KINEMATICAL AND DYNAMICAL ANALYSIS OF LONG JUMP TAKE-OFF: A FOUR CASES STUDY

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INTRODUCTION

Long Jump (LJ) is one of the technical Track and Field events which has been intensively studied since the sixties in order to maximise the athletic performance. The previous researches focused mainly on the kinematics of the LJ performance. Publications on dynamical analysis are rare, and there are even less combined studies available.

The LJ main problem, relates to the changing of the horizontal velocity (Vx) developed during the run-up, to vertical velocity (Vy) with the least losses of Vx. This process starts in the three last strides of the run-up. However, it is in the take-off that the process ends, and it is here that we can observe a great production of the Vy. This is the reason why take-off is considered as one of the most important phases of the LJ.

Despite the multiple information available, it has been note possible to establish the role of the Vy in take-off. In the same way, there are a lack of knowledge about the relationship between the kinematical and the dynamical variables in take-off. So, the purposes of this work were: (1) to analyse the variations that occurs during the take-off on the biomechanical parameters of the jump; (2) to establish relationships between kinematical and dynamical variables, and (3) to verify which of the moments of the take-off is more important to the production of the Vy, as well as to determine the final result of the jump.

METHODOLOGY

A sample of 4 athletes was studied, each one performing 6 maximal trials. Each execution of the take-off was videotaped in the sagital plan, using a video camera JVC-SVHS. The pictures were analysed bi-dimensionally through the Peak 5 System (Peak Performance Technologies Inc.), using a sampling frequency of 50 Hz. The dynamical data were registered through a Kistler 9281 B force-plate, with a sampling frequency of 250 Hz, connected to a Macintosh II VX computer through a Biopac AD converting system.

The kinematical parameters studied were the following: (1) resultant velocity of the centre of mass (VCM); (2) horizontal velocity of the centre of mass (Vx); (3) vertical velocity of the centre of mass (Vy); (4) velocity of the knee of the lead leg (VklI); (5) velocity of the touchdown foot (VTD); (6) horizontal velocity loss (lVx); (7) gain of vertical velocity (gVy); (8) centre of mass/heel angle in the instants of touchdown (CM/hTD) and take-off (CM/hTO); (9) knee angle (AngK); (10) support time (ST); (11) touchdown distance (DTD); (12) take-off angle (AngTO).

With the exception of the centre of mass/heel angles, the described parameters were determined in the following instants: (1) touchdown (TD); (2)

maximum knee flexion (MKF), and (3) take-off (TO).

The dynamical parameters studied were: (1) resultant vertical impulse(Iy); (2) active vertical impulse (Iyact); (3) passive vertical impulse (Iypass); (4) maximum vertical force (Fy máx); (5) time variation to achieve maximum vertical force (DT/Fy máx); (6) time variation of the passive vertical impulse (DTIypass); (6) time variation of the active vertical impulse (DTIyact); (8) horizontal anterior posterior impulse (Ix); (9) horizontal lateral impulse (Iz).

Statistical procedures included means (X) and standard deviations (SD), Pearson correlation coefficients. The level of significance was establish at a 0.05.

RESULTS

In relation to Vx and its loss, the results shown, a contradictory behaviour. In two cases, the major losses were verified between the touchdown instants and the maximum knee flexion ((MKF), which agrees with Lees et al. (1994) pervious report. Meanwhile, in the other two cases, the major losses were observed in the phases between the MKF and the TO. However, it was verified that, to the best results of the Vx in the TD instant has corresponded the major jump length, which agrees to with Hay (1994). In the same way, to an increase of the Vx, has corresponded one reduction of the CM/hTD.

Table 1 - Horizontal (Vx) and vertical (Vy) velocities of the athlete (Ath)

		TD				MKF				TO			
Ath		1	2	3	4	1	2	3	4	1	2	3	4
Vx	b	9,36	10,4	8,86	9,49	8,90	10,09	7,66	9,11	8,20	8,75	7,88	9,61
	x	8,77	9,4	9,06	9,03	7,78	8,57	7,85	8,29	7,7	7,96	7,75	8,40
	sd	0,39	0,97	0,5	0,58	0,74	1,04	0,27	0,63	0,41	0,73	0,53	0,98
VY													
	b	-0,49	-1,11	-0,70	0,12	1,68	1,13	1,74	2,09	3,00	3,40	3,10	3,20
	x	-0,51	-0,5	-0,47	-0,37	2,62	2,55	2,74	2,25	3,46	3,79	3,77	3,45
	sd	0,31	0,43	0,39	0,42	0,64	1,27	0,78	0,58	0,89	0,26	0,67	0,38

In what concerns the vertical velocity, we have registered negative values in the TD instant, which suggested that has existed a downward displacement of the CM. From this moment till the TO, we have found an increasing of the Vy, reaching a maximum value during the time gap between the TD and MKF instants.

