Pole Vault and the use of Dartfish Software

Results and Observations from 2004 USATF High Performance Designated Meets

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Protocol for Data Collection Utilizing Dartfish Video Software

Basic Set Up

- Digital video cameras utilized and recorded @ 60 frames per second.
- Camera positioned (when possible) perpendicular to the runway at a mark located between 4 and 5 meters from the back of the plant box.
- Camera focused (zoomed) so that the athlete centered and roughly ½ the height of vertical screen height when standing on the runway at the 4/5 meter mark described above. The athletes is then panned through the entire vault from beginning of the approach to landing in the pit.
- Camera placed (when possible) so that it is 5-10 feet above the runway thereby to minimize loss of picture due to potential ground traffic.
- Marks (easily visible in camera) placed on both sides of the runway at 4 meters and 9 meters back from the top of the plant box (5 & 10 meters - men) for use in measurement of velocity in last 5 meters prior to take off.
- A one meter reference mark, easily visible by the camera, will be placed on either the vault standard and/or the landing pit for measurement purposes. *Note that other reference marks were used equally if not more effectively such as the UCS standard upright pads at the Olympic Trials.*

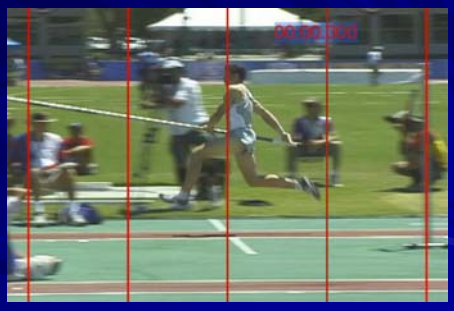
General Data Collection

- Athlete's name
- Competition and date
- Height attempted
- Result (o – clearance, x – failure)
- **Note: Height and weight of the athlete was not collected but may be of interest in future study. Also of future interest is pole size* (length, weight, flex number) and grip height for each vault.

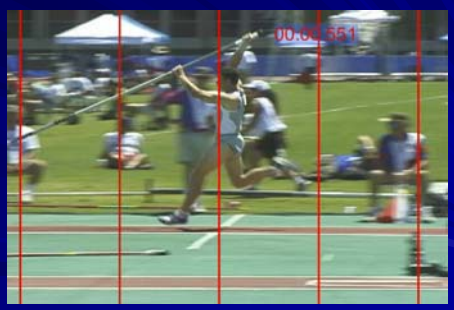
Video Software Generated Data

- **Critical Approach Velocity - M**easurement of the velocity of the last five meters of the approach (just prior to touchdown of the take off foot) was taken by utilizing the marks placed adjacent to the runway as described in the Basic Set Up above. Athletes were timed via video from the point the torso passes the first mark until passing the second mark. Timing was done utilizing the Dartfish software. The men's timed 5 meter segment was placed at 5 and 10 meters, whereas the women's was placed at 4 and 9 meters. The significance of this velocity serves as an estimate of the kinetic energy available just prior to pole contact with the plant box correlating well with vaulting height potential.

Measuring 5 meter velocity - beginning



End 5 meter zone



Calculation

- 5 meters / 0.551 seconds = 9.07 mps

Angle of Contact – C angle

- **Angle of Contact** - Defined as the angular measure of the body's position when the pole contacts the back of the plant box. As the pole is planted in the box, the video is advanced to the point where it is obvious that the pole tip has hit the back as evidenced by the flex of the pole in a direction up and toward the pit. At this moment the body position the athlete is measured by drawing a line from the ball of the takeoff foot up through the acromion process (estimated) of the leading shoulder (bottom arm or left shoulder of the right handed vaulter). Using the perpendicular line (90 degrees) from the runway as the zero degree mark any line drawn that tilts toward the pit is recorded as a positive angle and conversely, if this body line angled away from the pit it is recorded as a negative angle. The significance of this measurement is similar to step placement. When the pole hits the back of the box later in the plant/takeoff process (more positive angle), it is generally purported that the athlete has likely had a better opportunity to complete a forceful energetic take off.

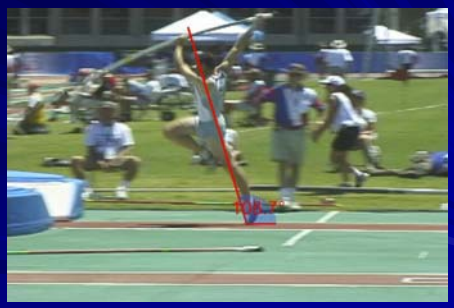
Miles: C angle of +9.1 degrees

Suttle: C angle of -18.2 degrees

Angle of Departure – D angle

- **Angle of Departure** - Like the angle of contact, angle of departure uses the perpendicular line to the runway as the zero point for reference measurement of the body angle just prior to the takeoff foot leaving the ground. A line is drawn from the furthest point of contact of the take off foot from the plant box just prior to leaving the ground and correspondingly up through acromion process of the leading shoulder. This a measurement of the number of degrees the athlete's body is tipped toward the pit. This observation tests the coaching cues of "drive through the take off" or "run over the take off foot". Further, it is notable that World record holder Sergey Bubka's angle of contact and angle of departure on his 6.01m (19'9") winning vault at the 1999 World Championship were very close to the same (nearly a free take off).

