Vertical Jump Testing ……
Which tool should you use?

Swift Performance - 2017

Vertical Jump - Testing History

In the 1980's, an Italian researcher named Carmelo Bosco began his career studying muscular mechanics and the effects of pre-stretching on force production. He subsequently developed a series of performance tests, predominantly based around the Vertical Jump. These are now referred to as the "Bosco Tests" and many would say they represent the epitome of Vertical Jump testing.

Bosco Tests are now used worldwide and are regarded as an easy and non-invasive way to determine power output and muscular work.

Before Bosco began his research, the most common test used for Vertical Jump assessment was the Sargent Test – where athletes jump up and slap a wall with chalk on their hands to make a mark, then measured to signify jump height. Then, as technology in sports performance continued to expand, mechanical measuring systems like the Yardstick and Vertec devices became the commonly used industry practice.

Of course, Bosco understood that there is more to Vertical Jump than assessing the total height or maximal reach and sought to quantify the 'Contact Time' of an athlete prior to leaving the ground, which lead to his use of a 'Contact or Jump Mat'.

A Jump Mat employs an electrical switch that recognizes when an athlete is either on, or off the mat. These two (2) physical states are commonly referred to as Contact Time (Ct) and Flight Time (Ft).

Measuring jump height is fairly simple using a Jump Mat. By applying simple physics, Jump Height is quantified by recording the Flight Time of a jump when the athlete is off the mat.

Given that a Jump Mat can measures two key (2) times, that being total Flight time and Contact Time, the following is a description of data that can be taken from these measurements.

Measurement definitions:

- Flight Time (Ft)
    - This is the time when the athlete is airborne. The time between leaving and arriving on the back on the mat. It's crucial that the athlete doesn't attempt to extend Flight Time by holding the feet up before landing. This will extend the Ft, but introduce an error.
    - It is also worth noting that in the equation used, the Flight Time is divided by (2), solely because Newtonian physics state that the times to rise, and fall, under the influence of gravity will be equal.
    - Therefore, if the Total flight time was not divided by (2), in the calculation, there would be a much larger jump result, which would be incorrect.

    - Ft is measured in milliseconds (mS) to ensure good resolution in calculated jump height.
- Contact Time (Ct)
    - The time recorded between successive jumps.
    - Ct is measured in milliseconds (mS) to ensure good resolution in calculated Power and Reactive Strength Index measurements … *described later*
    - Note that Ct is something that cannot be measured with a Vertec or Yardstick style product.

Calculating Jump Height

$Ft = Flight\ Time$

$$Jump\ Height(m) = 4.91 * (\frac{Ft}{2})\text{^}2$$

Based on basic Newtonian physics, this measurement method works on two (2) principles:

1. acceleration due to gravity
2. time

* Thus, calculating the *displacement of an athlete's Center Of Mass.*

Mechanical measuring devices "vs" Jump Mats

This statement is not intended to portray a competitive divide as both devices do have their place in a Strength + Conditioning Coach's arsenal of tools.

In this industry, it is often heard "this Jump Mat gives low readings … or … I can jump higher than that." In fact, if you have been testing your maximal reach on a YardStick or Vertec and then you use a Jump Mat, you may in fact see lower values.

With a mechanical device, athletes use both the swing of their arms and the inertia they provide to propel themselves upwards off the ground. This is what happens during practice or competition when a ball is introduced. Note that the athlete reaches as high as possible to tap the highest target possible, bringing shoulder girdle rotation and flexibility into the overall reach measurement.

Thus, you are measuring maximum reach, but not true vertical jump power. And it will be effected by both the inertial assistance the arms provide and the shoulder rotation achieved in reaching overhead.

Note: *Although reaching above the head is a basic function of sport – i.e. grabbing a rebound in Basketball or catching a pass in Football, the reach measurement from a Yardstick or Vertec gives the coach no idea on the Power an athlete is generating to achieve this height or how it is being generated.*

Thus, to obtain this strict measurement, arm swing inertia should be removed - like in the stricter Bosco tests, and a Jump Mat should be used.

Important Consideration:

Some Jump Mat systems add a "constant" to their calculated Jump Height formula to compensate for shoulder rotation + overhead reach and it gives a number closer to what a Vertec might deliver. This makes it easier for a coach who has been using a Vertec to reconcile the results between a Jump Mat and the mechanical Vertec. However, this creates a training progression error!

