BIOMECHANICS OF TAKEOFF TECHNIQUES IN MODIFIED JUMPING ACTIVITIES

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Introduction

It is an accepted fact that a fast approach run is of significant importance for success in certain jumping events, such as the long jump and triple jump. This claim is supported, at least subjectively, by the observation that several of the world's greatest jumpers have also been world-class sprinters. Theoretically, maximum distance in jumping requires that the jumper attain not only a high H_v at the takeoff point but also some V_v as well, to ensure a sufficient flight time. Some horizontal jumpers intuitively place the takeoff leg well ahead of the center of gravity (C of G) of the body and lean backwards in an effort to achieve a greater V_v and thus a higher jump. Practical experience, however, dictates that "reaching" with the takeoff leg does not improve overall performance, perhaps because it causes a loss of H_v at the point of takeoff. It has been suggested that technique which emphasizes height in the jump might only increase the final V_v at the expense of a greater reduction of H_v (Tellez, 1980). That is, there might possibly be a tradeoff between vertical and horizontal velocities at takeoff.

Since H_v of the jumper is closely related to superior performance

(Flynn, 1973), coaches have suggested that "reaching" for the takeoff board in the long jump should be avoided to prevent excessive losses of H_v (Tellez, 1980). In the triple jump, coaches have recommended the use of "active landings" involving a backward motion of the takeoff leg relative to the body C of G just prior to impact with the ground. Although long and triple jump takeoffs always produce some loss of H_v (Bosco, Lugtanen and Komi, 1976; Fukashiro and Miyashita, 1983; Ramey, 1970), active landings are thought to minimize these losses during the step and jump takeoffs. The H_v losses seem to be related to the duration of the takeoffs (Fukashiro and Miyashita, 1983) and are restricted to the first half of the takeoff (Fukashiro et al., 1981). However, the exact mechanism for the changes in vertical and horizontal velocities using different takeoff techniques is not fully understood. Biomechanics research has yet to determine the specific factors which may cause the V_v to be increased, while the H_v is decreased when performing a technique emphasizing height (i.e., "reaching"). Coaches would be better able to predict the outcomes of modification of takeoff technique if this information was available.

The purpose of this study was threefold:
1. To determine if placement of the takeoff leg well in front of the body ("reaching") produced a greater V_v and a greater; reduction in H_v than an active landing technique;
2. To determine if the active landing technique following a step is effective in minimizing the reduction in H_v; and
3. To determine what specific factors are responsible for the changes in V_v and H_v during a takeoff.

Methods

The theoretical basis for the methodology was derived from the impulse-momentum relationship, which can be expressed algebraically:

$F \times t$ (impulse) = $mv_f - mv_i$ (change in momentum)

where: F = force
t = time
m = mass
V_f = final velocity
V_i = initial velocity

Since the mass of the jumper's body remains constant, any change in velocity (V_f - V_i) is proportional to the impulse of the takeoff. Therefore changes in V_v and H_v of the jumper during the takeoff were determined from measurement of takeoff impulse.

Twelve male subjects with previous experience in the horizontal jumping events were each required to perform modified jumps utilizing two different takeoff techniques. Thus, the independent variable in this study was takeoff technique. Since laboratory conditions were required for analysis of takeoff forces, competitive jumping could not be performed. Limited space permitted a two-stride approach followed by a step (i.e., a jump from one leg to the other) so that the subject landed on the usual takeoff leg. After landing, subjects were required to immediately takeoff in an attempt to jump a maximum distance utilizing the following takeoff techniques:

1. Active landing - the takeoff leg was first extended in front of the body and then moved backwards so that it landed as close as possible to the line of gravity of the body at impact. The takeoff and jump were then performed as quickly as possible without concern for height.

2. Height technique - the landing leg was placed well in front of the body so that the heel of the foot made impact with the ground. The following takeoff and jump were performed with the emphasis on achieving height.

All takeoffs were measured and analyzed by an Advanced Mechanical Technology Inc. (A.M.T.I.) computerized biomechanics force platform system. Vertical forces (F_z) and horizontal forces in the anteroposterior plane (F_y) were recorded and plotted. All jumps were filmed with a Locam 16 mm camera operating at 100 frames per second. Film data were subsequently collected and kinematics of the C of G were determined. Segmental endpoints were filtered using a Butterworth fourth order low-pass digital filter with a cutoff frequency of 10 Hz and, therefore, a sampling to cutoff ratio of 10.

