Effect of Pressure on PGA Golfer's Performance

Jeffrey Wu[1], Russell Zaretzki[2], Yunfeng Dai[3]
[1]Eastside High School, 1201 Southeast 43rd Street, Gainesville, FL 32641
[2]Department of Business Analytics and Statistics, University of Tennessee, 255 Stokely Management Center, Knoxville, TN 37996
[3]Department of Biotatistics, University of Florida, 2004 Mowry Road, Gainesville, FL 32610

Abstract

It is commonly believed that the sport of golf is one of the most mentally intense sports played around the world. Along with meticulous strategy and sharp focus, the ability to perform well under pressure may be a quality that separates the good golfers from the elite ones. In this paper, we investigate the effect of pressure on performance using the ShotLink™ data from the PGA TOUR collected between 2003 and 2014. Focusing on the top ten (plus ties) players after three rounds of each tournament, we try to answer the following two questions: 1) How does the pressure of winning a tournament affect how well a player performs in the final round of that tournament? 2) Does the player's previous winning experience, ranking after 3 rounds, and age impact the way that they respond to the pressure effect?

First, to determine how well a player performed in the final round, we selected 7 statistics: relative to par score (RTP), driving distance in yards (DD), driving accuracy, i.e., fairways percentage (DA), greens in regulation percentage (GIR), proximity to the hole in foot (PTH), strokes gained putting (SGP), and saving percentage (SP). In order to adjust for course specific conditions and facilitate comparison across tournaments, each top player's performance measures were centered by subtracting the average of those players who played the final round but were not in the top ten entering the final round. We next compared the top ten players' final round adjusted performance to their average performance in rounds that they played at other tournaments where they entered the final round but not in the top ten. Finally, we performed regression analysis to study whether age, experience and ranking influence the pressure effect.

Our results indicate that: (1) Overall, players performed better in RTP, DD and GIR but worse in PTH while in the top ten. (2) Players with major winning experience performed significantly better in RTP, DD, DA, GIR and PTH than those without major wins, and they were affected significantly less by pressure in DA and PTH. (3) The higher the rank after the first three rounds, the larger the pressure effect on SP; and there is a trend suggesting that the rank affects players in DA and PTH. (4) Younger players drove the ball farther and less accurately than older players, but age did not have a significant impact on the pressure effect.

Key Words: PGA TOUR, pressure of winning, relative to par score, driving distance and accuracy, greens in regulation, proximity to hole, strokes gained putting, saving percentage

1. Introduction

It is widely accepted that golf is one of the most mentally intense sports in the world. One mental quality that is very important is the ability to perform well under pressure. Do the big moments that professional golfers face every week have any significant effect on their performance when everything is on the line? This question arises because professional golfers often seem like automatic machines that are incapable of hitting bad shots and at other times, they implode and play very poorly. In many cases, the ability to function under enormous pressure is what separates the elite golfers from the merely good ones. The best players in the world usually end up playing on the PGA (Professional Golf Association) Tour where they make their livelihoods playing in tournaments every week throughout the year. So how good are these golfers at performing well under pressure? The general conclusion is that, in the heat of the moment, a bad performance is caused by "choking" but it is an interesting challenge to quantify the effect of tournament pressure on the player's performance.

With recent advances in technology, the location of the golf ball can be determined to the inch for every single shot of every player in almost every PGA TOUR tournament. Such detailed data opens up unprecedented possibilities for the analysis of golf statistics (Connolly and Rendleman, 2008). For example, Hickman and Metz (2015) used the ShotLink™ data from the PGA TOUR collected between 2004 and 2012 to study putting on the 18th hole of the final round of golf tournaments, where pressure is typically high. They estimated that as a putt's value increases by $50,000, the likelihood that the player will make that putt decreases by 1 percent; consequently they concluded that golf pros play worse under pressure.

In this investigation, using the 2003-2014 ShotLink™ data, we attempted to determine how much effect pressure had on a PGA golfer's performance in the final round of tournament. Focusing on the top ten (plus ties) players after three rounds of each tournament, we try to answer the following two questions: 1) How does the pressure of winning a tournament affect how well a player performs in the final round of that tournament? 2) Does the player's previous winning experience, ranking after 3 rounds, and age impact the way that they respond to the pressure effect?

2. Study Approach

2.1 The Game of Golf

A PGA TOUR golf tournament is usually played over four days, in most cases Thursday through Sunday. Each day, players play 18 holes, using various clubs to hit balls into the holes in as few strokes as possible. Each hole must contain a tee box to start from and a putting green containing the actual hole, with other standard forms of terrain (such as fairway, rough, and hazards) in between. After the second round, approximately half of the players with the best scores make "the cut" and advance onto rounds 3 and 4. The winner of the tournament is the player with the lowest number of strokes.

