A Biomechanical Investigation into Weight Distribution and Kinematic Parameters During the Putting Stroke

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ABSTRACT

This study examined the set-up position of 30 elite PGA professional golfers (2007 Season), in comparison with 30 amateur golfers (Handicap +3 to 9) while attempting the same putt of 25ft on a flat surface with a stimpmeter reading of 12. Video analysis at 50 frames per second was used to record kinematic parameters of the golfers' set-up and posture. All golfers performed their typical putting action while standing on an RSscan International 1.0 m x 0.4 m pressure platform. The RSscan Footscan® and Quintic Biomechanics 9.03 v14 software were synchronised to enable key positions of the putting stroke to be identified. Each golfer used their own personal putter. The main difference between the amateur and professional golfers was in set-up. This was found to be significant with amateurs' weight distribution 59.60% Right and 40.40% Left while the Professional Group was 48.34% Left and 51.66% Right, much closer to a balanced set-up. Students' t-test was used to compare the group means for each parameter with a level of significance set at $p < 0.05$. There is a trend to suggest that the wider the stance, the smaller the centre of pressure movement during the putting stroke. Although there was no significant difference in stance width, there was a significant difference in the total amount of centre of pressure movement ($p < 0.05$) between the two groups of golfers.

Key words: Centre of Pressure, Golf Putting, Weight Distribution

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T.J. Tomasi (Nantucket Golf Club, USA)

INTRODUCTION

Putting has been described as a game within a game on numerous occasions or even a 'black art'. It has caused much heartache in the search for the perfect stroke. Putting represents close to half the strokes most golfers would use in a full round of golf and is in many ways a miniature version of the full golf swing, yet perplexingly it remains the area of the game least taught.

The majority of coaching magazines, manuals, textbooks suggest 'feel' as the key to success, along with a 'good technique'. However the emphasis should be the other way – a good technique is required to create the confidence (feel) necessary to hole putts [1]. Pelz [2] describes the putting stroke as only one of several different types of golf swing and also iterates that that it accounts for nearly half of all swings made – it is easy to draw the inference that putting does not account for half of all tuition. However, what kinematic parameters constitute a good technique? The author believes putting is a strength exercise, the ability to create a stable posture and pivot point is essential if the putter is to be returned consistently from address to impact. It is often stated by golf professionals that it is best to stand comfortably at address and relaxed over the ball prior to hitting the putt. This creates a very individual style of putting. The two questions the author would like to pose are firstly, what constitutes a comfortable set-up? and secondly, is comfortable (for the individual) the optimal position to execute the putting stroke?

Cochran and Stobbs [3] state that the putter head, while actually in contact with the ball, behaves almost as though it were disconnected from the shaft. Research conducted at the Quintic laboratory with high-speed cameras filming at a frame rate of 15,000 fps has shown that the contact time for a medium putt (18 ft) is approximately half a millisecond. Half a millisecond is a miniscule period of time. If the putter head is opening and closing during the impact zone "2 inches before contact and 2 inches after impact" then the chances of finding the clubface square to the target line at impact is significantly reduced [2]. Therefore, it increases the need for the golfer to create a stable, balanced and solid base, along with a fixed pivot point in which to execute the stroke consistently. Successful putting is all about repeating the stroke mechanics under pressure and starting the ball on your intended line; without this ability, the ability to read the green becomes of secondary importance [1]. It is the opinion of the author that the address position is the first stage in developing a consistent and repeatable technique. In order to create a stable base and fixed pivot point for the shoulders to rotate around, static equilibrium is required. This is when the system of forces acting on a body produces no motion, the body is said to be in static equilibrium.

Putting is a strength exercise, but it does not require the body to produce explosive power, such as a weightlifter performing the clean and jerk. It requires stability and balance. The main focus of such balance within the body is as a result of proprioreceptors. These are receptors, which respond to stretch or pressure within the body and are widely distributed within our skin, tendons and skeletal muscles. Because of the abilities of these receptors to sense the amount of stretching our tendons and muscles are withstanding, the human body is able 'to know where its body parts are at any given moment'; subsequently this sensory information is reported to reflex centres of the central nervous system for interpretation and

subsequent motor response.

Our ears are not only organs of hearing. They also help the body maintain balance. The position of your head is important during the putting stroke, not only will it influence distance perception and alignment, it is the first organ for detecting balance. Your inner ear consists of two sacs called the utricle and the saccule. Within these sacs are receptors called maculae. They are made of sensory hair cells covered by a gel-like cap with tiny crystals inside. Whenever you tilt your head, gravity causes the crystals to slide to one side, creating a pull on the gel and the sensory hairs. This triggers the hair cells to fire nerve impulses along the vestibular nerve to your brain. The rotational axis of your head can also influence balance. In addition, your eyes are also delivering important information about your body's position.

