

Battle of the Sexes: Is Professional Golf Two Separate Games?

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Abstract

The popularity of the Ladies Professional Golf Association (LPGA) has exploded, but the quality of golf played has not. Despite easier course set-ups, LPGA players fail to match the scores recorded by members of Professional Golfers Association (PGA). Some experts argue that evolution is to blame, and not a lack of skill; men are stronger and always will be. Statistical analysis suggest otherwise. While women struggle with driving distance compared to men, both are evenly-matched in other strength categories. Some members of the LPGA even excel. The explanation for disparity lies elsewhere, and will be found by looking at the opposite end of the spectrum: the short game. Putting is one of the least athletic parts of golf. However, this part of the game is overlooked and under-emphasized. Research shows that it is not *an* important part of golf, but it is *the* most important area of the game.

1 Introduction

Interest in the differences between the Ladies Professional Golf Association (LPGA) and the Professional Golfers Association (PGA) grows in proportion to the achievement of the LPGA. Given the advances of women's rights groups which pushed for inclusion in the sport, golf is supposedly no longer dominated by men, a claim which will receive scrutiny in this study. The LPGA tour has seen a surge in players, and it is inevitable that a comparison between the LPGA Tour and the exclusively-male PGA Tour would result. However, there is not as much data available for the LPGA Tour as there is for the PGA Tour, which adds complexity to the comparison.

There is no arguing that members of the PGA Tour routinely shoot lower scores than their LPGA Tour counterparts, and do so on longer, more difficult golf courses. Critics of the PGA Tour have pointed to this as a consequence of few resources for talented female golfers. Male golfers, they argue, have long drawn much of the publicity, sponsorship and teaching resources and this has given them an unfair advantage.

A plausible (but unpopular) case has been made for this talent discrepancy: Female golfers are not as talented as males because of several factors—physical and non-physical—but always skill related. These attributes—not discrimination—separate the best PGA golfers from everyone else.

No doubt, there are even more theories concerning the difference between the two tours than the ones mentioned here. Rather than focusing on one particular hypothesis and acquiring data to prove it, we will proceed in an inductive manner. This study utilizes a series of tests, which analyze differences between tours and determine whether these differences are statistically significant. From these results, we will draw a conclusion.

2 Development

2.1. Definitions

We will now explain and define some of the important terms utilized in golf. For the purpose of this study, we will examine the two major golfing organizations in the U.S. The **Professional Golfers Association (PGA)** is the most competitive male golfing organization in the world. Similarly, the **Ladies Professional Golf Association (LPGA)** is the most talented group of female players.

Unlike most sports, professional golf is not played on a specified field or arena. Golf courses are as diverse and unpredictable as the topography of the landscape and the imagination of the architect who designed them. However, certain conditions are satisfied despite the venue. Every golf course has a unique **course yardage**. The course yardage is the sum of the yardage for the 18 different golf holes on the course, each of which has its own unique yardage and contributes to the total yardage of the course, which may range from 5,000 to 8,000 yards.

Each of the 18 holes has a unique yardage, as well as **par**. Par refers to the number of strokes in which a golfer is expected to hole out, and is often determined by the length of the hole. There are exactly three types of pars which a regulation golf course could assume: **par 3, par 4 and par 5**, where par 3s are typically the shortest and par 5s the longest. Most golf courses feature the following layout: 4 par 3s, 10 par 4s and 4 par 5s. The **course par** is the sum of par for these 18 different holes, and is in this case 72, which is most common. Exceptions do exist, and some courses have pars of 70, 71 or even 73.

Similar to golf course layouts, the game itself is anything but one-dimensional. Multiple skills affect a player's performance. We will investigate the two broadest categories, the **long game** and the **short game**. The long game focuses on moving the golf ball towards the target, in as few shots as possible. This skill requires a combination of strength and accuracy.

Within the long game exists a unique category known as **driving distance (carry)**. This area of golf relies on exactly one club of the 14 which a player may legally carry: the **driver**. The driver is sometimes referred to as a 1-wood, and with the exception of the putter, is the least-lofted club in a player's bag. Similar to a player's driver or 1-wood is the **3, 5 and 7 wood**. A player may carry all of these or none if he so chooses. The term "wood" derives from the original design of the shaft, which was not made of graphite or iron but of hickory.

The **irons** which a player carries are similar to a player's woods, but are engineered for distance and accuracy, emphasizing precision over power. A player chooses a set of irons (4 iron, 5 iron, 6 iron etc.) each of which travels a precise yardage. These clubs are ideal for landing the golf ball on the **green**, often the flattest surface on the course with tightly-mown grass. This idea of the green gives rise to the term **Greens in Regulation (GIR)**. Like the par of a hole, the GIR is the expectation that a player lands his ball on the green within a certain numbers of strokes. For a par 3, the first stroke, for a par 4 the second, and for a par 5 the third.

Shots that occur very close to the green comprise the areas of the **short game**. Previously mentioned, the green is a unique part of the golf course, around which the short game is focused. In the long game, a player is concerned with advancing his ball towards the green. Of course, every shot a player makes is struck with the hope of holing out, but few players expect to make a shot with a driver or iron. However, as a player gets very close to the green, the player's expectations change. The player no longer hopes to make the next shot, but expects to.

The act of **putting** is one of the most important acts which takes place on the green. A competitor no longer advances his ball through the air. Instead, the golfer must roll the ball on the green towards the hole, with a club known as the **putter**. The putter is the only club in a player's bag with less loft than the driver, but it would be erroneous to assume that its purpose is distance. Strokes made with the putter are often within 50 feet of the hole, and are much shorter and less violent than swings made with other clubs. The extremely low loft of the putter prevents the ball from bouncing or becoming airborne.

A key term concerning a player's putting ability is the **Average Number of Putts**. This statistic is often interpreted poorly and deserves special discussion.

Consider the following situation. On a par 4, player 1 hits a drive and is faced with a 150 yard approach to the green. The player hits the greens in regulation (GIR), and takes 2 putts to finish the hole. Assume the player repeats this style of play for the remainder of the round. The total number of putts equals 18·2. The average number of putts is therefore $\frac{36}{18} = 2$.

Player 2 has a slightly different approach. On a par 4, player 2 hits a drive and is faced with a 150 yard approach to the green. Player 2 misses the green in regulation (GIR). However, the second shot is played from a much shorter distance than his first. Player 2 recovers nicely and hits the next shot close to the hole, requiring only one putt to hole out. If player 2 proceeds in a similar manner for the rest of the round, the total number of putts equals 18·1. The average number of putts is $\frac{18}{18} = 1$.

This area has fallen victim to statistical abuse in the past. As a result, the average number of putts is **only measured when the player hits the green in regulation (GIR)**.

2.2 Hypotheses

This research examines sets of hypotheses. The first three are stated here. For the full list of hypotheses, refer to Appendix I.

H_0 1: There is no difference in scoring average between the LPGA Tour and PGA Tour.

H_1 1: There is a difference in scoring average between the LPGA Tour and PGA Tour.

H_0 2: There is no difference in driving distance average between the LPGA Tour and PGA Tour.

H_1 2: There is a difference in driving distance average between the LPGA Tour and PGA Tour.

H_0 3: There is no difference in driving accuracy average between the LPGA Tour and PGA Tour.

H_1 3: There is a difference in driving accuracy average between the LPGA Tour and PGA Tour.

2.3 Methodology

The purpose of this study is to answer the set of hypothesis which we have laid out. The data collected in this study is from all members of the PGA Tour for the 2013 season and for all members of the LPGA Tour for the 2013 season. We can compare the two sets of data and notice a difference, but it is insufficient to conclude a difference exists. In reality, samples are not always indicative of the population. To establish a difference, a reliable statistical test is required.

In order to establish a significant difference between two sets of data, the t -test assuming unequal variances is used. To perform the t -test assuming unequal variances, we first realized that the variance of the PGA Tour population is not equal to the variance of the LPGA Tour population.

Next, we decided to test our hypotheses at the .05 significance level, or the 95% confidence level. That is, we claim our hypotheses to be true, admitting the possibility of error is less than 5%. The observant reader may note that 5% error is a significant level of uncertainty. While true, t -tests concerning sports research are rarely tested at a level of greater significance. Results taken at the 1% level often do not contradict the measurements taken at the 5% level. More precise methods are found in medical research.

Returning to our methodology, the t -test assuming unequal variance was used to indicate whether we can reject our null hypothesis—that there is no difference between our data sets—or whether we must reject our research hypothesis—that there is a difference in our data. A visual aid is helpful in understanding this process.