2.2 Data Source and Performance Measures

We used the ShotLink™ data from the PGA TOUR collected over the last twelve years (2003-2014). The data contains detailed information about every single shot of every player in almost every PGA TOUR tournaments, with the location of the ball determined to the accuracy of 1 inch.

To determine how well a player performed in the final round, we selected seven performance measures. They include: 1) relative to par score (RTP) in total, where par is the number of strokes a skilled golfer should require to complete play of a hole. 2) Driving distance in yards (DD): for simplicity, we included distance of tee shots for par-4 and par-5 holes. 3) Driving accuracy (DA): percentage of par-4 and par-5 tee shots ending up in fairways. 4) Greens in regulation percentage (GIR): to reach the green within "par minus 2" strokes. 5) Proximity to the hole in feet (PTH): distance between the hole and the ball once it reaches green. 6) Strokes gained putting (SGP): the concept of SGP was initiated by Broadie (2008). We evaluated SGP based on Fearing, Acimovic and Graves (2010), which combines two models to calculate expected-stroke-to-putt: one on the probability of making the putt and the other leaving it close when missing. 7) Saving percentage (SP): *saving* par refers to a situation where the golfer scores par or better on a hole when not hitting a GIR

2.3 Statistical Analysis Methods

In order to adjust for course specific conditions and facilitate comparison across tournaments, each top player's performance measures were centered by subtracting the average of those players who played the final round but were not in the top ten entering the final round. We next compared the top ten players' final round adjusted performance to their average performance in rounds that they played at other tournaments where they entered the final round outside of the top ten. Paired-t and Wilcoxon signed rank tests were conducted to investigate pressure effect. In addition, we performed either the two-sample t-test or ANOVA to study whether age, experience and ranking can influence the pressure effect. Finally, regression analysis was conducted to jointly analyze all three pre-specified factors.

3. Analysis Results on 4th Round Performances

A total of 5,720 top ten player rounds were identified from 2003 to 2014. In addition to the course adjusted statistics (Table 1b, 2b, 3b), we also present the data without course adjustment (Table 1a, 2a, 3a) because it is more familiar to readers.

The "Overall" column in Table 1a shows that, in the final round, the top ten players had relative to par (RTP) score of -0.5 ± 3.1 strokes, driving distance (DD) of 262.8 ± 10.7 yards, driving accuracy (DA) of 62.2 ± 17.9 percent, greens in regulation (GIR) of 65.3 ± 15.8 percent, proximity to hole (PTH) of 21.2 ± 4.7 feet, strokes gained (SGP) per 100 putts of 0.4 ± 9.8, and saving percent (SP) of 61.7 ± 23.0. More importantly, players performed significantly better in RTP, DD and GIR but significantly worse in PTH while in the top ten. Specifically, compared to their performance while they were not in top ten, RTP improved 0.1 ± 2.8 strokes, DD increased by 0.7 ± 4.8 yards, GIR improved by 1.1 ± 11.7 percent, but PTH increased by 0.4 ± 4.3 feet (See Table 1b).

3.1 *Comparison between Players with and without Major Winning Experience*

Table 1b also shows that players with major winning experience performed significantly better in RTP, DD, DA, GIR and PTH than those without major wins. Furthermore, they were affected less by pressure in DA and PTH. Fourth round DA decreased by 0.2 ± 13.2 percent when in top ten compared to not in top ten for players without major winning experience, in contrast to an increase of 1.0 ± 13.7 for those with major wins (p=0.015). Similarly, PTH increased by 0.5 ± 4.3 feet for players without major winning experience

compared to an increase of 0.1 ± 4.3 feet (p=0.0087) for those with major winning experience.

Table 1a. Comparison between Players With and Without Major Winning Experience (WITHOUT course adjustment)

