The Value of Distance

Table of Contents

1. Introduction (page 2)
2. Methods (page 2)
3. Definitions (page 4)
4. Summary of Findings (page 5)
5. Impact of Distance (page 7)
    A. Impact of Driving Distance Ability Through Bag (page 7)
    B. Correlation Between Driving Distance and Relevant Stats (page 7)
        I. LPGA TOUR
        II. PGA TOUR
        III. Driving distance over-time on PGA TOUR
        IV. Driving accuracy over-time on PGA TOUR
6. Value of Distance for Mens Professional (page 11)
    A. Shot-by-Shot Level (page 11)
    B. Hole-by-Hole Level (page 15)
    C. Round-by-Round Level (page 18)
    D. Season-by-Season Level (page 22)
7. Value of Distance for Ladies Professional (page 26)
    A. Hole-by-Hole Level (page 26)
    B. Round-by-Round Level (page 28)
8. Value of Distance for Amateurs (page 30)
    A. World Amateur Handicap Championship (page 30)
    B. Game Golf (page 33)
    C. Comparison of Values of Distance (page 37)
9. Supplemental Analysis (page 34)
    A. Spread in Performance in relevant statistics on PGA TOUR (page 38)
    B. Correlation of Driving distance to Strokes Gained statistics (page 39)
    C. Aging & Change in Composition of the Tour (page 40)
    D. Impact of Aging on Driving distance (page 41)
    E. Aging Curve for Distance (page 41)
    F. Driving distance change by Era (page 42)
        I. Raw Driving Distance change by era
        II. Raw Driving Distance average by age in each era
    G. Elite Player Driving Performance (page 44)
    H. Course Specific Impact of Distance (page 46)
    I. Physical Changes in Tour Players (page 48)
    J. On-course value of fairway in yards (page 49)

1. Introduction

This report is part of the Distance Insights project launched by the R&A and USGA in 2018 to study the impact of distance on golf. This report examines the impact of driving distance on scoring on the major professional tours – PGA TOUR, European Tour, and LPGA Tour – and on the amateur game. We seek discover the value of distance in the current game, place that in historical perspective over the last 30+ years, and compare the value of distance between studied populations (mens professional, ladies professional, amateur).

2. Methods

For this report we have utilized the following data sources:

a) PGA TOUR Shot Link data from 2004-2018
b) PGA TOUR hole level and round level data from 1983-2018
c) European Tour hole level data from 1999-2018
d) LPGA Tour hole level data from 2007-2018
e) LPGA Tour round level data from 1993-2018
f) Game Golf Shot Link-esque data collected in recent years
g) World Amateur Handicap Tournament data collected in 2006, 2007, 2008, and 2010

Utilizing this data we can examine the value of distance at a shot-by-shot level, a hole-by-hole level, a round-by-round level, and season-by-season level. Not all levels of data were available from each source, but we have managed to compare like to like data for each population.

Tour	Shot-by-Shot	Hole-by-Hole	Round-by-Round	Season-by-Season
PGA TOUR	2004-18	1983-2018	1983-2018	1983-2018
European Tour	2017-18	1999-2018	1999-2018	1999-2018
LPGA Tour	NA	2007-2018	1993-2018	1993-2018
Amateur	Game Golf / WAHC	NA	NA	NA

When producing models predicting scoring as a function of driving distance and driving accuracy we have taken the following steps:

a) Adjusting scoring to the average of the field for that hole or round or season
b) Adjusting driving distance to the average of the field for that hole or round or season
c) Adjusting driving accuracy to the average of the field for that hole or round or season

This is to account for the varying difficulty of holes, the varying approach distances on holes, and the varying driving accuracy on holes across and within seasons. This allows us to isolate every player's performance on a hole relative to their peers on that day. See Section 3 below for more explanation of these relative values.

The use of these adjusted measures will enable us to compare different seasons and events with different underlying statistics. Although it is important to look at both these relative measures and also absolute measures.

These adjusted measures will be referred to as relative stats or strokes gained stats throughout (eg, **rel_score, rel_distance, rel_fairway**)

For the value of distance models, we primarily utilized OLS linear regression in the form:

rel_score ~ rel_distance + rel_fairway

In order to look at the linkage between factors we use linear regression. The outcomes of this analysis is to find out the level of the changes in the outcome which can be associated with the predictor. This can include multiple factors.

This model produces a best fit coefficient, a standard error around that mean, and a R^2 value showing the amount of variance explained by the model. Those three statistics will be our main analytic tools to judge the impact of distance, the variability of that impact, and the overall explanatory power of distance.

The best fit coefficient can be explained as the amount of change in a value given a change of 1 in a variable. For example, if you change the driving distance by 1 yard, what is the scoring impact in strokes.

The standard error around the mean reflects the range of uncertainty around that coefficient. For variables with small sample sizes, this standard error will be higher than for variables with large sample sizes. We can be more confident in the value of a coefficient taken from 3 million observations than one taken from 100 observations.

The R^2 value shows the amount of observed variance explained by the model. For example, the scores on an average PGA TOUR hole have a variance of 0.44. Using the model which we used throughout this research where we find the impact on scoring of driving distance and driving accuracy, we find a typical R^2 of about 0.10. This indicates that the model explains about 10% of the variance in scoring on that hole. Other factors not including in the model (including performance on other shots, player skill, weather, and random variation) explain the other 90% of the variance in scoring.

We have referred to p-values throughout the report. P-values are commonly used as signs of statistical significance (often measured at the 95% or 99% confidence level). This measures the probability of observing the results of a model if the predictor variables (for example, driving distance and driving accuracy) actually have no effect on scoring.

P-values are a measure of statistical significance. In this research there are many model which consider millions of observations. At this sample size, it's common to find results which are statistically significant, but not practically significant. An example using made-up data is finding the value of distance on the PGA TOUR in 1990 equal to 0.004 SG per yard per hole and the value of distance on the PGA TOUR in 2000 equal to 0.0042 SG per yard per hole. The difference between those values could be statistically significant, but the actual on-course value of a 20 yard difference in driving distance between those seasons would add up to only 0.004 shots per hole.

To compare the significance of coefficients between two or more different eras, we added interaction terms to the model (eg, interaction of **time period** on **rel_distance** and **rel_fairway**).

3. Definitions

Value of Distance – In this report we define the value of distance as the amount of strokes 1 yard is worth over a single hole or single round. Because almost every pro tournament has 14 driving holes (par 4s and 5s), we have shown the value of distance at round level as 14 * value of distance at hole level.

This Value of Distance can come about from a large number of possible areas: course set-ups (hole yardages, cut of rough, cut of fairway, mowing direction of fairway, pin placements), differing abilities between the longer and shorter driving distance populations, a difference in the types of holes measured drives are calculated on, a change in the value of hitting less or more club, etc. We have presented these value of distance figures as best estimates of the gap without proposing definitive causes.

Strokes Gained – At its simplest, strokes gained is the performance of a player on a hole relative to the field's performance. Eg, a score of 4 on a 4.30 hole would gain +0.3 SG on the field. We use this interchangeably with **Relative Score** in this report.

Strokes Gained also can be broken down into individual components (SG Driving or Off the Tee, SG Approach, SG Around Green, SG Putting) which utilizes a benchmark of performance from each lie and distance to show how much a player gains or loses with their shots. Eg, a putt missed from 8 feet is -0.5 SG because a player is expected to get down in 1.5 shots and they got down in 2.0 shots.

Relative Values – in this report we utilize fairways hit vs field and driving distance vs the field. Like Strokes Gained or Relative Score, these statistics are compared to the field average (**rel_distance**, **rel_fairway**). Hitting a fairway when 60% of the field hit it gains +0.4 fairways hit. Driving it 310 yards when the field drives it 295 yards gains +15 yards. These adjustments are necessary to consider a wide-range of scoring and difficulty conditions, as well as changes in the distance the ball is struck between 1980s (around 265 yards) and 2010s (over 290 yards).

4. Summary of Findings

1. Driving distance ability is correlated with the distance a player hits the other clubs in their bag. In general, a player's distance ability relative to the field with driver translates to their distance ability relative to the field with 4 iron, 6 iron, or 9 iron by between 72% and 80%. **(5A)**.
2. The correlation in 2016-18 on PGA TOUR between driving distance and positive statistics (birdie making, bogey avoidance, SG on field, and GIR %) has increased overall versus the previous three decades, especially in the decade since 2006-08. At the same time, there has been a steady decline in the correlation between driving accuracy and those same positive statistics **(5B II/III/IV)**.
3. The value of distance at the shot-by-shot level has varied with a range of 0.10 strokes gained per round between 2004 and 2018. For example, for a player 15 yards longer than the field, their maximum value of distance in a season was +1.07 SG per round and their minimum value of distance in a season was +0.97 SG per round. There is no overall trend in those 15 seasons, though the last three seasons have seen general decline in value of distance **(6A II and 6A III)**.
4. The difficulty – in terms of the scoring average on that hole relative to shots from the fairway - of the two most common non-fairway lies (rough and fairway bunker) has decreased since 2004 on PGA TOUR **(6A II and 6A III)**.
5. On par 4 holes, the value of distance is lower and the value of fairway is higher than on par 5 holes looking at PGA TOUR data at both Shot Link and hole-by-hole level **(6A IV)**.
6. The value of distance on the European Tour vs PGA TOUR in 1999-2018 is slightly lower, but translates to a difference of less than 0.10 SG per round for the longest hitters on European Tour vs PGA TOUR **(6B III and 6C III)**.
7. At a season-level, the value realized by longer hitters relative to shorter hitters has grown by about 22% in 2016-18 relative to 2011-15 (a raw increase of 0.4 SG per round). In general, the rewards to being 1 standard deviation better than the field in driving distance have increased relative to the rewards to being 1 standard deviation better than the field in driving accuracy **(6D II and III)**.
8. The value of distance is higher on LPGA Tour than PGA TOUR using two different data-sets. When evaluating data at the round-level (most widely available for 26 seasons), the value of distance is 50% larger on the LPGA Tour, while the value of hitting the fairway is the same **(7A III and 7B II)**.
9. The value of distance is higher in the Amateur golf data we evaluated (from two different sources) when compared with comparable Shot Link data from PGA TOUR. The value of distance was almost 50% higher in one source compared to PGA TOUR and 46% higher in the other source compared to PGA TOUR **(8C)**.
10. The value of distance for male and female amateurs differed with female golfers seeing larger value of distance by over 50% versus male players **(8B IX)**.
11. Based on our estimates of value of distance for mens and ladies professional and mens and ladies amateur data, we find that as the driving distance of the population decreases, the value of distance increases. This research is dependent on accurate measurement of value of distance for amateurs.
12. The distribution of player performance in driving distance has grown wider over the last 36 years on PGA TOUR at the same time the distribution of player performance in all other

stats examined (scoring average, driving accuracy, greens hit, proximity, etc) has narrowed **(9A)**.

13. The change in driving distance due to aging from year to year has grown larger, producing an aging curve which has grown steeper since the 1980s. When compared to field average, players lose more driving distance between ages 25 and 45 in 2010s than in 1980s **(9E)**.

5. Impact of Distance

A. Impact of driving distance ability through the bag

Using 2018 data collected by the European Tour caddies which had distance to pin and club used for all shots, we analyzed the distance each player hit each club relative to the field. For example, Ryan Fox was the longest hitter with driver on Tour last year; he hit driver 108% as far as the Tour average. He hit his 4 iron 107% as far as Tour average, his 6 iron 108% as far as Tour average, and his 9 iron 101% as far as Tour average.

The data used for this analysis was derived by comparing the distance to the pin each player hit each club.

We ran linear models of **club_distance_% ~ driver_distance_%** to find how much of distance with driver translated through the bag.

For 4 iron, the resulting regression line was given by 0.20 + (0.80 * driver_distance).

For 6 iron, the resulting regression line was given by 0.27 + (0.72 * driver_distance).

For 9 iron, the resulting regression line was given by 0.20 + (0.80 * driver_distance).

B. Correlation of driving distance and relevant statistics

*I. Correlation of driving distance to statistics on **LPGA Tour** (2007-2018)*

Players with 20+ rounds

Table 1

Statistic	Correlation to Driving Distance	Correlation to Driving Accuracy
SG on field	0.33	0.32
Driving Distance	-	-0.46
Driving accuracy	-0.46	-
GIR	0.46	0.32
Scrambling	-0.11	0.47
Birdie or better	0.53	0.08
Bogey or worse	0.22	0.42
Par 3 scoring	0.03	0.32
Par 5 scoring	0.44	0.17
Three putt avoidance	0.01	-0.13

This data compares the correlation of various statistics in the first column of Table 1 with driving distance and driving accuracy. This is season-level data for all players with 20+ rounds in a season over 2007-18.

Driving distance is correlated at 0.33 to overall SG over the course of a full season. Distance is negatively correlated to driving accuracy (-0.46) and scrambling (-0.11). Scrambling includes holes where players hit a drive into a recovery situation (hazard, trees, etc) and were unable to play their 2nd shot towards the green (placing themselves in a very tough up and down situation). Scrambling is correlated much more strongly (0.47) to driving accuracy.

Driving distance on LPGA Tour is more correlated to making birdies (0.53) than avoiding bogeys (0.22). It is more correlated to par 5 scoring (0.44) than par 3 scoring (0.03).

Driving accuracy on LPGA Tour is much more correlated to avoiding bogeys (0.42) than making birdies (0.08). It is more correlated to par 3 scoring (0.32) than par 5 scoring (0.17).

Driving accuracy has the same correlation to overall SG in a round (0.32) as driving distance.

Comparing 2007-09 correlations with 2016-18 correlations yields the same general insights, but the strength of the relationship of distance with SG per round, birdie or better, par 5 scoring, and GIR % have all declined over that decade. Distance is less correlated with these positive outcomes. The correlation between driving accuracy and SG per round, birdie or better, and par 5 scoring have decreased by a less amount and did not decrease for GIR % between 2007-09 and 2016-18.

*II. Correlation of driving distance to relevant statistics on **PGA Tour** (2007-2018)*

Players with 20+ rounds

Table 2

Statistic	Correlation to Driving Distance	Correlation to Driving Accuracy
SG on field	0.27	0.27
Driving Distance	-	-0.50
Driving accuracy	-0.50	-
GIR	0.35	0.37
Scrambling	-0.12	0.25
Birdie or better	0.48	-0.01
Bogey or worse	0.09	0.38
Three putt avoidance	-0.18	0.04

To compare with LPGA correlation results, this data compares the correlation of various statistics in the first column of Table 2 with driving distance and driving accuracy. This is season-level data for all players with 20+ rounds in a season over 2007-18.

These results are similar to those on LPGA Tour for the same time period.

Driving distance is correlated the same amount to SG on field as driving accuracy, while being more correlated to birdie-making than bogey avoidance, and vice-versa for driving accuracy.

The correlation between driving distance and driving accuracy is -0.50 – very similar to -0.46 figure from LPGA Tour.

*III. Comparing correlations of statistics to driving distance over time (1986-1988, 1996-1998, 2006-08, 2016-2018) on **PGA TOUR***

Table 3

	DD 1986-88	DD 1996-98	DD 2006-08	DD 2016-18
SG on field	0.27	0.30	0.18	0.36
GIR %	0.29	0.35	0.27	0.41
Driving Accuracy	-0.39	-0.40	-0.56	-0.49
Birdie or better	0.50	0.50	0.43	0.52
Bogey or worse	0.10	0.12	-0.01	0.20

Table 3 compares season level correlations of statistics to driving distance for three year periods (1986-88, 1996-98, 2006-08, and 2016-18) for all players with 20+ rounds played.

Since the late 1980s, the correlation between scoring (SG on field) and distance has first decreased and then increased again to a higher level (0.27 in 1986-88 to 0.36 in 2016-18).

Along with that has been a decrease in the correlation between distance and driving accuracy (-0.39 in 1986-88 to -0.49 in 2016-18), an increase in the correlation between distance and GIR % (0.29 to 0.41), and an increase in the correlation between distance and bogey avoidance (0.10 to 0.20). The correlation between distance and birdie or better is very similar (0.50 to 0.52).

In general, the correlation between distance and positive outcomes remained similar between 1986-88 and 1996-98, fell between 1996-98 and 2006-08, and rose past previous levels between 2006-08 and 2016-18.

Driving distance and driving accuracy became less correlated over this time period.

