GOLF DRIVE LAUNCH ANGLES AND VELOCITY: 3D ANALYSIS VERSUS A COMMERCIAL LAUNCH MONITOR

Matthew Sweeney[1], Jacqueline Alderson[1], Peter Mills[2], and Bruce Elliott[1]

[1] School of Sport Science, Exercise and Health. University of Western Australia, Perth, Australia; [2]School of Physiotherapy and Exercise Science. Griffith University, Gold Coast, Australia

The purpose of this study was to compare initial ball direction and velocity for a golf drive collected using a commercially available launch monitor and 3D data, collected using a retro-reflective motion analysis system. Six golfers (handicap: 2-20) completed 10 drives each, with data simultaneously recorded by both a 12 camera Vicon MX system (400Hz) and a Vector Pro launch monitor. Both systems produced outputs for launch angle, side angle and ball velocity. The launch monitor data were compared against the 'benchmark' 3D results and showed a high correlation (0.93 – 0.96). Mean errors (launch angle 0.5°, side angle 1.1°, ball velocity 1.1m/s) were also relatively small. The results of the study suggest that if a high speed 3D system is not available or practical, a launch monitor such as the one tested, should provide accurate measurements of golf ball launch data.

KEY WORDS: golf, ball velocity, kinematics

INTRODUCTION: The effectiveness of each golf shot is dictated at all times by the inter-relationship of distance and accuracy. Although external factors including; wind, air density and friction of the landing surface play a role in this outcome, the components controlled by the player are the initial ball velocity and direction, as well as the spin imparted on the ball. The ability to accurately measure these component variables is important in attempting to better explain the outcome of a particular shot. Being able to predict the outcome of a shot in situations where the ball is not able to reach its potential endpoint, such as in a laboratory environment may also be valuable.

While launch monitors are most commonly used by golf coaches and club fitters to produce quantitative measurements of specific components of ball flight, they have also been used to obtain quantitative data that form the basis of scientific studies (Myers et al., 2008). Most launch monitors purportedly measure ball direction, velocity and spin, however their accuracy has yet to be validated. Conversely, while the accuracy of 3D retro-reflective measurement systems in tracking objects over space is established (CMMAS 2002, Richards, 1999), they have yet to be employed in the measurement of ball spin rate or spin axis of rotation in golf. This study will aim to compare the results of a Vicon MX system with a Vector Pro launch monitor in measuring initial golf ball direction and velocity.

METHODS: Six male golfers with handicaps ranging from 2 to 20 were recruited for the study. After a warm up, each golfer was required to hit 10 drives with their own driver, using their natural swing to achieve both distance and accuracy. The drives were performed in a laboratory setting, whilst standing on an artificial golf surface, with a net situated approximately 5 m in front of the participant. Each drive was recorded using a 12 camera Vicon MX (Oxford Metrics, Oxford, UK) system operating at 400 Hz, as well as a Vector Pro 2 launch monitor (Accusport, Winston-Salem, USA). The golf balls were new Titleist NXT's, with retro reflective tape attached to one side and two marks drawn on the other in accordance with the calibration procedures recommended by the manufacturer of the launch monitor (Figure 1).

The Vicon system is a retro-reflective system that uses multiple cameras to track the position of reflected light in a 3D space over time. As there was reflective tape on the golf ball it was treated as a single marker with its position tracked in the laboratory space over 5 m of flight before reaching the net.

At each time point, the velocity was calculated using the change in displacement from the previous frame divided by the change in time between frames. The launch and side angles reported using the 3D system were both taken at the time point of maximum velocity. Both the launch and side angle of the golf ball at every frame was calculated using the following equations.

$$\text{Launch angle } \theta = \tan\theta = (Z_c - Z_i) \div (X_c - X_i)$$
$$\text{Side angle } \theta = \tan\theta = (X_c - X_i) + (Y_c - Y_i),$$

Where X_c is current position of ball in forward direction, X_i is initial position of ball in the forward direction, Y_c is current position of ball in lateral direction, Y_i is initial position of ball in the lateral direction, Z_c is current position of ball in vertical direction and Z_i is initial position of ball in the vertical direction

In contrast to the 3D system, the launch monitor uses two photographs of the golf ball taken immediately following impact from two cameras located in the unit to calculate ball direction, velocity and spin. Velocity is differentiated from the forward displacement (horizontal) of the ball between the photos, launch angle is calculated from the vertical angle created of the ball between the two photos and side angle calculated by the difference in size of the ball between the two shots (Figure 1).