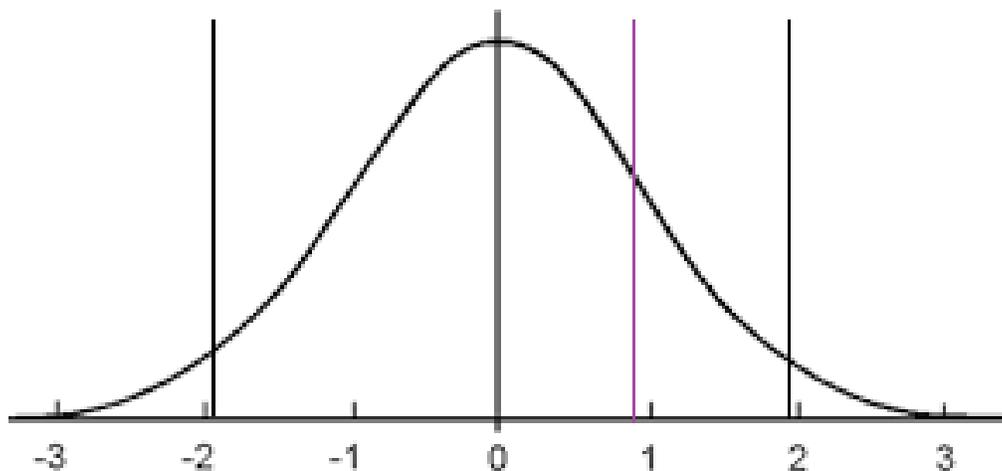


Figure 1: The normal curve with test statistic [8]

Figure 1 depicts the familiar normal curves. Note the grey lines in this figure. These represent the critical values in a t -test assuming equal variance, and the critical values are determined by the confidence level being used. The higher the confidence level being tested, the more extreme these critical values are and the greater their respective absolute values. If a data point falls within the region bounded by the critical values, we cannot conclude that it is significantly different from the average against which we are testing, even if we observe a numerical difference. In this example, the vertical purple line represents the data point. The null hypothesis cannot be rejected.

In Figure 2, we illustrate a different situation.

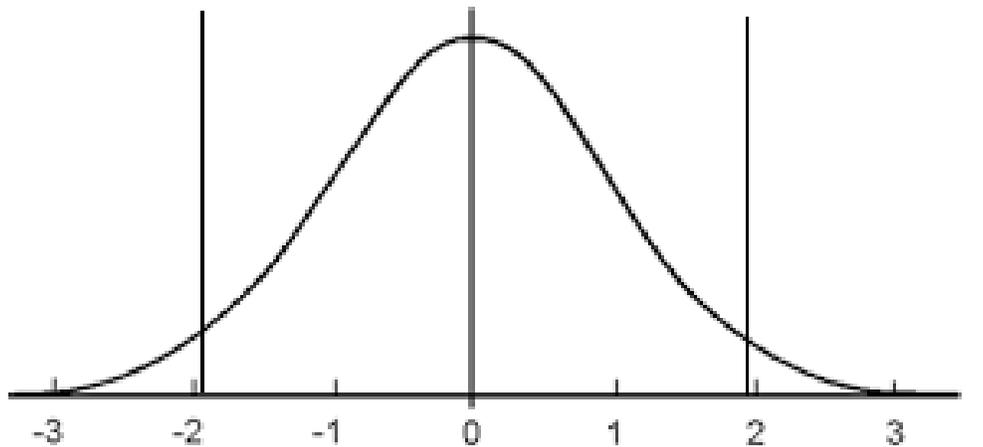


Figure 2: The Normal Curve with Extreme Positive Test Statistic [8]

Figure 2 is different from Figure 1 in one important regard: the data point does not fall between the critical values. Indeed, it lies far to the right of the critical values. The null hypothesis is indeed rejected. We accept the research hypotheses. Furthermore, we note that the sign of the test statistic is positive. This is because the test statistic falls on a positive region of the graph. Hence, the average in question is significantly greater than the average against which it is being tested.

Figure 3 provides yet another situation.

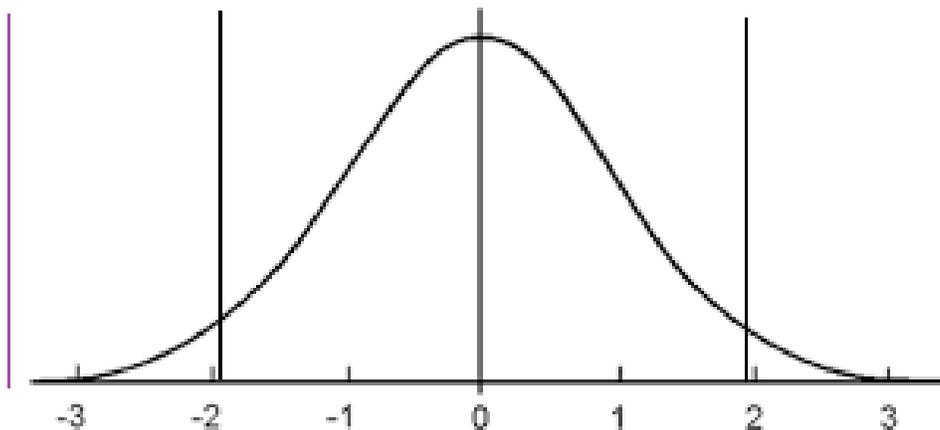


Figure 3: The Normal Curve with Extreme Negative Test Statistic [8]

Similar to Figure 2, the test statistic is not within the region bounded by the critical values. We make the decision to reject the null hypothesis and accept the research hypothesis. In this example, however, the test statistic falls on a negative region of the graph. We interpret this to mean that the average in question is significantly lower than the average against which it is being tested.

A second key test is performed in this study, and it is very similar to the t -test assuming unequal variances. In our study, we examine two LPGA players, Michelle Wie and Annika Sorenstam who played rounds on the PGA Tour. By participating in sanctioned PGA Tour events, both players recorded official PGA Tour statistics, statistics which are not kept for LPGA Tour events.

For these two players, we cannot assume that they represent an entire population. The size of this population is not large enough to provide relevant results. However, we can look at Wie and Sorenstam as part of the PGA population, and test whether their individual averages are significantly different from the population average.

The test used in this case is similar to the t -test assuming unequal variances, in that it sets forth a null and research hypothesis. The test also stipulates a specific criteria for rejecting or accepting the null. In order to establish a significant difference between a population member and the population itself, we must compute the p -value. This term is synonymous to the test statistic for the purpose of our study. If the p -value is less than the .05 significance level, we conclude that there is a difference between the member of the population and the population itself.

However, this test can only be used if the population in question is approximately normal. That is, the PGA Tour averages against which Wie and Sorenstam are compared must follow the bell-shape curve, without significant irregularities. If this condition is not met, then the individual average cannot be tested against the population. However, barring extreme circumstances, the population is most often normal.

3 Results

The first category examined in this study was the scoring average between the PGA and LPGA Tour, but we will first provide a context for our research.

The first category in this research is scoring average, to which we will apply our t -test assuming unequal variance.

H_0 1: There is no difference in scoring average between the LPGA Tour and PGA Tour.

H_1 1: There is a difference in scoring average between the LPGA Tour and PGA Tour.

First, we note our data in Figure 4 which compares the averages.

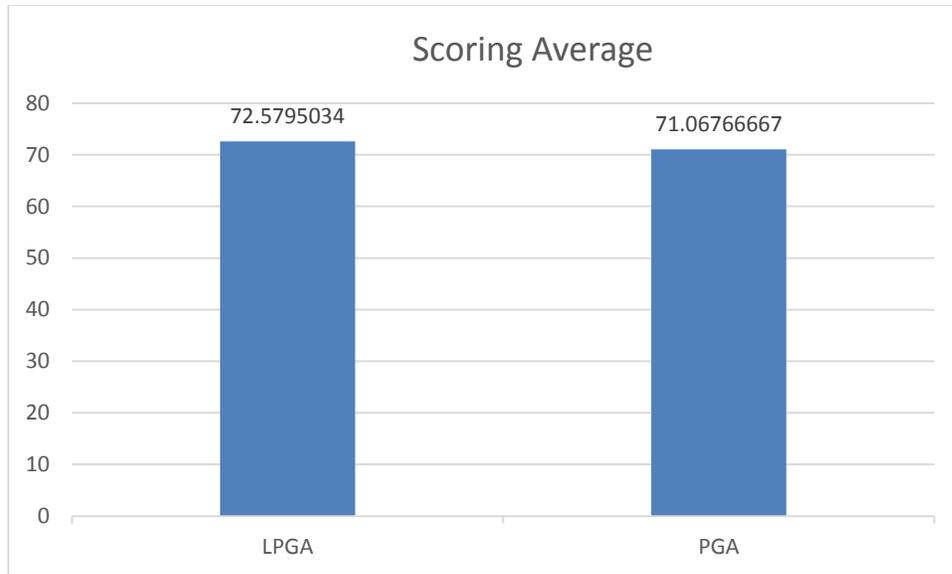


Figure 4: Scoring Averages for PGA Tour and LPGA Tour

The difference between two averages is just over 1.5 strokes, seemingly insignificant. The *t*-test in Figure 5 proves otherwise.