*IV. Comparing correlations of statistics to driving accuracy over time (1986-1988, 1996-1998, 2006-08, 2016-2018) on **PGA TOUR***

Table 4

	DA 1986-88	DA 1996-98	DA 2006-08	DA 2016-18
SG on field	0.48	0.36	0.29	0.24
GIR %	0.53	0.45	0.38	0.33
Driving Distance	-0.39	-0.40	-0.56	-0.49
Birdie or better	0.17	0.09	-0.01	-0.01

Bogey or worse	0.57	0.45	0.42	0.33

Table 4 compares season level correlations of statistics to driving accuracy for three year periods (1986-88, 1996-98, 2006-08, and 2016-18) for all players with 20+ rounds played.

In comparison, the correlation between driving accuracy and all positive outcomes has been declining steadily since the late 1980s. It has been halved in terms of SG on field (0.48 in 1986-88 to 0.24 in 2016-18).

2016-18 was the only one of these four periods measured where the correlation between SG on field and driving distance was larger than the correlation between SG on field and driving accuracy.

6. Value of Distance in Mens Professional Golf

A. Shot-by-Shot data

Since 2004, the PGA TOUR has collected Shot Link data – shot-by-shot data which measures the distance to the pin and lie at the start and end of the shot for all shots in most PGA TOUR events. For 2018, 39 of 48 events collected Shot Link data on at least one course used in the event and all shots were captured for 35 of 48 events. This yields a dataset of 17.5 million shots across 15 seasons of play. 62% of fairways were hit within this data.

This Shot Link data represents the best measure of on-course value of distance. It can judge the value of a drive of 300 yards which leaves 145 yards to the pin compared to a drive of 280 yards which leaves 163 yards to the pin. Shot Link also provides more granular lie data than most of our data sources which allows us to compare not just the value of fairway hit or missed, but the value of hitting the Fairway vs Semi Rough vs Rough vs Fairway Bunker vs Other lies. Shot Link also allows us to examine the value of distance on holes where many players do not hit driver.

I. Individual Components (Distance or Lie Type)

Knowing the specific lie type after a drive explains much more of the variance in scoring than knowing the distance of the drive (or distance to the pin after the drive).

The R^2 of **rel_score ~ rel_distance** for all 15 seasons is only 0.03 with a SE of the residuals of 0.64.

The R^2 of **rel_score ~ lie_type** for all 15 seasons is 0.09 with a SE of the residuals of 0.62.

II. Distance + Specific lie_type

Next, we added the lie_type for the result of all tee-shots on par 4s and 5s in the form Fairway, Semi Rough, Rough, Fairway Bunker, Other, and Hazard.

rel_score ~ rel_distance + lie_type (where lie_type intercepts are judged relative to Fairway)

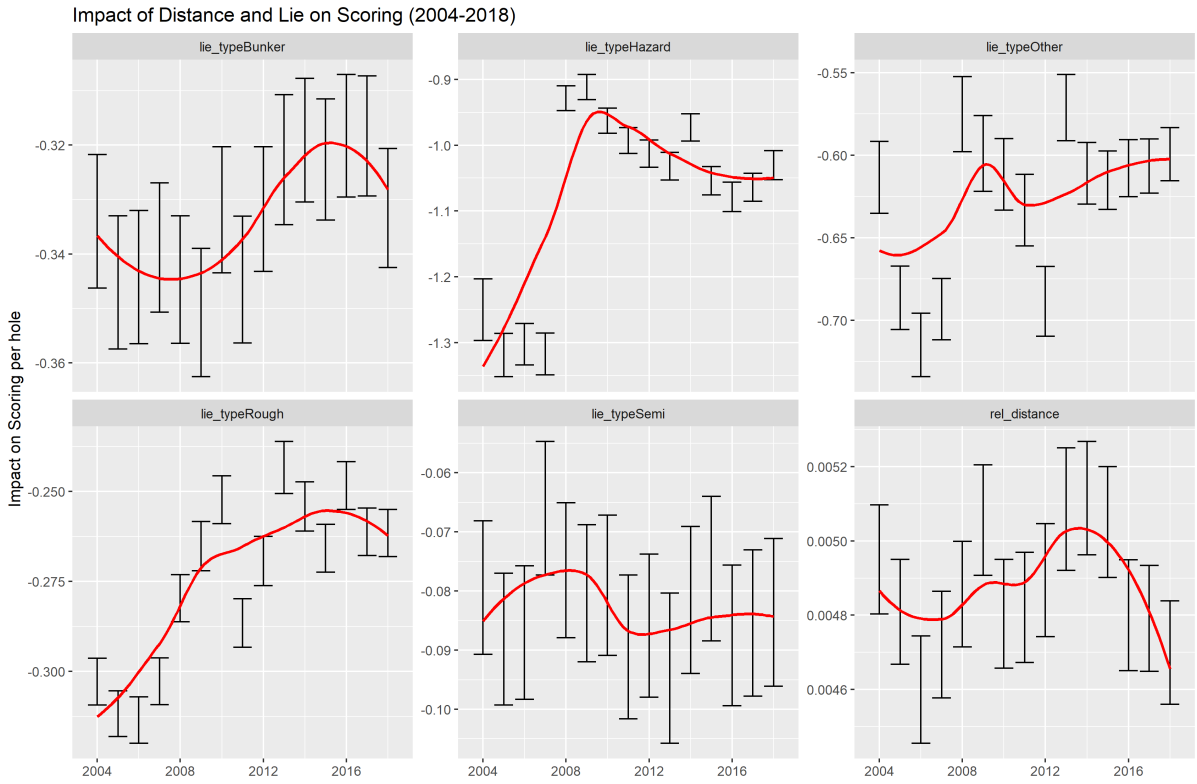


Figure 1

The value of distance for all 15 seasons is estimated to be in a tight range between 0.0046 SG per yard per hole and 0.0051 SG per yard per hole. There are typically 14 drives per round so the impact of 1 yard of distance on SG per round is estimated between 0.06 and 0.07 SG for all 15 seasons. The standard error for a season is less than 0.0001. The value of distance for all 15 seasons is 0.0049 SG per yard per hole. The R^2 for this model was between 0.09 and 0.12 with an average of 0.11 across 15 seasons.

The value of each lie_type is:

Table 5

Lie Type	15 Seasons Coefficient relative to fairway	15 Seasons SE
Semi Rough	-0.08 SG	0.0015
Rough	-0.28 SG	0.0009
FW Bunker	-0.33 SG	0.0015
Hazard	-1.03 SG	0.0029
Other	-0.63 SG	0.0025

There is little trend for the value of distance in this analysis. The value of distance generally increased from 2006 to 2014 and generally has decreased from 2014 to 2018. The value of distance for a player 15 yards longer than field average peaked at +1.07 SG per round in 2014 and was lowest at +0.97 SG per round in 2006. That range of 0.10 SG per round in the range in value of distance achieved by a long hitter (+15 yards) between 2004 and 2018.

The difficulty of the Rough has reduced from -0.31 SG in 2004-06 to -0.26 SG in 2017-18.

Of the other common lie_types, Fairway Bunker difficulty has reduced from around -0.34 SG from 2004-09 to around -0.32 SG from 2013-17 and Semi Rough difficulty has remained steady at around -0.08 SG to -0.09 SG.

III. Comparing 2016-18 with prior seasons

Table 6

	2004-15 Coeffcient	2004-15 SE	2016-18 Coefficient	2016-18 SE
Value of Distance	0.00490 SG per yard per round	0.00002	0.00476 SG per yard per round	0.00004
Semi Rough	-0.08 SG	0.0017	-0.09 SG	0.0035
Rough	-0.28 SG	0.0010	-0.26 SG	0.0019
Fairway Bunker	-0.34 SG	0.0017	-0.32 SG	0.0032

Looking at 2016-18 compared to 2004-15, the value of distance has not changed in any practical sense at this on-course shot-by-shot level. Over 14 drives in a round, the gap between the value of distance has changed from 0.069 SG per yard per round or 1.04 SG per 15 yards per round in 2004-15 to 0.067 SG per yard per round or 1.00 SG per 15 yards per round.

The longest hitters may be gaining 0.04 SG per round less in the last three seasons than in 2004-15, while the shortest hitters may be gaining 0.04 SG per round more in the last three seasons than in 2016-18.

To test for significance, we re-ran the model in 6A II including interaction terms for season < 2016 (2004-15 and 2016-18).

The value of distance difference between 2004-15 and 2016-18 is significant at the $p < 0.01$ level.

The value of lie differences between 2004-15 and 2016-18 are significant at the $p < 0.001$ level for Rough and at the $p < 0.01$ level for FW Bunkers.

IV. Par of hole

Par of hole is a significant factor in value of distance. In the 15 year model, breaking the data into par 4s and par 5s yields a spread of **0.00466 SG per yard per hole for par 4s** (SE = 0.00002) and **0.00563 SG per yard per hole for par 5s** (0.00004). In an average tournament with 11 par 4s and 3 par 5s, a player 15 yards longer than field average will gain 0.77 SG on par 4s and 0.25 SG on par 5s.

There are also small, but significant, differences in the value of resulting lies for the Rough and Fairway Bunkers.

Table 7

Lie Type	Par 4s	Par 5s
Semi Rough	-0.082 SG (SE = 0.002)	-0.083 SG (SE = 0.003)
Rough	-0.288 SG (SE = 0.001)	-0.229 SG (SE = 0.002)
Fairway Bunker	-0.336 SG (SE = 0.002)	-0.317 SG (SE = 0.003)

The value of distance, value of rough, and value of FW bunker were all significant at the $p < 0.001$ level when tested in a linear model using an interaction term for hole par.

V. Other statistics

At the shot-by-shot level within holes, the standard deviation of distance relative to the field is 18.5 yards across 2004-18.

The distribution of extreme drives (those gaining 20+ yards on the field on that hole) is 11.8% in 2004-15 and 12.4% in 2016-18. Those losing 20+ yards on the field on that hole is 11.5% in 2004-15 and 12.2% in 2016-18.

B. Hole-by-Hole data

The PGA TOUR has hole-by-hole data showing measured driving distance for two drives per round, the score, and whether the fairway was hit or missed for most rounds since 2001. This yields a dataset of between 25k and 32k holes for each season over 18 years. About half (49%) of holes are par 4s vs par 5s.

The holes chosen generally are ones where most players are hitting driver. Like the Shot Link data, this provides an on-course measure of the value of distance at a granular level, without the precision of knowing the exact lie_type.

I. Distance + Fairway Hit

Next, we added whether the fairway was hit or missed to the model.

rel_score ~ rel_distance + rel_fairway

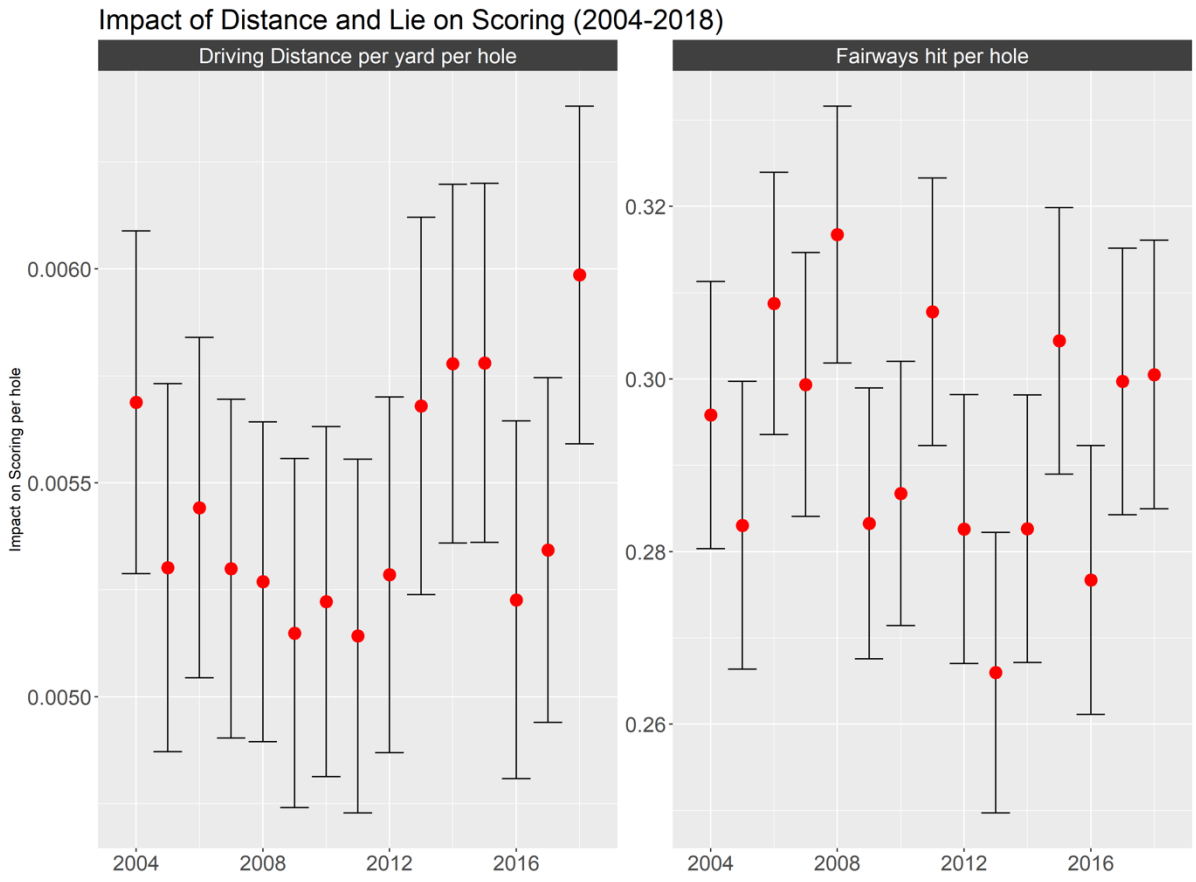


Figure 2

The value of distance on these holes is generally slightly higher than the value of distance on all holes (Shot-by-Shot data above). The spread in value of distance is between 0.0051 and 0.0060 SG per yard per hole with an average of 0.0054 SG per yard per hole (compared to 0.0049 SG per yard per hole using all drives). The yearly SE is about 0.0002.

The value of fairway on these holes is between 0.26 and 0.32 SG per hole with an average of 0.29 SG. The yearly SE is about 0.01.

The R^2 of this model varies between 0.07 and 0.10 – it explains less of the scoring variance than the Shot-by-Shot model.

II. Par of Hole

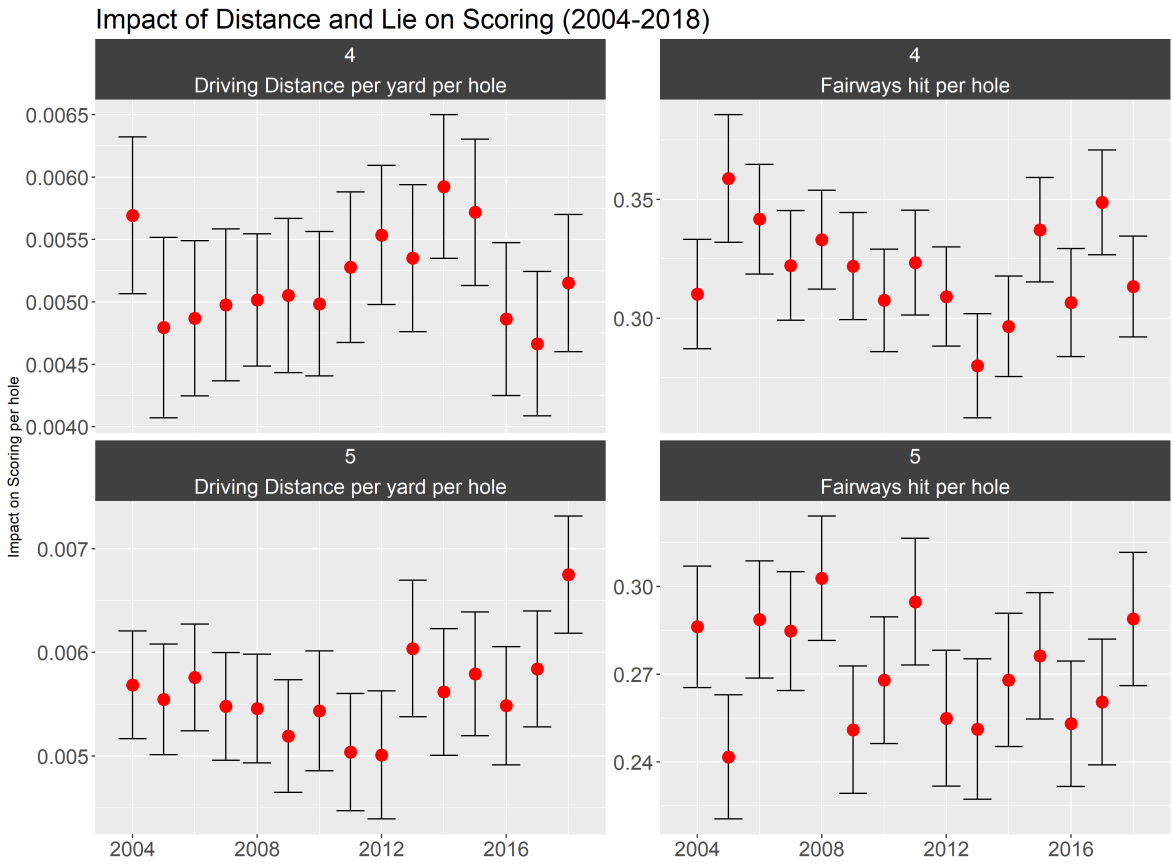


Figure 3

Overall, over the 15 seasons, the value of distance on par 5s is significantly higher than on par 4s (0.0056 SG vs 0.0052 SG, SE < 0.0001). The value of fairway is lower on par 5s (0.27) than par 4s (0.32) with a SE of 0.003.

