3D KINEMATIC ANALYSIS OF THE THREE MAIN STROKES IN PADDLE TENNIS MOTOR PATTERNS

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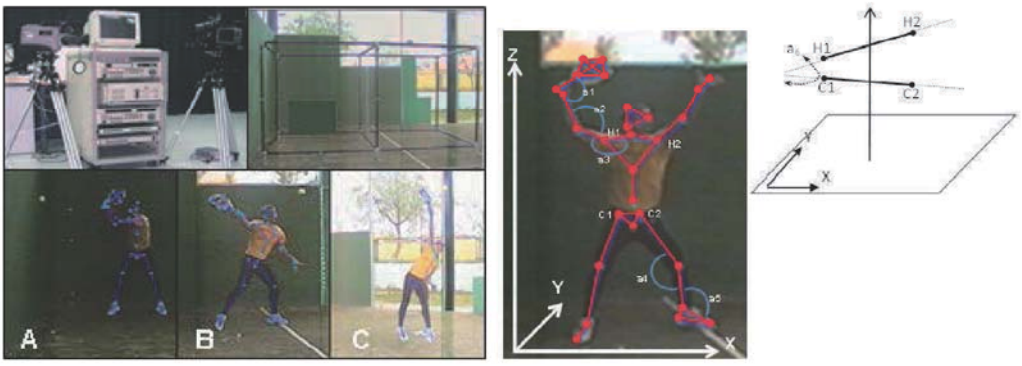
Paddle tennis coaches are lacking of scientific support in order to devise the most effective individual training program of stroke technique. Therefore, 3D kinematics and the temporal structure of the movements of three paddle tennis strokes have been analysed. Specifically, they have been calculated spatial-temporal variables of two successful trials of three main strokes (Tray-smash, Hook-smash and Exit-wall drive) performed by a world class player.

KEY WORDS: Biomechanics, 3D Kinematics, Sport Technique, Paddle Tennis.

INTRODUCTION: It is well known that during the last decades many studies were driven focused on the biomechanics of tennis technique (Elliot & Reid, 2002; Bahamonde, 2002). However, up to now, there is lack of relevant scientific information concerning kinematics and dynamic of paddle tennis, despite of its evolution and potential development. Besides, there is an augmented demand from coaches and athletes to know the biomechanical characteristics of the stroke technique in paddle tennis. In this sense, the purpose of the present study was to evaluate the individual technique of an elite world class player (world champion of open category in 2008) in the three main strokes of paddle tennis by characterizing the spatiotemporal and temporal variables.

METHODS: Two S-VHS video-cameras (Panasonic AG-DP800H, AG-DP200E) were used to record at sampling rate of 50 Hz the player during two executions of the three main strokes: A) an exit-wall drive, B) a tray-smash, and C) a hook-smash (Fig. 1). The recorded videos were processed by the Kinescan/IBV 3D video photogrammetry system and the 3D coordinates of the markers were calculated using DLT. The mechanical model is defined by 25 markers namely vertex, nose, occipital, 7th cervical, xiphoid, left and right joint centers: glenohumeral, elbow, wrist, hip, knee, ankle, and left and right: 3rd metacarpal, heel, tip-of-foot, plus 5 markers on the racket (Fig. 1). Data "smoothing" and interpolation was carried out with Quintic Splines according to the "True Predicted Mean-squared Error" criterion. In this sense, a standardized errors analysis process took place calculating the "splines" parameters of the 3D coordinates of the markers (variance of 3D coordinates). Namely, the mentioned calculated



a1: angle of racket - a2: angle of elbow. a3: angle of shoulder - a4: angle of knee - a5: angle of ankle - a6: projected angle of the shoulder and hips axes - a7: angle of hip.

Figure 1: Experimental set up and model (strokes: A = exit-wall, B = tray-smash, C = hook-smash).

variance was better than 0.009 m. Finally, all spatiotemporal variables were calculated. The definition of the phases and sub-phases of every stroke was done as follows:

I. Preparation phase, which is defined between the instant of first support of the left foot (t_{a1i}) and the instant of second support of the left foot (t_{a2i}):
   a. *Sub-phase A*: Support of the left foot (t_{a1i}) - Take off the right foot (t_{dd})
   b. *Sub-phase B*: Take off the right foot (t_{dd}) - Support of the right foot (t_{ad})
   c. *Sub-phase C*: Support of the right foot (t_{ad}) - Take off the left foot (t_{di})
   d. *Sub-phase D*: Take off the left foot (t_{di}) – Second support of the left foot (t_{a2i})

II. Stroke phase, which is defined between the instant of the second support of the left foot (t_{a2i}) and the stroke instant (t_i).
   e. *Sub-phase E*: Support of the left foot (t_{a2i}) - Take off the right foot (t_{d2d})
   f. *Sub-phase F*: Take off the right foot (t_{d2d}) - Take off the left foot (t_{d2i}) (only in hook-smash)
   g. *Sub-phase G*: Take off the right foot (t_{d2d}) or (t_{d2i}) – stroke (t_i)

III. Follow-through phase, which is defined between the stroke instant (t_i) and the finish of the movement.

Thus, during the *preparation-phase* four sub-phases have been established and during the *stroke-phase* three ones.