Miles: D angle of 16.7 degrees



Suttle: D angle of 12.2 degrees

Timing of Extension

- **Timing of the Extension** - The measurement of time is taken from the instant the athlete achieves an inverted straight body position (hip near top hand) until the pole is fully straightened. It is generally assumed that "beating the pole to vertical" is a good attribute for the effective transfer of stored energy in the pole to the vaulter. This observation tests that cue and measures actual timing.

Beginning of timing of extension

Ending of timing of extension

Angle of Inversion – I angle

- **Angle of Inversion** - The inverted angular position of the body in relation to the ground at the instant of pole straightening is the referred to as Angle of Inversion. A line is drawn from the top of the sternum (jugular notch) to the crotch. This serves as a reflection of the direction the body will travel when releasing from the pole. Angles of 75+ degrees can be considered as exemplary with 90 degrees as a practical limit (or is that impractical limit?).

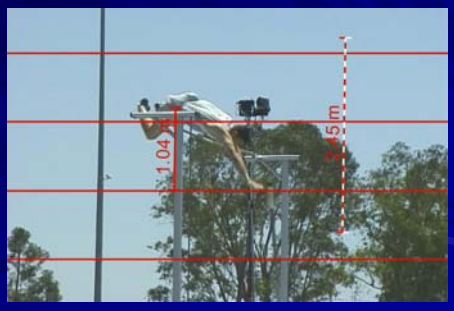
Dragila: I angle of 77.2 degrees

Hip Height Above Top Hand (push off)

- **Hip Height Above Top Hand** - The measurement is the difference in centimeters between the top of the top hand at pole release to the maximum hip height. The hip height is measured at the greater trochanter of the lower hip (if one is lower than the other. Frequently athletes have very good vaults at low heights where the magnitude of the jumping height is measured only by the height of the bar not by how high the athlete is in the air or how well they can propel themselves above their top hand. Note! - Of all the measurements, this one is most suspect in terms of accuracy and be best utilized as a comparison in the same competition and not as overall comparison.

Making a reference tool

Miles – hip height above top hand



Calculated Data

- Efficiency – men's equation
  = (Height/((Velocity * .542) + .85)) * 100
  The efficiency equation is the work of Dr. Peter McGinnis who constructed a best line of fit graph for exemplary performance. With an immense bank of data, runway velocities (X axis) were compared with heights cleared (Y axis). This equation reflects the closeness to that line as a percentage.
- Angle (C + D) This calculation is a graphic indicator of the relationship of how much time is spent in a positive position (push) side of the take off
- Angle (D – C) Or "angular degrees of contact" is the measure of how long the athlete is resisted by the pole on the last step from touch down to takeoff. A "free take off" will have an angle of contact of 0 degrees.

Limitations

- It is important to recognize that the measurements are approximations not within rigorous scientific standards. However, the data appears to be reliable (repeatable) and is reflective of what has occurred. Further, as the number of trials increases there will likely be a more accurate reflection of tendencies.

Coach/Athlete Utilization of High Performance Centers

- Because of the time required for collection, coaches and athletes were not given the data immediately following the meet. Therefore the best immediate feedback was typically visual analysis and imagery.
- Collected data was presented within a week or two following the competition either by mail or handed out at a subsequent competition. Reception of the meaningfulness of the data seemed to be determined by understanding and familiarity.
- It was unclear how data was utilized and it appeared that there was a desire for meaningful comparative parameters. Runway velocity has been a long established comparative tool and was well received. Contact angle became more understood as an alternative measure of take off step and gained then next best acceptance. Hip height over top hand drew quite a bit of interest and, although flawed, deserves further review in method and enhanced accuracy.

Cross Comparison Analysis

To analyze the data 8 measured or calculated factors were inter-compared (height, velocity, C/D/I angles, timing of extension, efficiency, degrees of contact). Each category was placed in order best to worst and the top & bottom 15-20% of each was extracted. For each of these sub-categories averages were calculated for all observed/calculated data. This resulting data was then charted and compared with the other seven sub-categories. The following is that comparison for each gender.

Cross Comparison Graphs

Men:

..\My Documents\USATF Vault Documents\DF men's X comparison graph.xls

Women:

..\My Documents\USATF Vault Documents\DF women's X comparison graph.xls

Then, utilizing the data obtained, the following is a comparison of all Men and Women in this study:

	Men Makes	Men Misses	Women Makes	Women Misses
Height	5.55	5.57	4.27	4.36
Velocity	9.17	9.18	8	7.78
C angle	-2	-2	-9	-9
D angle	11	12	10	10
Timing	0.1	0.1	0.08	0.07
I angle	69	66	57	52
hip height	129	127	63	59
Efficiency	95	nd	82	nd
C + D	10	9	2	2
D - C	13	14	19	21