	Overall			Without major winning experience			With major winning experience			
variable	meanSd	medianIQR	N	meanSd_0	medianIQR_0	N_0	meanSd_1	medianIQR_1	N_1	p-value
Relative to Par Score (Strokes)										
Top 10	-0.5 ± 3.1	-1 [-3, 2]	5720	-0.4 ± 3.1	-1 [-2, 2]	4781	-0.8 ± 3.2	-1 [-3, 1]	939	**0.0003**
Paired difference from non-top10	-0.2 ± 3.3	-0.4 [-2.4, 2]	5675	-0.2 ± 3.3	-0.4 [-2.4, 1.9]	4742	-0.1 ± 3.4	-0.3 [-2.4, 2.2]	933	0.439
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		0.247	0.247		
Driving Distance (Yards)										
Top 10	262.8 ± 10.7	262.7 [255.5, 270]	5524	262.5 ± 10.5	262.4 [255.4, 269.6]	4610	264.1 ± 11.5	264.2 [256.3, 271.8]	914	**<.0001**
Paired difference from non-top10	0.9 ± 9.7	1.2 [-5.6, 7.6]	5481	0.9 ± 9.6	1.2 [-5.6, 7.6]	4574	0.9 ± 10.0	1.1 [-5.9, 7.7]	907	0.997
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**0.0077**	**0.0077**		
Driving Accuracy (%)										
Top 10	62.2 ± 17.9	64.3 [50, 71.4]	5720	62.1 ± 17.9	64.3 [50, 71.4]	4781	63.0 ± 17.4	64.3 [50, 73.3]	939	0.134
Paired difference from non-top10	0.6 ± 17.9	1.9 [-9.5, 12.5]	5675	0.5 ± 18.0	1.8 [-9.5, 12.6]	4742	1.1 ± 17.6	2.5 [-8.7, 12.2]	933	0.370
P-value from paired t tests	**0.009**	**0.0089**		**0.0434**	**0.0434**		0.056	0.056		
Greens in Regulation (%)										
Top 10	65.3 ± 15.8	66.7 [56.3, 76.5]	5720	65.1 ± 16.0	66.7 [55.6, 76.5]	4781	66.4 ± 14.7	66.7 [58.8, 77.8]	939	**0.020**
Paired difference from non-top10	1.9 ± 16.5	3.1 [-6.3, 12.3]	5675	1.9 ± 16.6	3.1 [-6.1, 12.4]	4742	2.0 ± 15.6	2.4 [-7.2, 12]	933	0.916
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Proximity to Hole (Feet)										
Top 10	21.2 ± 4.7	20.9 [17.9, 24]	5524	21.3 ± 4.7	21.1 [17.9, 24.1]	4610	20.6 ± 4.5	20.4 [17.3, 23.4]	914	**<.0001**
Paired difference from non-top10	0.3 ± 4.9	0.2 [-3, 3.3]	5481	0.4 ± 4.9	0.2 [-3, 3.4]	4574	0.1 ± 4.9	-0.3 [-3, 3.3]	907	0.139
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		0.504	0.504		
Strokes Gained per 100 Putts										
Top 10	0.4 ± 9.8	0.3 [-6, 6.9]	5524	0.4 ± 9.8	0.2 [-6, 6.9]	4610	0.5 ± 10.0	0.9 [-6.2, 7]	914	0.613
Paired difference from non-top10	-0.2 ± 10.3	-0.4 [-6.9, 6.6]	5481	-0.2 ± 10.2	-0.4 [-6.8, 6.6]	4574	-0.4 ± 10.9	-0.5 [-7.7, 6.5]	907	0.499
P-value from paired t tests	0.095	0.095		0.2066	0.2066		0.219	0.219		
Saving Percentage (%)										
Top 10	61.7 ± 23.0	60 [50, 77.8]	5707	61.7 ± 22.8	60 [50, 75]	4772	62.0 ± 24.0	60 [50, 80]	935	0.670
Paired difference from non-top10	0.5 ± 24.4	0.6 [-15.1, 17.2]	5662	0.7 ± 24.1	0.9 [-14.8, 16.9]	4733	-0.5 ± 25.7	-1.7 [-16.7, 18.7]	929	0.187
P-value from paired t tests	0.120	0.120		**0.048**	**0.048**		0.584	0.584		

Table 1b. Comparison between Players With and Without Major Winning Experience (WITH course adjustment)