RESULTS: Data allowed for obtaining the temporal structure of sport technique (Table 1). Furthermore, in every characteristic instant of the stroke phase, the angles of the main joints and of the racket and the joint angular velocities have been calculated (Fig. 2; Tables 2 and 3).

Table 1: Duration time (ms) of the phases and sub-phases of the three strokes expressed also as percentage of its respective total duration.

PHASES	Preparation Phase	Stroke Phase
STROKE 1: *Tray-smash*		
1st trial	660 ms (72%)	260 ms (28%)
2nd trial	560 ms (52%)	340 ms (38%)
STROKE 2: *Exit-wall Drive*		
1st trial	560 ms (58%)	400 ms (42%)
2nd trial	500 ms (56%)	400 ms (44%)
STROKE 3: *Hook-smash*		
1st trial	640 ms (59%)	440 ms (41%)
2nd trial	620 ms (57%)	460 ms (43%)

SUBPHASES	A	B	C	D	E	F	G
STROKE 1: *Tray-smash*							
1st trial	160 ms (17%)	180 ms (19%)	40 ms (4%)	280 ms (30%)	240 ms (26%)	-	20 ms (2%)
2nd trial	-	180 ms (20%)	40 ms (4%)	340 ms (38%)	200 ms (22%)	-	140 ms (15%)
STROKE 2: *Exit-wall Drive*							
1st trial	120 ms (13%)	120 ms (13%)	100 ms (10%)	220 ms (23%)	280 ms (29%)	-	180 ms (13%)
2nd trial	120 ms (13%)	140 ms (16%)	20 ms (2%)	220 ms (24%)	200 ms (22%)	-	200 ms (22%)
STROKE 3: *Hook-smash*							
1st trial	140 ms (13%)	120 ms (11%)	80 ms (7%)	300 ms (28%)	220 ms (20%)	180 ms (17%)	40 ms (4%)
2nd trial	200 ms (19%)	200 ms (19%)	100 ms (9%)	120 ms (11%)	340 ms (31%)	20 ms (2%)	100 ms (9%)

DISCUSSION: The definition of temporal phases and sub-phases into which a paddle tennis stroke can be divided is considered as the first step of the analysis of its technique. The phase analysis allowed to establish the temporal relationship between the phases and sub-phases, herein of three different strokes, and thus to study the consistency in performance of an individual technique. It is clear that there is consistency between the temporal structure of the trials at each stroke and between angular kinematics especially for the tray-smash and the exit-wall drive. This is because the instant of the hook-smash stroke when the ball is hit (t_i) commonly is performed with the feet of the player off the ground.

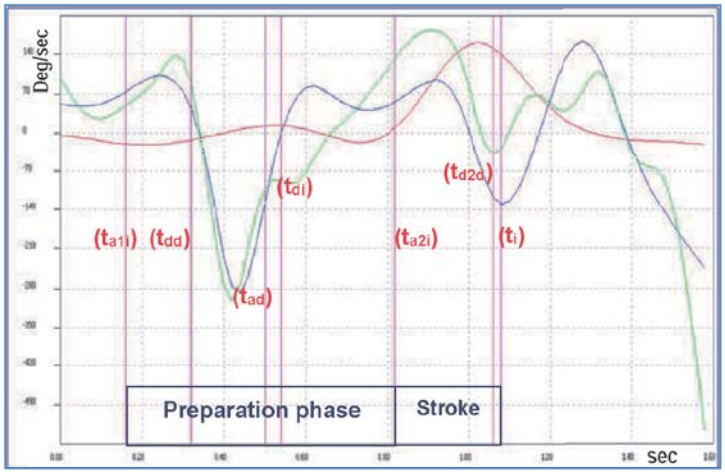


Figure 2: Definition of the phases and characteristic instants during representation of the angular velocity of the right hip (__), right knee (__) and right ankle (__) in the "tray-smash". Positive values indicate extension and negative flexion of the joint.

Table 2: Angles (°) at the defined characteristic instants for the three different strokes.

