

## WRIST KINEMATICS DURING THE GOLF DRIVE FROM A BILATERALLY ANATOMICAL PERSPECTIVE

Matthew Sweeney<sup>1,2</sup>, Peter Mills<sup>3</sup>, Aditi Mankad<sup>2,4</sup>, Bruce Elliott<sup>2</sup>, Jacqueline Alderson<sup>2</sup>

<sup>1</sup> Australia Catholic University, Brisbane, Australia <sup>2</sup> University of Western Australia, Perth, Australia. <sup>3</sup> Centre for Musculoskeletal Research, Griffith Health Institute, Griffith University, Gold Coast, Queensland, Australia, <sup>4</sup>CSIRO, Brisbane Australia

Despite the reported importance of the wrist 'un-cocking' measure in the golf swing, only anecdotal evidence exists with respect to the three dimensional or bilateral nature of wrist motion. Through the downswing such anecdotal reports suggest that good players generally maintain a fixed flexion/extension position at the left (lead) wrist but perform rapid flexion at the right (trail) wrist. To assess these anecdotal assertions, 3D wrist kinematics of 8 skilled male golfers were determined during a high velocity golf drive. Each participant used their preferred driver, with data recorded using a Vicon 3D opto-reflective system operating at 400 Hz. The results support anecdotal recommendations with respect to the large extent of right wrist flexion. However, all players underwent a considerable amount of left wrist flexion, which was in contrast to common coaching recommendations.

**KEY WORDS:** golf, wrist, kinematics.

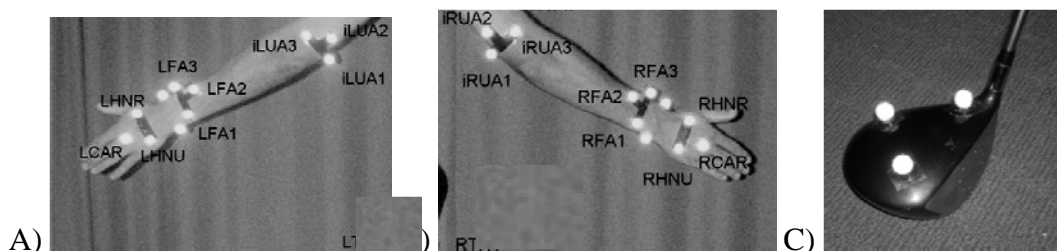
**INTRODUCTION:** A common theme of both empirical and simulation golfing research has been the importance of the un-cocking the wrists in creating high club-head velocity at impact (Springings & Neal, 2000; Chen, Inoue & Shibara, 2007; Chu, Sell, & Lephart, 2010). This measure of wrist un-cocking treats the interaction between the club and golfer as a solitary joint operating in a fixed plane. However, in reality, the golfer employs both arms during the swing, with no segment operating in a single plane for any length of time (Coleman & Rankin, 2005). From an applied perspective this leave the coach to make non-evidenced based recommendations with respect to the anatomical nature of the wrist motion during the swing. Consistent across anecdotal reports of wrist motion in the swing, is that the left wrist should neither undergo flexion or extension through the downswing. A failure to lock the joint is generally referred to as a 'breaking down' of the wrists. Common also is that view that there is bilateral ulnar deviation (sometimes referred to as 'hinging') at the wrists, with the right wrist undergoing a dramatic range of true flexion (Cochran & Stobbs, 1968; Hume, Keogh & Reid, 2005)

Differences do exist though, in the ideal position that coaches recommend for the left wrist at the top of the backswing. Many coach's advocate that players should achieve a 'straight' (neutral flexion/extension) left wrist position at the top of backswing (Leadbetter, 1990; Wiren, 1990). Others recommend a slightly 'bowed' (flexed) left wrist at the top of backswing. Hume et al. (2005) even specifically proposed that players maintain the left wrist joint in a flexed position of approximately 35° during downswing. In contrast to both of these, Ben Hogan suggested that the secret to his swing was actually achieving a 'cupped' (extended) wrist at the top of backswing, so when he 'bowed' (flexed) the left wrist in the downswing, it did not result in a hook (Hogan, 1955).

