



Certain Scientific Aspects of the Horizontal
Jumps:
Commonalities and Differences

Presented by

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General Overview

- Videos of classic long and triple jumps
- The four stages of the jumps
- Insights provided by Newton's Law
 - Translation
 - Rotation
- The significance of the Ground Reaction Force
- The role of the testing program at the USOC Training Center

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- Videos of the long jump
- Mike Powell
 - Carl Lewis

- Videos of the triple jump
- Willie Banks
 - Mike Conley
 - Jonathan Edwards

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Both Jumps have four primary phases:

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However, the Triple Jump is more complex because it links together three consecutive long jump-type flight phases.

Triple Jump Phases

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Newton's Laws of motion can be used to characterize the most fundamental aspects of the jumps--particularly in the support and flight phases.

We have to be mindful that Newton's Laws describe both translational and rotational motions.

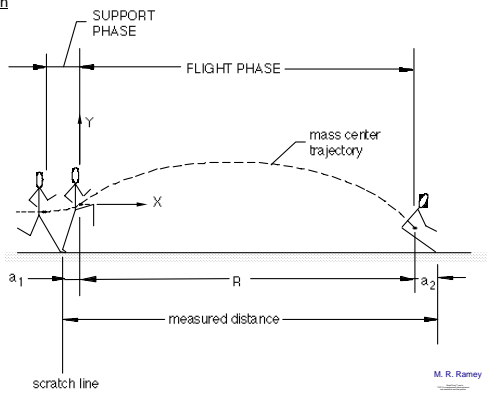
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- We'll consider translation first for the flight phase.
- The athlete can be modeled by a single mass point positioned at his/her center-of-mass (CM)
- Newton's Second Law, Force = mass x acceleration,

$$F = ma = m \frac{dv}{dt} \quad \text{Eq. 1}$$
 can be used to determine the distance traveled during the flight phase.

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Translation



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Translation

Expansion of Eq.1 shows the importance of the velocities in determining the distance jumped.

$R = (\text{HorizVelocity}) \times (\text{Modified VertVelocity})$

$$R = \frac{1}{g} v_x (v_y + \sqrt{v_y^2 + 2g y_o}) \quad \text{Eq. 2}$$

(This equation is relevant for all projectile motion)

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Translation

Measurements show that the Horizontal Velocity is about 2.5 times larger than the Vertical Velocity for competitive long jumps. This gives a takeoff angle of about 22°

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Translation

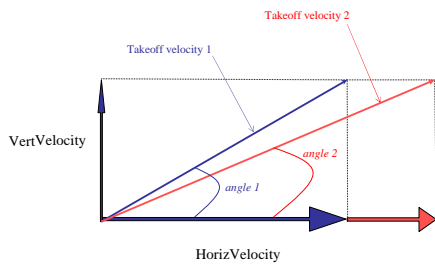
However, please keep in mind that the takeoff velocities are the important factors that influence the distance jumped and **NOT** the takeoff angle.

Let me illustrate.

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Translation

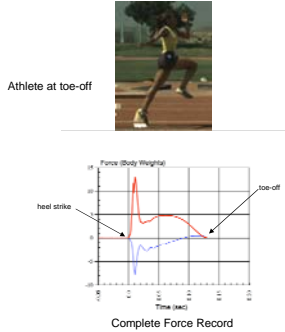
The Horizontal and Vertical Velocities, which are vectors, are added to produce the angle at which the jumper leaves the board for the flight phase.



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Translation

The ground reaction forces are critically important in the development of the velocities. Typical force records are shown below



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Translation

The Impulse-Momentum form of Eq. 1 yields:

Takeoff Velocity =
Area Under the Force Curve
+
Heel Strike Velocity

OR

$$V_{TO} = \frac{1}{m} \int_{t_{HS}}^{t_{TO}} (F) dt + V_{HS} \quad \text{Eq. 3}$$

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Rotation

An additional application of Newton's Law shows that a quantity known as ANGULAR MOMENTUM is active in the jumps.

The Angular Momentum causes the athlete to experience a forward rotation during the flight phase. Thus the arm and leg motions seen in the different jumping styles are attempts to attenuate the rotation.

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Rotation

a) Sail

b) Hang

c) Heelkick

d) Somersault

Long jumping techniques

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Rotation

Research has shown that when the angular momentum is properly matched with the jump technique all techniques will yield the same performance. For example,

(a) HEELKICK

Angular Momentum
 $H_1 = -13.6 \text{ Nms}$
 $H_2 = +1.9$
 $H_3 = +2.7$

Landing Orientation
 $\theta_1 = -37^\circ$
 $\theta_2 = 0$
 $\theta_3 = +19^\circ$

(b) SOMERSAULT

Angular Momentum
 $H_1 = -38.6 \text{ Nms}$
 $H_2 = +1.9$
 $H_3 = 0$

Landing Orientation
 $\theta_1 = -34^\circ$
 $\theta_2 = 0$
 $\theta_3 = 0$

Simulation of the flight of the heel-kick and somersault long jumps

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Rotation

The angular momentum is a result of the moment caused by the ground reaction forces acting on the foot during the support phase.

QuickTime™ and a decompressor are needed to see this picture.

From Hay, J. G., "Citius, Altius, Longius (Faster, Higher, Longer): The Biomechanics of Jumping for Distance, J. Biomechanics Vol.26, Suppl.1, pp 7-21, 1993

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Rotation

The rotational part of Newton's Law is

$$M(t) = \frac{dH}{dt}$$

which when expanded is similar to the translation equation (see Eq. 3)

$$H_{TO} = \int_{t_{HS}}^{t_{TO}} M(t) dt + H_{HS} \quad \text{Eq. 4}$$

where H_{TO} and H_{HS} are the angular momenta at Toe-off and Heel strike, respectively, and $M(t)$ is moment acting on the athlete.

Note: $M(t) = (x)(F_y) + (y)(F_x)$ and the "∫" indicates that the area under the moment curve is determined.

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Rotation

The angular momentum that exists at take-off, which remains constant in the flight phase, is sensitive to the moment generated during the support. Small changes in the placement of the support foot can greatly change the moment as evidenced by the first term in the expression for the moment.

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Closing Remarks

These factors--velocities, forces, angular momentum-- are the similar items in the horizontal jumps (other than the fact that same facility is used) but the actual application of them is what makes the events different, ie,

- 1) Approach speeds are different
- 2) Set-up for the support phase(s) is different
- 3) In-flight management of the angular momentum is different
- 4) Landings are different
- 5) Use of both legs in the triple jump makes them different

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Closing Remarks

So, how does knowing any of this help improve our horizontal jumpers?
(or so what?)

- 1) Identifies the basic performance variables
- 2) Knowing item 1 makes it possible to quantify the variables
- 3) There is a large body of published knowledge concerning these variables as well as considerable coaching experience on their application
- 4) Combining items 1-3 in focused testing/training directed at individuals will help improve our jumpers

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Closing Remarks

Current testing taking place at the USOC Training center in Chula Vista, as part of the High Performance program, is capturing the ground reaction forces as well as quantifying the approach and take-off velocities. High speed digital videography is synchronized with the force records to produce new insights about the take-offs. We are coupling this information with the knowledge available in the coaching and scientific literature and applying it to individual athletes.

A later session will be devoted to detailed descriptions of the Chula Vista activities and implications for training and performance

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