

# Golfer's Driver Swing Technique Analysis Of Factors Affecting Success Rate

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This study aimed to identify the influencing factors and swing paths of players who exhibited failed swing techniques by comparing the characteristics of successful and failed driver swings, and to propose methods for improving success rates. Using a three-dimensional motion capture system and force table, biomechanical analyses were conducted on 10 professional golfers. Results showed that during the setup phase, differences in ball position, stance width, shoulder line angle, center of gravity displacement, and ground reaction forces influenced the ball's release angle and direction. In the backswing, variations in shoulder line angle, lateral club angle, and left elbow angle affected release direction. During the transition phase, center of gravity shifts and right foot ground reaction forces influenced release speed and offset. In the downswing, wrist-forearm angle and vertical center of gravity changes also impacted ball trajectory. A total of 50 professional golfers participated in the study, with swing kinematics and kinetics recorded using a three-dimensional motion capture system, force platform, and radar-based ball tracking equipment. Key factors affecting success included stance width, ball position, shoulder rotation, overswing, transition timing, and center of gravity control.

**Keywords:** Golf; driver; Body posture angle; Center of gravity; Ground reaction force; Hitting parameters; Success rate.

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## 1. Introduction

In golf, the success of a technical action is usually judged based on the effect of the shot [1, 2]. The effect of the shot can be reflected by multiple indicators, including clubhead speed, ball speed, ball angle, ball direction, and takeoff angle. In the PGA Tour, the off-the-Tee (OTT) of professional players [3, 4]. Sitaraman et al. proposed an improved YOLO-based object detection model incorporating Clou

loss for enhanced localization accuracy and real-time recognition. In our golf driver swing analysis, this approach is adopted to precisely detect and track body posture and club movement, improving performance evaluation and success rate assessment. In addition, the distance and direction of the shot, as factors affecting the effect of the shot, have been quantified as indicators such as clubhead speed, ball speed, ball angle and takeoff angle [5]. It can be seen that judging the success or failure of a swing action requires

multi-dimensional measurement. This study proposes an unsupervised neural network-based golf swing analysis system that synchronizes motion sequences, detects fine-grained discrepancies in latent space, and generates interpretable intermediate poses to support self-training. A key limitation is that the system relies solely on motion similarity without labeled biomechanical knowledge, which may restrict precise identification of performance-critical corrections.

The driver is the most commonly used club for teeing off, and it has the characteristics of a long shaft and a long hitting distance [6] such as changes in wrist angle [7], fluctuations in center of gravity [8, 9] and weight transfer [10, 11]. Compared with professional players, amateur players often show more problems in swing technique [12]. In addition, research shows that even small differences in technique can significantly affect the hitting effect [13]. Previous research results show that increasing the radial deflection angle of the wrist during downswing helps to improve clubhead speed [14]. Center of Gravity (COG) is an indicator of the whole-body movement [15] and reveals how players maintain their body balance throughout the swing. Weight transfer during the swing can be quantified by changes in plantar pressure [16]. Ground reaction forces affect clubhead speed and ball speed, thereby altering the distance of the shot [17]. High-level players are usually able to utilize weight transfer more effectively to generate power, thereby increasing the success rate of their swing technique [18].

In recent years, research on golf swing technique in China has focused on the kinematic characteristics of players' swing technique, electromyographic characteristics, and plantar pressure analysis [19].

Previous research on golf driver biomechanics has mainly examined individual kinematic or kinetic variables and has primarily focused on characteristics of successful swings. The biomechanical mechanisms leading to failed swing performance remain insufficiently explored. This study differentiates itself by systematically comparing successful and unsuccessful driver swings using an integrated analysis of body posture, center of gravity displacement, ground reaction force, and ball flight parameters.

This study evaluates driver swing performance by quantifying distance, direction, and accuracy using launch parameters and clubhead offset displacement obtained from synchronized 3D motion capture, force platform, and radar measurements. The present study aims to investigate biomechanical differences between successful and unsuccessful driver swings in professional golfers by analyzing kinematic and kinetic characteristics during key swing

phases.

