ORIGINAL ARTICLE

Case study based on ball trajectory and motion analysis of international long-drive distance golf player

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ABSTRACT

This study aimed to measure the ball trajectory, club face control, and body movements of a long-drive distance golf player (LDP) who excels in international competitions. The participant randomly executed 10 shots of three trajectory types—straight, draw, and fade—using a driver in an indoor facility. The results indicated that the fade shot exhibited a significantly longer ball carry distance (S: 329.7 ± 31.7, D: 301.8 ± 30.6, F: 345.7 ± 18.4 yards). The offline distance also showed a significant increase (S: 3.6 ± 37.3, D: −12.0 ± 26.4, F: 30.8 ± 42.2 yards) for the fade shot. If shots exceeding the 60-yard width of the offline distance resulting in invalid attempts were counted, there were 2 of 10 attempts for straight, 0 of 10 attempts for draw, and 4 of 10 attempts for fade. Analysis of the ball trajectory of draw shots revealed a statistically significant trend towards lower peak height and descent angle. In all three trajectories, there were no significant differences observed in ball speed (S: 189.3±6.3, D: 192.1±5.0, F: 193.3±4.1 mph) and club head speed (S: 137.2 ± 1.6, D: 137.0 ± 1.2, F: 137.7 ± 2.2 mph). For the draw shots, the club path exhibited in-to-out trajectory, moving the club face, and the face angle was open during the ball impact. It is evident that even in golf players aiming for the maximum distance in a single shot, club head speed and grip speed tend to remain relatively constant. The findings indicate that the LDP executes precise movement and face control tailored to the three ball trajectories, demonstrating sophisticated motor control.
Keywords: Performance analysis, Golf, Club head speed, Ball carry, Long-drive distance player.

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INTRODUCTION

Golf is a sport in which players compete to achieve the lowest score. Sam Snead (1912–2002, USA), who holds the tied record for the most wins in Professional Golfers' Association of America (PGA) Tour history with 82 wins, emphasized the importance of the short game by stating, "*60 percent of golf scores are made within 125 yards*." In the past, it was believed that even if the first shot did not cover a great distance, players could compensate for a less-than-ideal score with their ability to execute shots beyond the initial one. Furthermore, Dave Pelz, a putting researcher, analysed that regardless of a golfer's skill level, "*43% of the score is determined by putting*" (Pelz & Mastroni, 2004). Masashi Ozaki, born in 1947 in Japan, holds the world professional tour record for the most victories, with 113 wins. He expressed the sentiment that "*distance provides the first advantage,*" embodying the idea that in the competitive world of professional golf, having a longer driving distance can give a player a strategic edge over others. Studies have shown that in the PGA (men's division), the longer and more accurate the first shot, the better the score (within the top 40) (Broadie, 2014; Pelz & Mastroni, 2004). Research investigating the relationship between performance in PGA, LPGA (women's), and SPGA (senior) events and various golf statistics has revealed that in PGA, driving distance contributes the most to performance. In LPGA, green in regulation, representing the percentage of times a player hits the green (e.g., three or fewer strokes for Par 5, two or fewer strokes for Par 4, and one stroke for Par 3), was identified as the most influential factor, with driving distance ranking second (Pfitzner & Rishel, 2005). However, in senior PGA, the scramble rate (the probability of making a par or birdie on a hole when not hitting the green) was reported to have the highest contribution, with driving distance ranking fourth (Fried et al., 2004). For international male golfers, a longer driving distance from the first shot is a crucial performance factor in modern golf. Achieving a greater driving distance is closely tied to the clubhead speed (CHS), and there is a strong correlation between the CHS just before impact and the distance the ball carries with the driver (Fletcher & Hartwell, 2004; Keogh et al., 2009).