Table 2 - Horizontal losses (L.Vx) and vertical gains (G. Vy)

	L.Vx TD-MKF				L.Vx MKF-TO			
Ath	1	2	3	4	1	2	3	4
b	-0,46	-0,31	-1,58	-0,38	-0,70	-1,34	-0,14	-0,50
x	-0,99	-0,85	-1,27	0,74	-0,09	-0,61	-1,13	-0,11
sd	0,35	0,75	0,35	0,38	0,45	0,73	0,48	0,48
	G.Vy TD-MKF				G.Vy MKF-TO			
b	2,17	2,24	2,44	1,97	1,32	2,27	1,36	1,62
X	3,13	3,05	3,01	2,62	0,83	1,23	1,23	1,19
sd	0,74	1,13	1,02	±0,9	0,81	1,13	0,97	±0,46

This is also in agreement with Lees et al. (1994) findings. The increasing of Vy has corresponded to a proportional decreasing of the Vx in the same time interval.

Considering now the loss and gains of Vx and Vy, we verified that the best jump length were obtained when were observed increases of the touchdown foot velocity and touchdown distance, which seems to agree with the defenders of the one active take-off foot (Hay and Koh,1990; Ozolin, 1965; Schmolinski,1983).

The main problem the studied athletes seems to be related to the CM/h, both in the instants of TD and TO. We verified that, when the values are situated out of the theoretical limits defined by Fischer (1975), the result is prejudiced, which undertakes technical problems.

The lead leg knee gets its maximal velocity in the MKF instant, which seems to be important to the take-off leg extension in the instant of take-off.

Table 3 - Touchdown distance (DTD), center of mass heel angle (CM/h) and velocity knee lead leg (Vkll).

Ath	DTD			CM/H			VKLL		
	b	x	sd	b	x	sd	b	x	sd
TD									
1	43	38,5	±3,1	61,40	71,2	±6,53	13,48	12,87	±0,63
2	40	37	±5,35	57,03	70,70	±9,30	14,48	14,30	±0,21
3	45,3	43,65	±4,24	70,0	72,03	±1,99	12,33	12,71	±0,49
4	32,4	40,02	±5,71	70,00	70,43	±2,14	14,00	±12,77	±0,88
MKF									
1							14,30	14,42	±0,18
2							17,71	15,78	±1,32
3							15,25	13,13	±2,48
4							14,31	14,8	±0,60
TO									
1				63,80	67,5	±3,14	8,20	8,70	±0,58
2				65,52	68,63	±4,34	11,85	9,34	±3,75
3				74,1	70,84	±2,44	10,00	8,68	±0,65
4				66,50	66,09	±1,39	10,66	9,82	±0,45

Dynamical results pointed out that Fy peak seems to be determinant to the jump length (r = 0.99).

Table 4 - Support time (ST), maximum vertical force (Fy Max), passive impulse (Iy pass), time variation to achieve passive impulse (DTIy pass), active impulse (Iy act), time variation to achieve active impulse(DTIy act), percentage of the passive impulse in relation to active impulse, horizontal anterior impulse (Ix).

		ST (s)	Fy Max (N)	Iy Pass (Kg.m. s^{-1})	DT/Iy pas (s)	Iy act (Kg.m.s^{-1})	DT/Iy act (s)	%Iypass/ Iy act	Ix (Kg.m.s^{-1})
1	b	0,136	7441,5	142,41	0,04	236,20	0,09	60	-52,55
	x	0,144	7074,2	136,,86	0,04	243,16	0,10	56	-57,36
	sd	±0,007	±425,9	±10,12	±o	±13,92	±0,006	±6	±8,67
2	m	0,12	9108,1	125,52	0,032	173,71	0,088	72	-47,77
	x	0,127	7454,3	110,16	0,031	196,37	0,097	57	-57,08
	sd	±0,005	±1137	±11,31	±0,002	±18,61	±0,007	±11	±12,09
3	b	0,13	7264,3	130,06	0,036	195,63	0,098	66	-42,02
	x	0,145	5842,5	111,97	0,038	216,33	0,108	52	-58,53
	sd	±0,01	±800,2	±12,29	±0	±14,01	±0,008	±9	±14,63
4	b	0,132	5549,8	97,82	0,04	177,1	0,09	55	-54,39
	x	0,140	5251,2	96,02	0,037	213,2	0,103	47	-57,08
	sd	±0,007	±222,7	±0,037	±0,004	±22,47	±0,008	±7	±12,09

In the same way, an increase of the peak maximum vertical force has, as a consequence, the increase of the percentage of the passive vertical impulse (Iy) in relation to the active vertical impulse (Iy act), and a reduction of the time variation of the active impulse. This situation implies the reduction of the support time and the performance increase. We observed a positive and significant correlation between Ix and jump performance (r =0.95).

CONCLUSIONS

Our research allow us to conclude the following:

(1) The production of Vy occurs mainly at the phase between the touchdown and the maximum knee flexion.

(2) The angles of CM/h in the touchdown and take-off instants were different of those proposed by the theorical model of Fischer (1975), resulting in a prejudice of the final result.

(3) The knee lead leg contributes to the extension of the take-off leg in the take-off instant.

(4) Higher peaks of maximum vertical force leads to a reduction of DTlact, which improves the final result of the jump.

(5) Higher peaks of maximum vertical force increase the percentage of Iy Pass/Iy Act which contributes to the increasing of the result.

(6) The reduction of support time has a consequence like the increasing of the jump length.

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