To learn if your jump system is adding a constant to replicate Vertec results, try a simple test by doing a tiny jump on your Jump Mat. Try and keep it as small as possible … less than 1" if possible. If this 'correction' is being added, you will see a recorded jump height value of up to 5". It is important to understand what you are measuring and how your results might vary compared to other jump measuring devices.

An athlete will want to know why his or her 'jump' is lower on a Jump Mat that measures the displacement of the "Center of Mass" and does not add that corrective constant, rather than it is on Vertec style device.

The answer is … "You cannot measure Power or how it is applied with a Vertec that measures maximal reach and nothing more. An accurate Jump Mat measures the displacement of your Center of Mass, which is what is needed to calculate Power and other performance factors. If we used a Jump Mat that adds a corrective constant, and tried to calculate Power using this corrected jump height, the Contact Time and the athlete's mass, our result would be incorrect … and could be either over <u>or</u> under-measured."

Why is this a problem?

*If you are only doing single jumps and using your Jump Mat in the same way you would on a Vertec, it's not a problem at all. But, be aware that as an athlete fatigues over multiple jump bouts and jump heights get lower, the added correction constant could result in the Jump Mat giving a reading "higher" than the Vertec. Swift Performance's position is that Jump Mats should not add any calculations to make results appear similar to a Vertec and its **ezejump** system does not.*

Consider this example:

- *A Vertec measures a 29" Jump. A Jump Mat, using Flight Time, calculates a jump height of 24".*
- *If the Jump Mat software then adds 5" for shoulder rotation, etc. to match the Vertec. This equates to 17% of the Vertec measured result.*
- *After several jumps, athlete fatigue sets in and on the Vertec, now jumps 22" … showing that the athlete's performance has dropped 24%.*
- *The Jump Mat measures the same jump height at 24% lower or 18.25".*
- *Then, the 5" Jump Mat "correction constant" is added to give a result of 23.25".*
- *In this example, the Jump Mat shows the final jump height at 1.25" higher than the Vertec, or almost 6% in error.*
- ***Consider the improvements you hope to see during your athletes' training. A 6% increase is most likely way outside the margins of improvement that you would hope to see in a single session.***

- *You might think then that the above scenario proves that a Vertec is more accurate. But this assumption would be true only if your Jump Mat is one that adds this correction amount.*

  *In fact, an accurate Jump Mat like the **ezejump** that measures the displacement of the Center of Mass of the athlete, over successive jumps, while looking at Contact Time and Reactive Strength Index is actually a more powerful and accurate tool for a performance coach and offers a more in-depth analysis of your athlete's ability to generate Power.*

Comparing Explosive Power

Example 1

Two (2) athletes - one at 220lbs and one at 180 lbs. Both are exactly the same height, both have the same standing vertical reach and both achieve the same vertical jump score relative to the device being used, i.e. Vertec or Jump Mat. All that is known is that the heavier athlete certainly needs to generate more Power to achieve that height. What is not known is how that Power was generated.

We can investigate this only if we have Contact Time, which can be provided by the **ezejump**.

Now, force development, is directly related to Contact Time. This can only be measured from a Drop Test (see below) where the measurement of Contact Time is recorded. It's with this measurement that you can begin to assess the athlete's ability to generate power quickly and this is where the Reactive Strength Index comes into play. RSI shows an athlete's ability to change quickly from an eccentric to a concentric contraction and their ability to develop maximal forces in minimal time – the core principle of plyometric training. This invaluable piece of data is not able to be captured using a mechanical device like a Vertec.

Example 2

Two (2) athletes – both 180 lbs. Both are exactly the same height and have the same standing vertical reach. Both achieve the same vertical jump score. This is a classic example of what happens when using a mechanical device like a Yardstick or Vertec … the coach can make no assumptions on Power generation at all. The assumption might be made that these two athletes are identical in performance. In actuality, this may not be true. Thus, without a Jump Mat or a Force Plate, the S+C Coach is not obtaining all of the relevant test data.

Other metrics a Jump Mat should provide

Armed with an accurate Jump Mat, the following metrics can give a coach even more interesting insight into an athlete's performance. Below are listed some common industry metrics that **ezejump** can provide:

CMJ = Countermovement Jump Height
SJ = Squat Jump Height
ABK = Abakolv Jump Height *(with use of arm swing allowed … like with a Vertec)*

- Elasticity index: elastic energy = ({CMJ - SJ}/CMJ)x100
- Upper Limbs Coordination index: ((ABK - CMJ)/ABK)×100

- % of Fast-Twitch Fibers: uses a protocol developed by Bosco w/ multiple Drop Jumps
- Peak Velocity: Jump Height = peak velocity ^ 2 / (2 * 9.81)
- Average Power: using Harman's formula

Jump testing – landing technique

Straight leg landing??