	Overall			Without major winning experience			With major winning experience			
variable	meanSd	medianIQR	N	meanSd_0	medianIQR_0	N_0	meanSd_1	medianIQR_1	N_1	p-value
Relative to Par Score (Strokes)										
Top 10	-0.4 ± 2.7	-0.5 [-2.3, 1.3]	5720	-0.3 ± 2.7	-0.4 [-2.2, 1.5]	4781	-1.0 ± 2.9	-1 [-2.9, 0.8]	939	**<.0001**
Paired difference from non-top10	-0.1 ± 2.8	-0.2 [-2, 1.7]	5675	-0.1 ± 2.8	-0.2 [-2, 1.7]	4742	-0.1 ± 2.9	-0.2 [-2, 1.7]	933	0.939
P-value from paired t tests	**0.008**	**0.008**		**0.016**	**0.016**		0.271	0.271		
Driving Distance (Yards)										
Top 10	1.5 ± 6.7	1.3 [-2.8, 5.7]	5524	1.3 ± 6.5	1.1 [-2.8, 5.4]	4610	2.3 ± 7.3	2.2 [-2.4, 6.8]	914	**<.0001**
Paired difference from non-top10	0.7 ± 4.8	0.7 [-2.4, 3.8]	5481	0.7 ± 4.8	0.8 [-2.4, 3.8]	4574	0.6 ± 5.0	0.6 [-2.5, 4]	907	0.536
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Driving Accuracy (%)										
Top 10	0.3 ± 13.3	0.5 [-8.5, 9.3]	5720	0.0 ± 13.2	0.1 [-8.6, 9]	4781	1.5 ± 13.7	1.6 [-7.2, 10.5]	939	**0.002**
Paired difference from non-top10	0.0 ± 13.2	0 [-9, 8.9]	5675	**-0.2 ± 13.2**	**-0.2 [-9.2, 8.8]**	**4742**	**1.0 ± 13.7**	**1.4 [-7.7, 9.7]**	**933**	**0.015**
P-value from paired t tests	0.970	0.970		0.339	0.339		**0.0303**	**0.0303**		
Greens in Regulation (%)										
Top 10	1.5 ± 11.2	1.6 [-5.6, 9.1]	5720	1.3 ± 11.2	1.2 [-5.9, 8.7]	4781	3.0 ± 11.4	3.5 [-4.2, 10.4]	939	**<.0001**
Paired difference from non-top10	1.1 ± 11.7	1.2 [-6.5, 8.9]	5675	1.1 ± 11.6	1.2 [-6.5, 8.7]	4742	1.4 ± 12.2	1.2 [-6.3, 9.3]	933	0.419
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Proximity to Hole (Feet)										
Top 10	-0.1 ± 4.2	-0.2 [-2.9, 2.6]	5524	0.1 ± 4.2	-0.1 [-2.8, 2.8]	4610	-0.9 ± 4.1	-1 [-3.8, 1.6]	914	**<.0001**
Paired difference from non-top10	0.4 ± 4.3	0.3 [-2.6, 3.2]	5481	**0.5 ± 4.3**	**0.4 [-2.6, 3.3]**	**4574**	**0.1 ± 4.3**	**-0.1 [-3, 2.9]**	**907**	**0.0087**
P-value from paired t tests	**<.001**	**<.001**		**<.0001**	**<.0001**		0.695	0.695		
Strokes Gained per 100 Putts										
Top 10	0.1 ± 9.5	0 [-6.2, 6.3]	5524	0.0 ± 9.5	-0.2 [-6.2, 6.2]	4610	0.2 ± 9.7	0.7 [-6.6, 6.5]	914	0.690
Paired difference from non-top10	-0.2 ± 10.0	-0.3 [-6.9, 6.4]	5481	-0.1 ± 9.9	-0.2 [-6.9, 6.4]	4574	-0.4 ± 10.5	-0.5 [-7.2, 6.4]	907	0.399
P-value from paired t tests	0.157	0.157		0.3385	0.3385		0.197	0.197		
Saving Percentage (%)										
Top 10	1.3 ± 21.9	1.7 [-12.5, 15.9]	5707	1.1 ± 21.6	1.6 [-12.5, 15.4]	4772	2.5 ± 23.2	2.5 [-12.4, 19.1]	935	0.077
Paired difference from non-top10	0.3 ± 23.1	0.7 [-14.2, 15.8]	5662	0.4 ± 22.7	0.9 [-13.9, 15.5]	4733	-0.5 ± 24.7	-0.3 [-15.8, 17.2]	929	0.258
P-value from paired t tests	0.345	0.345		0.180	0.180		0.543	0.543		

3.2 *Comparison between Top 5 versus 6-10th Players*

Table 2a and 2b present results comparing the top five players and those ranked 6-10th. SP for the top five players decreased by 0.5 ± 23.3 percent when they were in top ten versus not on the leaderboard, compared to an increase of 1.2 ± 22.8 percent for players ranked 6-10th (p=0.006). Hence, the higher the rank after the first three rounds, the larger the pressure effect on SP. Also, for both groups, DD, GIR and PTH improved significantly; however, there is trend suggesting that the higher the rank the larger the pressure effect on a player in DA and PTH.

Table 2a. Comparison between Top 5 versus 6-10th Players after three rounds (WITHOUT course adjustment)