Such varying accounts relating to left wrist position at the top of the backswing highlight the limitations of relying on purely anecdotal evidence to describe the kinematics of such an important motion. An anatomical breakdown of skilled players' wrist kinematics during the swing will provide coaches and players with a quantitative understanding of what is possible and/or desirable at this joint. The aim of the current study is to biomechanically describe 3D, bilateral wrist kinematics in skilled golfers during the drive.

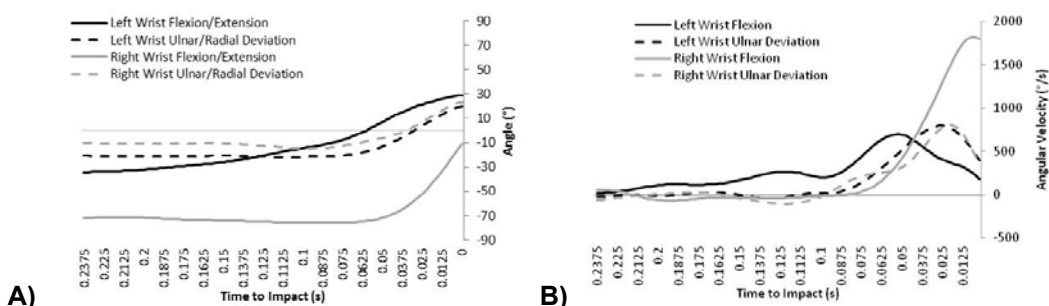
**METHODS:** Ten highly skilled male golfers were recruited for the study, with a mean  $\pm$ SD handicap, height and mass of  $2.7 \pm 1.6$ ,  $1.79 \text{ m} \pm 0.09$  and  $76.6 \text{ kg} \pm 9.4$  respectively. After providing written consent and performing a 5 minute warm-up, each participant performed a drive into a net situated 5 m in front of them. Participants were asked to use the natural technique they would employ for a drive on the golf course. Each swing was recorded using a 12 camera Vicon (Oxford, UK) MX system operating at 400 Hz. Twenty five reflective markers, of 16 mm diameter, were affixed to participants' arms, hands and club during the calibration procedure (Figure 1). Nineteen of these markers, including four semi-rigid 'T-bar' clusters remained during the dynamic trials and defined the technical coordinate systems (TCSs) used to calculate the movement of the arms, hands and club-head. The other four markers affixed in the calibration procedure were located on the radial and ulnar side of wrists and were held in the TCSs of the hands. The respective midpoints of these wrist markers acted as the left and right wrist joint centres. A pointer method (Cappozzo et al., 1995) was used to identify the 3D position of lateral and medial epicondyles for both elbows, with the locations of these landmarks held in the TCSs of each upper arm and the midpoints acting as the elbow joint centre. A similar method allowed the creation of a club-face plane that was held relative to a TCS created from three markers affixed to the top of the club-head (Sweeney, Alderson, Mills & Elliott, 2009).

The anatomical coordinate system (ACS) of the forearm and hand were defined using ISB recommendations (Wu et al., 2005) with wrist kinematics calculated from the rotations of the hand ACSs relative to the forearm ACSs.