The value of distance on par 5s has generally increased in the last 5 seasons and hit a 15 year high in 2018 (0.0067 SG per yard per hole vs 0.0055 SG in the other 14 seasons). Par 4 value of distance has declined in 2016-18.

The R^2 of these models is 0.09 for par 4s and 0.07 for par 5s. Overall, how well a player drives the ball (in terms of distance and accuracy) explains more of the variance in scoring on par 4s.

III. European Tour data

For the European Tour, hole-by-hole data is only available for 2017 and 2018. Prior to 2017, it is not possible to identify which hole a measured drive came on.

We have repeated the above analysis for the impact of distance and fairway just on those two seasons.

The value of distance was 0.0037 SG per yard per hole in 2017 and 0.0043 SG in 2018. SE of 0.0002 each season. This is significantly lower than on the PGA TOUR for those seasons (PGA TOUR in 2017 was 0.0053 and in 2018 0.0060).

The value of fairway was between 0.33 and 0.34 SG for both seasons (SE of <0.01). This is significantly higher than on the PGA TOUR for those seasons (PGA TOUR in 2017 was 0.30 and in 2018 0.30).

The R^2 of these two seasons is 0.07 and 0.08, both in the same range as PGA TOUR data.

The value of distance difference between PGA TOUR and European Tour for 2017 and 2018 was significant at the $p < 0.001$ level and the value of fairway difference between PGA TOUR and European Tour for 2017 and 2018 was significant at the $p < 0.01$ level.

C. Round-by-Round data

To address the inability to measure driving distance at the hole level on European Tour prior to 2017, we will measure for PGA TOUR and European Tour at the round level. This data is the most complete available stretching back to 1983 for PGA TOUR, 1999 for European Tour, and 1993 for LPGA Tour.

This data-set shows the SG per round on the field, the relative driving distance vs the field on the measured drives, and the relative fairways hit vs the field. For example, in R2 at 2000 WGC NEC Invitational Tiger Woods shot 61 (rel_score of 8.92 shots better than the field average), hit 9 fairways (rel_fairways of 0.78 fairways better than the field average), and averaged 322 yards on two measured drives (rel_distance of 31.7 yards longer than the field average).

rel_score ~ rel_distance + rel_fairways

I. Distance + Fairways hit on PGA TOUR

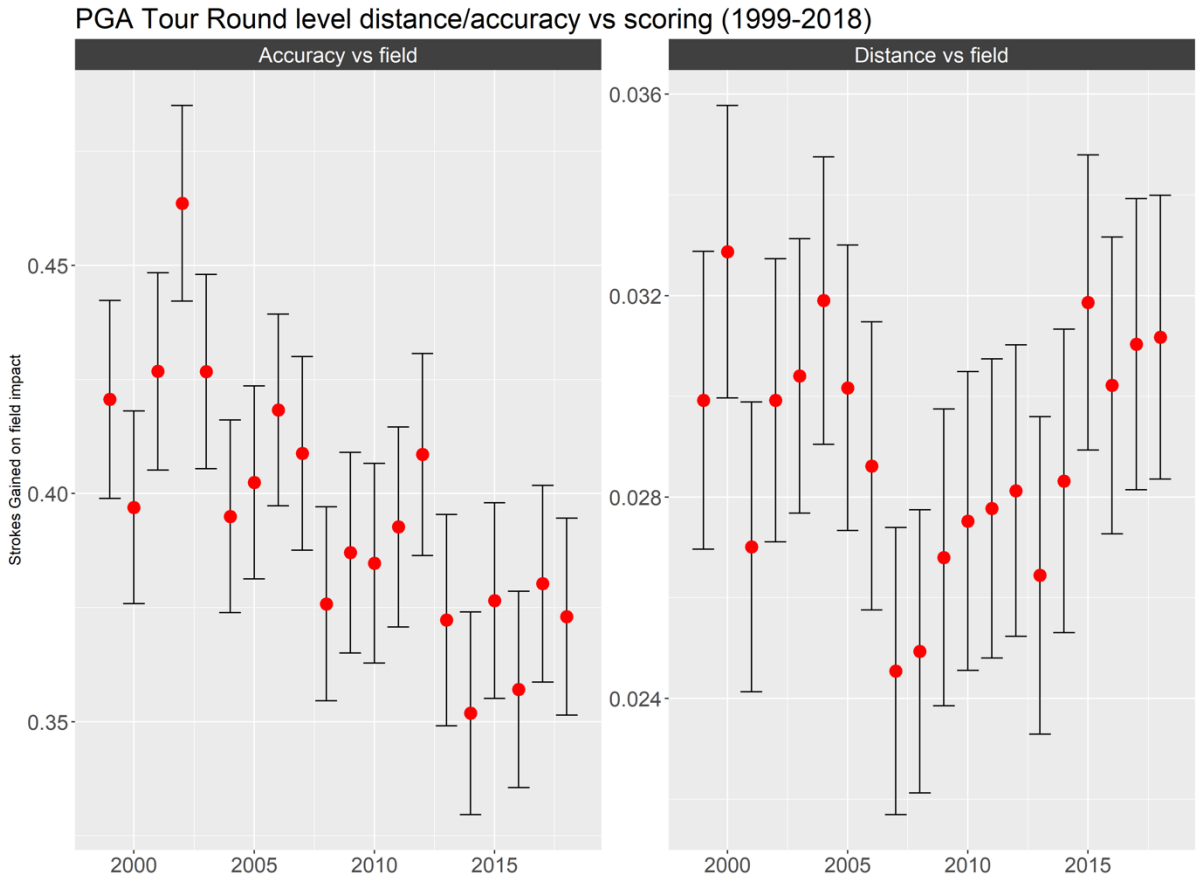


Figure 4

The average coefficients for the value of distance are smaller in this analysis than the on-course value of distance shown by hole-by-hole data.

The value of distance is between 0.025 SG per yard per round and 0.033 SG per yard per round (which translates to between 0.0018 SG per yard per hole and 0.0024 SG per yard per hole). The

average coefficient between 1999 and 2018 is 0.029 SG per yard per round. The SE each year is 0.0015 at the season level.

The value of fairway is between 0.35 and 0.45 SG per fairway from 1999-2018. The average is 0.40 SG. The SE is 0.01 each season.

The R^2 of this model is the same as for the hole-by-hole model, 0.07 to 0.10.

The value of distance decreased from 1999 to 2008 before steadily increasing from 2008 to 2018. By this measure, the value of distance is approximately the same in 2018 as in 1999.

The value of fairway has decreased steadily in the last two decades from about 0.42 SG per fairway in 1999-2001 to about 0.37 SG per fairway in 2016-18.

II. Distance + Fairways hit on European Tour

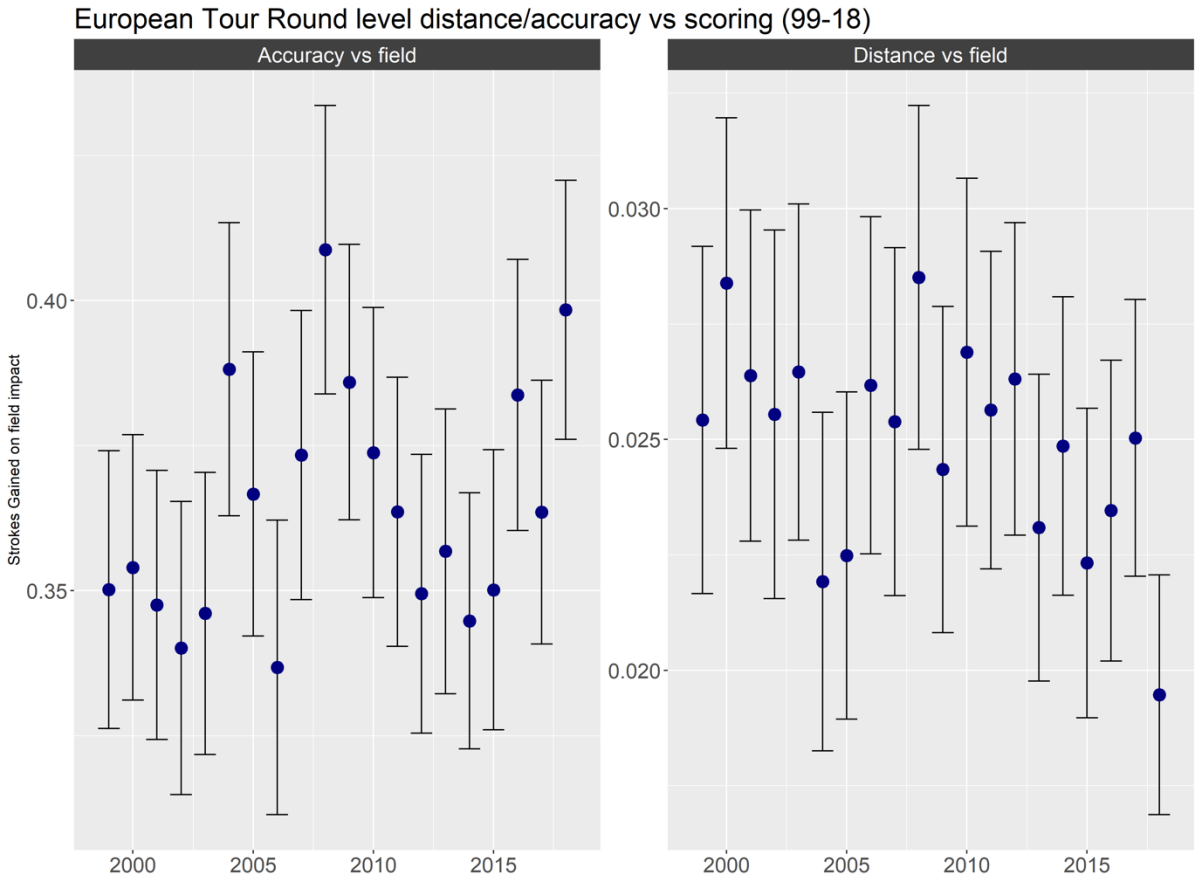


Figure 5

The value of distance is between 0.02 and 0.03 SG per yard per round from 1999-2018. The average season coefficient is 0.025 SG per yard per round. The SE is 0.002 each season. This is generally slightly lower than PGA TOUR (significant at $p < 0.001$ level).

The value of fairway is between 0.34 and 0.41 SG per fairway from 1999-2018. The average coefficient is 0.36 SG. The SE is 0.01 each season. This is lower than for PGA TOUR (significant at $p < 0.001$ level).

The R^2 of this model is between 0.07 and 0.09 – the same as for the PGA TOUR.

2018 is the season with the lowest value of distance of any in the 20 seasons. In general, the value of distance has decreased since 1999.

2018 was the 2nd highest value of fairway season since 1999.

III. Value of Distance on PGA TOUR vs European Tour (1999-2018)

Table 8

Tour	Average Season	Lowest Season	Highest Season	Season SE Average	Season R^2 Average
PGA TOUR	0.029 SG per yard per round	0.025 (2007)	0.032 (2000)	0.0015	0.083
European Tour	0.025 SG per yard per round	0.019 (2018)	0.029 (2008)	0.0018	0.076

IV. PGA TOUR All Available Data

We focused on just 1999-2018 to compare with European Tour, but have repeated the same analysis covering the full 36 year sample (1983-2018).

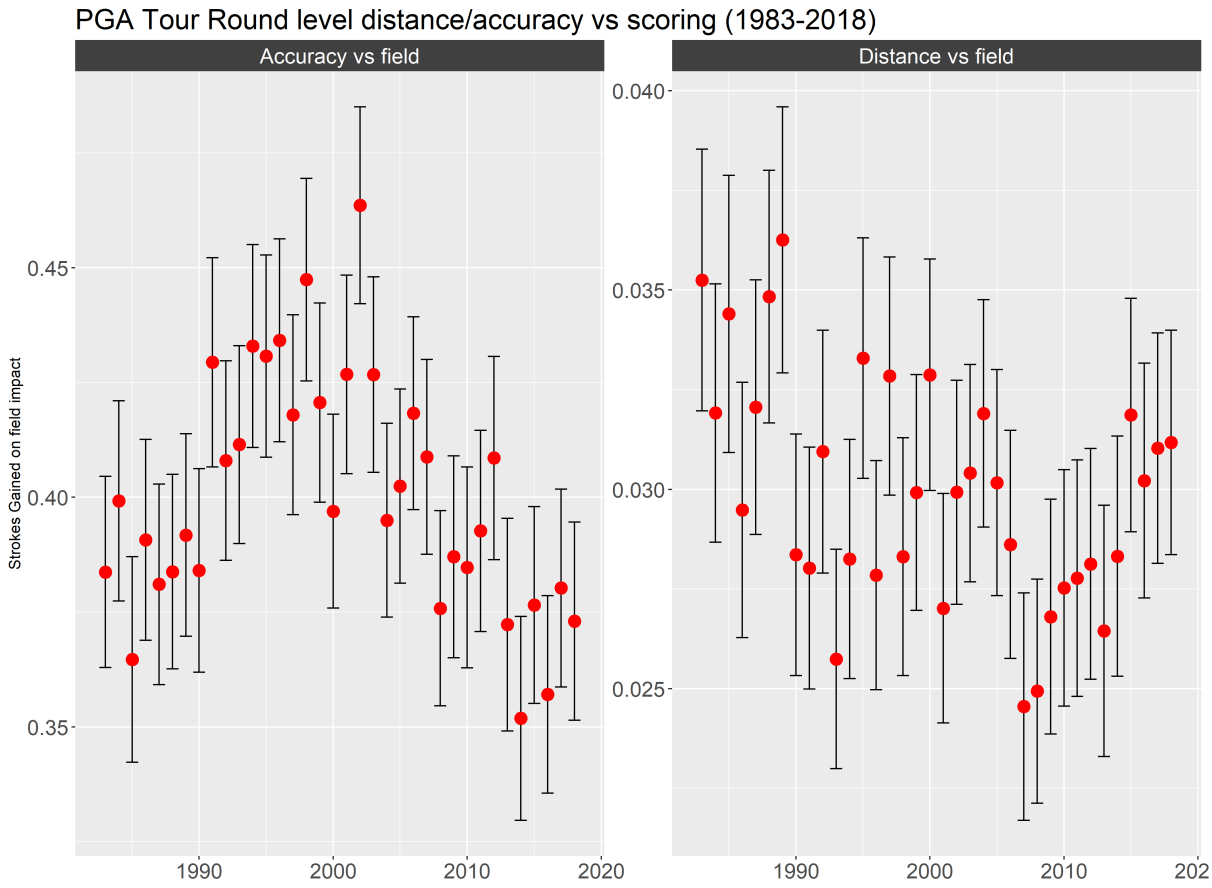


Figure 6

This shows wide ranges for both value of distance and accuracy over nearly 40 years of PGA TOUR golf.