Driving Distance	LPGA	PGA
Mean	72.5795	71.06767
Variance	1.664751	0.346987
Observations	147	180
Hypothesis	0	
Df (degrees of freedom)	195	
T Stat	13.13274	
P(T<=t) one tail	6.12E-29	
T critical one tail	1.652705	
P(T<=t) two tail	1.22E-28	
T Critical two tail	1.972204	

Figure 5: The *t*-test Assuming Unequal Variances for PGA and LPGA Scoring Averages

Figure 6 highlights a dramatic distance in driving distance.

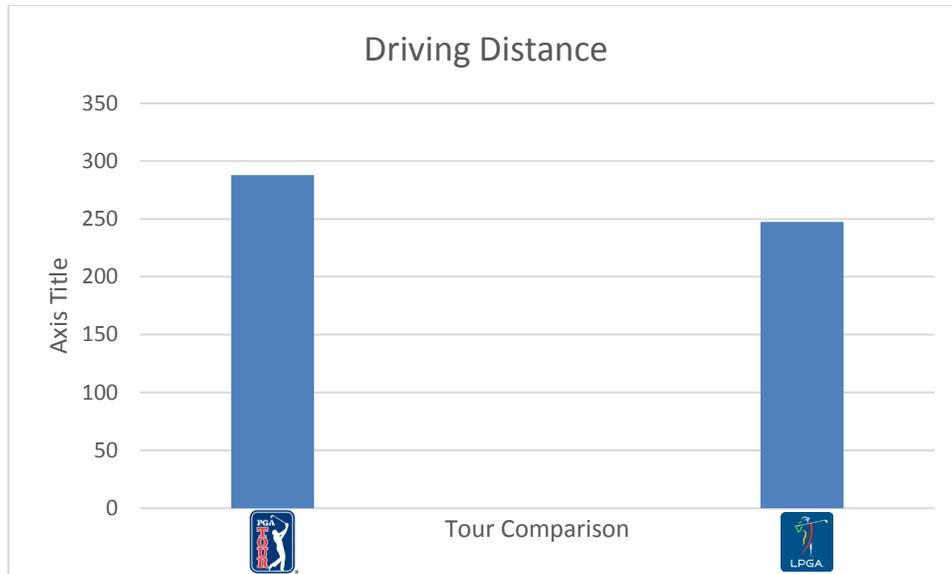


Figure 6: Driving Distance Averages for PGA and LPGA Tour [3, 4]

H_0 2: There is no difference in driving distance average between the LPGA Tour and PGA Tour.

H_1 2: There is a difference in driving distance average between the LPGA Tour and PGA Tour.

To prove a difference between the groups, the absolute value of the test-statistic must be greater than the critical value for our two-tailed graph. Figure 7 shows this condition is met.

Driving Distance	LPGA	PGA
Mean	247.495	287.8508
Variance	90.28026	63.63072
Observations	147	179
Hypothesis	0	
Df (degrees of freedom)	285	
T Stat	-40.983	
P(T<=t) one tail	8.5E-122	
T critical one tail	1.650218	
P(T<=t) two tail	1.7E-121	
T Critical two tail	1.968323	

Figure 7: The t -test Assuming Unequal Variance for PGA and LPGA Driving Distance [3, 4]

The next category to be considered is driving accuracy.

H_0 3: There is no difference in driving accuracy average between the LPGA Tour and PGA Tour.

H_1 3: There is a difference in driving accuracy average between the LPGA Tour and PGA Tour.

We consider the results of the t -test assuming unequal variances in Figure 8.

Driving Accuracy	LPGA	PGA
Mean	70.50272	61.292
Variance	55.73438	22.52082
Observations	147	180
Hypothesis	0	
Df (degrees of freedom)	237	
T Stat	12.97077	
P(T<=t) one tail	9.89E-30	
T critical one tail	1.651308	
P(T<=t) two tail	1.98E-29	
T Critical two tail	1.970024	

Figure 8: The t -test Assuming Unequal Variances for PGA and LPGA Driving Accuracy [3, 4]

The p -value is zero for all practical purposes. Hence, we reject the null, and accept the research. The LPGA driving accuracy category is better than the PGA driving accuracy.

The next category to consider is the greens in regulation (GIR). We formally state our null and research hypotheses.

H_0 4: There is no difference in greens in regulation (GIR) average between the LPGA Tour and PGA Tour.

H_1 4: There is a difference in greens in regulation (GIR) average between the LPGA Tour and PGA Tour.

Figure 9 provides the results of the t -test.

Greens in Regulation (GIR)	LPGA	PGA
Mean	65.5048	64.99139
Variance	27.5119	6.358364
Observations	147	180
Hypothesis	0	
Df (degrees of freedom)	200	
T Stat	1.086955	
P(T<=t) one tail	0.139182	
T critical one tail	1.652508	
P(T<=t) two tail	0.278365	
T Critical two tail	1.971896	

Figure 9: The *t*-test Assuming Unequal Variances for PGA and LPGA GIR Averages

Because of the large *p*-value, we are not able to reject the null hypothesis at the .05 significance level. Hence, we cannot conclude that there is a difference in greens in regulation (GIR) between tours.

Next, we turn our attention to the opposite end of the spectrum: the short game. The first category to compare is putting average.

Figure 10 shows the difference in putting average between the PGA and LPGA Tour.

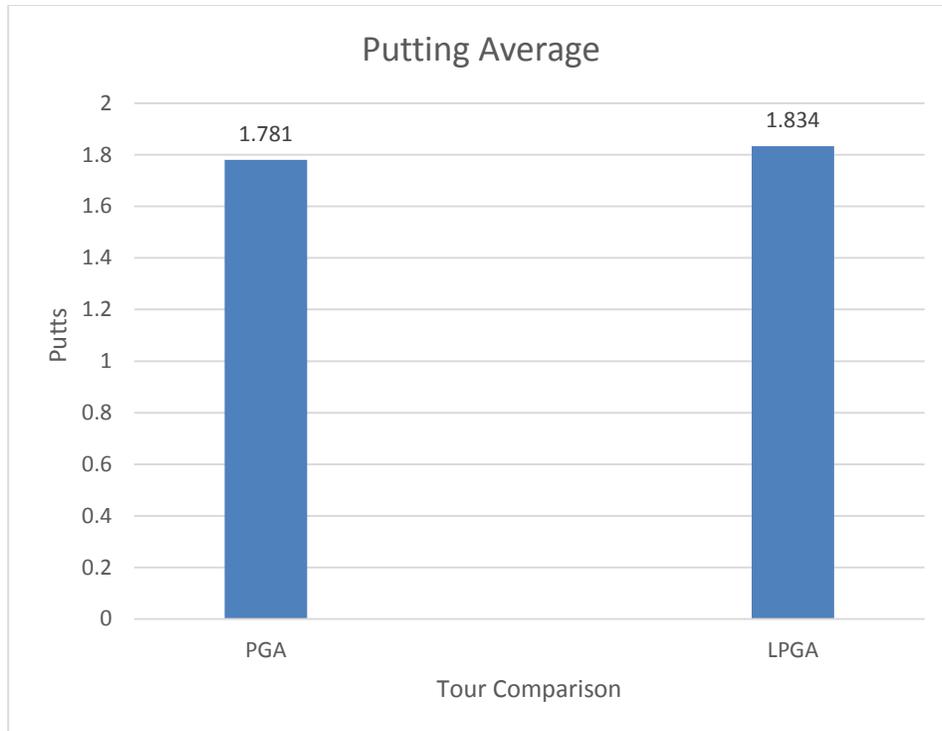


Figure 10: Putting Averages for PGA and LPGA Tour [3, 4]

Immediately, a difference seems very small. However, it is still significant and we will prove it.

H_0 5: There is no difference in putting average between the LPGA Tour and PGA Tour.

H_1 5: There is a difference in putting average between the LPGA Tour and PGA Tour.

Figure 11 lists the results of the t -test.

Putting Average	LPGA	PGA
Mean	1.834349	1.781494
Variance	0.001264	0.000803
Observations	149	180
Hypothesis	0	
Df	281	
T Stat	14.68878	
P(T<=t) one tail	6.16E -37	
T critical one tail	1.650294	
P(T<=t) two tail	1.23E -36	
T Critical two tail	1.968442	

Figure 11: The *t*-test Assuming Unequal Variances for PGA and LPGA Tour Putting Averages [3, 4]

Note that the magnitude of the *t*-statistic still allows us to reject the null. We note that the sign is positive, which indicates that the LPGA has a higher putting average than the PGA.

