THE RELATIONSHIP OF VAULT RUN SPEEDS AND FLIGHT DURATION TO SCORE

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The vault event makes up approximately 17% of the male all-around gymnast. The vault is unusual in gymnastics in that it is not composed of a routine of several skills, but rather a single skill. The vault is broken down into several components or phases: (a) run, (b) hurdle, (c) board take off, (d) pre-flight, (e) support, (f) post-flight, and (g) landing. The vault run has been considered a predictive component of vault performance in both ease of execution and performance score (13). Sands and Cheetham (13) showed approximately 91% of the variability in optional vault scores of female gymnasts could be predicted by knowing the maximal run speed and the number of steps in the approach, with maximum speed being almost five times more important in predictive capability than the number of steps in the approach.

Post-flight height and distance have been identified as critically important to the scoring potential of men's vaulting (9). Takei (16) studied the handspring vault at the 1987 Pan American Games and found that post-flight duration correlated highly with final score. A comparison of Olympic athletes with U.S. National Team gymnasts indicated that Olympic gymnasts had significantly longer post-flight durations than U.S. National Team gymnasts (17).

The purpose of this study was to investigate the approach run up, and the duration from horse contact to mat contact of male gymnasts at the 1995 Winter Cup Challenge competition held at the United States Olympic Training Center (USOTC) in Colorado Springs, Colo. Specifically, the goal of this study was to correlate the approach run up speed in five sections and the duration of horse contact to mat contact with final score. The information obtained from this investigation may be helpful in focusing training goals at specific performance levels and skill segments to maximize score.

Methods

Site

Data collection was performed in conjunction with the 1995 Senior Men's Winter Cup Challenge competition held at the USOTC in Colorado Springs, Colo., on January 27–28.

Subjects

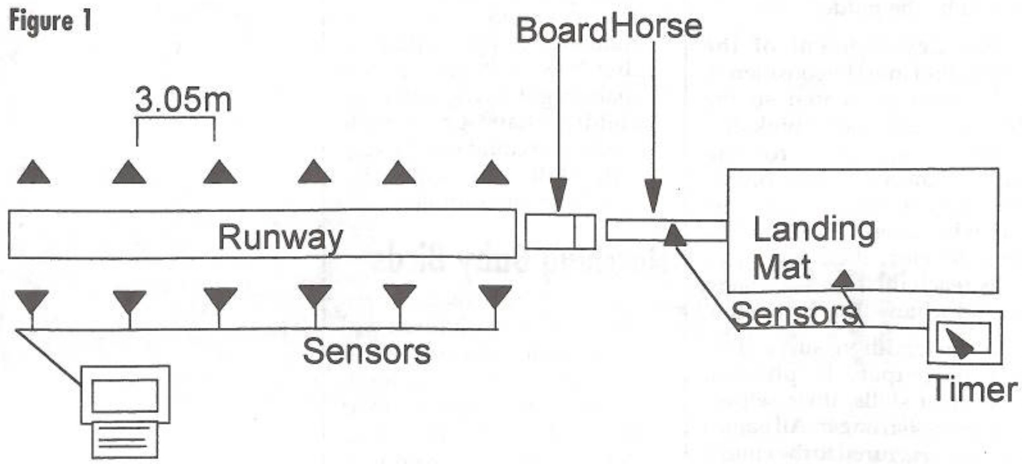
The athletes were senior level male gymnasts involved in the preparation for the 1996 Olympic Games. The Winter Cup Challenge competition was important for athletes who were seeking placement on the U.S. National Team in addition to those already qualified as members of the 1994 World Championships Team. Although several World Championships Team members participated in the Winter Cup Challenge competition, they were not included in placings nor provided cash awards.

Equipment

The vault runs were timed by photocell timers interfaced directly to a personal computer. Six photocell/reflector pairs were placed perpendicular to the approach runway at 3.05 m (10 ft) intervals starting at the end of the horse and continuing to 60 feet from the horse. The photocells and reflectors were placed at a height of 1.34 m (53 in), roughly the height of the shoulder or head of the vaulter. The photocells, reflectors, computer, software, and interfacing cables were provided by the Biomechanics Division of Sport Science at the USOTC (Figure 1). The computer determined the time and speed of the athletes from point to point in the sensor array. Time was recorded to the nearest 0.001 s. and speed to the nearest 0.001 m/s.

A second timer was used to detect the interval between horse contact and mat contact. Specifically, the second timer was activated at horse contact and deactivated at landing. A vibration sensor was taped to the undersurface of the horse

Figure 1



and placed inside the mat to detect initial impact with the horse and landing on the mat. The timer was designed by Ed Isabelle of Woodward Gymnastics Camps. The timer recorded to the nearest 0.001 s.

Procedures

Each athlete was allowed one vault in the competition based on International Gymnastics Federation (FIG) rules. One investigator initiated timing of the vault run photocells via a computer key press. The results of the timing were immediately displayed on the computer screen and recorded. A second investigator observed the horse to mat event timer and recorded the event time, number of landing steps, and score. All timers were then reset and prepared for continued vaulting attempts.

