KINEMATIC SEQUENCING OF THE SHORT GAME SWING IN MALE COLLEGIATE GOLFERS

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Approach shots are crucial to the success of elite golfers. The primary purpose of this study was to compare kinematics of golf shots at four target distances (30, 50, and 70 yards, and full swing) in college-aged, male golfers. Participants were instructed to hit five successful shots at each target distance. A motion capture system recorded kinematic and temporal parameters of the golfers and a golf simulator collected ball carry distance of each shot. Distance had a significant ($p \leq 0.05$) effect on swing phase timing, angular velocities, and motion sequencing. Movement sequencing within the short game displayed irregular patterns across all distances and phases. The findings of this study show that the short game swing did present its own unique motion patterns that will require practice as its own skill.

KEYWORDS: Biomechanics; Golf Swing; Golf; Short Game; Kinematic Sequence.

INTRODUCTION: Golf appeals to over 40 million people in the US (National Golf Foundation, 2021). In the sport of golf there are four main golf shots: the drive, iron play, approach play, and the putt. According to U.S. PGA tour data, accuracy of approach shots has been positively correlated with player proficiency, since the outcome of this shot determines the distance of the first putt (James & Rees, 2008). Partial shots have been found to be a difficult skill, as researchers have identified a 17% reduction in accuracy of shots that were 50-100 yards when compared to shots of 100-200 yards (James & Rees, 2008). Proximal-to-Distal sequencing (PDS) is demonstrated in golf, as proximal segments initiate rotation to generate energy for distal segments. However, partial shots were not found to be biomechanically the same as full shots (Todd et al. 2020, Putnam 1993, Tinmark et al. 2010). Kinematic phases for full swings have been defined in a number of previous papers (Han et al. 2019, Madrid et al. 2020), Han et al. 2019, Kwon et al. 2012). But, a comprehensive kinematic sequence for a partial shot has not been yet established. At the time of this study, there were no published study that had attempted to investigate the effect of short distances (<100 yards) on the axel-chain system of the golfer. An axel chain system of a golfer is where the trunk is an inclined axel and it is linked to an open chain (Han et al. 2019). The primary **purpose** of this study was to collect comprehensive data on 3D biomechanical variables of the short game (including timing, angular velocities and PDS) at four target distances in college-aged, male golfers. It was hypothesized that (1) timing and peak angular velocities of body segments would be significantly correlated with the distance of the shot, and (2) PDS would be observed in the backswing, transition, and downswing phases of the swing.

METHODS: Fifteen male collegiate golfers volunteered to participate in this study. The average (± SD) age, height, body mass, and handicap of the participants were 20.5 ± 1.2 years, 183.9 ± 5.7 cm, 76.9 ± 12.4 kg, and 2.3 ± 1.0, respectively. All participants gave informed written consent in accordance with the requirements of the institutions Ethics Committee. The average (±SD) wedge moment of inertia, mass, and swing weight were 2745.5 ± 65.6 kg*cm^2, 473.7 ± 11.6 g, and 451.9 ± 8.9 g, respectively. Reflective, adhesive markers were placed for static capture (49 markers for the golfer, 11 markers on the club, and five markers on the synthetic turf surface, including a marked ball). After static collection, 14 markers were removed before dynamic trials. Five successful shots were collected at each target distance (30yds, 50yds, 70yds, and full swing (± 5yrds). Each shot block was completed before moving up in yardage. Positional data of all 65 reflective markers was recorded using an 11-camera motion capture system (Vicon Nexus 2.9.2, Oxford, UK) sampled at 250 Hz. The cameras and testing space were calibrated before each testing session. The lab space also included a

GCQuad Golf Simulator (San Diego, CA, USA) to record ball measurements for each trial. Captured trials were stored in C3D files and imported into Kwon 3D Motion Analysis Suite (Visol Inc., Seoul, Korea) for data processing. Through this processing, golfer hip line (HL), shoulder line (SL), upper lever (UL), and club vectors were defined along the functional swing plane (FSP) to detect body segment motion.
Data Processing was achieved used Kwon 3D Motion Analysis Suite (Visol Inc, Seoul, Korea) and IBM SPSS Statistics (Version 28, SPSS Inc, Armonk, NY).
The swing events defined in Han et al. (2019) (figure 1) were used for the subsequent analysis: BA (Breakaway), MB (Mid Backswing), LBA, (Late Backswing, Arm-Based), LB (Late Backswing), EPR (End of Pelvis Rotation), TB (Top of Backswing), EDA (Early Downswing, Arm-Based), ED (Early Downswing), MD (Mid Downswing), BI (Ball Impact), MF (Mid Follow-Through), and LF (Late Follow-Through) (Figure 1). From these events, the backswing, downswing, and transition phases were defined by BA-TB, TB-BI, and EPR-TB, respectively.