US Male Olympians makes / misses

	Mack - o	Mack - x	Stevenson - o	Stevenson - x	Miles - o	Miles – x
Height	5.64	5.57	5.73	5.85	5.62	5.76
Velocity	9.31	9.36	9.47	9.5	9.08	8.99
C angle	-1	0	-5	-5	8	8
D angle	12	14	11	11	15	15
Timing	0.16	0.1	0.13	0.12	0.15	0.15
I angle	74	69	78	71	73	73
hip height	131	128	147	168	109	99
efficiency	96		96		99	
C + D	11	13	7	6	23	22
D - C	13	14	15	17	7	7

Female Olympians

	Dragila – o	Dragila - x	Schwart - o	Schwartz - x	Suttle - o	Suttle - x	Isinbayeva	Isinbayeva	Feofanova	Feofanova
Height	4.50 o	4.72 x	4.34 o	4.58 x	4.30 o	4.47 x	4.91 o	4.75 x	4.55 o	4.75 xo
Velocity	8.21	8.22	8.09	8.21	7.9	7.92	?	?	?	?
C angle	-9	-7	-6	-7	-15	-13	-3	-1	11	13
D angle	12	11	14	14	13	14	14	14	15	13
Timing	0.14	0.15	0.04	0.06	0.05	0.05	0.17	0.1	?	.07?
I angle	72	71	55	57	48	48	71	62	45	?
Hip Height	82	81	54	65	64	69	?	?	?	?
Efficiency	85		83		80		?	?	?	?
C + D	3	4	8	6	-2	1	11	13	26	26
D - C	20	18	20	21	27	27	17	15	4	0

Individual Examples

Toby Stevenson:

..\My Documents\Pole Vault\StevensonT - comparison.xls

Stacy Dragila:

..\My Documents\Pole Vault\DragilaS comparison.xls

Summary / Observations

Men vs. Women

Similarities

Both groups show little difference between misses and makes within the parameters measured

Differences

Women are under more, in contact with the pole longer on the take off step, have less contact on the positive side of the take off step, and are less efficient (by men's efficiency tables).

General Observations

- Clearance of higher heights seem to have a strong positive relationship with:
  1. Runway velocity
  2. Inversion angle
  3. Efficiency

  And a positive but less strong relationship with:
  4. Departure angle
  5. Timing of extension

- There does not appear to be a positive or negative relationship with Contact Angle! ……..raising the question:

"Does it not matter whether the athlete is under, on, or out?"!!

Further Observations and Consideratons

- Men vault higher than women and have a notably more positive C Angle
- Those exhibiting a more free take off (positive C angle) seemed to have more problems with inversion and extension mechanics (negative correlation).
- Yet those with a more positive C angle appeared equally efficient (women) and more efficient (men) than those with a more negative C angle!
- Individual style vs. Coach driven? Examples of range in C angle are Earl Bell: Miles and Suttle / Greg Hull: Markov and Dragila.
- Question: "If a free takeoff is ideal, why is it difficult and what is the missing teaching link?"

Dave's Thoughts

- In a more free take off the athlete has more time to rotate forward (axis) over the take off foot.
- When the pole strikes the box the rotation is in the opposite direction created by the grounding of the take off foot.
- It appears that on an under take off that the trade off of dissipation of energy due to early pole strike may be a trade off for adjustments in posture and transitioning to swing mechanics.
- Both timing and initial position of the swing (tap) appear to be very challenging technically and psychologically (commitment).
- Analogy between triple jumper trying to stay upright on phases?

Giant Swings on a High Bar Analogous Event Skill?

Note Petrov's moveable high bar as teaching tool for a missing link. Example of early and late tap when trying to perform giant swing on high bar:

..\My Documents\Pole Vault\early tap.wmv.dartclip

..\My Documents\Pole Vault\late tap.wmv.dartclip

Future Exploration

Take Mechanics

1. Revisit take off angles
2. Foot strike on take off
3. Postural changes (e.g. angular) of torso through take off on efficient jumps
4. Compare long jump vs triple jump kinetic energy at take off

Notes regarding take off in long and triple jumps

- From studies in the 1980's including athletes such as Lewis, Myricks, Banks, and Conley:

	LJ	TJ
Last Step HV	10.8mps	10.3mps
Take off HV	9.2	9.6
Take off VV	3.3	2.2
Take off angle	19.7	12.9
Resultant velocity	9.77	9.85
% Loss of HV @ TO	15%	7%

Closing Item – Safety Grid
Is it a worthwhile rule?

- Approved NCAA Facility Marking for Pole Vault Runways
- NCAA Track and Field Rule 1-5-2
- The runway may be marked with seven permanent marks with the first mark placed at 15 feet from the back (top) of the plant box stop board and the next six placed at one foot intervals toward the box. The marks shall follow a regular pattern of three short lines (one foot long) followed by one long line (three feet long) at 12 feet then repeating three short lines. The lines shall be two inches wide. If it is deemed necessary to have marks closer to the plant box they are to follow the same pattern, i.e. a line at eight feet shall be three feet in length. (see Figure 8)

Diagram