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# Wrist Lagging Angle Impact on Both Golf Driving Distance and Accuracy

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**Abstract** The purpose of this study was to examine whether the wrist lagging angle in golf down swing had an impact on both driving distance and driving accuracy for NCAA Division I female golfers. Seven female golfers all freshmen from a mid-Atlantic region NCAA Division I school volunteered to participate in the research with consent from their head coach. A Full Swing Golf Simulator was used to obtain variables and Dartfish was utilized to measure the wrist lagging angles in the down swing. Multivariate General Linear Regression (MGLR) was conducted to explore the possible cause and effect relationship and to identify a correlation matrix among driving distance, accuracy and wrist angle and other variables. The results indicated that only wrist angle and club head speed were significant in predicting both driving distance and accuracy. Other variables such as club head speed, smash effect, side spin and back spin were also found significant in the MGLR model ($p < .01$). Future studies should focus on identifying how wrist lagging angle affect male golfers and how does it affect irons in both distance and accuracy.

**Keywords** Wrist lagging angle, Driving accuracy, Female golfer

## 1. Introduction

When compared to traditional sports (e.g., basketball, swimming, volleyball, and soccer), golf as a relatively novel Olympic sport has become more popular and attracts people at different ages across 206 countries (World Golf Foundation, 2015). According to Business Report (2009), golfer worldwide has been estimated to reach more than 60 million in nearly 34,000 golf clubs. This population is comprised of amateurs and professionals. The increasing number of amateur golfers participated in golf game for health benefits, whereas professionals played for external reward (Farahmand, Broman, De Faire, Vågerö, & Ahlbom, 2009; Zhang, 2007). Regardless of their goals of playing golf, both amateur and professional golfers have always been searching for the most optimal methods to maximize their golf performance so that they can succeed in the game.

One of the primary focuses for the majority of golfers is to optimize driving performance during the golf swing (Wiseman & Chatterjee, 2006). Driving distance and driving accuracy are the most important parameters for evaluating golf driving performance, which have been extensively examined (Hume, Keogh, & Reid, 2005; Libkuman, Otani, & Steger, 2002; Pearce, 2013; Wiseman, Habibullah, & Friar, 2012). The driving distance is measured by the length of displacement of a golf ball hit by a golfer using a wood or long irons. A maximum displacement of the golf ball is achieved based on whether golfers have the ability to effectively maneuver the body and club for maximizing the transfer of energy into the golf ball (Adlington, 1996; Farrally et al., 2003). For better golf driving performance, golfers are not simply required to perform a full golf swing to displace the golf ball a maximum distance, but also the golfers need to ensure that the location of where the golf ball lands is as close as possible to the optimal area to lay a solid foundation for each hole.

According to Hume, Keogh, and Reid (2005), a substantial number of biomechanical studies were conducted to identify the contributing factors for maximizing driving performance. In particular, researchers utilized mathematical models to investigate the relationship between driving performance and biomechanical variables during the golf swing (Milburn, 1982; Miura, 2001; Penner, 2003). For example, a double pendulum model was applied to determine whether swing-related variables (e.g., delayed release of uncocking wrist, increased torque applied in the hubs of arms, and torso-pelvic separation) were associated with an increased angular velocity of golf club head, leading to better driving distance (Cochrane & Stobbs, Jorgensen, 1994; Sharmus & Sharmus, 2001). An alternative approach was also used to identify the key elements of enhancing the

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driving performance, involving in comparing professional golfers with amateur counterparts (McLaughlin, 1994; Robinson, 1994; Springs & Neal, 2000). Although different research approaches were applied, researchers consistently agree that wrist lagging angle plays very critical role in improving the club-head velocity and ball velocity for maximizing driving distance. It is mainly attributed to that the delayed release of wrist lagging angle at the stage of downswing can help a golfer apply centrifugal force and conserve angular momentum to achieve maximum club-speed at impact (Chu, Sell, & Lephart, 2010; Myers, J., Lephart, S., Tsai, Sell, Smoliga, & Jolly, 2008; Neal & Wilson, 1985, Tang, 2002; White, 2006). Additionally, Milburn (1982) utilized three-dimensional analysis to investigate the contribution of joint-related variables (shoulders, wrist, spin, and hips) to the golf swing, suggesting that out of these joints, the wrist movement is identified as the most important factor and accounted for a variance of 70% of the golf swing.