	Overall			Top 5 after three rounds			6-10th after three rounds			
variable	meanSd	medianIQR	N	meanSd_0	medianIQR_0	N_0	meanSd_1	medianIQR_1	N_1	p-value
Relative to Par Score (Strokes)										
Top 10	-0.5 ± 3.1	-1 [-3, 2]	5720	-0.5 ± 3.1	-1 [-3, 1]	2965	-0.5 ± 3.2	-1 [-3, 2]	2755	0.652
Paired difference from non-top10	-0.2 ± 3.3	-0.4 [-2.4, 2]	5675	-0.2 ± 3.3	-0.3 [-2.4, 1.9]	2949	-0.2 ± 3.3	-0.4 [-2.4, 2]	2726	0.854
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**0.002**	**0.002**		
Driving Distance (Yards)										
Top 10	262.8 ± 10.7	262.7 [255.5, 270]	5524	263.0 ± 10.9	262.8 [255.5, 270.5]	2859	262.6 ± 10.4	262.4 [255.6, 269.4]	2665	0.272
Paired difference from non-top10	0.9 ± 9.7	1.2 [-5.6, 7.6]	5481	0.8 ± 9.8	1 [-5.9, 7.8]	2843	1.0 ± 9.5	1.3 [-5.4, 7.4]	2638	0.430
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Driving Accuracy (%)										
Top 10	62.2 ± 17.9	64.3 [50, 71.4]	5720	61.7 ± 17.7	64.3 [50, 71.4]	2965	62.7 ± 18.0	64.3 [50, 76.9]	2755	**0.030**
Paired difference from non-top10	0.6 ± 17.9	1.9 [-9.5, 12.5]	5675	0.4 ± 17.8	1.7 [-9.5, 12.1]	2949	0.9 ± 18.1	2.1 [-9.5, 12.9]	2726	0.342
P-value from paired t tests	**0.009**	**0.009**		0.216	0.216		**0.013**	**0.013**		
Greens in Regulation (%)										
Top 10	65.3 ± 15.8	66.7 [56.3, 76.5]	5720	65.4 ± 15.9	66.7 [58.8, 76.5]	2965	65.3 ± 15.7	66.7 [55.6, 76.5]	2755	0.848
Paired difference from non-top10	1.9 ± 16.5	3.1 [-6.3, 12.3]	5675	2.0 ± 16.7	3.2 [-6.2, 12.6]	2949	1.9 ± 16.2	2.8 [-6.4, 12.1]	2726	0.886
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Proximity to Hole (Feet)									.	
Top 10	21.2 ± 4.7	20.9 [17.9, 24]	5524	21.2 ± 4.6	20.9 [17.9, 23.9]	2859	21.2 ± 4.8	21 [17.8, 24.1]	2665	0.900
Paired difference from non-top10	0.3 ± 4.9	0.2 [-3, 3.3]	5481	0.3 ± 4.8	0.2 [-2.9, 3.3]	2843	0.3 ± 5.0	0.2 [-3.1, 3.4]	2638	0.799
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**0.001**	**0.001**		
Strokes Gained per 100 Putts										
Top 10	0.4 ± 9.8	0.3 [-6, 6.9]	5524	0.2 ± 9.7	0.1 [-6.2, 6.8]	2859	0.5 ± 10.0	0.7 [-5.9, 7.1]	2665	0.243
Paired difference from non-top10	-0.2 ± 10.3	-0.4 [-6.9, 6.6]	5481	-0.4 ± 10.2	-0.7 [-7.3, 6.6]	2843	-0.1 ± 10.5	-0.1 [-6.7, 6.6]	2638	0.250
P-value from paired t tests	0.095	0.095		0.043	0.043		0.746	0.746		
Saving Percentage (%)										
Top 10	61.7 ± 23.0	60 [50, 77.8]	5707	61.1 ± 23.2	60 [50, 75]	2959	62.4 ± 22.7	62.5 [50, 77.8]	2748	**0.044**
Paired difference from non-top10	0.5 ± 24.4	0.6 [-15.1, 17.2]	5662	-0.2 ± 24.6	0 [-16, 16.4]	2943	1.3 ± 24.0	1.4 [-14.5, 18.4]	2719	**0.017**
P-value from paired t tests	0.120	0.120		0.597	0.597		**0.005**	**0.005**		

Table 2b. Comparison between Top 5 versus 6-10th Players after three rounds (WITH course adjustment)