Data analysis

The data were analyzed via descriptive statistics, a 2 x 5 analysis of variance (ANOVA) (compulsory or optional by approach run up segment), and multiple regression. The critical region for rejection was set at alpha = .025 (14).

Results

Descriptive statistics

Twenty-one gymnasts participated in the optional session, and 22 gymnasts participated in the compulsory session. The discrepancy in subject count was due to one gymnast waiving the optional portion of the competition. The mean and standard deviations of the vault run speeds during each approach run up segment are shown in Figure 2.

Inferential statistics

A 2 x 5 ANOVA was calculated on the run up speeds. The results indicated that speeds differed by session ($F(1,41) = 19.73$, $p<.001$), by segment ($F(4,164) = 343.33$, $p<.001$), and the interaction ($F(4,164) = 3.32$, $p<.012$). A Tukey Honesty Significant Difference (14) post hoc test showed that all pairs of means were different except the following: (a) compulsory second segment with the optional first segment, (b) compulsory third segment with the optional second segment, (c) compulsory fourth segment with the optional third segment, (d) optional fifth segment with optional third and fourth segments, and (e) optional fifth segment with optional fourth segment.

Multiple regression using the backward method (12) was undertaken to determine a statistical model for score prediction based on the five approach run up segment speeds, interval from horse contact to mat contact, and number of steps on landing. The multiple correlation coefficient for optional vaults was $r = .63$, ($F(3,21) = 7.29$, $p<.004$). The variables meeting the inclusion criteria were reduced to the number of steps on landing, and the time interval between the horse contact and mat landing. The beta values for these variables indicated that the number of steps on landing was nearly twice as predictive in determining the final score than the interval from horse contact to landing. The adjusted $r^2 = .34$, indicating approximately 34% of the variability in optional vault scores could be predicted by this equation. The regression equation obtained was:

Optional Score = Landing steps (−1.001521) + Support to landing interval (2.224091) + 7.087312

Compulsory vaults were also analyzed via multiple regression using the backward method. The multiple correlation coefficient $r = .74$, ($F(3.21) = 8.58$, $p<.001$), and adjusted $r^2 = .49$, indicating that approximately 50% of the variability in compulsory vault scores could be predicted by the obtained regression equation. The variables meeting the inclusion criteria were: (a) landing steps, (b) segment one speed, and (c) segment five speed. The regression equation is shown below:

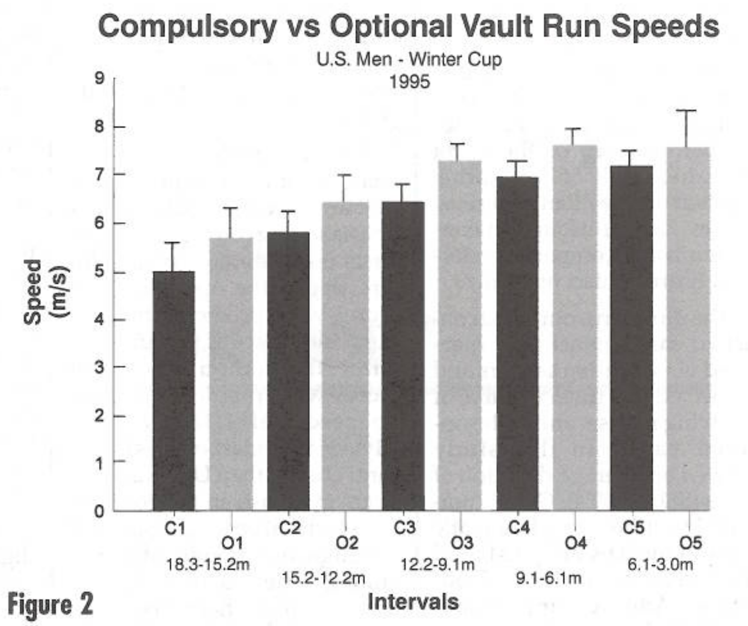


Figure 2

Compulsory Score = Landing steps (1.018712) + Segment 1 speed (0.899192) + Segment 5 speed (−998374) −81.506220

The beta values of these variables indicated the speed segments were approximately equal in their predictive capability, and the number of landing steps was only slightly less predictive than the speed values.

Discussion

Vaulting seems to be a preferred event for biomechanical analysis among investigators with many studies analyzing various kinetic and kinematic parameters (1–11, 15–19). The average maximal vault run speed for optional vaults for this study was 7.50 m/s (SD = 0.69 m/s). Takei (15) obtained average horizontal component velocity values of 7.2 m/s for U.S. National Team gymnasts and 7.93 m/s for Olympic gymnasts at board contact while performing handspring front tuck vaults. A study by Dillman, Cheetham, and Smith resulted in an average horizontal component velocity of 7.79 m/s for handspring type vaults at board contact at the 1984 Olympic Games. Tichonov found approach run speeds of 7.9 m/s in the handspring full twist vaults, 7.9 m/s in the handspring front tuck faults, and 8.0 m/s in the Tsukahara vaults.