The verticla impulse responsible for the final V_v achieved during the takeoff is due to F_z greater than the force of the subject's body weight, and begins at the point in time when the body's C of G starts to rise (when positive work begins). This impulse was called the net vertical impulse in positive work.

Horizontal jumping takeoffs involve the application of a negative or braking horizontal impulse which reduces the H_v of the jumper, and a positive horizontal impulse which accelerates the body forward. Therefore, the overall loss of H_v produced during the takeoff is a result of the relatively greater braking horizontal impulse.

Twelve dependent variables consisting of takeoff velocities, impulses, forces and temporal data were measured and tested for statistically significant differences between the takeoff techniques using paired t-tests. These dependent variables were chosen on the basis of their apparent importance revealed in previous research. Product-moment correlation coefficients were also computed in an attempt to observe interrelationships among the selected variables.

Results and Discussion

The mean values recorded on the major dependent variables measured in this study are listed in Table 1, along with the t-ratios reflecting the results of paired t-test analysis of between-technique differences.

Table 1

Means and Standard Deviations for Dependent Variables

($N = 12$)

Dependent Variables	Independent Variables: Takeoff Technique — Active Landing $\bar{x}$	Active Landing S.D.	Height $\bar{x}$	Height S.D.	t Ratio
V_v at takeoff (m/s)	2.93	0.51	3.49	0.47	- 3.08*
H_v at takeoff (m/s)	3.25	0.50	1.96	0.38	11.09*
Change in H_v (m/s)	0.01	0.38	- 1.07	0.35	8.33*
Braking horizontal impulse (N.s)	-29.2	16.61	-91.4	24.61	8.23*
Time of braking horizontal impulse (s)	0.146	0.05	0.274	0.0	- 7.67*
% time of braking horizontal impulse	45.7	13.92	72.9	5.73	- 6.52*
Maximum braking F_y (N)	-395.8	72.2	-638.2	185.0	3.75*
Maximum F_z in positive work (N)	2768.6	336.0	2681.1	396.0	1.48
Time of positive work (s)	0.19	0.02	0.22	0.03	- 3.43*
% time of positive work	60.3	3.58	60.4	4.44	- .06
Total takeoff time (s)	0.320	0.03	0.376	0.05	- 4.97*

* statistically significant differences at $P < .05$.

Table 1 shows that the height technique produced a significantly greater V_v at takeoff and a greater reduction in H_v than the active landing technique. This supports the notion that placement of the landing leg well in front of the body does allow greater generation of V_v (and therefore a higher jump), but only at the expense of a greater loss of H_v compared to the active landing technique. The increase in V_v over the active landing technique was relatively small (19%), compared to the relatively large decrease in H_v at takeoff (40%). Table 1 also shows that the maximum F_z produced during positive work was no greater using the height technique. Rather, the greater V_v achieved using this technique was obtained by a significantly greater time of F_z application. Since the proportion of the total takeoff consisting of positive work was not significantly different between the takeoff techniques, the longer duration of F_z application was available simply due to a greater total takeoff time. In other words, the height technique enabled the jumpers to acquire greater V_v due to the longer time in which to apply F_z to the ground. A possible explanation for the inability of the jumpers to increase the magnitude of their F_z application may be that the large load placed on the takeoff leg at landing (which would be similar for both techniques) might inhibit the effectiveness of the following takeoff. This would be consistent with the findings that the average force of contraction of the leg extensors is reduced following very high impact loads encountered in depth jumping form very high drops (Bosco et al., 1982).

Table 2 lists correlation coefficients reflecting the relationships between both V_v at takeoff and change in H_v and other selected variables. These were determined for both "active landing" and "height" jumps.

Correlation analysis revealed that the V_v at takeoff was significantly related to the loss of H_v (Table 2) in both types of jump. This indicates that an individual may have to increase braking horizontal impulse to acquire greater V_v from one jump to another.