	Overall			Top 5 after three rounds			6-10th after three rounds			
variable	meanSd	medianIQR	N	meanSd_0	medianIQR_0	N_0	meanSd_1	medianIQR_1	N_1	p-value
Relative to Par Score (Strokes)										
Top 10	-0.4 ± 2.7	-0.5 [-2.3, 1.3]	5720	-0.4 ± 2.7	-0.4 [-2.3, 1.3]	2965	-0.4 ± 2.8	-0.6 [-2.3, 1.4]	2755	0.835
Paired difference from non-top10	-0.1 ± 2.8	-0.2 [-2, 1.7]	5675	-0.1 ± 2.8	-0.1 [-2, 1.7]	2949	-0.1 ± 2.9	-0.3 [-2, 1.7]	2726	0.407
P-value from paired t tests	**0.008**	**0.008**		0.176	0.176		**0.017**	**0.017**		
Driving Distance (Yards)										
Top 10	1.5 ± 6.7	1.3 [-2.8, 5.7]	5524	1.7 ± 6.7	1.4 [-2.7, 5.8]	2859	1.3 ± 6.6	1.2 [-2.9, 5.4]	2665	**0.030**
Paired difference from non-top10	0.7 ± 4.8	0.7 [-2.4, 3.8]	5481	0.7 ± 4.8	0.7 [-2.5, 3.8]	2843	0.7 ± 4.8	0.8 [-2.4, 3.8]	2638	0.868
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Driving Accuracy (%)										
Top 10	0.3 ± 13.3	0.5 [-8.5, 9.3]	5720	-0.1 ± 13.2	0 [-8.6, 8.5]	2965	0.7 ± 13.4	0.9 [-8.4, 10.2]	2755	**0.012**
Paired difference from non-top10	0.0 ± 13.2	0 [-9, 8.9]	5675	-0.3 ± 13.1	-0.5 [-9.4, 8.5]	2949	0.3 ± 13.4	0.5 [-8.5, 9.4]	2726	0.061
P-value from paired t tests	0.970	0.970		0.200	0.200		0.173	0.173		
Greens in Regulation (%)										
Top 10	1.5 ± 11.2	1.6 [-5.6, 9.1]	5720	1.6 ± 11.2	1.7 [-5.4, 9.2]	2965	1.4 ± 11.3	1.6 [-5.9, 9.1]	2755	0.527
Paired difference from non-top10	1.1 ± 11.7	1.2 [-6.5, 8.9]	5675	1.1 ± 11.6	1.4 [-6.5, 8.9]	2949	1.2 ± 11.8	1.2 [-6.5, 8.8]	2726	0.873
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Proximity to Hole (Feet)										
Top 10	-0.1 ± 4.2	-0.2 [-2.9, 2.6]	5524	0.0 ± 4.2	-0.2 [-2.9, 2.6]	2859	-0.1 ± 4.3	-0.2 [-3, 2.6]	2665	0.486
Paired difference from non-top10	0.4 ± 4.3	0.3 [-2.6, 3.2]	5481	0.5 ± 4.3	0.3 [-2.5, 3.3]	2843	0.3 ± 4.4	0.3 [-2.8, 3.1]	2638	0.087
P-value from paired t tests	**<.001**	<.001		**<.001**	**<.001**		**<.001**	**<.001**		
Strokes Gained per 100 Putts										
Top 10	0.1 ± 9.5	0 [-6.2, 6.3]	5524	-0.1 ± 9.4	-0.2 [-6.5, 6.1]	2859	0.2 ± 9.7	0.1 [-5.9, 6.5]	2665	0.184
Paired difference from non-top10	-0.2 ± 10.0	-0.3 [-6.9, 6.4]	5481	-0.4 ± 9.8	-0.4 [-7.3, 6.4]	2843	0.0 ± 10.2	-0.1 [-6.4, 6.4]	2638	0.21
P-value from paired t tests	0.157	0.157		0.055	0.055		0.939	0.939		
Saving Percentage (%)										
Top 10	1.3 ± 21.9	1.7 [-12.5, 15.9]	5707	0.8 ± 22.2	1.5 [-12.9, 15.5]	2959	1.9 ± 21.6	1.9 [-11.9, 16.7]	2748	**0.048**
Paired difference from non-top10	0.3 ± 23.1	0.7 [-14.2, 15.8]	5662	**-0.5 ± 23.3**	**-0.3 [-14.7, 15.1]**	**2943**	**1.2 ± 22.8**	**1.7 [-13.9, 16.8]**	**2719**	**0.006**
P-value from paired t tests	0.345	0.345		0.230	0.230		0.008	0.008		

3.3 *Comparison among Three Age Groups*

Table 3a and 3b present results on the relationship between age and the pressure effect. As expected, we found that younger players drove the ball farther and less accurately than older players. Furthermore, players improved DD and GIR but performed worse in the PTH outcome across all three age groups. In other words, age did not have a significant impact on the pressure effect.

Finally, it is worth noting that all results presented in Sections 3.1-3.3 remain the same based on nonparametric tests or linear regression analysis that considered three factors altogether.

Table 3a. Comparison among Three Age Groups (WITHOUT course adjustment)

