THE 3D KINEMATIC ANALYSIS OF THE GOLF SWING ON UP AND DOWN SLOPES

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In order to analyze the 3D golf swing on different slopes in the course, six golfers of handicap under 7 swung on a adjustable tilt golf platform in up & down slopes situations. Their center of gravity displacement, joint angle velocity and club head speed in each swing phase were measured and analyzed. The intent of this kinematical measurement was to provide parameters for beginners who can swing on the slope ground in court and the measurements in this research found two main results as followed. One was the sequence of lower body lead upper body to swing which is the same trend as in the flat ground, and the other was more hip joint rotational movement and more club head speed could be obtained at follow through phase.

KEY WORDS: golf, swing, kinematics

INTRODUCTION: Many golf reports had found the sequential movement during down swing and the correlation factors concerned with the club head speed on a flat ground but no study has been proceeded on different slopes. Result of the sequential movement on flat ground was lower body lead upper body to whip and hit which had been tested by EMG (Jobe et al., 1993, 1995), by force plate (Richard. et al., 1985), by photo images (Linning, 1994) and by grip pressure (Budney, 1979). Correlation factors concerned with the club head speed was found as followed. The obvious torque force on foot could cause the speed of club head faster (Richard. et al., 1985) and the sequence of lower body lead upper body to whip could increase the club head speed (Wang. et al., 2001). Even so, the skill between golf swing on flat and slopes might be different. And it was need for us to test on different slopes to provide parameters for golf beginners.

METHODS: Before test, each of 6 golfers whose handicap under 7 stood on an adjustable golf tilt platform (Figure 2) to do full swing practice, and 7° slope was the largest tilt slope that they could do full swing. In the test, they swung with 7 iron on 7° up and down slopes for at least 3 balls landing in a circle of 5m radius in a 150 yards flag. During test, subjects wore short pants, tighten shirt and markers were attached on joints (ankles, knees, hips, shoulders, elbows and wrists) as to measure joints position, joints angular velocity and club head speed. And Medilogic Pressure Insole was to collect the displacement of center of gravity (Figure1). The absolute coordinate system was defined as left to right directions of X axis, posterior to anterior direction of Y axis and Inferior to superior of Z axis.

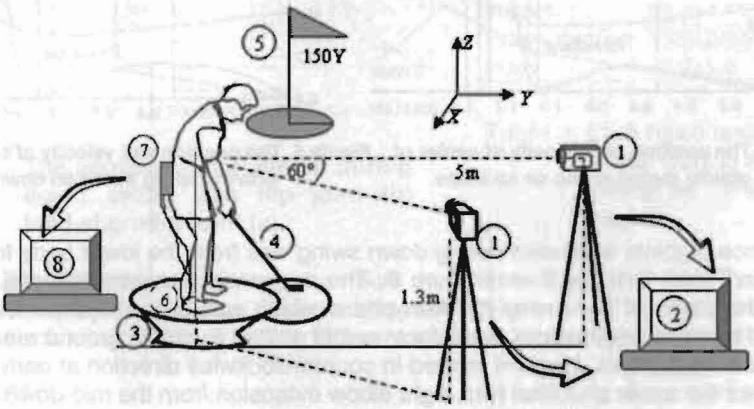

Figure 1 1) 2 set of SONY digital videos (1/240sec) was fixed between 60° corner, 1.3m vertical height and 5m horizontal distance. 2) SIMI Motion analysis software system which analyzed the displacement of segments and 3) An adjustable golf tile platform. 4)

7 iron. 5) 150 Yards target flag with 5m radius circle. 6) Medilogic Pressure Insole. 7) Wireless emitter. 8) Medilogic 2.19 of pressure analysis software system.

Figure 2 An adjustable golf tilt platform, changeable in 3D horizontal degrees and directions as different slopes, invented by Shiang, T.Y (2003).