As described below, Bosco insists that landing straight legged is required for test validity.

However, as is widely known, landing in an extended, straight leg position with knees locked is dangerous and counters the training philosophy of many professionals in the industry of landing in a safer, bent leg, more stable position while decelerating.

Bosco's description of landing 'straight legged' is very general. And in effect, a description defining "landing with legs extended, toes first, and ready for normal flexion on landing" would be a better description. Following this more accurate description, test validity is maintained and athletes will feel more comfortable in executing a familiar landing technique.

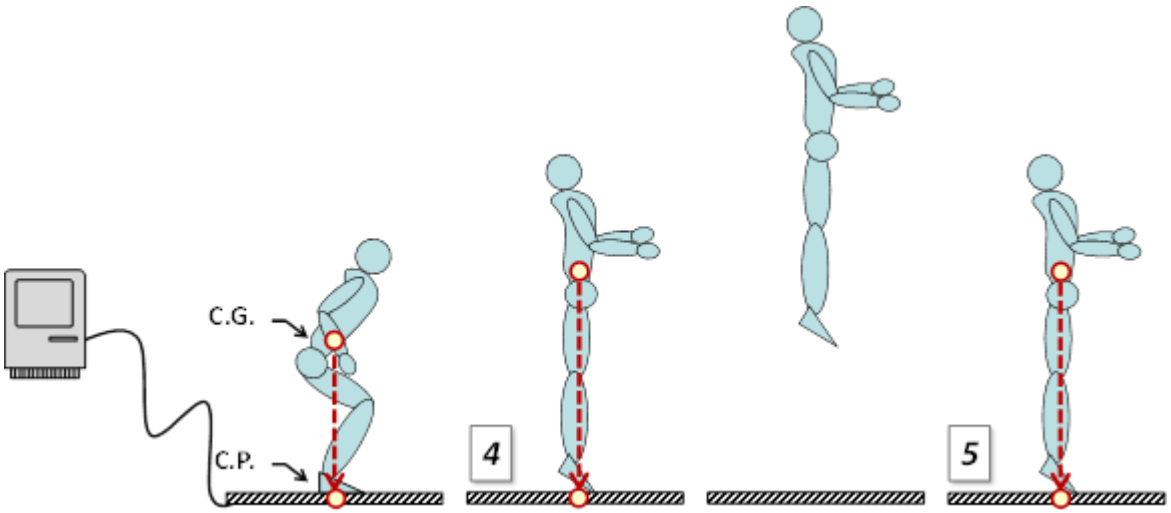
Finally, it is very easy to observe if an athlete is openly trying to extend flight time to achieve a better jump height, so be sure to correct and eliminate this action while occurring.

Bosco Jump Tests

Bosco prescribes a few very different protocols using a jump mat:

Squat Jump *(single jump)*

- Athlete starts from a position where knees are bent at 90 degrees
- Hands remain on hips through the entire jump *(although these graphics shows arms up at 90 degrees, which is not ideal)*
- Athlete moves upwards, accelerating and rapidly extends his or her legs
- Landing must occur with legs in a straight-leg, fully extended position *(please acknowledge the previous notes on the proper landing technique)*