The value of distance was highest in the 1980s at around 0.035 SG per yard per round. It declined to 0.025 SG as seen previously around 2007-08, but has recovered about 3/4ths of the way back to the 1980s peak in the last decade.

The value of fairway was highest around the turn of the millennium – peaking in 2002 at 0.46 SG per fairway. That was an increase of nearly 0.10 SG versus the 1980s. Since, it has declined a similar amount and the value of fairway was been at its lowest in the last six seasons (0.37 SG on average).

The R^2 and SE values are similar to the 1999-2018 data shown above.

We will compare 1993-2018 on PGA TOUR to the LPGA Tour for the same period of time later in this report (7AIII, 7BII).

D. Season-by-Season data

Using PGA TOUR data at the season level, we implemented similar value of distance and value of fairway models. With restricted our analysis to players with 20+ rounds on the PGA TOUR that season. This yielded between 203 and 255 player seasons for each season between 1983-2018 (8295 total seasons).

I. Distance + Fairways hit

Without breaking the data down by season, we constructed the previous **rel_score ~ rel_distance + rel_fairways** model.

The value of distance was 0.056 SG per yard per round (SE = 0.001) and the value of fairways was 0.70 SG per fairway (SE = 0.012). The R^2 of this model was 0.34.

About three to four times more variance in scoring is captured by this model than the shot-by-shot, hole-by-hole, or round-by-round models. The value of a fairway is about double the value of fairway found in those previous models, while the value of distance at the season level is between the SG per yard per round value found by shot-by-shot analysis (0.069 SG per yard per round) and round-by-round analysis (0.030 SG per yard per round).

Going season-by-season with this analysis yields the following trends:

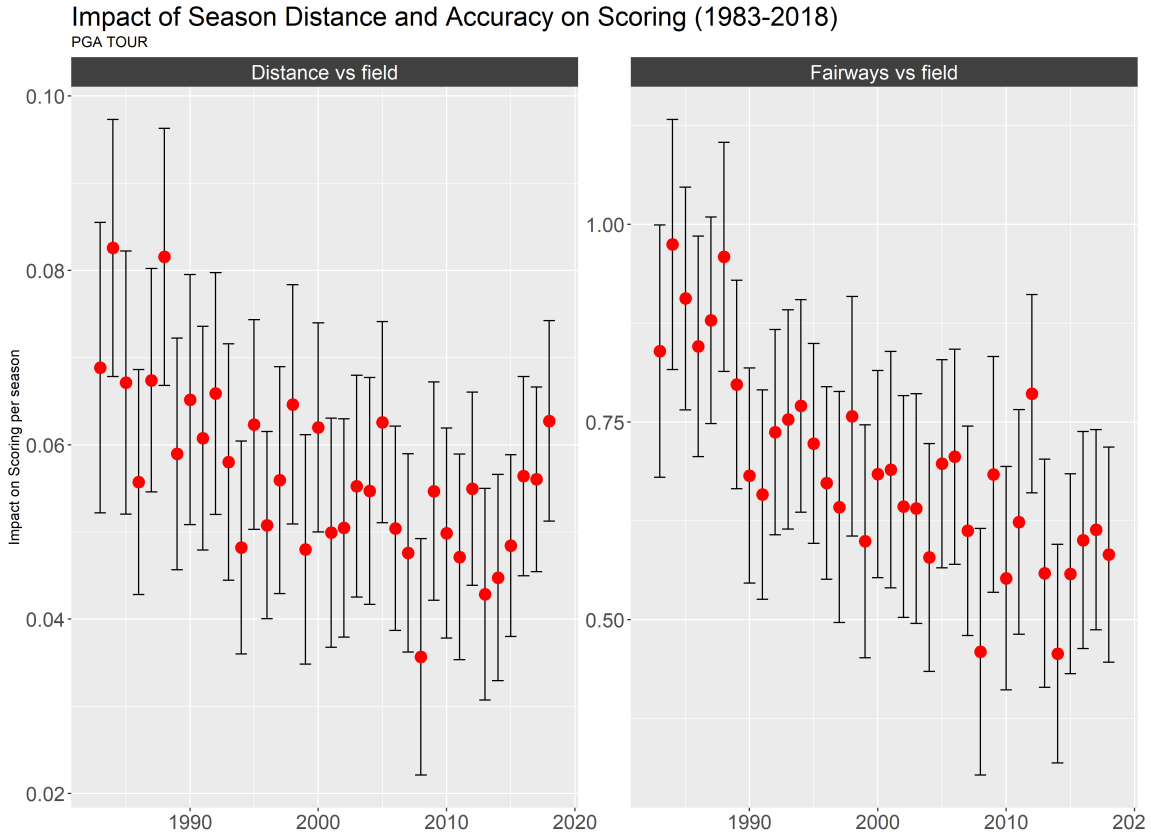


Figure 7

The value of distance generally fell on PGA TOUR between 1983 and 2013 from about 0.075 SG per yard per round to about 0.042 SG per yard per round (decline of 44% in 30 years). The value of distance has increased steadily the last five seasons to 0.062 SG per yard per round in 2018 (the highest value since 1998 and an increase of 48% in five years versus 2013).

The difference in value of distance in 2018 vs 2013 is significant at the $p < 0.05$ level, while there is no significant difference in value of fairways.

The difference in value of fairways in 2018 vs 1983 is significant at the $p < 0.05$ level, while there is no significant difference in value of distance.

II. Over-time between 1983 to 2018

Looking at the above data in five year bins (1983-1985, 1986-1990, etc to 2011-15, 2016-18):

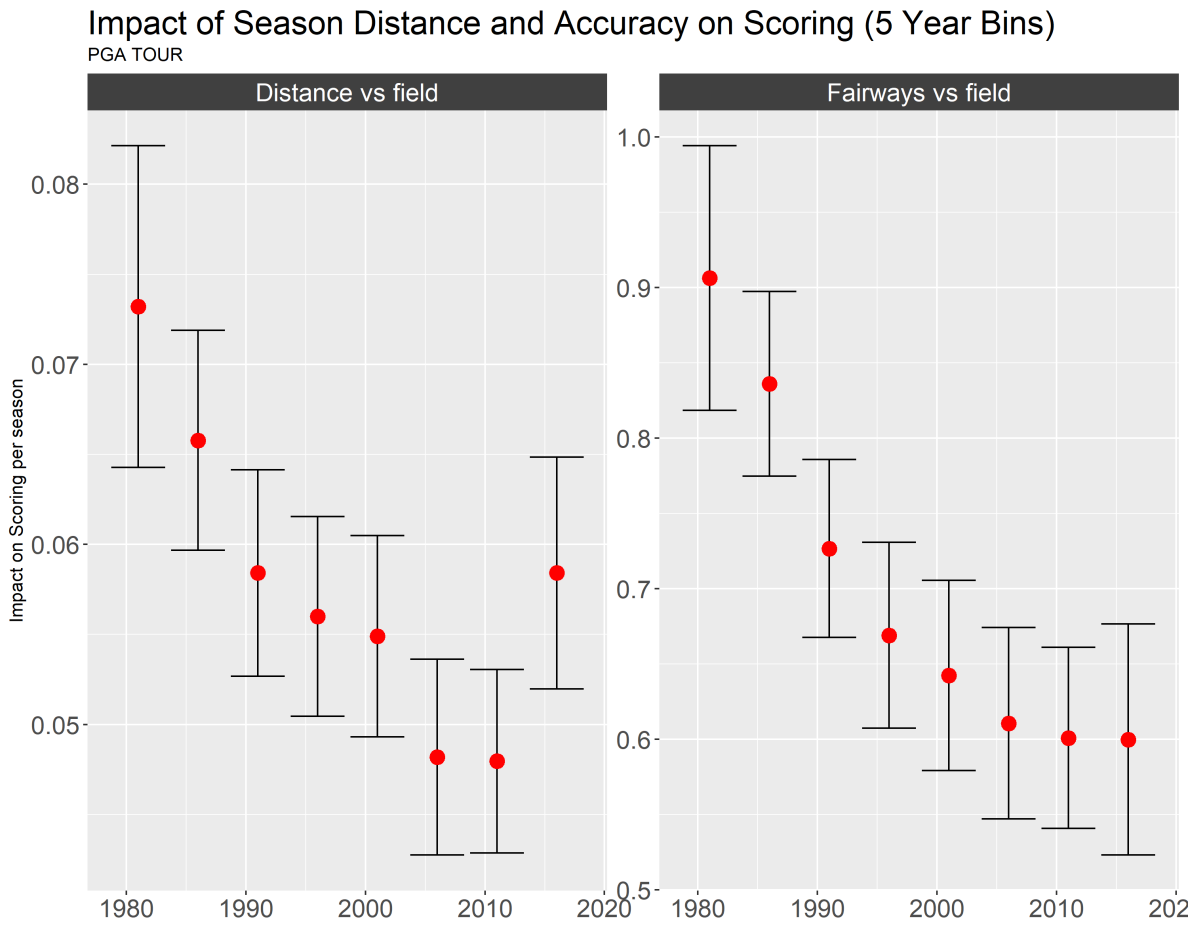


Figure 8

The value of distance was highest in 1983-1985 and declined in every five year period since, but increased sharply in 2016-18 vs previous decade lows. Spread in value of distance was 0.048 SG per yard per round to 0.073 SG per yard per round. SE of each five year period was 0.003 (0.005 for 1983-85 and 0.003 for 2016-18).

The value of fairways was also clearly highest in 1983-85 and has declined in every five year period since with the rate of decline tapering to almost nothing in the last decade. The spread in value of fairway was 0.60 SG per fairway to 0.91 SG per fairway. SE of 0.03 for each five year period (0.04 for 1983-85 and 2016-18).

The R^2 of these models was between 0.26 (2006-10) and 0.45 (1986-1990). In general, the R^2 of these models declined from the 1980s to 2011-15, before increasing in 2016-18. This indicates driving performance explains more of the variance in scoring over the last three seasons than the 15 previous seasons and as much as 1996-2000.

When comparing 2011-15 & 2016-18, the difference in season-long value of distance was significant at the $p = 0.01$ level, while there was no difference in season-long value of fairways.

When comparing 1983-1985 & 2016-18, the difference in season-long value of distance was significant at the $p < 0.01$ level and the difference in value of fairways was significant at $p < 0.001$ level.

III. Implications of changes in value of distance and accuracy

The implications of these results are that at the season level players who hit it longer than the field have seen a gain of about 0.01 SG per yard per round in 2016-18 versus 2011-15. Rory McIlroy was +22 yards longer than the field in 2018, while Jim Furyk was -17 yards shorter than the field in 2018. Using the value of distance for 2016-18, McIlroy's advantage of 39 yards was worth 2.28 SG per round (39 * 0.0584). Using the value of distance for 2011-15, McIlroy's advantage of 39 yards was worth 1.87 SG per round (39 * 0.0496). This is a 22% increase in value of distance.

In 2018, the most accurate driver on Tour was Henrik Stenson (1.85 more fairways per round than the field) and the least accurate driver on Tour was Smylie Kaufman (-2.51 fewer fairways per round than the field). Using the value of fairways for 2016-18 the gap per round between them would be 2.62 SG per round.

For 2016-18, the standard deviation in performance for driving distance vs the field is 8.5 yards. The standard deviation in performance for driving accuracy vs the field is 0.71 fairways. Using 2016-18 values of distance and fairways, a player 1 standard deviation better in driving distance would gain 0.50 SG per round and a player 1 standard deviation better in driving accuracy would gain 0.43 SG per round. In the table below we have shown the value of being 1 standard deviation better than the field in distance or accuracy for each five year period.

Table 9

	SD Distance	SD Fairways	Value Distance	Value Fairways
1983-85	7.0 yards	0.71 fairways	0.51 SG	0.64 SG
1986-90	7.5 yards	0.74 fairways	0.49 SG	0.62 SG
1991-95	7.9 yards	0.76 fairways	0.46 SG	0.55 SG
1996-2000	8.1 yards	0.72 fairways	0.45 SG	0.48 SG

2001-05	8.5 yards	0.75 fairways	0.47 SG	0.48 SG
2006-10	8.7 yards	0.74 fairways	0.42 SG	0.45 SG
2011-15	8.5 yards	0.72 fairways	0.41 SG	0.44 SG
2016-18	8.5 yards	0.71 fairways	0.50 SG	0.43 SG

Generally, the standard deviation in distance is higher after the year 2000 than previously and deviates 24% from highest to lowest five year period, but the standard deviation in fairways hit is very consistent year to year (the same in 1983-85 as 2016-18) and deviates 7% from highest to lowest five year period.

2016-18 was the first period in 36 years where a player 1 standard deviation better than the field in driving distance (0.50 SG) gained more than a player 1 standard deviation better than the field in driving accuracy (0.43 SG). On average, the 1 SD of distance was worth 11% less than 1 SD of accuracy from 1983-2015, but is worth 17% more in 2016-18.

7. Value of Distance in Womens Professional Golf

A. Hole-by-Hole data

The LPGA Tour has hole-by-hole data showing measured driving distance for two drives per round, the score, and whether the fairway was hit or missed for most rounds since 2007. This yields a dataset of 218k holes between 2007 and 2018. 49% from par 4s, 51% from par 5s.

The holes chosen generally are ones where most players are hitting driver.

I. Distance only vs Fairway hit only

Setting up separate models of rel_score ~ rel_distance and rel_score ~ rel_fairway shows that the model with fairway hit explains slightly more variance in scoring (R^2 = 0.043 for fairway hit only vs 0.034 for distance only). Separate models are inferior to a combined model at explaining scoring on a hole.

II. Distance + Fairway hit

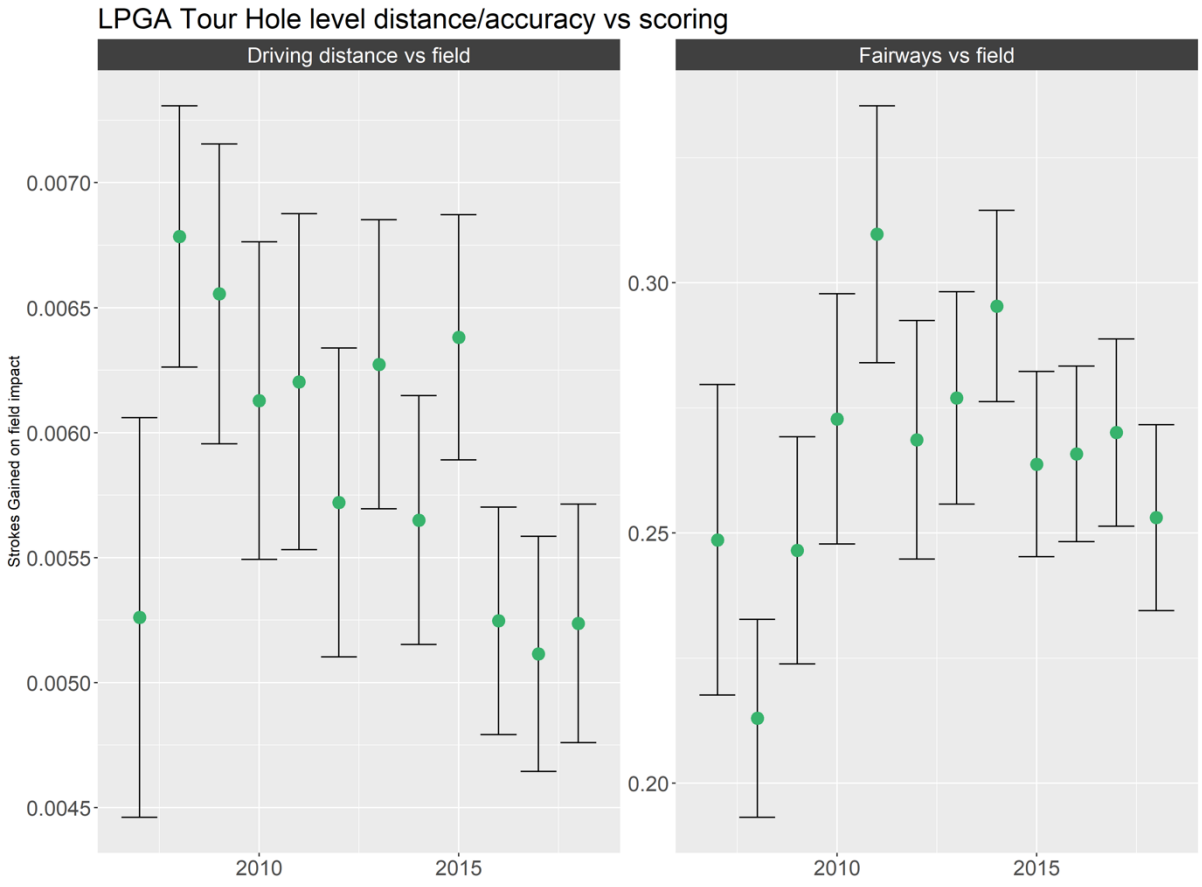


Figure 9

Coefficients for value of distance range between 0.0051 and 0.0068 SG per yard per round. Average coefficient is 0.0059 SG per yard per round. SE is 0.0003 each season.