Golf competitions specializing in driving distance have become popular in recent years. Similar to track-and-field throwing events, these competitions involve competing to achieve the maximum distance within specified boundaries for the ball to stop, and such events are regularly held worldwide. The Pro Long Drive World Championship uses a competition format in which players hit six balls within 2 min and 30 s and compete for the longest distance. Bryson DeChambeau, a prominent figure representing the PGA (USA), has participated in the Long Drive World Championship during breaks from regular golf tours. His involvement sparked controversy, leading to debates about the introduction of golf balls designed to limit maximum distance, potentially influencing golf rules (Edgar, 2023). Jamie Sadlowski (CAN), a two-time champion of the World Long Drive Championship, stands out for achieving the personal best of 445 yards despite his slender build, with a height of 178 cm and weight of 76 kg (Holt & Holt, 2013). However, only a few studies have been published on long-drive distance players (LDPs), and research on ball trajectories at speeds of approximately 200 mph, which is above the speed of PGA Tour players, is scarce (Broadie & Henrikson, 2022; Holt & Holt, 2013). We are conducting preliminary experiments targeting Japanese LDPs involving indoor motion and ball trajectory analyses. As a result, we repeatedly observed that markers attached to the clubhead for motion analysis are damaged upon impact when subjects strike the driver with ball speeds approaching 200 mph. Additionally, we found that these players often used long golf tees exceeding 100 mm for ball setting and striking, which is uncommon among regular golfers. Consequently, in the indoor trajectory measurements, we identified instances where infrared ball trajectory analysers which functioned from behind were ineffective owing to their unique LDP setup. The reasons mentioned above could explain why the analysis of LDP has not progressed significantly. In addition, the game requires appropriate ball control because wind conditions and directions always change. Athletic skills are also required to control three different trajectories (straight [S], draw [D], and fade [F]) and the flying distance. An LDP may have a gap in the subjective and objective sense in obtaining the maximum distance and may need to conduct movement analysis under a research protocol that does not provide knowledge of the results. We aimed to address this gap by employing measurement protocols that can accurately accommodate the LDP, striving to conduct both ball trajectory and motion analyses. Therefore, this study investigated the shot performance characteristics of a nationally represented LDP in Japan, who was instructed to randomly hit three different shots in an indoor environment.

MATERIALS AND METHODS

The study participant was Taiga Tazawa, a representative Japanese player ranked 13th (longest distance: 428 yards) in the Pro Long Drive World Championship 2021 (height: 182.5 cm, weight: 106 kg, age: 27 years). The golf club used was a JLIDEN YS-01J beam driver (Jbeam Red Max: X shaft with a length of 47.5 inches: static loft angle was 6.1º, static lie angle was 59.6º). Driver shots (S, D, and F) were performed in three random trials of 10 sets each to record the data for 30 balls. The participant was asked to imagine the trajectory described on the card and perform the shots, and no feedback was provided. The ball trajectory analysis equipment used was GC2 (Foresight Sports, USA) placed in front of the participant (Figure 1). GEARS (Gears Sports, USA) was used for body and clubhead movement analyses. Gears is a golf-specific motion analysis system, an optical camera-based tracking system with eight 1.7-megapixel cameras operating at 360 frames per second. The participant wore a motion-capture suit, 14 golf club-mounted reflective markers, and an automatically detected golf ball to capture the swing data. Table 1 presents the club and body data.

