The Physics of Pole Vault

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Introduction

Over the past thirty-four years I have had the opportunity to coach hundreds of pole vaulters. Most of them were on the Watkins Memorial High School track team, but there were always “guest” vaulters who joined in. I also coached at various camps and clinics, and more recently, I started “independent” coaching.

I learned as much from the vaulters I coached as they learned from me. A significant part of my vault knowledge was gained by “problem solving” their various technical issues. I appreciate the trust they have shown in me, and their willingness to try something different to be better.

I also had the opportunity to be around some great “pole vault minds” in my career. Starting with the legendary coaches Marshall Goss at Indiana University and Bill Falk of Rhode Island University and MF Athletics in the late 80’s and early 90’s, I went to camps and clinics to learn. The greatest influence on my vault knowledge was Coach Mark Hannay. Mark ran the Slippery Rock Pole Vault Camps from the 1990’s to the mid 2000’s. Mark was a true believer in a comprehensive system of talking about and teaching pole vault, he also believed that Vitaly Petrov had “cracked the code” in the physics of vault.

Slippery Rock also served as an incubator of coaching knowledge and discussion, as some of the best coaches in the Midwest debated the finer points of pole vault technique and training (“so what do you do with the left arm, and you can’t flex in until you close off”). It was through those discussions that we tried to discover a common pole vault technique. I have tried in a small way, to recreate that atmosphere at our own camps here at Watkins.

One of the foundations of my coaching philosophy is the belief that an athlete needs to know why they are doing what the coach is asking them to do. A smart vaulter, who is aware of the goals of each part of the vault, will be able to take those ideas and put them into physical practice. It is because of this belief that I decided to write this paper, to try to explain the “physics” of each portion of the vault technique.

Coach and author Dave Bussabarger makes a strong point in Track Coach Magazine in his long running debate about the “Petrov Method”, stating that individual athletes will adapt their technique to their own physical needs. While I am ultimately highly influenced by the “Petrov Method”, I also agree that individuals will adapt to what works for their bodies. The current world record holder, Renaud Lavillenie, is a clear example of this.

So the purpose of this paper: to give vaulters an intellectual reason for the technique I am asking them to learn. I know that those athletes will take what I say, filter it through their own experiences and physical abilities, and come out with a vault “product”. Together, we will work to maximize that product, and hopefully, to vault higher and safer!!!

The Goal

The ultimate goal is to get "upside down on a bent pole". Like any six word answer, it is short, simple, and incomplete. It does give vaulters the visual that I want them to have: the picture of being completely inverted, lined up with the top of the pole, as the pole unbends and thrusts their body vertically above the crossbar. It is the "vision" of Sergy Bubka reaching the bar (that vaulters and coaches of the 90's remember with Van Halen blaring "Dreams" in the background). Check out this youtube selection of him: https://www.youtube.com/watch?v=JlnAFsMh44g. The "model vaulter" that I find most demonstrative of this technique is Maxim Terasov (see https://www.youtube.com/watch?v=v3JTBj7zUaU).

Every segment of the vault, from picking up the pole at the end of the runway, to finishing off above the crossbar, is geared to getting into and using that position. And of course, it's about going higher. So doing this with higher hand holds, improving speed and energy to use bigger poles, all to get to that one point: upside down on a bent pole.

From the Beginning – Holding the Pole

Pick up a vaulting pole. Where and how you hold that pole will determine everything that occurs in the vault. Your hands are the points of contact, the points where all energy will be stored into the pole, and all energy will be returned from the pole. In the "machine" of athlete/pole, it is your hands that become the literal pivot points as you swing into the inverted position. How you hold a pole is important.

Where on the pole (handhold height) you place your hands will be subject of a lot of discussion later in this study (page 18). Right now, the literal question is how to hold the pole. Basics: top hand faces out (from your body), lower hand faces in (towards your body). More advanced question: how far apart should your hands be placed?

The top hand will serve several roles in the athlete/pole machine. When the pole is planted in the box, the top hand is the primary energy imparting point. Most of the energy created in the pole run and the takeoff both horizontal and vertical, should be imparted through the top of hand into the pole. This occurs both in the plant phase, and also in the drive phase after takeoff.

The top hand will also serve as the primary pivot point as the vaulter swings from the head up position, to inversion ("upside down on a bent pole"). And finally, the top hand will serve as the "energy return" point, where the energy stored in the bent pole will be returned (and should the vaulter be in the correct position) will vertically lift the athlete.

The bottom hand has been the subject of a great deal of debate. It certainly plays a role in energy storage in the plant and drive phases. However, as it is farther down the pole (the pole being approximately 1 ½ pounds stiffer per inch from the top) it is not the "best" place to store energy, since the pole is stiffer it is more difficult to store there.

The bottom hand helps store energy in the pole (creating bend) at takeoff. As important, it helps create the correct body position by aligning the body in the "reverse 'C'" position. The position of the bottom hand should be such that, on planting, the top hand being vertical (zero degrees), the lower hand should be less than 45 degrees. In simpler terms, the top hand is directly overhead in line with the vaulter's ear (head is straight) and the lower hand should be up in front of the forehead. A consistent way of placing the hands: find the top handhold position, place the top arm elbow on the pole, place the bottom hand about a "thumb's length" below the elbow.

Why not place the lower hand even lower, perhaps closer to ninety degrees upon plant? That position will store a great deal more energy, and will create enormous bend in the pole. However, there are two problems with this position. First, the bend created through the lower hand will be a "low bend", causing the pole to bend more through the section below the sail piece (below the label). This bend will drive towards the pit, but will unbend with less vertical lift. It will also not create the "space" needed to effectively swing up under the pole, therefore making it more difficult to get inverted, to get "upside down on a bent pole".

Second, it will cause the "pivot point" of the vaulter to become the lower hand/shoulder instead of the upper hand/shoulder. The vaulter will swing up on a lower point, reaching a horizontal position, but being unable to swing above the lower hand/shoulder. Put more simply, the vaulter will only be able to swing to horizontal, then "flag off" the pole at the top.

So why not place the hands even closer together? Check out the youtube video of Cornelius Warmerdam clearing 15'4" (https://www.youtube.com/watch?v=brGUAkC9aO0). He held the world record for bamboo pole vaulting, the technique was to hold the pole with a wide grip (bamboo is heavy) for the pole run, then slide the hands together (bottom hand up) at plant to create a single pivot point to invert. In modern pole vault, while a single pivot point (the top hand) is ultimately what you swing on, the lower hand stores energy on takeoff (unlike bamboo and steel poles which stored very little energy) and creates better body position.

Carrying the Pole

The goal of the pole carry has two parts. Part one is a carry that allows the vaulter to create the most energy in the pole run. Part two is a carry that allows for the most effective planting action without creating "erratic" energy forces creating negative vault outcomes.

How can the vaulter carry the pole to get the most speed down the runway? Running with a pole vault pole is difficult for three reasons. First (and probably least important) is the weight of the pole. While a pole is relatively light (6 to 10 pounds) it still has mass. Second, that mass is increased as the pole is lowered from vertical to horizontal, making the pole "heavier" as felt by the vaulter. Third, the vaulter still need to have good "sprint mechanics" while dealing with the movement of the pole mass, both in dropping and planting the pole, and in controlling erratic movements.

