Elite golfers' kinematic sequence in full-swing and partial-swing shots

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Analysis of elite golfers' kinematic sequence in full and partial shots

Fredrik Tinmark

Abstract

Aim

The purposes of the present study were, to determine if partial and full-swing shots performed by skilled golfers were organized in a proximal-to-distal sequencing (PDS) pattern and to examine the speed-summation effect at pelvis, upper torso and hand segments.

Method

Three-dimensional kinematic recordings of pelvis, upper torso, and hand were made while forty-seven skilled golfers stroke three different clubs a range of submaximal and maximal shot distances.

Results

This study showed a clear proximal-to-distal temporal relationship of movement onset and peak angular speed at the pelvis, upper torso and hand segments in the golf swing. The same temporal structure was evident at all test conditions, among different gender and level of expertise. Further, results revealed a summation effect of angular velocity from proximal-to-distal, with each succeeding segment generating a larger rotational speed than the proximal segment. However, the increment in speed from proximal-to-distal was different among gender and level of expertise.

Conclusions

The temporal relation of segment kinematics suggests a common PDS organization in partial and full-swing shots for skilled golfers. A speed-summation effect of segmental angular speed indicates that participants did utilize interaction torques in a proximal-to-distal manner. The role of the observed PDS organization and speed-summation effect in partial shots might be to improve accuracy and, potentially, golfers should concentrate on speed initially in learning the golf swing.

CONTENTS

1 Introduction

Each shot in golf has two requirements − distance and direction. The speed of the club head centre immediately before ball contact is one of the main determinants of ball speed, and ultimately shot distance. Attempts to understand how this speed is generated can be divided into two major approaches. Double and triple pendulum planar models of the golf swing have been used to describe the kinematic and kinetic characteristics of the upper limb that result in a large clubhead speed at ball contact.[1,2,3,4,5] More recently, the focus of several studies has been the transverse plane rotations of the pelvis and upper torso and their relationship with performance.[6,7,8,9] Aspects of a proximal-to-distal sequencing (PDS) pattern has been observed in these studies as in most throwing and striking skills whose goals are to maximize speed in the most distal segment of an open-link system.[10]

Typical for the kinematics of a PDS pattern is that proximal segments initiate rotation before the distal segments, and that proximal segments begin to slow down before the distal segments have reached peak angular velocity.[11] An immediate mechanical reward for this strategy is that proximal muscle torques creates a dynamic foundation for the entire limb motion and beneficial interaction torques for distal joint rotations.[12,13] What is important for

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[1] A.J. Cochran, J.Stobbs, *The Search for the Perfect Swing* (Philadelphia: J.B. Lippincott Co., 1968), pp. 8-147.

[2] D.R. Budney, D.G. Bellow, "On the swing mechanics of a set of matched golf clubs", *Research Quarterly for Exercise and Sport*, 53 (1982), pp.185-192.

[3] P.D. Milburn, "Summation of segmental velocities in the golf swing", *Medicine and Science in Sports and Exercise*, 14 (1982), pp. 60-64.

[4] E.J. Sprigings, R.J. Neal, "An insight into the importance of wrist torque in driving the golf ball: A simulation study", *J. App. Biomechanics*, 16 (2000), pp. 356-366.

[5] Rod White, "On the efficiency of the golf swing", *American Journal of Physics*, 74 (2006), pp. 1088-1094.

[6] M. McTeigue, S.R. Lamb, R. Mottram, F. Pirozzolo, "Spine and hip motion analysis during the golf swing", in *Proceedings of the 1994 World Scientific Congress of Golf*; 1994 Jul 4-8; St Andrews, ed. A.J. Cochran, M.R. Farally, (London: E & FN Spon, 1994), pp. 50-58.

[7] A.M. Burden, P.N. Grimshaw, E.S. Wallace, "Hip and shoulder rotations during the golf swing of sub 10-handicap golfers", *Journal of Sports Sciences*, 16 (1998), pp. 165-176.

[8] P.J. Cheetham, P.E. Martin, R.E. Mottram, B.F. St Laurent, "The importance of stretching the "X-Factor" in the downswing of golf: The "X-Factor Stretch"", in *Optimizing performance in golf*, ed. P.R. Thomas, (Brisbane, Australia: Australian Academic Press, 2001), pp. 192-199.

[9] C.I. Egret, O. Vincent, J. Weber, F.H. Dujardin, D. Chollet, "Analysis of 3D kinematics concerning three different clubs in golf swing", *International Journal of Sports Medicine*, 24 (2003), pp. 465-469.

[10] C.A. Putnam, "Sequential motions of body segments in striking and throwing skills: Descriptions and explanations", *Journal of Biomechanics*, 26 (1993), pp. 125-135.

[11] R.M Enoka, *Neuromechanics of Human Movement,* (Champaign, IL, USA: Human Kinetics, 2002), p. 204f.

[12] M. Hirashima, K. Kudo, T. Ohtsuki, "Utilization and Compensation of Interaction Torques During Ball-Throwing Movements", *Journal of Neurophysiology*, 27 (2002), pp. 1784-1796.

