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Pole vault – the state of the art

By Vitaly Petrov

ABSTRACT

Flexible fibreglass vaulting poles have been in use for more than 40 years and during this period a considerable amount of practical and theoretical information has accumulated. In this article, the coach of World Record holder Sergey Bubka (UKR) and 2003 World Champion Guiseppe Gibilisco (ITA) surveys the state of modern pole vault technique. Following the line of the technical model he uses for the event, he provides details and insights on key points taken from his experience and observation of the world's top performers. He highlights aspects (ie the importance of the left hand in preparing for the take-off, the drop of the swinging leg during the hang) that are not always emphasised by other commentators on the event. He also provides a number of practical recommendations and interesting supplementary data on top vaulters and their best performances. This article was originally given as the keynote presentation at the Pole Vault 2004 – Facts and Vision Symposium at the German Sports University in Cologne, 12 –14 March 2004.

AUTHOR

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Introduction

It was in 1961 that the IAAF formally approved the flexible fibreglass pole as an official implement. Since then the men's world record, which stood at 4.80m (using a metal pole), has risen to 6.15m and, hopefully, it will continue to rise in the future. As the record has improved over the last 40 years a considerable amount of practical and theoretical information about vaulting with a fibreglass pole has accumulated, making it possible to assess the patterns and peculiarities in modern vaulting technique and giving us a framework to discuss the state of the art in the discipline.

Although, opinions regarding various aspects of pole vaulting can differ, the physical and mechanical principles of the event are irrefutable. The system of two pendulums changing in length (with the pole as the 1st pendulum, and the vaulter as the 2nd) is the mechanical basis of pole vault technique. The angular velocity of each pendulum is to a certain extent controlled by the distance from the vaulter's centre of mass to the axis of rotation around the hand and the shoulder girdle. From this a technical pattern of pole vaulting has been developed. Although this pattern is based on biomechanical laws, differences in physique, physical fitness, psychological concentration abilities, and coordination skills lead to certain deviations and these can be interpreted as individual approaches to the implementation of the pattern.

To help us examine the nuances of the modern pole vaulting pattern, we can divide the event into the following phases:

1. Pole Grip and Carry
2. Approach (beginning and middle part)
3. Pole Drop and Plant
4. Take-off and Penetration
5. Swing-up and rock-back
6. I Position
7. Turn and Bar Clearance

Note that throughout this article I am referring to right-handed vaulters. Coaches of left-handed vaulters will, of course, reverse the descriptions.

Pole Grip and Carry

The grip of the pole during the approach is one of the most important details in a modern vaulter's technique. To reach the maximum controlled velocity during the approach, to naturally proceed to the hang on the pole with the subsequent muscle effort shift and to transfer from the hang to the overturn on the pole, it is necessary for the vaulter to free himself/herself as much as possible from the retarding effect of the pole. This can be accomplished to a considerable extent through the correct hold, which includes both the grip and the width of the grip on the pole, eg the distance between the hands.

The ideal width of the grip varies from one athlete to another and depends on the athlete's height, length of arms, arm strength, mobility in the shoulder and mobility in the wrist joints. A survey of the modern technique pattern suggests the width of the grip should be 60cm - 70cm (distance measured from the thumb of the left hand to the thumb of the right hand).

The effects of variations to the width of the grip can be summarised as follows:

Narrow Grip

Disadvantages:

1. Causes a great degree of tension in the arm and shoulder muscles and, consequently, limits the freedom of their movements
2. Drives the centre of mass forward thus decreasing the inclination of the vaulter's body forward and forcing him/her to hold the pole in the higher position for a longer time (distorting the smoothness in the process of lowering the pole for planting)
3. Complicates the planting technique (rigidity of the right shoulder and right hand)
4. Shortens the forward movement of the shoulder after penetration, jerking the shoulders and thus causing the pelvis (centroidal axis) to outstrip the shoulders
5. Reduces the loading of the pole with the right hand
6. Delays and reduces the power of the shoulders' stoppage for the subsequent turnover

Timothy Mack / Photo: © Getty Images

Advantages:

1. The beginning of the approach is more standardised and high
2. The left hand pushes the pole from a higher position

Wide Grip

Disadvantages:

1. Carries the centre of mass in the vaulter/pole system forward (early acceleration right from the first steps of the approach)
2. Blocks the shoulders' movement in the middle part of the approach
3. Hampers the lowering and planting of the pole (it is rather a lateral flip than a planting)
4. The lower grip of the left hand blocks the vaulter's momentum in the push, which results in the delay in penetration and hampers the turn

Taking due consideration of all the advantages and disadvantages of the various possibilities, each coach must establish the most appropriate width of grip for his/her vaulter. In my work with Sergey Bubka I had to change his width of grip 3 times and the optimum width was established only in the winter of 1991.