Good sprint mechanics is another way of saying use of a running method that produces the most speed efficiently. Good sprint mechanics includes the following:

- running upright, with a high head, chest, and hip alignment
- running with high knees, creating greater stride length without overstriding
- running with a rapid turnover (recognizing that the turnover needs to be consistent both

So running in the pole vault is much like running in the 100 meter dash after the start and drive phases. Running tall, high knees, rapid stride turnover: all will maximize the speed of the athlete. But the issue in vaulting, is all of that is done while carrying a pole that has weight, and more importantly mass. Every movement of the pole will have some impact on the position, cadence, and speed of the athlete carrying the pole. Therefore, the pole carry has to minimize the "bad" effects of the pole, and maximize the benefits.

The pole should be carried as high on the body as possible. This is different than a "high pole carry" (carrying with the tip nearly directly overhead). Carrying the pole high on the body means to have the top hand at or above the hip, and behind the hip. A more colorful way of saying this, is that the top hand should carry the pole directly above the "butt-cheek". This allows for the following:

- it allows the body posture in the run to remain tall, creating better sprint posture
- it allows for a plant progression that goes directly up the body to above the head, without having to move the pole forward or backward.

The lower hand should hold the pole (using the handhold developed above) so that the pole is in line with the runway. At no point in the run should the pole be diagonal to the direction of the runway. The lower hand should hold the pole so that the pole tip is approximately 45 degrees to vertical. Note: newer vaulters will have the pole tip lower (eye level) to make the planting action easier, as the vaulter improves and the pole length increases, the height of the pole tip on the pole carry will increase as well.
In addition, the lower hand wrist should be bent so that the hand is "up" (palm facing the side of the pole rather than the top of the pole). This allows for an even higher body position on the carry, in addition to setting up a better position for the eventual pole plant.

Here are some things that look like they'd work – but they don't. The first is a high pole cross carry (carrying the pole at what the military would call "port arms"). This carry allows for a high running posture, and therefore good speed while running on the runway. The problem is, at some point in the run, the pole will swing from diagonal to the runway to parallel. At that point, the mass of the pole will transmit the swinging energy (Newton's action/reaction) to the running body of the vaulter. The running body will absorb and adapt to that swinging energy, by altering the step pattern (as the pole rotates, the hips will counter rotate and the vaulter will cross the runway, then compensate by crossing back). Not only does this slow the vaulter down and take energy, but it also makes it more difficult to get a consistent run/step count to the plant.

The second is a low body pole carry: carrying the pole with an extended top arm (hanging straight below the hip). This creates bad running posture, and makes it difficult to maximize speed down the runway. It also allows the pole to pendulum from the "hanging" top arm, either drifting back and forth, or in and out. Both of these actions will cause the hips of the running vaulter to respond (action/reaction) either by lengthening and shortening strides, or by crossing back and forth on the runway. Either of these actions will reduce stride consistency and runway speed. If a vaulter is kicking her/his own leg during the run, the pole is moving side to side.

Third is a low pole carry (tip at eye level and lower) parallel to the runway. While beginners will need a carry like this to manipulate the pole properly in the plant, as a vaulter improves, the tip of the pole should go higher, at least greater than 45 degrees. Holding a pole low will slow the vaulter down, as they lean back against the mass of the pole. It also will cause a lower knee lift on the run, reducing stride length and therefore speed.

Things that work, but "aren't what I'd recommend". First is a pole carry position beginning in front of the hip, then moving back behind the hip two or three steps down the runway. The advantage seems to be that the mass of the pole in front of the vaulter encourages an increase in speed, like the "drive" phase of the sprint. The vaulter leans into the mass pulling forward. My concern with this is that at some point energy in the run has to be expended, and stride length will be altered, by moving the pole back behind the hip. The later that action occurs, the more likely it is to effect speed and technique at the plant phase.

Second is extreme high pole carry (still parallel to the runway). While this reduces the mass of the pole significantly, making it very "light" on the run, it requires a really well executed pole drop and plant. Given that, the higher the carry, the better. An "intermediate" carry is easier to execute properly.

Pole Drop

The pole drop is the part of the pole carry, where the pole is lowered to the box in preparation for the plant/takeoff phase of the vault. The pole drop should be a "free drop", using gravity to simply allow the pole tip to fall to the appropriate place. In a "free drop" state, the pole has no mass that needs to be carried, therefore in terms of the vaulter running, the pole is weightless. That allows the vaulter to maximize speed in the run. Also, a "free drop" allows the arms to move freely in the plant phase.

The difficult part of the "free drop" is developing the timing allowing the pole to drop without assistance, ending in a continuation into the planting action into the box. This requires a great deal of practice, and alters with the length of the pole and the run.

An exception: a "free drop" is much more difficult to execute when there is a crosswind that alters the path of the poles' fall. Crosswinds require the vaulter to exert force with the lower arm handhold to control the direction of the pole, and will therefore make it more difficult to "free drop".

Finally, the "free drop" ends with the pole tip entering the box and the plant action being executed. It should be a continuum of motion, starting from the beginning of the "free drop" and ending with the plant execution and takeoff.

Consistency in Run and Plant/Takeoff

Like the long jump, the pole vault requires that an athlete run down a runway, and places the takeoff foot in a near exact position for optimal takeoff. In short, run very fast for 20 to 35 meters, each time ending with the takeoff foot in the exact same spot. This requires a "system" to create consistency of plant position.

A counting system allows for that consistency. A vaulter begins their approach standing on the runway with their takeoff foot forward and their non-takeoff foot back. The vaulter then begins the approach by taking a first step with the non-takeoff foot, then counting the takeoff foot's step. The vaulter continues to count the takeoff foot "touchdowns" until that foot reaches the plant/takeoff position. Right handed vaulters will count their left steps, left handed vaulters their right. The counting will develop a “memorable progression” that can be repeated on the runway. It will also allow for pole drop and plant timing.

In order to maintain plant consistency through varying numbers of steps, the vaulter should countdown in groups of three (“3-2-1, 3-2-1”).

So a right handed vaulter on a 14 stride (7 left) approach would count as follows:

- take the right step with the foot placed back – make it a driveoff step like pushing out of the starting blocks
- take the accelerating left step (3)
- next right step, continuing to accelerate
- next left step (2)
- next right
- next left (1)

Continue to smoothly accelerate through the next set (3-2) then maintain speed and begin the planting action (1). While executing the planting action, try to make the next right and left steps as quick as possible (flattening the steps) in order to maintain speed and provide for a better hip position for takeoff. The full count would be: 3-2-1, 3-2-1, flat-flat. The pole drop would begin somewhere in the around “3” of the second set, and the “flat-flat” is the last right/left as the plant is being executed.

The advantages of “3-2-1’s” over other counting methods are the ability to increase tempo through each set of “3-2-1’s”, the ability to add or subtract steps at the end of the run without altering the plant sequence (1, 3-2-1, 3-2-1, flat-flat for 8 step, or 1, 3-2-1 flat-flat for 5 step), and the ability to add a mid-point mark in the approach (on the last “1” of the first full sequence of 3-2-1) without difficulty.

Other counting methods are “better than none”. Count-ups and countdowns each still provide a rhythm that can be “remembered” for a consistent run, though they do not have the flexibility of “3-2-1”.

Many vaulters do not count at all, but simply run in using their ability to “steer” their step to the appropriate mark. Steering is the ability to “triangulate” visually where they want to jump from (takeoff step) and adjust their stride length as they approach in order to hit the mark. Many are very good at this.