[13] Putnam, pp. 125-135.

maximizing speed is that utilization of the interaction torque enables larger joint angular velocity than the muscle torque can produce on its own. For a well-organized PDS motion, increments or carry-over effects of rotational velocity from the proximal to distal segments could be maximized.[14]

Accomplished golf performance requires not only high ball speed but also accuracy. Skilled golf players are able to alter their swings to hit the ball accurately to different submaximal distances with the same club. In other motor skills it has been proposed that motions of different speeds are planned based upon keeping some features invariant in order to reduce storage and computational costs in the central nervous system (CNS). One widely acclaimed invariant feature of movement is relative timing. Abernathy et al.[15] examined temporal aspects of swing kinematics in maximal and submaximal shots, but no evidence was found to suggest that subjects maintained the relative duration of subphases invariant across changes in total swing duration. The speed-invariant strategy,[16] in which joint rotations of different speeds have the same joint angles and amplitudes but are scaled in time, has been observed in relatively slow two-joint planar movements. Considering that skilled golf players previously have been found to increase the range of joint motions to hit the ball further,[17] appearance of the speed-invariant strategy in a well-coordinated golf swing is not likely.

Although PDS primarily is associated with mechanical rewards when the speed requirement is high, this temporal order has also been found in relatively slow (peak velocity of the hand 0.3–0.8 m·s^{-1}) multi-joint movements of skilled individuals.[18] It has recently been implicated that PDS can improve accuracy in multi-joint movements of different speeds. Hirashima[19] et al. demonstrated that skilled ball-throwers increase ball speed by increasing beneficial

[14] Putnam, pp. 125-135.

[15] B. Abernathy, R.J. Neal, M.J. Moran, A.W. Parker, "The influence of club length and shot distance on the temporal characteristics of the swings of expert and novice golfers", in Science and Golf: Proceedings of the First World Scientific Congress of Golf; 1990 Jul 9-13; St Andrews, ed. A.J. Cochran, M.R. Farally, (London: E & FN Spon, 1990), pp. 36-42.

[16] J.M. Hollerbach, T. Flash, "Dynamic interactions between limb segments during planar arm movement", *Biological Cybernetics*, 44 (1982), pp. 67-77.

[17] Abernathy et al., pp. 36-42.

[18] S. Furuya, H. Kinoshita, "Roles of proximal-to-distal sequential organization of the upper limb segments in striking the keys by expert pianists", *Neuroscience Letters*, 421 (2007), pp. 264-269.

[19] M. Hirashima, K. Kudo, K. Watarai, and T. Ohtsuki, "Control of 3D limb dynamics in unconstrained overarm throws of different speeds performed by skilled baseball players", *Journal of Neurophysiology*, 32 (2007), pp. 680-691.

interaction torques at the shoulder, elbow and wrist. This was done by regulating muscle torque at the shoulder and trunk but not at the elbow and wrist. It was concluded that this strategy can be helpful to minimize the consequences of signal-dependent noise in motor command (for review, see Faisal et al. 2008[20]).

Proximal-to-distal sequencing may be important for meeting the mutual requirements of speed and accuracy in golf. However, no research to date have demonstrated whether PDS is a common characteristic in partial and full-swing shots of skilled golf players. The purposes of the present study were, therefore, to determine if the golf swing performed by skilled golfers was organized in a PDS pattern when hitting golf shots to maximal and submaximal distances, and to examine the speed-summation effect (in terms of increment of the peak segmental angular velocity) at pelvis, upper torso and hand segments.

2 Methods

2.1 Participants

Eleven male tournament professionals [height 1.82 ± 0.04 (mean $\pm$ 1SD) m; body mass 83 ± 6 kg; age 28 ± 5 years], 23 male amateurs [height 1.81 ± 0.05 m; body mass 74 ± 10 kg; age 17 ± 1 years; handicap 0 ± 2 strokes], and 13 female amateurs [height 1.68 ± 0.07 m; body mass 59 ± 9 kg; age 16 ± 1 years; handicap -2 ± 2 strokes] volunteered to take part in the study. Written informed consent was obtained from parents or guardians of the participants in case of underage, otherwise from the participants themselves.

2.2 Measurement device and experimental set-up

Three-dimensional data were collected using a Polhemus Liberty electromagnetic tracking system (Polhemus Inc., Colchester, VT, USA), sampling at 240 Hz. A transmitter, which contains three orthogonal coils (solenoids), generates three different electromagnetic fields in the region of 1–4000×10^{-9} T. Sensors, which also contain three orthogonal coils, record

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[20] A.A. Faisal, L.P. Selen, D.M. Wolpert, "Noise in the nervous systems", *Nature Reviews. Neuroscience*, 9 (2008), pp. 292-303.

magnetic flux in the three different fields. Magnetic flux generates proportional currents used to calculate a vector signifying the direction and strength of the magnetic field at the site of the sensor. Dedicated software computes the position and orientation of tracking sensors. According to the manufacturer, the static accuracy is 0.076 mm RMS for sensor position and 0.15° RMS for sensor orientation. In a pilot study, the dynamic accuracy was compared to an optical (infrared) 3D motion analysis system (8-camera ProReflex MCU1000 System, Qualisys AB, GBG, Sweden). In full-swing shots using a five iron, the Bland-Altman[21] mean difference for hand angular speed was -24.0 degrees per second (limits of agreement: -174.7, 126.7). The magnitude of the difference between the systems was variable with changing angular speed, and exceeded the negative limit of agreement for 8 out of 321 positions sampled. At minimum and maximum mean angular speeds the magnitude of the difference between the systems was -4.0 and -17.9 degrees per second respectively.

