A CINEMATOGRAPHICAL AND MECHANICAL ANALYSIS OF THE HECHT VAULT

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

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1970

A CINEMATOGRAPHICAL AND MECHANICAL ANALYSIS OF THE HECHT VAULT

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Health, Physical
Education and Recreation

Approved

Professor of Physical Education
Thesis Advisor

Head of Department of
Physical Education

1970

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

At the 1962 World Gymnastics Championships, the Japanese competitor Yamashita performed an original vault on the long horse. It is now called the Yamashita vault and is a free body rotation in a piked position. This was, for gymnasts all over the world, the signal which opened the way for the search for more and more complex vaults. Some variations of the Yamashita vault have already been executed. In 1963 the Bulgarian Adamov performed Yamashita's vault with a full twist. Since then, no new modifications have been witnessed in the long horse event, not even at the 1968 Olympic Games. In contrast, the pommel horse, high bar, and floor exercises have all seen innovations. This might be explained by the following:

1. The points awarded to the vaults according to the International Gymnastics Federation do not motivate the athletes to study and perform more complex vaults.
2. There is a lack of emphasis on horse vaulting during the training periods.
3. There is a lack of research in this particular event.

In the areas of science, education, and technology, research provides new knowledge, improved teaching methods and innovations in technique. This can also be true for athletics. Through trial and error methods, gymnasts have been looking for something new. Trial and error can bring about modifications and can also improve teaching methods; but as one knows, it is a rather slow process. It appears that new knowledge is necessary. Biomechanical research of gymnastics may help. This research will take two forms. First, the descriptive form will elaborate the components of movements in terms of time, velocity, force, angles etc. A better understanding of this knowledge will develop a sound basis upon which corrections, improvements, or modifications of the form as well as teaching methods will take place. These descriptions will also produce hypotheses for the second form of research. This will be the experimental method which will improve teaching methods and will possibly bring suggestions for completely new movements. In fact Mikov (8) in a previous biomechanical research on long horse vaulting concluded that all possibilities for original performances have not been exhausted.

In previous studies on the long horse done by Fetz and Opavsky (3), Gombos (4), Guerrera (5), Kotelnikova(7), Vanis (10) and Wiemann (12), it has been found that the horizontal velocity, the take-off angle from the board, the angle of the body with the horse at initial contact, the height of the free flight and the horizontal landing distance are the most important factors which differenciate good vaulters from bad ones. Most of these studies have been done with subjects of a high level. With subjects having less experience, are these same factors the most important?

From a practical point of view, a vault is considered good or bad when it has been evaluated according to the F. I. G. judging criteria. It is stated that the vault should be evaluated mainly according to the angle of the body with the horse at initial contact (minima 25-30 degrees), the height of the free flight and the horizontal landing distance (minima 1600 mm). It would then be interesting to compare the different movement components with those criteria stated by the F. I. G. It is the writer's interest to investigate the long horse vault in light of the rapid development and increased popularity of gymnastics in Canada as well as abroad.

The Problem

Based on the lack of quantitative description and the criticisms of the evaluation of the "hecht" vault the purposes of this study were:

1. To describe quantitatively, with the aid of cinematography, the biomechanical movement components of a hecht vault.

2. To find the relationship between those movement components and the criteria for judging this vault as stated in the F. I. G. rule book.

Limitation of the Study

The problem was delimited mainly by the number of subjects. Four amateur gymnasts were subjects for this study.

Definition of Terms

Approach: The approach refers to the phase of the vault before the take-off from the springboard.

Take-off: The take-off refers to the phase of the vault when the gymnast is in contact with the springboard.

Pre-flight: The pre-flight refers to the phase of the vault from take-off until the vaulter contacts the long horse with his hands.

Initial contact: Initial contact refers to the moment the vaulter touches the springboard or the long horse.

Last contact: Last contact is defined as the final moment the vaulter is touching the long horse.

Free-flight: Free flight is the phase of the vault from last contact to the moment the vaulter's feet touch the ground at the landing.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature relevant to the present study can be divided into two categories: (a) that dealing with the descriptive form of research; and (b) that dealing with current opinions on evaluation criteria.

Literature Related to the Descriptive Form

Several studies have been conducted to describe quantitatively the different biomechanical components of a "hecht" vault. Tarakanov (9) studied the importance of the run in the learning process in long horse vaulting. He stated that a well adjusted run is of prime importance and that it facilitates the learning process and the fundamental technique of vaults and therefore makes it easier to perform them. In other respects, Wiemann (11) worked on the basic mechanics of forward rotation in gymnastics. He concluded, after having analysed movements performed by Dr. Oto, Yamashita, Endo, Nagosawa, Heckkinen, Minicelli and Hillebrandt, that contrary to popular opinion, the thrust at take off does not increase the rctational impulse but rather decreases it. He stated that as soon as the feet touch the board, a great angular velocity is created which afterwards is reduced by the thrust just prior to final contact. Comparing the take off phase of a Yamashita vault, as executed by its creator and by Endo, with a "hecht" vault, performed by Minicelli, he found that in a jump such as the "hecht" which does not need as much rotation as the Yamashita vault, the unilateral stoppage creates a proportional angular velocity which is completely absorbed by the thrust on the board. In an another study Wiemann (12) stated that the time of contact on the horse is the factor that differentiates good vaulters from bad ones.

Fetz and Opavsky (3) give some biomechanical component values of the hecht vault obtained in their study. They found a horizontal velocity of 6.3 m. per second at last contact with the ground prior to the preparatory jump and an elevation of the center of gravity in the free flight of 32 cm. They also found that the angle of body at contact with the horse is less than in all the other vaults. Gombos (4) found similar data in his study of the hecht vault. Guerrera (5) sought to quantify the mechanics of both the handspring and the hecht vault and to relate them to the scores awarded by the judges. He found that the higher scoring hecht vaults demonstrated a greater range of angular movement of the center of gravity on the springboard, a larger take-off velocity, a higher angle of the legs at initial contact and a greater rise of the center of gravity after last contact with the long horse.

Kotelnikova (7) compared the performances of the hecht vault of three famous world gymnasts: Krbecs, Chaklin, Yamashita. It was found that the highest score was attained by the gymnast who had the greatest speed, the greatest horizontal distance from the hand contact with the horse to the landing spot, the greatest horizontal distance from the take-off to the nearest end of horse, and the smallest angle with horizontal at take-off.

Literature Related to the Evaluation Criteria

The Federation of International Gymnastics established the standards for the competitive evaluation of performances. Figure I depicts perfect performance of a hecht vault. Thus, in order to be awarded a perfect score of 10.0, the vaulter's performance must parallel the performance illustrated in Figure 1.

The F. I. G. (1) also has established standards for specific phases of the vault. Figure 2, shows the different positions of the vaulter at initial contact. Points deductions with respect to these positions are as follows:

1. The maximum of 10.0 points will be given if the angle formed by the support of the hands through the stretched body (that is to say, the line from hands through the feet) with the top of the horse is at least 30 degrees.

