RELATIONSHIP OF BIOMECHANICAL AND PSYCHOLOGICAL PARAMETERS BETWEEN PRACTICE AND COMPETITION IN POLE VAULTING

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The purpose of this study was to examine relationships of biomechanical parameters, cognitive anxiety, somatic anxiety, and self confidence changes between competition and practice in the pole vault. Seven pole vaulters were videotaped in practice and competition and completed the Competition Sport Anxiety Inventory-2 (CSAI-2). A Pearson Correlation was computed to examine relationships between the difference score of the means for the competition and practice vaults of all the parameters. Several significant correlations were found ($p \leq .05$) which included: maximum horizontal velocity with maximum vertical velocity and with second to last stride length, maximum vertical velocity with last stride length, horizontal velocity at the last step with elbow extension, and second to last stride length with self confidence.

KEY WORDS: pole vault, Competition Sport Anxiety Inventory-2, competition, practice, horizontal velocity, vertical velocity

INTRODUCTION: Although the relationships between some components of the pole vault have been established, the relationships between other biomechanical and especially psychological components of pole vaulting have received little attention. There have been several studies published describing in detail various aspects of pole vaulting (Angulo-Kinzler, et al., 1994; Gros, H., Adamczewski, H., & Wolf, J. 1994; Gros, H. & Kunkel, V. 1990; Linthorne, 1994; McGinnis, 1995, 1997; Sutcliffe, 1989; Vaslin, Couetard, & Cid, 1993), however the relationships between biomechanical parameters and psychological parameters do not appear to have been examined.

The Competition Sport Anxiety Inventory-2 (CSAI-2) developed by Martens, Vealey, and Burton (1990) has been used extensively by sport psychologist to examine the level of cognitive anxiety, somatic anxiety, and self confidence in a wide range of sports from swimming to track and field. Many researchers have used the CSAI-2 to examined the psychological changes that an athlete goes through before, during and after a competition (Burton, 1988; Gould, Petlichkof, & Weinberg 1984; Krane, & Williams, 1987) and others have examined how a psychological technique such as relaxation, visual imagery, and hypnotism may affect performance in competition or simulated competitions (Burton, 1988; Gerson & Deshaies, 1978; Lanning & Hisanaga,1983; Weinberg & Genuchi, 1980). These studies have used outcome measures, such as the race time in swimming, free throw percentage, and batting average. However, no published studies were found that analyzed specific technique changes between practice and competition and the possible relationship of the changes to psychological issues. This study attempted to get past the casual observations and outcome measures of performances to examine the relationship between specific changes in technique and the psychological changes.

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. 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 90 degree 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 of the CM (MHVCM), maximum vertical velocity of the CM (MVVCM), horizontal velocity of CM at the last step (HVCMLS), vertical velocity of the

CM at take off (VVCMTO), 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.

The pole vaulters also completed the CSAI-2 before each practice and competition. The CSAI-2 has 27 items which respondents rate on a 4-point Likert scale. The CSAI-2 has three subscales: cognitive anxiety (Cog Anx), somatic anxiety (Som Anx), and self confidence (Self Con) consisting of nine items each; therefore, the lowest possible score is nine and the highest possible score is 36 for each subscale. The questionnaire was administered within one hour of videotaping.

Each pole vaulter's averages were computed for each parameter in practice and competition. Difference scores then were computed between the practice and competition means for each pole vaulter. A Pearson Correlation Coefficient was calculated between all the parameter's difference scores. An alpha level of 0.05 was used as the test of statistical significance.

RESULTS: The results are presented in Table 1. There were five pairs of parameters that had statistically significant ($\leq$.05) correlations and would be considered moderate to highly correlated (Vincent, 1995). They included: MHVCM with MVVCM, MHVCM with SL 3 to 2, MVVCM with SL 2 TO 1, HVCMLS negatively with EE, and SL 3 to 2 with Self Con. All of the correlation coefficients for these parameters were .75 or higher. There were three pairs of parameters which were close to statistical significance and would be considered moderately correlated (Vincent, 1995). They included MHVCM with HTHH, MHVCM with Self Con, and EE negatively with Som Anx. Finally, there were four pairs of parameters that would be considered to have low correlations but still demonstrated some trends. They included MVVCM with Self Con, SL 3 to 2 negatively with Cog Anx, SL 2 to 1 with Self Con, and MHVCM with SL 3 to 2.