Unfortunately, we are not able to make a comparison for the next two categories (putting from 3-5' and 3-putt avoidance) because no LPGA data exists. We will explore this more in depth in our discussion.

We continue with the next fundamental part of the short game, which is the birdie average.

H_0 6: There is no difference in birdie average between the LPGA Tour and PGA Tour.

H_1 6: There is a difference in birdie average between the LPGA Tour and PGA Tour.

Figure 12 shows the results of the *t*-test for birdie average.

Birdie Average	LPGA	PGA
Mean	3.022674	3.442944
Variance	0.21821	0.086862
Observations	172	180
Hypothesis	0	
Df	286	
T Stat	-10.0428	
P(T<=t) one tail	7.95E-21	
T critical one tail	1.650199	
P(T<=t) two tail	1.59E-20	
T Critical two tail	1.968293	

Figure 12: The *t*-test Assuming Unequal Variances for PGA and LPGA Putting Averages [3, 4]

In Figure 13, we find a discrepancy in course yardage between the PGA and LPGA Tour.

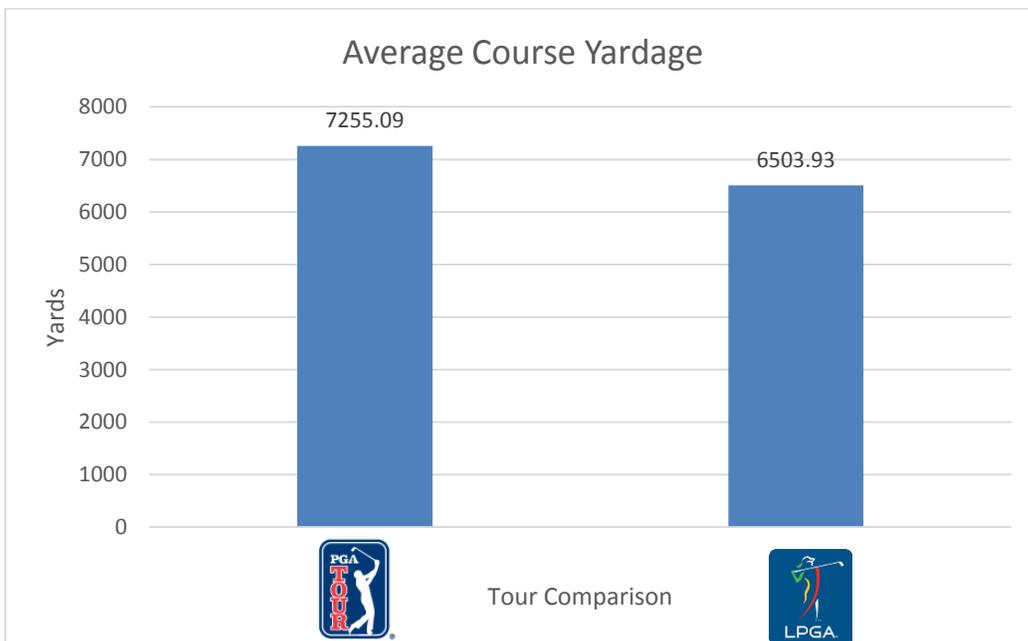


Figure 13: Course Yardage Averages for PGA and LPGA Tours [3, 4, 6, and 7]

Next, we consider whether this difference makes a difference in playability between Tours. We will make the assumption that a player attempts to reach the green when possible. Furthermore, we will assume that the PGA course follows the standard layout of 10 par 4s, 4 par 3s, and 4 par 5s.

In a typical round, we will assume a PGA player hits driver off every par 4 and an iron to the green. On a par 5 the pro hits driver off the tee, his next shot towards the green with a 3 wood and finally an iron onto the green. On every par 3 the player will hit an iron. Trackman Golf yields key yardages for PGA and LPGA professionals.

Figure 14 highlights the important ball-striking categories and averages for members of the PGA and LPGA Tour.

	PGA	LPGA
Course Yardage	7255.09 yards	6503.93 yards
Driving Distance Carry	275 yards	218 yards
3 Wood Carry	243 yards	195 yards
6 Iron Carry	183 yards	152 yards

Figure 14: Key PGA and LPGA Yardage Averages [1, 3, 4, 6, and 7]

We let d , w and i represent the player's driver, 3 wood and iron, respectively. Next, we set forth the equation for course yardage in terms of these clubs: $14d+4w+18i = 7255.09$. Substituting in the appropriate yields $14(275) + 4(243) + 18i = 7255.09$. We solve for i : $i=173.79$. A 6 iron (183 yards) is required to cover.

We will develop a similar equation for the LPGA players. We represent the driver, 3 wood and iron with the variables d , w and i . This yields: $14(218) + 4(195) + 18i=6503.93$. We again solve for i : $i=148.44$, which requires a 6 iron (152 yds) to cover. Note that on average, the same club (6 iron) is required for members of both tours.

Now, we move to the other end of the spectrum: the short game. The data in this regard is harder to understand, and the discrepancy is not so obvious:

We will determine whether there is a difference between Annika Sorenstam's play on the PGA Tour and the averages of the PGA Tour itself. We will begin by analyzing the long game.

Sorenstam's statistics are listed in Figure 13, with PGA and LPGA averages provided for comparison.

	Drive Accuracy	Drive Distance	Greens In Regulation
Sorenstam	85%	268.0 yds	66%
PGA Tour 2013	61.29%	289.76 yds	64.99%
LPGA Tour 2013	70.5%	247.50 yds	65.5%

Figure 15: Sorenstam and Tour Averages [3, 4]

The first category to examine is driving distance. In Figure 16, we note that driving distance on the PGA Tour follows a normal distribution.

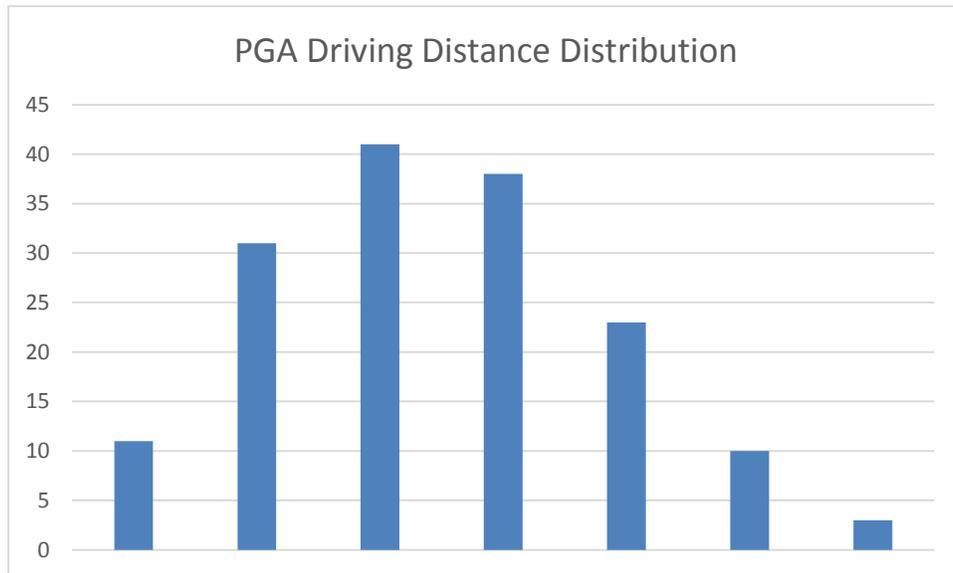


Figure 16: PGA Tour Driving Distance Distribution [3, 4]

Hence, we continue with our hypotheses.

H_0 7: There is no difference between Sorenstam's driving distance average and PGA Tour driving distance average.

H_1 7: There is a difference between Sorenstam's driving distance average and PGA Tour driving distance average.

The PGA mean driving distance μ is 287.92 yards with a standard deviation σ of 8.01 yards. Sorenstam's average driving distance x in PGA Tour events was 268.0 yards. We substitute these values into the equation for z-score: $z = \frac{x-\mu}{\sigma}$. This yields: $z = \frac{268.0-287.92}{8.01} = -2.49$.

The probability of a value more extreme (p -value) is: $0.5-0.4936 = 0.0064$, or .64%. Testing at the .05 significance level, this allows us to reject the null hypothesis. Thus, the research hypothesis is accepted.

Next, we will test the driving accuracy category. Figure 17 illustrates the distribution of driving accuracy on the PGA Tour.