The orientation of the right-handed orthogonal global frame (G) was such that the positive X-axis pointed parallel to the direction of the target line, the positive Z-axis pointed vertically upwards, and the positive Y-axis pointed forward from the right-handed golfer. The performance area was a synthetic golf mat positioned right next to the transmitter (see Fig. 1). The experimental setup yielded a measurement space where the distance from transmitter to sensors ranged from 0.164 m to 1.41 m during recordings.
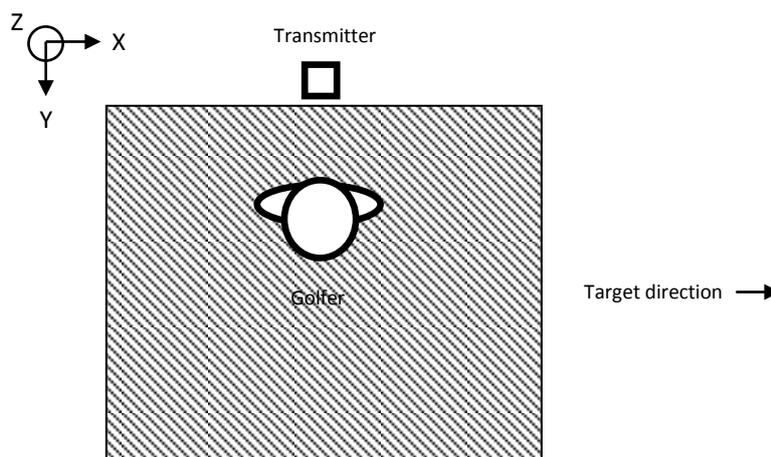

Fig. View of experimental setup from above, with the global frame superimposed in the upper left corner.

[21] J.M. Bland, D.G. Altman, "Statistical methods for assessing agreement between two methods of clinical measurement", *Lancet,* 335 (1986), pp. 307-310.

2.3 Data collection

Participants performed a warm-up session of their choice, which also served as a habituation period. Generally, the warm-up lasted approximately 10 min and involved hitting golf balls. Next to the habituation period, three sensors were attached to each participant at the following locations: (1) the lumbo-sacral joint (pelvis); (2) between the shoulders at the level of the third thoracic vertebra (upper torso); and (3) the dorsal part of the leading hand (hand). The pelvic and upper torso sensors were mounted on a harness and the hand sensor was secured with a golf glove.

Following the collection of a static trial, in which the participants were required to stand in the anatomical position (parallel to the target line), spatiotemporal data were collected of the participants' swings as they performed three trials under each of five different test conditions. These test conditions consisted of hitting a wedge to targets at three discrete distances (40, 55 and 70 m) in addition to full-swing shots with a five iron and a driver in the same direction for maximal distance. The order of test conditions for the wedge was assigned such that participants had to hit the ball progressively further for each shot. This procedure was repeated three times, thus they did not aim for the same target twice in a row except when the ball finished closer to another target (target zone radius = 7.5 m). Such a trial was discarded and followed by a new trial to the same target. Finally, three consecutive full-swing shots were performed using a five iron and driver respectively in the same direction as for the wedge trials.

Participants were allowed to use their own clubs during data collection. Type of wedge was chosen individually and governed by the criteria that it should be the most lofted club the participant repeatedly hit further than 70 meters with a full-swing shot. Data collection took place at four different practise facilities, where submaximal targets consisted of plastic cones or target flags placed at the set distances from the performance area.

2.4 Kinematic analysis

The raw data were smoothed using a second-order, bidirectional, low-pass Butterworth filter with a cutoff frequency set at 14 Hz, determined through residual analysis.[22] To analyze the motions of the pelvis, upper torso and hand respectively, a local frame was attached to each segment. The directions of the three axes of each frame were assigned so as to approximate the different anatomical axes of rotation for each segment. This was accomplished by determining rotation matrices for the static alignment trial, in which the segment axes were aligned with the global frame. These rotation matrices were then applied for each sampling interval in the movement trials.

In order to examine the sequencing pattern and the angular speed of segment motions in this study, the magnitude of the angular velocity vector of each segment was computed (hereafter defined as angular speed). The angular velocity vector was determined by calculating the finite difference (i.e. central difference method) of the rotation matrix.[23] Segment angular speeds for each participant and shot condition were represented by the mean of three successfully performed trials. All kinematic and temporal parameters were calculated using Visual3D v.3.90 Beta and v.3.99 (C-Motion, Inc., Rockville, MD, USA).