Value of fairway ranges from 0.21 SG to 0.31 SG per fairway. Average is 0.27 SG per fairway. SE is 0.01 each season.

R^2 is between 0.06 and 0.08 with an average of 0.07.

Comparing an overall model on LPGA Tour to the PGA TOUR hole-by-hole model across just 2007-2018, the value of distance is slightly higher than PGA TOUR (0.0058 SG per yard per hole vs 0.0054 SG per yard per hole on PGA TOUR).

In that overall model, value of fairway on LPGA Tour is slightly lower (0.27 SG vs 0.29 SG on PGA TOUR).

The LPGA hole-by-hole model explains less variance (R^2 = 0.07 vs R^2 = 0.08 on PGA TOUR).

III. Value of distance on PGA TOUR vs LPGA Tour in same seasons

Table 10

Hole-by-Hole model	Value of distance	Value of fairway	R^2 of model
PGA TOUR (2007-18)	0.0054 SG (SE = 0.00006)	0.265 SG (SE = 0.002)	0.080
LPGA Tour (2007-18)	0.0058 SG (SE = 0.00008)	0.293 SG (SE = 0.003)	0.067

The LPGA data was significantly different than PGA data at the $p < 0.001$ level for both distance and accuracy.

IV. Par of hole

Breaking it down by par of hole, the value of distance is higher on par 4s than par 5s (opposite of what we found on PGA TOUR), but the value of fairway is lower on par 5s than par 4s (similar to what we found on PGA TOUR). Both differences were significant at $p < 0.001$ level.

The R^2 of the par 4 model was 0.085 vs 0.050 on par 5s. Driving the ball well explains more of variance in scoring on par 4s on LPGA Tour. This is consistent with PGA TOUR results (higher R^2 on par 4s).

Table 11

	Coefficient (all 12 seasons)	SE (all 12 seasons)
Par 4 value of distance	0.0063 SG per yard per hole	0.0001
Par 5 value of distance	0.0054 SG per yard per hole	0.0001
Par 4 value of fairway	0.31 SG per fairway	0.004
Par 5 value of fairway	0.22 SG per fairway	0.004

B. Round-by-Round data

The LPGA Tour has round-by-round data in similar form to PGA and European Tours dating back to 1993. There are between 4k and 12k rounds available for each season between 1993-2018 for a total of 256k rounds.

This data-set shows the SG per round on the field, the relative driving distance vs the field on the measured drives, and the relative fairways hit vs the field. For example, in R4 of Meijer LPGA Classic in 2018 Ariya Jutanugarn shot 62 (rel_score of 7.88 shots better than the field average), hit 7 fairways (rel_fairways of -0.34 fairways worse than the field average), and averaged 265 yards on two measured drives (rel_distance of 4.2 yards longer than the field average).

rel_score ~ rel_distance + rel_fairways

I. Distance + Fairway Hit

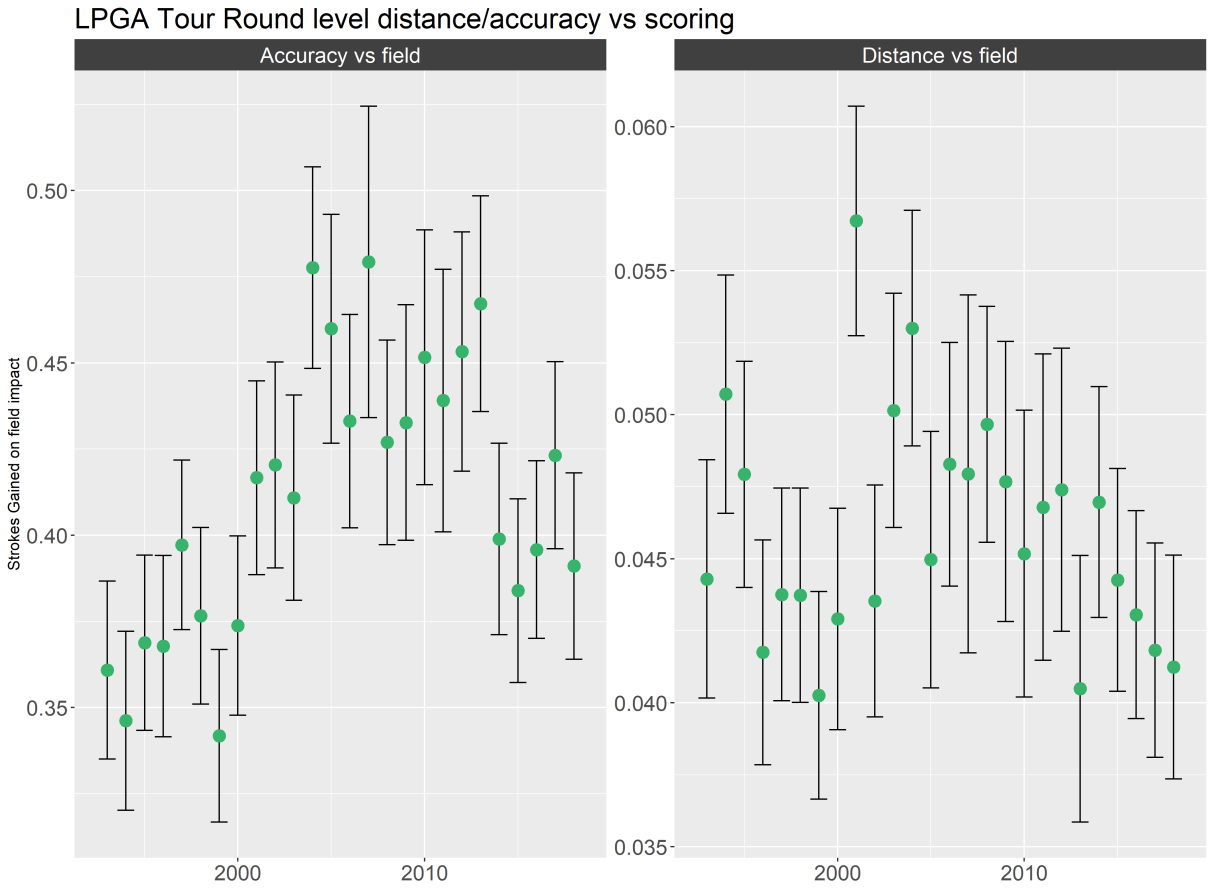


Figure 10

The value of distance on the LPGA Tour has been in steady decline since the early 2000s. The value of distance in 1993-2018 has ranged from 0.040 SG per yard per round to 0.057 SG per yard per

round (about double the range of the PGA TOUR in that same time period). The average is 0.046 SG per yard per round. The SE per season is 0.002 to 0.003.

The value of fairways on the LPGA Tour increased steadily from 1993 to peak around 2010, but has declined since. In the last five seasons it has averaged 0.40 SG per fairway. The average for all 26 years is 0.41 SG per fairway. The SE is 0.015 each season.

The R^2 for these models is between 0.08 and 0.14 with an average of 0.10.

The value of distance of LPGA Tour is 60% higher (0.046 SG vs 0.029 SG per yard per round) over the same period on the PGA TOUR. This was significant at the $p < 0.001$ level.

The value of fairways is almost exactly the same (0.41 SG on LGPA Tour and 0.40 SG on PGA TOUR). The difference was significant at only the $p < 0.05$ level, but significant if not practical differences are likely when dealing with such a large sample of data.

This R^2 is slightly higher than what we saw on PGA TOUR or European Tour – perhaps suggesting that distance explains slightly more of the variance in scoring on LPGA Tour.

II. Value of Distance on PGA TOUR vs LPGA Tour

Table 12

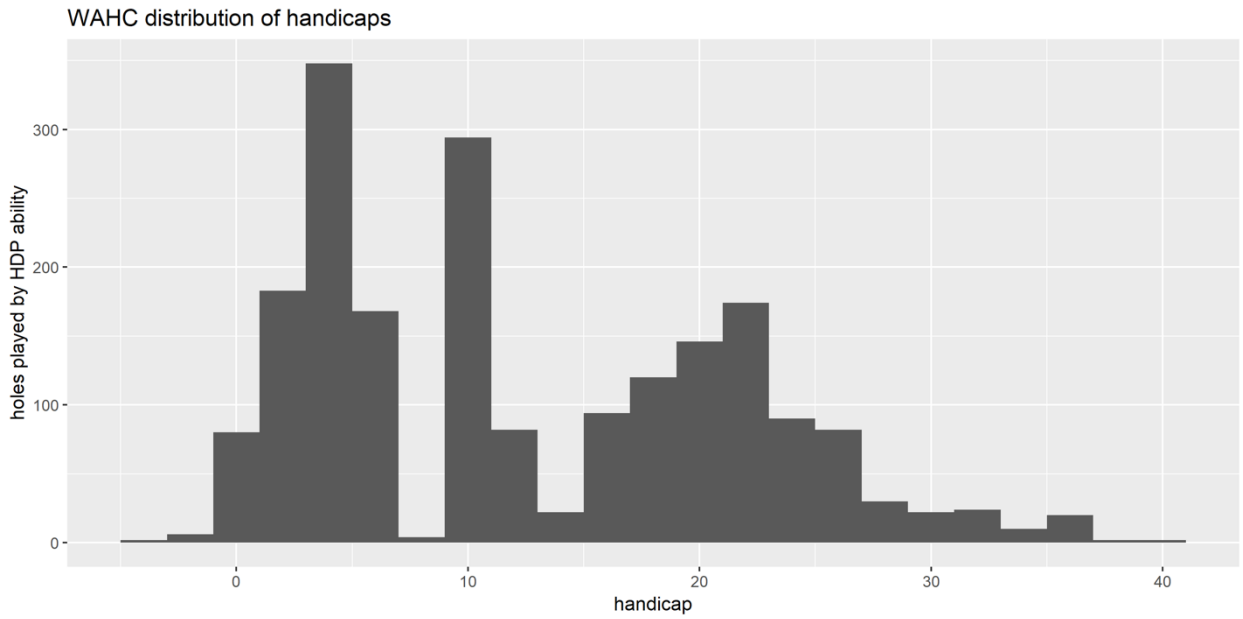
Tour	Average Season	Lowest Season	Highest Season	Season SE Average	Season R^2 Average
PGA TOUR	0.029 SG per yard per round	0.025 (2007)	0.033 (2000)	0.0015	0.086
LPGA Tour	0.046 SG per yard per round	0.040 (1999)	0.057 (2001)	0.0025	0.104

8. Value of Distance for Amateurs

Data for Amateur golfers is less widely available than for professional tours. We have drawn upon data from a decade ago in the World Amateur Handicap Championship (2006-10) and for recent years using the Game Golf sensor system (2013-16). As we will show, both data sources produce similar values of distance.

A. World Amateur Handicap Championship (WAHC)

This data is Shot Link equivalent collected for two holes over four years. In total, there are 2k shots where we have drive distance, score, handicap, and detailed lie_type. This tournament divides players into tournaments based on their reported handicap. The data-set shows handicaps between +4 and 39.1 with 31% in the better than 5 HDP category, 28% in the 5-15 HDP, 31% in the 15-25 HDP, and 10% in the 25+ HDP categories. The average handicap is 12.7 and the median handicap is 10.8.



I. Summary statistics

Table 13

Average driving distance	207 yards	SD = 47 yards
Average score (both par 4s)	5.41	
Average fairways hit	47%	
Average handicap	12.7	SD = 9.1
Median handicap	10.8	

II. Compared to male amateurs in UK in 2006-10 (as measured by the 2018 USGA/R&A Distance Report)

Table 14

	R&A/USGA Distance Report	World Am Handicap
5 handicap or better	242 yards	235 yards
6-12 handicap	221 yards	218 yards
13-20 handicap	200 yards	183 yards
21+ handicap	181 yards	170 yards

Above we have compared the driving distances from this WAHC data for 2006 to 2010 to the average driving distances from 2006 to 2010 among male amateurs in the UK for each range of handicap. Because the WAHC data comes from only two holes, this data is presented as a simple comparison without any claim that there is a true difference between populations.

III. Distance + Fairway Hit + Handicap

We have included Handicap in this regression to attempt to control for ability. Our prior research has shown the range of estimated scoring ability is about 3-4 shots in a PGA Tour or European Tour event. However, the data available here varies widely with the 90th percentile at 2.7 and the 10th percentile at 24.7. If handicap is a robust measure of ability, 1 shot of handicap should translate to about 1 shot gained per 18 holes.

rel_score ~ rel_distance + rel_fairway + handicap

Value of distance for this dataset is 0.0074 SG per yard per hole (SE = 0.0006). If these holes are generalizable to all golf holes, this would be an impact of about 0.10 SG per yard per round.

The value of hitting the fairway is 0.42 SG with a SE of 0.05

The value of 1 stroke of handicap is 0.042 SG per hole which over 18 holes would equate to about 0.75 SG per round – in the neighborhood of the 1 stroke it is estimated to represent. SE = 0.003.

The R^2 value of this model is 0.36.

IV. Distance + Fairway Hit only

Without controlling for handicap, the model yields an R^2 of 0.27. The value of fairway is the same (0.42 SG per fairway), but much of the value of the handicap flows to the value of distance which increases to 0.011 SG per yard per hole (49% higher than the model which uses handicap as a control).

V. Driving distance predicted by handicap

We set-up a similar model to predict driving distance based on the handicap provided by each player.

rel_distance ~ handicap

Overall, the relationship between handicap and driving distance is that 1 stroke of handicap is worth about 2.75 yards worth of distance advantage (SE = 0.1 yards).

The SE of the residuals is 38.5 yards and the R^2 of this model is 0.30 – handicap explains just under a third of the variance in driving distance.

Extrapolating out, the gap between a 5 handicap and 15 handicap would be approximately 27 yards of distance. Across the 14 drives in a round and using the 0.0074 SG per yard per hole value of distance, the gap in terms of driving distance for 5 handicap vs 15 handicap would be about 2.8 SG. Distance represents about 28% of the gap between a 5 handicap and 15 handicap (estimated to be 10 shots overall).

VI. Value of Distance compared to Shot Link data

The limitations of this dataset should not be understated; it represents two holes worth of data collected a decade ago. However, the value of distance for PGA TOUR in the same seasons (2006-10 from Shot Link) was 0.0048 SG per yard per hole. This WAHC data suggests a value of distance about 50% larger (0.0074 SG per yard per hole).

Table 15

Data source	Value of Distance per hole	Value of Distance per round
Shot Link for 2006-10	0.0048 SG per yard	0.067 SG per yard
World Amateur Handicap	0.0074 SG per yard	0.104 SG per yard

The value of distance difference between WAHC and Shot Link for those years is significant at the $p < 0.001$ level.

B. Game Golf data

The Game Golf data comprises about 163k shots collected between 2013 and 2016 (with the majority from 2014). To further weed out potential erroneous data we restricted our analysis to the middle 99% of hole lengths (210 to 434 yards for par 4s and 319 to 552 yards for par 5s). This left 161,476 shots.

There were 5,489 different courses represented in the dataset. We estimate based on course played, gender, and age this data represents around 8k unique player/course pairs and about 17k unique rounds. No course contributes more than 500 shots to the dataset. We also estimate we have the data from at least two different players for 9+ holes for 1.3k courses (representing around 80k of the 162k total shots).

For each shot, in addition to course and date, we had the gender and age of the player, the par of the hole, score on the hole, drive distance, whether the fairway was hit or missed, which club was used on the drive, and the Game Golf handicap (a proprietary metric not equal to an official handicap).