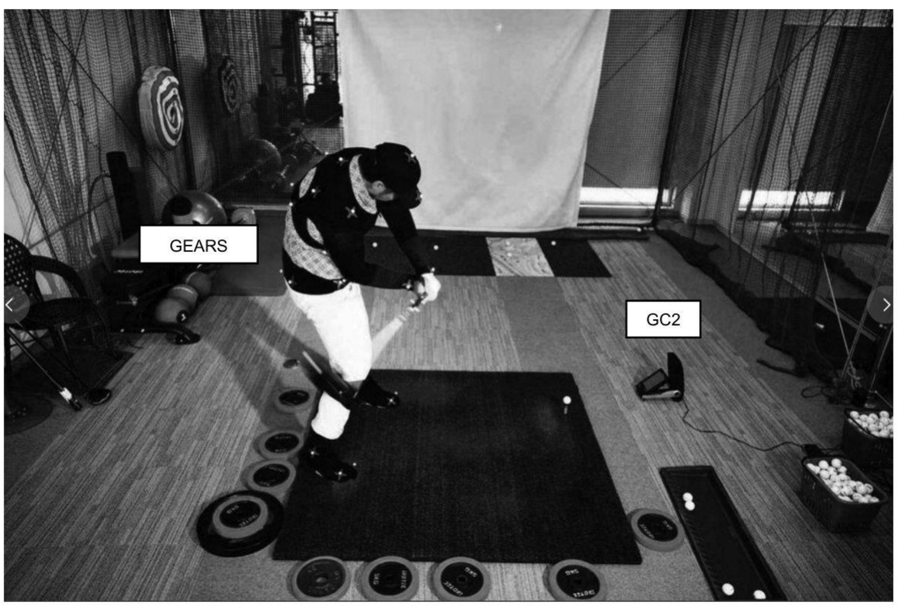

Figure 1. Experimental setup (GEARS and GC2).

The face angle was relative to the target line at the ball impact. The club path angle was the entry of the club just before impact, with in-to-out indicated by plus and out-to-in indicated by minus. The face-to-path angle was defined as the club-path angle minus the face-to-target angle. Positive attack angle values indicated an upward club angle of impact, and negative values indicated a downward club angle of impact (Bishop et al., 2024). This study was approved by the Academic Research Ethics Review Board of the Tokyo International

University (2022-15). To prioritize respect for human rights and safety in all phases of research involving human participants, we abided by the principles of the Declaration of Helsinki regarding the protection of human rights. IBM SPSS Statistics version 28 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses, with statistical significance set at 5%.

RESULTS

All data were reported as the mean value and standard deviation (SD). A one-way analysis of variance (ANOVA) of shot types (S, D, and F) was performed for the ball trajectory, club, and body data. Post-hoc tests involved multiple repeated-measures t-tests with Bonferroni correction (S vs. D, S vs. F, and D vs. F). Ball speed (S: 189.3 ± 6.3, D: 192.1 ± 5.0, F: 193.3 ± 4.1 mph) and CHS (S: 137.2 ± 1.6, D: 137.0 ± 1.2, F: 137.7 ± 2.2 mph) were not significantly different among the three types of shots (Table 1). However, the fade shot had a significantly further carry distance (S: 329.7 ± 31.7, D: 301.8 ± 30.6, F: 345.7 ± 18.4 yards) and significantly larger offline distance (S: 3.6 ± 37.3, D: −12.0 ± 26.4, F: 30.8 ± 42.2 yards; positive values indicate the right direction) compared to the draw shot. The carry distance (Y) was also significantly correlated with the offline distance (X) (Y = 322.84 + 0.387 × X, $p < .05$, Figure 2). Back spin (rpm) with draw shots was significantly smaller than that with straight shots (D: 1054.7 ± 269.8 vs. F: 1548.2 ± 422.2 rpm), and side spin (rpm: positive values indicate a clockwise spin) with draw shots was smaller (counter clock spin) than that with fade shots (D: −870.9 ± 450.9 vs. F: 148.0 ± 459.8 rpm). Ball peak height and decent angle (angle of impact on the ground) with draw shots was significantly smaller than that with straight shots (S: 41.8 ± 14.7 vs. D: 24.0 ± 6.0 yards, S: 38.1° ± 8.5° vs. D: 24.9° ± 5.9°). The fade shot had a significantly smaller club path angle (S: 2.0° ± 0.9°, D: 5.7° ± 1.1°, F: −0.2° ± 0.9°), face-to-path angle (S: 2.0° ± 2.3°, D: 3.4° ± 2.2°, F: −0.9° ± 1.6°), and attack angle (S: 7.9° ± 1.0°, D: 8.2° ± 1.1°, F: 6.6° ± 0.7°) compared to the straight and draw shots. In contrast, there were no significant differences in the launch angle (S: 13.9° ± 2.7°, D: 13.1° ± 1.3°, F: 13.9° ± 1.9°; positive values indicate an upward ball launch direction) or attack angle (S: 7.9° ± 1.0°, D: 8.2° ± 1.1°, F: 6.6° ± 0.7°; positive values indicate an upward club head face direction) among the three groups. In addition, there were no significant differences in the kinematic sequences of the pelvis, torso, and arm during ball impact.