The delayed release of wrist lagging angle during the golf downswing has been consistently recognized as one of the performance-determining factors, which provides insightful instruction on how to help golfers carry out optimal golf swings for maximizing driving distance. However, researchers emphasize that determining an optimal golf driving performance should not only be individually reflected by a maximum driving distance, but driving accuracy should also be taken into account as one of an important component (Engelhardt, 1995, 2002; Wiseman, Habibullah, & Friar, 2011). In addition, a recent study conducted by Wiseman and Chatterjee (2006) demonstrated a negative relationship between driving distance and driving accuracy among professional golfers. In other words, if golfers achieved a maximum driving distance resulting from the greatest amount of club-head velocity through the delayed release of wrist lagging angle during golf downswing, driving accuracy would be impaired. To date, limited studies have been done to determine whether the delayed release of wrist lagging angle is associated with both driving distance and driving accuracy during the golf downswing. In addition, Chu, Sell, and Lephart (2010) emphasized most of studies examining the relationship between wrist lagging angle and club-head velocity for driving distance in professional golfers, but few studied on female intercollegiate golf athletes. Therefore, the purpose of this study was to examine whether wrist lagging angle had impact on both driving distance and driving accuracy for NCAA Division I female golfers.

## 2. Methods

*Participants*

Seven female golfers, all freshmen from a mid-Atlantic region NCAA Division I school volunteered to participate in the research with consent from their head coach. All seven right handed golfers were free of injury and had no significant history of joint injury at the time of testing. Prior to the test, all participants signed a consent form approved by the University's Institutional Review Board. Demographics of the golfers is presented in Table 1.

**Table 1.** Demographics of the golfers (mean ± SD)

| *Subject* | *Age (years)* | *Height (m)* | *Weight (kg)* | *Experience (years)* | *Handicap* |
|---|---|---|---|---|---|
| *Golfers* | *18 ± .5* | *1.68 ± .008* | *58.7 ± 5.2* | *6.2 ± 0.6* | *7.2 ± 3.2* |

**Table 2.** Descriptive Statistics for independent and dependent variables (N = 70 = 7 golfer x 10 shots)

| | **Independent variables** | | | | | | **Dependent variable** | |
|---|---|---|---|---|---|---|---|---|
| | **CHS** | **SE** | **BSPIN** | **SDSPIN** | **WLG** | **SLA** | **DD** | **DA** |
| ***M*** | 199.57 | 1.41 | 4458.71 | -90.63 | 117.29 | 98.70 | 199.57 | -2.53 |
| ***SD*** | 26.31 | .098 | 1360.77 | 513.41 | 18.21 | 14.65 | 26.31 | 26.38 |
| ***Minimum*** | 139 | 1.17 | 2648 | -800 | 75.4 | 67.90 | 139 | -72 |
| ***Maximum*** | 248 | 1.56 | 9090 | 800 | 137.5 | 129.80 | 248 | 50 |

Note. M = Mean; SD = standard deviation; CHS = club head speed; BSPD = ball speed; SE = smash effect; BSPIN = backspin; SDPIN = sidespin; WLG = wrist lag angle; SLA = Shoulder level angle; DD = Driving distance; DA = driving accuracy.

**Table 3.** Correlation between Independent and Dependent variables (N = 90 = 7 golfers x 10 shots)

| | | **Independent variables** | | | | |
|---|---|---|---|---|---|---|
| | | CHS | SE | BSPIN | SDSPIN | WLG |
| ***Dependent Variable*** | DD | .475 ** | .274 * | -.388 ** | -.16 | -411 ** |
| | DA | -.151 | .117 | -.001 | .708 ** | -.465 ** |

Note. CHS = club head speed; SE = smash effect; BSPIN = backspin; SDPIN = sidespin; WLG = wrist lag angle; HT = height; DD = Driving distance; DA = driving accuracy. **p* <.05, ***p* <.01.