Table 1 Correlations of Difference Scores (n=7)

Parameter	MHVCM	MVVCM	HVCMLS	VVCMTO	SL 3 TO 2	SL 2 TO 1	HTHH	EE	Cog Anx	Som Anx
MHVCM	--									
MVVCM	.81*	--								
HVCMLS	.57	.54	--							
VVCMTO	.07	.12	-.57	--						
SL 3 TO 2	.64	.52	.45	-.03	--					
SL 2 TO 1	.91**	.79*	.53	-.05	.34	--				
HTHH	.70	.46	.15	.55	.24	54	--			
EE	-.54	-.24	-.79*	.35	-.23	-.53	-.36	--		
Cog Anx	.06	-.11	-.40	.26	-.61	.35	.26	-.04	--	
Som Anx	-.13	-.27	.57	-.44	.10	-.22	-.18	-.68	-.42	--
Self Con	.72	.63	.26	-.10	.75*	.60	.24	.02	-.18	-.45

Note. maximum horizontal velocity of the CM = MHVCM, maximum vertical velocity of the CM = MVVCM, horizontal velocity of CM at the last step = HVCMLS, vertical velocity of the CM at take off = VVCMTO, 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, Cogitative Anxiety = Cog Anx, Somatic Anxiety = Som Anx, Self Confidence = Self Con.
*p$\leq$.05. **p$\leq$.01.

DISCUSSION: The two highest correlation coefficients were maximum horizontal velocity with maximum vertical velocity and maximum horizontal velocity with the last stride length. These high correlations support McGinnis' (1995, 1997) results that getting as much horizontal velocity as possible is very important to the height cleared. As the pole vaulters in this study had more horizontal velocity, their maximum vertical velocity and last stride length increased. These pole vaulters had more horizontal velocity in the meets. Therefore, it may be important for a pole vault coach to realize that the pole vaulters will probably have more horizontal velocity, which

will result in a longer stride length, which could cause their steps to be off during the competitions.

Another pair of variables that were highly correlated was the last step and the maximum vertical velocity achieved. For the pole vaulters in this study, as their last stride length increased in the competition, their maximum vertical velocity also increased. However this is probably a result of their greater horizontal velocity, which led to the increased stride length. Another pair of parameters that were highly negatively correlated was the horizontal velocity at the last step and elbow extension. This is a correlation that is important to coaches because less elbow flexion makes it harder for the pole vaulter to start to bend the pole and makes the take off less smooth. As the pole vaulters in this study had a greater horizontal velocity at the last step, their elbow extension tended to be less. Therefore, a coach would want to observe a pole vaulter's elbow extension during competitions.

Two parameters that were highly correlated were the second to last stride length and self confidence. Rather surprisingly, these pole vaulters had slightly higher levels of self confidence on average during the competitions. As their self confidence tended to increase, the length of their second to last stride tended to increase. However, a large part this high correlation is probably explained by the lower but still related correlation between the maximum horizontal velocity with the second to last stride length, and the moderate correlation between maximum horizontal velocity and self confidence. It appears that self confidence is important to an increase in maximum horizontal velocity, which is related to an increase in stride lengths. These relationships probably make sense to coaches. If pole vaulters were lacking self confidence, they would probably be less likely to run as hard during the run up, which would result in shorter stride lengths. Therefore, if a coach notices that pole vaulters seem to be lacking self confidence, he or she may have to encourage the athletes to have a strong run up and pay attention to their steps.

Maximum horizontal velocity was found to be moderately positively related to the height of the top handhold. This is somewhat surprising considering that elbow extension was found to be highly negatively correlated to the horizontal velocity at the last step. Apparently the pole vaulters in this study were getting better extension in the rest of their bodies but not in their top arm as their horizontal velocity increased.

Elbow extension and somatic anxiety were two parameters that were found to be moderately negatively correlated. Somatic anxiety is the physiological feeling of anxiety such as butterflies in the stomach. Therefore, it appears that somatic anxiety may have caused the pole vaulters in this study to have less elbow extension. Somatic anxiety was found to have little correlation with the height of the top hand hold. Therefore, it appears that the somatic anxiety may have lead to a selective effect of less extension in the elbow but not in the rest of the body.

Another pair of parameters that had a low correlation was the pole vaulter's maximum vertical velocity and self confidence. As the pole vaulters' self confidence rose, so did their maximum vertical velocity. Although this was probably related to an increase in horizontal velocity, it makes sense that more confident pole vaulters would attack the pit with more vigor. Again, the importance of self confidence to the horizontal and vertical velocity was demonstrated. Not only may a lack of self confidence lead to a lower run up velocity, it could affect vertical velocity, which could have disastrous effects on technique after take off.

A final pair of parameters that had a low negative correlation was cognitive anxiety and the second to last stride length. Cognitive anxiety is thinking or worrying about things such as the competition. As the pole vaulters' cognitive anxiety went up, their second to last stride length tended to get shorter. Therefore, if a coach notices that a pole vaulter seems to be worrying excessively, the coach may need to pay special attention to the pole vaulter's second to last stride length to make sure the steps are not off.

CONCLUSIONS: The results of this study demonstrated that the maximum vertical velocity that the pole vaulters could achieve was directly related to their horizontal velocity. Coaches may also need to pay special attention to pole vaulters' elbow extension as the pole vaulters horizontal velocity and somatic anxiety increase. The pole vaulters' self confidence was found to

be related to horizontal velocity, vertical velocity, and stride lengths. Cognitive anxiety was found to be negatively related to the second to last stride length. The results give coaches some indications of what may happen to pole vaulters' techniques as aspects of their technique or psychological readiness change.

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