International Journal of Golf Science, 2014, 2, 151-162
http://dx.doi.org/10.1123/ijgs.2014-0022

INTERNATIONAL JOURNAL OF
GOLF SCIENCE
Official Journal of WSCG
www.IJGS-Journal.com
ARTICLE

The Effect of Static Club Head Loft of a Driver on Golf Ball Launch Variables and Distance

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The driver is the club which receives the greatest scrutiny by golfers and the most marketing efforts by manufacturers. One characteristic often indicated and believed to effect driver performance is the degree of loft on the clubface. The purpose of the current study was to investigate the effect that the loft of a driver and gender has on golf ball launch variables and distance. The variables that were examined included club head speed, ball speed, launch angle, descent (impact) angle, total spin, carry, and total distance. Fifteen participants (12 male, 3 female) with a handicap of eight or lower were used to test three different degree drivers (9.5°, 10.5°, and 13°) on the variables listed above. Participants performed ten tested swings for each driver and the variables were measured. The data were analyzed with a two (gender) by three (club face loft) repeated-measures ANOVA. There were significant differences ($p < .05$) in total spin rate, descent angle, and total distance between the clubs. The male participants produced significantly greater values for the variables of club head speed, ball speed, descent angle, carry, and total distance when compared with the female participants. For the current study, the main finding was that the low lofted driver produced the greatest amount of total distance, 234.95 meters, compared with 226.57 meters for the high lofted driver and 232.58 meters for the medium lofted driver. This is likely due to the low lofted driver producing a lower total spin rate and descent angle than the medium and high lofted driver, resulting in a greater amount of run and total distance for the low lofted driver.

Keywords: drive, swing, distance, carry

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The driver is the club which receives the greatest scrutiny by golfers and the most marketing efforts by manufacturers. In these marketing efforts, the club being promoted is often described to possess the necessary characteristics for best golf performance (Hume, Keogh, & Reid, 2005). Researching efforts for designing golf clubs has been centered on increasing overall drive length and reducing the effects of off center impacts on ball flight (Penner, 2003). One characteristic often indicated and believed to effect driver performance is the degree of loft on the clubface, which is considered to be the angular difference between the club face and the ground (Penner, 2001a). The degree of loft has been suggested to influence golf ball trajectory and distance of ball travel after club impact due to several factors such as backspin, launch angle, and ball speed (Lamb 2012). A recent study reported that there is a scarcity of peer-reviewed literature on launch conditions, as much of this information has been reported within the club fitting community (Lamb, 2012). These factors will be discussed in more depth in the following paragraphs.

One of the basic principles of the golf swing is to generate club head kinematics at ball contact to strike the ball so that it travels the greatest distance possible in relationship to the hole (Hume, Keogh, & Reid, 2005). The distance a golf ball travels is directly related to the linear velocity of the club at impact (Keogh & Hume, 2012). The distance the ball travels after impact is dependent upon the initial launch conditions such as club head speed, ball speed, and launch angle (Keogh & Hume, 2012). Other factors will affect the distance that the ball travels, including drag force, lift force, and the amount of backspin (Goff, 2013). Drag force acts in the opposite direction of the projectile's velocity, and will thus decrease the total range of the projectile (Goff, 2013; Penner, 2001a).

Backspin is necessary to provide lift to the golf ball so that it can remain in the air and overcome drag (Lamb 2012). Air is asymmetrically pulled down off the backside of the ball while it is spinning. The upward component of this force, which is perpendicular to the velocity vector, is the lift force (Goff, 2013; Penner, 2001a). Previous studies have reported that the optimum amount of backspin will vary depending on the loft of the club, ranging from 3,600 rpm for a launch angle of 10° and ball speed of 209 kph (Bearman & Harvey, 1976) to 2,500 rpm for a club with a degree of loft of 12° (Kai, 2008). A study that examined drive characteristics of professional golfers reported backspin rates that ranged from 2,500 rpm to 3,500 rpm, with the best drives have a spin rate of approximately 2,700 rpm (Lamb, 2012).

