THE USE OF ACTIVE LANDINGS IN THE HORIZONTAL JUMPS

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INTRODUCTION

Coaching and scientific literature has often cited the importance of using a "pawing" action in the landing leg as a means of maintaining horizontal velocity during ground contact in the horizontal jumps. This is referred to as an "active landing." Koh and Hay (1990a,b) defined an active landing as one in which the jumper employs a backward sweeping of the landing leg prior to ground contact. The pawing action is thought to reduce the horizontal ground reaction force encountered at impact, which would act as a braking force on the jumper's horizontal momentum. The loss of forward momentum would be detrimental to performance since the overall distance achieved is highly dependent upon the ability to maintain the horizontal velocity (built up during the approach run), particularly over the span of the three takeoffs in the triple jump (Dyson, 1962).

Very little research has been conducted to support the claim that an active landing can help reduce the loss of horizontal momentum during ground contact (Koh & Hay, 1990a,b; Marino & Young, 1990). The studies conducted by Koh and Hay (1990a,b) examined the horizontal foot velocities at ground contact in elite male long and triple jumpers. In the long jump, they found that all of the subjects used active landings during their last two strides and takeoff, resulting in mean relative velocity values of -9.02 m/s, -8.37 m/s and -6.46 m/s respectively. In the triple jump, they found relative touchdown velocities of -6.93 m/s, -6.43 m/s and -5.18 m/s for the last approach stride, the hop landing and the step landing, respectively. While statistically inconclusive, results from these two studies led the researchers to believe that large negative relative foot velocities at touchdown may reduce the breaking forces at ground contact (Koh & Hay, 1990a). They further speculated that elite jumpers may use more active landings than less skilled athletes (Koh & Hay, 1990b).

The present study investigated the use of active landings in the long jump (LJ) takeoff and the step takeoff in the triple jump (TJ). The relationship between the "activeness" of the landing and the loss of horizontal velocity during ground contact was of key interest. It was hypothesized that: (a) the TJ step contacts would be more active than the

LJ takeoffs; and, (b) the use of active landings would reduce losses in the horizontal velocity of the total-body centre of mass (CM) during ground contact.

METHODS

The data collection took place at the 1995 Atlantic Championships, at the Canada Games Stadium in Saint John, NB. The subjects were finalists in the men's LJ and TJ who consented to take part in the study. The top four long jumpers and the top three triple jumpers from the respective finals were selected for analysis, with the three triple jumpers also placing second through fourth in the long jump competition. The subjects had all previously competed at national-level competitions in either the LJ or TJ.

The camera used to collect all data was an 8 mm video camera filming at 60 Hz with a 250 ms exposure. For the LJ filming, the camera was positioned at a distance of 11.0 m from the plane of motion with a 5 m field of view centered on the takeoff board. For the TJ, the camera was positioned 11.7 m from the plane of motion with a 5 m field of view centered on a point 5 m beyond the takeoff board, coinciding with the approximate hop distance for the subjects.

The best two trials from each subject were selected for analysis; this selection was based on the competitive distances recorded by the officials, , thus eliminating faulted jumps. The video footage was transferred from 8 mm to VHS video format for digitizing on a Peak Motion Analysis system (version 5.0.7), using a 21-point spatial model. Raw coordinate data was uploaded to a VAX4500 mainframe computer for analysis using the TORKP kinematic analysis program (Putnam, 1981). All raw coordinate data was digitally filtered at 6 Hz within TORKP. Subsequent output was downloaded to a Pentium-PC for further analysis and graphing using Microsoft Excel (version 5.0) software. Statistical analyses were performed using MiniTab for Windows (version 9.2) statistical software.

Touchdown (TD) was defined as the first frame in which the contacting foot was seen to contact the runway. Takeoff (TO) was defined as the first frame in which the contacting foot was seen to lose contact with the runway. The active landing measure for the contacting foot was defined as the horizontal velocity of the segmental centre of mass of the foot relative to the CM ($relV_{foot}$) in the frame before TD. The horizontal velocities for the CM (V„) during flight were taken as averages over several frames to accommodate for any fluctuations in the calculated values. For the TJ trials, the in-flight VCM was calculated as the average horizontal velocity over the five frames prior to TD and the five frames after TO. For the LJ trials, the in-flight V_{CM} was calculated as the average horizontal velocity over all of the frames between the last stride takeoff and TD (approximately three), and the five frames following TO. The changes in V_{CM} during ground contact (ΔV_{CM}) were defined as the differences in the V_{CM} during flight before TD and following TO. Ground contact time in seconds was calculated by multiplying the number of frames from TD to TO by 1/60 (i.e., frames x frames/second). Jump distances were the official distances recorded by the competition officials.

