INDIVIDUAL BIOMECHANICAL PROFILES OF CHANGES IN TECHNIQUE BETWEEN PRACTICE AND COMPETITION IN SEVEN COLLEGIATE POLE VAULTERS

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The purpose of this study was to examine individual changes in technique between competition and practice in the pole vault. Seven collegiate pole vaulters were videotaped and analyzed in two or three competitions and two or three practices. Means for competition and practice were computed in eight parameters. The eight parameters included: maximum horizontal velocity, maximum vertical velocity, horizontal velocity at the last step, vertical velocity at take off, stride length from the third to the last step to the second to last step, stride length from the second to last step to the last step, the height of the top hand hold at pole plant, and elbow extension at pole plant.

KEY WORDS: pole vault, individual profiles, competition, practice, horizontal velocity, vertical velocity.

INTRODUCTION: Many coaches and athletes notice that athletes often have differences in their technique between competition and practice. This is especially noticeable in complex sport skills when the athlete performs very poorly or much better in competition. There have been many studies published describing in detail various aspects of pole vaulting (Angulo-Kinzler, et al., 1994; Gros, Adamczewski, & Wolf, 1994; Gros & Kunkel, 1990; McGinnis, 1995, 1997; Sutcliffe, 1989; Vaslin, Couetard, & Cid, 1993), however differences in technique between competition and practice has received little attention.

This study exams individual differences of seven pole vaulters between competition and practice in eight important aspects of the pole vault. The parameters in this study were chosen because previous research has shown them to be important to the height attained and/or the successful coach of these pole vaulters felt they were important parameters to examine. Examining changes in technique from practice to competition shows possible changes that a pole vaulter may make unconsciously or consciously in his or her technique when competing. Being aware of possible changes will assist the athlete and coach in watching for and dealing with the changes in technique during competition that may have a negative effect on their performance.

METHODS: Four male and three female pole vaulters from a NCAA Division I university were used in this study. Three of the male pole vaulters and two of the female pole vaulters were videotaped at three practices and three competitions. The other male and female were videotaped during two practices and two competitions. The personal best of the male pole vaulters in this study were 4.95m, 5.18m, 5.22m, and 5.26m. The personal best of the female pole vaulters in this study were 3.70m, 3.90m, and 3.96m. A total of 207 jumps were analyzed. The pole vaulters were videotaped using a Peak5 two-dimensional video system (Peak Performance, Englewood, CO). The camera was set at a 900 angle to the runway and a sampling rate of 120 Hz was used. The Peak Performance Technologies Motion Measurement computerized digitizing system was used to analyze the video data. The variables that were analyzed included: maximum horizontal velocity (MHV), maximum vertical velocity (MVV), horizontal velocity at the last step (HVLS), vertical velocity at take off (VVTO), stride length from the third to the last step to the second to last step (SL 3 to 2), stride length from the second to last step to the last step (SL 2 to 1), height of the top hand hold at pole plant (HTHH), and elbow extension of the top arm at pole plant (EE). The stride lengths and height of the top hand hold parameters were normalized to a percentage of the pole vaulter's height.

Each pole vaulter's averages were computed for each parameter in competition and practice. Differences between competition and practice were then examined for any differences between the competition and practice means.

RESULTS: The means computed for each pole vaulter in competition and practice for all eight of the parameters are presented in Table 1.

Table 1 Profiles of Individual Means of Parameter Results.

Pole Vaulter	MHV Competition	MHV Practice	MVV Competition	MVV Practice	HVLS Competition	HVLS Practice	VVTO Competition	VVTO Practice
A (male)	8.90	8.42	3.45	3.25	7.26	7.42	2.23	2.05
B (male)	8.75	8.57	3.35	3.13	7.76	7.31	2.20	2.19
C (male)	8.78	8.50	3.46	3.04	7.56	7.50	2.29	2.15
D (male)	8.47	8.32	2.95	2.86	7.32	6.99	2.30	2.53
E (female)	7.65	7.76	2.54	2.35	6.72	6.73	2.13	2.20
F (female)	7.73	7.07	2.65	2.13	6.61	6.15	1.79	1.85
G (female)	7.16	7.61	2.28	2.33	5.97	6.29	2.08	2.01

Note. Maximum horizontal velocity = MHV, maximum vertical velocity = MVV, horizontal velocity at the last step = HVLS, vertical velocity at take off = VVTO. All parameters in this table are in meters/second.