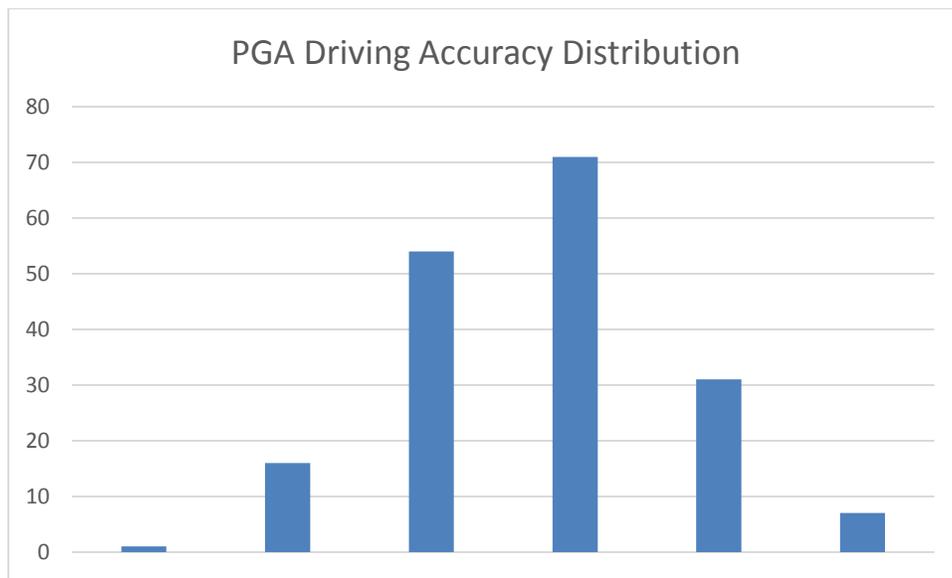


Figure 17: PGA Tour Driving Accuracy Distribution [3, 4]

Driving accuracy on the PGA Tour follows a normal distribution.

H_0 8: There is no difference in Sorenstam's driving accuracy average and the PGA Tour driving accuracy average.

H_1 8: There is a difference in Sorenstam's driving accuracy average and the PGA Tour driving accuracy average.

The average driving accuracy for the PGA Tour is 61.28 with a standard deviation σ of 4.75. Sorenstam's driving accuracy is 85. Substituting these values into the equation for z-score yields

$$z = \frac{85-61.28}{4.75} = 5.00.$$

Standard Z-tables do not have probabilities available for such extreme values. For our study, the p -value is zero, which is less than the .05 critical value needed to reject the null. The null hypothesis is rejected; the research hypothesis is accepted.

The next category to be tested is Greens in Regulation (GIR). We describe the GIR distribution for the PGA Tour in Figure 18.

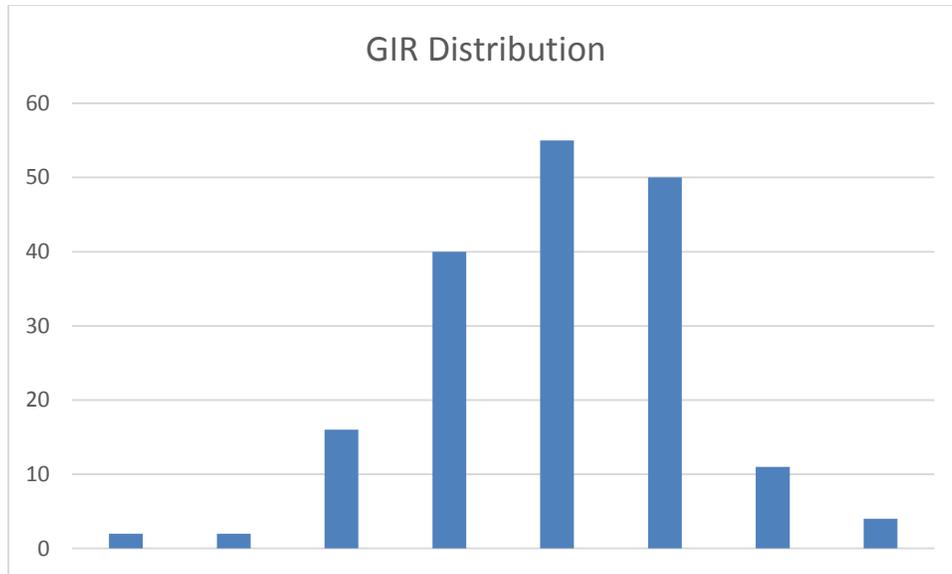


Figure 18: PGA Tour GIR Distribution [3, 4]

PGA Tour averages follow the normal distribution.

On the PGA Tour, the GIR average μ is 64.99 with a standard deviation of 2.52. Sorenstam's GIR percentage is 66. Making the necessary substitutions into the equation, we obtain: $z = \frac{66-64.99}{2.52} = 0.40$

This z-value corresponds to a probability of .16, which is greater than the .05 critical value needed to reject the null. The null hypothesis is not rejected, and the research hypothesis cannot be accepted. There is no difference in GIR between Sorenstam and the PGA Tour.

The next categories we will examine pertain to the short-game and scoring. Figure 19 highlights Sorenstam's short-game statistics compared to PGA Tour and LPGA Tour averages.

	Putting from 3-5'	3-putt avoidance	Birdie Average	Scoring Average
Sorenstam	80.00%	11.11%	1.00	72.43
PGA Tour 2013	86.50%	2.94%	3.44	70.91
LPGA Tour 2013	N/A	N/A	3.02	72.58

Figure 19: PGA Tour Short Game Averages [3, 4]

The distribution of putting from 3-5' is listed in Figure 20.

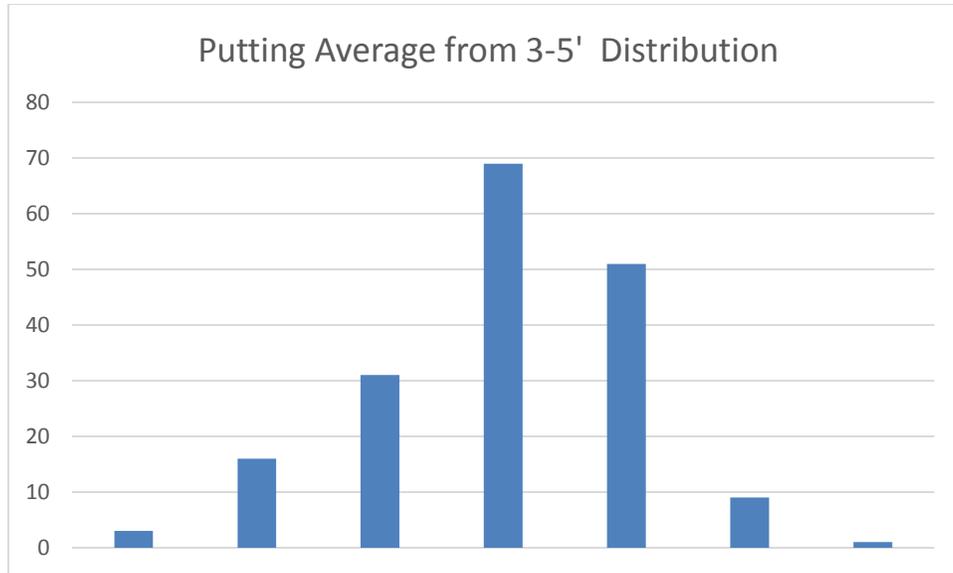


Figure 20: PGA Tour Putting Average from 3-5' Distribution [3]

Indeed, PGA Tour putting averages from 3-5' are normally-distributed.

H_0 : There is no difference in Sorenstam's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

H_1 : There is a difference in Sorenstam's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

The PGA Tour average μ from 3-5' is 86.50 with a standard deviation σ of 3.23. Sorenstam's putting average from 3-5' is 80. Substituting these values into the equation for z-score yields:
$$z = \frac{80 - 86.50}{3.23} = -2.01$$
 This z-value corresponds to a probability of 0.02, which is less than the 0.05 critical test value. Hence, the null is rejected and the research is rejected.

The next category to be tested is 3-putt avoidance. The distribution is found in Figure 21.