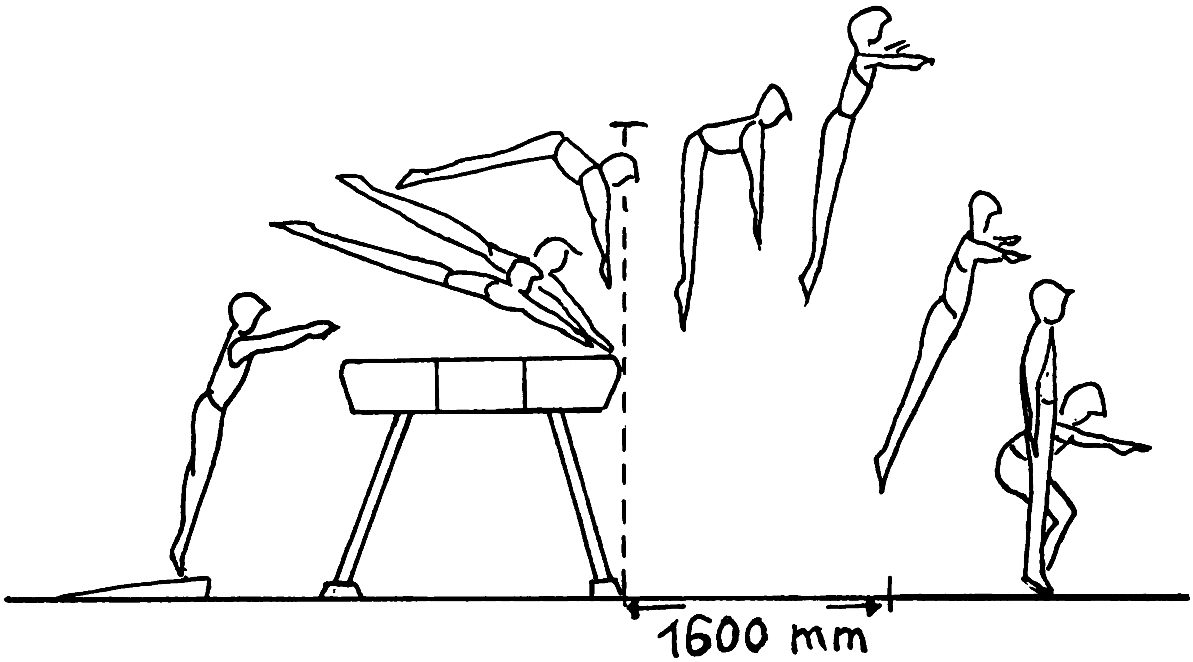

Figure 1. Perfect Hecht Vault Execution

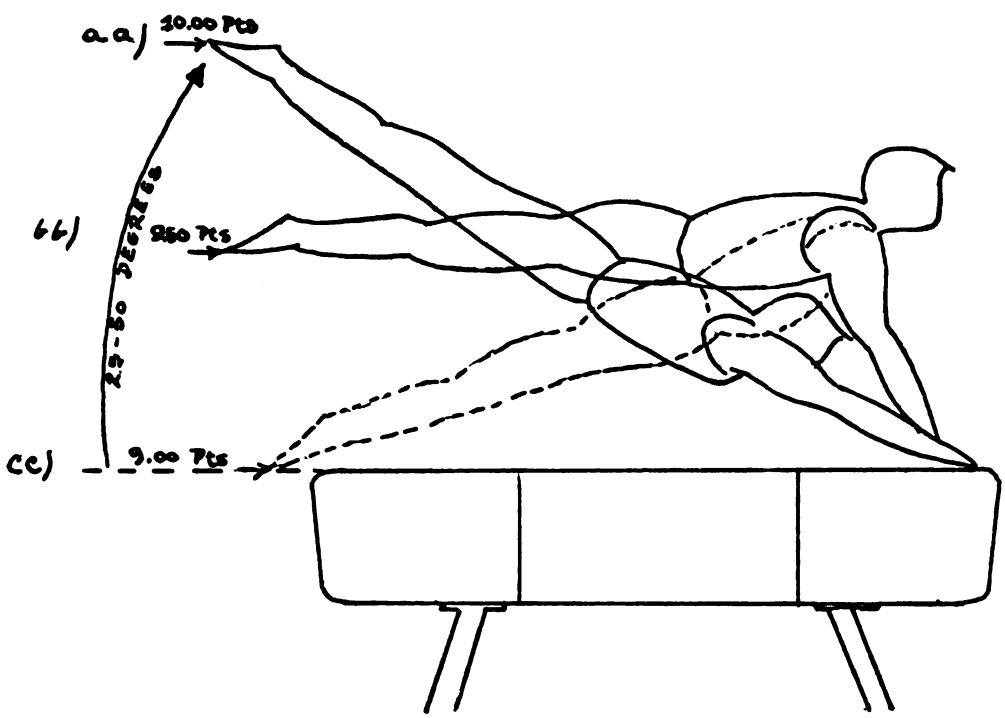

Figure 2. Initial Contact Evaluation

2. The maximum will not be more than 9.50 points for a horizontal support . . .
3. The maximum will not be more than 9.0 points if the feet are not higher than the top of the horse, and the score will decrease (proportionately) if the feet are still lower.
4. Of course, intermediary scores such as 9.10, 9.20, 9.60 and 9.70 points, etc., are applicable.

The F. I. G. stated that the vaults must show development during the second phase, demonstrating a high and long free flight. The following point deduction system applies to long horse vaults.

1. Flight and support of the hands below 30 degrees (see Figure 2, page 8)	1/10 to 10/10 points
2. Flight too low and not long enough following the support .	1/10 to 5/10 points
3. When, after the vault and at the landing, the gymnast is not at a distance which corresponds to the drawing (see Figure 1, page 8)	1/10 to 5/10 points
4. Too strong a flexion of the body forward before landing . .	1/10 to 5/10 points
5. Bad direction of the vault . .	1/10 to 5/10 points

6.	Placing the hand (s) in the (400 mm.) zone on the neck or croup side, or partly touching these zones (This rule recently changed). . . .	10/10 points
7.	Placing the hand(s) in the zone (400 mm.) in the center of the horse, or partly touching this zone	5/10 points
8.	Bad position of the feet, legs, body, head, unnecessary straddling of the legs, each time .	1/10 to 3/10 points
9.	If the faults just mentioned are committed during the entire vault	4/10 to 10/10 points
10.	Touching the body of the horse with the feet, the legs, the knees, or other part of the body	2/10 to 5/10 points
	For even more serious cases . .	6/10 to 10/10 points
11.	Arms bent during the execution of the handspring	1/10 to 10/10 points
12.	Knees bent during the execution of the hecht (swan) vault . .	1/10 to 10/10 points

13. Standing at the end of the vault. The landing after the vault is judged in the same manner as for the apparatus and floor exercise, that is:

    a. Small step or hop . . . 1/10 to 2/10 points
    b. Several steps or hops, touching the floor with hands without real support . . . . 2/10 to 3/10 points
    c. Sitting, kneeling, falling on the back, or very bad posture . . . . 3/10 to 5/10 points
    d. If undesirable behavior before and after the vault 1/10 to 3/10 points

Fetz (2) deals at length with the problem of two long horse evaluation criteria: The grip zones and the preflight angle. He rejects both criteria believing the vault should be evaluated principally for height and distance. Faults of preflight and grip should only be considered according to their bearing on height and distance. The author's fundamental question is: Does the preflight angle constitute a value intrinsically pertaining to the vault? From his viewpoint, good hechts often have a lesser angle than 30 degrees.