Another factor that affects the range of a projectile is the launch angle (Arnold, 2010). The launch angle is considered to be the angle between the direction of launch and the horizontal line, for the golf swing this would be the ground. As club head speed increases, a lower launch angle is better because less lift is needed compared with a golf shot with a lower club head speed (Lamb, 2012). Different researchers have reported different launch angles to maximize the total distance of the drive, with launch angles typically being around 11° (Lamb, 2012) or 12° (Kai, 2008). Regardless of the optimal launch angle, it has been reported that as impact speed increases, the amount of dynamic loft decreases (Penner, 2001a; Penner, 2003). Penner (2001b) found for a designated club head speed, increasing the loft on the face of the club head would result in a lower launch speed, higher launch angle, and increased backspin for the golf ball (Penner, 2001b). The optimum value for dynamic loft (different than standard clubface loft) was 13.1 degrees which correlates to 10 degrees club face loft (Penner, 2001b). The advanced aerodynamics of the club head allows for the integral control of the club trajectory and generation of maximum club head velocity, which greatly increases the distance of the ball (Nesbit & McGinnis, 2009).

Along with degree of loft, club head speed is another characteristic of the golf swing. Club head speed is known as the velocity at which a golf club is traveling when it impacts with a golf ball and has been suggested to be a valid indicator of performance in golfers. With a linear regression analysis, club head speed was found to be highly correlated with the handicap of golfers (Fradkin et al., 2004). In general, the greater the club head speed at the time of impact, the lower the desired loft because the greater club head speed will induce a higher spin rate which requires a lower launch angle to eliminate the zone of diminishing returns (Penner, 2001b). This zone is reached when the spin and launch angle are too high and cause the ball to soar and result in a loss of distance.

Another variable to be examined in the current study and its effect on golf ball launch variables is gender. Previous research has reported the males and females use different upper extremity kinematics to strike a golf ball (Horan, Evans, & Kavanagh, 2011). The authors examined 19 skilled female and 19 skilled male golfers. The primary purpose was to measure movement variability during the downswing. The authors found that the females demonstrated greater variability in pelvic rotation, axial rotation, and thorax-pelvis coupling, leading the authors to conclude that skilled male and female golfers use different upper extremity movement strategies to achieve the same goal (Horan et al., 2011). Another study examined the swing kinematics of professional male and female golfers. They reported that the male golfers produced higher angular velocities at the elbow, wrist, and club shaft. (Zheng, Barrentine, & Flesig, & Andrews, 2008). Although there has not been a large amount of research investigating differences in golf performance between males and females, these two studies appear to indicate that there is a difference. These differences may also be present when examining the effects of club head loft on golf performance between male and female participants.

Based on the earlier reported findings, the purpose of the current study was to investigate club head speed, ball speed, launch angle, descent angle, total spin, carry, and total distance in an attempt to determine performance measures of three different lofted drivers. It is hypothesized the low lofted driver (9.5°) would produce greater performance measures due to an increased distance of run after carry which results in a net increase of total distance. This is believed to be true because the participants being tested are considered above average players which would increase their swing speed and control of the club to place them closer to the level of professionals. A secondary purpose of the current study was to compare these performance measures between male and female golfers.

Methods

Participants

Fifteen participants (12 males, 3 females) with a mean age of 20.47 ± 1.76 years, were recruited from the Professional Golf Management program at Mississippi

State University. Each person in the program is required to maintain a handicap of 8 or lower. Participants had a mean of 10.07 years of experience and played an average of 10.53 rounds of golf per month. Before participation each participant was required to provide Informed Consent (IC) for participation in the study. All methodologies were approved by the Institutional Review Board (IRB) for treatment of Human Subjects. Table 1 provides descriptive data for the participants used in this research study.

Table 1 Descriptive Data for Participants.

Gender	N	Average age	Average years of play	Average rounds of golf/month	Average score per 18 holes
Males	12	20.83 ± 1.8	11.25 ± 4.65	11.33 ± 5.0	76.58 ± 2.35
Females	3	19.0 ± 0.0	5.33 ± 0.58	6.33 ± 1.53	84 ± 4.58
Total	**15**	**20.47 ± 1.76**	**10.07 ± 4.80**	**10.53 ± 4.97**	**78.07 ± 4.10**