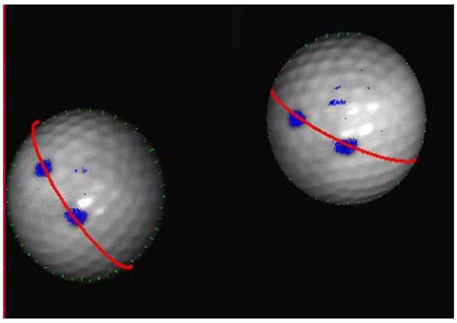

Figure 1: Composite picture of two shots taken by launch monitor with two marks and perimeter of the ball identified by the software.

The common variables examined across both systems were launch angle, side angle and ball velocity. Launch angle was defined as the angle created vertically between the ground and the golf ball direction, whilst the side angle is defined as the angle created horizontally between a line going directly toward the target and the actual ball direction

Due to the accepted accuracy and reliability (CMMAS 2002, Richards, 1999) the 3D system was used as the benchmark for comparing the two approaches.

RESULTS: The reported outputs from each trial (n=60), for launch angle, side angle and velocity are plotted between the two methods in Figure 2.

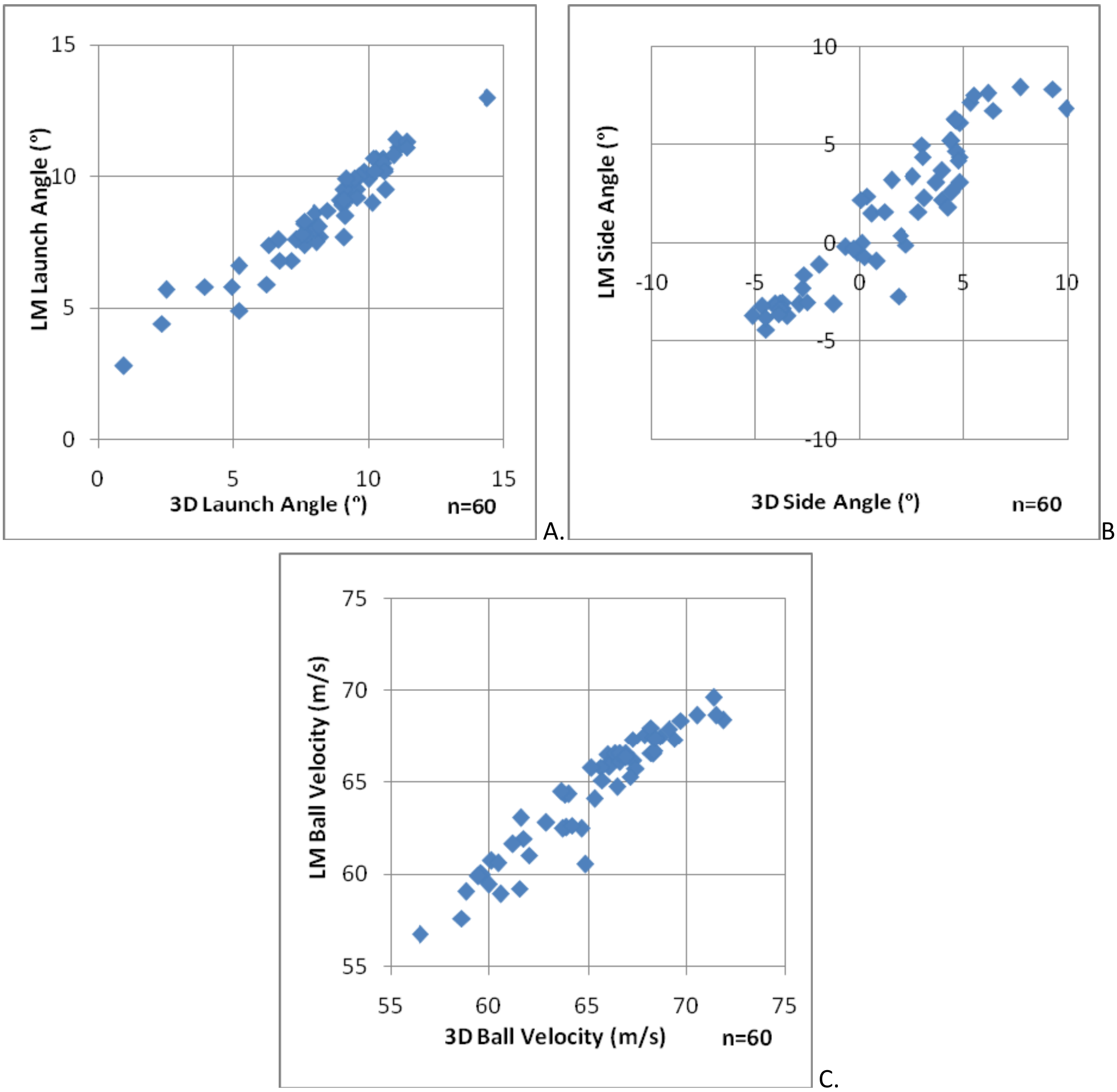

Figure 2: Data for each trial outputted by both the 3D system and launch monitor (LM) for launch angle (A), side angle (B), and ball velocity (C).

Correlations were run between methods, for each of the common measurements to give an indication of the relationship between the outputs (Table 1). Also, the mean error (absolute) and maximum error of the launch monitor outputs, compared with the 3D system, were calculated and reported alongside the standard deviation of the 3D data in Table 1.

Table 1: Mean correlation, mean error, maximum error and 3D standard deviations for the two data collection procedures.

Variable	Correlation	Mean Error	Maximum Error	Std Dev of 3D data
Launch Angle	.96	0.5º (±.6)	3.2º	2.4º
Side Angle	.93	1.1º(±.9)	4.6º	3.9º
Ball Velocity	.95	1.1m/s(±1.0)	4.8m/s	14.3m/s

DISCUSSION: Launch monitor data compared favourably with the benchmark 3D system for all variables analysed. Further, the mean error of each of variable was small in comparison to the standard deviation of the 3D data. This would indicate a good level of agreement between the 3D system and the launch monitor, for the variables analysed.