CHAPTER III

METHODS

The purpose of this chapter is to describe the procedures used in this study.

Subjects

The subjects were four male volunteers. Their physical characteristics are presented in Table 1.

TABLE 1.--The physical characteristics of the subjects.

Subject	Age	Weight (Kg)	Height (m)	Vertical Jump (m)*	Standing Broad Jump (m) *
A	23	76.4	1.676	0.660	2.667
B	21	63.6	1.676	0.724	2.731
C	19	65.9	1.727	0.552	2.375
D	21	62.3	1.689	0.648	2.693

*The best of three trials.

All had earned a degree in physical education. They possessed different degrees of jumping abilities and therefore, provided a range of scores. All of them were familiar with the sport as gymnasts but only two were competing in the senior category.

In preparation for the testing, the subjects were directed to wear only shorts and gymnastic shoes. This made it possible to determine the position and movements of the subjects' body segments by cinematographical techniques. Points of articulation at the shoulder, hip, knee and ankle points were determined by palpation and then marked to form black spots on the skin approximately 2.5 cm in diameter. The distance between each of the spots, as well as the heights of the performers while standing erect were also determined. Performances such as standing broad jump, vertical jump (Table 1) were also recorded to determine possible relationships between these data and the movement components.

Direct Measurement of the Approach Velocity

An apparatus (Figure 3) was built with a "breaking circuit switch" and a wooden pedal in order to determine the average running velocity between the starting point and the initial contact with the board.

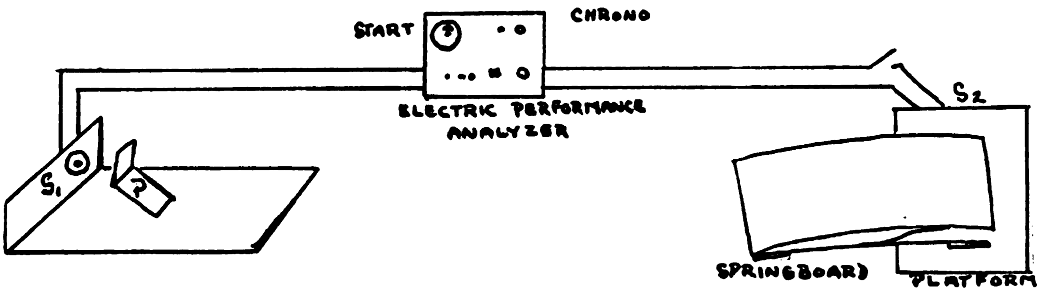

Figure 3. Time Recording Apparatus

This switch was connected to an Athletic Performance Analyzer which recorded the length of time (in hundreth of a second) during which the switch was open. A platform was placed underneath the springboard and served to break the circuit.

The subject was asked to stand on the pedal (P) with the foot that he was going to move first; the contact at S1 was closed and the chronometer was set at zero time. As the foot left the pedal, the chronometer started and worked until the athlete contacted the springboard. This contact with the platform stopped the chronometer. The average running velocity was calculated from the measured time and distance.

Cinematographical Procedures

Filming Equipment

The photographs were taken with a Bolex 16 mm motion-picture camera which was mounted on a stationary tripod. A telephoto lens was used in order to get a better picture and minimize any perspective errors. Kodak tri-X reversal film no. 7278 was employed. The subjects were photographed against the espaliers which served as a background grid. The horizontal and some of the vertical wooden bars were covered with white masking tape. The espaliers were 1.5 m from and parrallel to the field of motion. The distance between the vertical bars was 90 cm while the distance which separated the marked horizontal ones was 30 cm. An official springboard and long horse were used in this study. The height at the top of the horse was set at 1.35 m. The photographic data were collected in the Maisonneuve Recreation Center, Montreal, Canada. The regular artificial lighting of the gymnasium was of sufficient intensity to meet the needs of good photography.

Filming Technique

The camera speed was set at 64 frames per second with a lens opening of f 2.8. The shutter speed provided a clear picture for later analysis. To minimize the effects of reduced spring tension on the camera spring, the camera was kept wound as fully as possible and was always started a few seconds prior to the testing in order to permit the camera to reach its regular speed before the picture taking began.

The camera was installed 30 m from the field of motion as diagramed in Figure 4. In order to avoid "to from" distortion introduced by "panning" Hubbard (6) states that the camera must be 30 to 40 feet from the subjects. The camera was placed so that its lens was parallel to and directly opposite the approximate mid point of the field of motion. This was about 10 m. and included: the last stride length, the length of the preparatory jump, the distance from the springboard to