Drivers and Equipment

All drivers were 2012 TaylorMade RBZ with Matrix Ozik XCon-5 shafts of Regular Flex. Although a recent study that included 40 participants found that the type of shaft flex caused a difference in club head speed for 27 of the participants, they concluded that the type of flex that resulted in maximum club head speed was golfer specific (Worobets and Stefanyshyn, 2012). A Regular flex shaft was chosen as a matter of availability and convenience, as it was beyond the scope of the current study to match each participant with the optimum type of shaft flex to produce maximum club head speed. All shaft loft settings were set to Standard (STD) loft. The TaylorMade RBZ drivers are manufactured with optional settings for loft and club face weight. The adjustable dials are used to alter the shaft while the bottom of the club head possesses weights that can be moved from the front to the rear to tailor the club to the individual's swing. Driver shafts were a standard 46" (inches) which placed the participant an equal length from the ball between individuals. The experimental protocol used three different loft drivers (9.5° = Club A, 10.5° = Club B, and 13° = Club C). To reduce potential of variability from the golf ball, all swings were performed using a Titleist Pro-V1 golf ball. All trials were performed on the hitting set-up which consisted of a Callaway turf hitting mat and a two inch standard wooden golf tee. The camera system used for measuring and recording of the variables was the Foresight Game Changer (Foresight Sports HQ, San Diego, CA) golf analysis system. This high speed system allowed for the capture of impact and flight characteristics and was linked to a computer accessed by the researcher. Due to the link between the two systems, data were recorded by the Foresight Game Changer system and then organized by the computer. The radar was directly connected to the Foresight Game Changer system and used to collect the club head speed at the moment of impact. A projector was used to create a virtual ball flight displayed on a projection screen. In front of the projection screen was a Callaway hitting net, which was used to allow for indoor sessions and to protect the projection screen.

Driver Testing

Following retrieval of consent, each participant completed all procedures during a single research session with random assignment of club order. Sessions incorporated three trials with ten swings per club. Each trial consisted of a different lofted driver (Club A, Club B, Club C). All testing sessions were conducted in an indoor facility provided by the Mississippi State University Institute of Golf. This indoor facility allowed for a controlled environment to remain homogenous between each participants testing trial. All markings of club specifications were covered on each driver for all participants to remain blinded. Participants completed a total of 30 test swings, ten with each driver, to evaluate the measurement variables and eliminate any variability in miss hits. Participants were allotted five minutes for a warm-up process consisting of free swings in an open area with no golf ball. Following warm-up, participants were assigned a one of the three drivers in random order and at this time the Titleist Pro V-1 golf ball was placed on the two inch (2") tee for testing to begin. Participants were instructed to swing the club consistent with their normal characteristics for each tested swing. After the swing was performed and data were recorded on the computer monitor, the participant was instructed to back away from the hitting mat to allow investigator to return the testing area to previous setting and place the next golf ball on the tee. This ensured no increased effort was required from the participant other than the swing of the driver. Following the tenth swing with a specific driver, participants were allotted a two minute rest period where each participant remained standing in the testing area but did not perform any swings. Once the two minute rest period was completed, the testing of the second drive began and the process of testing was repeated from above. Each session included one warm-up, three testing periods, and two rests which resulted in a total of approximately 25 min for each participant's experimental session. All performance characteristics (in Measurements section) were recorded and organized for access via computer and video system.

Foresight Game Changer is a stereoscopic high speed digital camera system which monitors and records all aspects of impact and ball flight. The computer system, linked to the Foresight Game Changer system, retrieved the data for each swing and listed the variables in a folder created for each participant. The manual set up for the testing sessions consisted of a Callaway golf hitting net, projector screen and projector, Callaway turf hitting mat, Foresight Game Changer computer system and camera, and a computer linked to the camera which projected all flight variables following each swing. These variables were not presented to the participants after each swing to eliminate judgment of each club. In front of this projection screen was the Callaway golf hitting net which stood approximately eight feet in height and allowed ample space for participants to hit anywhere into the net. The Callaway turf mat was placed eight feet in front of the hitting net to provide sufficient space to swing a full length driver with no interference from an external surface. The Titleist Pro V-1 golf ball was placed on the right side of the turf hitting mat in a designated circle which lied eight inches from the right edge. The Foresight Game Changer camera system was aligned two feet to the right of the turf mat and one foot forward from the ball. This placement was necessary to not only capture the point of impact but also the flight of the golf ball as it left the club face. The computer monitor and system unit were linked to the Foresight