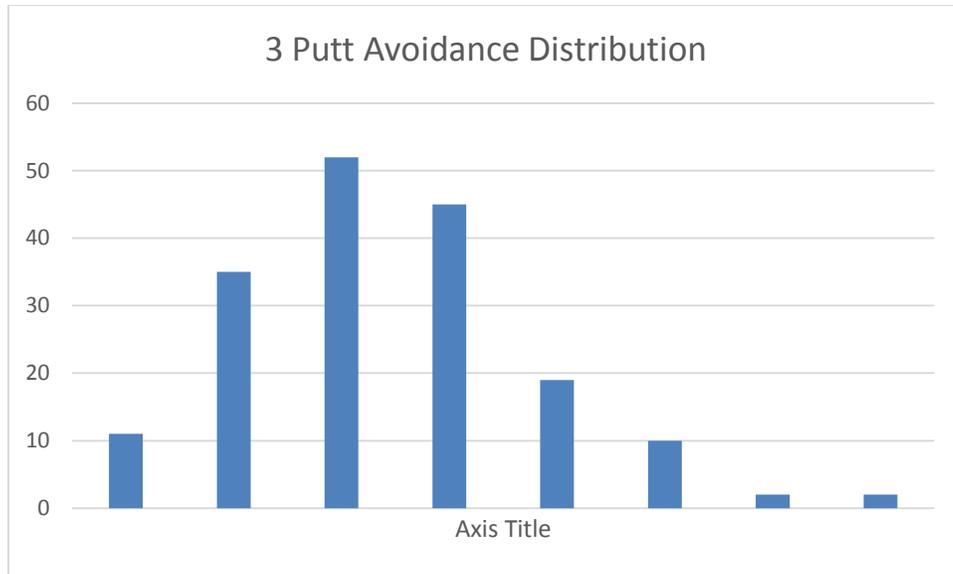


Figure 21: PGA Tour 3 Putt Avoidance Distribution [3]

The PGA Tour 3-Putt Avoidance averages are normally-distributed.

H_0 10: There is no difference in Sorenstam's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

H_1 10: There is a difference in Sorenstam's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

The PGA Tour average 3-putt avoidance μ is 2.94 with a standard deviation σ of 0.69. Sorenstam's 3-putt avoidance is 11.11. We compute the z-score and find: $z = \frac{11.11 - 2.94}{0.69} = 11.89$

Standard normal tables do not account for values this large. For our purposes, the p value is zero, and is therefore less than the 0.05 critical test value. Hence, the null is rejected and the research is respected. Sorenstam's 3-putt avoidance is worse than the PGA Tour average.

The next category to investigate is birdie average. Figure 22 describes the birdie average distribution on the PGA Tour.

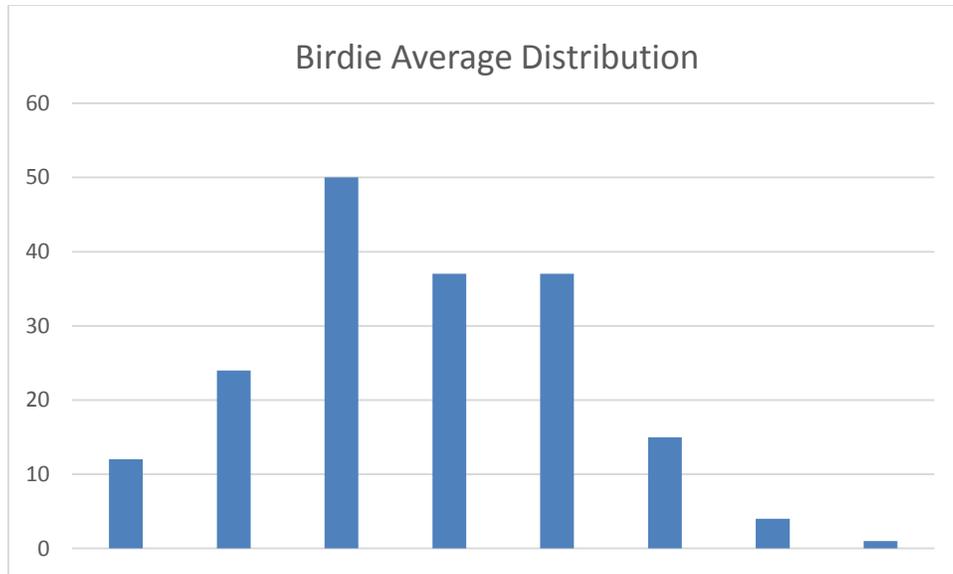


Figure 22: PGA Tour Birdie Average Distribution [3]

The birdie average for the PGA Tour is normally distributed.

H_0 11: There is no difference in Sorenstam's PGA Tour birdie average and the PGA Tour birdie average.

H_1 11: There is a difference in Sorenstam's PGA Tour birdie average and the PGA Tour birdie average.

The mean PGA Tour birdie average μ is 3.44, with a standard deviation σ of 0.29. Sorenstam's birdie average x is 1.00. Substituting these values into the equation for z-score yields: $z = \frac{1.00-3.44}{0.29} = -8.29$.

Standard z-tables do not report probabilities for such extreme values. For practical purposes, we may assume that the p -value is zero. Hence, we reject the null hypothesis; the research hypothesis is accepted. Sorenstam's birdie average is not as high as the PGA Tour average.

The next category we will examine is scoring average. The scoring average distribution of the PGA Tour is listed in Figure 23.

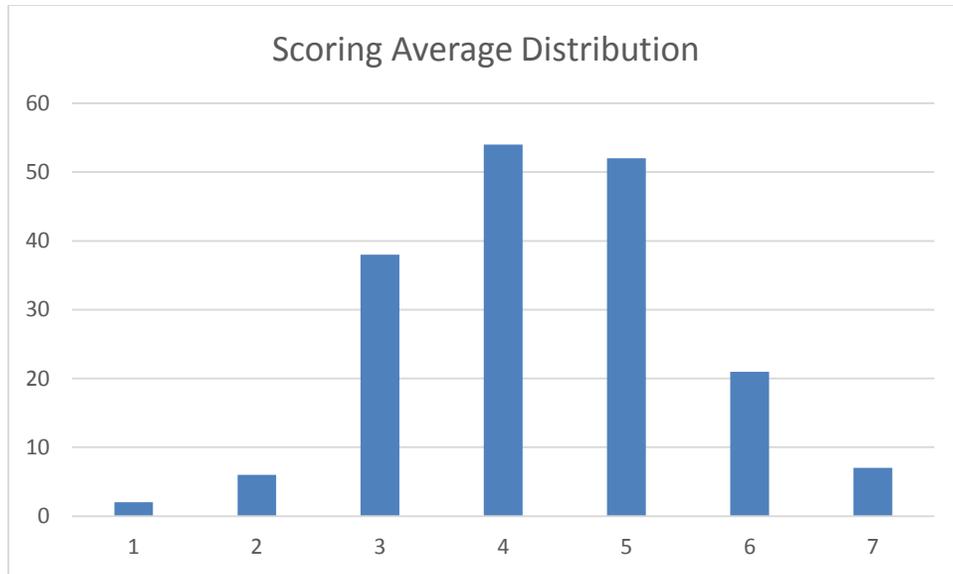


Figure 23: PGA Tour Scoring Average Distribution [3]

The scoring averages on the PGA Tour are normally distributed.

H_0 12: There is no difference in Sorenstam's PGA Tour scoring average and the PGA Tour scoring average.

H_1 12: There is a difference in Sorenstam's PGA Tour scoring average and the PGA Tour scoring average.

The scoring average for the PGA Tour μ is 70.91, with a standard deviation σ of 0.59.

Sorenstam's scoring average x is 72.43. Substituting these values into the equation for z-score yields: $z = \frac{72.43 - 70.91267}{0.59} = 2.59$.

This z-value corresponds to a probability of 0.0048, which is less than the 0.05 critical test value. Hence, the null is rejected; the research is accepted. Sorenstam's scoring average is higher than the PGA Tour average.

We will now perform similar tests, comparing instead the results of Michelle Wie to the PGA Tour. Wie played more events on the PGA Tour than did Sorenstam, and her success will be examined here. We have already determined that the PGA Tour averages are normally distributed in our areas of interest, and will not bother to state this for each category. What interests us now is Wie's results against these averages. These results are found in Figure 24.

	Drive Accuracy	Drive Distance	Greens In Regulation
Wie	55.57%	270.84	48.22%
Sorenstam	85%	268.0 yds	66%
PGA Tour 2013	61.29%	287.85	64.99%
LPGA Tour 2013	70.5%	247.50	65.5%

Figure 24: Long Game Categories for Wie, Sorenstam and PGA and LPGA Tour [3, 4]

We will first focus on driving distance, formally stating our hypotheses.

H_0 13: There is no difference between Wie's PGA Tour driving distance average and PGA Tour driving distance average.

H_1 13: There is a difference between Wie's PGA Tour driving distance average and PGA Tour driving distance average.

The average driving distance on the PGA Tour μ is 287.92 with a standard deviation σ of 8.01. Wie's driving distance x is 270.84. Substituting these values into the z-score equation yields: $z = \frac{270.84 - 287.92}{8.01} = -2.13$

The probability of a value more extreme p -value equals 0.017 which is less than the .05 significance level. Hence, the null hypothesis is rejected and the research hypothesis is accepted. Wie's driving distance is not as good as the PGA Tour results. Thus, the null hypothesis is rejected; the research hypothesis is accepted.

The next category we will examine is driving accuracy.

H_0 14: There is no difference between Wie's PGA Tour driving accuracy average and the PGA Tour driving accuracy average.