As previously stated, the ability to create a repeatable set-up position with the putter is crucial if unwanted manipulation of the putter face is to be limited during the putting stroke. The address position is the first stage in developing a consistent and repeatable technique. This article reports differences in set-up position between professional and amateur golfers attempting the same 25 ft putt on a flat surface. It studies weight distribution and balance, which are two variables that are vital if the golfer is to have a consistent impact position.

Due to the lack of research into the weight distribution and centre of pressure movement in putting, the purpose of the study was to describe these variables along with kinematic parameters of both amateur and professional golfers. Many players and coaches spend a considerable amount of time focusing on these technical areas without first having an understanding of the ranges professional and amateur golfers operate within.

METHODS

SUBJECTS

Thirty male PGA European Tour Golfers performed their typical putting action under the test condition for this study. A total of four out of the 30 professional subjects finished in the top 10 of the European PGA 2007 Order of Merit. Thirty male amateur golfers (handicap +3 to 9) also performed their typical putting action under the test conditions. All subjects were right-handed and given a number of practice putts with their own putter in order to familiarise themselves with the required putt. Each subject putted towards a hole positioned 25 ft away in a straight line with a stimpmeter rating of 12. Subjects wore their personal golf shoes and attire. The trials were all carried out in the Quintic Putting Laboratory over a period of six-month period during the competitive PGA European Tour 2007 season. The distance of 25 ft was chosen as the test distance, because this is the length of a medium to long demanding putt. Each subject used their own putter and used it until they were able to hole the putt. This was deemed to be a successful putt. Every participant holed six successful putts. An average of the six putts was created for each individual. Each golfer was encouraged to go through their normal pre-shot routine prior to each putt.

APPARATUS

A Footscan® pressure plate 1.0 m x 0.4 m, 4 sensors/cm^2 (8192 sensors total) with a sampling rate of 125 Hz was used to collect the data. The foot function was analysed

using RSscan Footscan 7.9 2nd generation software. The range of the Footscan® pressure measurement system was 0.7 N/cm^2 – 155 N/cm^2. The cross in Figure 1, represents the centre of pressure (COP) of the golfer at frame 1 (40 ms before the beginning of the stroke – movement of the clubhead). The COP is the point on a body where the sum total of the pressure fields acts, causing a force and no moment about that point. The COP can move in two directions, medial/lateral and in the anterior/posterior direction. In the example below, during the putting stroke the COP moves towards the heels of the golfer. The cross enables the four quadrants to specify the % weight distribution of the golfer at specific time intervals. For example in Figure 1: Left Heel = 14.72% / Left Toe = 28.37 / Right Heel = 31.41% / Right Toe = 25.50%.

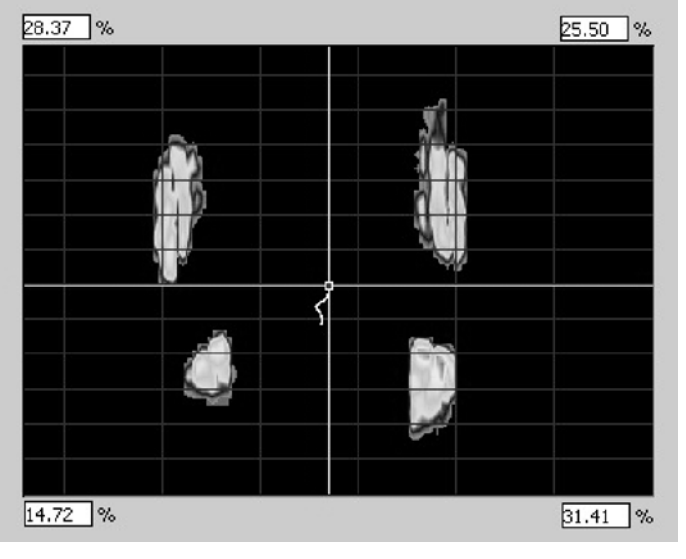


Figure 1. RSscan Pressure Platform Image of the Feet of a Right-Handed Golfer

TEST PROCEDURE

The putting stroke was filmed using a standard digital video Sony TRV 900E camcorder. The camcorder was placed at 90˚ to the path of the golf ball, level with the putting surface. The RSscan Footscan® and Quintic Biomechanics 9.03 v14 software were synchronised using a 'key controller', a software package designed specially to link the two software programs. This enabled the key positions of the putting stroke to be identified and calculate the amount of COP movement for each category.