The compulsory vaults in this study were performed with a slower approach run up speed at all intervals when compared to optional vaults (Figure 1). This may have been related to the nature of the hecht compulsory vault which requires extreme care in avoiding too much forward rotation (angular momentum) during the pre-flight phase. The hecht vault requires the gymnast to begin rotating forward following board departure, and then arrest and reverse this forward rotation (angular momentum) by actions during the support phase. This can be problematic and dangerous if the gymnast fails to adequately reverse his forward rotation (angular momentum) following support. Gymnasts failing to accomplish this reversal may land uncomfortably on hands and feet or worse. The average maximal run up speed of the compulsory vaults in this study was 7.15 m/s (SD = 0.35 m/s). Tichonov (19) studied the hecht vault and showed an average maximal approach run up speed of 7.1 m/s. Arnold (1) studied American male gymnasts and indicated that the horizontal component velocity at vault board take-off was 5.5 m/s in the fourteen highest scoring vaults and 5.8 m/s in the fourteen lowest scoring vaults.

Arnold's information further emphasizes the need for controlled horizontal velocity for the performance of the hecht vault. In a study of handspring vaults at the 1987 Pan American Games, Takei (16) found an average horizontal component velocity at board contact of 7.5 m/s.

The duration from horse contact to mat contact was measured via vibration sensors and connected to a timer capable of resolving milliseconds. The optional vaults in this study showed an average duration of 1.17 s (SD = 0.09 s). Other comparable studies used kinematic measurement techniques based on observations of film and videotape. Adding support and postflight durations together for comparison purposes, shows values of 1.03 s in the handspring type vaults (15), 1.04 s in the handspring front tuck vault (6), and 1.14 s in Tsukahara type vaults (8). Tichonov (19) found support and post-flight durations of 1.12 s in handspring full twist vaults, 1.10 s in handspring front tuck vaults, and 1.05 s in Tsukahara vaults. The slightly longer time period recorded in this study may have been due to real time differences due to longer support and flight times, or the differences may be due to the means of measurement. The kinematic assessment methods used in other studies relies on visual observation and judgment of when the hands and feet contact their respective surfaces. The measurement technique used in this study relied on the transmission of a vibration from the impact to a vibration sensor. Moreover, the type of vault performed in the present study was most commonly a type of Tsukahara (40 our of 55, 73%). The alternate hand placement on the horse will result in longer support times being registered by the vibration sensor, and thus longer total times.

The compulsory vault duration from horse contact to mat contact in this study was 1.00 s (SD = 0.08 s). Tichonov (19) showed a support and post-flight duration of 0.946 s. The handspring compulsory vault in the 1987 Pan American Games resulted in an average support and post-flight duration of 1.0 s (16).

The multiple regression analyses of these data indicate that an important point of emphasis among coaches and gymnasts on landings remains. Interestingly, the optional vault scores were predicted by support and post-flight duration, while the compulsory vault scores were predicted by run-up speeds. Takei (17) found that Olympic gymnasts were significantly better than U.S. National Team gymnasts in the horizontal velocity at board contact, and postflight duration and distance among other factors. Simple correlation coefficient between score and various kinematic variables in a study of the handspring front tuck somersault (18) ranged from r = .12 to r = .97. Interestingly, postflight duration correlated with judges' scores at r = .97, showing that post-flight duration was highly predictive of score. Multiple regression values obtained using kinematic variables by Takei (18) in studying the handspring front tuck vault ranged from r = .76 to r = .85. This study used various run-up speeds and duration from support to landing to obtain a multiple correlation coefficient of r = .63 for optional vaults. The compulsory vault in Takei's 1989 study also included multiple regression analysis and resulted in values ranging from 5 = .51 to r = .70. Interestingly, 50% of the variation in judges' scores was predicted by horizontal velocity at take off from the board and from the horse (18). The multiple correlation value of r = .74 in this study was obtained in studying a completely different vault which may account for the slightly higher value.

The somewhat lower predictive capability of the variables used in this study for optional vaults may be offset by the relative ease of acquisition of these variables when compared to those of kinematic analysis requiring high speed film or videotape and subsequent computer analysis. The slightly higher value for multiple correlation in the compulsory vault may be due to the inherent performance problems gymnasts often have with vaults from the hecht family. The gymnast must be very careful not to run too fast and rotate too quickly in the pre-flight in the hecht in order to avoid a clearly disastrous result. This may put a premium on the run up speeds expressed by those athletes who have mastered the technique of the hecht vault, allowing them to capitalize on this ability and thus increase their run-up speed and score.

Vault approach run-ups and flight times would appear to be logically linked to scoring potential of the gymnast. Certainly, the judging criteria for evaluation of vaulting evaluates these parameters or the direct results of them. The ability of simple measures to predict approximately one third of the variability of vault scores in optional vaults, and half of the variability of vault scores in compulsory vaults, indicates that coaches and gymnasts may profit from further real-time analyses of these parameters for implementation in training.

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