H_1 14: There is a difference between Wie's PGA Tour driving accuracy average and the PGA Tour driving accuracy average.

On the PGA Tour, the average driving accuracy μ is 61.28 with a standard deviation σ of 4.75. Wie's driving accuracy x is 55.57. Substituting these values into the equation for z-score yields: $z = \frac{55.57 - 61.28}{4.75} = -1.20$

This z-value corresponds to a probability of 0.13, which is greater than the 0.05 significance level. Hence, we fail to reject the null hypothesis, and the research hypothesis cannot be accepted. There is no difference in driving accuracy between Wie and the PGA Tour.

The next category of interest is Greens in Regulation (GIR).

We formally state our null hypothesis and research hypothesis.

H_0 15: There is no difference between Wie's PGA Tour GIR average and the PGA Tour GIR average.

H_1 15: There is a difference between Wie's PGA Tour GIR average and the PGA Tour GIR average.

The PGA Tour GIR average μ is 64.99 with a standard deviation σ of 2.52. Wie's GIR statistic x is 48.22. After substituting these numbers into the z-score equation, we obtain: $z = \frac{48.22 - 64.99}{2.52} = -6.65$

Standard normal tables do not accommodate such extreme values. The p -value is zero for our purposes. Hence, the null hypothesis is rejected and the research hypothesis is accepted. Wie's GIR results are not as good as those for the PGA Tour.

We have finished our examination of the areas associated with the long game. We turn our attention towards the short game. The first category to consider is putting from 3-5'. Figure 25 lists short game results for Wie, Sorenstam and the PGA and LPGA Tour averages.

	Putting from 3-5'	3-putt avoidance	Birdie Average	Scoring Average
Wie	86.80%	4.34	2.64	74.25
Sorenstam	80.00%	11.11%	1.00	72.43
PGA Tour 2013	86.50%	2.94%	3.44	70.91
LPGA Tour 2013	N/A	N/A	3.02	72.58

Figure 25: Short Game Categories for Wie, Sorenstam and Professional Tours [3, 4]

H_0 16: There is no difference between Wie's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

H_1 16: There is a difference between Wie's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

The PGA Tour putting average μ from 3-5' is 86.50 with a standard deviation σ of 3.23. Wie's putting average is 86.80. After substituting these values into the equation, we find: $z = \frac{86.80-86.50}{3.23} = 0.09$

The corresponding probability is 0.46, which is greater than the 0.05 which we are willing to accept. Hence, we fail to reject the null hypothesis; the research hypothesis cannot be accepted. There is no difference between Wie's PGA Tour putting from 3-5' average and the PGA tour putting from 3-5' average.

The next category we will look at is 3-putt avoidance. We formally state our hypotheses.

H_0 17: There is no difference between Wie's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

H_1 17: There is a difference between Wie's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

On the PGA Tour, the average 3-putt avoidance μ is 2.94, with a standard deviation σ of 0.69. Wie's 3-putt avoidance x is 4.34. We then calculate the z-value to yield: $z = \frac{4.34-2.94}{0.69} = 2.03$.

The corresponding p -value is 0.02. We reject our null hypothesis and accept the research. Wie's 3-putt avoidance results are worse than the PGA Tour averages.

The next category to investigate is birdie average.

H_0 18: There is no difference between Wie's PGA Tour birdie average and the PGA Tour birdie average.

H_1 18: There is a difference between Wie's PGA Tour birdie average and the PGA Tour birdie average.

The birdie average μ for the PGA Tour is 3.44, with a standard deviation σ of 0.29. Wie's birdie average x is 2.64. After substituting these values into the equation for z-score, we obtain: $z = \frac{2.64-3.44}{0.29} = -2.72$

The corresponding p -value is 0.0033, which is less than the 0.05 critical value. This confirms the research hypothesis. Wie's birdie average is not as good as the PGA Tour averages.

The final category we will measure is scoring average. We state our two hypotheses

H_0 19: There is no difference between Wie's PGA Tour scoring average and the PGA Tour scoring average.

H_1 19: There is a difference between Wie's PGA Tour scoring average and the PGA Tour scoring average.

The scoring average μ on the PGA Tour is 70.91, with a standard deviation σ of 0.59. Wie's scoring average x is 74.25. We then calculate the z-score and obtain: $z = \frac{74.25-70.91}{0.59} = 5.69$.

Standard z-tables do not list probabilities for such extreme values. We may assume that the p -value is zero. Hence, our null hypothesis is rejected, and we accept the research hypothesis. Wie's scoring average is worse than the PGA Tour averages.

4 Conclusion and Directions for Further Research

One of the successes of this study is that it illustrates the major ramifications of minor differences. Figure 27 lists the four putting hypotheses which were confirmed.

Hypotheses
$H_1 5$: There is a difference in putting average between the LPGA Tour and PGA Tour.
$H_1 9$: There is a difference in Sorenstam's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.
$H_1 10$: There is a difference in Sorenstam's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.
$H_1 17$: There is a difference between Wie's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

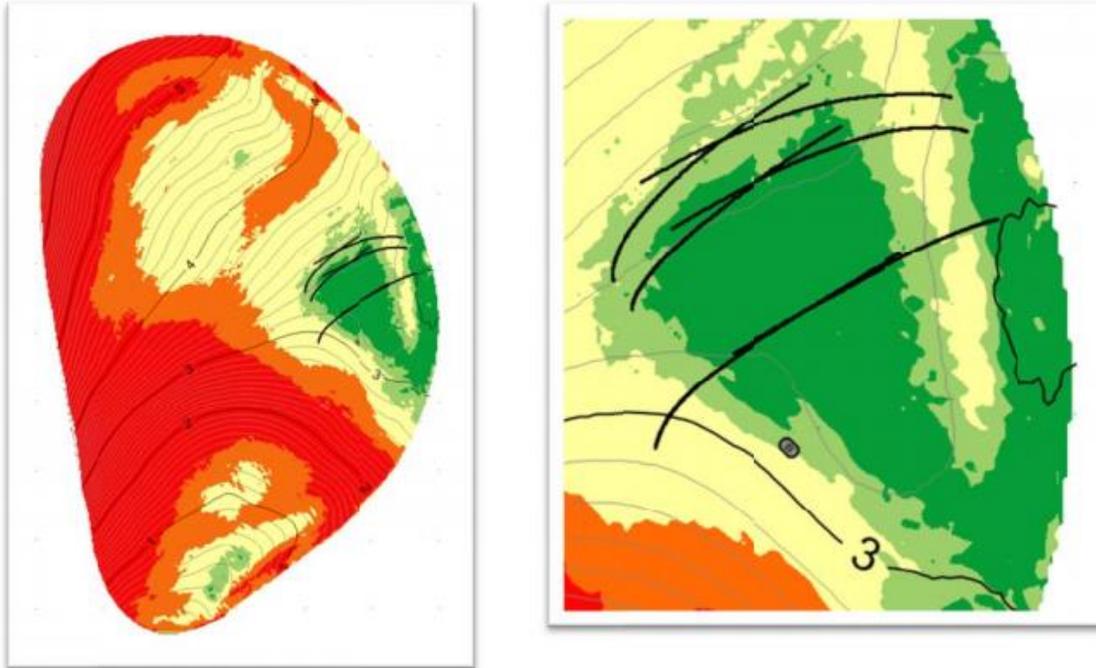
Figure 27: Confirmed Putting Hypotheses

The only exception was $H_1 16$, which measured Michelle Wie's PGA Tour putting from 3-5' and the PGA Tour putting average from 3-5'.

Moreover, Wie's putting averages are in general important to consider. Although she, like Sorenstam, failed to make any cuts on the PGA Tour, her putting averages were significantly better than Sorenstam's. A possible explanation for this is Wie's repeated attempts on the PGA Tour. Sorenstam struggled on the greens in her first event, and did not make subsequent attempts to qualify, but Wie played in multiple PGA events.

Could this really have made a difference, and if so, why should it? It is not as if Wie became physically stronger as a result of playing against men, but she certainly learned about the difficulty of the putting surfaces on the PGA Tour. Moreover, adjusting to the speed and severity of the greens on the PGA Tour would have been difficult for Sorenstam in her one event, than for Wie in repeated attempts.

Although little qualitative evidence exists to compare the greens of the PGA Tour with the greens of the LPGA Tour, an examination of a PGA Tour green itself will provide some important information. Figure 28 is a diagram of a green complex at a PGA Tour. Stimp meter readings are taken by Mark Sweeney, founder of AimPoint Technologies.



Bethpage Black 15th Green

Figure 28: Green Complex [5]

This green is typical of those played on the PGA Tour, and is anything but routine. The areas marked in red, are extremely sloped, those marked in orange are very sloped, with those in green being more level. So difficult is this particular green, that it is almost impossible to get an accurate reading of the green's speed. The black lines indicate readings of the green taken in one of the few flat areas on the green.