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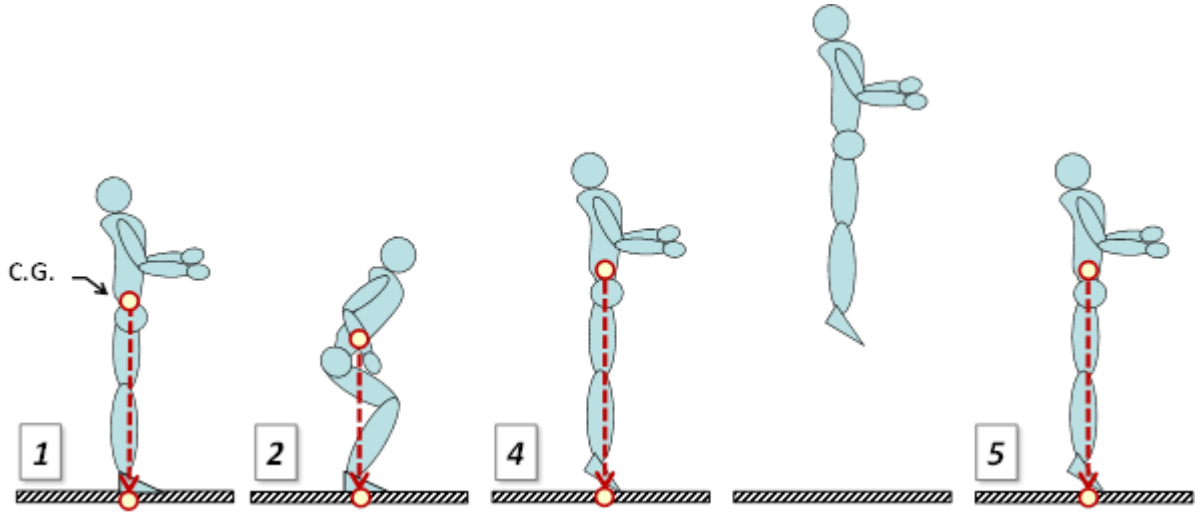
Countermovement Jump *(single jump)*

- Similar to the Squat Jump, but the athlete drops from a standing position
- This introduces Elastic component to the test
- Results will be higher than a Squat Jump



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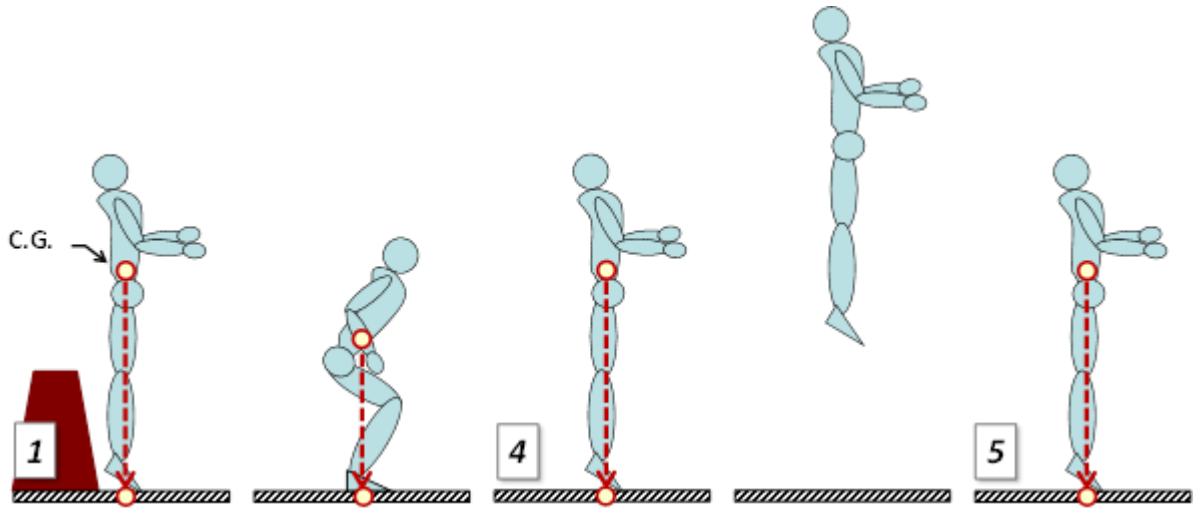
Drop Jump *(single jump)*

- The Drop Jump follows the same positional protocols as earlier jumps described, but introduces an elevated start position
- Dropping off a box brings heightened elastic moments and often a deeper jump
- Again, results will be higher than the static Squat Jump or the Countermovement jump due to greater elastic contribution to the movement pattern



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Jump Measurement Technology

There are many methods to measure Vertical Jump.

Below are descriptions and the Pros & Cons of each type of the common measurement systems.

- **Vertec**
  - The Vertec is perhaps the most common device for measuring vertical reach. As can be seen from the Bosco methods above, it actually measures a different metric - that being 'ultimate reach'. Adopted widely in the US, with the prolific nature of Basketball & Football where athletes need to grab or catch a ball overhead, it gives the ability to reach for that target well above the head.

  - The video found here *(hit Control + point the cursor on here)* shows a similar product 'Yardstick' in use. It should be noted that mechanical device measurements will be on average 11cm or almost 5" higher than a comparable Counter Movement jump using Bosco's method on a Jump Mat.

    * Research conducted by Dr. Warren Young of University of Ballarat Vic in Australia shows a strong correlation between results of these two (2) tests as an indicator of lower body strength even though the heights are different.