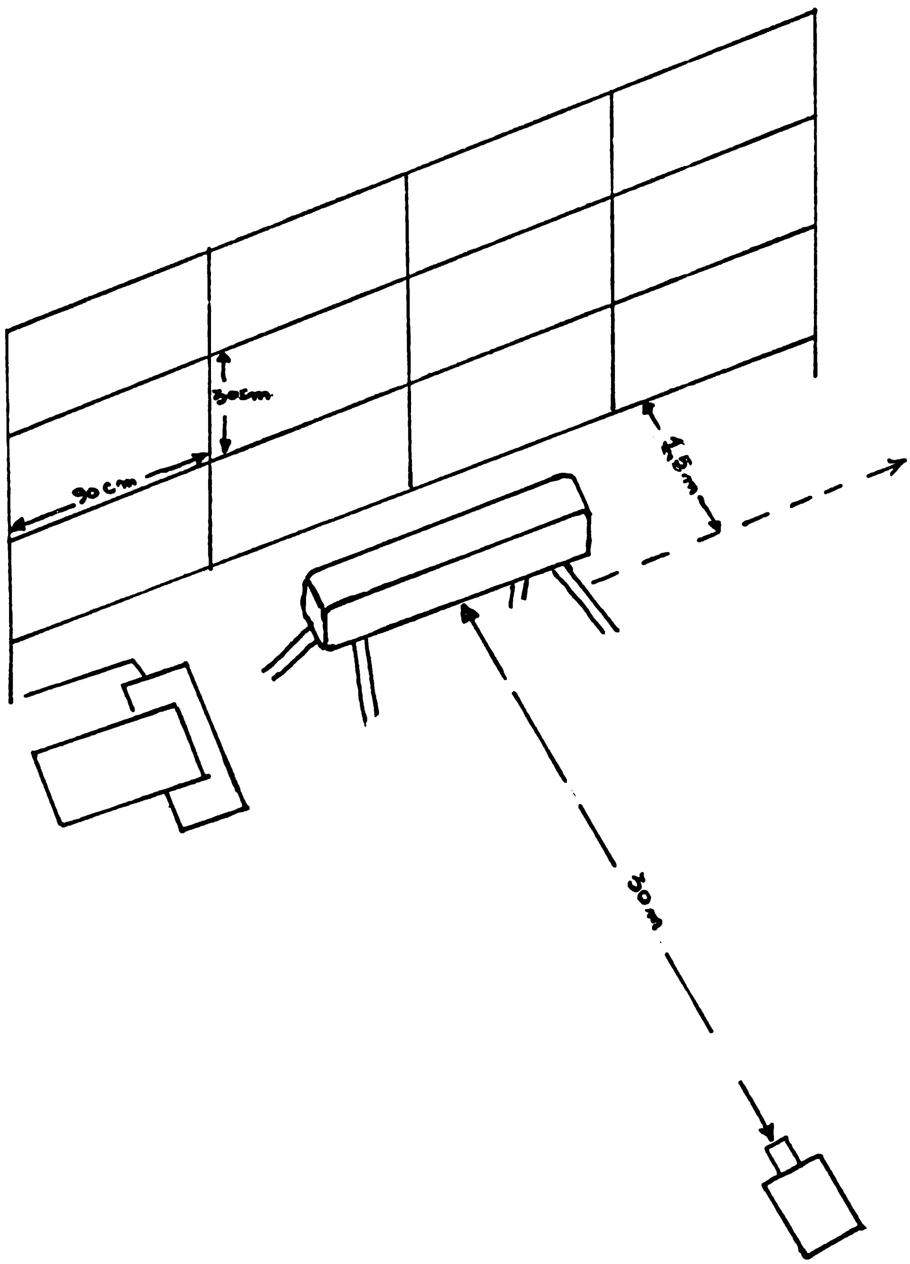

Figure 4. Placement of the Camera in Relation
to the Long Horse and the Grid
(Posterolateral View)

the horse, the length of the horse and the distance from the horse to landing. The 30 m distance between the field of motion and the camera, together with the use of a telephoto lens, reduced as much as possible any perspective error. At this distance, it was not necessary to move the camera from left to right in order to photograph the movement of a vaulter throughout his execution. The height of the camera above the floor was set at 1.5 m.

Calibration of the Camera

A medicine ball weighing 1.73 Kg was used to verify and determine the reproductibility of camera speed. The ball was filmed as it dropped from a height of 2.43 m. The elapsed time was calculated between the moment the ball was released and the moment it contacted the floor. The following formula was used: $S=1/2\ gt^2$. The value of g used was $9.80 m/sec^2$. The calculated time (t) was equal to 0.6746 of a second. Later, by careful observation of the film, the number of frames from the moment the ball was released until it reached the floor was determined by means of a film counter on the projector. Knowing that the ball fell 2.43 m in 0.6746 second, it was possible to check the true speed of the camera. The ball was filmed two times while dropping, and the camera speed was found to be one frame for each 0.01933 seconds of time.

Calculation of the Multiplier

This factor was computed on the basis of the photographed distance marks. A 3.658-m bench was photographed in the field of motion. When the film was projected on the wall, this bench appeared to be 76.3 mm long. After calculation, the multiplier was found to be .04794 to give all the measurements in meters. The multiplier was used to convert distances measured after the projection of the film to lifesize distances.

Analysis Equipment

The developed film was placed in a 16 mm Spectro Analyser Projector, and each of the frames to be studied was projected on 1 mm graph paper fixed to a board mounted at right angles to the optical axis of the projector. In order to eliminate multiplier fluctuations, the projector was fixed and was operated at distance by mean of a cable control. Some marks like the long horse and the vertical and horizontal lines from the grid were drawn from the first frame of each sequence in order to see if the projected pictures showed the chosen marks in exactly the same relative positions. If through panning or otherwise there were discrepancies, corrections were made to coordinate plots on the squared paper. The next step was to pin a sheet of transparent typing copy-paper over the squared master-sheet and to project onto it each frame to obtain the different angles of the body segments. The trajectory of the estimated center of gravity of the body was traced onto the master sheet (squared paper). Information such as distances, point of contact with the springboard, point of contact with the horse, point of contact at landing, etc. were also recorded.

Judging Procedures

Each gymnast was asked to perform five jumps. The first one was said to be for warming up, but it was recorded as well as the four others. The four remaining vaults were performed as if the gymnasts were competing, i. e. two consecutive vaults executed twice by each of the gymnasts. All the vaults were evaluated according to the F. I. G. criteria. One chief judge and four other judges composed the jury. From the four judges scores, the lowest and the highest scores were rejected and the score employed was the mean of the two other judges scores.

Variables and Methods of Calculation

This study involved five general catagories of variables: (a) center of gravity, (b) velocities, (c) distances, (d) angles, and (e) times. These measures were selected to provide a comprehensive description of all phases of the vault. The statistical calculations (i. e. the mean, the standard deviation and the simple

Pearson coefficient of correlation) were calculated on an Olivetti Underwood Programma 101.

Center of Gravity

According to Dempster (13), the position of the center of gravity (c. of g.) with the body in the anatomical position is located at hip height (the crest of the ilium). If the arms are raised above the head simulating the body position of the vaulter through nearly all phases of the vault, the position of the center of gravity is shifted slightly toward the head. For purposes of analysis, the investigator believed that an estimate of the position of the center of gravity was justified. The path of a vaulter's center of gravity covered a horizontal distance of approximately 6 m. Therefore, any slight error of estimation along the path in relation to the large distance traveled would be insignificant. Furthermore, since the body segments maintained a relatively constant relationship to one another throughout all phases of the vault, the position of the c. of g. would not significantly shift within the body. This also minimized the effects of the estimation process. The c. of g. positions were estimated for each vault at every two frames from the last contact with the ground prior to the preparatory jump to the contact with the ground at the landing. Positions were estimated at initial and final contact with the springboard and the long horse and at the highest position of free flight.

Velocities

The velocity variables were the average horizontal velocity from the start to the initial contact with the board and the horizontal velocity of the preparatory jump. Velocities were calculated according to the formula $V=d/t$ where V is the horizontal velocity, d is the distance and t the time. The latter was an estimate of the horizontal velocity using the distance between the point when the c. of g. is over the last contact prior to the preparatory jump and the c. of g. at initial contact with the springboard. This velocity approaches more closely the horizontal velocity at initial contact with the springboard. A greater error would have perhaps appeared, if the velocity had been calculated using the small distance between the last two positions of the c. of g. prior to the initial contact.

Distances

The horizontal and vertical distances were quantified from the projected film and converted to life size using the multiplier. The following distances were determined.

1. The horizontal distance from the starting point to the near end of the long horse. Note: This distance was measured directly.

2. The horizontal distance from the last contact with the ground prior to the preparatory jump to the vaulter's toe at take-off.
3. The greatest vertical height of the center of gravity above the floor during the preparatory jump.
4. The horizontal distance from the far end of the springboard to the vaulter's toe at take-off.
5. The horizontal distance from the far end of the springboard to the near end of the long horse.
6. The vertical height of the center of gravity above the long horse at initial contact.
7. The vertical height of the center of gravity above the horse at last contact.
8. The greatest vertical height above the long horse of the vaulter's center of gravity during the free flight.
9. The horizontal distance from the far end of the long horse to the vaulter's toe at landing.

Angles

The angles formed by the horizontal and the legs, the legs and the thighs and the trunk and the thighs were measured at initial contact with the springboard. With respect to the horizontal, the angles formed by the toe contact and the center of gravity at initial and final contact were determined to know the range of motion of the vaulter on the springboard. The take-off angle was evaluated using the horizontal and the tangent to the pre-flight trajectory.