Amongst the two common variables concerned with direction (launch and side angle), outputs for launch angle produced the highest correlation (.96), as well as the smallest mean error (0.5°). In comparison the outputs for side angle, although also having a very strong correlation (.93) produced a higher mean difference (1.1°). This may be explained by difference in accuracy between predicting an angle based on the distance of a spherical object away from a 2D camera position, rather than one calculated based on the absolute position of the ball in two shots moving in a plane perpendicular to the camera.

CONCLUSION: There was a high level of agreement between the two methods of producing launch angle, side angle and velocity of the golf ball. Caution, however should be taken when collecting the above variables with a launch monitor as the maximum errors reported could produce misrepresentative data.

Although a 3D system with a high frame rate may still be the optimal for collecting launch data, it is not always feasible or practical and therefore a launch monitor, such as the one used in this study could provide suitable measurements for coaching, club fitting and selected research designs.

REFERENCES

Myers, J., Lephart, S., Tsai, Y., Sell, T., Smoliga, J., and Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences*, 26(2), 181-8

Results: Basic measurement accuracy, and processing time. Paper presented at Comparison Meeting of Motion Analysis Systems 2002; Japan Technology College, Tokyo, Japan. *http://www.ne.jp/asahi/gait/analysis/comparison2002/Result/basic/basic_eng.html*

Richards, J. (1999). The measurement of human motion: A comparison of commercially available systems. *Human Movement Science*, 18 (5), 589-602

Acknowledgment

The authors of this paper would like to greatly thank Titleist for the use of the launch monitor and assistance in technical difficulties through the research.