A multiple regression model was used to account for the use of multiple within-subject trials in the analysis. The general model used for the regressions was:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ (+\beta_4 x_4)$$

where: x1 was the independent variable, x2-x4 were subject markers (x_2-x_3 for TJ, x_2-x_4 for LJ). Subject markers were removed in a step-wise fashion using a p-value of 0.10 as the criteria for elimination from the model, with the largest p-values being removed first.

RESULTS

A summary of the main kinematic variables is given in Tables 1 and 2. The mean distances of the analyzed trials were 6.53 m for the LJ and 13.23 m for the TJ. All foot contacts were "active," with mean relV_{foot} of -3.62 m/s for LJ and -4.28 m/s for TJ. All contacts resulted in a net loss of V_{CM}. In examining the relationship of relV_{foot} and the ΔV_{CM} during contact, a significant relationship was found in the TJ data ($F=10.67$, $p=0.031$). In the LJ data, a potentially significant subject effect ($p=0.109$) may have confounded the analysis of relV_{foot} and ΔV_{CM} although it was subsequently removed from the model ($F=4.17$, $p=0.087$). The relationship of relV_{foot} to AV, is presented graphically in Figure 1. The relationship of relVfoot and contact time was determined to be significant for both the TJ data ($F=17.97$, $p=0.013$) and the LJ data ($F=23.04$, $p=0.003$), without significant subject effects.

Table 1.
Data from the triple jump

Subject	Distance	Contact Time	ΔV_{CM}		$relV_{foot}$
	(m)	(s)	(m/s)	(%)	(m/s)
P.L.1	12.92	0.134	-0.52	(6.4)	-5.13
P.L.2	13.33	0.167	-0.94	(12.1)	-3.82
P.B.1	12.51	0.150	-0.72	(9.2)	-4.85
P.B.2	12.82	0.150	-0.90	(11.2)	-4.21
C.H.1	13.97	0.150	-0.80	(9.2)	-4.50
C.H.2	13.84	0.167	-0.92	(10.9)	-3.17
mean	13.23	0.153	-0.80	(9.8)	-4.28

Table 2.
Data from the long jump

Subject	Distance	Contact Time	ΔV_{CM}		$relV_{foot}$
	(m)	(s)	(m/s)	(Yo)	(m/s)
C.B.1	6.73	0.134	-1.79	(19.3)	-2.98
C.B.2	6.88	0.117	-1.31	(14.2)	-3.84
P.L.1	6.12	0.134	-1.07	(11.9)	-3.49
P.L.2	6.25	0.117	-1.33	(14.9)	-4.60
P.B.1	6.62	0.117	-1.62	(18.1)	-4.83
P.B.2	6.55	0.100	-1.27	(14.0)	-5.09
C.H.1	6.58	0.150	-1.93	(20.7)	-1.19
C.H.2	6.53	0.150	-1.71	(18.5)	-2.94
mean	6.53	0.127	-1.50	(16.4)	-3.62

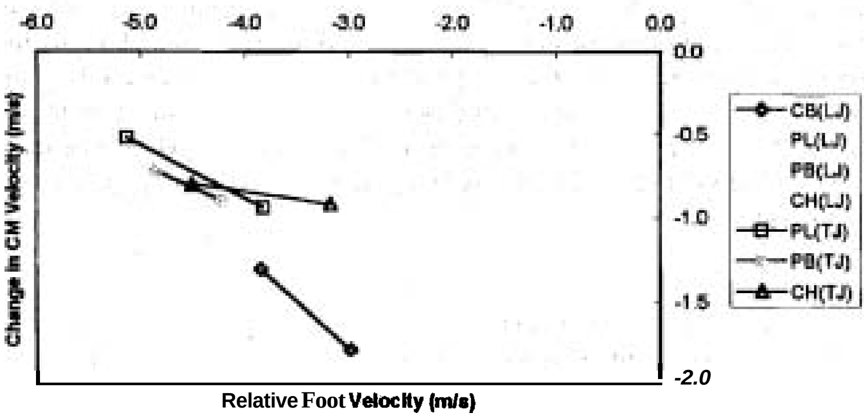

Figure 1. Relationship **of** horizontal foot velocity to change in CM velocity.

DISCUSSION

The bulk of the research conducted on the horizontal jumps has used data collected on world-class athletes at international competitions. Koh and Hay (1990a) indicated that a broader range of subjects should be studied to help clarify the relationships between kinematic parameters and performance. The present subject group was made up of skilled, non-elite athletes who had all competed at the national level. The performances of the subjects in this study ranged from 5.90-6.88 m for the LJ and 11.97-13.97 m for the TJ. Much of the previous research has focused on elite athletes capable of attaining long jumps of 7.50 m or more and triple jumps of over 16.00 m.