**Figure 1: Retro-reflective markers on A) left upper limb, B) right upper limb and the C) golf club-head.**

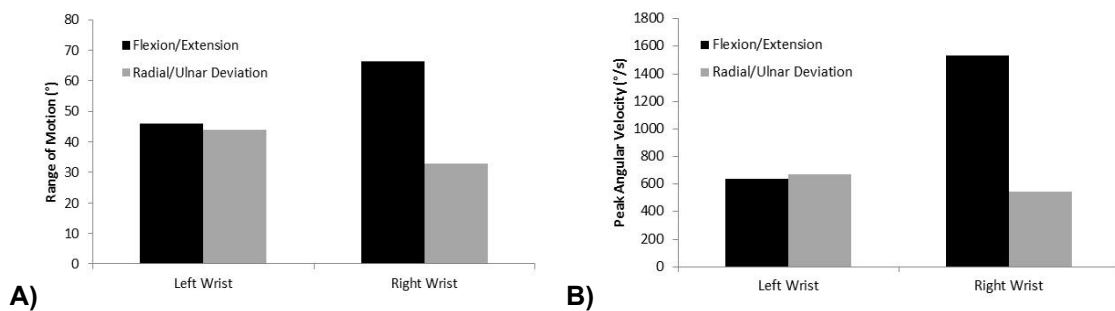
**RESULTS:** The average ( $\pm$ SD) club-head velocity produced by players at impact was  $45 \text{ m/s} (\pm 3.2)$ . Wrist kinematics for a typical trial showed players predominantly underwent flexion and ulnar deviation at both wrists throughout the downswing phase (Figure 2). At the top of the backswing the players displayed an average left wrist position that was  $27^\circ (\pm 8)$  extended and  $9^\circ (\pm 15)$  radially deviated. The average right wrist position at the same point was  $58^\circ (\pm 12)$  extended and  $16^\circ (\pm 21)$  ulnar deviated.



**Figure 2: A representative trial showing both left and right wrist A) angle and B) angular velocity through the downswing (+ve angle represents wrist flexion & ulnar deviation).**

The left wrists underwent an average of  $46^\circ \pm 10$  of flexion and  $44^\circ \pm 10$  of ulnar deviation, whilst the right wrist underwent  $66 \pm 12^\circ$  of flexion and  $33 \pm 14^\circ$  of ulnar deviation (Figure 3). The peak angular velocities achieved were  $636 \pm 213^\circ/\text{s}$  for left wrist flexion,  $669 \pm 210^\circ/\text{s}$  for

left wrist ulnar deviation,  $1531 \pm 345^\circ/\text{s}$  for right wrist flexion and  $548 \pm 155^\circ/\text{s}$  for right wrist ulnar deviation.



**Figure 3: A) The average range of flexion and ulnar deviation at both wrists through the downswing B) The peak angular flexion and ulnar deviation velocity at both wrists through the downswing.**

**DISCUSSION:** The average club-head velocity at impact across participants was similar to that reported in previous investigations using highly skilled golfers (Nesbit & Serrano, 2005; Meister et al., 2011). The golf swings executed by participants can therefore be considered as being of high performance. Interestingly, at the top of backswing each participant's left wrist was extended to some degree. This is contrary to the widespread coaching suggestion that players achieve a 'flat' (neutral) or 'bowed' (flexed) wrist position at the top of backswing. It does however, support Ben Hogan's account of his own swing where he describing his left wrist position at the top of backswing as somewhat 'cupped' (extended).

During the downswing, both left and right sides underwent substantial wrist flexion and ulnar deviation, achieving considerable peak angular velocities. The considerable flexion of the left wrist during this time is in contrast to the anecdotal suggestions that the left wrist flexion/extension angle should remain stable throughout the downswing (Palacios-Jansen, 2011). These results do not rule out that attempting to minimise flexion/extension in the left wrist is advantageous, nor does it show that maintaining a completely 'stable' flexion/extension angle is impossible. However, it does demonstrate that some movement in this direction is typical amongst a group of skilled golfers.

As well as being inconsistent with current coaching recommendations, the flexion of the left wrist observed in this study is meaningful from a bilateral coordination perspective. Specifically, due to the closed chain nature of the hands gripping the club, one might expect a coupling pattern where the left wrist complementarily extends while the right wrist flexes. Instead, there was bilateral flexion of the wrists through the phase leading to impact. This suggests that the wrists axes are not parallel during the swing, otherwise flexion at both wrists would not be possible over the same time period.

Of the four degrees of freedom anatomically possible at the wrists, it was clear that flexion on the right side underwent by far the greatest range of motion and peak angular velocity for each player analysed. This would suggest that flexion at the right wrist is likely to play a major role in the simplified motion known as wrist 'un-cocking' (Springings & Neal, 2000; Chu et al., 2010).