## 2. Material and methods

### 2.1. Research Subjects

Using GPower 3.1.9.7 to calculate the predicted sample size, a minimum sample size of 44 is required with an effect size of 0.4,  $\alpha = 0.05$ , and a statistical power of 80%. The selected effect size (0.4) was determined based on previous biomechanical studies reporting moderate differences in kinematic and kinetic parameters between different swing performance conditions. Recruiting professional athletes also helped reduce variability associated with skill level differences.

All participants had good physical function and motor ability, no sports injuries within the past three months, and signed informed consent forms. The experiment has been approved by the Medical Ethics Committee of Wuhan Sports University (Approval No.: 2023042). Basic information of the participants is shown in Table 1.

**Table 1.** Summary of Participant Characteristics.

Basic Information	Mean $\pm$ Standard Deviation
Age (years)	21.4 $\pm$ 1.78
Height (cm)	177.3 $\pm$ 5.96
Weight (kg)	75.8 $\pm$ 9.83

All participants were professional golfers with a mean playing experience of 11.8  $\pm$  3.2 years and regular participation in competitive tournaments, ensuring a high and consistent skill level suitable for biomechanical performance analysis.

### 2.2. Research Methods

#### 2.2.1. Testing Instruments

A 3D motion capture system (Vicon, UK, 250Hz sampling frequency, 9 T40 4-megapixel cameras) was used to collect swing kinematic data; a Kistler 3D force table (Kistler, Switzerland, model 9260AA6, 1000Hz sampling frequency) was used to collect ground reaction force data; and radar monitoring equipment (Trackman, Denmark, model 3e) was used to collect shot data. The integration of the 3D motion capture system, force platform, and radar equipment enabled simultaneous acquisition of kinematic, kinetic, and ball flight parameters for comprehensive swing analysis.

#### 2.2.2. Test Procedure

Participants completed a 5-minute treadmill warm-up at 6.5 km/h followed by 5 minutes of driver swing practice, after which calibrated motion capture, force platform, and radar systems recorded static and swing trials using 54

reflective markers placed according to a modified Vicon Plug-in-Gait model.

A national-level coach evaluated swing effectiveness using five valid shots per participant, with radar determining fairway landing to classify successful and unsuccessful swings, and the averaged results used for analysis. This approach allowed intra-individual swing variability to represent each participant's typical performance characteristics rather than treating individual swings as independent observations. Consequently, comparisons between successful and unsuccessful swings primarily reflected biomechanical differences at the participant level rather than repeated-measure effects.

### 2.3. Stages of Movement

The golf swing was divided into four key moments—preparation (E1), peak backswing (E2), downswing initiation (E3), and impact (E4)—and four phases including backswing (P1), transition (P2), downswing (P3), and follow-through (P4). These phases describe movement progression from swing initiation to post-impact deceleration. The classification enables phase-based biomechanical analysis of swing coordination and performance.

### 2.4. Test Indicators

In this study, the coronal axis was defined as the X-axis, the sagittal axis as the Y-axis, and the vertical axis as the Z-axis. The body posture angle, center of gravity, ground reaction force, and hitting parameters at each stage of the swing were selected as the research content. The specific indicators and definitions are shown in Tables 2 and 3.

Note: Center of Gravity (COG) and Ground Reaction Force (GRF) were collected as changes in each phase of motion. Ground reaction forces for both feet were collected, denoted by L for the left foot and R for the right foot. Hereafter, L / R will be used. Figure 1 illustrates these parameters. Fairway landing was selected as the success criterion because it represents a practical performance outcome integrating both directional accuracy and distance control, which are critical determinants of effective driver performance under competitive golf conditions. right toe markers at the preparation moment; when  $AD > 0$ , the ball's initial flight direction is biased to the right of the target line; when  $AD < 0$ , the ball's initial flight direction is biased to the left of the target line; when  $AD = 0$ , the ball flies along the target direction. The success rate, defined by fairway landing outcomes, provides an integrated measure combining distance and directional accuracy under realistic performance conditions. The operational definitions of accuracy and success rate were selected to reflect ecologically

valid performance outcomes representative of competitive golf situations.