An active landing was defined as one in which the contacting foot attained a negative horizontal velocity relative to the total-body centre of mass. Results from this study found $relV_{foot}$ was -3.62 m/s for the LJ takeoff and -4.28 m/s for the TJ step takeoff, thus supporting the hypothesis that the TJ contact was more active than the LJ contact. However, the previous findings of Koh and Hay (1990a,b) did not agree with this trend, reporting measures of -6.46 m/s and -6.43 m/s for the LJ and TJ step respectively. It is unclear why the trend differed between studies. The elite level jumpers in the Koh and Hay studies used much more active landings than the subjects of the present study. This supports the hypothesis of Koh and Hay (1990b) that elite jumpers use greater activeness than non-elite jumpers.

The results showed that losses of horizontal velocity occurred in both the LJ (-1.50 m/s) and the TJ step takeoff (-0.80 m/s), with the LJ takeoff resulting in a greater loss. It may be that, while maintaining horizontal velocity in the LJ is important for performance, there is a "trade-off' for vertical velocity, which is also essential for effective long jumping. Again referring to Koh and Hay (1990a,b), they found changes of -1.20 m/s and -1.25 m/s for the LJ and TJ step respectively, which did not follow the trend of the present data set. Again, it is unclear where the differences arose from.

Statistical analysis of the TJ step takeoff found a significant relationship between the $relV_{foot}$ prior to touchdown and the ΔV_{CM} during ground contact. This supports the notion that active landings reduce the loss of horizontal velocity during ground contact. Koh and Hay (1990b) reported a non-significant relationship in the TJ, but they indicated that the homogeneous nature of their subjects' skill levels may have masked the true relationships. The relationship of the $relV_{foot}$ to the ΔV_{CM} in the LJ was not found to be significant at the 0.05 level, and there may have been a significant subject effect which drove the relationship in the other direction (see PL(LJ) in Figure 1). Koh and Hay (1990a) reported a non-significant relationship in the LJ, again citing an overly-homogeneous sample. An examination of Figure 1, which combines results from both the LJ and TJ step, shows that there does seem to be a strong relationship between active ground contacts and changes in horizontal momentum.

The ground contact time of the LJ (0.127s) was shorter than the TJ step ground contact time (0.153s). This was probably related to two main factors: more negative vertical velocity prior to TD in the TJ step (due to the flight path of the preceding hop phase of the TJ) and a slower horizontal V_{CM} in the TJ. Both of these factors would result in prolonged ground contact times in the TJ step as compared to the LJ takeoff. Statistical analysis of both the LJ and TJ step data found a significant relationship between $relV_{foot}$ and the contact time in which greater levels of activeness result in shorter ground contact times.

CONCLUSION

The following conclusions may be made:

* Triple jumpers employ more active landings than long jumpers. The present study found this to be the case when comparing the long jump takeoff with the step takeoff in the triple jump.
* Elite-level horizontal jumpers tend to use more active landings than non-elite level horizontal jumpers.
* There is a significant relationship between the horizontal velocity of the foot relative to the total-body centre of mass and changes in the total-body horizontal momentum during ground contact. This is to say that, active landings tend to reduce losses in the jumper's horizontal velocity during ground contact.
* Greater levels of activeness result in shorter ground contact times.

It is evident that more studies are needed to better understand the use of active landings in the horizontal jumps. As previously noted, it may be necessary to gather data from a wider range of subjects (i.e., novice to elite) to clarify the relationships amang kinematic variables and performance parameters. Longitudinal within-subject designs might also be valuable in identifying the interactions of these variables. While there have been many kinetic analyses of the horizontal jumps carried out in the past, very few have examined the question of active landings. For example, Marino and Young (1990) examined both kinetic and kinematic parameters in two types of horizontal jump takeoffs. Future studies should attempt to combine kinetic data on the ground reaction forces with kinematic data of activeness measures to gain insights into the relationship of active landings and reductions in the braking forces at ground contact. As a follow-up to the present study, the researcher is carrying out an investigation of the relationship between pre-contact foot velocity and the impulses encountered during the ensuing ground contact. Following the work of Koh and Hay (1990a,b) and Marino and Young (1990), it is expected that greater levels of activeness in the contacting foot will result in smaller braking impulses and decreased losses in total-body horizontal momentum.

REFERENCES

Dyson,G. (1962). The mechanics of athletics. New York: Holmes and Meier Publishers.

Koh,T.J. & Hay, J.G. (1990a). Landing leg motion and performance in the horizontal jumps I: the long jump. International Journal of Sport Biomechanics, 6, pp.343-360.

Koh,T.J. & Hay, J.G. (1990b). Landing leg motion and performance in the horizontal jumps II: the triple jump. International Journal of Sport Biomechanics, 6, pp.361-373.

Marino,G.W. & Young,W.B. (1990). Biomechanics of takeoff techniques in modified jumping activities. In E.Kreighbaum & A.McNeill (Eds.), Biomechanics in Sports VI (pp.187-195). Bozeman, MT: ISBS.

Putnam,C.A. (1981). TORKP [Fortran program]. Halifax, NS: Author.