2.5 Phase and event definitions

The swing was divided into two phases defined by three events (see Fig. 2). The address position was defined as the instant just before the initial movement of the club away from the target. The top of the backswing was determined once the first segment reached minimum angular speed between address and impact. The backswing was defined as the period between the start of the backswing and top of the backswing, the downswing as the period between the top of the backswing and the instant that the left hand returned to its address position (impact). Representative angular velocity curves of the pelvis, upper torso, and hand during

[22] D.A Winter, *Biomechanics and Motor Control of Human Movement* (New York: John Wiley & Sons, 2005), pp. 49-50.
[23] G.L. Kinzel, A.S. Hall, Jr. and B.M. Hillberry, "Measurement of the total motion between two body segments–I. Analytical development." *Journal of Biomechanics*, 1 (1972), pp. 93-105.

the entire period of the golf swing at the shortest and longest shot distance are shown in Figure 3.
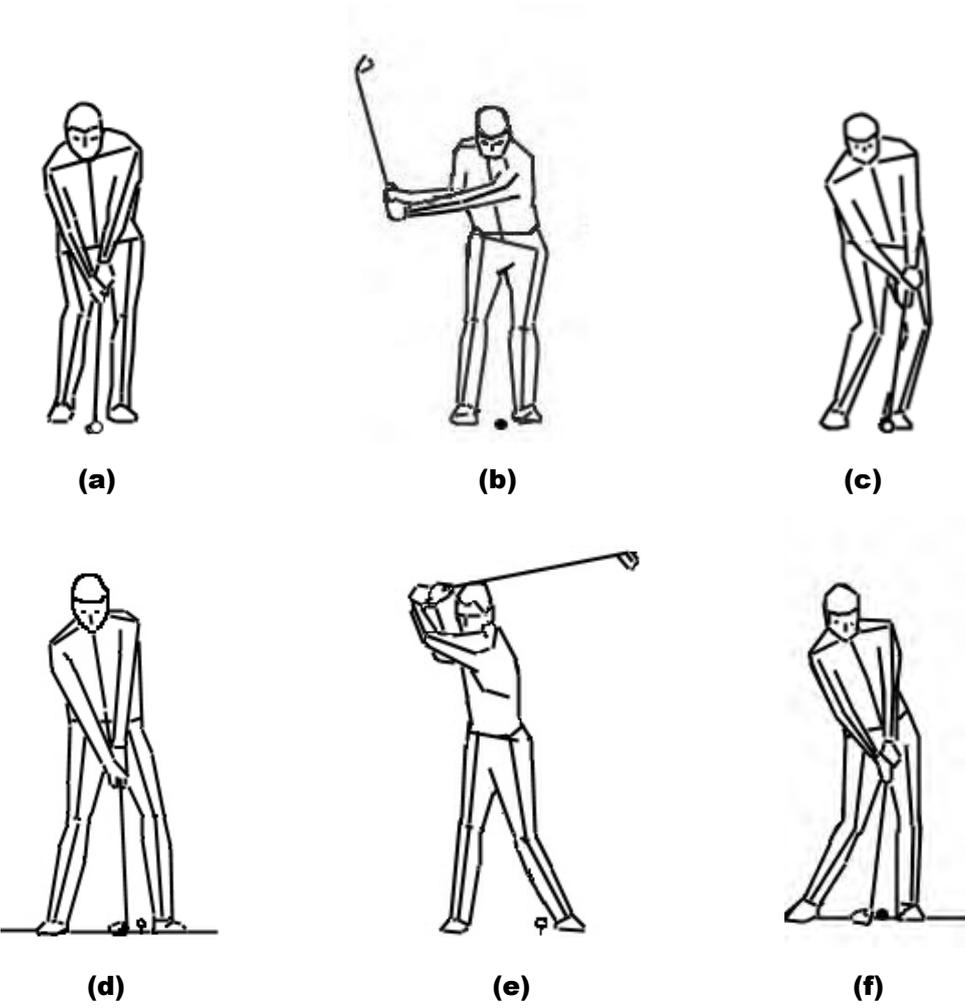