Approach

An effective approach in the pole vault is also largely dependent on the vaulter's acceleration. The requirement is the ability to reach maximum controllable running velocity within a given distance. Important features are the increment value of the acceleration and valulter's the ability to maintain a certain velocity over a given distance.

Acceleration as an element of the pole vault has its own components which are interrelated and which determine the vaulter's activity during the approach. Any changes or disturbances in any of the components will retard the speed and efficiency of the acceleration. A survey of today's top vaulters' shows that their average approach length is about 42m - 46m and the average number of strides is 18-20. This length provides scope for the optimal utilisation of an athlete's running abilities and allows for a smooth acceleration (see Table 1 and Table 2).

To fully understand the approach we need to look at a number of aspects in the beginning and middle parts:

The beginning of the approach

This takes place over a distance usually covered in four to six strides and it is here that the vaulter lays the foundation of the quality of the approach through the:

1. Set up of single system: vaulter/pole
2. Evolving pattern of the first strides
3. Run-up rhythm (acceleration), stride length and stride frequency

Maximum speed and its rationality towards the end of the approach are established and depend on the first strides of the approach being performed correctly. It is necessary to stress here that the position of the pole and the vaulter/pole system influence the stride length and stride frequency in the beginning of the acceleration.

A low pole position at the beginning of the approach forces the vaulter to make the first strides more rapid, which will result in a fast acceleration, rigidity of the movements and a tying-up of the muscles. An excessively high pole carry in the beginning will make the first strides longer and result in an up and down swing of the system's centre of mass, also affecting the smoothness of the approach. In the beginning of the first part of the approach, the vaulter should keep the pole at 65° - 75° to the horizon, and by the end, with smooth acceleration, he/she should bring it to 50° - 60°.

Result for 100 meters [sec]	Number of strides	Horizontal velocity in the last 5 metres [m/s]	Grip height [m]	Indication of efficiency [kj]	Result of the jump [m]
10.2 – 10.5	20 - 22	9.8 – 10.0	5.15 – 5.20	120 - 125	6.15 – 6.25
10.6 – 10.9	18 - 20	9.6 – 9.7	5.05 – 5.10	105 - 115	5.90 – 6.05
11.0 – 11.4	16 - 18	9.2 – 9.4	4.85 – 4.95	85 - 95	5.50 – 5.70
11.5 – 12.0	14 - 16	8.8 – 9.0	4.70 – 4.80	70 - 80	5.20 – 5.40
12.1 – 12.5	12 - 14	8.3 – 8.4	4.50 – 4.65	50 - 65	4.80 – 5.10
12.6 – 12.9	10 - 12	8.0 – 8.1	4.25 – 4.40	25 - 40	4.30 – 4.60
13.0 – 13.5	10	7.5 – 7.6	4.00 – 4.20	10 – 20	4.00 – 4.20

Table 1: Correlation between velocity and technical ability of the pole vaulter

Top Jumpers					
Event	Result V – last 5 metres [m/s]	Men	Result V – last 5 metres [m/s]	Women	%
Long Jump	11.20	Lewis (USA)	10.25	Drechsler (GER)	91.8
Triple Jump	10.90	Edwards (GBR)	9.50	Kravets (UKR)	86.1
Pole vault	9.90	Bubka (UKR)	8.60	Feofanova (RUS)	86.2
Europe 2002					
Long Jump	10.83	Lamela (ESP)	9.58	Kotova (RUS)	88.8
Triple Jump	10.68	Edwards (GBR)	9.44	Hansen (GBR)	88.3
Pole Vault	9.81	Averbukh (ISR)	8.60	Feofanova (RUS)	86.5

Table 2: Comparison of the approach speed shown by selected top male and female jumpers (long jump, triple jump, pole vault) and the male and female winners at the 2002 European Championships in Athletics

It is preferable to launch the vaulter/pole system into its acceleration while controlling the pole with the left hand. Various changes in the rate of the movements or pole position and irregular running often occur as a result of a vaulter's attempts to start the approach with various jumps, imitating the start of the approach in the long jump and triple jump. This gives rise to so many irregularities and errors that some-

times it is hard to understand the reason for the movements. There are other ways of starting the approach – for example four to six measured walking steps taken to the starting mark, with the pole held in the same position as for the acceleration. Such a start is more uniform in its acceleration, similar to high jumpers starting the approach with strides. The transition from walking to running is inconspicuous and natural.