### 2.5. Data Processing

Model preprocessing was performed on Vicon Nexus 2.9.1, and the data was output as C3D format and imported into Visual3D (C-Motion, Inc., Germantown, MD, USA) software to create a static skeletal model of a golf driver swing. Raw kinematic data obtained from the motion capture system were filtered using a fourth-order zero-lag low-pass Butterworth filter with a cut-off frequency of 6 Hz, while kinetic data from the force platform were filtered using a low-pass Butterworth filter with a cut-off frequency of 20 Hz to reduce measurement noise without affecting movement characteristics.

### 2.6. Statistical Methods

Normality was assessed using the Shapiro-Wilk test in IBM SPSS 22, data were expressed as mean  $\pm$  standard deviation after outlier removal, and Pearson or Spearman correlation analyses were applied accordingly with significance set at  $p < 0.05$  and correlation strength classified as weak, moderate, or strong based on  $r$  values.

## 3. Results and discussion

### 3.1. Success rate of swing technique

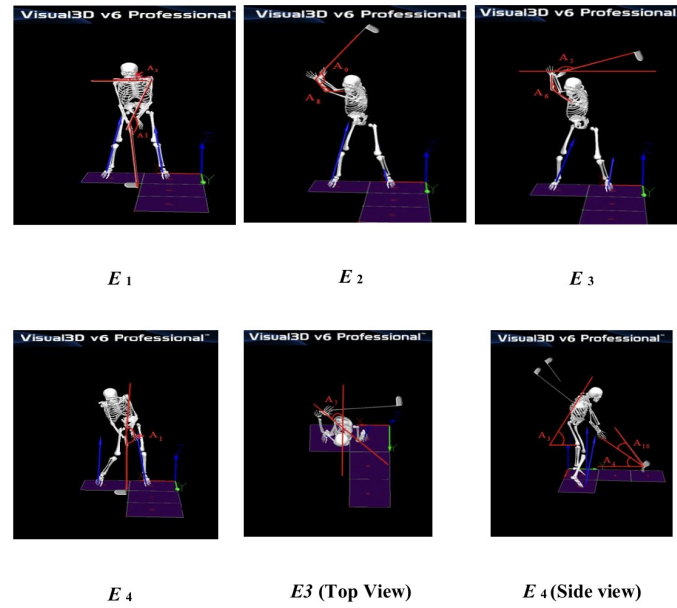
As shown in Table 4, The driver swing success rate was 46.00%, with the successful group showing higher average ball speed (70.36 m/s) and clubhead offset (0.09 m), while launch angle and direction were comparable between successful and unsuccessful swings.

The differentiation between successful and failed swings provides important practical insight beyond performance comparison. Identifying biomechanical characteristics associated with swing failure enables coaches to recognize specific technical deficiencies rather than relying solely on outcome-based evaluation.

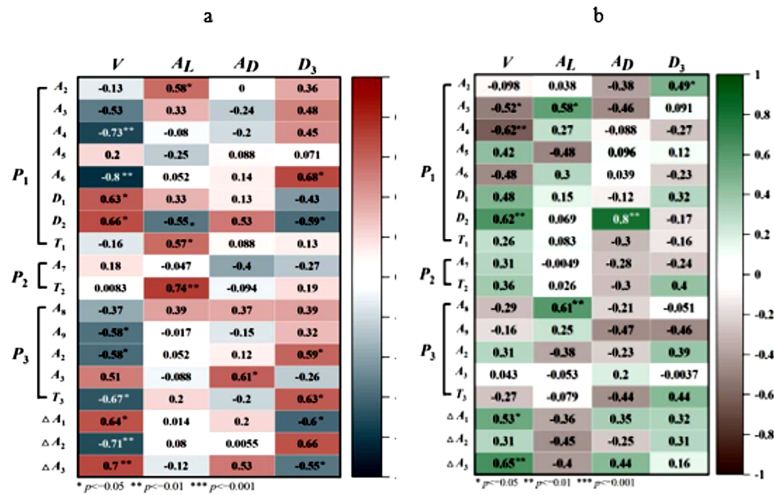
### 3.2. Results of Correlation between Body Posture Angles