Fig. 2 Address, top of backswing and impact events, for a partial shot (a-c) and a full-swing shot (d-f) respectively.
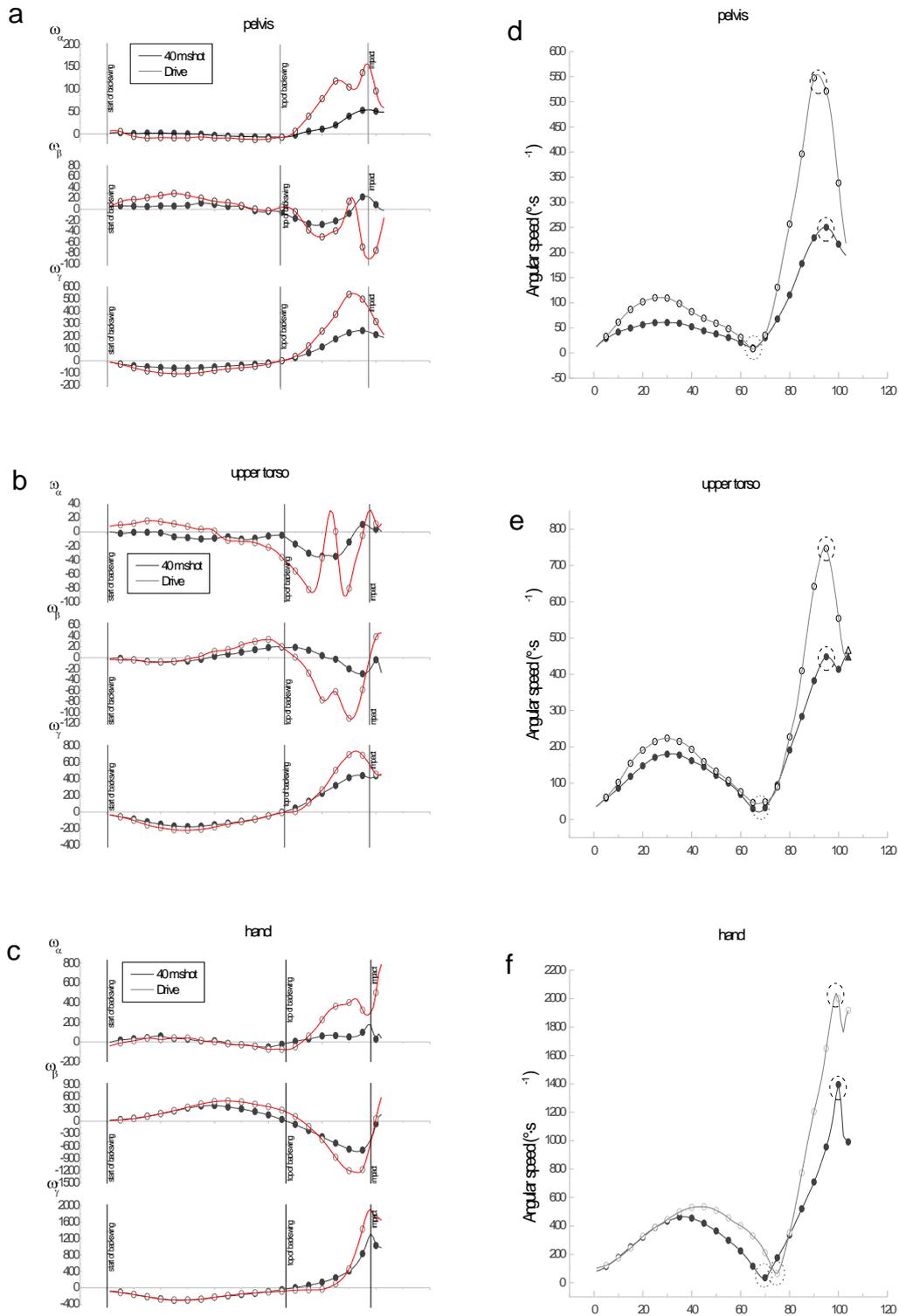
Fig. 3 The normalized time-history curves for pelvis, upper torso, and hand segment angular velocities (°·s⁻¹) (ω_α denotes local frame angular velocity for the bilateral axis, ω_β for the antereo-posterior axis, and ω_γ for the axial axis) in one representative participant when hitting shots to 40 m (filled circles) and with driver (open circles) (a-c). The circles in the corresponding normalized time-history curves for angular speed (d-f) indicates minimum angular speed (dotted circles) and maximum angular speed (dashed circles).

2.6 Statistical analysis

Statistics were calculated using SPSS 15.0 (SPSS, Inc., Chicago, IL., USA). Shapiro Wilk´s W test was applied to test normality in the distribution of data. The individual measures in this study were analyzed in separate repeated-measure ANOVAs with group as between-subjects factor, and test condition and body segment as within-subjects factors. Pre-planned pairwise comparisons were Bonferroni corrected. If data did not conform to the assumption of sphericity P-values were Greenhouse-Geisser adjusted. Significance level was set at $P < 0.05$.

3 Results

3.1 Temporal characteristics

At first, it was examined whether participants were starting the downswing in a proximal-to-distal order. Repeated-measures ANOVA revealed a main effect of segment on time for minimum angular speed [$F_{(2, 84)} = 12.86$, $P < 0.001$, Greenhouse-Geisser adjusted]. There was no interaction between segment and test condition [$F_{(8, 336)} = 0.613$, $P = 0.649$, Greenhouse-Geisser adjusted] or between segment, test condition and group [$F_{(16, 672)} = 0.984$, $P = 0.449$, Greenhouse-Geisser adjusted]. Pre-planned comparisons indicated significantly smaller occurrence times for minimum angular speed at pelvis than at upper torso or at the leading hand ($P < 0.05$). Thus, participants moved pelvis into the downswing before upper torso and hands.