Concentration before the vault, a desire to vault and confidence that this very vault will be the best are often the decisive factors for successful performance.

If the top of the pole is held a little to the left (from the run-up line), the left hand will be positioned in a more comfortable and elevated position, and the whole vaulter/pole system will become more compact (without shifting forward or to the right).

Throughout the approach, including the pole drop, the left hand should be held high enough, at chest level. It provides the direction and the pivot point around which the drop and the plant take place. If this is the case, then during the run it must remain motionless, positioned higher than the left elbow at all times. Any motions of the left hand (forward, backward, down or sideways) will break the single vaulter/pole system.

The right hand, which plays the major part in the drop and plant through the support of the left hand, moves more than the left during the approach. In the various parts of the run its work, position and strength of the grip are different.

The second or middle part of the approach

This takes place in a stretch covered in eight to ten strides. The main task here is to achieve 90-95 % of the vaulter's maximum running velocity (see Figure 1). The pole is carried at an angle of 45° - 60°. At the end of this part of the approach, the athlete reaches maximum stride length. The acceleration is maintained by a slight movement of the shoulders, which synchronises the work of the upper part of the body with the work of the legs (without, however, moving the pole in any direction). If in the beginning of the approach run the main effort is focused on the push from behind then in the middle part, as the speed increases, the vaulter is stretching and switches over to an active "drawing through" of the hips, accompanied by an active counter movement forward of the swinging leg which is bent to the maximum.

The whole foot is placed on the ground with a bias for an instantaneous roll (active placement); the shock absorption phase will increase if the foot is placed starting with the toe.

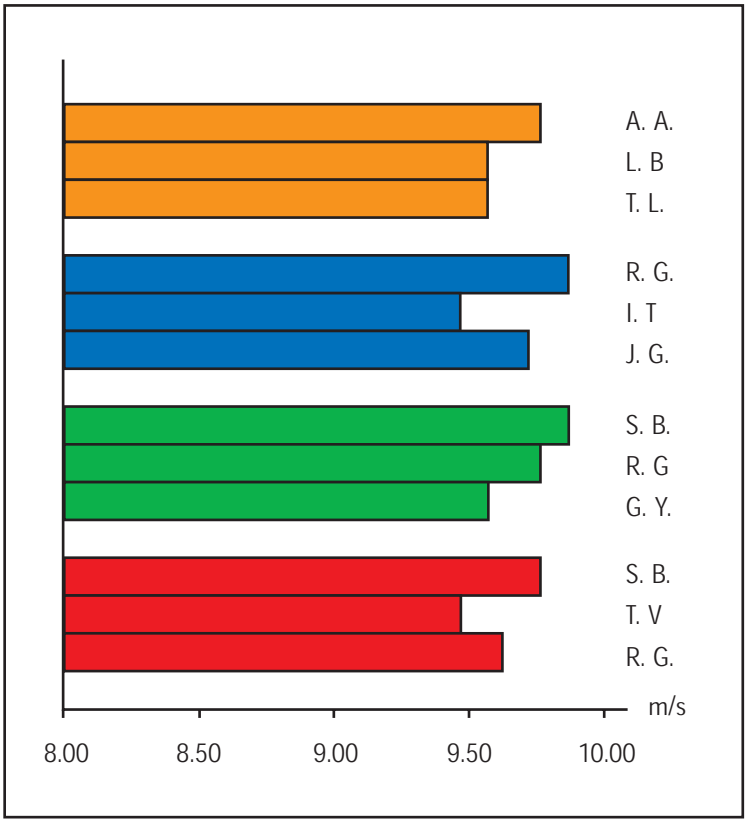
Pole Drop and Plant

The key to correct vaulting technique – for both for beginners and advanced vaulters – is in the movements of the pole drop and plant. This third and final part of the approach is characterised by increased stride frequency while the stride length remains the same, thus achieving the maximum approach speed. The stride length is a little shorter when compared to sprinting and the body is more upright. The length of the strides should not change abruptly. The penultimate stride is longer than the last one by 10cm - 20cm (optional).

We have observed that this part of the approach for the world's top vaulters is 17m - 17.5m (measured from the back of the box) and is covered in six strides.

Without changing the running velocity and running position, the vaulter begins the drop five to six strides before the plant. This is done with the help of a pulling and rotation (initial) of the right hand.