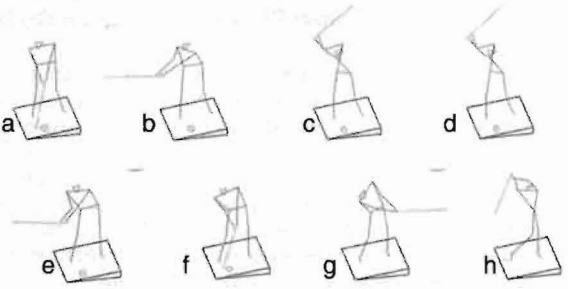

Figure 3 Phases during golf full swing were (a) aim-stance, (b) mid-upswing, (c) top swing, (d) early down swing, (e) mid-down swing, (f) impact, (g) follow through and (h) finish.

RESULTS AND DISCUSSION: Results of displacement of center of gravity were shown in Figure 4 & 5. The average displacement was small in X and Y axis on both up and down slope swing which indicated that the trunk rotation keep steady to hit the ball. No matter how the position of center of gravity changed in vertical direction (Z axis), the position at hit phase was similar to the position in aim-stance phase to hit the ball. The displacement of center of gravity increased twice as to form velocity curve in two peaks and the bottom was around the top swing phase. From the bottom of velocity curve to the second peak was just 0.3 sec and the peak of velocity curve was occurred just before or after the hit phase, it showed that the speed of center of gravity moved faster before hit the ball.

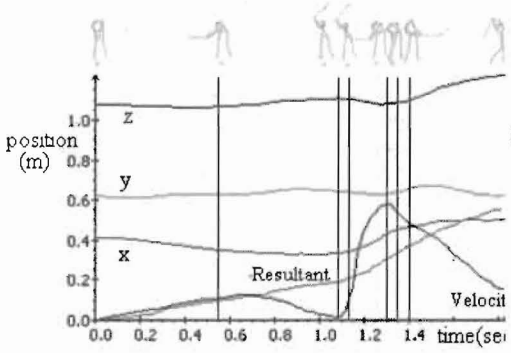

Figure 4 The position and velocity of center of gravity during swing on up slope.

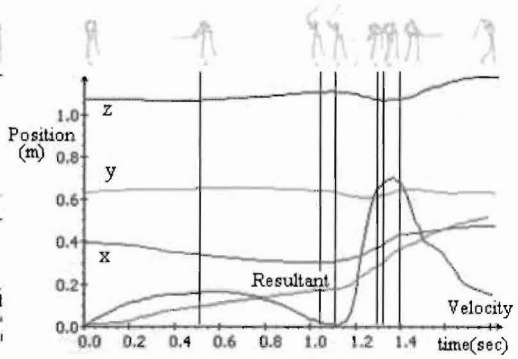

Figure 5 The position and velocity of center of gravity during swing on down slope.

The sequence of joints extension during down swing was from the lower body to upper body as shown in Table 1, Table 2 and Tigure 6. The sequential movement during down swing was from the stage of top swing to finish phase which was proceeded as followed. Right knee flexed to move body weight to left foot, weight shifted to obtain ground reaction force to cause left knee extension, hip joint rotated in counterclockwise direction at early down swing phase to lead the upper shoulder joint, right elbow extension from the mid-down swing phase and left elbow maintained extension until final finish phase.

Club head speed (m/s) was almost the same when subjects swung on different slopes except for the speed at follow through phase (Table 3). Reviewing Table 1 and 2, it might be

the different hip joints pivot degree (-72 & -74) to cause the different club head speed at follow through phase.

Table 1 The joint angles when subjects swing on up slope.