I. Summary Statistics

Table 16

Average driving distance	217 yards	SD = 49 yards
Average score (par 4s)	4.88	
Average hole length (par 4s)	329 yards	SD = 40 yards
Average fairways hit	29.3%	
Average handicap	11.7	SD = 8.4
Median handicap	10.3	

This data is unique in comparison to the other data-sets we have used as there is not an exact reference population to compare each shot to (eg, the field average). Instead, we set drive distance, fairway hit, hole length, and score relative to the population averages for each par to create **rel_score, rel_distance, rel_fairway,** and **rel_hole_length** variables.

II. Game Golf Handicap & driving distance

Similar to our model to explain driving distance using handicap with the WAHC data, we modeled the impact of Game Golf handicap on driving distance. As this handicap is a proprietary metric, it may include driving distance ability as an input. We modeled **rel_distance ~ driver_used + handicap**.

The R^2 was 0.15 – handicap explained about 15% of the variance in driving distance.

The coefficient for handicap was 1 stroke of Game Golf Handicap = 2.1 yards of distance (SE = 0.01).

Driver usage was associated with 20.5 yards longer drives than all other clubs combined.

The residual SE was 45.2 yards.

This outcome is similar to the one for WAHC. The model fit is worse (as it is comparing two holes under controlled conditions with thousands of holes over several years), but the coefficients are similar; 1 shot ability in handicap equals between 2 and 3 yards worth of distance.

III. Distance + Fairway Hit

lm(rel_score ~ rel_distance + rel_fairway)

Residual standard error = 0.965

R^2 = 0.16

Value of distance = 0.0081 shots / yard / hole

Value of fairway = 0.24 shots / fairway

IV. Distance + Fairway Hit + Hole Length

lm(rel_score ~ rel_distance + rel_fairway + rel_hole_length)

Residual standard error = 0.949

R^2 = 0.19

Value of distance = 0.0091 shots / yard / hole (SE of 0.00005)

Value of fairway = 0.24 shots / fairway (SE of 0.005)

Value of yard of hole length = -0.0046 shots / yard (SE of 0.00006)

This shows shortening a hole by 2 yards has the same scoring impact as driving the ball 1 yard further.

V. Hole Length only

Hole length is a strong proxy for difficulty of the hole independent of any other variable. A model of just **rel_score ~ rel_hole_length** shows a value of 1 yard of hole length to be equal to 0.0015 shots (so a par 4 67 yards longer than average par 4 would play 0.10 shots tougher than an average length par 4).

VI. Adding specific course

Mixed effects model using **rel_score ~ course_id** where the model finds a coefficient for the impact of each course on scoring independently. Including course_id in the model improves the residual standard error from about 0.95 to about 0.91. However, there is a chance this represents

substantial over-fitting which would not replicate out of sample. For this section, we only considered those 80k shots from courses where we estimate at least two players played at least 9 holes each. We also examined more restrictive samples of data (eg, at least five players played at least 9 holes each – 9k shots considered) and found similar results.

Including course_id has the affect of increasing the penalty for missing the fairway (by about 0.06 shots) and decreasing the value of distance (by about 0.001 shots / yard / hole).

VII. Restricting only to drives with Driver

We replicated the model with Distance, Fairway Hit, and Hole length just for the 81% of data with Driver used.

Residual standard error = 0.947

R^2 = 0.19

Value of distance = 0.0093 shots / yard / hole (SE of 0.00006)

Value of fairway = 0.22 shots / fairway (SE of 0.006)

Value of yard of hole length = -0.0042 shots / yard (SE of 0.00007)

VIII. Adding in Game Golf Handicap

This data comes with a Game Golf Handicap figure which is generated from a proprietary formula (which may include driving distance ability within it). Nevertheless, we tested its predictive ability alongside Distance + Fairway Hit + Hole Length model using all clubs.

Residual standard error = 0.905

R^2 = 0.26

Value of distance = 0.0070 shots / yard / hole (SE of 0.00005)

Value of fairway = 0.21 shots / fairway (SE of 0.005)

Value of yard of hole length = -0.0052 shots / yard (SE of 0.00006)

Value of shot of GG handicap = -0.037 shots / stroke (SE of 0.0003)

One would expect including a control for ability would reduce the value of distance (better players drive it longer, so some value that was accruing to distance should actually accrue to general ability) and increase the value of hole length (as some of the value that accruing to the length of the hole should actually accrue to general ability as at least in this data better players played longer holes).

It's difficult to know the correct way to control for ability in amateur data. While we are confident that the players on PGA TOUR or LPGA Tour reside in the same 5-6 shot band of ability, amateur golfers reside in a band of ability at least five times as wide.

As we found in the WAHC data collected under very similar conditions for each player, handicap is highly correlated with driving distance ability (R = 0.54). In Game Golf data, Game Golf handicap is correlated at 0.39 with driving distance. In comparison, PGA TOUR data over a season is correlated at 0.27 to SG Total and LPGA Tour data over a season is correlated at 0.33 to SG Total.

The results listed under the sub-heading *IV. Distance + Fairway Hit + Hole Length* give the results of this same model ignoring Game Golf Handicap.

In this model, the value of distance is reduced to 0.0070 shots / yard / hole (down 0.0021), the value of fairway is reduced to 0.21 shots / fairway (down 0.03), and the value of hole length is increased to -0.0052 shots / yard (up 0.006).

The impact of one stroke of GG handicap is equal to 0.037 shots / hole or 0.67 shots / round – similar to the value of handicap from WAHC data (0.75 shots / round).

The R^2 of this model is 37% - higher than the model considering just distance, fairway hit, and hole length.

IX. Male vs Female Amateurs

There are only about 5k shots from female amateurs (3% of the total) in the dataset.
Using the simple Distance + Fairway Hit + Hole Length model from above on both populations shows the value of distance higher for female amateurs.

The difference with male amateurs was significant at the $p < 0.001$ level, while value of fairway and impact of hole length was not a significant difference between the two populations.

Table 17

	Male Amateurs	Female Amateurs
R^2	0.18	0.26
Value of distance	0.0089 shots per yard per hole (SE = 0.00005)	0.0139 shots per yard per hole (SE = 0.0003)
Value of fairway	0.24 shots per fairway (SE = 0.005)	0.20 shots per fairway (SE = 0.03)
Value of hole length	-0.0048 shots per yard (SE = 0.00006)	-0.0047 shots per yard (SE = 0.0004)

X. Final Evaluation

We consider the most reliable and comparable estimates of the value of distance and fairways to come from the Drive Distance + Fairway Hit + Hole Length + GG handicap model using all clubs (as PGA TOUR Shot Link analysis includes around 30% non-drivers as well). This includes our best controls for non-distance and accuracy abilities (handicap & hole length).

C. Value of Distance Comparison

Table 18

Data source	Value of Distance per hole	Value of Distance per round
Shot Link for 2006-10	0.0048 SG per yard	0.067 SG per yard
World Amateur Handicap	0.0074 SG per yard	0.104 SG per yard
Shot Link for 2013-16	0.0050 SG per yard	0.070 SG per yard
Game Golf Data	0.0070 SG per yard	0.098 SG per yard

Game Golf data yields similar value of distance to WAHC and much higher value of distance than Shot Link and much lower value of fairway than either (0.22 shots vs 0.42 SG in WAHC and 0.32 SG in Shot Link data for 2004-18). The wide discrepancy in WAHC value of fairway relative to Game Golf or Shot Link can be explained by only coming from two unique holes (in comparison to thousands in the other datasets).

Game Golf value of distance and fairways is significantly different at the $p < 0.001$ level when compared to PGA TOUR Shot Link data for 2013-16. Game Golf value of distance is significantly different at the $p < 0.001$ level when compared to WAHC data. We ignored the value of fairways given the difference in sample (two holes in WAHC vs thousands in Game Golf).

Both amateur data sources suggest the value of distance is higher in the amateur game than in the men's professional game using like-to-like data sources. Also, the Game Golf data suggests an even higher value of distance for female amateurs than male amateurs. This is similar to our finding that the value of distance is larger on LPGA Tour than PGA TOUR. It may be that value of distance increases as players drive it shorter.

9. Supplemental Analysis

A. Spread in Performance in relevant statistics on PGA TOUR

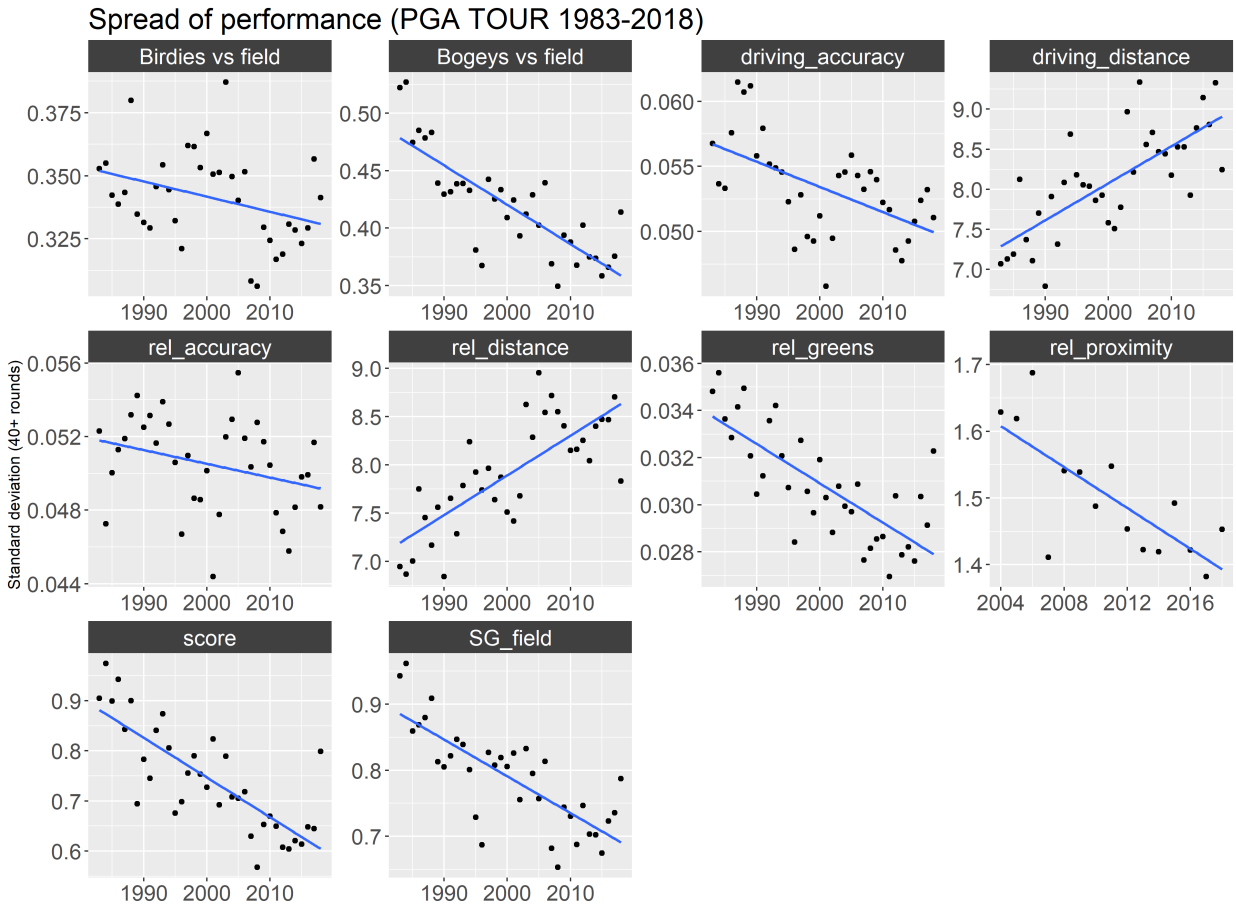


Figure 11

Above are standard deviations from PGA TOUR round level data aggregated by player and season. Eg, in 1983 the standard deviation of season-long driving distance over all players with 40+ rounds played was 7.0 yards and 8.2 yards in 2018. The prefix "rel" above indicates that stat is compared to the field average for each round.

All other statistics (greens in regulation, proximity to the pin, driving accuracy, scoring, birdie-making, and bogey avoidance) have seen a decline in the spread of performance across the Tour. This indicates the abilities of the players on Tour are getting closer together.

However, driving distance has not only proven immune to this decline; the spread in driving distance performance has grown with a trend of nearly two yards in the 36 seasons from 1983-2018. The spread in distance has grown by 25% versus a decline of 7% in the spread of driving accuracy, 17% in the spread of GIR %, 12% in proximity to the pin, 6% in the spread of birdie or better, 24% in the spread of bogey avoidance, and 22% in SG on the field.

This indicates the distribution of performance in driving distance has grown wider at the same time the distribution of performance has grown narrower for all other relevant statistics examined.

B. Correlation of Driving distance to Strokes Gained statistics

Strokes Gained statistics are available for all years that Shot Link data was collected (2004-18). Strokes Gained statistics account for the difficulty of each shot (how the Tour average performs from each lie and distance) and credits or debits a player for advancing the ball into a better or worse situation. In this way, the non-Driving Strokes Gained statistics can be considered uninfluenced by driving distance.

Table 19

Correlation (R)	Overall DD	Overall DA	2004-06 DD	2004-06 DA	2016-18 DD	2016-18 DA
SG Driving	0.73	-0.12	0.73	-0.15	0.77	-0.04
SG Approach	0.05	0.12	0.07	0.18	0.17	0.07
SG ARG	-0.13	-0.11	-0.11	-0.07	-0.08	-0.11
SG Putting	-0.14	-0.03	-0.10	-0.02	-0.07	-0.02

We collected all season-long Strokes Gained data for PGA TOUR for players with 20+ rounds played and found the Correlation between each SG area & Driving Distance and Driving Accuracy. We repeated this for just 2004-06 and just 2016-18.

Driving distance is negatively correlated with performance on shorter shots (SG Putting & SG Around the Green) and barely correlated with performance on approach shots (SG Approach). Driving accuracy shows a similar trend.

Comparing the correlations for 2004-06 and 2016-18 shows that driving distance became more correlated (0.05 to 0.17) with SG Approach and became less negatively correlated with both SG ARG and SG Putting.

The same comparison shows driving accuracy became less correlated (0.18 to 0.07) with SG Approach, more negatively correlated (-0.07 to -0.11) with SG ARG, and was uncorrelated with SG Putting in both periods (-0.02).

This can be interpreted as longer hitters becoming better at the non-driving distance parts of the game, while accurate hitters were becoming worse at the non-driving accuracy parts of the game.

C. Aging & Change in Composition of the Tour

Over the full stretch of 36 years where statistical data is available, the PGA TOUR has undergone two dramatic changes in terms of the age composition of the Tour players.

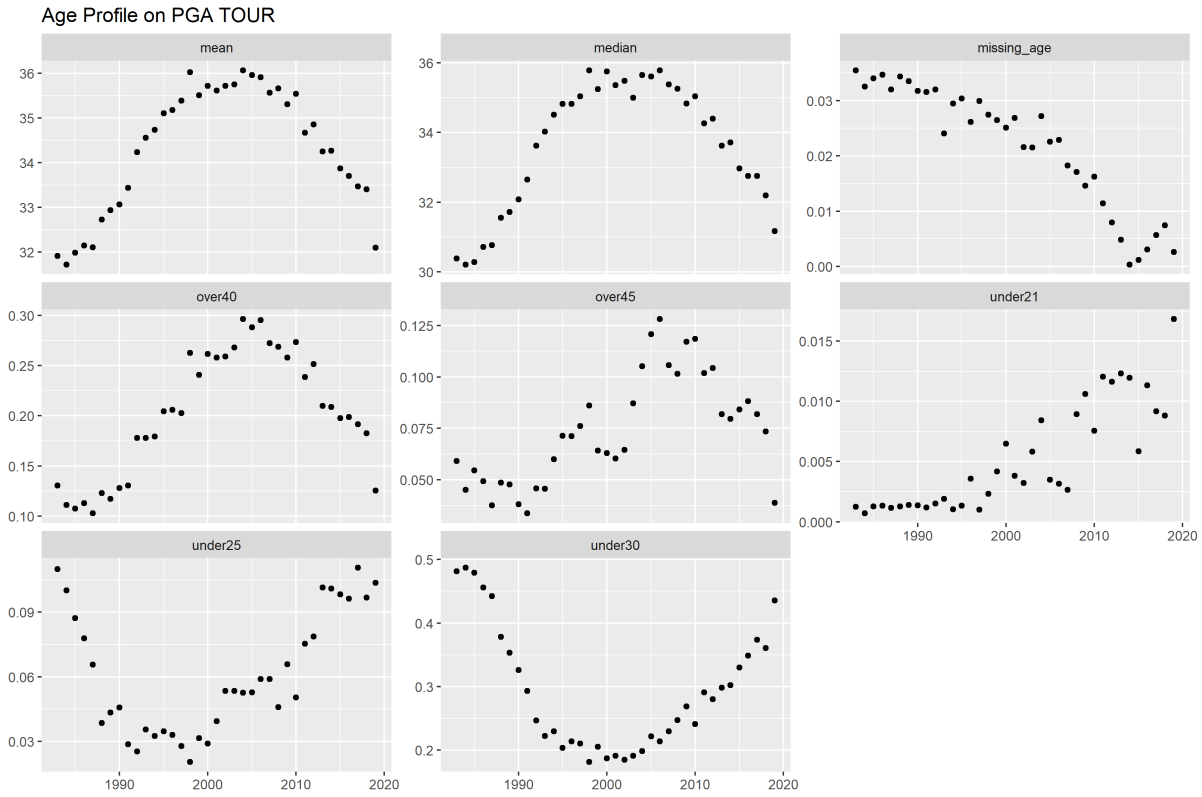


Figure 12

Between 1983 and 2005 the median age on Tour increased from 30 to 36 years old and from 2005 to 2018 the median age decreased from 36 years old to 32 years old. We saw similar rises and falls mirroring those trends in terms of % of players under 30 (nearly 50% in 1983, 20% in 2000, and 35% in 2018) and % of players over 40 (12% in 1983, 30% in 2000, and 17% in 2018).