The same analysis was also performed to assess the order in time by which segments attain maximum angular speed. Repeated-measures ANOVA revealed a main effect of segment [$F_{(2, 84)} = 202$, $P < 0.001$, Greenhouse-Geisser adjusted], and test condition [$F_{(4, 168)} = 11.11$, $P < 0.001$, Greenhouse-Geisser adjusted] on time for maximum angular speed. There was an interaction between segment and test condition [$F_{(8, 336)} = 15.12$, $P < 0.001$, Greenhouse-Geisser adjusted] but no interaction between segment, test condition and group [$F_{(16, 672)} = 0.849$, $P = 0.550$, Greenhouse-Geisser adjusted]. Further analysis revealed a temporal order for the moment of maximum angular speed from proximal-to-distal at all test conditions (Fig. 4).
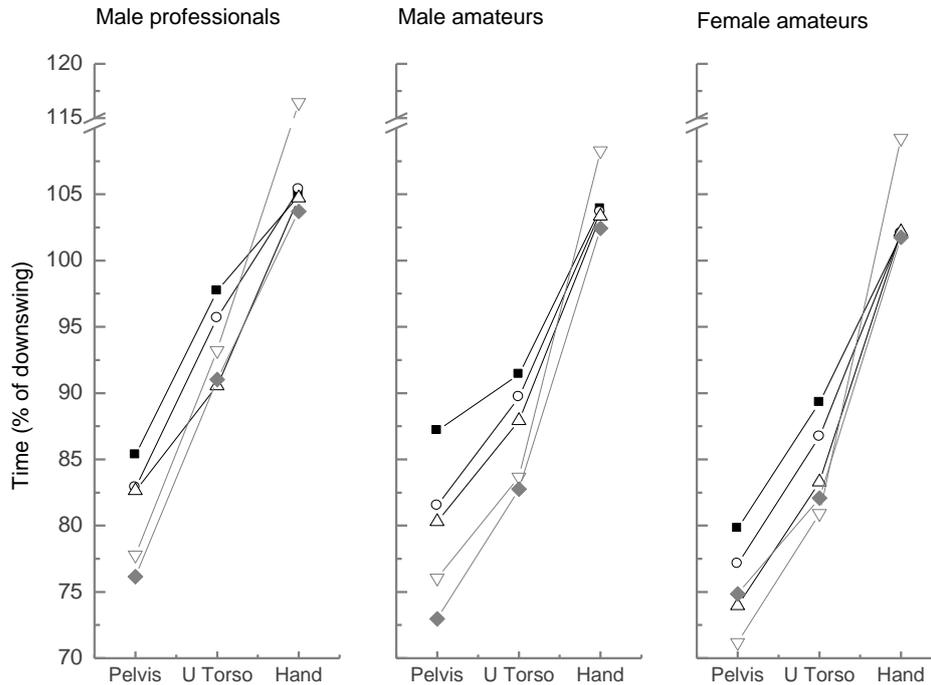
Fig. 4 The mean values of the occurrence times for maximum segment angular speed at 40m (filled squares), 55m (open circles), 70m (open triangles), with five iron (open downward triangles) and driver (filled diamonds) for each of the male professional, male amateur and female amateur groups (in percent of downswing duration).

3.2 Maximum angular speeds

There was a main effect of segment [$F_{(3, 126)} = 3310$, $P < 0.001$, Greenhouse-Geisser adjusted], and test condition [$F_{(4, 168)} = 838$, $P < 0.001$, Greenhouse-Geisser adjusted] on maximum angular speed. In addition, there was an interaction between segment and test condition [$F_{(12, 504)} = 185.1$, $P < 0.001$, Greenhouse-Geisser adjusted], and among segment, test condition and group [$F_{(24, 1008)} = 3.56$, $P = 0.010$, Greenhouse-Geisser adjusted]. Pre-planned comparisons indicated a significant increase in maximum angular speed from proximal-to-distal for all test conditions. In addition, maximum angular speed for all three segments amplified with the shot distance in partial shots. Further, magnitudes were larger for full shots compared to partial shots and increased from 5 iron to driver with the exception of hand angular speed magnitude (Fig. 5).
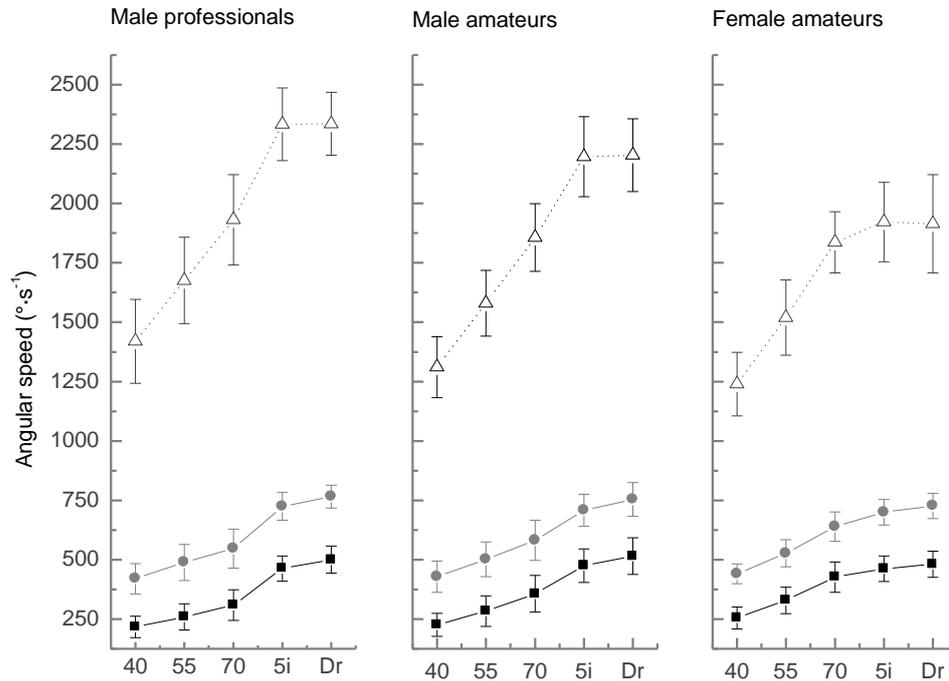
Fig. 5 Mean values and 1 SD for maximum segment angular speed ($°·s^{-1}$) in the downswing at pelvis (filled squares), upper torso (filled circles), and hand (open triangles) segments for each of the male professional, male amateur and female amateur groups.