*Instrumentation*

A Full Swing Golf Simulator (About-Golf Ltd., Maymee, OH.) placed in an indoor 15 ft x 15 ft x 30 ft booth on the campus practicing facility was used. Golfers were allowed to play on a photographically simulated driving range or golf course. A big screen of the Full Swing Golf Simulator was located 5 m away from the left shoulder of all right-handed golfers while performing a full swing. The big screen showed a virtual golf environment consisting of a golf hole in the tee box, fairway, and green with a pin and flag. The simulator allows researchers to obtain driving performance variables (club head speed, smash effect, sidespin, height of flying ball, and backspin) through tracking and analyzing projection and contact information of ball and club. The total driving distance and driving accuracy illustrated as off distance to the left or right for each shot can also be estimated by the simulator. A high-speed camera capable of 60 frames per second was synchronized with the Simulator to film the movement of each swing, especially for the wrist lagging angle. The films were downloaded to a computer for Dartfish software analysis (www.dartfish.com). Dartfish is a popular golf swing analyzing software, which can capture detailed angles and movements created in the golf swing. Dartfish was used to measure two wrist angles, one when the down swing started and the hands traveled at shoulder level and the other one when the hands traveled to the waist level before releasing the wrists were released.

*Procedures*

Each female golfer was instructed by her head coach to carry out a stretching-dominant exercise prior to data collection. Subsequently, each golfer used her own driver to hit golf balls at the simulator three to five times as practice to warm up. Then each golfer hit 10 shots off an artificial turf tee box into a projected practice range image on the screen while golf performance variables were collected. The researchers limited the number of swings by each golfer to ten because they wanted to control the influence from each individual golfer to the group data. Among the variables generated by the simulator, driving accuracy was a combination of off distance to the left (draw or hook) and off distance to the right (slice) captured by the system. The researchers inputted the off distance to the left as positive numbers and off distance to the right as negative numbers as one dependent variable: Driving Accuracy.

*Statistical Analysis*

Golf down swing wrist lagging angle or delayed wrist release has been studied and analyzed by both professionals and researchers. However, there is no study so far to examine the relationship among down swing wrist lagging angles and driving accuracy and driving distance. In the world of golf, no one can argue the importance of both golf drive distance and accuracy. Since they are both pivotal to the success of the game of golf, it is necessary to analyze both as covariates instead of as individual dependent variables (Alonso, Rodriguez, Tibaldi, & Cortinas, 2002; Bruin, 2006; Fahrmeir & Tutz, 2001; Morrison, 1990; Fox &Weisberg, 2011; Zhang et al, 2012). First step of data analysis, a Pearson Product-moment Correlation Coefficient (PPMCC) was conducted to determine whether a relationship existed between lagging angles with driving accuracy and distance. Then a Multivariate General Linear Regression (MGLR) analysis was used to explore the possible cause and effect relationship and to identify a correlation matrix among driving distance, driving accuracy, and the independent variables. The purpose of this study was to examine the contribution of down swing wrist lagging or retaining angles to both driving distance and driving accuracy. Other variables such as club head speed, back spin velocity, side spin velocity, ball height and smash factor found to have relationships with driving distance and accuracy were also included in this study as independent variables (Cochrane et al., 1994; Sharmus & Sharmus, 2001; Tang, 2002).

# 3. Results

Mean and standard deviation for independent and dependent variables is presented in Table 2. Particularly, wrist lagging angle as the primary independent ranged from 75.4 to 137.5 (117.29 ± 18.21). The results of PPMCC indicated that driving distance was significantly positively correlated with club head speed ($r = .475, p < .01$) and smash effect ($r = .274, p < .05$), but was significantly negatively correlated with backspin ($r = -.388, p < .01$) and wrist lagging angle ($r = -.411, p < .01$). Driving accuracy was significantly correlated with sidespin ($r = .708, p < .01$), but was significantly correlated with wrist lagging angle ($r = -.465, p < .01$). Ball fly height and shoulder level wrist angle had no significance to either driving distance and accuracy. Multiple separate correlations between independent and dependent variables are presented in Table 3.

The multivariate generalized linear regression (MGLR) analysis indicated in Residual SSCP Matrix that driving distance was significantly negatively correlated with driving accuracy ($r = - .277, p < .05$). Only when the correlation coefficient of the two dependent variables is zero, the MGLR is equivalent to the separate multiple linear regression model (Fahrmeir & Tutz, 2001). The results of the MGLR analysis indicated that five (club head speed, smash effect, sidespin, backspin and wrist lagging angle) of the six independent variables were significant in predicting the two dependent variables. Variable height of flying ball was dropped from the model. The final model with five remaining independent variables showed R Squared = .678 (Adjusted R Squared = .653, $p < .01$).