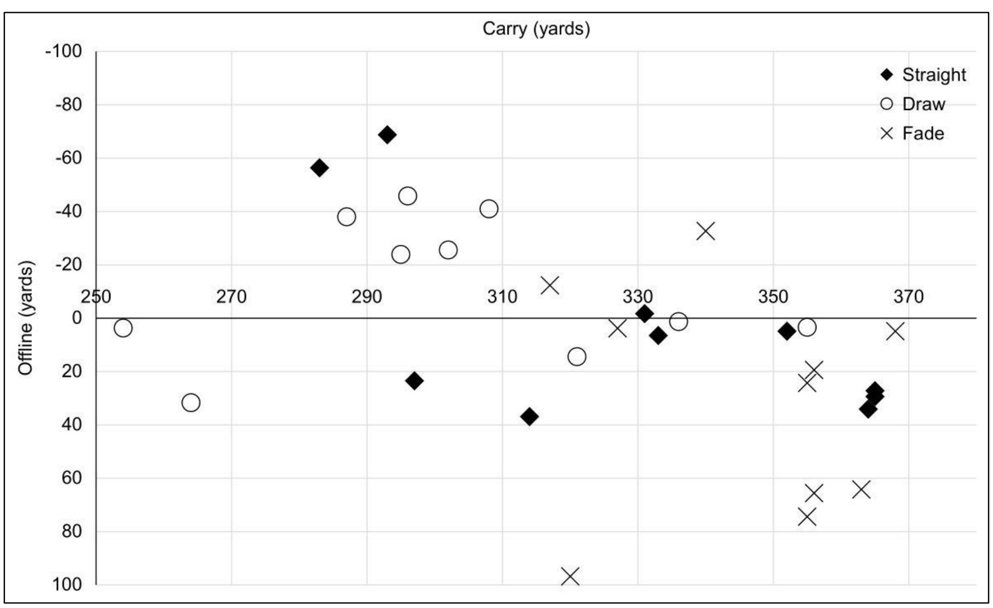

Figure 2. Results of carry and offline distance.

Table 1. Ball trajectory, club head, and body kinematic data at straight, draw, and fade shots.

		Straight: S	Draw: D	Fade: F	ANOVA
Ball	Ball speed (mph)	189.3 ± 6.3	192.1 ± 5.0	193.3 ± 4.1	n.s
	Launch angle (deg: + is up)	13.9 ± 2.7	13.1 ± 1.3	13.9 ± 1.9	n.s
	Back spin (rpm)	1945.3 ± 681.8	1054.7 ± 269.8	1548.2 ± 422.2	S > D
	Side spin (rpm: + is clockwise)	-292.1 ± 636.6	-870.9 ± 450.9	148.0 ± 459.8	D < F
	Carry (yards)	329.7 ± 31.7	301.8 ± 30.6	345.7 ± 18.4	D < F
	Offline (yards: + is right)	3.6 ± 37.3	-12.0 ± 26.4	30.8 ± 42.2	D < F
	Peak height (yards)	41.8 ± 14.7	24.0 ± 6.0	35.1 ± 11.4	S > D
	Decent angle (deg)	38.1 ± 8.5	24.9 ± 5.9	32.2 ± 9.6	S > D
Club	Club head speed (mph)	137.2 ± 1.6	137.0 ± 1.2	137.7 ± 2.2	n.s
	Grip speed (mph)	22.1 ± 0.7	22.1 ± 0.8	22.0 ± 0.7	n.s
	Face angle (deg)	0.0 ± 2.3	2.4 ± 2.9	0.7 ± 1.6	S < D. S < F. D > F
	Club path (deg)	2.0 ± 0.9	5.7 ± 1.1	-0.2 ± 0.9	S < D. S > F. D > F
	Face to path (deg)	2.0 ± 2.3	3.4 ± 2.2	-0.9 ± 1.6	S > F. D > F
	Attack angle (deg: + is up)	7.9 ± 1.0	8.2 ± 1.1	6.6 ± 0.7	S > F. D > F
Body	Pelvis kinematic sequence (deg/sec)	325.0 ± 50.1	283.9 ± 51.5	297.7 ± 71.1	n.s
	Torso kinematic sequence (deg/sec)	649.5 ± 63.9	609.9 ± 88.3	621.7 ± 35.4	n.s
	Arm kinematic sequence (deg/sec)	479.7 ± 28.2	465.6 ± 56.2	460.0 ± 34.0	n.s