  - **Pros**
    - Mechanical & Simple
    - Well accepted
    - Only (1) device required to successively measure many athletes
    - Low cost
  - **Cons**
    - Not overly portable

        - Cannot measure Fatigue
        - Cannot measure Contact Time
        - Cannot Estimate Power
        - Cannot Calculate Reactive Strength Index (RSI)
        - Does not internally record results

- **Jump Mats**
    - Jump Mats use basic switches measuring the athlete time off and on the mat
    - Measure the time the subject is on the ground (Contact time - Ct) and the time the subject is in the air (Flight Time - Ft)
    - **Pros**
        - Contact Time which allows reactive strength measurements
        - Measures the true displacement of Center of Mass of the athlete
        - Allows estimation of power through published peer researched methods – Harman, etc.
        - Allows Multiple jumps to assess Fatigue
        - Portable
        - Allows electronic recording of data
        - Quick testing of a large group is possible
        - Medium cost
    - **Cons**
        - The reaction time of the switch to the de-weighting of the athlete can have a detrimental effect on measured contact time if not designed properly.
        - Does not measure ultimate reach
        - Can be 'cheated' if the athlete extends Flight Time by bending knees before landing … so the coach must ensure this does not happen.

- **Accelerometer based systems**
    - The advent of small MEMS based accelerometers has resulted in a plethora of devices for measuring movement. Vertical Jump is an obvious candidate for these devices.
    - These devices are small & are attached to waist of the athlete, close to the Center Of Mass
    - Using the recorded acceleration wave-forms and the ground impact allows measurement of Contact Time – Ct
    - **Pros**
        - Allows acceleration measurement before the athlete leaves the mat.
        - Small, lightweight
    - **Cons**
        - Cost of implementing these devices across a large testing group is high
        - Data download can be tedious
        - Management of multiple devices can be tedious w/ charging, data download etc.

- **Optical-Based systems**
    - An array of Infrared transmitting diodes and a matching receiver arrays are setup transversely across the jump area. This creates a 'horizontal 'curtain' of light. Any interruption of these beams indicates a movement. The most commonly known product is 'Optojump' from Microgate from Italy.

- Accuracy is very high, in fact, we validate our **ezejump** product against Optojump and are happy to say there is no significant difference between the two products
- **Pros**
  - Can measure left/right foot placement in one (1) direction
  - Can be extended over many meters for gait or sprint analysis
  - Quick testing of a large group is possible
- **Cons**
  - Very expensive
  - Requires a PC connection which limits mobility

Conclusions

All the above systems are valid tests for measuring Vertical Jump, however some are more suited for specific data outcome requirements.

If you are simply looking for a measure of maximal reach, then a mechanical product will suffice.

But, if you are looking for a much wider assessment and more comprehensive data that better explains an athlete's performance including: explosivity, power and fatigue, then you will be better served with a Jump Mat device that can measure the two (2) necessary variables of Contact Time and Flight Time.

- Explosivity
  - With both Contact Time and Flight Time, jump height can be calculated. Then, the ratio between Jump Height and Contact Time can be used to provide the Reactive Strength Index (RSI) which shows athletes' ability to change quickly from an eccentric to a concentric contraction and their ability to develop maximal forces in minimal time.
  - Consider that two (2) athletes - A & B - might achieve the same jump height. Both may be the same weight and height. However, if athlete A generates power in less time, which is observed as a shorter Contact Time, the jump was in fact more 'explosive' than athlete B … thus the 'reactive strength' is higher. This may be an indicator of a range of factors from Fast Twitch muscle fiber percentage to better plyometric training.
- Power
  - Given Contact Time (Ct), Flight Time (Ft) and an athletes' mass, Power and Peak Impulse Power can be estimated using published algorithms.
  - Although these numbers are estimated and may not match power calculated from force plate testing, the results are repeatable and come at a much lower equipment outlay cost than a Force Plate.
- Fatigue
  - Many research papers offer the suggestion that Drop tests and multiple Counter Movement Jump tests can give an indication of general athlete fatigue or overtraining. Some elite teams use such a test on a daily basis to monitor this aspect of their athletes' training and performance load to avoid over training.

* Acknowledgements: Graphics borrowed from http://smartlifting.org/2014/07/il-metodo-di-bosco-per-il-calcolo-dellaltezza-e-della-potenza-meccanica-del-salto-finale/