Results from MGLR identified that club head speed ($F = 286.29, p < .01$), smash effect ($F = 62.36, p < .01$), sidespin ($F = 4.37, p < .01$), backspin ($F = 22.19, p < .01$) and wrist lagging angle ($F = 6.78, p < .05$) were significant for driving distance. For drive accuracy, club head speed ($F = 5.52, p < .05$), sidespin ($F = 73.98, p < .01$) and wrist lagging angle ($F = 32.45, p < .01$) were significant. Meanwhile smash effect and backspin were found not significance for accuracy. Table 4 reported the fitted MGLR equations for driving distance and accuracy. Finally, Figure 1 demonstrated the correlation matrix among driving distance, accuracy and independent variables.

**Table 4.** The Multivariate Generalized Linear Regression Equations for Driving Distance and Accuracy

| Dependent variable | Parameter | Estimate | t | P value |
|---|---|---|---|---|
| **Total Driving Distance** | Intercept | -256.89 | -5.44 | .00 |
| | Club head velocity | 2.95 | 16.92 | .00 |
| | Sidespin | - .005 | - 2.09 | .041 |
| | Smash | 176.42 | 7.96 | .00 |
| | backspin | -.007 | -4.71 | .00 |
| | Waist lagging angle | -.186 | -2.61 | .011 |
| **Driving Accuracy** | Intercept | 131.68 | 1.78 | .080 |
| | Club head velocity | -.64 | -2.35 | .022 |
| | Side Spin | .032 | 8.60 | .00 |
| | Smash | -9.85 | -.28 | .78 |
| | backspin | .003 | 1.38 | .172 |
| | Wrist lag angle | -.64 | .11 | .00 |

## 4. Discussion

The result from MGLR accepted the hypothesis that wrist lagging angle in down swing for female golfers has significant impact on driving accuracy and distance. The direct result from smaller wrist angle at releasing point was longer club head travel distance to the impact point at the ball. Every five-degree wrist angle difference at waist level could cause 9.5cm driver head travel distance (a / sin A = b / sin B), given average driver's length is 109.22cm. The 18.59-degree difference between should level angle (mean = 98.70, SD = 14.65) and waist level angle (mean = 117.29, SD = 18.21) could result in loss of 35.32cm club head travel distance to the impact.

Similarly, the negative correlation between wrist lagging angle and driving distance presented in this study support the role of wrist lagging angle in maximizing driving distance, especially emphasizing the delayed release of small wrist lagging angle (Milburn, 1982; Pickering & Vickers, 1999; Springs & Neal, 2000; Kostis & Miland, 2006). It may be mainly attributed to that the delayed release of uncocking wrist angle maximized impact of club head on golf ball. Interestingly, there was a significant relationship between wrist angle and driving accuracy. Although it appeared to be negative, researchers could not claim it was a negative correlation due to the nature of the data input (off distance to the left were documented as positive numbers and off distance to the right were documented as negative numbers). This result indicated that wrist angle had a relationship to the ball fly to the right. Therefore, the researchers proposed the future research to further study the relationship between wrist angle and accuracy by change all off distance to positive numbers.