Note: Values are mean ± SD, one-way analysis of variance (ANOVA), p < .05.

DISCUSSION

This study analysing a representative player in Japanese professional golf long driving showed no significant differences in ball speed and CHS for the three trajectories, but the carry distance increased with offline distance. For the participant, ball carry was longer for fade shots, which was considered closer to the ideal value in terms of club face and shaft control. However, in an actual competition, there is a rule that the ball must stop at a grid 45–60 yards wide to the left or right to be recorded. The offline distance was over 60 yards two out of 10 times for straight shots, zero times for draw shots, and four times for fade shots.

Based on the above results, the participant was most likely to be deemed invalid in the case of a fade shot during a competition. Therefore, considering the constraint of six shots in the regulations of a match, it may be advisable to start with draw shots, which tend to have a smaller offline distance in the early stages, to ensure valid attempts. Subsequently, transitioning to fade shots could be part of a strategic approach to achieve an even greater maximum distance. The subjective kinematic feedback obtained from the participant after the experiment indicated that draw shots provided the longest distances in a competition. The discrepancy between the objective data of this study and the subjective kinematic feedback from the participant can be attributed to several factors. First, the participant's extensive experience with successful attempts, as indicated by shorter offline distances, may have influenced his perception. In addition, the tendency of the draw shots to have a significantly lower peak height and descent angle may have contributed to a more stable and less negatively affected trajectory under various wind conditions, thus influencing the feedback. Furthermore, long-drive events often occur in large sports complexes where the ground surface is generally dry and firm. These conditions could affect the behaviour of the ball and, consequently, the player's experiences during the experiment. In tournaments where scores are competitive, the wet-bulb temperature, serving as an indicator of ground hardness, significantly influences the scores (Jowett & Phillips, 2023). Furthermore, considering outdoor settings without windbreaks, the wind direction substantially impacts the ball. It is presumed that headwinds or tailwinds and hitting against the wind from the side might result in reduced distance. Therefore, prior observations of the external factors in the surrounding environment are crucial (Malik & Saha, 2021; Thornes, 1977). For the reasons mentioned above, it is plausible that the subjective kinematic feedback of LDPs is influenced by their experiences of success with draw shots that are slightly lower and have a lower spin. To effectively plan for competition days, LDPs must conduct detailed investigations into landing areas at tournament venues and prevailing wind conditions, allowing them to plan for optimal ball trajectories, accounting for both elevation and lateral movement.

Controlling club faces is crucial for managing the three ball trajectories: straight, draw, and fade (Ichikawa et al., 2022). In the participant's draw shots, the club path exhibited a characteristic in-to-out trajectory towards the ball, with the face angle noticeably open at impact. In contrast, in fade shots, there was a significant tendency for a smaller attack angle, indicating a slightly out-to-in path and a tendency to strike the ball more shallowly. Surprisingly, even when altering various ball trajectories, LDPs competing for the maximum distance in a single shot maintained an almost constant CHS and grip speed. No significant differences were observed in the angular velocities of the pelvis, torso, or arm. This suggests that in the vicinity of the impact, the LDP in this study could differentiate ball trajectories by precisely controlling the club face path without altering trunk movement. In other words, the LDP exhibited precise control of the club face near impact and the skill to differentiate between three ball trajectories, a technique essential for adapting to external factors such as surfaces and wind conditions in competitive environments.

