A BIOMECHANICAL ANALYSIS OF THE COMPULSORY HECHT VAULT

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INTRODUCTION

In the sport of gymnastics, a new Olympic quadrennium brings with it the challenge of new compulsory routines - specific sets of skills which must be mastered and perfected in four years. One of the most important compulsory skills this quadrennium for men is the compulsory hecht vault. While the hecht vault is not new to gymnastics, the preflight and repulsion techniques required to perform this vault are new to the gymnasts who must master the hecht vault. This vault, unlike other vaults being performed in optional competition, requires the gymnast to change his direction of rotation between the preflight and postflight phases of the vault. Consequently, appropriate techniques for the hecht vault differ from those used for handspring front or tsukahara-type vaults which have been analyzed previously (Kwon, 1990; Elliot, 1991; Takei, 1992) and which gymnasts today are more accustomed to performing.

In this study, junior and senior elite gymnasts competing in the 1993 Men's Winter Cup Challenge were videotaped performing the compulsory hecht vault for the first time in national competition. A two-dimensional biomechanical analysis was conducted to compare characteristics of high scoring vaults to those of low scoring vaults and to provide coaches with actual quantitative information regarding those characteristics believed to be critical to success.

METHODOLOGY

Gymnasts were videotaped at 200 Hz using a NAC HSV-400 camera placed in the stands perpendicular to the vaulting horse. Of the 48 vaults videotaped, 14 of the highest scoring vaults (ranging from 9.30 to 9.55), 14 of the lowest scoring vaults (ranging from 8.15 to 8.65), and an additional 10 vaults performed by national team members (ranging from 8.80 to 9.30) were digitized at 100 Hz and analyzed using a PEAK Performance, Inc. motion measurement system.

Each gymnast's board contact, preflight, horse contact, and much of postflight was digitized using an 8-segment model. The data were then filtered with a Butterworth digital filter with cutoff frequency of 8 Hz. Kinematic variables of interest, such as the gymnasts' horizontal and vertical velocities during preflight, body angles at contact, shoulder angles at contact, hip angles during repulsion and postflight, and heights attained during postflight, were calculated from the smoothed data. Because gymnasts' landings were not videotaped, their postflight distances were not measured directly but were instead estimated from the positions and velocities of the gymnasts' centers of mass at take-off from the horse.

Finally, the gymnasts were grouped according to score and t-tests were done to compare parameter means for the 14 highest and 14 lowest scoring vaults. Gymnasts were also grouped according to the degree of hip flexion they exhibited during postflight, and the ANOVA technique was used to compare parameter means for the three groups.

For all statistical tests, a p-value of 0.05 or less was considered significant.

RESULTS AND DISCUSSION

Data from this study indicated that at this point in the quadrennium, elite American gymnasts are still learning appropriate preflight and repulsion techniques for the hecht vault. Of the 38 gymnasts analyzed, only 14 (38 %) met the requirement that body angle at contact be at least 20° above horizontal, and only 23 (60 %) met the requirement that hip angle during repulsion and postflight be no less than 150°. No gymnast attacked his approach at full speed, and no gymnast earned bonus points for distance.

Table 1 lists means, standard deviations, and ranges of critical kinematic parameters computed for 14 of the highest (mean 9.40) and 14 of the lowest (mean 8.40) scoring vaults, and Figure 1 illustrates some of the qualitative differences between a high (9.55) and a low (8.50) scoring vault. As shown in Table 1, the preflights of the high scoring vaults differed significantly from those of the low scoring vaults. The high scoring vaulters exhibited greater vertical velocities at board take-off (BT) and smaller vertical velocities at horse contact (HC) than the low scoring vaulters. Consequently, 12 of the 14 high scoring gymnasts met the minimum requirement that the body angle at HC be greater than 20° above horizontal while none of the 14 low scoring gymnasts did. Gymnasts in the two groups also differed in their shoulder angles and contact distances at HC. The high scoring gymnasts, on average, were more extended in their shoulders and were in a better position to exert a blocking force on the horse than the low scoring gymnasts. They were also in the air longer during preflight and contacted the horse much closer to its far end than the low scoring gymnasts.