		Tray-smash			*Hook-smash*				*Exit-wall Drive*		
Joints	**trial**	t_{a2i}/ t_{ai}	t_{d2d}	t_i	t_{a2i}	t_{d2d}	t_{d2i}	t_i	t_{a2i}	t_{d2d}	t_i
Racket	1st	111.9	126.2	138.9	134.1	101.4	118.2	180.9	103.9	115.4	147.3
	2nd	105.2	106.7	155.1	135.3	96.4	82.8	185.2	100.4	134.4	131.4
Elbow R.	1st	133.2	156.0	156.1	93.0	80.1	142.3	162.5	111.5	168.7	164.4
	2nd	114.1	156.1	163.7	110.2	91.5	96.9	158.6	127.7	162.5	166.1
Shoulder R.	1st	164.4	231.7	234.9	157.9	156.1	167.3	162.6	138.8	201.4	213.0
	2nd	156.5	171.7	129.9	148.7	166.9	172.6	201.8	166.1	176.1	140.4
Hip R.	1st	154.9	190.2	187.1	141.8	171.3	203.5	211.9	147.4	172.2	189.2
	2nd	154.9	158.9	179.7	140.4	189.6	195.1	216.1	149.8	170.5	187.8
Hip L.	1st	143.7	119.8	122.4	158.1	156.9	129.9	121.2	149.4	137.7	129.3
	2nd	136.9	138.7	124.9	165.4	156.8	150.9	121.1	149.0	139.4	133.5
Knee R.	1st	135.5	149.7	149.5	-13.3	-4.2	4.3	45.5	128.5	147.9	151.7
	2nd	140.8	156.9	148.9	110.3	150.4	174.8	169.5	143.4	161.2	157.7
Knee L.	1st	128.5	145.8	149.5	99.9	148.2	156.8	177.9	131.2	131.1	158.2
	2nd	130.4	123.6	146.4	118.9	146.6	176.2	170.2	139.6	128.4	150.0
Should-hips*	1st	-27.2	7.7	15.1	-21.7	-25.7	23.9	38.3	-33.7	-8.6	32.2
	2nd	-36.7	-22.9	16.8	-20.9	-20.4	-18.1	29.9	-38.0	-22.9	40.8

*Positive values indicate that the line H1-H2 is forward the C1-C2 (Fig. 1)

Table 3: Joint angular velocities of main joints (º/sec) at the defined characteristic instants for the three different strokes.

Joints	trial	*Tray-smash*			*Hook-smash*				*Exit-wall Drive*		
		t_{a2i}/ t_{ai}	t_{d2d}	t_i	t_{a2i}	t_{d2d}	t_{d2i}	t_i	t_{a2i}	t_{d2d}	t_i
Elbow R.	1st	220.0	-	-	-250.7	111.9	797.9	441.9	112.2	177.3	-242.9
	2nd	190.8	171.6	-13.2	-21.7	117.7	189.0	479.1	170.7	151.5	202.5
Should R.	1st	24.3	-473.5	387.3	147.8	13.2	-161.0	-171.8	151.6	-53.4	-347.7
	2nd	92.8	-24.7	-338.2	33.5	86.8	-44.8	-325.0	21.1	64.1	-156.7
Hip R.	1st	44.7	57.9	39.5	-1.3	226.8	253.4	160.0	-12.0	186.0	12.2
	2nd	14.5	78.5	56.0	-81.8	275.9	267.6	132.2	-12.0	186.0	12.2
Hip L.	1st	-48.6	-2.7	15.1	73.2	-152.7	-244.3	-180.8	-11.6	-75.3	-27.3
	2nd	26.8	-47.0	-42.4	154.7	-283.2	-307.7	-224.5	-9.3	-96.8	-12.8
Knee R.	1st	56.4	-115.7	-129.0	168.9	249.1	59.6	-45.6	56.1	199.9	-213.6
	2nd	101.8	56.1	-155.5	-68.4	285.0	301.5	93.7	64.8	24.3	-53.0
Knee L.	1st	39.4	129.2	118.7	-83.0	329.9	-66.1	-138.2	-12.1	256.0	-24.2
	2nd	-75.1	84.2	92.3	-2.1	284.4	232.1	-65.5	1.1	-38.9	88.2
Shou-hip	1st	-59.0	387.1	401.6	-95.2	282.6	340.5	250.2	-15.3	124.3	314.3
	2nd	-14.2	183.4	450.7	23.8	129.6	155.8	265.2	79.9	112.0	346.5

CONLCUSION: According to the authors' knowledge this is the first study regarding the 3D kinematic analysis of paddle tennis stroke technique. In this study we examined the joint movements of three main strokes and it is analyzed their temporal phase structure in order to provide useful information to coaches for training technique.

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