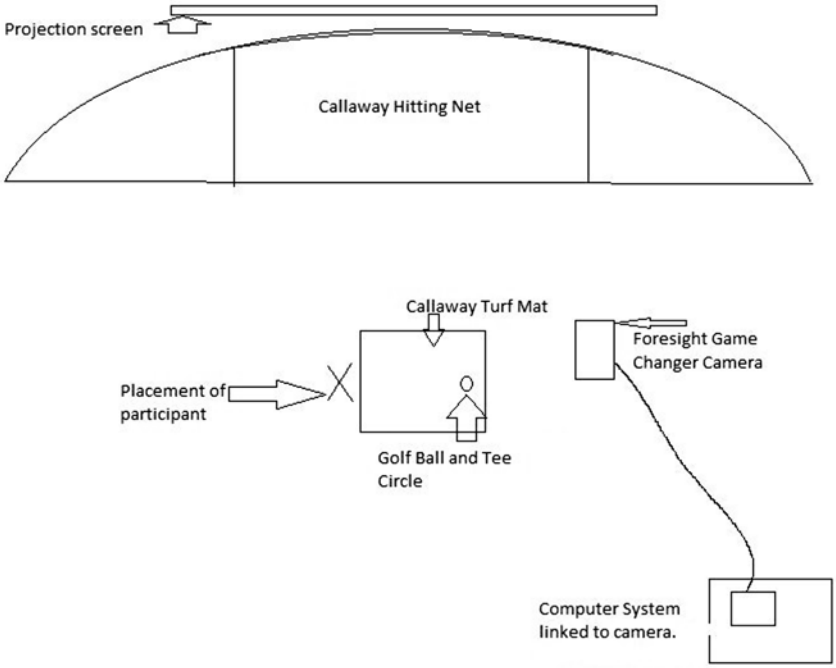

Figure 1 — Representation of the Testing Environment

Game Changer system. The computer system was located approximately nine feet behind and four feet to the right of the turf mat which provided an angle to observe the testing swings and also eliminate a visualization of the performance variables by the participant. Directly above the testing area the projector screen which was mounted to the 10 foot ceiling. Figure 1 shows the setup of the testing area.

Measurement Variables. For all swings, club head speed (m/s), ball speed (m/s), launch angle (deg), which is the angle between the direction of launch and the ground, descent angle (deg), which was the calculated angle at which the ball struck the ground (also referred to as the impact angle), total spin in revolutions per minute (rpm), which was a combination of backspin and side spin, carry measured in meters (m), and total distance in meters (m) was recorded (Foresight Sports Game Changer). Carry was defined as the calculated distance by the Foresight that the ball would have traveled from impact until it hit the ground, and total distance was the calculated distance that the ball would have traveled from impact until it stopped rolling. This data were organized (Foresight Sports Club Fitting Assessment) for analysis.

Statistical Analysis

The data for this study was organized concurrently with testing sessions through the Foresight Sports Club Fitting Assessment computer program. After all testing sessions were completed, data were retrieved and arranged into Microsoft Excel to determine the average for each variable for each club and each participant. All statistical analyses were conducted with IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. A two (gender: male/female) by three (club face loft: low/med/high) with repeated measures on the last factor were used to test for differences in the variables between the different clubs and genders (male/female) and Tukey post hoc testing was used with the a priori level set at $p < .05$.

Results

Tables 2–5 provide a summary of mean values found for each variable organized by club. There were no significant interactions between the club and gender for any of the variables. For the independent variable of gender, Significant differences ($p < .05$) were found between the male participants and female participants for ball speed, club head speed, descent angle, carry, and total distance. The male participants produced significantly greater values than the female participants. For the independent variable of club loft, there were significant differences ($p < .05$) for the variables of total spin, descent angle, and total distance. There was not a significant difference ($p > .05$) between the clubs for club head speed, launch angle, carry, or ball speed. The results of the Post hoc analyses for the total spin, descent angle, and total distance variables can be seen in Table 6.

Discussion

The variables discussed are imperative to the flight of a golf ball and to ultimately determine the performance of a golfer using the driver. Club face loft, measured in degrees, has the potential to affect each of the variables measured and can be a determining factor for the success of a golfer when using the driver from the tee box. The purpose of the current study was to investigate club head speed, ball speed, launch angle, descent angle, total spin, carry, and total distance in an attempt to determine performance measures of three different lofted drivers. Variables such as launch angle, club head speed, ball speed, and carry distance did not present any significant differences between drivers. The drivers used for this study possibly did not contain a large enough difference in loft from the low to high degree to produce an alteration in launch angle. Launch angle, unlike descent angle, is generally not affected by the level of spin and club head speed because the measure of launch angle is taken at the point of impact as it leaves the club before maximal spin is induced (Penner, 2003).