Steering depends on altering stride length (longer or shorter). In either case, it results in a reduction in approach speed. In order to steer effectively, a vaulter will by definition have to slow their run, an outcome that is not optimal. Steering also depends on a visual estimation (instinctively) using such factors as the pads of the pole vault pit to work. Therefore, differing pit sizes can change the triangulation equation, making it a problem to plant. Finally, steering is dependent on a set takeoff point (distance from the “zero point”). As a vaulter progresses, handgrips go up, and the takeoff point moves out. Vaulters who “steer” only, will instinctively move back to their old takeoff point, therefore having “under” vaults.

Counting allows the vaulter to systematize their approach, based on a counting rhythm and not on a visual triangulation. It creates a system of cues (pole drop on 3, plant on 1) giving the vaulter a definite answer for when to execute those actions. Counting creates a vault “equation” with defined variables, variables that can be systematically altered to reach the optimum outcome. Vaulters should have a counting system.

Physics of the takeoff phase

In the takeoff phase the vaulter/pole machine converts the horizontal energy of the run into the vertical/horizontal energy of the vault. There are several considerations in these actions. First is "pole rotation". This is the rotation of the pole around the pole tip as it goes from near horizontal (at the plant) to vertical. "Standing up the pole" means to get it past vertical, it is the definition of a safe vault (as a vaulter on a pole past vertical will be in a safer position to land in the pit). The higher the plant angle (the more acute the angle of the pole is to vertical) the closer the pole is to being "stood up" and therefore the safer the vaulter. Raising that plant angle, either by making the plant action more effective, or by gripping lower on the pole (or using a shorter pole) all has the effect of speeding up pole rotation and getting to vertical sooner.

"Pole bend" is the storage of energy in the fiberglass pole. The bend of the pole does several things. It "shortens" the pole, allowing a pole of longer length to be rotated to vertical. In other words, rotating a straight pole (no bend) to vertical requires more energy than rotating that same pole with bend to vertical. This is one of the reasons that fiberglass pole vaulting has allowed for higher height clearances.

A bending pole does allow for a higher handhold (or longer pole), but it is still the energy provided by the vaulter in the plant that "stands the pole up". The higher the handhold, the more energy is required. Vaulters should not confuse pole bend with pole rotation, pole rotation is the critical safety factor.

"Pole bend" also allows energy to be stored that will be returned to the vaulter as the pole unbends. IF the vaulter is in the appropriate position (upside down on a bent pole) the unbending pole can thrust the vaulter vertically over the crossbar. IF the vaulter is in less than an optimal position, the unbending pole will still transmit energy back to the vaulter, and depending on the vaulter's position, the vaulter will go in a given direction.

The Plant

The plant is the most significant part of the pole vaulting action. The plant is the point where energy transfer occurs, where the pole/vaulter machine goes from horizontal velocity creation to vertical energy creation and use. The plant is the technically most difficult part of pole vaulting. It's not just important: if the vaulter doesn't get the plant right, then the vault doesn't work.

The optimum plant will look like this when the pole tip hits the back of the box:

- The top hand will be directly above the toe of the takeoff foot (plumb takeoff)
- The top hand will be directly above and behind the vaulter's ear
- The vaulter will be as "tall" as possible, head high, chest high, and hips lifted
- The lower hand will be in front and above the vaulter's head.

As the vaulter begins to takeoff, the drive leg (right for right handed vaulters) will aggressively drive up to a 90 degree position, while the takeoff leg (left for right handed vaulters) will press up (vertical takeoff) and back (leg "drag") off of the ground. The takeoff action should be a "leap" off of the ground, without losing momentum from the pole run. This action is similar to a vertical bounding action, or a long jump takeoff.

The plant action is the motion of taking the pole from the "high body carry" position to the optimum plant position. It should be executed at the conclusion of the "free pole drop" so that the entire action, from the beginning of the pole drop to the takeoff, is a continuous action. As the pole drop passes through the horizontal, the top hand goes from the back of the hip up the side of the body to just under the armpit, then shoots directly overhead. The lower hand goes from chest high body center to follow the rising pole to a position in front and over the head. This is a "straight line" action: the top hand goes in a straight line from the hip to the overhead position. The lower hand goes from the mid-chest position in a straight line to its final position.

Clearly, the top hand shoulder is "in the way" as the pole moves from under the armpit to vertical above the head. While some coaches teach varying forms of "shoulder shrugs" to get the pole past this position, I find in my coaching that athletes will do this naturally without a lot of cuing or coaching.

The top arm is completely extended up just prior to the pole tip contacting the back of the box. The shoulders remain perpendicular to the runway. The extension of the lower arm depends on how high the handgrip is on the pole. As the vaulter is able to hold higher on the pole, the lower arm will be able to further extend. However, with lower handholds the lower arm will be bent. The critical point: the top arm needs to be fully extended and in proper position overhead. This will determine the location and the bend in the lower arm. Low handholds will require the lower arm to be bent to 90 degrees, high handholds will allow for a fully extended lower arm. If extending the lower arm causes the top arm to be pulled forward (towards the box) and out of line with the vaulter's head, then it should be bent.

The physics of the plant is complex. The vaulter has created tremendous horizontal energy by executing an optimum pole run. That energy is then converted into multiple areas. First it is converted into vertical energy, much like the long jump, as the vaulter jumps off of the takeoff leg. That vertical energy is added to by the driving of the drive knee, which helps translate the horizontal velocity into a more vertical one (approximately 22 degree takeoff angle).

Energy is also stored in the pole from the vaulter's takeoff position. There are different ways to store energy in the pole, many of them inefficient or even dangerous. As the pole is a bendable lever, it is easier to store energy higher in the pole than lower (the lower the energy storage, the stiffer the pole, and therefore the less energy is able to be stored). A high plant, with the majority of the energy stored through the position of the top hand, will store more effective energy in the pole.

The energy stored in the pole is crucial, as this energy, along with the vertical energy created by the vaulter in the jump, will create the energy used to both go higher and achieve safe penetration into the pit. Effective energy storage is an important consideration. For example: a top hand/takeoff foot position that is outside of plumb (an "out" takeoff) will store a great deal of energy in the pole. However, that energy will be almost completely horizontal, generating a huge bend in the lower part of the pole, but not creating enough pole rotation to allow for a good vault and safe penetration into the pit. That energy will be returned to the vaulter, but following Newton's law of action/reaction, it will return energy in the same horizontal plane it was stored. In short, it will send the vaulter back down the runway, putting the athlete in a dangerous position.

Energy stored effectively in the pole will create a higher bend in the pole, allowing for the vaulter to both rise vertically as well as rotate the pole horizontally. This puts the vaulter in a safer and more efficient position to vault higher.

Finally, the plant also should serve as a energy storage activity for the vaulter's body. By placing the top hand directly overhead, and by driving the takeoff foot back (pushing back off of the ground as long as possible) the body will store energy (stretch energy) through the arm, chest, hips and legs. This stretch energy will be the energy used to swing the vaulter's body upside down in the "swing-up" phase discussed later on.