To examine the speed-summation effect, increment of the maximum segment angular speed from the pelvis to upper torso and from the upper torso to hand were calculated. Repeated-measures ANOVA revealed a main effect of segment [$F_{(1, 42)} = 1739$, $P < 0.001$, Greenhouse-Geisser adjusted], and test condition [$F_{(4, 168)} = 243$, $P < 0.001$, Greenhouse-Geisser adjusted] on increments of maximum angular speed. There was an interaction between segment and test condition [$F_{(4, 168)} = 152.2$, $P < 0.001$, Greenhouse-Geisser adjusted] and between segment, test condition and group [$F_{(8, 336)} = 4.66$, $P = 0.005$, Greenhouse-Geisser adjusted]. Further analysis revealed that the increments of the maximum angular velocity from the upper torso to hand were significantly larger for male professionals than for female amateurs at all shot conditions and significantly larger for male amateurs than for female amateurs at full-swing shots (Fig. 6).
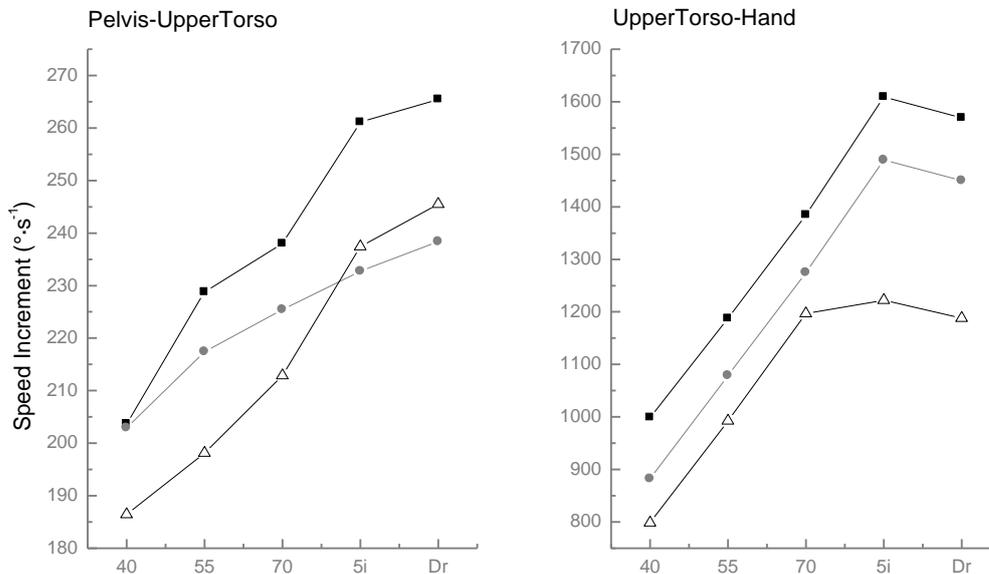
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Fig. 6 The mean increment of maximum segment angular speed in the downswing from the pelvis to upper torso (left) at all shot conditions, and from the upper torso to hand (right) for each of the male professional (filled squares), male amateur (filled circles) and female amateur groups (open triangles).

4 Discussion

This study showed a clear proximal-to-distal temporal relationship of movement onset and maximum angular speed at the pelvis, upper torso and hand segments in the golf swing. The same temporal structure was evident at all test conditions, among different gender and level of expertise. Further, results revealed a summation effect of angular velocity from proximal-to-distal, with each succeeding segment generating a larger rotational speed than the proximal segment. However, the increment in speed from proximal-to-distal was different among gender and level of expertise.

In this study, steps were taken to limit possible sources of error for the kinematic measurements. To minimize metal interference the capture volume for the EM system was distanced from any structural metals, but due to the participants' golf shafts, steel was used within the field. A pilot study, however, displayed similar results for kinematic data collected using the electromagnetic system setup compared to those of an optoelectronic system lacking the issue of metal interference. Other notable sources of error for both systems in vivo are

sensor (marker) displacement with respect to the underlying bone and inaccurate and inconsistent placement of sensors (markers). To limit inaccurate and inconsistent placement of sensors, the same investigator performed the sensor attachment procedures for all participants. To minimize displacement with respect to the underlying bone, sensors were placed at sites where the thickness of underlying tissue was minimal for the participants.

Motion sequences for full-swing shots have previously been investigated in the literature. Studies have either demonstrated that the pelvis segment moves into the downswing ahead of the upper torso, or that the shoulder joint attain maximum angular velocity prior to the wrist joint. Findings based on data where motions of pelvis and upper torso have been estimated by determining transverse plane rotations, whereas motions of the upper limb and golf club have been modeled as a planar movement in a single inclined plane. In the present study, the magnitude of the spatial angular velocity vector for each of three body segments was utilized to examine the sequence of motion. Consistent with previous observations of full-swing shots, results revealed that pelvis moved into the downswing ahead of the upper torso .[24,25,26] The proximal-to-distal order in which upper torso and hand segments reached maximum angular speed has not been reported earlier, but is in line with earlier observations in which the shoulder joint attain maximum angular speed prior to the wrist joint. [27,28] Although the role of PDS cannot be explained by kinematic data alone, the temporal relation between segments with a period where distal segments accelerated while the more proximal was decelerating indicates that participants could utilize interaction torques effectively to generate high club speed.