Fewer significant differences between high and low scoring vaults were observed in the repulsion and postflight parameters. As shown in Table 1, the high scoring gymnasts' velocities at take-off from the horse (HT) were similar to those of the low scoring gymnasts. Because position and velocity at HT determine postflight height and distance, postflight heights and distances for the high and low scoring gymnasts were also similar. Gymnasts' body angles and shoulder angles at HT, in contrast, did differ significantly. The high scoring gymnasts left the horse with a greater shoulder angle and a greater body angle relative to horizontal than the low scoring gymnasts.

When gymnasts were grouped according to their degree of hip flexion in postflight (Group A > 175°, Group B between 150 and 175°, and Group C < 150°), no significant differences were observed in the distribution of scores or average preflight parameters such as body angle or shoulder angle. Differences were noted, however, in the repulsion and postflight techniques used by gymnasts in each of the groups. A typical Group A gymnast, for example, closed his shoulder angle (mean shoulder angle of 73°) and arched (mean hip angle of 182°), driving his chest upward upon leaving the horse. A typical Group C gymnast, in contrast, opened his shoulder angle to a greater extent (mean shoulder angle of 93°) and piked (mean hip angle of 132°), lifting his hips rather than his shoulders upon leaving the horse. As a result, the gymnasts in Groups A and C did not, on average, attain the postflight distances that the gymnasts in Group B did.

Finally, to determine which characteristics of the hecht vault had the greatest influence on judges' scores, correlations between selected parameters and gymnasts' scores were computed. These calculations suggest that gymnasts' scores at this competition were influenced most strongly by body angle at HC (r=.77) followed by postflight height (r=.33). Scores were only slightly correlated to hip angle during postflight (r=.05) or to postflight distance (r=.22).

Table 1. Comparison of critical parameters for high and low scoring vaults. P-values are listed for parameters for which means differed significantly.

Parameter		High Scoring (n = 14)	Low Scoring (n = 14)	P-value
Vh @ BT	mean ± SD	5.5 ± 0.4 m/s	5.8 ± 0.5 m/s	-
	(max - min)	(6.0 - 4.6 m/s)	(6.4 - 4.9 m/s)	
Vv @ BT	mean ± SD	3.7 ± 0.2 m/s	3.4 ± 0.4 m/s	.05
	(max - min)	(3.9 - 3.4 m/s)	(4.2 - 2.6 m/s)	
Vv @ HC	mean ± SD	1.2 ± 0.5 m/s	1.7 ± 0.4 m/s	.01
	(max - min)	(1.7 - 0.03 m/s)	(2.8 - 1.2 m/s)	
body angle @ HC	mean ± SD	24 ± 5°	8 ± 4°	0
	(max - min)	(34 - 16°)	(15 - 0°)	
shoulder angle @ HC	mean ± SD	142 ± 5°	128 ± 13°	.001
	(max - min)	(148 - 131°)	(148 - 107°)	
contact distance	mean ± SD	18 ± 8 cm	40 ± 10 cm	0
	(max - min)	(39 - 9 cm)	(61 - 27 cm)	
preflight time	mean ± SD	0.28 ± 0.04 s	0.21 ± 0.14 s	0
	(max - min)	(0.37 - 0.23 s)	(0.26 - 0.17 s)	
Vh @ HT	mean ± SD	4.2 ± 0.4 m/s	4.3 ± 0.5 m/s	-
	(max - min)	(5.0 - 3.6 m/s)	(5.2 - 3.4 m/s)	
Vv @ HT	mean ± SD	2.0 ± 0.3 m/s	2.2 ± 0.4 m/s	-
	(max - min)	(2.3 - 1.3 m/s)	(2.9 - 1.6 m/s)	
body angle @ HT	mean ± SD	34 ± 5°	16 ± 6°	0
	(max - min)	(41 - 27°)	(28 - 7°)	
shoulder angle @ HT	mean ± SD	91 ± 10°	73 ± 16°	.001
	(max - min)	(113 - 77°)	(110 - 45°)	
hip angle (max pike)	mean ± SD	157 ± 20°	156 ± 26°	-
	(max - min)	(190 - 117°)	(187 - 105°)	
postflight height	mean ± SD	2.3 ± 0.1 m	2.2 ± 0.1 m	-
	(max - min)	(2.5 m - 2.1 m)	(2.5 - 2.0 m)	
postflight distance	mean ± SD	2.9± 0.4 m	2.6 ± 0.5 m	-
	(max - min)	(3.5 - 2.2 m)	(3.5 - 1.9 m)	