Energy will be stored in the plant. This includes erratic energy that could result in vaulter's straying from a straight path into the pit. A "roundhouse" plant, following a circular path from the hip to the overhead position, will result (action/reaction) in a response from the vaulter's moving body. As the right side (right handed vaulter) swings through the circle of a "roundhouse" plant, the hips will absorb this energy and rotate in the opposite plane. Therefore, a circular motion with the arm will create a left to right rotation of the opposite hip. This will cause the hips to be diagonal to the runway, causing the left leg to cross over the runway, and the left foot takeoff to be off-center. This will cause the takeoff drive to be off-line. And finally, this will cause the vaulter to land to the right side of the pit.

To some extent an "under" plant can create some of the same erratic forces. A slightly under plant (6" or less) will cause the pole to start to lift the vaulter prior to the vaulter takeoff. This is a less than efficient storage of energy, as both the takeoff position is lower (the height of the top hand position) and the amount of energy stored is less (used in lifting the vaulter rather than the vaulter getting an optimum takeoff with the pole). A plant that is further under will cause the hips and even the shoulders of the vaulter to rotate as the takeoff leg gets far out of line. This will cause the hips to go diagonal to the runway, causing the vaulter to jump off angle. In addition, turning the shoulders will accentuate the off angle jump, putting the vaulter at risk of missing the pit. Finally a badly under plant will cause such energy loss, that the vaulter will not be able to create enough horizontal energy to make the pit, and could land short of safety.

There has been a great deal of controversy in the pole vault community regarding the timing of the plant action. Advocates of the Petrov method, including myself, speak of a "free takeoff". This takeoff occurs at exactly the moment that the pole tip reaches the back of the box, such that the vaulter is jumping up on a pole that is still straight. The vaulter leaving the ground and the pole striking the back of the box are simultaneous.

This is similar if not the same as an "on takeoff". The distinction that should be made is the difference between an on or free takeoff, and a takeoff that occurs after the pole tip has struck the back of the box. On those takeoffs, the vaulter is jumping up into an already bending pole, and misses an opportunity to store more vertical energy in the pole.

Some vault coaches go even farther, and suggest that vaulters should "pre-jump". This is a takeoff where the vaulter actually strives to leave the ground prior to the pole tip contacting the back of the box. The theory of pre-jumping is that this increases energy storage by raising the angle of the plant (the top hand will be even higher on takeoff). The concern is that the vaulter will have already expended the vertical jump energy prior to the pole bending, and therefore will store more horizontal energy into the pole.

Pre-jumping requires the vaulter to maintain the vertical plant position through the takeoff phase as the pole strikes the back of the box. Vaulters cannot "push" the plant forward to the box, as that will reduce the plant action, and ultimately create just an "out" plant with all of the issues and dangers listed above.

In viewing thousands of vaults from rookies to world class, I have seen very few examples of effective "pre-jumpers" (one example: Swetlana Feofanova's vault in Munich at 4.60 meters, http://www.stabhochsprung.com). Most of the vaults at the world class level are of the "free-takeoff" variety.

Here are some things that look like they'd work – but they don't.

Vault taking off from 12" to 16" under the top hand. Many vaulters do this not because they want to, but because they are unable to adjust their steps to higher handholds. They do swing up to vertical quickly. However, because of the lower plant angle, and the pole losing energy by "lifting" the vaulter, the pole often does not have enough pole rotation to make the pit. It is a dangerous situation, as the vaulter gets swept up quickly, may well be inverted, but might not be far enough into the pit to land safely.

Drive the lower arm straight into the pole (pushing out), using a wide gripped carry. This will create a great deal of bend in the pole. If the other parts of the plant are correct (step is on) then the vaulter will be able to takeoff, and the straight push into the pole will generate a large bend. However, this large bend will be located in the lower portion of the pole, and will not have the vertical component that a high plant bend would have created.
Pushing into the pole with the lower arm will bend the pole from a lower handhold (where the pole is significantly stiffer, approximately 20 to 30 pounds) and therefore will not store as much energy. In addition, it will create a block to the drive/swing preventing the vaulter's body from storing swing energy, and will keep the vaulter from swinging above the lower arm's shoulder.

Finally, the plant should be as high as possible, directly over the top of the head. It should be a vertical action, and should not be pushed forward, as that will lower the plant angle, requiring more energy for pole rotation, and place the torso behind the "peak of the pendulum", which will dramatically reduce the effective of the "drive/swing" phase.

Drag - Drive – Swing Phase

The Drive-Swing phase begins from the moment the vaulter leaves the ground with an effective plant. The vaulter begins in the "plant position" (see above). The vaulter drives the chest forward, and presses both the top and lower arms up into the pole. Note: the lower arm can press up into the pole even though it may remain bent. Pressing both arms up is opposed to pushing both arms towards the pit. Pushing will prevent the vaulter from storing energy in the body and pole, and will prevent an adequate swing-up. Pressing simply increases the "plant height", and allows the top and bottom hand/arms to "drag" back behind. This will result in the vaulter's head going from being aligned with the top arm, to the base of the "triangle" formed by both arms with the head in the middle.

The takeoff leg presses off of the ground as long as possible. This is not a "slow" action. The takeoff is a leaping action, with the takeoff leg pressing back after takeoff. The ultimate position will put the vaulter in the "reverse C", with the top of the "C" being the top hand, the body of the reverse "C" going through the head and body, and the bottom of the "C" the extended takeoff leg.

While the terminology is to "drag" back, the term drag is somewhat misleading. Drag sounds like a passive action, but in fact, it is an active muscular movement. Both arms are pressed up, as well as the shoulders. This allows the shoulders to pivot, creating the "drag". The takeoff leg is also physically pressed back, creating the leg "drag". The result of this dragging action is tremendous energy storage in the vaulter's body. That energy will soon be used in the Swing-up phase of the vault, as the vaulter inverts.

The Drive phase continues to store energy in the pole, as well as the vaulter. While the Drive phase is relatively short, it is crucial to the goal of "getting upside down on a bent pole". There are multiple ways to "mess up" the drive phase. The first is to try to swing too soon, before the energy storage has occurred. This particularly occurs in later vaults, when the focus of the vaulter or coach becomes getting inverted. They get in a hurry, and the vaulter leads with the hips from the ground instead of the chest, causing the body to start to swing up. The end result of this is that the vaulter does not get fully inverted, and may well not get enough penetration to complete the vault safely. The second is to "pull" the takeoff leg, bending the knee and "reaching" for the bar. This also creates an early swing preventing the vaulter from fully inverting.

The final controversy regarding the Drive phase is the action of the drive leg (the front leg with knee drive on takeoff). The Petrov model has the drive knee continuing to "rise" through the Drive/Swing phase of the vault. The knee does NOT drop, in fact it continues to drive up and forward. However, there are several world class vaulters who do in fact drop their lead knee. In Lavillenie's world record vault, he clearly drops (but does not unbend) his lead knee (https://www.youtube.com/watch?v=mvA7AZEyciM). 2008 Olympic Gold Medalist Steve Hooker has a similar action (https://www.youtube.com/watch?v=Tk8BC_S3_gQ). And Ohioan and Tennessee Volunteer Jake Blankenship clearly doesn't drive his knee until he begins his swing phase (a dropped lead leg at takeoff) (https://www.youtube.com/watch?v=L_iGVZOTl3w). The impact of this is to increase the horizontal energy of the drive phase by delaying the beginning of the swing phase.

However, there are many more examples of world class and world record vaulters keeping the
drive knee up, including women's record holder Yelena Isinbayeva (https://www.youtube.com/watch?v=PwJsmDowiYU) . This is an area where as a coach, I believe that vaulters adapt to their own bodies, finding effective ways to achieve their goal of vaulting high. I do believe that there is a penalty to be paid for the dropping lead knee, which is a slower swing-up phase (though it's tough to see that in Hooker's vault).