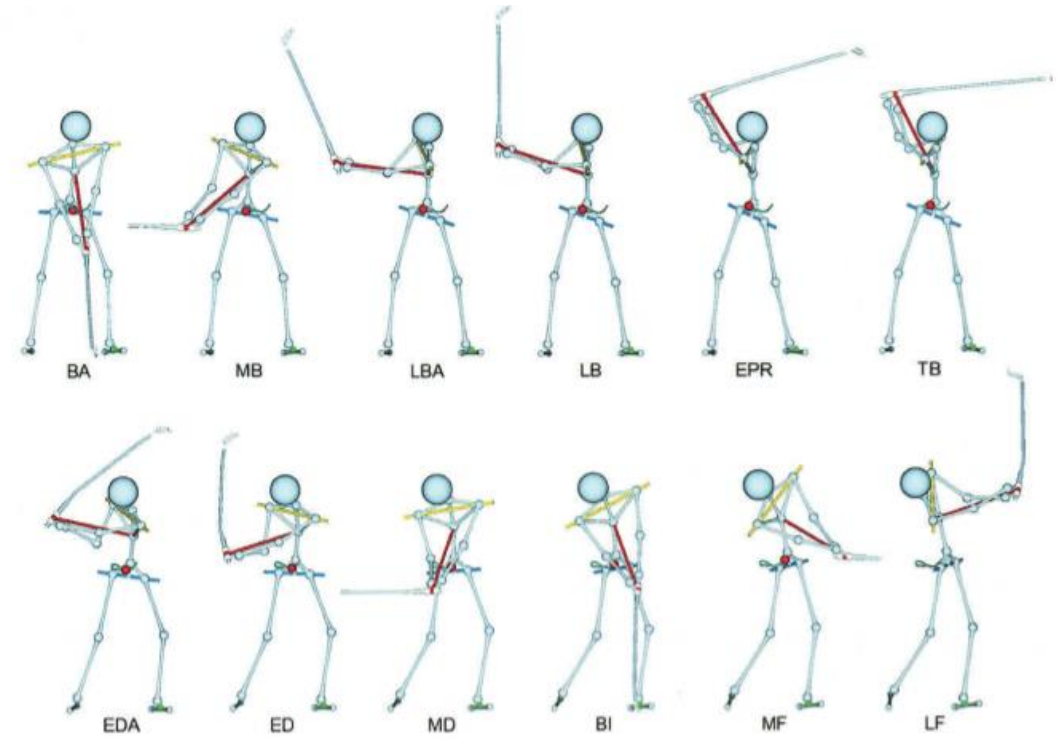

Figure 1: Club and lead arm position-based swing events; BA (Breakaway, MB (Mid backswing), LBA (Late backswing - AB), EPR (End pelvis location), TB (Top of backswing), EDA (Early downswing - AB), ED (Early downswing), MD (Mid downswing), BI (Ball impact), and LF (Late follow through).

Similar to Han et al. (2019) and Madrid et al. (2020), the following temporal and kinematic characteristics were analyzed: Phase times (ms): backswing, downswing, and transition. Peak backswing and downswing angular velocities (°/s): HL, SL, UL, and club (backswing only). Peak-to-BI angular velocity decrease (°/s): HL, SL, and UL. Times of peak backswing and downswing angular velocities, relative to BI (ms): HL, SL, UL, and club (backswing only). Transition times, relative to BI (ms): HL, SL, UL, and club.