Heatmap analysis of the successful group revealed clear phase-dependent correlations, with significant negative relationships between velocity and specific joint angles in P1 and P3, and moderate to strong associations during impact moments (E1–E4).

Heatmap analysis of the failed group showed generally weak and inconsistent correlations across phases, with unstable and sometimes opposing posture–performance relationships, reflecting poor coordination and inefficient segmental interaction loadings.



**Fig. 1.** Time and Stage Division. Note: Backswing phase (E1 - E2), transition phase (E2 - E3), downswing phase (E3 - E4).



**Fig. 2.** Comparison of pelvis and torso angular displacement ( $^{\circ}$ ) across normalized swing time (%) between successful and failed golf driver swings.

The timing of pelvis-torso separation plays a fundamental role in optimizing kinetic chain efficiency during the golf swing. Earlier rotational acceleration of the pelvis followed by delayed torso rotation promotes effective angular velocity transfer from proximal to distal segments enhancing clubhead acceleration at impact.

Note:  $\Delta A1$ ,  $\Delta A2$ , and  $\Delta A3$  are the changes in values at times E1 and E4, in angle units ( $^{\circ}$ ) and in velocity units (m/s).

### 3.3. Correlation Results of Center of Gravity and Ground Reaction Characteristics

Fig. 2(a) shows In the successful group, strong correlations appeared in P1 (notably AD and D3 with COG and GRF variables), moderate COG- and RGRF-related associations were observed in P2, and in P3 ball speed (V) was positively related to RGRF-Z and negatively to COG-Z, while other variables showed weak correlations.

Fig. 2(b) shows In the failed group, correlations across P1 and P2 were generally weak, with only small relationships between swing angles and COG or GRF variables ( $|r| \leq$

**Table 2.** Selection of Metric Names and Definitions.

	Indicator name	symbol	definition
Backswing	Left arm - club angle	$A_1$ ( $^\circ$ )	The angle formed by the left arm and the club at the moment of preparation
	shoulder line angle	$A_2$ ( $^\circ$ )	The angle between the line connecting the left and right acromion markers and the target line at the moment of preparation
	trunk angle	$A_3$ ( $^\circ$ )	At the moment of preparation, the angle between the midpoint of the line connecting the left and right acromion markers and the left and right posterior superior iliac spine markers and the horizontal plane
	Upper rod plane angle	$A_4$ ( $^\circ$ )	The angle between the plane formed by the club during the backswing and the horizontal plane
	Lateral club angle	$A_5$ ( $^\circ$ )	The angle between the club and the horizontal plane at the apex
	Left elbow angle	$A_6$ ( $^\circ$ )	The angle of the left elbow at the peak moment
	Station width	$D_1$ (m)	coronal plane distance between the left big toe and the right big toe
	ball position	$D_2$ (m)	coronal distance between the left big toe and the ball
transition phase	time	$T_1$ (s)	Time between the preparation moment and the peak moment
	X-factor	$A_7$ ( $^\circ$ )	The angle between the line connecting the left and right acromion 1 andmarks and the line connecting the left and right anterior superior iliac spines.
	time	$T_2$ (s)	The time between the end of the left-hand swing deceleration and the start of the downswing acceleration
Downswing	Wrist-forearm angle	$A_8$ ( $^\circ$ )	The angle between the left forearm and the coronal plane when the wrist begins to accelerate during the downswing.
	Minimum club-forearm angle	$A_9$ ( $^\circ$ )	Minimum angle between the club and the left forearm
	Left arm - club angle	$A_1$ ( $^\circ$ )	The angle formed by the left arm and the club at the moment of impact
	shoulder line angle	$A_2$ ( $^\circ$ )	The angle between the line connecting the left and right acromion markers at the moment of impact and the coronal plane
	trunk angle	$A_3$ ( $^\circ$ )	The angle between the midpoint of the line connecting the left and right acromion markers and the left and right posterior superior iliac spine markers at the moment of impact and the horizontal plane.
	Swing plane difference angle	$A_{10}$ ( $^\circ$ )	Angle between the upper rod plane and the lower rod plane
	time	$T_3$ (s)	Time between the downswing and the moment of impact
	Center of Gravity	COG (m)	Weighted average location of the mass of different parts of the human body
	Ground reaction force	GRF (N)	The reaction force exerted by the ground on the human body