In my experience as a coach, vaulters that drop their lead knee have a more difficult time either swinging up to the top of the pole (full inversion), or, if they do get to the top of the pole, do so "late" and get less vertical lift from the unbending pole. Training athletes from the ground up, I would avoid having them drop the lead knee, emphasizing the knee as a vertical energy creator.

Swing-Up (Close-off)

The swing up is considered part of the drive/swing phase, because without the appropriate setup in the drive, the swing-up doesn't occur. The swing up is when the vaulter goes from the plant/takeoff/drive position, to complete inversion. The swing up is the part where the vaulter gets "upside down on a bent pole".

After an effective plant/takeoff/drive the pole bends towards the pit. As the bend rolls of the pole to the sail piece, or thickest part of the pole, the pole will begin to swing to the side (the side opposite to the top hand, right handed swings to the left, left to the right). As the pole swings to the side, the vaulter will slow down in travelling towards the pit. This slow down, and the swinging of the pole, are the "triggering event" for the swing-up.

As the pole's momentum towards the pit slows, the energy stored in the vaulters body during the takeoff and drive phase will begin to be released. The takeoff leg will start to swing through and up. The vaulter will keep the leg long (and the drive knee up). The vaulter "closes off" which means that both the top and bottom arm drive from the takeoff/drag position to the vaulter's shins. This is the swing-up action, with closing off meaning to close the angle between the hands and the legs.

The swing up is a pendulum action, with the vaulter's body swinging on the long pivot point of the top hand. At this point the bottom hand needs to allow the pole to swing to the side, not block the pole towards the pit. The takeoff leg stays long, as far away from the pendulum pivot point (the top handhold) as possible. The drive knee stays tight and continues to drive upward, creating the balance that allows the vaulter to swing the takeoff foot all the way to and past the top of the pole.

The process of swinging up creates a momentum force at the end of the pole, and therefore keeps the pole bent. As soon as the swinging stops, the pole will begin to unbend. It is critical that the vaulter maintain the swing (the long takeoff leg and extended top arm) through to the "top of the pole" and even past. Shortening the takeoff leg, or pulling with either arm, will cause the swing to stop, and the pole to begin to unbend.

This is the point where dropping the drive knee will change the momentum of the pendulum. A dropped drive knee (double leg) makes the pendulum too slow, and makes it difficult to fully invert. In order to overcome the added mass at the end of the pendulum, double legging vaulters need to bend both knees as their hips reach horizontal, then "curl and shoot". While many have a great deal of success with the "curl and shoot" method, the process of the slower swing and the curling process slows the process of inversion, which means that the vaulter takes longer to get "upside down on a bent pole". That limits the amount of energy return from the pole.

Many coaches emphasize the arm action in the close off, talking about "active hands" as they focus on driving the arms to the shins. In addition many coaches spend a lot of training time on drills and exercises to build core strength to increase the ability to close off. While I certainly agree that every bit helps, I believe the vast majority of the energy driving an effective close off is the swing energy stored in the drive phase. The power of the swinging takeoff leg creates the swing-up. While I agree that the hand/arm drive also helps, I am concerned that an over-emphasis on arm actions will interfere with the "dragging" action, an action that creates a great deal more swing energy. In short, drag back on takeoff, then drive forward on swing up: do both.

There are some things that look like they work, but they don't. The biggest mistake any vaulter makes in the drive/swing phase of the vault is "pulling" on the pole with either arm, but particularly the top arm. As young vaulters begin to compete and clear bars, it seems completely natural to use their top arm to lift their body higher over the bar. Certainly there will be a point in the vault where the top arm goes into action (the pull and turn phase) but pulling with the top arm early stops the pendulum, causing the swing up action to end. As vaulters move onto longer poles, the timing of the actions at the top of the pole changes, and the vaulter needs to alter or delay when the pulling action begins.

Vaulters struggle with what to do with the lower hand/arm during the swing phase. After the lower hand has pressed up into the pole at takeoff, then "dragged" to above the head, and the pole has begun to swing to the side, then the lower hand/arm participates in the close off action, driving to the shins. If the vaulter doesn't allow the lower arm to drag, but instead pushes into the pole on takeoff, the pivot point in the swing-up will become the lower hand instead of the upper hand. The shorter pivot point will shorten the pendulum which increases the swing-up speed, but the vaulter will only pivot to the lower point, then stop. The swing only gets to horizontal, and will force the vaulter to either curl and try to shoot, or "flag off" the pole never fully inverting.

Flex-in

The flex-in action is when the vaulter, after closing off, becomes inverted. It starts by a rotation of the lower arm/hand and bending of the elbow. The arm rotates to the outside (thumb rotates down and away) and the elbow flexes, drawing the back of the lower hand towards the vaulter's chest. The lower arm elbow bends and raises so that ultimately the pole nestles between the vaulter's wrist and elbow. The upper arm remains long, pressed against the inside of the thigh of the takeoff leg. At the same time, the vaulter brings hips to the pole, extending the body up the pole and allowing the shoulders and head to "drop back" (the purpose of the "Bubka drill"). The view is one of being "at attention" upside down on the pole, with the feet vertical and the head down and aligned with the pole.

The goal of the vaulter is to be as close and aligned to the pole as possible. Hitting this position on a bent pole will allow the vaulter's body to absorb all of the energy of the pole vertically. The pole literally unbends through the vaulter, thrusting up. Since the vaulter still has horizontal momentum through pole rotation, the vaulter is shooting up over the crossbar while still travelling towards the pit.

In my experience, vaulters who first experience the position of getting "shot vertically" get disoriented and confused. They feel that they are going vertical, and don't feel the continuing momentum of pole rotation. Their interpretation is that they are going straight up (and coming straight down) and they often "bail" out of the vault. That is a normal and appropriate response, and it takes several experiences with vertical lift to build comfort with the positions.

Here are some things that get in the way of full inversion. Pressing out with the lower arm, causing a space between the body and the pole, will cause the swing-up to end early, and the vaulter to come off the pole at an angle. Watching the crossbar, and therefore dropping the chin in order to maintain eye contact, will cause the body to bow away from the pole and again angle off of the pole rather than vertically. Finally, pulling on the pole or turning early will create space, and again, the vaulter will not get vertically “shot”.

The pole bend will send the vaulter in some direction. An unbending pole is a powerful force, and if the vaulter is not vertically aligned, the power of the pole will follow the direction of the vaulter. A vaulter who “flags off” of the pole, turning over the crossbar, is one who either stopped the swing or came up too late to “beat the pole” to the top.

Pull – Turn – Extend

Once the vaulter is in the goal position, “upside down on a bent pole”, lined up with the pole to get shot vertically, the rest is a matter of timing. As the pole unbends the vaulter will time the “pull” on the pole. The pull is when the vaulter finally gets to bend the top arm, thrusting it from the takeoff leg thigh up and along the body past the head. The lower arm also thrusts along the body, trying to add to the vertical thrust of the pole. The vaulter tries to maintain close alignment to the pole throughout the pull, following the thrust line of the unbending pole to maintain the vertical energy.