RESULTS: The first one-way RM MANOVA examined the duration of each swing phase and yielded a significant ($p \leq 0.05$) distance effect (Wilks' $\lambda = 0.051$, $F(3,9) = 25.972$, $p < 0.001$). Follow up pairwise comparisons revealed significant inter-distance differences in backswing, downswing, and transition phase time (Table 1). Backswing duration significantly increased as target distance goals increased from 30 yards to 70 yards. Downswing duration significantly decreased as target distance goals increased from 50 yards to full swing. Transition duration at 70 yards was significantly longer than at all other distances. The second two-way RM ANOVA examined the downswing sequence to peak angular velocity and yielded significant distance * body interaction (Wilks' λ = 0.143, Greenhouse-Geisser $F(4,12) = 6.746$, $p = 0.002$). The post-hoc test revealed significant inter-distance differences in all body segments but only inter-body differences in the 30-yard condition (Table 2).

Table 1. Phase times (M ± SD; in ms)

	30 yards	50 yards	70 yards	Full	Sig. Diff.
Backswing (BA-TB)	663 ± 62	704 ± 78	736 ± 89	741 ± 71	30 < 50 < 70/F
Downswing (TB-BI)	313 ± 33	308 ± 38	296 ± 37	268 ± 39	30/50 > 70 > F
Transition (EPR-TB)	79 ± 44	81 ± 50	112 ± 46	91 ± 54	30/50/F < 70

Table 2. Transition times and peak angular velocity times (M ± SD; in ms, relative to BI)

	Hip Line	Shoulder Line	Upper Lever	Club	Sig. Diff.
Backward peak angular velocity time					
30 yards	–684 ± 38	–640 ± 43	–592 ± 38	–595 ± 60	HL<SL<UL/Club
50 yards	–714 ± 58	–671 ± 57	–609 ± 53	–603 ± 64	HL<SL<UL/Club
70 yards	–714 ± 59	–694 ± 72	–615 ± 64	–614 ± 68	HL/SL<UL/Club
Full (F)	–712 ± 70	–687 ± 77	–600 ± 75	–562 ± 68	HL/SL<UL/Club
Sig. Diff.	-	30<50<70	-	70<F	
Transition time					
30 yards	–364 ± 19	–329 ± 16	–320 ± 20	–312 ± 32	HL<SL/UL/Club
50 yards	–363 ± 20	–326 ± 17	–315 ± 24	–308 ± 37	HL<SL/UL/Club
70 yards	–360 ± 29	–317 ± 20	–306 ± 25	–298 ± 37	HL<SL/UL/Club
Full (F)	–339 ± 39	–291 ± 20	–280 ± 29	–273 ± 38	HL<SL/UL/Club
Sig. Diff.	50/70<F	30/50/70<F	30<F, 50<70<F	30< F, 50<70<F	
Downward peak angular velocity time					
30 yards	–39 ± 44	–36 ± 28	–61 ± 15	-	SL< UL
50 yards	–51 ± 35	–51 ± 24	–59 ± 11	-	-
70 yards	–75 ± 27	–62 ± 22	–59 ± 7	-	-
Full (F)	–75 ± 20	–71 ± 12	–65 ± 6	-	-
Sig. Diff.	30<70/F, 50<70	30<50/70/F, 50<F	70<F		

DISCUSSION: It was hypothesized that (1) timing and peak angular velocities of body segments would be significantly correlated with the distance of the shot, and (2) PDS would be observed in the backswing, transition, and downswing phases of the swing. Our results support the first hypothesis but not the second.

Regarding the first hypothesis, conventional wisdom would tell us that if we just kept moving everything a little faster that the club head would move accordingly faster and would hit the ball farther. Regarding our second hypothesis, movement sequencing within the approach shots displayed irregular patterns across all distances and phases. It is likely that with a golf drive in which maximum or near maximum distance is desired, PDS is necessary, but with shorter shots there are likely be numerous combinations of sequencing that can all produce similar submaximal distances. In other words for maximum shots a golfer needs to produce optimal timing and PDS to achieve maximum distance, but variations in timing or angular velocities may result in the same short game shot. In this case, each golfer would be able to choose the sequencing combination that they are most comfortable with. The practical implications of this are that partial shots may not be scaled versions of full shots so from a coaching and training perspective the partial shots should be viewed as their own skill.

CONCLUSION: Distance had a significant effect on timing of the swing phases, peak angular velocities, and golfer motion sequencing. The secondary hypothesis that proximal to distal sequencing is a common pattern among the backswing, downswing, and transition phase, cannot be accepted. Movement sequencing within the approach shot displayed irregular patterns across all distances and phases, with partial PDS at best. The similarities and differences between distances in the short game presented in this study suggest that the short game is not just a scaled version of a golf drive, but rather its own unique skill.

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