0.24).

In P3, V and D3 showed modest positive correlations with RGRF-X, while AL was slightly negatively related to COG-Z, indicating overall low correlation strength across phases. The Fig. 3 shows the variation of ground reaction force and clubhead velocity across normalized swing time for successful and failed golf driver swings.

### 3.4. Preparation Time

At preparation moment E1, D2 significantly influenced AL in the successful group, while stance width (D1) showed opposite correlations with D3 between groups, with a wider stance in the unsuccessful group likely restricting hip rota-

tion and reducing impact consistency. Both groups shifted COG rightward, but the successful group loaded more on the outside of the right foot, whereas the unsuccessful group relied more on vertical right-foot force for stability. Shoulder line angle ( $A_2$ ), stance width, and ball position at E1 are key elements of the basic stance, directly affecting clubface alignment, weight transfer, swing trajectory, and shot outcome.

### 3.5. Backswing Phase

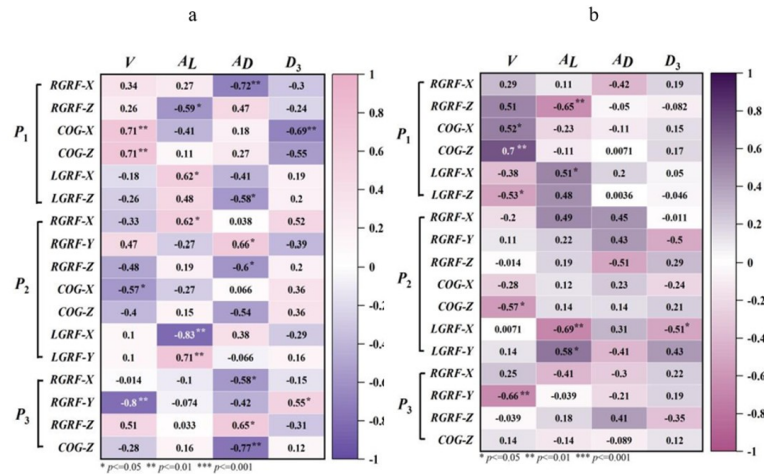
Skilled players can maintain trunk stability even with a large  $A_5$  angle, but overswing from left elbow flexion should be corrected by adopting a shorter, wider backswing

**Table 3.** Overview of Ball Flight and Shooting Parameters.

Indicator name	symbol	definition
Ball Exit Speed	$V$ (m/s)	The speed of the ball at the instant it leaves the clubface
Launch Angle	$A_L$ ( $^\circ$ )	The angle between the ball's flight path and the target line in the horizontal direction
Launch Direction	$A_D$ ( $^\circ$ )	The angle of deviation of the ball's initial flight direction relative to the target line when it leaves the clubface
clubhead migration displacement (Club head Displacement)	$D_3$ (m)	Difference in the position of the clubhead marker at setup and at impact