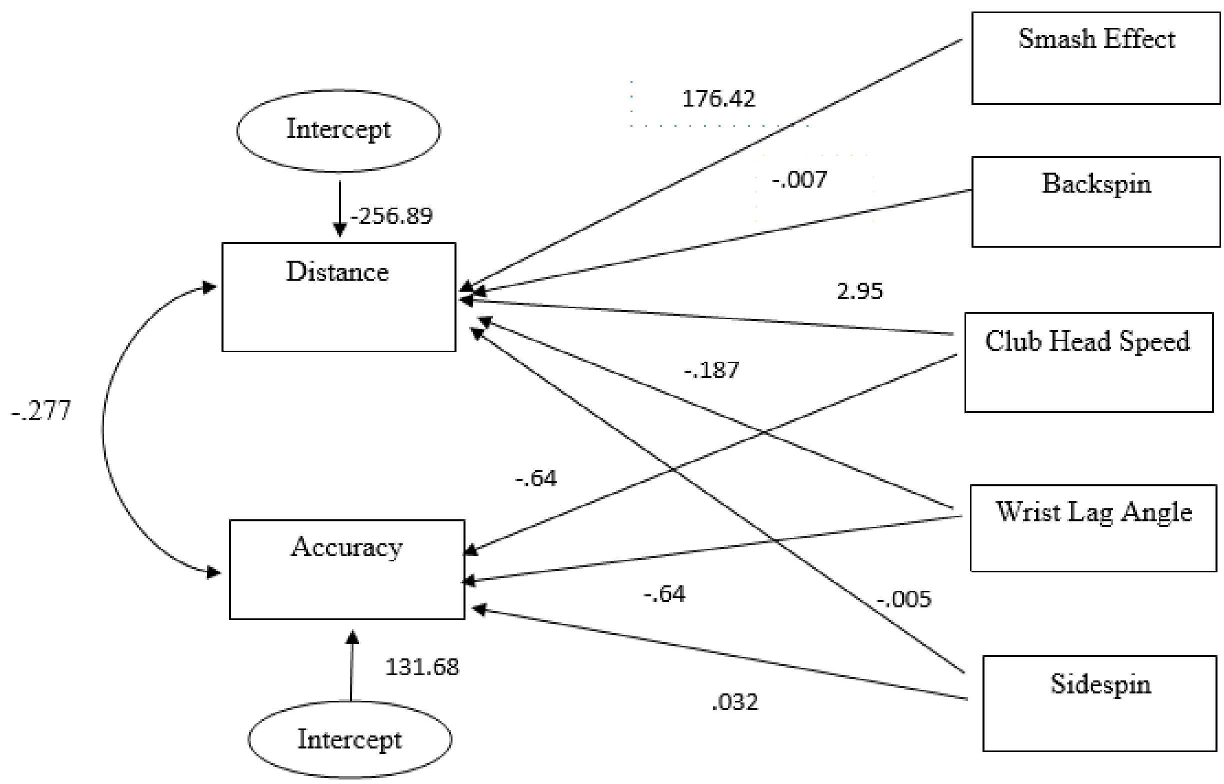


**Figure 1.** The correlation matrix among driving distance, accuracy and independent variables

However, golf swing is a complex combination of body coordination, bio-mechanics and psychological effect. No single element alone can explain the results of each golf swing especially when amateur golfers' skill or performance can vary in a wide range in any given day (Hume et al., 2005). This presented a huge challenge for golfers and golf coaches who want to improve performance or skills. Traditional swing statistics such a club head speed, back spin, side spin, ball height, and smash effect were direct results of existing swing and did not offer any clue how to change or improve their swings. This research focused on down swing wrist lagging angles direct impact on driving distance and accuracy. By focusing on wrist angle in down swing, amateur golfers can practice control distance and accuracy through retaining wrist angles. The results of the present study showed for female golfers retaining should level wrist angle was not as difficult as retaining wrist angle in the waist level mainly due to the nature gravity from the club head at top swing. However, when down swing at lower level, the gravity was working against the wrist angle, golfers need to practice and to increase wrist strength to retaining smaller wrist angle as long as possible hence to release the club head later to achieve the greatest club head velocity at the impact on the ball.

Although, lagging angle has significant impact on both wrist distance and accuracy, it showed quite different strength for distance (B = -.186, $p < .05$) and accuracy (B = -.637, $p < .01$) in the MGLR matrix. Surprisingly, wrist angle had bigger impact on accuracy than distance. This provided insight to golfers and golf coaches that when an individual tried to achieve further driving distance by retaining smaller wrist angle, it might affect her accuracy in a greater fashion.

The results of the present study indirectly agree with the negative relationship between driving distance and accuracy (Wiseman & Chatterjee, 2006). In other words, the smallest wrist lagging angle can maximize club head velocity, finally contributing to the greatest displacement of a golf ball, but it is possible to magnify deviation of the golf ball from a hole or target. This reflects the speed-accuracy trade-off phenomenon, where an increase in club head speed for maximizing driving distance is related to accuracy trade-off (Plamondon & Alimi, 1997; van den Tillaar & Ettema, 2006; Wickelgren, 1977). According to Schmidt, Sherwood, Zelaznik and Leikind (1985), sources of error in quick movements (e.g., hitting a golf ball) is attributed to inconsistency of muscle contraction force increases with increased force due to noise at connection (nerve impulse). In other words, more force generates more variability and thus causes more errors in movement direction or driving accuracy. But how does it impact on accuracy needs to be further explained in future studies (e.g., smallest wrist lagging angle leads a golf ball to land on the left side of the center line and vice-versa). One the other hand, this study only analyzed driver. How the wrist angle impact on irons should be examined too, given the short length of the iron-clubs could result in different effects. Furthermore, the future studies should look into male golfers, since males are presumably having more strength than female golfers, hence the wrist lagging patent might be different from females. The authors hope a series of related study could provide better scientific guidance for golfers to improve their golf swing. Finally, the results of this research can only apply to young college age female golfers who have developed decent golf skills.

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