04
OFFSET	.150"	.140"	.130"	.120"	.110"	.100"	.095"	.090"	.085"	56°	60°
BOUNCE	0°	1°	2°	3°	4°	5°	6°	7°	8°	14°	4°
LOFT	**19°**	**22°**	**25°**	**28°**	**31°**	**35°**	**39°**	**43°**	**47°**	**64°**	**64°**
LENGTH	39.50"	39.00"	38.50"	38.00"	37.50"	37.00"	36.50"	36.00"	35.75"	35.25"	35.00"
LIE	59°	60°	61°	62°	62.5°	63°	63.5°	64°	64°	RH/LH	RH
SWINGWEIGHT	D2	D2	D2	D2	D2	D2	D2	D2	D2	Digger	Slider

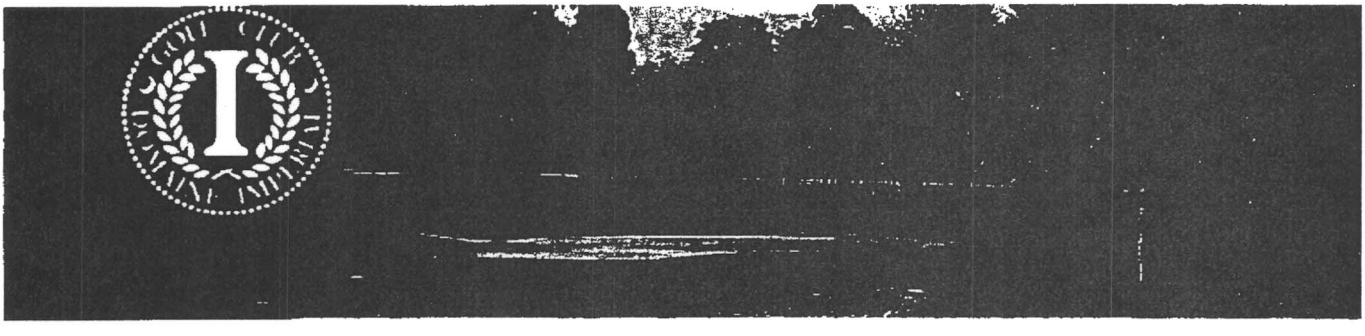
Titleist®

My golf clubs spec sheet, provided by www.titleist.com



A caption by caption view into the swing I used for each shot. I maintained a constant set up with my feet exactly 60cm apart.

The Golf Club Du Domaine Impérial, Gland, Switzerland



The Bonita Bay Golf Club, Bonita Springs, Florida

Bibliography

For mathematical Processes and Calculations:

Mathematics for the international student, Studies SL, International Baccalaureate Diploma Program, **Haese and Harris Publications**

Golf Club Statistics and Information on Loft:

http://www.titleist.com/golfclubs/irons/735cm.asp

Pictures and complementary information:

http://www.titleist.com

http://www.bflivexchange.com/pix/venue/golf-course.jpg

http://www.sciencebuddies.org/mentoring/project_ideas/Sports_img045.jpg

www.domaineimpérial.ch

www.bonitabay.com