At the initial and final contact with the long horse, angles with the horizontal and the forearm, the arms and the trunk, and the trunk and the legs were measured. The measurements used to indicate the range of motion of these segments were determined as the differences between the initial and last contact angles.

Times

Since the time between frames was determined to be 0.01933 second, the amount of elapsed time in certain phases of the vault was calculated by multiplying that time by the number of frames used for each phase in question. The percentage time of each phase of the vault was determined as the ratio of the phase time to total vault execution time. The following phases and percentages were studied (a) contact with the springboard, (b) pre-flight, (c) contact with the long horse, (d) free flight, and (e) the time taken to perform the total vault from initial contact with the springboard to the landing.

Selection of Vaults

All the 20 hecht vaults filmed were used for the analysis. But, after having taken all the information from these sequences, it appeared that for one sequence the camera had not worked with the same running speed as for the other vaults. This sequence was eliminated from the data.

CHAPTER IV

ANALYSIS OF DATA

This chapter has been divided into the following major sections: (a) statistical techniques, (b) results and discussion, and (c) graphic presentation of the biomechanical movement components.

Statistical Techniques

Ranges, means, standard deviations, and correlations served the purposes of this analysis. The means provided measures of central tendency for each of the variables, while the standard deviations showed the variability. The simple Pearson coefficient of correlation was found for each of the variables and the judges' scores. However, a limitation existed in the latter technique because a single component was correlated with vault scores which are a measure of total performance. It was possible for certain vaults to be awarded identical scores even though specific components of the vaults were quite different.

Results and Discussion

To serve the purposes of this study, this section is divided as follow: (a) results and discussion of the quantitative aspect, and (b) relationships between movement components and the F. I. G. criteria for judging this vault.

Quantitative Aspects

This section is divided into the following phases: (a) the approach, (b) the take-off, (c) the pre-flight, (d) the take-off from the horse, and (e) the free-flight and the landing. References are made to the literature whenever applicable. Raw data for the different movement components and the inter correlations between all variables can be found in Appendices A and B respectively.

Approach

Table 2 shows the results of the approach. It can be seen that no significant correlations were found between those movements components and the scores. According to some studies on long horse vaulting (3, 4, 5, 7, 10), one might have expected a greater correlation with variable three. Mechanically, it can be said that for a better performance (i. e. a greater height of the c. of g. above the horse in the pre-flight, and a greater distance from springboard to landing) a greater velocity is needed. But, the score is given according to the overall form of the vault, and a greater velocity does not mean necessarily a greater score. If one compares the 8.7 scores of B4 and C3 to the 3.0 score of D5 (see Appendix A), it is noticed that the best scores were

TABLE 2.--Approach Results

No	Name of Variable	Mean	Range	Standard Deviation	Correlation with Score
1	Height of the preparatory jump (meters)	.132	.096 - .168	.022	-.197
2	Length of the preparatory jump (meters)	2.355	2.076 - 2.828	.159	.278
3	Horizontal velocity (m/sec.)	5.782	5.337 - 6.288	.244	-.275
4	Angle between the legs and the horizontal at initial contact with springboard (degrees)	83.55	72.0 -90.0	4.50	-.198
5	Angle between the legs and thighs at initial contact with springboard (degrees)	141.9	125.0 -158.0	12.2	.011
6	Angle between the trunk and thighs at initial contact with springboard (degrees)	123.0	91.0 -136.5	9.74	.092

N = 17 degrees of freedom

* = coefficient of correlation significant at .05 level of significance - an r of .456 was necessary to be significant.

executed with almost the lowest velocities (5.66 and 5.79 m per second respectively) whereas the lowest score was achieved with a much higher velocity of 6.29 m per second.

Take-off

Three significant correlations (Table 3) were found in the take-off phase. The results showed a .50 correlation between score and variable 9. (range of c. of g. movement on springboard), which suggests that the vaults performed while the range of movement of the center of gravity of the gymnast contacting the springboard was greater received the higher scores. Guerrera (5) found similar data in his study. Fetz (3) found in his study an elevation of the center of gravity of 0.61 m from the last contact on the springboard to the initial contact with the horse which might mean that the vaulter took-off at a low angle and that his center of gravity while contacting the horse traveled through a great range of movement.

On the other hand, a correlation coefficient of .53 with variable 10 suggests that the higher scores were obtained when the vaulters spent more time contacting the springboard. This contradicts Guerrera's data (5). He found a negative coefficient of correlation for this same variable. Mechanically speaking, for a greater performance the time spent on the board should be short. But, as in

TABLE 3.--Take-off results

No	Name of Variable	Mean	Range	Standard Deviation	Correlation with Score
7	Angle between the horizontal and the c. of g. at initial contact with the springboard (degrees)	58.04	57.0 - 69.0	12.46	-.187
8	Angle between the horizontal and the c. of g. at final contact with the springboard (degrees)	102.53	96.0 - 111.0	3.65	.192
9	Range of c. of g. movement on springboard (degrees)	41.26	32.0 - 50.0	4.80	.501*
10	Time on board (seconds)	.140	.116 - .155	.014	.526*
11	Percentage of time on board	10.63	8.69 - 12.14	1.03	.492*

N = 17 degrees of freedom

* = coefficient of correlation significant at .05 level of significance - An r of .456 was necessary to be significant.

the approach (running velocity) it is dependent upon the athlete's abilities.

A negative coefficient of correlation of -.54 was found between variable 11 and variable 18 which suggests that when the vaulter spent more time contacting the springboard he hit the horse (angle between forearm and the horizontal at initial contact) with a lower angle. The correlations (appendix A) between the variables 7, 9 and 10 (Table 3) of the take-off phase from the springboard and the variables 18, 20, 21 and 23 (Table 5) of the take-off phase from the horse, show that there is a great deal of relationship between the body position of the gymnast on the springboard and the body position at initial contact with the horse.

Pre-flight

No significant coefficient of correlation was found between the variables 12 through 17 (Table 4) and the scores. A high coefficient of correlation between variable 15 (take-off velocity) and the scores might have been expected. Guerrera (5) found a significant coefficient of correlation of .63 with the same variables.

Take-off from the Long Horse

Table 5 shows the take-off results from the long horse. It can be seen that a significant negative coefficient of correlation of -.635 was found between

TABLE 4.--Pre-flight results

No	Name of Variable	Mean	Range	Standard Deviation	Correlation with Score
12	Distance from toe to far end of springboard (meter)	.426	.278 - .588	.067	-.165
13	Distance from far end of springboard to near end of horse (meter)	.586	.527 - .695	.047	.133
14	Take off angle (degrees)	39.2	32.0 -49.0	3.47	.211
15	Take off velocity (m/sec)	5.088	4.14 - 6.35	.51	-.169
16	Pre-flight time (seconds)	.251	.174 - .290	.030	.020
17	Percentage of time for pre-flight	18.86	13.63 -22.07	2.20	.078

N = 17 degrees of freedom

* = coefficient of correlation significant at .05 level of significance - An r of .456 was necessary to be significant.

TABLE 5.--Results of take-off from the long horse.