From the three clubs used by fifteen participants, total spin, descent angle, and total distance were the variables which presented significant differences for golf performance measures. For this research study, the high lofted (13°) driver and the average lofted driver (10.5°) resulted in a total spin rate significantly greater than the low lofted (9.5°) club (Tables 5–6). This increased amount of spin rate was likely a factor in the high lofted club producing significantly less total distance than the average lofted and low lofted club by reducing the amount of run after contact with the ground. In the same pattern of increasing values from low to high was the descent angle, or the calculated angle at which the ball struck the ground, from each measured club. The descent angle is thought to be affected by the total spin rate of

Table 2 Mean (± *SD*) Launch Angle and Descent Angle

Variable	Group (Club, Gender)	N	Mean (± *SD*)	P value
Launch Angle (deg)	Club A, male	12	12.267 (3.090)	0.649
	Club B, male	12	12.542 (2.250)	
	Club C, male	12	13.425 (2.665)	
	Club A, female	3	12.967 (5.793)	
	Club B, female	3	13.333 (2.610)	
	Club C, female	3	14.400 (4.597)	
Launch Angle (deg)	Club A, total	15	12.407 (3.519)	0.193
	Club B, total	15	12.700 (2.249)	
	Club C, total	15	13.620 (2.960)	
Variable	**Group (Club, Gender)**	**N**	**Mean (± *SD*)**	**P value**
Descent Angle (deg)	Club A, male	12	41.583 (5.054)	0.001
	Club B, male	12	43.083 (3.029)	
	Club C, male	12	45.417 (3.147)	
	Club A, female	3	27.667 (10.017)	
	Club B, female	3	31.333 (32.667)	
	Club C, female	3	32.667 (9.238)	
Descent Angle (deg)	Club A, total	15	38.800 (8.222)	0.013
	Club B, total	15	40.733 (6.169)	
	Club C, total	15	42.867 (6.917)	

the golf ball (Penner, 2001b; Penner 2003). The descent angle is proportional to the total spin rate of the golf ball and club face loft (Penner, 2003). In the current study, the low lofted driver had a significantly smaller descent angle than the average and high lofted driver (Tables 2 and 6). This likely led to an increase in run for the low lofted driver and a greater total distance than the other two drivers (Penner, 2002).

Total distance is the most important variable when assessing the driver performance (Okuda & Armstrong, 2002). All of the factors leading up to ball contact are extremely vital to acquire maximum distance, so the second shot can be precise with higher club selection (McNitt-Gray et al., 2013). As the club face loft increased from 9.5° to 13°, the total distance ultimately decreased, while there was not a significant difference in club head speed and ball speed. Total mean distance was 234.95 m with Club A. This was the lowest lofted club of the three used for testing and these findings are in agreement with those of Stachura and Wishon (2003) and Penner (2001a). Penner (2001a) found the optimal loft which produces the greatest distance to be approximately 10°, which is similar to the loft of Club A, which had a loft of 9.5° in the current study. The difference in mean total distance from Club

Table 3 Mean (± *SD*) Club Head Speed and Total Ball Speed

Variable	Group (Club, Gender)	N	Mean (± *SD*)	P value
Club Head Speed (m/s)	Club A, male	12	46.935 (1.264)	.01
	Club B, male	12	46.898 (1.554)	
	Club C, male	12	46.302 (1.882)	
	Club A, female	3	33.674 (1.807)	
	Club B, female	3	33.376 (1.367)	
	Club C, female	3	32.929 (0.931)	
Club Head Speed (m/s)	Club A, total	15	44.283 (5.645)	0.063
	Club B, total	15	44.193 (5.789)	
	Club C, total	15	43.628 (5.793)	
Variable	**Group (Club, Gender)**	**N**		
Ball Speed (m/s)	Club A, male	12	68.194 (1.886)	.01
	Club B, male	12	68.182 (2.323)	
	Club C, male	12	67.460 (2.641)	
	Club A, female	3	49.095 (2.584)	
	Club B, female	3	48.693 (1.737)	
	Club C, female	3	48.142 (1.317)	
Ball Speed (m/s)	Club A, total	15	64.374 (8.141)	0.94
	Club B, total	15	64.285 (8.354)	
	Club C, total	15	63.596 (8.349)	

A to Club C was 8.38 m. As the loft increased, the total spin rate and descent angle increased. Carry distance was not significantly different between the clubs, but total distance was significantly different between the high and low lofted drivers, with the low loft having a further total distance. Since there was no difference in carry distance, this difference in total distance is likely related to a decrease in roll distance for the high lofted club due to its significantly higher total spin rate and its increased descent angle. Penner (2002) stated that the most important factor in determining the length of the first bounce and the overall run of the golf ball after contact with the ground is the descent (impact) angle. The steeper the angle of impact, the lower the horizontal rebound velocity which results in a smaller first bounce and less run of the golf ball (Penner, 2002). In the current study, the high lofted driver had a significantly greater descent (impact) angle when compared with the medium and low lofted driver. The steeper descent angle for the high lofted driver likely resulted in less run than the other two drivers and a significantly less amount of total distance. In addition, while total spin was measured in the current study and not backspin, the high lofted driver had a significantly greater amount