CONCLUSIONS

The data from this study suggest that the preflight and repulsion phases of the compulsory hecht vault are critical. Gymnasts must attain the rise and rotation off the board necessary to achieve the desired body position at contact - that is, a contact angle of at least 20° above horizontal and a shoulder angle as extended as possible. Such a position puts the gymnast in a good position to exert a strong force against the horse which, in turn, serves to change his direction of rotation and determine his postflight height and distance. In this study, body angle at contact was the key parameter that distinguished the high scoring gymnasts from the low scoring gymnasts. The high scoring gymnasts had an average contact angle of 24°, while the low scoring gymnasts had an average contact angle of only 8°. In addition, the gymnasts who maintained a "hollow" or straight body position through the repulsion stage of the vault, blocking through their

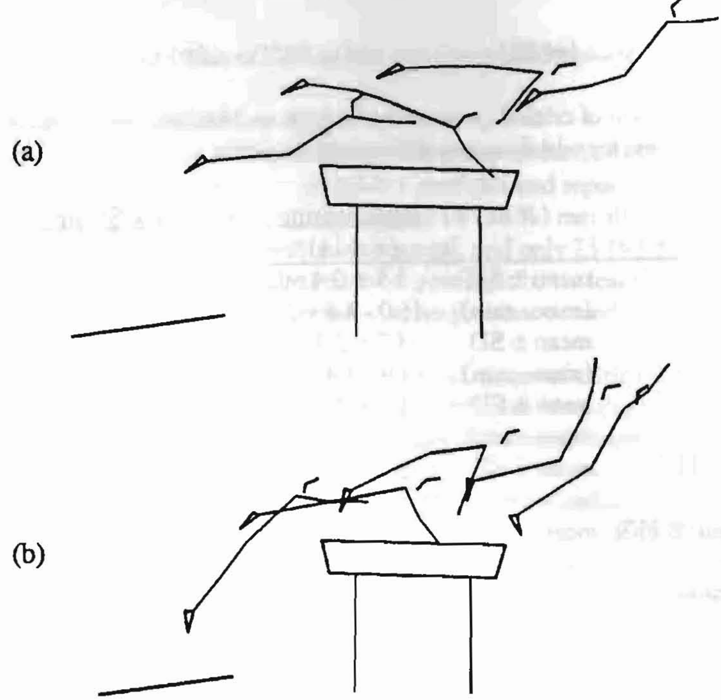

Figure 1. Comparison of (a) one of the high scoring vaults (9.55) to (b) one of the low scoring vaults (8.50).

shoulders, achieved greater distances on average than the gymnasts who closed their shoulder angles and "arched" or the gymnasts who lifted their hips and "piked". Lastly, gymnasts' horizontal speeds at board take-off did not necessarily determine success in this competition. However, because postflight distance is determined by horizontal velocity at take-off from the horse and time in the air, and because bonus is earned by maximizing postflight distance, horizontal velocity is likely to become a more important determinant of gymnasts' scores in the future.

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