In her event on the PGA Tour, Sorenstam did not face greens nearly this severe, but admitted that she could not adapt to the putting surfaces. Wie, on the other hand, had nowhere close to the ball-striking ability of Sorenstam, yet had improved statistics.

Mark Sweeney's company AimPoint Technologies published research on the importance that putting can make for a player. AimPoint analyzed winners on the PGA Tour from 2005-2009 to understand why they achieved victory. The results are startling and are listed in Figure 29.

Winning Avg	2005	2006	2007	2008	2009	Avg
Driving Accuracy	65.1%	68.7%	67.0%	64.5%	66.9%	66.4%
Driving Distance	297 Yds	294 Yds	280 Yds	292 Yds	293 Yds	291 Yds
GIR	74.0%	72.9%	73.1%	72.2%	72.5%	72.9%
Go For Its	64.0%	60.0%	58.7%	58.8%	50.2%	58.3%
Putts Per Round	27.7	27.1	27.9	28.0	27.6	27.6
Putts Per GIR	1.672	1.676	1.679	1.682	1.680	1.678
Total Scrambling	73.4%	71.1%	70.6%	70.3%	70.3%	71.1%

Figure 29: Winning PGA Tour averages [5]

The most important area was putting, in terms of birdie conversion and average number of putts per GIR. Winners convert 33% of birdies vs. 17% compared to other players. That is approximately twice as many birdie putts converted per round. Winners are literally shaving shots off in this area.

Moreover, winners do not putt this well from week-to-week. In fact, the best putter on the PGA Tour at the time of the study could not break the 1.700 average. However, winners routinely break the 1.7 average on a tournament level. In our study, we found only about a 0.05 stroke difference in putting between the PGA Tour and LPGA Tour, and this was significant. Consider that the difference between the winner on a PGA Tour and a PGA Tour average is very close as well, with only a 0.08 stroke difference.

Of what importance, then are the other statistics? Surely, they must have some importance. In truth, they are far less consequential.

The results showed that 66% driving accuracy is sufficient to win. Furthermore, some winners won with only 45% driving accuracy and some won with 88% driving accuracy. The range is extremely large. In our study, we found that Sorenstam drove the ball even better than PGA Tour averages, yet it failed to contribute significantly to her game. Although her skill in this category is exceptional, it seems to be misplaced.

The greens in regulation statistic is more significant than the driving accuracy category; winners hit 2.5% more than losers. However, the lowest GIR percentage was 54%; the average for a winner is 72.5%. Clearly, however, the range is much smaller than for driving accuracy. Greens in regulation is therefore a more important statistic, than driving accuracy. It is interesting to note

that Michelle Wie excelled in putting compared to Sorenstam, but she lagged behind in greens in regulation. Perhaps, her scores would have improved if she had done better in this category.

Perhaps as surprising as the importance of strong putting is the benefit of driving. Although our study found that there were significant differences in driving distances between the PGA Tour and LPGA Tour as well as Sorenstam and Wie, the AimPoint study found that only 7 yards separates the winner on the PGA Tour from the 70th place finisher. This seems to downplay the idea that winners are hitting the golf ball significantly farther. Winners do not seem to be winning directly as a fact of increased distance.

Clearly, then, the putting statistic is dominant. So how can the playing field be leveled in this category? It is clear that LPGA players struggle on the PGA greens, and it is extremely rare for them to qualify for PGA Tour events. An LPGA player might become discouraged, thinking that improving on the greens requires her to qualify for PGA events, during which she will likely struggle because of a lack of experience.

The solution to this problem is simple. LPGA players have no need of playing difficult PGA Tour greens. Part of the reason the PGA Tour plays venues with such difficult greens is because their scoring averages are so low. Our study showed that PGA Tour Pros shoot significantly better than LPGA players. Hence, the reason PGA players play difficult venues is in order that their scores might not be too low. The talent of these players has actually caused anxiety among tournament directors and course architects. These individuals have resorted to extremely fast, undulating and difficult greens as a sort of last resort; otherwise par on the golf course becomes obsolete and the tournament could risk losing notoriety and the privilege of hosting the event itself.

LPGA players do not have to contend with such extreme conditions, which should cause not comfort but concern. Theoretically, LPGA players should have far better putting averages. Because LPGA players already struggle in this area, there exists no reason for the LPGA to either improve or toughen its green complexes. Only once scores begin to plummet does this even become an area of interest, and such is not the case currently. The talent of LPGA players is what could cause this to happen.

Additionally, it would benefit the LPGA and its constituents if more putting statistics were added. The LPGA currently carries two statistics concerning putting. The PGA has 97. If putting is the most important area of the game, the LPGA Tour ought to address it as such. Yes, the strides which the LPGA Tour has taken just to popularize the game are commendable, and now it is time for LPGA players to begin to understand the game. The lack of information on putting is certainly not helping members of the LPGA Tour. As long as the putting on the PGA Tour keeps improving, the LPGA must work harder in this area as well.

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- [6] Briggs, Meg, PGA Tour Communications Administrative Assistant (personal communication, September 12, 2014).
- [7] Haas, Matt, LPGA Tour Media Coordinator (personal communication, September 12, 2014).

Appendix I.

H_0 1: There is no difference in scoring average between the LPGA Tour and PGA Tour.

H_1 1: There is a difference in scoring average between the LPGA Tour and PGA Tour.

H_0 2: There is no difference in driving distance average between the LPGA Tour and PGA Tour.

H_1 2: There is a difference in driving distance average between the LPGA Tour and PGA Tour.

H_0 3: There is no difference in driving accuracy average between the LPGA Tour and PGA Tour.

H_1 3: There is a difference in driving accuracy average between the LPGA Tour and PGA Tour.

H_0 4: There is no difference in greens in regulation (GIR) average between the LPGA Tour and PGA Tour.

H_1 4: There is a difference in greens in regulation (GIR) average between the LPGA Tour and PGA Tour.

H_0 5: There is no difference in putting average between the LPGA Tour and PGA Tour.

H_1 5: There is a difference in putting average between the LPGA Tour and PGA Tour.

H_0 6: There is no difference in birdie average between the LPGA Tour and PGA Tour.

H_1 6: There is a difference in birdie average between the LPGA Tour and PGA Tour.

H_0 7: There is no difference between Sorenstam's driving distance average and PGA Tour driving distance average.

H_1 7: There is a difference between Sorenstam's driving distance average and PGA Tour driving distance average.

H_0 8: There is no difference in Sorenstam's driving accuracy average and the PGA Tour driving accuracy average.

H_1 8: There is a difference in Sorenstam's driving accuracy average and the PGA Tour driving accuracy average.

H_0 9: There is no difference in Sorenstam's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

H_1 9: There is a difference in Sorenstam's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

H_0 10: There is no difference in Sorenstam's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

H_1 10: There is a difference in Sorenstam's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

H_0 11: There is no difference in Sorenstam's PGA Tour birdie average and the PGA Tour birdie average.

H_1 11: There is a difference in Sorenstam's PGA Tour birdie average and the PGA Tour birdie average.

H_0 12: There is no difference in Sorenstam's PGA Tour scoring average and the PGA Tour scoring average.

H_1 12: There is a difference in Sorenstam's PGA Tour scoring average and the PGA Tour scoring average.

H_0 13: There is no difference between Wie's PGA Tour driving distance average and PGA Tour driving distance average.

H_1 13: There is a difference between Wie's PGA Tour driving distance average and PGA Tour driving distance average.

H_0 14: There is no difference between Wie's PGA Tour driving accuracy average and the PGA Tour driving accuracy average.

H_1 14: There is a difference between Wie's PGA Tour driving accuracy average and the PGA Tour driving accuracy average.

H_0 15: There is no difference between Wie's PGA Tour GIR average and the PGA Tour GIR average.

H_1 15: There is a difference between Wie's PGA Tour GIR average and the PGA Tour GIR average.

H_0 16: There is no difference between Wie's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

H_1 16: There is a difference between Wie's PGA Tour putting from 3-5' average and the PGA Tour putting from 3-5' average.

H_0 17: There is no difference between Wie's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

H_1 17: There is a difference between Wie's PGA Tour 3-putt avoidance average and the PGA Tour 3-putt avoidance average.

H_0 18: There is no difference between Wie's PGA Tour birdie average and the PGA Tour birdie average.

H_1 18: There is a difference between Wie's PGA Tour birdie average and the PGA Tour birdie average.

H_0 19: There is no difference between Wie's PGA Tour scoring average and the PGA Tour scoring average.

H_1 19: There is a difference between Wie's PGA Tour scoring average and the PGA Tour scoring average.