Table 4 Mean (± *SD*) Carry and Total Distance

Variable	Group (Club, Gender)	N	Mean (± *SD*)	P value
Carry (m)	Club A, male	12	228.523 (9.683)	0.001
	Club B, male	12	229.027 (11.134)	
	Club C, male	12	223.519 (12.225)	
	Club A, female	3	138.623 (17.226)	
	Club B, female	3	140.765 (12.679)	
	Club C, female	3	138.127 (14.213)	
Carry (m)	Club A, total	15	210.545 (38.751)	0.379
	Club B, total	15	211.375 (38.751)	
	Club C, total	15	206.440 (37.367)	
Variable	**Group (Club, Gender)**	**N**		
Total Distance (m)	Club A, male	12	250.422 (9.045)	0.001
	Club B, male	12	248.954 (11.020)	
	Club C, male	12	241.988 (12.594)	
	Club A, female	3	173.042 (15.949)	
	Club B, female	3	167.177 (16.012)	
	Club C, female	3	164.886 (8.747)	
Total Distance (m)	Club A, total	15	234.946 (33.572)	0.008
	Club B, total	15	232.597 (35.760)	
	Club C, total	15	226.568 (33.980)	

Table 5 Mean (± *SD*) Total Spin Rate

Variable	Group (Club, Gender)	N	Mean (± *SD*)	P value
Total Spin (rpm)	Club A, male	12	3149.583 (542.509)	0.528
	Club B, male	12	3389.500 (638.223)	
	Club C, male	12	3727.083 (655.221)	
	Club A, female	3	2498.667 (671.697)	
	Club B, female	3	3623.000 (1750.805)	
	Club C, female	3	3268.667 (918.257)	
Total Spin (rpm)	Club A, total	15	3019.400 (606.906)	0.001
	Club B, total	15	3436.200 (875.953)	
	Club C, total	15	3635.400 (702.709)	

Table 6 Results of the Post Hoc Analysis

Variable	Comparison	P value
Descent Angle (deg)	Club A to Club B	0.027*
	Club A to Club C	0.013*
	Club B to Club C	0.054
Total Distance (m)	Club A to Club B	0.089
	Club A to Club C	0.008*
	Club B to Club C	0.098
Total Spin (rpm)	Club A to Club B	0.001*
	Club A to Club C	0.001*
	Club B to Club C	0.950

*Indicates a statistically significant difference ($P < .05$).

of total spin than the other two drivers, which likely means it had a greater amount of backspin. A greater amount of backspin also decreases the amount of run and the total distance of the shot (Penner, 2003).

There was a significant difference between the male and female participants for the variables of descent angle, club head speed, ball speed, carry, and total distance. These results were expected, as previous research has reported that skilled male and female golfers use different upper extremity movement patterns during the downswing (Horan et al., 2011). A study has also reported that among the sample of professional golfers in their study, male golfers produced significantly greater angular velocities at the elbow, wrist, and of the club shaft when compared with female golfers (Zheng et al., 2008). Although it was not measured in the current study, the male participants were likely able to produce greater club head speed than the female participants due to an increase in muscular strength and the male golfers may have had more mechanically efficient swing patterns. The increase in club head speed found in the current study for the male golfers also caused an increase in ball speed, carry, and total distance when compared with the female participants.

Research in this area of golf is limited and should be further examined. Limitations of this study include a lack of access to professional golfers, although all the golfers in the current study had a handicap of eight or lower. The level of consistency is higher when using the elite population and these variables should be looked at through the professional field (Clark, 2005). The participants, PGM members, were at the highest level of performance and consistency that was available to the researchers at this time. In addition, the number of participants was limited to the PGM program, and should be expanded to contain a larger population. While a comparison was made between male and female golfers, this was limited by having only three females in the current study. Another limitation of the current study was the lack of tracking of off-centered hits by the participants. However, the smash factor was calculated for each trial by dividing the ball speed by the club head speed. The values ranged from 1.448 to 1.473, with an average smash factor of $1.455 \pm .004$. Based on these numbers, none of the trials were excluded from the study for being an off-centered hit by the participants. An additional limitation was that only total spin was measured. Future research should include a measure of backspin, side spin, and total spin.

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