All golfers used their normal putting stroke and personal putters. Digital video film (50 Hz) was recorded giving the set-up, top of backswing, impact and follow through. After processing, the film was analysed using a personal computer running Quintic Biomechanics v14 video analysis software. Each video was calibrated in the horizontal plane using the pressure platform in the video (1 m scale). All putting

strokes were digitised at a rate of 50 Hz. The putter head of each golfer was digitised and tracked using automatic tracking Quintic Biomechanics v14 and the resulting kinematic data smoothed using a low pass Butterworth filter (10 hz).

The students' t-test was used to compare the group means for each parameter and investigate if any were significantly different. The level of significance was set at $p < 0.05$.

RESULTS

WEIGHT DISTRIBUTION

For each of the 60 golfers, the weight distribution for the Left and Right feet at set-up along with the weight distribution of Heels and Toes were calculated (see Table 1 & 2). The values were obtained for set-up 40 ms prior to the club-head moving. The notion of 40 ms was used, because a number of golfers actually had a body movement away from the ball before the putter head even moved. In addition, the percentage of weight distribution in each quarter (Left Heel / Left Toe / Right Heel / Right Toe) was also calculated 40 ms before club-head movement.

Table 1. Weight Distribution at Set-Up for the 30 Amateur Golfers (S.E. = Standard Error)

					LEFT FOOT		RIGHT FOOT	
	LEFT	RIGHT	HEELS	TOES	HEEL	TOES	HEEL	TOES
Mean	40.40%	59.60%	47.70%	53.43%	19.57%	21.00%	27.17%	32.43%
± S.E.	3	5	4	4	3	3	4	3

Table 2. Weight Distribution at Set-Up for the 30 Professional Golfers (S.E. = Standard Error)

					LEFT FOOT		RIGHT FOOT	
	LEFT	RIGHT	HEELS	TOES	HEEL	TOES	HEEL	TOES
Mean	48.34%	51.66%	45.55%	54.45%	21.37%	26.97%	24.18%	27.48%
± S.E.	3	4	3	3	3	3	3	4

It is interesting to note that amateur golfers show a weight distribution at address of 60% right and 40% left, very similar to PGA recommended weight distribution for a long iron or even a driver at set-up [4]. This would justify the statement made in the introduction that putting in many ways is a miniature version of the full golf swing – with the majority of coaching suggesting feel and standing comfortable as the key to success. What is a comfortable set-up for the majority of golfers? Typically it is what they do the most of, i.e. practice the full swing. Only 5 amateur golfers had a set-up position of more than 50% weight on the left side. Interestingly, one amateur, a former international table tennis player had a set-up of 50% Left and 50% Right. This isn't that surprising given the nature of the game of table tennis, explosive reactions, both left and right, forward and backwards.

For the amateur group, there was a small bias in percentage favouring the toes at address 53%, again possibly reflecting the full-swing set-up posture. However, it

should be noted that there was a considerable variation at set-up ranging from 10% to 90% weight distribution for the toes at address.

The professional golfers showed a more balanced weight distribution at address of 52% right and 48% left (Range 29% – 75% Right Side) to that of the amateur golfers. This was significantly different ($p < 0.05$) to that of the amateur golfers. Ten professionals had a slight bias towards the left side. However, the professional golfers at set-up exhibited an increase in percentage favouring the toes at address, 55% toes, ranging from 32% to 86%.

CENTRE OF PRESSURE MOVEMENT

For each of the sixty golfers, the centre of pressure movement was calculated for the total movement of the putt from start to finish (Mean Total Body COP movement). The putting stroke was broken down into three categories: 1) Start (40 ms before club-head movement), to the Top of Backswing; 2) Top of Backswing – Impact; and 3) Impact – Finish. The amount of COP movement was calculated for each category by synchronising the RSscan pressure platform with the Quintic video software program.

Table 3. Centre of Pressure Movement for the 30 Amateur and 30 Professional Golfers

	Mean Total COP Movement	Start – Top of Backswing	Top of Backswing – Impact	Impact – Finish
Amateur	83.10*	17.61*	12.23	53.26*
± S.E.	6	3	4	5
Professional	64.34	12.24	10.13	41.97
± S.E.	6	2	3	5

Centre of Pressure movement (mm); *Significant difference $p < 0.05$
SE = Standard Error

It is interesting to note that amateur golfers showed a significant increase in total amount of COP movement compared to the professionals. The amateur golfers on average moved 83.10 mm during the putting stroke. This compared to 64.34 mm of movement for the professional golfers. This was significantly different for the two groups of subjects at $p < 0.05$. In each section of the putting stroke, the average amount of movement was greater for the amateur group than for the Professional golfers. It is also interesting to note that the Start – Top of Backswing and Impact – Finish category were also significantly lower for the professional group.

