KIN 335 - BIOMECHANICS

LAB: Measurements of Vertical Jumping Performance

Introduction: In a maximal effort vertical jump performance, the goal of the task is simply to jump and reach as high as possible. In many sports, the height to which an athlete can jump and reach is often of critical importance. In the absence of air resistance and other external forces, the upward projection of the whole body center of mass (CM) is completely determined by the vertical velocity at the instant of takeoff and the acceleration due to gravity. However, this quantity does not completely describe the overall jump and reach height that is observed.

Purpose: The purpose of this laboratory is to measure and compare vertical jumping performance using three different methods.

The Deterministic Factors of Vertical Jumping: The block diagram in Figure 1 is called a *deterministic model*. It provides an objective basis by which all important aspects of an athletic performance can be subjectively evaluated. The factors (blocks) of the deterministic model serve to describe the mechanical or mathematical relationships that govern vertical jump and reach performances. From Figure 1, it can be seen that the actual vertical height to which an athlete can jump and reach may be described by the sum of four lesser heights: takeoff height, flight height, reach height, and loss height (see Equation 1 and Figure 1).

Jump and reach height = Takeoff Height + Flight Height + Reach Height – Loss Height **(1)**

Jump and reach height may be considered to be the actual vertical height at which the athlete contacts the ball during a volleyball attack, releases a ball during a basketball lay-up, or touches the slats of a vertical jump testing device. *Takeoff height* defines the height of the athlete's center of mass (CM) at the instant the athlete leaves the ground. *Flight height* refers to the actual height to which the CM is elevated during the in-flight phase of the jump. *Reach height* describes the vertical distance from the CM to the fingertips of the athlete at the instant the maximum height is evaluated (instant of ball contact, instant the slat is touched, etc.). *Loss height* refers to the difference between the absolute peak height of the CM and the height of the CM at the instant the maximum height is evaluated. This last factor can usually be attributable to a mistiming of the final reach by releasing a ball or touching the measuring device on the way down (or up).

In standing two-foot vertical jumps, takeoff height, flight height, and reach height have been found to account for about 41%, 17%, and 42% of the overall jump and reach height, respectively. Among skilled jumpers, loss height has been found to be negligible, accounting for about 0.2% of the overall jump and reach height. It may be surprising (and perhaps somewhat discouraging!) to note that the contribution of flight height is so much smaller than that of takeoff height and reach height. Regardless, it is clear that an overwhelming percentage of the overall jump and reach height is determined *not* by the vigorous muscular effort required to propel the body upward, but simply by the physique of the jumper and the position and orientation of the body about the CM at the instant of takeoff and again when the maximum height is evaluated.

Unfortunately, it is one of the smallest contributors, *flight height*, which we as physical educators, coaches, athletes, and exercise scientists most often attempt to manipulate and measure. As such, it becomes important for us to realize the strengths and weaknesses of the methods that are available to us.

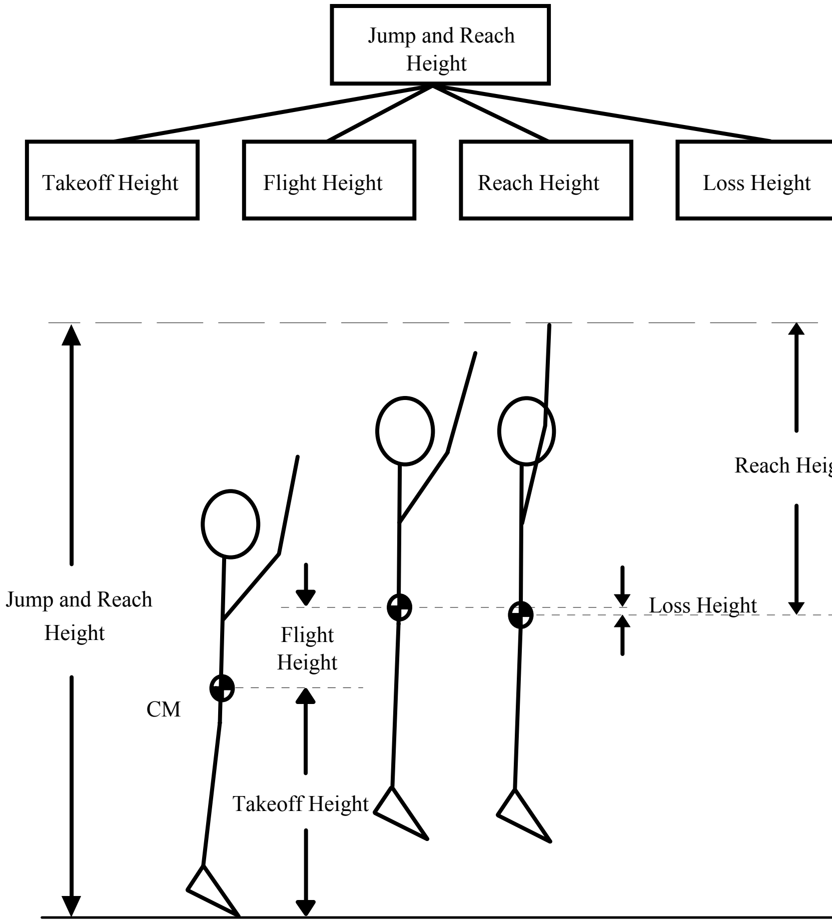

Figure 1. Deterministic model and illustration of simple factors that determine overall jump and reach height. Note: relative proportions of the four sub-heights are drawn approximately to scale.