During the next two strides, the vaulter's attention is focused on the slight thrust of



MONACO – 2002
1. Alex Averbukh (ISR) - 5.85m
2. Lars Börgeling (GER) - 5.80m
3. Tim Lobinger (GER) - 5.80m

HELSINKI – 1994
1. Rodion Gataullin (RUS) - 6.00m
2. Igor Tradenkov (RUS) - 5.85m
3. Jean Galfione (FRA) - 5.85m

SEOUL - 1988
1. Sergey Bubka (URS) - 5.90m
2. Rodion Gataulin (URS) - 5.85m
3. Grigory Yegorov (URS) -5.80m

ROME – 1987
1. Sergey Bubka (URS) - 5.85m
2. Thierry Vigneron (FRA) - 5.85m
3. Rodion Gataulin (URS) - 5.80m

Figure 1: Velocity between 10m and 5m from the box for top pole vaulters in selected competitions.

the hips forward without losing control over the shoulders, maintaining their leading role in the approach.

While the right hand is being pulled, the right elbow is gradually drawn behind the back, thus making it possible to lift the right hand with the pole up to the right shoulder during the last two steps of the approach.

The left hand remains at the same level as it was at 6 steps before the plant; while moving slightly ahead, it controls the height and advance of the pole. Two steps before the plant, the pole is a little higher – 10cm - 15cm above the vaulter's centre of mass.

All these movements cannot be considered as a static position; the vaulter has already

begun the drop four steps back, and here the pole simply crosses its horizontal line.

The drop must not be abrupt (if the vaulter was not late in initiating it) and it must fall within the rhythm of the last strides.

In the last two steps of the drop, the vaulter should not "lose" the pole by stretching the left arm forward (as if looking for support or the box). All the movements during the drop take place while the left hand is kept over the left elbow. During the last six strides, and especially during the last three, the vaulter must keep the abdominal muscles tight without breaking the line of his advancement; this will help him to drive the shoulders back even before the drop. A very important detail of the drop that will save him/her from squatting during the penultimate step, is raising the pole over the head before the vaulter arrives at the vertical position of the right leg. If he/she does this on time, then the right foot will take an active step, beginning to accelerate the pole for the plant. The most dangerous moment during the drop is an early touch of the box when the transition is made from the right to the take-off foot.

Take-off and penetration

The efficiency of this phase depends on the vaulter's skill in the drop/take-off junction, on whether he/she is able to begin the push before the pole is set against the box. The pole must be smoothly transferred to the plant position when the vertical take-off plane is crossed. The technically correct movement is characterised by the right acceleration of the pole at the moment the vaulter reaches the vertical take-off plane.

The left arm is not trying to bend the pole; it plants it firmly towards the box and then transfers the effort to the right hand, so that the pole is bent by the impact of the vaulter's speed and mass. The vaulter, alert to the resilience of the pole, must perform all the subsequent actions on the pole as on a rigid support.

The primary purposes of the support-pushing part of the vault are as follows:

1. To perform the drop and plant with minimal losses in horizontal speed at the angle of 20° - 22º, eg at a tangent to the future swing on the pole;
2. Maximum transfer of kinetic energy to the pole by means of the impact made by the "pivotal" junction.

Of great importance is the depth of the body's forward advance during the take-off. With this in mind, even during the take-off the athlete must release the shoulder girdle from tension and drive his chest forward/upward, while at the same time taking off with the support leg and swinging with the free leg.

The quickness and depth of the take-off greatly influence the technique of all the next elements of the vault: the hang, swing and rock-back. Moreover, the performance of the take-off phase determines the rhythm of the subsequent parts of the vault.

The take-off point of the top pole vaulters in the world is somewhere between 4.20m and 4.40m from the back of the box. The taller vaulters take off at a distance of 4.10m - 4.20m, shorter ones do so at 4.30m - 4.40m.

Continued acceleration in the last four strides is an indication of good skills acquired in this part of the pole vault (pole drop/plant). In his best vaults, Sergey Bubka continued to increase his velocity until the take-off, as follows:

- Four strides before take-off: 9.5m/sec
- Two strides before take-off: 9.7m/sec
- Immediately prior to take-off: 9.9m/sec

Based on the above I would like to make the following recommendations for the take-off phase:

1. Begin the pole acceleration for the "push" from the swinging leg

2. Before the take-off leg contacts the ground, the vaulter needs to create a maximum space between himself/herself and the pole. The arms must be stretched, the right arm continues the line of the body, whereas the left arm is at a right angle to the pole axis.
3. Before the vertical position, the vaulter should try to increase this space to the maximum. During and after the take-off, he/she must aim to "rush" as far upward as possible, trying to reach the left elbow with his/her head.
4. The foot should be placed for the take-off firmly with a quick roll-up on the ball of the foot. The vaulter must pay more attention to the swing with the right (left) leg bent to a maximum in order to move the hips forward, trying to keep the shoulders in the front position, until the end of the hang.