It is the opinion of the author that the lower the amount of centre of pressure movement, the greater the stability and balance of the golfer during the putting stroke. The lowest total amount of COP movement (mm) during the whole stroke was 23 mm, with 18 mm of this movement coming after impact. It is interesting to note that this professional golfer had a 52% left and 48% right weight distribution with also an equal split heels and toes.

The highest amount of movement was recorded post impact to finish. The finish of the stroke was calculated as the moment the putter reached the furthest horizontal position from impact. The majority of this movement is a reaction to the impact as

the head moves backwards (away from the target line). As a result, the putter head can often be seen to rise steeply after impact. A number of amateur golfers had movements of 75 mm during this phase of the stroke.

The professional group has an average stance width of 28.84 cm, 4 cm wider than that of the amateur group. This value may well explain some of the difference in COP movement. However, none of the kinematic parameters presented below in Table 4 were significantly different between the two groups at $p < 0.05$.

By means of comparison, the average amount of body movement for the same time length as performing a putt (2 seconds), when trying to stand still in a normal standing position was 24.28 mm of mean total body movement. Therefore it can be approximated that the notion of swinging a putter causes the Amateur group to increase their COP movement by 58.82 mm and the Professional group a further 40.06 mm.

KINEMATIC PARAMETERS

Table 4. Kinematic Parameters
SE = Standard Error

		Pros		Amateurs	
Parameter	**Units**	**Mean**	**SE**	**Mean**	**SE**
Stance Width	cm	28.84	3.24	24.21	3.45
Height: Sternum – Floor	cm	136	4.10	135	3.39
Stance Width / Sternum Height	%	21.29	3.84	17.98	2.68
Ball Position / Stance Width	%	71.11	5.76	63.24	6.28
Ball Position: Sternum	cm	2.51	2.55	2.63	2.44
Ball Position: Left Eye	cm	-0.57	2.87	0.68	1.90
Ball Position: Bottom of Arc	cm	109	3	88	5

Stance Width

Stance width was measured from inside the left heel to inside the right heel (see horizontal line in Figure 2)

Professional Stance Width (cm)	
Average	28.84
S.E.±	3.24
Range	17 – 43

Amateur Stance Width (cm)	
Average	24.21
S.E.±	3.45
Range	15 – 37

Figure 2. Stance Width

Height: Sternum – Floor

This was the vertical distance measured from the sternum to the floor (see vertical line in Figure 3)

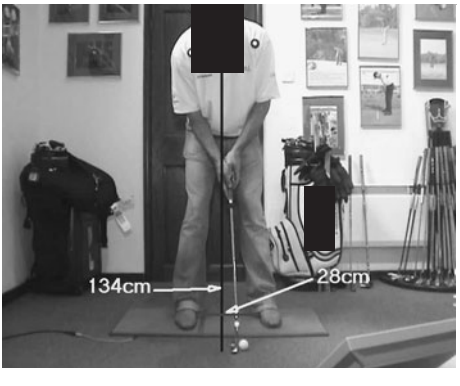
Professional Height: Sternum – Floor (cm)	
Average	136
S.E. ±	4.10
Range	125 – 144

Amateur Height: Sternum – Floor (cm)	
Average	135
S.D.±	3.39
Range	126 – 149

Figure 3. Sternum Height Above Floor

Stance Width/Sternum Height

For this measure, stance width was expressed as a percentage of sternum height. Both stance width and sternum height were measured in the manner above.



Professional Stance Width/Sternum Height (%)	
Average	21.29
S.E. ±	3.84
Range	10.71 – 33.07

Amateur Stance Width/Sternum Height (%)	
Average	17.98
S.E.±	2.68
Range	6.73 – 25.88

Figure 4. Stance Width 28cm / Sternum Height 134cm x 100= 20.90%

Ball Position/Stance Width (%)

Firstly, the horizontal distance between the inside right heel to the back of the ball was measured. See example in the photo below (Figure 5). This was then expressed as a percentage of the stance width (as measured above).

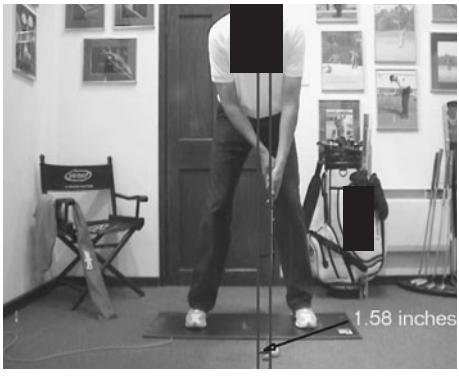
Professional Ball Position/Stance Width (%)	
Average	71.11
S.E. ±	5.76
Range	56 – 95

Amateur Ball Position/Stance Width (%)	
Average	63.24
S.E.±	6.28
Range	45 – 96

Figure 5. 24cm / 43cm x 100 = 55.81%
Note: A value of 100% means ball is positioned opposite left heel.

