EFFECT OF TWO TAKEOFF STYLES ON FOOT PARTICIPATION IN VERTICAL JUMPS

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The aim of this paper was to determine the participation of the supporting feet in vertical jump take-off with run-up. Vertical and horizontal components were recorded for total impulse, brake impulse and acceleration impulse. 23 physical education undergraduates and baseball/basketball players participated in the study (average height 179 ± 6.1 cm.; average mass: 70.96 ± 8.82 kg). Two force platforms were used (Dinascan – IBV), one for each supporting foot, time-synchronised to a high speed video camera (Redlake Motion Space 1000 S) at 250 Hz. The results show that the second foot delay does not influence vertical component mean acceleration impulses, so there will be no advantage in CG height. Horizontal component impulse, developed by the first supporting foot, is greater when the time between foot contact is increased ($p<0.001$) but no differences were found for the second foot.

KEY WORDS: impulse, force platforms, 2D photogrammetry.

INTRODUCTION: Different ways or styles of performing takeoff in vertical jump with two-foot contact and run-up have been studied from a biomechanics viewpoint (Saunders, 1983; Vint and Hinrichs, 1996). Precisely, in vertical jumps with run-up foot contact in takeoff usually occurs in alternative style, unless adjusting movements are made in flight in the last stride to force simultaneous contact. This usually occurs in basketball or volleyball takeoffs when players are hitting, blocking or shooting. The purpose of this work is to determine the effect of this delay between foot contact in takeoff with run-up on the impulse components developed in each supporting leg.

On the basis of works by Dapena (1980) and Dapena and Chung (1988), it can be affirmed that run-up is a factor that determines the vertical jump mechanical model. The combined effect of rapid horizontal velocity and the backward inclination of the body at the start of the takeoff facilitates reflex tension and other pretension mechanisms in the negative takeoff period, which allows vertical force to increase during the positive period (Komí and Bosco, 1978; Cavagna, Dugman and Margaria, 1968).

Based on the vertical force recorded on a force platform and using a theoretical countermovement vertical jump model, Coutts (1982) found that two-foot contact takeoff time was shorter and the absorption or brake impulse was increased, but found no statistically significant differences in the acceleration impulse, implying that the delay between ground contacts has no influence on the height of the jump. The reduced takeoff time and increased brake impulse in two-foot contact takeoff may be caused by greater muscle pretension resulting from a vertical velocity increase at the end of the run-up, as is the case with countermovement jumps from different heights (Komí and Bosco, 1978; Asmussen and Bonde-Petersen, 1974).

In view of the above findings, we consider that second foot delay will not affect the components of the total impulse or the impulse developed in the acceleration phase, (although the mean force during the brake impulse will be reduced), favouring higher absorption of impact forces. This force reduction in the brake phase would produce a negative effect of the second foot on the acceleration impulse, by reducing the possibility of activating reflex tension and certain extensor muscle pretension mechanisms, especially in the second supporting leg (Komí and Bosco, 1978; Cavagna, Dugman and Margaria, 1968; Asmussen and Bonde-Petersen, 1974)2, 7, 3).

METHODS: Twenty-three physical education undergraduates participated in the study. 10 were recruited among university basketball players and the rest played university and national level volleyball (mean height: 179 ± 6.1 cm.; mean mass: 70.96 ± 8.82 kg). The protocol established a run-up and each player reached the speed he deemed appropriate to make the most effective vertical jump.
The variable used in the study is the lag between first and second foot ground contact, with two levels: a first level with second foot lag below 0.009 s, considered as simultaneous-foot ground contact (Hop Style), and a second level with second foot lag from 0.079 to 0.131 s, considered as alternative-foot ground contact (step close style).
Each subject performed five jumps in accordance with the conditions described for the first and second levels of the variable. This order was alternated for each subject. One of the five jumps recorded for each level of the variable was selected for subsequent analysis taking into account the mean takeoff time
Two force platforms (Dinascan – IBV), one for each supporting leg, time-synchronised to a high speed video camera (Redlake Motion Space 1000 S) at 250 Hz were used to quantify the force components. Integration constants were retrieved by means of 2D photogrammetric techniques from images coming from the video camera. Thus, for the calculation of the CG position a 14-segment mechanical model was used where segmental masses and centre of mass locations were calculated based on the data proposed by Leva (1996).
Takeoff was defined as the time interval between arrival of the first ground contact and takeoff of the last contact. Based on the radial distance (Vint and Hinrichs, 1996), the total takeoff impulse was divided into: a) brake impulse, from the first contact of the foot on the ground to minimum radial distance time and b) acceleration impulse, from minimum radial distance to takeoff of the last contact foot. The use of two platforms to record the force components in each ground contact allowed us to determine the impulses developed in each leg in the takeoff phase.
Data were statistically processed with Statgraphics 5.1 software from Statistical Graphics Corporation. Descriptive statistics and variance analysis for repeated measures (multi-factorial ANOVA) were used to quantify the differences between the impulses made in each of the test conditions.

RESULTS: Horizontal component mean impulse (I. Total-X) of the first ground contact is higher when the time between contacts is longer at takeoff ($p<0.001$). On the contrary, there were no statistically significant differences between the two takeoff styles in relation to the participation of the second ground contact. The opposite is true for the vertical component (I. Total-Z), where the second ground contact impulse is significantly higher ($p<0.001$) when two-foot takeoff is performed, but no statistically significant differences were found for the participation of the first supporting leg (table 1)
Horizontal component brake impulse (I. Brake-X) in the supporting leg (expressed in negative values in Table 1) is significantly higher in alternative takeoff ($p<0.001$), whereas second leg impulse is significantly higher in simultaneous takeoff. The only statistically significant differences for vertical component brake impulse ($p<0.001$) were found in second foot participation in two-foot takeoff.