phases	R. Knee(θ)	L.Knee(θ)	Hip pivot(θ)	Shoulder pivot(θ)	R.Elbow (θ)	L.Elbow (θ)
Aim-stance	160.9 ± 6.1	140.4 ± 10.3	0	0	166.4 ± 6.7	166.7 ± 4.3
Mid-upswing	153.9 ± 7.3	134.2 ± 10.2	11.6 ± 4.9	37.5 ± 10.2	144.8 ± 9.4	170.8 ± 2.8
Top-swing	152.1 ± 7.0	129.1 ± 6.8	36.3 ± 13.9	95.9 ± 13.2	90.2 ± 14.2	151.2 ± 8.4
Early down swing	150.6 ± 6.4	130.3 ± 5.5	22.9 ± 3.7	85.3 ± 7.9	88.1 ± 17.2	151.1 ± 6.7
Mid-down swing	146.9 ± 3.8	143.7 ± 5.7	-6.4 ± 1.8	23.4 ± 15.8	125.3 ± 8.8	163.2 ± 6.8
Impact	145.2 ± 5.9	146.6 ± 6.8	-14.8 ± 3.2	-2.9 ± 6.4	143.9 ± 5.3	164.5 ± 4.6
Follow through	143.5 ± 7.9	149.6 ± 7.1	-28.0 ± 6.1	-41.4 ± 9.6	161.2 ± 3.2	158.5 ± 2.5
finish	139.4 ± 8.0	156.9 ± 10.6	-72.9 ± 15.5	-132.1 ± 5.8	154.0 ± 15.2	98.9 ± 23.1

Table 2 The joint angles when subjects swing on down slope.

phases	R. Knee(θ)	L.Knee(θ)	Hip pivot(θ)	Shoulder pivot(θ)	R.Elbow (θ)	L.Elbow (θ)
Aim-stance	150.2 ± 6.9	149.3 ± 3.0	0	0	159.1 ± 8.0	165.9 ± 7.1
Mid-upswing	154.8 ± 11.6	148.8 ± 5.4	11.1 ± 5.3	32.9 ± 4.9	144.6 ± 7.1	170.6 ± 2.5
Top-swing	155.1 ± 11.1	138.5 ± 8.2	32.0 ± 5.3	92.0 ± 12.4	84.7 ± 5.6	155.2 ± 4.9
Early down swing	152.4 ± 9.5	136.8 ± 7.2	22.3 ± 8.5	87.4 ± 11.3	84.9 ± 7.6	156.2 ± 6.9
Mid-down swing	134.1 ± 4.1	145.2 ± 9.2	-4.3 ± 4.1	14.3 ± 9.0	126.4 ± 11.6	163.2 ± 4.9
Impact	131.1 ± 3.8	148.7 ± 9.3	-16.0 ± 8.9	-7.5 ± 10.1	143.5 ± 3.7	163.1 ± 4.0
Follow through	127.0 ± 3.4	152.2 ± 5.8	-32.6 ± 10.6	-44.2 ± 5.2	165.3 ± 3.7	160.4 ± 4.0
finish	119.6 ± 8.1	160.8 ± 6.9	-74.5 ± 18.4	-143.3 ± 15.5	123.7 ± 28.6	87.9 ± 32.8

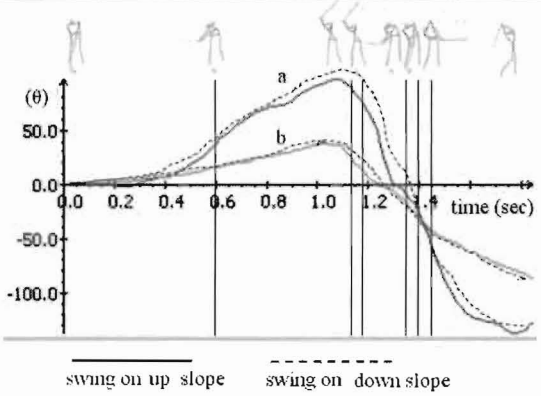

Figure 6 The sequential movement during down swing was hip joint (b) lead shoulder joint (a).

Club-head speed (m/s)		
Phases	up slope	down slope
Aim-stance	0	0
Mid-upswing	5.8±1.5	5.4±1.4
Top-upswing	2.4±1.1	2.3±1.3
Early down swing	3.1±0.6	3.0±0.7
Mid-down swing	20.7±1.4	21.8±1.6
Impact	22.4±1.1	22.5±0.8
Follow through	19.3±2.1	19.8±1.9
finish	2.2±1.9	1.6±1.1

Table 3 Club head speed in each phase during subjects swung on up and down slopes.

CONCLUSION: The kinematical measurement in this study found that the sequential movement when players swing on different slopes has similar trend on flat ground. Golfers should keep trunk rotation steady on any different slopes to accurately hit the ball.

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