No	Name of Variable	Mean	Range	Standard Deviation	Correlation with Score
18	Angle between forearm and the horizontal at initial contact (degrees)	47.5	36.5 - 56.0	5.1	-.635*
19	Angle between forearm and the horizontal at last contact (degrees)	108.3	87.0 - 114.0	5.29	.453
20	Range of movement of forearm (degrees)	60.8	31.0 - 73.5	8.53	.659*
21	Angle between trunk and upper arm at initial contact (degrees)	128.8	109.0 - 141.0	7.68	.665*
22.	Angle between trunk and upper arm at last contact (degrees)	76.2	58.0 - 99.0	11.98	-.214
23	Range of movement of trunk in relation to upper arm (degrees)	52.0	28.5 - 71.5	14.57	.563*
24	Angle between trunk and legs at initial contact (degrees)	174.8	150.0 - 188.0	7.93	.073
25	Angle between the trunk and legs at last contact (degrees)	156	119 - 192	22.04	.515*
26	Range of movement of the legs in relation to the trunk	-----	17.0 - 63.0	-----	-----
27	Vertical distance of the highest c. of g. above the long horse at initial contact (meter)	.392	.229 - .575	.075	.327
28	Vertical distance of the highest c. of g. above the horse at last contact (meter)	.540	.441 - .642	0.052	.117
29	c. of g. height difference between initial and final contact (meter)	.149	.048 - .244	0.051	- 368
30	Time contacting the long horse (seconds)	0.249	.174 - .290	0.031	.114
31	Percentage of time of the take-off from the long horse	15.71	13.24 - 17.91	1.31	-.015

N = 17 degrees of freedom

* = coefficient of correlation significant at .05 level of significance - An r of .456 was necessary to be significant.

variable 18 (angle between forearm and the horizontal at initial contact) and the scores. This suggests that the smaller the angle at contact, the higher the score. The results show four other significant correlations of scores with variables 20, 21, 23 and 25.

A .665 correlation was found for variable 21, which suggests that the greater the angle between trunk and the upper arm at initial contact with the horse the greater the score.

This phase is, of course, very important since it is from the hand contact with the horse that the specific vault is performed. Everything done before this phase prepares the gymnast to perform the vault. This vault is initiated just like any other vault, i. e. with a clockwise rotation to be completed after the hand contact with a counterclockwise rotation. The gymnast must then hit the long horse at an angle such that the push with the upper segments creates a counterclockwise rotation. What should this angle be? The angle could differ slightly from one gymnast to another, but it could not be as great as the one used to perform the yamashita vault. Weimann (11) states that the take-off action of the upper arms on the long horse cancels the clockwise rotation. Therefore, for a given take-off force, there should be an optimum angle which will allow the vault to be well executed in the form prescribed by the F. I. G. Because of the excentric thrust, a part of the force exerted on the horse will be used for height while the other part will be used for counterclockwise rotation. To maximize height, the gymnast will bring his center of gravity as close as possible over his hands by a piking action. In this study, a .515 correlation of score with variable 25 (i. e. angle between trunk and legs at last contact) was found. This suggest that the greater the angle between the trunk and the legs, the greater the score. A mean angle of 156 degrees was found between those segments. When one compares the scores of 3.0 of D_5 and 8.7 of C_2, it is noticed that D_5 had angles of 56.0, 109.0 and 130 degrees respectively for variables 18, 21 and 25 while C_2 had angles of 43.0, 133.5 and 156.0 degrees.

Free Flight and Landing

Table 6 shows the results of the free flight and the landing. The height and the horizontal distance from the horse to the landing are the principal criteria used to judge any vault. The .539 and .678 correlations between score and variables 32 and 33 suggest that the highest c. of g. above the long horse and the c. of g. height difference between last contact and the highest c. of g. above the horse are well related to the score. These results are in agreement with the findings of Guerrera (5), Kotelnikova (7) and Fetz (3). A negative coefficient of correlation of -.596 was found between variable 34 and

TABLE 6.--Results of free flight and landing.

No	Name of Variable	Mean	Range	Standard Deviation	Correlation with Score
32	Vertical distance of highest c. of g. above the long horse (meter).	.750	.599 - .877	0.077	.539*
33	c. of g. height difference between last contact and the highest c. of g. above the horse (meter).	.210	.096 - .273	0.052	.678*
34	Horizontal distance from finger tips on the horse to toe contact with the ground (meter).	2.74	2.109 - 3.176	.268	-.596*
35	Time of free flight (seconds)	.723	.677 - .754	.038	-.123
36	Percentage of time of the free flight.	54.8	50.73 - 60.57	2.88	-.23
37	Angle between the legs and the horizontal at landing (degrees).	81.8	70.0 - 99.5	6.96	-.106
38	Angle between the thighs and the legs at landing.	147.1	137.0 -160.0	7.22	-.094
39	Angle between the thighs and the trunk at landing.	104.3	72.5 -133.5	16.84	-.590*
40	Total vault time (seconds)	1.32	1.276 - 1.392	0.03	.228

N = 17 degrees of freedom

* = coefficient of correlation significant at .05 level of significance - An r of .456 was necessary to be significant.

the score. The horizontal distance at landing is dependant upon the horizontal velocity. It has been said previously in this study that the best vaults were performed with almost the lowest horizontal velocities. Consequently, the highest scores were achieved where the horizontal distance was the smallest. But, it must be said that all of the vaults met the F. I. G. criterion that the vaulter must land at least one long horse length (i. e. 1600 cm) from the horse. Kotelnikova (7) and Guerrera (5) found similar data; but there was no significant coefficient of correlation with score. A negative correlation coefficient between score and variable 39 (angle between the thighs and the trunk at landing) suggests that the smaller this angle, the higher the score.

Relationships to F. I. G. Criteria

As mentioned previously, the F. I. G. criteria for judging a long horse vault depend upon (a) the angle between the longitudinal axis joining the ankles, the hips, the shoulders and the hands (figure 2) and the horizontal; (b) the hand zones; (c) the height of the free flight; and (d) the horizontal distance from the horse to the landing.

The data found in this study from variables 18, 21 and 24 (Appendix A) show that none of the vaults were performed in accord with the first criterion. A mean angle of 128.8 degrees between the trunk and the upper arm was found which is similar to Guerrera's findings (5). A question comes to mind. Why should this criterion be used to evaluate a hecht vault? It is wrong, as it is done at present, to judge only the line from the ankles to the shoulders at initial contact with the long horse. All other things being equal, the results of two hechts performed by two gymnasts could differ if the angle between the forearm and the horse (variable 18) and the angle between the upper arm and the trunk (variable 21) were not the same for the two performers. Coefficients of correlation with the score of -.635 and .665 were fourd for variables 18 and 21 respectively.

The author agrees with Fetz's statement (2) which says that from the viewpoint of biomechanics, the longitudinal axis need not necessarily be at an angle of 30 degrees. "Good hecht often have a lesser angle".

No significant coefficient of correlation was found in this study between variable 34 and the score. Nevertheless, in the writer's opinion, important progress would be made if the hecht vault were to be evaluated mainly according to the height of the free flight and distance.