The current study extends findings from previous studies by adding support for a universal kinematic sequence in partial and full-swing shots of skilled golf players. The temporal parameters tested were not significantly affected by group. Thus, timing did not change significantly with gender or level of expertise among participants. The temporal relationship of movement onset and maximum angular speed at the pelvis, upper torso and hand segments

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[24] McTeigue et al., pp. 50-58.
[25] Burden et al., pp. 165-176.
[26] Cheetham et al., pp. 192-199.
[27] N. Zheng, S.W. Barrentine, G.S. Fleizig, J.R. Andrews, "Kinematic analysis of swing in pro and amateur golfers", *International Journal of Sports Medicine,* 6 (2008), pp. 487-493.
[28] Milburn, pp. 60-64.

showed a clear PDS organization for all shot conditions (Fig. 4). While there exists a solid body of evidence in support for that PDS provides mechanical merits when the largest possible ball speed is required, merits of PDS in partial golf shots are less evident. However, Hamilton et al. reported that a given torque or force can be more accurately generated by a stronger muscle than a weaker muscle.[29] A potential role of PDS, therefore, can be to improve accuracy and minimize the speed-accuracy tradeoff.[30]

A common kinematic characteristic of PDS is a summing effect of segmental speed.[31] Participants' maximum segment angular speeds increased in a PDS pattern for all test conditions (Fig. 5). This is in line with earlier findings in full-swing shots regarding the increase in maximum angular speed from pelvis to upper torso[32] and from upper torso to left wrist and club shaft.[33] However, this summing effect of segmental speed has previously not been reported for partial shots. The significantly larger increments of maximum angular velocity from upper torso to hand for the male players compared to the female amateurs in full-swing shots (Fig. 6) are consistent with results reported by Zheng et al.[34] where the major differences between male and female professionals were significantly lower wrist and elbow joint angular velocity for the females. These results can help explain differences in hand speed and performance factors such as driving distances in full-swing shots. Interestingly though the significantly larger increments of maximum angular velocity from upper torso to hand for the male pros compared to the female amateurs in full-swing shots were also present in partial shots, where participants were required to hit the same distances. This indicates that the observed differences between gender may exist due to disparities in anthropometrics, flexibility and strength characteristics. Another interpretation may be that the different increments of maximum angular velocity from upper torso to hand in partial shots reflect a

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[29] A. Hamilton, K.E. Jones, and D.M. Wolpert, "The scaling of motor noise with muscle strength and motor unit number in humans", *Exp. Brain. Res.*, 157 (2004), pp. 417-430.

[30] P.M. Fitts, "The information capacity of the human motor system in controlling the amplitude of movement", *Journal of Experimental Psychology*, 47 (1954), pp. 381-391.

[31] Putnam, pp. 125-135.

[32] J. Myers, S. Lephart, Y-S. Tsai, T. Sell, J. Smoliga, J. Jolly, "The role of upper torso and pelvis rotation in driving performance during the golf swing", *Journal of Sports Sciences,* 26 (2008), pp. 181-188.

[33] N. Zheng, S.W. Barrentine, G.S. Fleizig, J.R. Andrews, "Kinematic analysis of swing in pro and amateur golfers", *International Journal of Sports Medicine,* 6 (2008), pp. 487-493.

[34] N. Zheng, S.W. Barrentine, G.S. Fleizig, J.R. Andrews, "Swing kinematics for male and female pro golfers", *International Journal of Sports Medicine,* (2008), Epub ahead of print.

difference in level of expertise, where the male pros with long-term training should have developed a more efficient way to produce the preferred performance goal.

An interesting future direction to investigate is how instruction affects segment interaction and ultimately performance. Southard[35] reported that in a task of striking a ball on a tee using the hand, subjects who were instructed to perform the task as fast as possible acquired the PDS organization of segmental motions by the end of five days practice. However, those who emphasized accuracy of the ball placement did not acquire the PDS segmental motion. There were no significant differences in accuracy by conditions or day of practice even though there were significant differences in velocities by condition and practice. In what way initial conditions/instructions influence the progress of segment interactions in golf, has not been reported.

In conclusion, the temporal relation of segment kinematics suggests a common PDS organization in partial and full-swing shots for skilled golfers. The temporal relation and speed-summation effect of segmental angular speed indicates that participants did utilize interaction torques in a proximal-to-distal manner. A role of the observed PDS organization and speed-summation effect in full and partial shots might be to improve accuracy and, potentially, golfers should concentrate on speed initially in learning the golf swing in order to enhance a change in movement organization.

Acknowledgements

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[35] D. Southard, "Changes in limb striking pattern: effects of speed and accuracy", *Research Quarterly for Exercise and Sport*, 60 (1989), pp. 348-356.

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KÄLL- OCH LITTERATURSÖKNING

Frågeställningar: *Här skriver du uppsatsens frågeställningar.*

VAD?

Ämnesord	Synonymer
Golf, biomechanics, kinematics, proximal-to-distal	

VARFÖR?

Ordet golf för att få idrottsspecifika träffar, "biomechanics" och "kinematics" för att finna artiklar som undersöker mekanik och "proximal-to-distal" för att finna artiklar som behandlar just detta temporala mönster.

HUR?

Databas	Söksträng	Antal träffar	Antal relevanta träffar
PubMed	*Golf and biomechanics* *Golf and kinematics* *Proximal-to-distal*	*86* *82* *745*	*5* *4* *1*

KOMMENTARER:

Utöver ovanstående sökningar har manuella sökningar gjorts i referenslistor och i Science and Golf I-IV. I PubMed har även funktionen "related articles" använts vid relevanta träffar.