Although it is commonly believed that increased driver distance leads to decreased accuracy, research comparing tour players and amateurs has reported evidence suggesting the opposite, where the dispersion of ball landing positions converges closer to the centre of the fairway for tour players than for amateurs (Broadie, 2008). This phenomenon is thought to be because individuals who can hit the ball farther tend to have more efficient swings, leading to higher accuracy. This implies that for LDPs, beyond the ability to contribute to maximum distance, face control is an essential motor skill intricately related to finesse in golf. It has become evident that, as a foundation, striking a balance between skill-related face control and physical fitness is crucial when devising a training plan.

The contribution of lifting weights in exercises such as bench presses and squats to increase the CHS has been highlighted in previous studies (Brennan et al., 2024; Fletcher & Hartwell, 2004; Johansen et al., 2023). However, strengthening the arms and trunk requires a significant amount of time, and the effectiveness of such training may not always translate into increased CHS (Hume et al., 2005). As previously mentioned, Jamie Sadlowski, who reported a CHS of over 150 mph, emphasized the importance of lifting speed using a human ballistic move that utilizes muscle reflection as a training method (Holt & Holt, 2013). This paper also discusses Tiger Woods' attempt to increase CHS by gaining 30 pounds (13.6 kg) in 2008, which led to a knee injury. Sadlowski attempted a similar weight gain strategy, but it resulted in minimal changes in CHS. Considering the risks and lack of significant improvements in CHS, this study suggests that such weight-gain strategies are not recommended for a long golf career. Therefore, the height of the CHS depends on factors such as initial muscle function and age, and achieving meaningful results requires consistent and appropriate training.

Understanding the motion mechanism of normal acceleration may allow for the transient increase in the CHS in a teed-up driver shot. This swing theory suggests that by pulling the grip end inward (normal direction) just before impact, the club head accelerates through the increase in the shaft's rotational acceleration, known as "*parametric acceleration*" (Miura, 2001). This movement is similar to the technique used in hammer throws in track and field events. In the hammer throw, athletes pull the grip inward against the opposing weight of the distal hammer, reducing the rotation radius and obtaining normal acceleration to propel the hammer over a great distance. However, it is important to note that any shift in the hand position may complicate face control during ball impact in golf. Therefore, careful attention is required to maintain proper face control during impact when mastering this technique. Furthermore, the feasibility of intentionally acquiring the skill of parametric acceleration and its applicability to LDPs remain uncertain. Future research focusing on the motor-learning aspect of this technique could provide insights into its practical use in LDPs.

CONCLUSION

This study focused on an international LDP and analysed ball trajectories, club face control, and body movements when performing straight, draw, and fade shots. The results, particularly regarding distance, indicate that fade shots achieved the longest distance. However, considering the strategic aspects for an actual competition, draw shots exhibited the most stable tendencies. In distance-based golf competitions, it is important to fully understand an individual's kinematic characteristics and use different trajectories according to the wind and field-of-view environments. Therefore, it is crucial that LDPs make trajectory choices based on crosswind and against-the-wind conditions during competition. This study found no differences in CHS and grip speed across different trajectories; therefore, LDPs need to analyse external factors, such as the constantly changing natural environment. This highlights the need for LDPs to assess and adapt to these conditions during competition. Conducting outdoor experiments and analyses during actual competitions is essential to validate these findings.

AUTHOR CONTRIBUTIONS

Daisuke Ichikawa (Drafting the work or revising, agreement to be accountable for all aspects of the work). Akihiko Sakai (The conception or design of the work). Takeru Suzuki (Drafting the revising). Taiki Miyazawa (Analysis of data). Isao Okuda (Interpretation of data for the work). John Patrick Sheahan (English editing and research support).

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DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

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