The results indicate that the higher scoring hecht vaults were characterized by a greater range of movement of the center of gravity and a greater contact time on the springboard. Furthermore, the angle between the forearm and the horizontal at initial contact was smaller, the angle between the trunk and the upper arm at initial contact was greater, and the angle between the trunk and the legs at last contact with the horse was greater. The range of movement for both the forearm and the trunk was comparatively higher. Lastly, the free flight was higher and the horizontal distance of the landing was smaller. It appears that the pre-flight angle is not a valid criterion for judging the long horse vault.

Graphic Presentation of Selected Hecht Vaults

Two long horse vaults are graphically presented: a high-scoring vault (C 2) and a low-scoring vault (D 5). The vaults are presented to elucidate the previous discussion. Figure 5 and 6 illustrate vaults with scores of 8.70 and 3.00. The correlation results indicate the following would be expected:

1. The 8.70 vaulter would spend more time on the springboard (variable 10) than the 3.0 vaulter. The resulting times were 1.55 and .116 seconds respectively.
2. The 8.70 vaulter would have a greater range of the center of gravity on the springboard (variable 9) than the 3.00 vaulter. The ranges were 42 and 33 degrees respectively.
3. The 8.70 vaulter's angle between the forearm and the horizontal at initial contact (variable 18) would be smaller than the 3.00 vaulter's. Those angles were 43 and 56 degrees respectively.

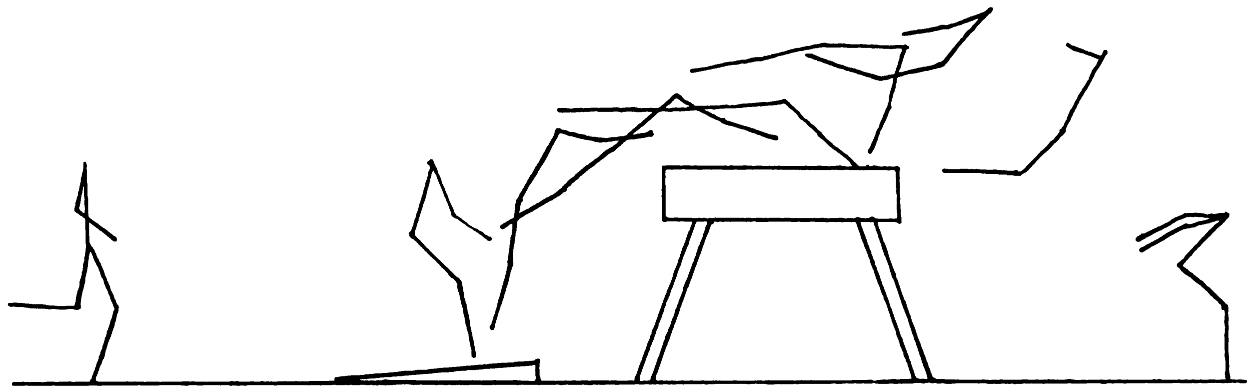

Figure 5. Hecht Vault of Subject C. 2 - Score 8.70

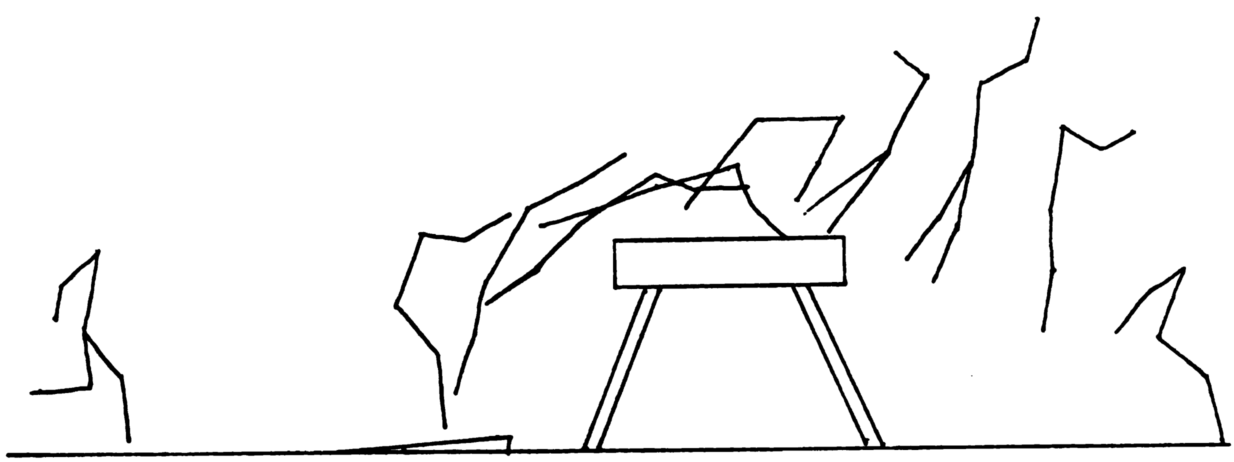

Figure 6. Hecht Vault of Subject D. 5 - Score 3.00

4. The range of movement of the 8.70 vaulter's forearm at initial contact would be greater than that of 3.00 vaulter. The ranges were 66 and 31 degrees respectively.
5. The 8.70 vaulter's angle between the trunk and the upper arm at initial contact (variable 21) would be greater than that of the 3.00 vaulter. The resulting angles were 133.5 and 109.0 degrees respectively
6. The 8.70 vaulter's range of movement of the trunk related to the upper arm (variable 23) would be greater than the 3.00 vaulter's. The resulting ranges were 67.0 and 36.0 degrees respectively.
7. The 8.70 vaulter's angle between the trunk and the legs at last contact (variable 25) would be greater than that of the 3.00 vaulter. The resulting angles were 156.0 and 130.0 degrees respectively.
8. The 8.70 vaulter's center of gravity would reach a higher distance above the long horse (variable 32) than the 3.00 vaulter's. The resulting heights were .815 and .599 meters respectively.
9. The 8.70 vaulter would have a greater height difference between the center of gravity at last contact and the highest center of gravity above the long horse (variable 33) than the 3.00 vaulter. The resulting height differences were .240 and .144 meters respectively.

10. The 8.70 vaulter's landing distance from the finger tips on the horse to toe contact with the ground (variable 34) would be less than that of the 3.00 vaulter. The resulting landing distances were 2.349 and 3.176 meters respectively.
11. The 8.70 vaulter would have a smaller angle between the thighs and the trunk at landing (variable 39) than the 3.00 vaulter. The resulting angles were 99.0 and 127.0 degrees respectively.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The author sought to: (a) quantify the biomechanical movement components of the hecht vault on the long horse, (b) relate those components to the scores awarded by four judges, and (c) find the relationships between those movement components and the criteria for judging this vault as stated in the F. I. G. rule book. Four volunteers were used for this study. All of them were familiar with the sport as gymnasts, but only two were competing in the senior category.

Cinematographical porcedures were used to film the vaults at a camera speed of 64 frames per second. Nineteen vaults were selected for analysis. A 16 mm Spectro Analyzer Projector was utilized to measure the data from the film. These basic data were used to determine 40 measures for each vault including time, distance, angle, and velocity variables.