Table 2

Correlation Coefficients for Selected Variables

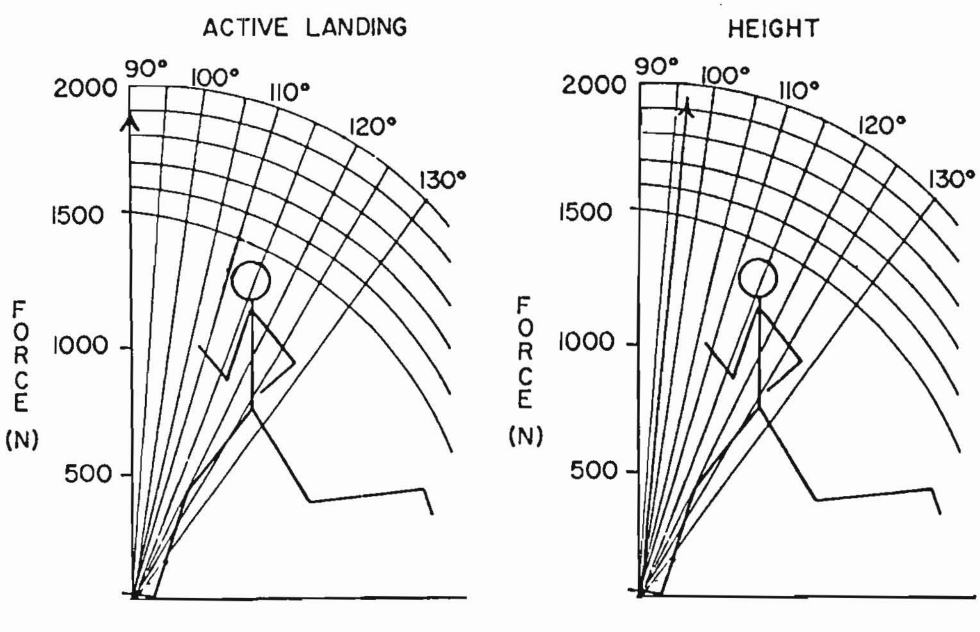
Variable	Takeoff Technique: Active Landing		Height	
	V_v at takeoff	Change in H_v	V_v at takeoff	Change in H_v
Change in H_v	-0.74*		-0.64*	
Braking hor. impulse		0.95*		0.98*
Maximum braking F_y		0.48		0.57
Time of braking hor. impulse		-0.92*		-0.10
Total takeoff time		0.03		0.37

* $p < 0.05$

Table 1 shows that the greater loss of H_v produced by the height technique was possible due to a significantly greater braking horizontal impulse. When the impulse factors (force an time) are examined, it is evident that the greater braking horizontal impulse appeared to be due to <u>both</u> a greater maximum braking F_y and a greater time of braking F_y

application. In fact, the proportion of the total takeoff time spent applying braking forces was also significantly greater for the height technique (Table 1). The loss of H_v was highly correlated to the braking horizontal impulse and to the time of braking F_y (for the active landing technique), but not significantly related to the maximum braking Fy application. The loss of H_v has not related to the total takeoff time. This suggests that the loss of H_v produced by the takeoff can be predicted best by the braking horizontal impulse and possibly the duration of this impulse.

Figure 1 shows the backward directed mean resultant ground reaction force vector which acts to reduce the forward velocity of the jumper using the height technique. It can also be seen that the mean resultant force vector for an active landing jump is approximately 90 degrees thus causing the reduction in velocity to be lower.



Conclusions and Possible Implications for the Jumping Events

It appears that placement of the landing leg well in front of the body in an attempt to achieve a higher jump does allow the jumper to generate a greater final V_v. This is achieved primarily as a result of increased takeoff time during which vertical forces are exerted and not by an increase in the magnitude of the forces. The inability to increase vertical force application when attempting to jump for height could be due to an inhibiting effect of the landing from a previous jump phase. In the triple jump, for example, where impact forces would be expected to be very high, inability to tolerate these loads may be a limiting factor in performance.

The increased reduction in H_v that accompanied the height technique was comparatively large, suggesting that this technique may not improve overall performance. In other words, the active landing technique was successful in minimizing the loss of H_v with a comparatively small sacrifice of V_v. The active landings allowed the application of the retarding braking forces to comprise a smaller proportion of the total takeoff time, and to be smaller in magnitude. This seems logical, since placement of the landing leg under the body would allow the C of G to pass more quickly over the supporting leg.

The step-and-jump task used in this study is quite different from the jump takeoff of the triple jump. Therefore direct application of these findings should be made with some caution. Nevertheless, the trends observed may provide coaches with a better understanding of the specific factors that operate when technique is modified. A more practical application of research findings could be made if direct measurement of takeoff forces was taken in the competitive triple jump. The specific biomechanical factors which operate in all three takeoffs and the inhibitory mechanism of the landings should be of major interest.

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