Swing-up and rock-back

Having moved the chest and hips forward during the hang, the vaulter begins to draw the shoulders back – mainly through the effort of the shoulder girdle muscles, thus switching the rotation axis from the hands to the shoulders.

Question: Is the drop of the swinging leg during the hang losing its importance?

Answer: At present top vaulters and their coaches pay more attention to the quickness and the amplitude (depth) of the "drive" on the pole than to the external observance of the position. After the shoulder girdle muscles "switch on", the vaulter strongly swings his/her whole body upwards. The rotation axis goes through the shoulder girdle. In this case, the swing on the pole is forceful and quick. The pole is bent to the maximum when the vaulter's body takes a horizontal position to the ground, and the shins of the bent legs pass by the bent pole and are raised to the level of the head and shoulders. It is worth mentioning here that the arrest of the shoulders after the deep penetration ensures the drive of the hips upwards to the pole, through active unbending of the left arm, whereas the acceleration of the vaulter's hips drive upwards was built up by the turn of the shoulders back and down.

I Position

The turn must be executed through simultaneous movements of the body parts: the legs go upward, and the shoulders drop down. The movement of the shoulders, or, to be more exact their acceleration in the swing, is a necessary element in vaulting with wide grips and rigid poles. It is especially important to maintain the movement of the shoulders when the vaulter has unbent his/her legs (knees) and taken the "L" position – body and legs at right angle.

As the vaulter is unbending, the pole also has its highest speed of uncoiling upwards, therefore, the combination of the pole's carrying capacity and the athlete's unbending movement generates an accelerated thrust upwards, and by the end of the unbending movement the centroidal axis reaches the maximum vertical speed (Bubka's speed was 6 m/s). An active turn over onto the shoulders should end when the arms come into use in order to stretch the body along the pole. By this movement the vaulter maintains the speed of the body's thrust upwards. One of the vaulter's tasks during the pull up is keeping the body close to the pole. The closer the vaulter's and the pole's lines are during the pull up and turn, the longer the acceleration upwards.

The turn and bar clearance

The pull and the turn are a continuous effort. There should not be even the shortest delay in performing these elements. While trying to maintain the vertical speed, the vaulter begins to stretch the body and turn, using the take-off speed. The arms keep the body close by the pole and maintain the speed.

In the transition to the push the vaulter – apart from the turn left to the pole – uses the rotation of the pole in the bearing point. With their high upward speed, many great vaulters,

are still in the vertical position after their right hand releases the pole. The vaulter needs to maintain the uniform motion of the body and by bending the knees increases the speed of rotation around the crossbar.

If the preliminary movements are performed correctly, the vaulter will be thrust up, and the bar clearance will be made in the most efficient style, the so-called "curved ascension". Not all of the world's top vaulters (see Table 5) have standardised motions during the bar clearance, but all of them are distinguished by the excellent "feeling of the bar" which allows them to perform the most efficient movements in order to avoid touching the bar.

Table 3: The "6 metre Club" (as of March 2004)

Athlete	Personal Record [m]	Height [m]	Weight [kg]	"V" – last 5 m [m/s]	Pole index 520]
Bubka (UKR)	6.15	1.83	80	9.94	10.6
Tarasov (RUS)	6.05	1.94	81	9.75	11.2
Markov (AUS)	6.05	1.81	80	9.84	11.8
Hartwig (USA)	6.03	1.94	92	9.73	10.8
Gataulin (RUS)	6.02	1.90	81	9.75	11.4
Trandenkov (RUS)	6.01	1.90	78	9.47	11.7
Brits (RSA)	6.01	1.96	88	9.74	11.0
Lobinger (GER)	6.01	1.90	82	9.62	11.4
Ecker (GER)	6.00	1.93	78	9.71	11.7
Galfion (FRA)	6.00	1.84	82	9.68	11.9

Athlete	Result at Selected Ages [m]				
	14	17	20	23	27
Bubka (UKR)	3.60	5.10	5.94	6.01	6.12
Tarasov (RUS)	3.80	5.40	5.85	5.90	6.05
Markov (AUS)	3.60	5.10	5.65	6.00	6.05
Hartwig (USA)	-	4.70	51.0	5.41	5.66
Gataulin (RUS)	4.00	5.20	5.75	5.90	6.02
Trandenkov (RUS)	3.30	5.10	5.50	5.65	5.85
Brits (RSA)	-	4.80	5.70	6.01	5.75
Lobinger (GER)	4.50	4.90	5.50	5.90	6.01
Ecker (GER)	3.80	4.90	5.72	6.00	-
Galfion (FRA)	-	5.16	5.80	5.92	5.94