Ball Position: Sternum-Back of Ball

Figure 6 highlights the ball position in relation to the sternum. This is the horizontal distance between the bottom of the sternum and back of ball. A negative figure indicates that the ball is positioned behind the sternum and a positive figure indicates the ball is positioned in front of the sternum.



Professional Ball Position: Sternum-Back of Ball		
	Inches	cm
Average	0.95	2.51
S.E. ±	1.04	2.55
Range	-0.79 / + 3.54	-1 / + 9

Amateur Ball Position: Sternum-Back of Ball		
	Inches	cm
Average	1.12	2.63
S.E. ±	0.89	2.44
Range	-0.99 / + 3.91	-1 / + 10

Figure 6. Ball Position – Sternum

Ball Position: Left Eye-Back of Ball

Ball position was measured in relation to the left eye. The horizontal distance was measured between the middle of the left eye and the back of the ball. A positive value indicates the ball is positioned ahead of the left eye. A negative value indicates the ball is positioned behind the left eye (see Figure 7).

Professional

Ball Position: Left Eye-Back of Ball		
	inches	cm
Average	-0.23	-0.57
S.E. ±	1.14	2.87
Range	-2.76 / +1.58	-7.00 / +5.00

Amateur

Ball Position: Left Eye-Back of Ball		
	Inches	Cm
Average	0.36	0.68
S.E. ±	1.26	1.90
Range	-2.06 / +1.98	-6.35 / +6.78

Figure 7. Ball Position – Left eye

Ball Position:Bottom of Arc-Back of Ball

Finally, ball position was measured in relation to the bottom of the arc of the through-swing to the back of the ball (Figure 8). The bottom of the arc was determined from the digitisation data and subsequently was the lowest vertical point. A negative figure means that the bottom of the arc occurs in front of ball. It is interesting to note that this measure indicates that the bottom of the arc of the putting stroke does not always fall under the sternum, the figure of – 1.58 inches highlights this.

Professional

Ball Position: Bottom Arc-Back of Ball		
	inches	cm
Average	2.35	5.97
S.E. ±	1.63	4.14
Range	-1.58 / +5.51	-4.00 / +14.00

Amateur

Ball Position: Bottom Arc-Back of Ball		
	inches	cm
Average	2.05	5.57
S.E. ±	1.43	3.89
Range	-2.08 / +5.34	-4.56 / +13.65

Figure 8. Ball Position – Bottom of Arc

CONCLUSION

This paper has reported various differences in set-up position between 30 elite PGA professionals and 30 amateur golfers while attempting the same putt of 25 ft on a flat surface with a stimpmeter reading of 12. The main difference between the amateur and professional group was in set-up. This was found to be significant with amateurs approximately 60% Right – 40% Left while the professional golfers were much closer to 50% on both sides. There is a trend ($p = 0.11$) to suggest that the wider the

stance width (professional), the smaller the centre of pressure (COP) movement during the putting stroke. Although there was no significant difference in stance width, there was a significant difference in the total amount of COP movement between the two groups. No significant differences were found between the kinematic parameters, most notably ball position and posture, between the amateur and professional golfers. The use of balance and pressure analysis is becoming more popular in the analysis of the golf swing, but there has been very little research into these parameters during the putting stroke. The pressure analysis enables the instructor to look at dynamics and body movement that the naked eye cannot see. Generally the instructor can see positional aspects of the golf swing such as address and top of backswing, but the balance/pressure software allows the instructor to critically review weight distribution and COP movement during the stroke. A good putting technique has the ability to create a stable posture and pivot point to allow the putter to be returned consistently from address to impact without manipulation. Standing comfortably at address and relaxed over the ball creates a very individual style of putting. However, in the author's opinion, "comfortably" and "optimum balance" (50% Toes / 50% Heels / 50% Left / 50% Right) are seldom the same position. None of the sixty golfers exhibited a set-up position with 25% of weight distribution in each of the four quadrants. Each individual had a bias to one or two particular quadrants. It is therefore the opinion of the author that it is possible for all golfers analysed during this study to obtain a more stable and balanced position for the putting stroke. Future research should focus on the effect of COP movement on performance and the importance of balance and weight distribution in reducing body movement during the putting stroke.

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