The aging composition of Tour matters because there is a relationship between age and driving distance. Over the full 36 year sample, we've found 1 year of age corresponds to about 0.44 yards of driving distance such that a player 10 years younger than median age (24 years old) would be expected to drive it 9 yards longer than a player 10 years older than median age (44 years old).

The relationship between age and driving distance strengthened significantly between 1983 and 1998 – increasing from 1 year = 0.27 yards in 1983-85 to 1 year = 0.52 yards in 1998-00. The relationship is 1 year = 0.50 yards in 2016-18. The SE of these estimates is about 0.015. The R^2 of these models increases from 0.03 in 1983-85 to 0.09 in 1998-00 where it remains for 2016-18.

D. Impact of Aging on Driving distance

We used the delta method (compare performance for a player in Year N vs Year N+1, then weight this difference based on harmonic mean of events in Year N vs Year N+ 1, and finally average weighted performance change over all players at that age).

We found the following per year impacts in terms of driving distance versus the field (all data was centered at the event level, ie a distance of 300 yards in an event with a 280 yard average is +20 yards).

Per year impact to age 20 is +1.0 yards

Per year impact from 21 to 50 is -0.7 yards

Per year impact from 51-60 is -1.4 yards

Per year impact after age 60 is -2.5 yards

This aging curve indicates that *relative to field average* an age 20 player will lose about 20 yards of driving distance by age 50 broken down into -4.5 yards from 21-30, -6.6 yards from 31-40, and -9.6 yards from 41-50. This is relative to the field, so it accounts for a player gaining distance overall, but just not as much as other players at that time.

E. Era Aging Curve for Distance

We have constructed similar aging curve for distance based on the years 1983-1991, 1992 to 2003, 2004-2014, 2015-2018 which broadly encompass the pre-titanium driver, pre-solid core ball, stable distance era, and the recent years which have seen an increase in distance again.

For each era we have examined the aging curve expected between age 25 and 45 as we have the largest sample of events for all those ages. Again, this is *relative driving distance* not absolute.

For 1983-1991: aging curve of 7.5 yards for 20 years

For 1992-1999: aging curve of 9.4 yards for 20 years

For 2004-2014: aging curve of 15.4 yards for 20 years

For 2015-2018: aging curve of 18.1 yards for 20 years

Applying the value of distance we've found throughout this study when looking a measured drives (0.0029 SG / yard / hole), aging related driving distance decline cost a player 0.30 SG per round in '83-91, 0.38 SG per round in '92-99, 0.63 SG per round in '00-14, and 0.73 SG per round in '15-18.

F. Driving distance change by Era

I. Raw driving distance change year over year

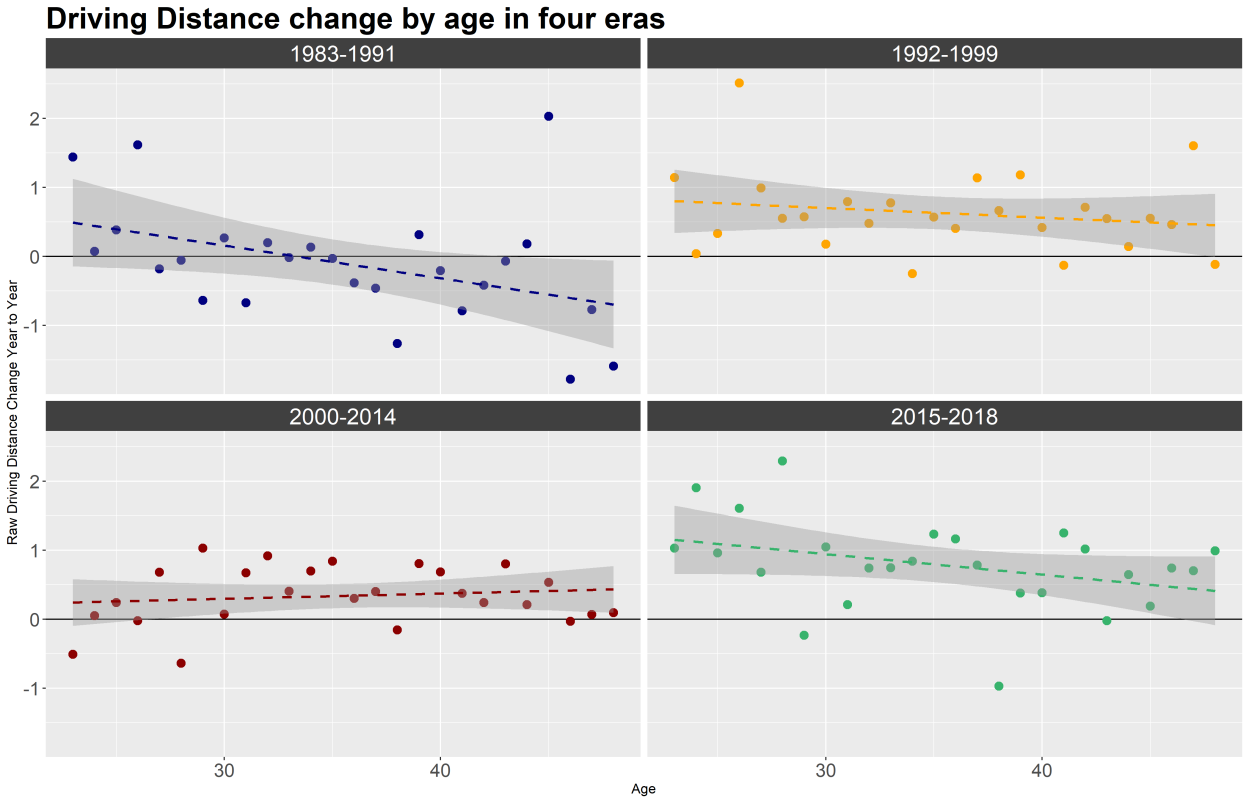


Figure 13

This shows the amount of driving distance change observed for players between year 1 of age X and year 2 of age X + 1 for four different eras corresponding to pre-titanium driver head (1983-91), pre solid core golf ball (1992-99), post-distance boom (2000-2014), and last four years (2015-18).

In 1992-99 and 2000-14, all ages shared in the distance gains of approximately 0.5 to 0.75 yards per season. In 1983-91, younger players disproportionately increased in driving distance by about 0.5 yards while older players decreased in driving distance by about 0.5 yards.

In 2015-18, younger players have again realized more of the distance gains than older players.

II. Raw Driving Distance average by age in each era

We averaged the raw driving distance for all players of each age from 20-50 for each era (minimum 42 players in 1992-99 for age 20 and maximum 499 for 2000-14 for age 34). Age 19/20/21 were combined to get a larger sample for the youngest age ranges.

The average by age ranged from 250.5 yards for age 50 from 1983-91 to 297.0 for age 22 from 2015-18.

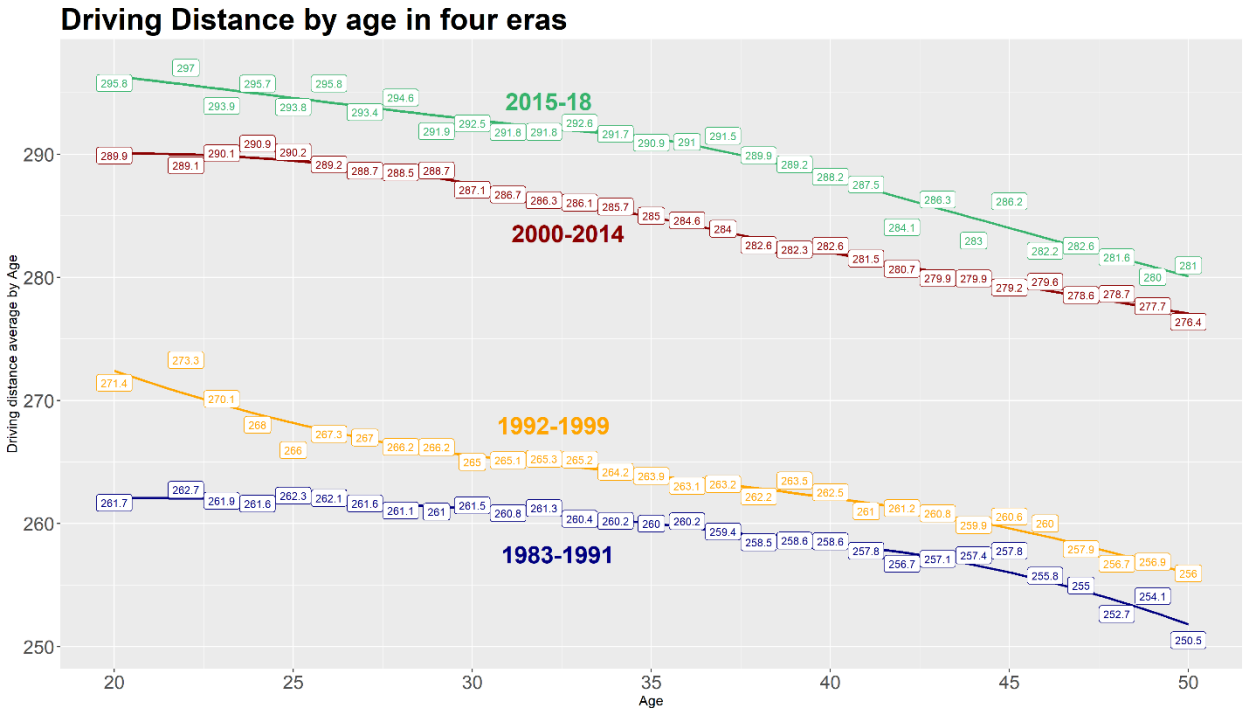


Figure 14

The average difference between an age in 1983-91 and 1992-99 is 4.7 yards, the average difference between an age in 1992-99 and 2000-14 is 20.7 yards, and the average difference between an age in 2000-14 and 2015-18 is 5.2 yards. About 68% of the overall average distance change came between 1992-99 and 2000-14.

Specifically, an age 35 player would be expected to drive it 260.0 yards in 1983-91, 263.9 yards in 1992-99, 285.0 yards in 2000-14, and 290.9 yards in 2015-18.

Comparing age 25 and age 35, the decline for 1983-91 was only 2.3 yards, for 1992-99 was 2.1 yards, for 2000-14 was 5.2 yards, and for 2015-18 was 2.9 yards. This is simply the average change between age cohorts, not the expected rate of change due to aging [ie, as players age those who age less in terms of distance (and other skills) will become more represented in the pool of players making the rate of aging look less than if we had observed every player for the full period of time].

Comparing age 20 and age 50, the decline for 1983-91 was 11.2 yards, for 1992-99 was 15.4 yards, for 2000-14 was 13.2 yards, and for 2015-18 was 14.8 yards. This is simply the average change between age cohorts, not the expected rate of change due to aging [ie, as players age those who age less in terms of distance (and other skills) will become more represented in the pool of players making the rate of aging look less than if we had observed every player for the full period of time].

G. Elite Player Driving Performance

These graphs plot the average distance and accuracy abilities from 1983-2018 for five quantile bands of players. Each quantile represents player skill measured by their overall scoring relative to the field. For example, a player in the Bottom 5% band would fall in the lowest 5% of scoring ability; a player in the 60-95% band would fall between the 60th and 95th percentiles of scoring ability; a player in the Top 5% band would be considered an elite player on tour, etc.

We have divided the 36 years of data available into six equal periods (1983-1988, 1989-1994, 1995-2000, 2001-2006, 2007-2012, 2013-2018).

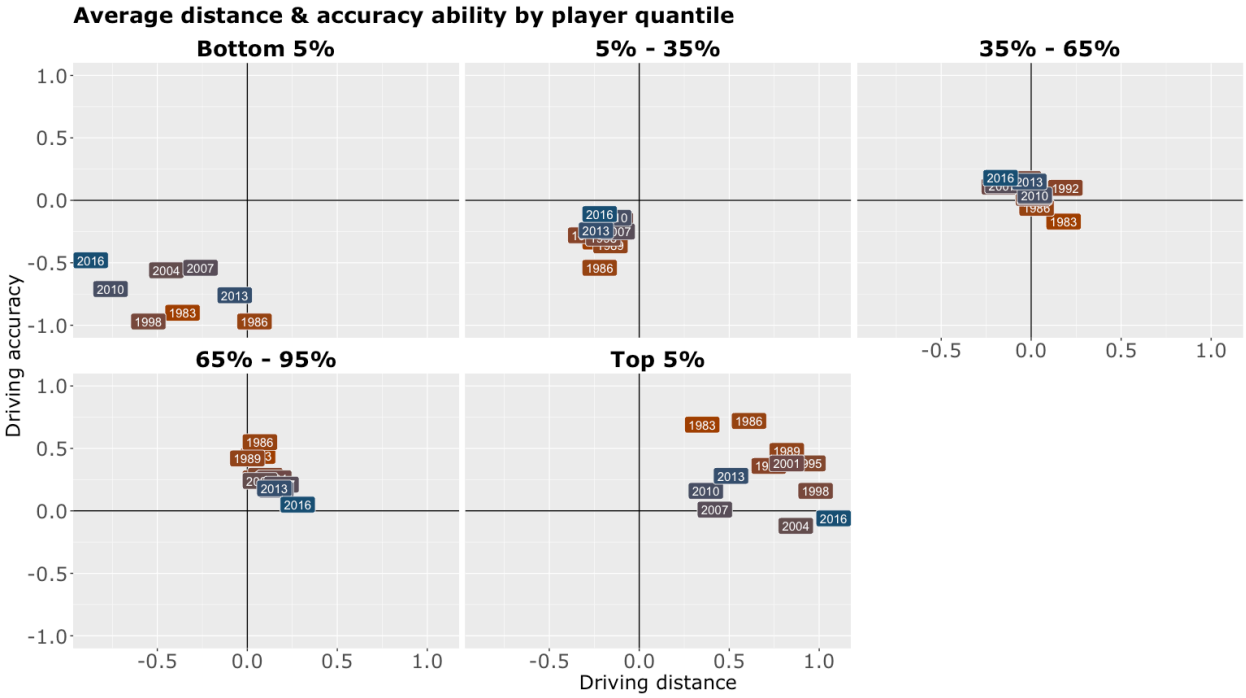


Figure 15

Elite players (defined as the Top 5% of scoring ability, or 95th percentile) from 1983-88 were defined by being straighter hitters (0.70 SDs in driving accuracy) than longer hitters (0.58 SDs in driving distance). That was the only period where the elite players rated higher in accuracy than distance.

Table 20

Period	SDs Elites in Distance	SDs Elites in Accuracy
1983-88	0.58	0.70
1989-94	0.73	0.53
1995-00	0.95	0.29
2001-06	0.85	0.23
2007-12	0.48	0.24
2013-18	1.04	0.04

In total of the 372 players in the elite player group for all periods, 41% ranked 1 SD or better in driving distance (1 SD = roughly 7 to 9 yards versus the field), while only 6% ranked 1 SD or worse in driving distance.