At the same time as the vaulter thrusts up, the vaulter begins to execute the turn. Turning is simple IF the vaulter has fully inverted. Turning is more difficult when the vaulter is not fully inverted and has to turn while coming off the pole at an angle. Inverted turns are cued be a simple cross of the feet, takeoff foot over drive foot. The turn should be executed on the runway side of the crossbar, as the vaulter is still travelling vertically. At that point, the vaulter should try to extend off of the top of the pole, releasing first with the bottom hand (the bottom hand at takeoff) and then the top hand.

There are many drills that simulate the pull, turn and extend, however many of them are based on strong muscle actions. While these may be of some help, getting in the proper position creates the conditions for an effective pull, turn and extend. If the vaulter fails to fully invert, or meets the unbending pole as it straightens and doesn’t get the energy from the pole, then pulling will be a difficult task. It’s not the pulling that requires muscle, it’s not being in the right position at the right time.

Pike – Cup – Snake - Smile

The final stage of the vault is perhaps the least practiced. And while on most vaults it won’t matter (if you did everything else right) it will be on the best vault, the one at the personal best height, that the vaulter will need to do it all. So, instead of just “flying away”, thrust high over the crossbar by the vertical impetus of the pole aligned with the vaulter’s body, here’s how to do it right.

The vaulter continues to extend vertically from the top of the pole and higher, maintaining the erect position established in the flex-in stage. When the vaulter releases the pole, the thumbs of both hands should be rotated clockwise so that the palms of the hands face out away from the pole. If the pole could strike the crossbar, the right hand should “flick” the pole back away towards the runway.

This sets up the cup and snake phases of later on. As the vertical lift slows, the vaulter pikes at the hips, creating a rotation over the cross bar with the hips as the pivot point. The vaulter should keep the thumbs/hands rotated out, creating a “cup” between the hips and chest as the arms hang “draped” over the crossbar. Finally the vaulter rotates down on the backside of the crossbar, first the bottom hand arm then the top are snaked over the bar.

Cupping and snaking will prevent knocking the crossbar with the chest as the vaulter clears the bar. It will keep the chest and arms away from the crossbar, the body parts most likely to knock the bar off on a great vault.

And finally, smile on the way down – after an outstanding vault!!!!!!

Conclusion

Pickup – Carry – Drive Off – Lift – Count – Drop – Plant – Takeoff – Drag – Drive – Swing – Close Off – Flex In – Pull – Turn – Extend – Pike – Cup – Snake – Smile!!!

These are the 19 steps to a successful vault. Each can be drilled separately, but to make it all work, it has to be a continuous flow of action, timed perfectly. It's a lot of work – but it's what makes pole vaulting something more than just another event in track and field.

> "***It's*** *supposed to be hard. If it wasn't hard, everyone would do it. The hard...is what makes it great!"*
>
> *Tom Hanks*

Choosing the Right Pole Vault Pole

Picking the right pole vault pole starts with the following "rule": the right pole is a legal pole. "Legal" means that it fits the rules established by the National Federation for a legal pole for the weight of the vaulter. The rule is simple – a vaulter must vault on a pole rated at or more than their actual body weight (with uniform and spikes).

Next is pole length, which is determined by the "grip" height of the vaulter. Grip height is where the vaulter's top hand (right hand for right handed) is located on the pole. Grip height will determine whether the vaulter is able to penetrate into the pit. The higher the grip height, the more technique/ability is required, but of course the higher the grip height the greater height that is possible to vault.

Beginning vaulters will start with a "reach grip". This means that the vaulter stands the pole straight up, then reaches with his top hand as high as he can grip. He then moves the hand 6" further up the pole. This is the starting position for all beginners. It allows the vaulter to learn the beginning drills and to easily swing up into the pole vault pit.

The pole weight at this time really doesn't matter, as long as the pole is legal. The pole is not going to bend holding this low anyway, nor should it. The pole length should be as short as possible in order to make it easier for the beginner to manipulate. In our program, we start beginners out on 11'6" or 12' poles.

As the vaulter improves in skills, the grip height is moved up the pole, one grip (the width of the top hand) at a time. This continues until the vaulter is actually holding in the actual "grip range" of the pole.

The "grip range" is the grip area where is pole is designed to be used. For a pole vault pole to perform (bending and unbending) as designed, the top hand needs to be within a certain distance of the top of the pole. For Spirit Poles (made by UCS) the grip range is from 6" down from the top of the pole (where the weight band of the pole is located) to 18" from the top of the pole (an area of 12"). Other pole brands have a grip range that starts higher on the pole (wherever the top grip label is legally placed) and extends 12" down the pole from there.

To "top grip" a pole is to grip as high as legally possible. To "grip down" on the pole is to hold lower in the grip range. To "cap" a pole is to vault holding above the grip range (this is not legal in National High School or USATF Youth rules).

As vaulters progress in their training and technique, and move their handhold into the grip range of a pole, they will begin to bend. While bending a pole isn't "the goal" (vaulting higher is) correctly bending the pole will enable the vaulter to vault higher.

Once a vaulter begins to bend the pole (again – it must be of legal weight for the vaulter) coaches can begin to determine the correct pole. That determination is made be watching the vault, and the landing. Using the attached pit diagram (figure 2), if the vaulter is landing too close to the box (Zones 1 and 2) then the coach should LOWER the vaulter's grip on the pole. This will make it easier for the vaulter to penetrate into the "coaching box" (Zone 4) (by shortening the lever of the pole, the pole rotation speed increases making it easier for the pole to move to vertical) where the vaulter will land safely.

As the vaulter continues to progress in speed/strength and technique, the coach can continue to move the handhold up towards the "top grip". While making sure the vaulter is landing in the "coaching area" (area 4 in figure 2), the coach should also look at the standard setting for the crossbar. Good vaulters will have deeper standard settings, but if the standards are all the way back (31 ½ inches or 80 centimeters) and the vaulter is "peaking" (reaching maximum hip height over the bar) beyond the bar; then it is time to move to a stiffer pole.

Note – grip height is determined by pit penetration. It is not an issue of "l want to hold higher" or "I top grip every pole". Top gripping a pole that is 12" longer without progressing onto it is a recipe for disaster.

The progression for moving to stiffer and longer poles is systematic. As seen in the pole progression diagram (figure 1) the top grip range of a pole is exactly at the bottom of the grip range of the pole that 's 12" longer.

In addition, as you move down the grip range of any pole, the relative "stiffness" of the pole will increase, approximately 1.5 pounds per inch. What this means, is that a 12'1" pole, rated at 140 pounds (at the top of the grip range) will feel stiffer by 1 ½ pounds per inch as you grip down, reaching a feel of 158 pounds at the bottom of the grip range.

Keep two things in mind:

- just because it feels like a 158 doesn't make it a 158, and therefore only 140 pound or lighter vaulters can use the pole
- while the pole feels stiffer holding down, it also makes the pole a shorter lever, increasing pole rotation, and therefore easier to get to vertical and get into the pit. Therefore, while holding down on a pole will make it feel stiffer, it also WILL make it easier to penetrate the pit to a safe landing.

So the system for determining the "right" pole is as follows:

1. The vaulter is on a legal pole
2. The vaulter is landing deep in the pit (Figure 2 - zones 4, 3, or 7)
3. The vaulter is peaking (hip height) beyond the crossbar (set beyond 30")
4. The vaulter is holding at the top of the grip range – or is over penetrating with a lower hand hold

If the vaulter is vaulting on a pole within 15 pounds of his body weight, then the vaulter needs a stiffer pole of the same length. Once the vaulter is vaulting on a pole at least 15 pounds stiffer than his body weight (holding at the top of the grip range) then the vaulter can "move up" to a longer pole (12" longer), holding at the bottom of the grip range on the new pole, and vaulting a pole rated at his body weight.