Table 1 (continued) Profiles of Individual Means of Parameter Results.

Pole Vaulter	SL 3 TO 2 Competition	SL 3 TO2 Practice	SL 2 TO 1 Competition	SL 2 TO 1 Practice	HTHH Competition	HTHH Practice	EE Competition	EE Practice
A (male)	112	111	109	106	106	106	157	160
B (male)	106	105	107	108	103	106	169	153
C (male)	99	105	105	101	103	104	160	160
D (male)	110	114	105	103	104	108	156	165
E (female)	105	106	105	105	102	110	160	157
F (female)	114	106	105	101	101	103	153	155
G (female)	106	110	101	107	106	110	159	150

Note. The stride length from the third to the last step to the second to last step = SL 3 to 2, stride length from the second to last step to the last step = SL 2 to 1, the height of the top hand hold at pole plant = HTHH, and elbow extension of the top arm at pole plant = EE. Elbow extensions of the top arm at pole plant are in degrees, the rest of the parameters are normalized to the percent of the pole vaulters height.

DISCUSSION: Overall five of the seven pole vaulters in this study were found to have greater maximum horizontal velocity during the competitions. Developing and maintaining horizontal velocity through the pole plant is critical for successful pole vaulting (Angulo-Kinzler, et al., 1994; McGinnis, 1995, 1997; Sutcliffe, 1989). The greater the kinetic energy developed through the run-up, the greater the amount of strain energy that can be stored in the pole and subsequently used to project the pole vaulter vertically. Six were found to have greater maximum vertical velocity during the competition. Four were found to have greater maximum horizontal velocity at the last step and vertical velocity at take off during the competitions. Three had a longer stride length between the third to the last step and the second to last step and four had a longer stride length between the second to last step and the last step. Stride lengths are a result of the pole vaulter's horizontal velocity, but can also be an indication of overstriding or under-striding, which could lead to a poor position at take-off (Angulo-Kinzler, et al., 1994). Six were found to have a lower height of top hand hold and three had greater elbow extension during the competitions. The height of the top hand hold and elbow extension give an indication of the extension that the pole vaulter has at pole plant. The higher the hand is at pole plant the easier it is for the pole vaulter to bend the pole and store elastic energy in the pole and the smoother the transformation of the horizontal velocity to vertical velocity (Sutcliffe, 1989; Gros & Kunkel, 1990). Individual profiles will be examined next for individual changes in technique.

Pole Vaulter A's maximum horizontal velocity was .48 m/s faster but his horizontal velocity as the last step was .16 m/s slower in the competitions. This pole vaulter had the greatest average maximum horizontal velocity of the group of pole vaulters. However, he had the lowest horizontal velocity of the male pole vaulters at the last step. He lost 1.64 m/s of horizontal velocity on average from his maximum to the last step. This was the greatest loss of

horizontal velocity of any of the pole vaulters in competition or practice. This could be a result of a run up which was too long. Despite slowing down considerably, Pole Vaulter A still had the second highest maximum vertical velocity in the competition and the greatest vertical velocity in practice. He also had the highest value for the percentage of height of the stride length from second to last step during competition. His stride was over 4% greater than the average of the other pole vaulters. This pole vaulter was likely overstriding, which leads to a breaking action when running. That would explain the decrease in horizontal velocity.

Pole Vaulter B had the highest average maximum horizontal velocity of the pole vaulters during practice. He also had the highest average horizontal velocity at the last step during competition, .2 m/s higher than the next pole vaulter. However, he lost 1.26 m/s from his maximum horizontal velocity and his velocity at the last step during practice. This indicates that he needed to work on maintaining his horizontal velocity during practices. Pole Vaulter B was the most consistent of all of the pole vaulters in his stride lengths. His stride length was the largest of the group as a percentage of his height during practice. This, like Pole Vaulter A, may indicate that he was overstriding, which would relate to his slow horizontal velocity at the last step during practice. This pole vaulter's height of top handhold during practice was 3% of his height greater during practice. However, he had 160 more elbow flexion on average during the competitions. The 16 degrees difference was by far the greatest of the pole vaulters. He had the greatest arm extension in competition and the second lowest in practice of the pole vaulters. Apparently this pole vaulter has good extension in his arm but not in the rest of his body during the competitions and vice versa during practices.