**Table 4.** List of Relevant Parameters.

	Successful swing		Failed swing	
	Average value	Standard deviation	Average value	Standard deviation
Ball speed (V)	70.36 m/s	4.8	69.23 m/s	4.68
Ball release angle (AL)	12.26 $^\circ$	3.63	12.35 $^\circ$	4.39
Direction of ball release (AD)	-0.27 $^\circ$	3.34	-0.115 $^\circ$	4.1
Club head offset displacement (D3)	0.09m	0.05	0.07m	0.04
Success rate	46.00%			

**Fig. 3.** Ground reaction force (N) and clubhead velocity (m/s) variations across normalized swing time (%) for successful and failed driver swings.

path, proper right-side loading, and improved upper-limb mobility. Strengthening trunk dynamic stability through mobility and rotation exercises enhances swing consistency and overall success rate.

### 3.6. Transition Phase

In P1, open shoulders (larger A2) increased rotational space but were negatively related to AD in the failed group, over-swing ( $A5 > 180^\circ$ ) lengthened T1, and in P2 insufficient rightward COG transfer in the unsuccessful group con-

trasted with a positive relationship between transition time (T2) and ball speed (V) in both groups. The transition phase (T2) plays a critical role in temporal coordination by facilitating the storage of elastic energy generated through pelvis-torso separation during the backswing. Previous studies indicate that players with a transition phase maximize the X-factor through pelvic and torso rotation, allowing sequential acceleration in which the wrists release after peak arm speed. In contrast, players without a transi-

tion phase rotate the pelvis and shoulders simultaneously, reducing segmental sequencing.

As the golf swing resembles a whipping motion, higher swing speed depends on the cumulative acceleration of body segments in sequence. At the same time, the allocation of the transition phase duration has a direct impact on the X factor, and extending the transition time can increase the X factor, thereby improving swing power. Therefore, the transition phase is very important in golf swing technique. Greater X-factor development and appropriate transition duration indicate effective energy transfer from the pelvis to the torso and subsequently to the upper limbs and club, which contributes to improved swing efficiency in the successful group [20].

This proximal-to-distal sequencing contributes directly to higher clubhead speed and improved shot accuracy observed in successful swings. In contrast, delayed or insufficient center of gravity transfer disrupts segmental sequencing, reducing X-factor utilization and leading to unstable clubhead control.

### 3.7. Downswing Phase

In early P3, limited hip motion in the failed group delayed leftward COG transfer, maintaining excessive right-foot load and reducing ball speed, indicating a lag in weight shift from back to front foot. From a clinical point of view, balance refers to the ability to maintain body stability by keeping the projection of the center of gravity within the boundary range of the supporting base. Balance exercises such as static squatting, standing on one leg, and standing on one leg under unstable conditions can effectively improve a player's balance.

The biomechanical characteristics observed in this study should also be interpreted in consideration of laboratory testing constraints. The use of motion capture systems and force platforms required participants to perform swings within a confined experimental space.

## 4. Conclusion

Key factors influencing driver swing success include stance width, ball position, shoulder rotation angle, backswing transition and timing, as well as center of gravity fluctuation and lag. Failed swings typically present a shallow, flat backswing with a downswing path either from inside-out or outside-in. Players should optimize stance and ball position, improve joint mobility to avoid overswing, and refine swing rhythm and transition timing, while future research should also consider muscle force and fatigue characteristics during the swing.

## Declarations

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### Conflicts of interests

Authors do not have any conflicts.

### Data Availability Statement

The data generated and analyzed during the current study are available from the author Zheng Weitao upon reasonable request but are not yet publicly available due to ongoing research.

### Code availability

Not applicable.

### Authors' Contributions

Xiao Yajun, Zheng Weitao, Liu Gan, Huang Yu, is responsible for designing the framework, analyzing the performance, validating the results, and writing the article.

Huang Ruifeng, Jia Mengyao, Ma Yong, Huang Zhiyong is responsible for collecting the information required for the framework, provision of software, critical review, and administering the process.

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