Here's a scenario:

Kyle is a 123 pound eighth grader. He is clearing 10'6" on a 12'1" pole rated at 130 pounds. He is holding at the top of the grip range. His standards are set at 30, and he is knocking the bar off on the way up. He is landing deep in zone 4.

The next move: put Kyle on a 12' 1" 140 pound pole (12' Spirit poles come in 10 pound increments).

If Kyle continues to over-penetrate the next move would be a 13'1" 130 pound pole, holding at the bottom of the grip range (the equivalent of a 12' 148 pound pole).
Then it's a matter of raising the grip height, maintaining penetration, and increasing clearance height until we reach the next barrier – moving onto a 14' pole.

To summarize – when is it time go to a stiffer pole

- When the vaulter is landing deep in the pit and hip height is passed the bar
- when the vaulter is less than 15 pounds lighter than then the "pole weight"
- when the vaulter is holding below the top of the grip range

When is it time to go to a longer pole

- when the vaulter is landing deep in the pit and hip height is passed the bar
- when the vaulter is 15 or more pounds lighter than the "pole weight"
- when the vaulter is holding at the top of the grip range

There is at least one exception to these rules. A vaulter who is unusually tall may find that simply because of their plant angle (extremely acute) they may need to move onto longer poles sooner than the "15 pound over" rule simply to make the pole "work".

Issues with Pole Selection

6" increment poles

While poles are designed for 12" transitions – 6" poles can make it easier.
Spirit Poles are available in 10'8", 11'7", 12'1", 13'1", 13'7", 14'1", 14'7". 15'1 and 15'7" increments.
When matching grips, the 11'7 would match the MIDDLE of the grip range of a 12'1". The difference would be 9 pounds instead of 18 (which would make it easier).

Also – 6" increment poles can be a big advantage for undersized vaulters (height). Some shorter guys can get on 14'7" that can't manage to get 15'1 poles to work.

16'1" poles – the 1½ pound per inch system does NOT work for 16'1" poles. Moving onto 16'1"s requires a very technically proficient vaulter. Few high school vaulters are ready for that.

Pole Manufacturers

There are no "bad" pole vault poles, other than perhaps the ones that somebody found underneath a tarp in an old shed. All of the manufacturers meet specific standards for the test weight of the pole. So what's the difference?

The way the pole is wrapped with fiberglass

- different manufacturers use different wrapping patterns which both determine the diameter of the barrel of the pole, and the overall strength of the pole

The material used in pole manufacturing

- some poles are manufactured with carbon fibers mixed with fiberglass. This makes the pole lighter for the same length and weight (versus a fully fiberglass poles)

The position of the "sail piece" in the pole

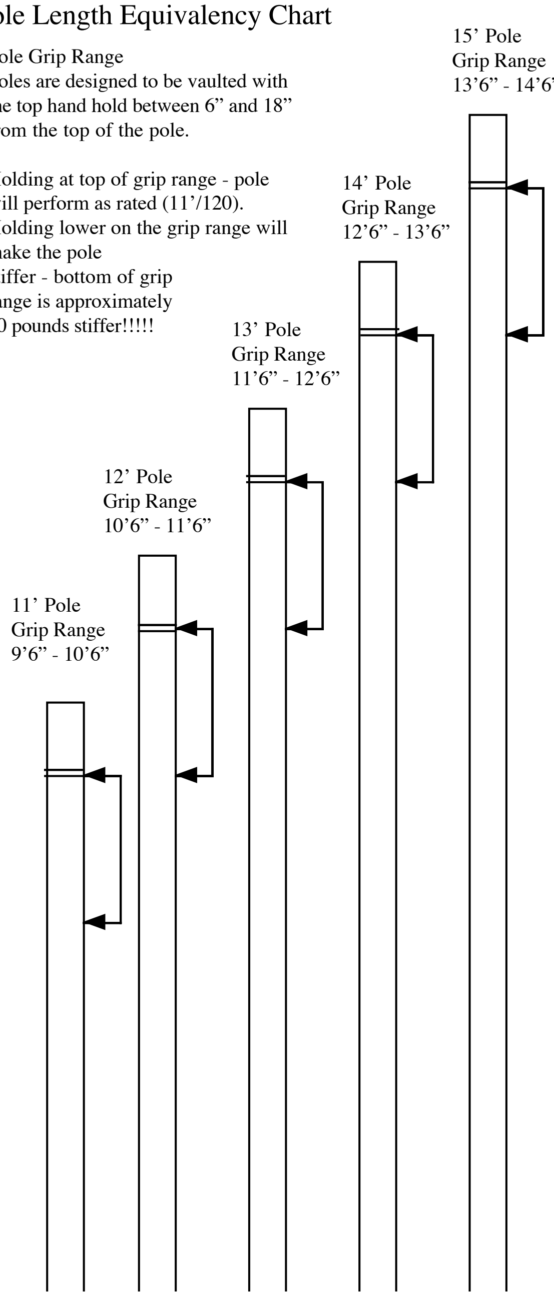
- the sail piece is the thicker section located somewhere near the middle of the pole. The sail piece is where the pole is stiffest, and normally the pole will bend towards to pit up to the sail piece, then swing to the side and start to unbend. The higher the sail piece is in the pole the more difficult it is to get penetration into the pit – but the more power the pole has as it unbends.
- The lower the sail piece, the easier it is to penetrate into the pit, but the unbending is slower and less powerful
- "High School" advertised poles usually have lower sail pieces

Most schools have to "use what they've got". If you have the opportunity to have a series of poles, staying with the same manufacturer helps reduce the variables other than weight and length. If you have to change manufacturers, the other variables listed above might come into play as well.

Pole Length Equivalency Chart

Pole Grip Range
Poles are designed to be vaulted with the top hand hold between 6” and 18” from the top of the pole.

Holding at top of grip range - pole will perform as rated (11’/120). Holding lower on the grip range will make the pole stiffer - bottom of grip range is approximately 10 pounds stiffer!!!!!



Factors in Determining when to move up to a longer pole.

1. You are holding near the top of the grip range of the current pole you are on.

2. You are vaulting on a pole that is 10 to 15 pounds stiffer than you actual body weight.

3. You are landing safely in the center of the pit or deep in the pit

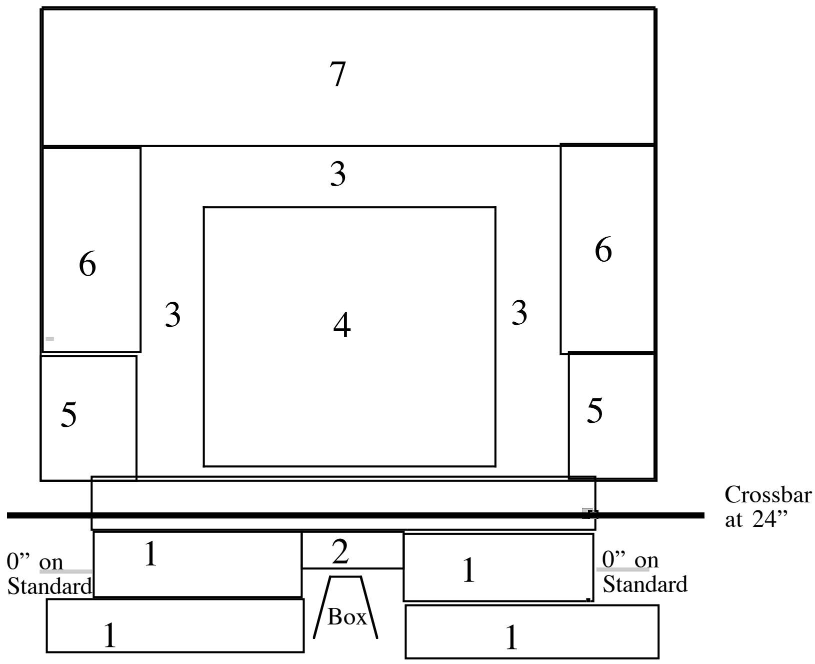
Example
Joe - weighs 135
Is on a 12’140
Is holding at the top of the grip range (11’6”)

When can Joe move up to a 13’ Pole?