	<30 years old			30-39 years old			40 or older			
variable	meanSd_1	medianIQR_1	N_1	meanSd_2	medianIQR_2	N_2	meanSd_3	medianIQR_3	N_3	p-value
Relative to Par Score (Strokes)										
Top 10	-0.5 ± 3.1	-1 [-3, 1]	1275	-0.5 ± 3.1	-1 [-3, 1]	2854	-0.5 ± 3.2	-1 [-3, 2]	1152	0.921
Paired difference from non-top10	-0.3 ± 3.3	-0.4 [-2.4, 1.9]	1263	-0.1 ± 3.3	-0.3 [-2.4, 2]	2842	-0.3 ± 3.3	-0.4 [-2.4, 1.9]	1141	0.325
P-value from paired t tests	**0.007**	**0.007**		**0.025**	**0.025**		**0.003**	**0.003**		
Driving Distance (Yards)										
Top 10	266.0 ± 10.3	266.1 [259, 273.1]	1232	262.8 ± 10.4	262.6 [255.8, 269.5]	2767	260.4 ± 10.8	259.9 [252.9, 267.3]	1105	**<.0001**
Paired difference from non-top10	1.1 ± 9.5	1.7 [-5.3, 7.8]	1221	0.9 ± 9.6	1 [-5.8, 7.6]	2756	0.7 ± 9.7	1.1 [-5.5, 7.2]	1094	0.6
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**0.016**	**0.016**		
Driving Accuracy (%)										
Top 10	59.3 ± 18.5	61.5 [50, 71.4]	1275	62.5 ± 17.4	64.3 [50, 71.4]	2854	63.7 ± 18.4	64.3 [57.1, 78.6]	1152	**<.0001**
Paired difference from non-top10	0.1 ± 18.5	1.2 [-10.7, 11.9]	1263	0.9 ± 17.7	1.8 [-9.2, 12.6]	2842	0.6 ± 18.4	2.6 [-9.1, 12.5]	1141	0.394
P-value from paired t tests	0.918	0.918		**0.008**	**0.008**		0.292	0.292		
Greens in Regulation (%)										
Top 10	64.8 ± 16.5	66.7 [55.6, 76.5]	1275	65.7 ± 15.2	66.7 [58.8, 76.5]	2854	64.9 ± 16.7	66.7 [55.6, 76.5]	1152	0.16
Paired difference from non-top10	1.7 ± 17.4	3 [-6.8, 12.5]	1263	2.2 ± 15.9	3.2 [-6, 12.4]	2842	1.8 ± 17.4	2.7 [-6.1, 12.5]	1141	0.637
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Proximity to Hole (Feet)										
Top 10	20.9 ± 4.6	20.8 [17.7, 23.7]	1232	21.2 ± 4.6	20.9 [17.9, 23.9]	2767	21.3 ± 4.8	21.1 [17.9, 24.3]	1105	0.171
Paired difference from non-top10	0.3 ± 4.9	0.2 [-3, 3.3]	1221	0.4 ± 4.8	0.2 [-2.8, 3.3]	2756	0.3 ± 5.0	0.2 [-3.2, 3.6]	1094	0.663
P-value from paired t tests	0.055	0.055		**<.001**	**<.001**		**0.051**	**0.051**		
Strokes Gained per 100 Putts										
Top 10	0.4 ± 9.8	0.2 [-6.2, 7]	1232	0.4 ± 9.8	0.3 [-5.9, 7.1]	2767	0.3 ± 10.0	0.5 [-6.4, 6.4]	1105	0.968
Paired difference from non-top10	-0.2 ± 10.4	-0.4 [-7, 6.9]	1221	-0.5 ± 10.3	-0.7 [-7, 6.1]	2756	0.2 ± 10.6	0.2 [-6.8, 7.2]	1094	0.217
P-value from paired t tests	0.589	0.589		**0.017**	**0.017**		0.601	0.601		
Saving Percentage (%)										
Top 10	61.3 ± 22.5	60 [50, 75]	1272	61.6 ± 23.2	60 [50, 77.8]	2848	62.2 ± 23.1	62.5 [50, 80]	1149	0.613
Paired difference from non-top10	0.6 ± 23.8	0.5 [-15, 17.3]	1260	-0.1 ± 24.7	0.5 [-15.6, 16.5]	2836	0.8 ± 24.5	0.5 [-14.5, 18]	1138	0.493
P-value from paired t tests	0.367	0.367		0.802	0.802		0.290	0.290		

Table 3b. Comparison among Three Age Groups (WITH course adjustment)