<u>Procedures</u>:

Three different estimates of "true vertical jumping performance" (i.e., *flight height*) will be compared in this lab: the traditional "Sargent Test"; the time of flight method; and the impulse-momentum method. For each of these methods, students will perform a maximum effort vertical jump using both an arm swing and a countermovement and will touch as high as possible on a vertical jump measuring device. This height will be defined as the overall jump and reach height (H_{touch}).

All jumps will be performed on a force platform that will collect vertical force data at a rate of 2000 samples per second. This method will allow us to simultaneously obtain three different measures of vertical jumping performance. It is important that each student begins their jump from a standing, stationary position with both feet on the force plate. It is equally important that students land back on the plate after landing from the jump.

The calculations required for each of these methods are described below.

1. *Sargent test*: Prior to or after the jump, each student will stand flat-footed and reach up with one hand to touch the slats of a vertical jumping device with the fingertips. This height is measured as "standing reach" (H_{reach}). Jump height ($H_{Sargent}$) is calculated as the difference between the jump height and the standing reach height measures.

$$H_{Sargent} = H_{touch} - H_{reach}$$

2. *Time of flight method*: Assuming the height of takeoff is the same as the height of landing, the in-flight elevation of the CM (H_{TOF}) can be calculated by:

$$H_{TOF} = -\left(\frac{a \cdot T_{total}^2}{8}\right)$$

where a is the acceleration due to gravity and T_{total} is the difference between the instant of landing and the instant of takeoff. The negative sign is needed to account for the sign of gravity.

3. *Impulse-momentum method*: If the jumper initiates the jump from a stationary position ($v_i = 0$), the impulse generated by the athlete can be used to calculate the velocity of the CM at the instant of takeoff. This velocity can then be used with the equations of uniformly accelerated motion to calculate the height to which the CM was elevated during the jump ($H_{impulse}$).

$$v_{takeoff} = \frac{\int_{t=o}^{t=takeoff} (GRF - W)dt}{m}$$

where GRF is the vertical ground reaction force, W is the body weight, m is the body mass, and $v_{takeoff}$ is the vertical velocity at the instant of takeoff. Integrating (∫) the net force ($GRF-W$) from the beginning of the jump until the instant of takeoff is simply a more formal mathematical expression of the impulse applied over that interval. From the vertical takeoff velocity, the maximum height to which the CM was elevated can be calculated:

$$H_{impulse} = -\left(\frac{v_{takeoff}^2}{2 \cdot a}\right)$$

where a is the acceleration due to gravity. Again, the negative sign is needed to account for the sign of gravity.

A computer program will display the results for the time of flight and impulse-momentum calculations for you after each jump. Record these values for each student on the following Table. You are responsible for calculating the Sargent height using the touch and reach height data. All final height measures should be expressed in meters (m). For each measure of “jump height”, calculate the average value across all students in your lab section. Answer the following questions.

Student	H_{reach}	H_{touch}	$H_{Sargent}$ *(m)*	H_{TOF} *(m)*	$H_{impulse}$ *(m)*
Average					

Questions*:* As part of your lab assignment, answer the following questions. As always, answers must be typewritten, explained thoroughly, and written in complete sentences.

1. How did the three different measures of flight height compare? Did any method yield consistently higher or lower values than the others? Explain and support your answer with data from the lab.

2. Vertical jumping performance is often used as a crude measurement of muscle power. Considering the various deterministic factors of jumping performance, which factor or sub-height is most closely related to vigorous muscular effort? In consideration of your answer, which method of estimating flight height is probably most appropriate? Explain.

3. Is the traditional Sargent method of evaluating jumping performance valid? What types of things are not accounted for in this method and how do these affect the flight height estimates? Specifically, do these factors tend to overestimate or underestimate "true" flight height?

4. Are there any problems or significant assumptions associated with the time of flight method? Is so, what are they and how do they affect the flight height estimates? Specifically, do these factors tend to overestimate or underestimate "true" flight height?

5. If you were a coach or athlete and you wanted to improve jumping performance over the course of one week, which deterministic factor(s) would you target and why? What would you do to bring about improvements in the deterministic factor(s)? If you had an entire year to improve performance, would you target the same factor(s)? Why or why not?

What to turn in:

- Completed table. Be sure to obtain data and compute means from all subjects in your lab section. All jump data should be expressed in meters.

- Typewritten answers to the 5 discussion questions listed above.

This lab is due Monday, November 24 at the beginning of the lecture period.