The current study is important in highlighting the anatomical breakdown of the wrist motion and therefore giving players and coaches a more quantitative account of what is achieved by skilled players across these two joints. Additional research is warranted in comparing the kinematics found in this study with those employed by golfers of a lesser skill level. Additionally, further biomechanical modelling research is recommended to assess the potential influence of three dimensional wrist kinematics on club-head kinematics at impact.

**CONCLUSION:** Contrary to anecdotal reports and widespread coaching opinion, the results of the current study indicate that skilled players do not have a 'flat' (neutral flexion/extension) left wrist position at the top of backswing, nor do they maintain this angle for any period during the downswing. All players achieved an extended wrist ('cupped') position at the left wrist at the top of backswing, before undergoing considerable bilateral wrist flexion and ulnar

deviation throughout the downswing phase. While it may be an effective teaching strategy to recommend players maintain a stable left wrist flexion, it should be noted that this technique is not typical in the downswing of skilled golfers.

#### REFERENCES:

- Cappozzo, A., Catani, F., Croce, U. D. & Leardini, A. (1995). Position and orientation in space of bones during movement: anatomical frame definition and determination. *Clinical Biomechanics*, 10(4), 171-178.
- Chen, C., Inoue, Y., & Shibara, K. (2007) Numerical study on the wrist action during the golf downswing. *Sports Engineering*, 10, 23-31.
- Chu, Y., Sell, T., & Lephart, S. (2010) The relationship between biomechanics variables and driving performance during the golf swing. *Journal of Sports Sciences*, 28(11), 1251-1259.
- Cochran, A. & Stobbs, J. (1968). *Search for the perfect swing*. Golf Society of Great Britain. Heinemann: London.
- Coleman, S., and Rankin, A. (2005) A three-dimensional examination of the planar nature of the golf swing. *Journal of Sports Sciences*, 23(3), 227-234.
- Hogan, B., (1955) This is my secret. *Life*, 39(6), 60-63.
- Hume, P., Keogh, J., & Reid, D. (2005) The role of biomechanics in maximising distance and accuracy of golf shots. *Sports Medicine*, 35(5), 429-449.
- Leadbetter, D. (1990) *The Golf Swing*. S. Greene Press.
- Meister, D., Ladd, A., Butler, E., Zhao, B., Rogers, A., Ray, C., & Rose, J. (2011) Rotational biomechanics of the elite golf swing: benchmark for amateurs. *Journal of Applied Biomechanics*, 27(3), 242-251.
- Nesbit, S., & Serrano, M. (2005) Work and power analysis of the golf swing. *Journal of Sports and Medicine*, 4(4), 520-533.
- Palacios-Jansen, K. (2011) *Golf Fitness: Play Better, Play Without Pain, Play Longer and Enjoy the Game More*. Taylor Trade Publications: Plymouth.
- Sprigings, E., & Neal, R. (2000) An insight into the importance of wrist torque in driving the golfball: a simulation study. *Journal of Applied Biomechanics*, 16(4), 356-66.
- Sweeney, M., Alderson, J., Mills, P., & Elliott, B. (2009) Timing of peak club-head velocity in the golf drive without the effect of impact. Proceedings on the 7th Australasian Biomechanics Conference. Gold Coast, 80.
- Wiren, G. (1990) Laws, principles and preferences – a teaching model. In A.J. Cochran (Ed.), *Science and Golf: Proceedings of the First World Scientific Congress of Golf* (pp. 3-14), University of St. Andrews, Scotland. London: E & FN Spon.
- Wu, G., van der Helm, F., Veeger, H., Makhsous, M., Van Roy, P., Anglin, C., et al. (2005) ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion – Part II: shoulder, elbow, wrist, and hand. *Journal of Biomechanics*, 38, 981-992.

*Acknowledgement:* The researchers would like to thank Titleist for their support of the research.