Table 1.- Mean values of rectangular components of total impulse (I. Total-X; I. Total-Z), brake impulse (I. Brake-X, I. Brake -Z) and acceleration impulse (I. Acceleration -X, I. Acceleration -Z) for both ground contacts in both test situations (Simultaneous and Alternative).

	Participation First Contact			Participation Second Contact		
	Simultaneous	Alternative	*p*	Simultaneous	Alternative	*p*
I. Total-X (Ns)	-41.34 ± 15.15	-63.91± 19.35	***	-41.42± 15.66	-40.51± 12.60	
I. Total-Z (Ns)	197.24 ± 23.08	207.04 ± 27.98		194.42 ± 27.31	138.56 ± 16.05	***
I. Brake-X (Ns)	-19.03 ± 7.23	-38.21 ± 12.27	***	-16.55 ± 7.56	-8.21± 4.14	***
I. Brake-Z (Ns)	79.74 ± 14.60	88.41 ± 21.96		73.96 ± 15.91	28.77 ± 9.93	***
I. Acceleration-X (Ns)	-22.85 ± 9.09	-27.37 ± 8.96		-24.43 ± 12.16	-32.74 ± 10.81	**
I. Acceleration-z (Ns)	117.14 ± 13.95	114.33 ± 13.47		120.02 ± 16.95	115.91 ± 12.37	

(Mean ± SD for 23 data) *** $p < 0.001$; ** $p < 0.01$; $p < 0.05$

There were some statistically significant differences between the two takeoff styles, at p<0.01 level, in the horizontal component acceleration impulse of the second foot (I. Acceleration -X) which is higher in simultaneous style, whereas first foot participation is similar in both takeoff styles (Table 3). There were no statistically significant differences between contact foot participation in relation to vertical component acceleration impulse (I. Acceleration –Z).

DISCUSSION: The data show that strain exerted in eccentric activity by the muscles in the second supporting leg is significantly lower in alternative style than in simultaneous style. Thus, stretching velocity, reflex tension and certain pretension mechanisms in the second leg muscles are reduced when the alternative style is used, and as a result the force applied in the positive period should be reduced, as shown by Cavagna, Dusman, and Margaria (1968), Komi and Bosco (1978) or suggested by Asmussen and Bonde-Peterson (1974) when comparing jumps at different heights with no countermovement. Our data do not confirm this as they find acceleration impulse to be similar in the second and first leg in alternative style (114.33 Ns and115.91 Ns for the first and second leg respectively). It should be noted that no statistically significant differences were found between the two takeoff styles in relation to second leg participation.

The non-influence of lower reflex activation and muscle pretension in the second supporting leg upon the force exerted in the positive period when one-foot takeoff is implemented coincides with reports by Andersen and Pandy (1993). They argue that use of elastic energy accumulated during the negative period influences local or segmental effectiveness in the next acceleration phase, although its effect on overall jump effectiveness or total performance has not been confirmed. This may be substantiated by the influence of segment participation on the strain exerted by the muscles in vertical jump, as reported by Lees, Vanrenterghem and De Clercq, 2004.

CONCLUSION: Neither style has an advantage over the other regarding CG height, since acceleration impulses were seen to be similar in both styles.

Horizontal velocity reduction is greater in one-foot take-off, which may be a good solution for sports actions which require a reduced horizontal velocity component, i.e to prevent fouls in volleyball hitting and blocking actions near the net or in basketball shots with an opponent.

REFERENCES:

Andersen, F. and Pandy, M. (1993); Storage and utilization of elastic strain energy during jumping. J. Biomech. 26(12):1413-1427.

Asmussen, E. and Bonde-Petersen, F. (1974): Storage of elastic energy in skeletal muscle in man. Acta Physiol. Scand. 91: 385-392.

Cavagna, G.A., Dusman, B. and Margaria, R. (1968): Positive work done by previously stretched muscle. J. App. Physiol. 24: 21-32.

Coutts, K.D. (1982): Kinetic differences of two volleyball jumping techniques. Med. Sci. Sports Exerc. 14: 57-59.

Dapena, J. (1980): Mechanics of translation in the Fosbury-flop. Med. Sci. Sports Exerc. 12(1): 37-44.

Dapena, J. and Chung, C.S. (1988): Vertical and radial motions of the body during the take-off phase of high jumping. Med. Sci. Sports Exerc. 20(3): 290-302.

Gutiérrez, M.; Ureña, A. and Soto, V.M. (1994): Biomechanical analysis of the hit in the volleyball spike. J. Human Mov. Studies. 26: 35-49.

Komi, P.V. and Bosco, C. (1978): Utilization of stores elastic energy in leg extensor muscles by men and women. Med. Sci. Sports 10: 261-265.

Lees, A., Vanrenterghem, j. and De Clercq, D. (2004) Understanding how an arm swing enhances performance in the vertical jump. J. Biomech. 37 (12): 1929-1940.

Leva, De, P. (1996): Adjustments to Zatsiorsky-Seluyanovs segment inertia parameters. J. Biomech. 29(9): 1223-1230.

Rojas, F.J., Cepero, M., Oña, A. and Gutiérrez, M. (2000): Kinematic adjustments in the basketball jump shot against an opponent. Ergonomics, 43 (10): 1651-1660.

Saunders, H.L. (1983). A cinematographical study of the relationship between speed of movement. Doctoral dissertation. Texas A&M University. College Stations, 1993.

Vint, P.F. and Hinrichs, R.N. (1996). Differences between one-foot and two-foot vertical jump performances. J. Appl. Biomech. 12: 338-358.