Pole Vaulter C's first interesting parameter is that this pole vaulter had the highest maximum vertical velocity, even though he didn't have the highest horizontal velocity on average. His maximum vertical velocity was .42 m/s greater in the competitions. A second interesting aspect of this pole vaulter's technique was his stride lengths. His stride length from the third to the last step to the second to last step was 6% less in competitions despite having a higher maximum horizontal velocity by .28 m/s. However, his stride length for the second to last to last step was 4% longer in the competitions as would be expected since his horizontal velocity was higher. It appears that this pole vaulter's steps may have been off throughout the run-up during the competitions as a result of his greater horizontal velocity, and he made up the over-striding difference by greatly shortening the second to last stride. This pole vaulter was very consistent in his technique in the rest of the parameters.

Pole Vaulter D had the lowest maximum vertical velocity in competition and practice of all the males. However, he had the highest vertical velocity at take off during the competitions and practice. This could be an indication that he was not taking advantage of his vertical velocity at take off, and needs to work on his rock back and tuck. Pole Vaulter D also had the longest stride length as a percentage of his height. This would indicate that he was overstriding during practice. He had the lowest maximum vertical velocity of any of the males by .28 m/s in competition and .10 m/s in practice. This could be an indication that the overstriding lead to the breaking action which resulted in his lower maximum horizontal velocity. This pole vaulter had the most elbow extension of all of the pole vaulters during practice.

Pole Vaulter E's first interesting parameter was her maximum horizontal velocity. She actually had a greater horizontal in practice by .11 m/s. This would indicate that she was not using her full potential in competition. She also had the greatest horizontal velocity at the last step and vertical velocity at take off of the female pole vaulters. Probably the most consistent part of this pole vaulter's technique was her stride lengths. Both stride lengths were nearly identical between competition and practice. She was the most consistent in this parameter of the pole vaulters. One of the most notable aspects of this pole vaulter's technique was her height of top hand hold. She had the second lowest value in this parameter as a percent of her height during competition. It was 8% of her height less in competition. However, her elbow extension was 30 greater in the competitions which was the second best of any of the pole vaulters. This would indicate that she was not getting full extension in the rest of her body during competitions.

Pole Vaulter F's first notable aspect was her maximum horizontal velocity. She had the highest

horizontal velocity of the females in competition, but had the lowest value in practice. This indicates that this pole vaulter needs to work on her horizontal velocity in practice to more closely match what actually happens in competition. Although she had the highest maximum horizontal velocity in competition for the females, she lost 1.12 m/s of velocity by the last step. She also had the longest stride length from the third to the step to the second step of any of the pole vaulters in competition. Combined with her loss of horizontal velocity, this pole vaulter seems to be overstriding and losing velocity because of the breaking action. Pole Vaulter F also had the lowest values in her vertical velocity at the take off in both competition and practice of any of the pole vaulters. Another interesting aspect of her technique that was probably related to the low vertical velocity at take off was her height of top hand hold and elbow extension. She had the lowest values of any of the pole vaulters in height of the top hand hold in both competition and practice. Her elbow extension was also the lowest of all the pole vaulters in competition. Her value for height of the top hand hold was only 101% of her height, in other words, barely above her head. The low values in both of those parameters would affect her ability to overcome the pole at take off. Her low vertical velocity at take off is a clear indication of this.

Pole Vaulter G's maximum horizontal velocity was .45 m/s slower in competitions. This is clear indication that she was not using her full potential in the competitions. She had the lowest maximum horizontal velocity of any of the pole vaulters during competition. Another notable aspect of this pole vaulter's technique was her stride length form second to last step to the last step. She has the lowest value as a percentage of her height by 4% of all of the pole vaulters during competition. It seems this pole vaulter was hesitant during the run up in competition since her horizontal velocity and stride length were so low in competition. Although this pole vaulter may have been hesitant during the run up it doesn't appear to have affected the extension of her body. She was tied for the highest value of he pole vaulters for the height of top hand hold in both competition and practice. However, it is interesting that her height of top hand hold was 4% higher in practice, but her elbow extension was 90 lower. In fact, her elbow extension in practice was the lowest of any of the pole vaulters. It appears that this pole vaulter has good extension in her body during the competitions with the exception of her elbow flexion.

CONCLUSIONS: The results of this study demonstrated that there were some common changes in technique that the majority of the pole vaulters did when in competition. These included a greater run up velocity, greater maximum vertical velocity, and a lower top hand hold at pole plant. These are aspects of the pole vault technique that may be likely to change when pole vaulters are in competition. Individual changes in technique were found in all of the pole vaulters for some of the other parameters.

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