If Joe moves onto a 13’140 now -- with an 11’6” grip, he will be vaulting the equivalent of a 12’150

When Joe can vault a 12’150 holding at 11’6”, then Joe is ready to move onto a 13’/140.

Pole Vault Pit - Diagram for Coaching Diagnosis



DANGER! Area 1 - not enough energy - handhold too high - step under - plant off line

DANGER! Area 2 - not enough energy - step under - handhold too high

Area 3 - safe area energy adequate

Area 4 - in the coaching box - adequate energy and form

DANGER! Area 5 - Plant off line - "roundhouse plant" or late - step way under

Area 6 - adequate energy - plant off line - roundhouse or late

Area 7 - need to move to stiffer pole

Glossary of Terms

"3-2-1"	a counting system for running in field events
active hands	to focus on the hands driving towards the legs during the close-off phase
Blankenship, Jake	2015 NCAA Pole Vault Silver Medalist (double leg takeoff)
box	the metal area where the pole vault pole tip is placed prior to vaulting
Bubka, Sergy	Former Soviet World Record Holder (Petrov method success!!!)
Bussabarger, Dave	Noted Pole Vault Author in Track Technique (Track Coach) Magazine
cadence	a rhythm in walking or running (hup – two – three – four – hup!!)
cap	to place the top hand at the very top of the pole
carbon poles	pole vault poles made with a mixture of carbon particles or fibers
close off	to close the angle between the hands holding the pole and the lower legs of the vaulter in swing
coaching box	the area marked on the pole vault pit to help coach's advise vaulters
cup	to pull the chest and stomach in during bar clearance
curl and shoot	to ball up at the end of the swing phase, then shoot the legs towards the crossbar
double leg	to drop the drive leg during the plant, takeoff and drive/swing phase of the vault
drag	to allow the hands and takeoff leg to pivot back from the body on takeoff
drive leg	the non-takeoff leg in the jump
drop back	to allow the shoulders and head to extend down the pole during inversion
Falk, Bill	Pole Vault Coach Rhode Island University, founded MF Athletics, PV “guru” of the 80s-90s
Feofanova, Swetlana	Russian women's world record holder (Petrov method success!!)
flag off	when a vaulter fails to invert, but comes off the top of the pole horizontally
flat-flat	quick steps allowing the hips to drop for in preparation for jumping
flying away	to come off the top of the pole and maintain and erect position over the bar
free drop	to allow the pole vault pole to fall using gravity without additional force
free take off	when the vaulter leaves the ground at the exact moment the pole tip strikes the back of the box
Goss, Marshall	Pole Vault Coach at Indiana University, Coached Dave Volz among others
grip down	to place the top hand in the grip range of a pole, but not at the top grip
grip height	where on the pole a vaulter places the top hand
grip range	the 12" area on the pole where the pole is designed to bend correctly on the vault
handhold height	Where on the pole the top hand is placed
Hannay, Mark	Former Pole Vault Coach Slippery Rock University, USATF PV Committee Northeast Chairma
high body carry	to carry the pole high on the body, above the hips with bent arms
Hooker, Stephen	Australian Olympic Gold Medalist (extreme double leg swing-up)
inversion	to swing upside down during the pole vault
Lavillenie, Renaud	Current World Record Holder from France
legal pole	A pole vault pole rated at or above the vaulter's body weight (HS Rules)
low bend	too much horizontal energy in the pole causing it to bend big in the lower part of the pole
lower hand	the hand which is farther down the pole (left for right handed)
mass	the property of matter that measures an objects resistance to acceleration
National Federation	the rule making body of high school track and field
on vault	to vault with the takeoff step located directly under the takeoff hand extended up
out vault	to vault with a takeoff step located farther from the box than the takeoff hand extended up
over striding	a running step where the foot lands ahead of the runners center of gravity
pendulum	a weight suspended from a pivot so that it can swing freely.
Petrov, Vitaly	Russian Coach of Sergey Bubka and many other vaulters
pike	to bend at the waist at the peak of the vault
pit	the foam pads used for landing in the pole vault
pivot point	point which becomes the "center" of a swing - pole is the tip, vaulter is the shoulder
plant	to place the pole vault pole tip in the box prior to jumping
plant angle	the angle of the pole on takeoff relative to vertical
plant height	the height of the top hand at the takeoff point
plumb takeoff	a takeoff which is on (see on takeoff)

pole bend	the amount of bend and location of bend in the pole
pole drop	to lower to pole from the carry position to the plant position
pole rotation	the rotation of the pole around the pole vault tip from horizontal to vertical towards the pit
port arms	military term- to hold a rifle diagonally in front of the chest
pre-jump	when the vaulter leaves the ground prior to the pole tip striking the back of the box
pressing plant	to press the hands/arms and body vertically during the takeoff phase
push plant	to thrust the pole ahead of the body during the planting action
reach grip	with the pole held vertically, tip on the ground, how far a vaulter can reach with the top hand
reverse 'c'	Ideal position of vaulter's body on takeoff from the top hand through the takeoff foot
roundhouse	to swing the pole in a circular motion during the plant
sail piece	the thickest part of the pole vault pole
snake	to pull the arms over the bar individually without pressing the chest forward
Spirit Poles	a brand of pole vault poles designed by the Chappell brothers, control over 80% of pole market
steer	use visual triangulation to control steps to a particular point
stretch energy	energy stored in the muscles, tendons of the body during the vault
swing-up	to go from feet down, head up, to feet up, head down in the vault
takeoff leg	the jumping leg in the jump
Terasov, Maxim	Olympic Silver Medalist (Petrov method example!!)
thrust line	the energy direction created by the unbending pole
top grip	to place the top hand at the top legal grip on a pole vault pole
top hand	the hand nearest the top of the pole (right for right handed)
triangle	an isosceles triangle created with the top hand, the head, and the bottom hand as the points
under vault	to vault with a takeoff step located closer to the box than the takeoff hand extended up
vertical takeoff	the jumping up energy in the takeoff in the vault
Warmerdam, Cornelius	Bamboo pole world record holder (1950's)
weight	A measure of the heaviness of an object
weight band	the label placed on a pole to designate the top grip under National Federation Rules
wrapping patterns	the method used to wrap fiberglass tape on a pole vault pole prior to "baking" the pole
zero point	point located at the back top of the box for measurement in pole vault