Of that same group, 24% ranked 1 SD or better in driving accuracy (1 SD = roughly 5 percentage points more fairways versus the field), while only 8% ranked 1 SD or worse in driving accuracy.

Specifically, in the last six seasons, 33 of 61 have ranked 1 SD or better in driving distance vs 1 at -1 SD or worse. 9 of 61 have ranked 1 SD or better in driving accuracy vs 10 at -1 SD or worse.

The interpretation based on these results show that driving distance has more come to define an elite player in 2018 (compared to the 1980s and early 1990s), while driving accuracy has steadily become less defining of an elite player (it has dropped in each period since the 1980s to current year).

H. Course Specific Impact of Distance

Using Shot Link data from 2004-2018, we applied our linear model for value of distance **(rel_score ~ rel_distance + rel_fairway)** independently to each golf course in the Shot Link data-set. We aimed to measure whether certain courses on Tour had a statistically significant impact on the value of distance or value of fairway. This was 91 different courses across 15 seasons. Our model tested the impact of the course using a binomial interaction term of whether the course was the one under consideration or all other courses in the data-set **(rel_score ~ rel_distance * specific_course + rel_fairway * specific_course)**.

Using that method, we found a coefficient for the value of distance and value of fairway with standard errors for each. The range between the lowest and highest value of distance at a specific course is 0.0037 SG per yard per hole to 0.0069 SG per yard per hole. The lowest was at Club de Golf Chapultepec (2017-18 WGC Mexico), while the highest was at Whistling Straits (PGA Championship in 2015).

For example, Whistling Straits had a coefficient for value of distance of 0.0069 SG per yard per hole for 2015 PGA Championship event. The average coefficient across 2004-18 on PGA TOUR courses with Shot Link data using this method was 0.0051 SG per yard per hole. The standard error for Whistling Straits was 0.00042 meaning that when compared to PGA TOUR average the value of distance at Whistling Straits is statistically different from the value of distance on average PGA TOUR course at the $p<0.001$ level.

Pebble Beach has a value of distance coefficient of 0.0052 SG per yard per hole from the Pro-am in 2004-18. The standard error is 0.00017 which means Pebble Beach does not have a statistically different value of distance from PGA TOUR average course.

Club de Golf Chapultepec (Club de Golf Ch-240 on the following graphs) has a value of distance coefficient of 0.0037 SG per yard per hole from 2017-18 WGC Mexico. The standard error is 0.00025 which means Chapultepec has a statistically lower value of distance from PGA TOUR average course at the $p<0.001$ level.

In terms of value of fairway, the range is between 0.21 SG per fairway and 0.46 SG per fairway. The low end is Tucson National (host of 2004-06 Chrysler Classic of Tucson) and the high end is Montreux G&CC (host of 2004-11 Reno Tahoe Open). The standard errors for both courses are about 0.01 SG. The average PGA TOUR course using this method has a value of fairway of 0.33 SG per fairway.

In Figure 16 and Figure 17 below we show the regression coefficients for the value of distance and value of fairway with 95% confidence interval. This means there is only a five percent chance the value of distance/fairway for that course falls outside that range. Eg, based on the coefficient (0.0064) and standard error (0.00013), we would expect the value of distance for GC of Houston-729 to fall between 0.00614 and 0.00666).

Of 91 courses, 23 courses had a value of distance significantly different at the $p<0.01$ level (11 significantly lower and 12 significantly higher).

Of 91 courses, 53 courses had a value of fairway significantly different from Tour average at the $p<0.01$ level (28 significantly higher and 25 significantly lower).

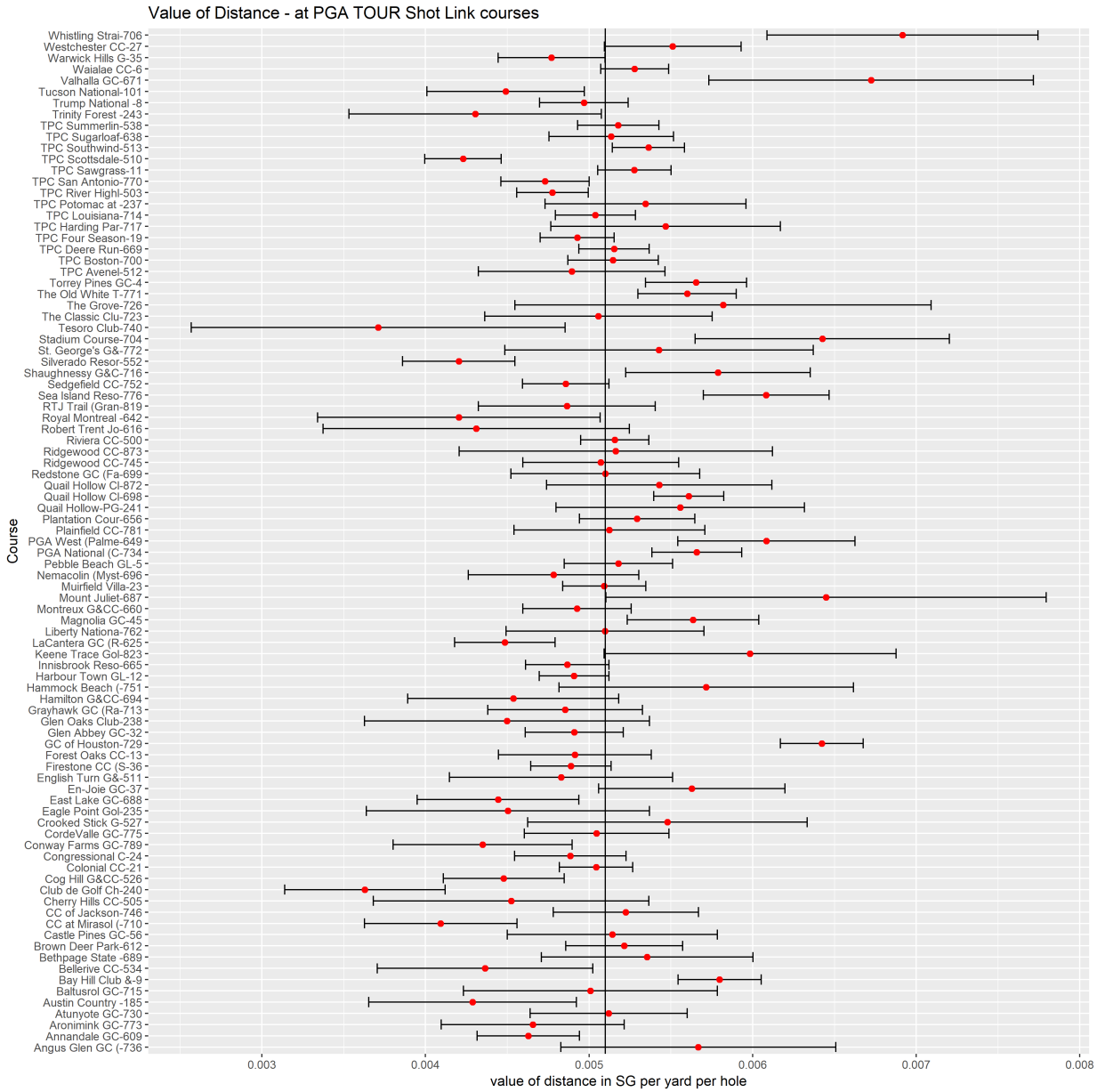

Value of Distance - at PGA TOUR Shot Link courses
Course
Whistling Strai-706
Westchester CC-27
Warwick Hills G-35
Waialae CC-6
Valhalla GC-671
Tucson National-101
Trump National -8
Trinity Forest -243
TPC Summerlin-538
TPC Sugarloaf-638
TPC Southwind-513
TPC Scottsdale-510
TPC Sawgrass-11
TPC San Antonio-770
TPC River Highl-503
TPC Potomac at -237
TPC Louisiana-714
TPC Harding Par-717
TPC Four Season-19
TPC Deere Run-669
TPC Boston-700
TPC Avenel-512
Torrey Pines GC-4
The Old White T-771
The Grove-726
The Classic Clu-723
Tesoro Club-740
Stadium Course-704
St. George's G&-772
Silverado Resor-552
Shaughnessy G&C-716
Sedgefield CC-752
Sea Island Reso-776
RTJ Trail (Gran-819
Royal Montreal -642
Robert Trent Jo-616
Riviera CC-500
Ridgewood CC-873
Ridgewood CC-745
Redstone GC (Fa-699
Quail Hollow Cl-872
Quail Hollow Cl-698
Quail Hollow-PG-241
Plantation Cour-656
Plainfield CC-781
PGA West (Palme-649
PGA National (C-734
Pebble Beach GL-5
Nemacolin (Myst-696
Muirfield Villa-23
Mount Juliet-687
Montreux G&CC-660
Magnolia GC-45
Liberty Nationa-762
LaCantera GC (R-625
Keene Trace Gol-823
Innisbrook Reso-665
Harbour Town GL-12
Hammock Beach (-751
Hamilton G&CC-694
Grayhawk GC (Ra-713
Glen Oaks Club-238
Glen Abbey GC-32
GC of Houston-729
Forest Oaks CC-13
Firestone CC (S-36
English Turn G&-511
En-Joie GC-37
East Lake GC-688
Eagle Point Gol-235
Crooked Stick G-527
CordeValle GC-775
Conway Farms GC-789
Congressional C-24
Colonial CC-21
Cog Hill G&CC-526
Club de Golf Ch-240
Cherry Hills CC-505
CC of Jackson-746
CC at Mirasol (-710
Castle Pines GC-56
Brown Deer Park-612
Bethpage State -689
Bellerive CC-534
Bay Hill Club &-9
Baltusrol GC-715
Austin Country -185
Atunyote GC-730
Aronimink GC-773
Annandale GC-609
Angus Glen GC (-736
0.003
0.004
0.005
0.006
0.007
0.008
value of distance in SG per yard per hole

Figure 16

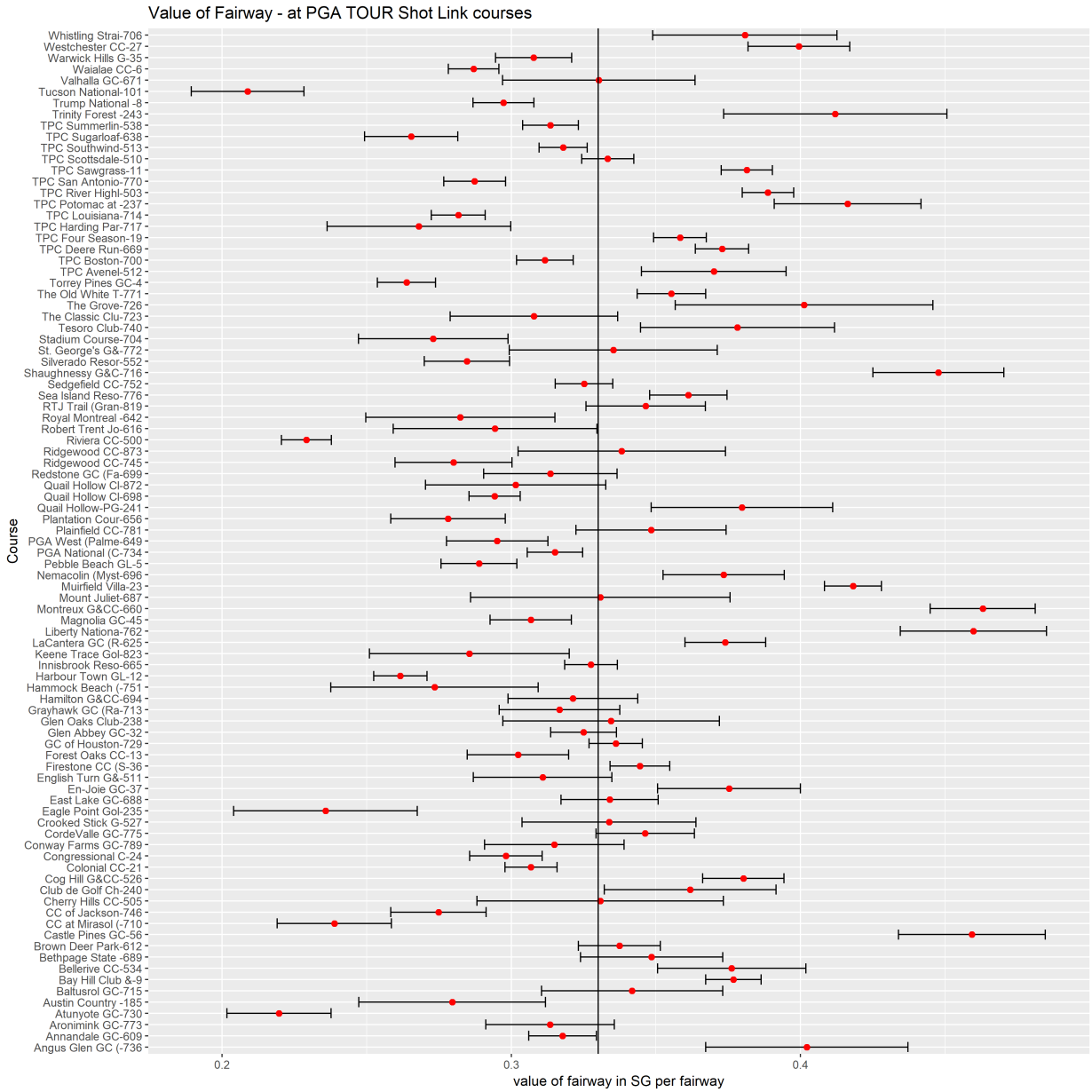


Figure 17

I. Physical Changes in Tour Players

The PGA Tour website makes available height and weight data for many current and former players. It is anticipated that this self-reported data which is rarely - if ever - updated so the overall utility may be limited. This data covers about 50% of player events in 2000, 75% in 2006, and around 90% in 2018.

Median values for the full sample of players (652 players) is 181 cm, 81 kg, and 24.5 BMI. From 2000 to 2018, average height has increased from 181 cm to 182 cm and average weight has decreased from 83 kg to 81.5 kg. Average BMI has decreased from 25.3 to 24.6.

J. On-course value of fairway in yards

In this research we have established estimated values for a yard of distance and a fairway hit vs missed in the semi rough, rough, fairway bunker, or other lie in section 6AII. These coefficients are derived from the linear regression model of **rel_score ~ rel_distance + lie_type**. We can compare those coefficients to the Tour average performance levels from each distance and lie which are generated to power the Strokes Gained methodology popularized by Mark Broadie (Baseline data).

In Shot Link era, 1 yard has been worth 0.0049 SG while fairway is worth 0.08 SG over semi-rough, 0.28 SG over primary rough, 0.33 SG over fairway bunker, and 0.63 SG over other (trees, native area, etc).

In Mark Broadie's 2011 *Assessing Golfer Performance on the PGA TOUR* he creates baseline tables for his strokes gained methodology which establish the value in terms of strokes left to hole-out from various lies and distances. For example, he gives the value of a ball 180 yards to the pin in the fairway as 3.08 strokes and the value of a ball 120 yards to the pin in the primary rough as 3.08 strokes as well. In other words, a professional player would be agnostic between a ball in the rough at 120 yards and a ball in the fairway at 180 yards. They would be equally difficult locations. That means roughly 60 yards is worth the gap between fairway and the rough.

Using our values for fairway and primary rough (0.28 SG gap), that would mean a value of distance of approximately 0.0047 SG per yard.

Using our value for 1 yard of distance (0.0049 SG per yard) over 60 yards, that would place the difference between fairway and primary rough at 0.29 SG.

In both cases, our estimates match the strokes gained methodology. For typical locations on a par 4 hole like 180 yards in the fairway and 120 yards in the rough, the gap between fairway and rough is worth approximately 60 yards of distance.

Using our value of distance and lies from Shot Link data, we have shown the approximate location a ball would need to be located in each lie to be worth an equal amount to a ball at 180 yards in the fairway.

Table 21

Fairway and Primary Rough	123 yards (57 yards ahead)
Fairway and Semi Rough	164 yards (16 yards ahead)
Fairway and Fairway Bunker	113 yards (67 yards ahead)
Fairway and Other lie	51 yards (129 yards ahead)