	<30 years old			30-39 years old			40 or older			
variable	meanSd_1	medianIQR_1	N_1	meanSd_2	medianIQR_2	N_2	meanSd_3	medianIQR_3	N_3	p-value
Relative to Par Score (Strokes)										
Top 10	-0.5 ± 2.8	-0.7 [-2.4, 1.2]	1275	-0.4 ± 2.7	-0.5 [-2.3, 1.4]	2854	-0.5 ± 2.8	-0.5 [-2.3, 1.2]	1152	0.647
Paired difference from non-top10	-0.2 ± 2.9	-0.2 [-2.1, 1.6]	1263	0.0 ± 2.8	-0.1 [-1.9, 1.8]	2842	-0.2 ± 2.8	-0.3 [-2, 1.6]	1141	0.085
P-value from paired t tests	**0.04**	**0.04**		0.754	0.754		**0.011**	**0.011**		
Driving Distance (Yards)										
Top 10	4.1 ± 6.3	3.9 [-0.2, 8]	1232	1.4 ± 6.4	1.2 [-2.6, 5.3]	2767	-0.5 ± 6.8	-0.7 [-4.7, 3.4]	1105	**<.0001**
Paired difference from non-top10	0.8 ± 4.6	0.9 [-2.3, 3.8]	1221	0.6 ± 4.8	0.6 [-2.5, 3.8]	2756	0.7 ± 4.8	0.7 [-2.4, 3.9]	1094	0.540
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**<.001**	**<.001**		
Driving Accuracy (%)										
Top 10	-1.8 ± 13.8	-1.4 [-11.3, 7.5]	1275	0.4 ± 13.1	0.6 [-8.3, 9.3]	2854	2.1 ± 13.1	2 [-6.3, 10.9]	1152	**<.0001**
Paired difference from non-top10	-0.2 ± 13.8	-0.4 [-9.3, 9.1]	1263	0.1 ± 13.2	0 [-9.2, 8.8]	2842	0.1 ± 13.0	0.4 [-8.3, 9]	1141	0.745
P-value from paired t tests	0.522	0.522		0.744	0.744		0.831	0.831		
Greens in Regulation (%)										
Top 10	1.4 ± 11.3	0.9 [-5.9, 9.4]	1275	1.8 ± 11.2	2.2 [-5.3, 9.2]	2854	1.5 ± 11.2	1.6 [-5.5, 9.1]	1152	0.658
Paired difference from non-top10	1.1 ± 11.7	1.1 [-6.8, 9.3]	1263	1.2 ± 11.6	1.5 [-6.3, 8.6]	2842	1.0 ± 11.7	0.6 [-6.2, 8.9]	1141	0.922
P-value from paired t tests	**<.001**	**<.001**		**<.001**	**<.001**		**0.003**	**0.003**		
Proximity to Hole (Feet)										
Top 10	-0.3 ± 4.2	-0.5 [-3.1, 2.3]	1232	-0.1 ± 4.2	-0.3 [-3, 2.5]	2767	0.0 ± 4.4	-0.1 [-2.9, 2.8]	1105	0.105
Paired difference from non-top10	0.3 ± 4.4	0.3 [-2.8, 3.3]	1221	0.5 ± 4.3	0.3 [-2.5, 3.2]	2756	0.4 ± 4.5	0.3 [-2.8, 3.3]	1094	0.699
P-value from paired t tests	**0.008**	**0.008**		**<.001**	**<.001**		**0.005**	**0.004**		
Strokes Gained per 100 Putts										
Top 10	0.2 ± 9.5	0 [-6.2, 6.4]	1232	0.1 ± 9.6	-0.1 [-6.1, 6.7]	2767	0.0 ± 9.6	0.1 [-6.6, 5.8]	1105	0.886
Paired difference from non-top10	-0.1 ± 10.0	0 [-6.9, 6.4]	1221	-0.4 ± 10.0	-0.6 [-7.1, 6.2]	2756	0.2 ± 10.3	0.1 [-6.6, 6.7]	1094	0.173
P-value from paired t tests	0.857	0.857		**0.021**	**0.021**		0.529	0.529		
Saving Percentage (%)										
Top 10	1.1 ± 21.7	1.7 [-12.3, 15.1]	1272	1.3 ± 22.1	1.7 [-12, 15.9]	2848	1.6 ± 21.8	2.2 [-12.6, 16.9]	1149	0.823
Paired difference from non-top10	0.4 ± 22.7	0.8 [-14.2, 15.1]	1260	-0.3 ± 23.3	0.4 [-14.5, 15.4]	2836	0.5 ± 22.9	1.1 [-13.8, 15.8]	1138	0.444
P-value from paired t tests	0.489	0.489		0.450	0.450		0.436	0.436		

4. Discussion and Conclusion

In this study, we assessed the effect of pressure on PGA TOUR golfer's performance using the ShotLink™ data from 2003 to 2014. The pressure effect is characterized by the difference in the final round performance when a player was ranked in top 10 versus when he is not in top 10. To our surprise, we found that players performed better while under pressure in relative to par score, driving distance and greens in regulation, but worse in proximity to the hole. Players with major winning experience were significantly less affected by pressure in driving accuracy and proximity to hole than those without major wins. In addition, the higher the rank after the first three rounds, the larger the pressure effect on saving percentage. Finally, there is trend suggesting that the higher the rank the larger the pressure effect on a player in driving accuracy and proximity to hole.

We note that the positive impact of prior winning experience against pressure is consistent with a similar finding of Hickman and Metz (2015). They evaluated PGA Tour players putting performance on the 18th hole of the final round of golf tournaments and quantified the pressure by the difference in prize money a player would receive depending on whether he made the putt or missed it. They found that golfers who have higher career earnings totals (which the authors defined as experience) are less affected by pressure than golfers who have less career earnings and that the likelihood that the player will make that putt decreases by 1 percent as a putt's value increases by $50,000. Also, our results on the relationship between rank after three rounds and the pressure effect are in line with Hickman and Metz's main conclusion that golf professionals play worse under pressure. Specifically, our analysis results indicate that the higher the rank, the larger the negative effect on saving percentage, driving accuracy and the proximity to hole.

We acknowledge that our definition of pressure in terms of the difference between top ten and non-top ten performances may not be ideal. A player's game may be in a better state during the weeks when they reached top ten after the first three rounds (Connolly and Rendleman (2008) show that the skill levels of PGA Tour players can change through time). However, our results on how the player's previous winning experience and ranking after 3 rounds impact the way players respond to the pressure effect are consistent with the findings of Hickman and Metz (2015).

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