The statistical analysis consisted of the calculation of the means, the standard deviations, and the correlation coefficients of the vault scores with each of the 40 variables investigated. Correlation coefficients also were calculated between all possible pairs of variables. All those calculations were performed on an Olivetti Underwood Programma 101. Significant positive correlations with the vault scores were found for the following variables: (a) the range of movement of the center of gravity on the springboard, (b) the time on the board, (c) the range of movement of the forearm, (d) the angle between the trunk and the upper arm at initial contact, (e) the range of movement of the trunk in relation to the upper arm, (f) the angle between the trunk and the legs at last contact, (g) the vertical distance of the highest center of gravity above the long horse, and (h) the center of gravity height difference between the last contact and the highest center of gravity above the horse. The following variables correlated negatively: (a) the angle between the forearm and the horizontal at initial contact, (b) the horizontal distance from finger tips on the horse to toe contact with the ground, and (c) the angle between the thighs and the trunk at landing.

Conclusions

Within the limitations of this study, the following conclusions seem justified. The findings indicate that the higher scoring hecht vaults are characterized by a larger range of angular movement of the center of gravity on the springboard and a greater contact time with the board. At initial contact, the angle between the forearm and the horizontal is comparatively smaller, the range of angular movement of the forearm is greater, and the angle and the range of angular movement of the trunk in relation to the upper arm are greater. At last contact, the angle between the trunk and the legs is greater and the free flight is both higher and shorter. At landing, the angle between the thighs and the trunk is smaller.

In some variables, one might have expected different results; but, the explanation for this lies in the big differences observed in performances. Generally, the results are in accord with authoritative opinion, although minor differences exist.

The pre-flight angle does not appear to be a valid criterion for judging the hecht vault.

Recommendations for Further Study

The investigator believes that more studies on long horse vaulting would clarify the techniques and consequently the means used to teach and coach the different vaults. A more detailed study of the support phase (i. e. the angles between the different body segments and the force applied on the long horse) would be beneficial.

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APPENDICES

APPENDIX A

RAW DATA FOR HECHT VAULT

RAW DATA FOR HECHT VAULT

(N=19) Variable Number	Vault Score 3.00	4.20	4.50	5.00	6.10	6.30	6.80	7.00	7.10	7.20
Subject	D	D	D	D	A	B	A	A	D	B
Trial	5	4	3	2	1	5	4	3	1	2
1	.129	.119	.134	.168	.096	.144	.120	.168	.168	.129
2	2.312	2.411	2.157	2.229	2.268	2.229	2.287	2.603	2.316	2.445
3	6.288	5.939	5.703	5.487	6.018	5.951	5.337	5.443	5.589	5.863
4	90.0	84.0	83.0	80.0	82.5	87.0	84.0	83.0	81.0	86.0
5	141.0	145.5	144.0	146.0	144.5	141.0	149.0	150.0	152.0	142.0
6	124.0	126.0	112.0	118.0	131.0	113.0	128.5	127.5	136.5	120.0
7	69.0	66.0	61.0	62.0	60.0	60.0	58.0	60.0	68.0	57.0
8	102.0	98.0	101.0	99.0	108.0	103.0	105.0	102.0	103.0	101.0
9	33.0	28.0	40.0	37.0	48.0	43.0	47.0	42.0	35.0	44.0
10	.116	.116	.135	.135	.155	.135	.155	.155	.135	.135
11	9.09	8.82	10.42	9.97	11.79	10.57	11.29	11.45	9.97	10.27
12	.465	.588	.374	.360	.552	.278	.417	.422	.408	.360
13	.588	.588	.527	.527	.623	.585	.575	.537	.695	.575
14	38.0	40.0	36.0	37.0	40.0	36.5	37.0	43.0	49.0	32.0
15	5.57	5.43	5.07	4.86	4.14	5.23	5.30	5.24	4.71	5.37
16	.232	.271	.213	.251	.290	.174	.251	.271	.290	.232
17	18.18	20.62	16.44	18.55	22.07	13.63	18.29	19.96	21.43	17.65
18	56.0	54.0	48.0	51.0	54.5	44.0	44.0	48.0	55.0	44.5
19	87.0	110.0	110.0	114.0	108.0	108.0	111.5	111.0	109.0	109.5
20	31.0	56.0	62.0	63.0	53.5	64.0	67.5	63.0	54.0	65.0
21	109.0	119.0	126.0	127.5	136.0	119.0	135.0	135.0	121.0	127.5
22	73.0	88.0	68.5	99.0	81.5	58.0	68.5	76.5	90.0	87.5
23	36.0	31.0	57.5	28.5	54.5	61.0	66.5	58.5	31.0	40.0
24	172.0	182.0	171.0	183.0	180.0	165.0	150.0	173.0	175.0	170.0
25	130.0	119.0	131.0	133.0	180.0	171.0	163.0	190.0	125.0	150.0
26	42.0	63.0	40.0	50.0	0.0	-6.0	-13.0	-17.0	50.0	20.0
27	.288	.384	.259	.350	.575	.360	.431	.460	.369	.393
28	.455	.537	.503	.575	.623	.494	.575	.585	.542	.575
29	.168	.153	.244	.225	.048	.134	.144	.125	.173	.182
30	.193	.213	.232	.213	.193	.193	.213	.193	.232	.174
31	15.12	16.21	17.91	15.74	14.68	15.12	15.52	14.26	17.14	13.24
32	.599	.686	.599	.738	.863	.719	.815	.738	.686	.813
33	.144	.149	.096	.163	.240	.273	.240	.153	.144	.240
34	3.176	2.941	2.876	2.972	2.733	2.828	2.924	2.781	2.733	2.858
35	.735	.715	.715	.754	.677	.773	.754	.735	.696	.773
36	57.60	54.41	55.21	55.72	51.52	60.57	54.95	54.32	51.44	58.82
37	75.0	85.0	85.5	82.0	81.5	76.0	85.0	77.5	84.0	91.5
38	156.0	145.5	148.0	155.5	142.0	149.5	139.0	148.0	144.0	139.5
39	127.0	126.5	128.0	133.5	84.5	94.0	97.0	86.5	118.0	104.5
40	1.276	1.314	1.295	1.353	1.314	1.276	1.372	1.353	1.353	1.314

RAW DATA (CONTINUED)

(N=19) Variable Number	Vault Score								
	7.30	7.70	7.70	7.80	8.00	8.20	8.40	8.70	8.70
Subject	B	A	C	A	C	B	C	B	C
Trial	1	2	1	5	4	3	3	4	2
1	.144	.120	.144	.144	.134	.129	.120	.096	.096
2	2.325	2.076	2.397	2.828	2.268	2.397	2.421	2.373	2.397
3	5.712	6.105	5.742	6.013	5.938	5.833	5.448	5.660	5.788
4	88.0	88.0	82.0	72.0	79.5	90.0	80.5	89.0	78.0
5	136.0	141.0	125.0	158.0	151.0	139.0	156.0	139.0	146.0
6	123.0	125.0	91.0	119.0	132.0	126.0	133.5	126.0	120.0
7	64.0	60.0	59.0	60.0	57.0	59.0	58.0	65.0	61.0
8	111.0	102.0	96.0	102.0	99.0	109.0	100.0	104.0	103.0
9	47.0	42.0	37.0	42.0	42.0	50.0	42.0	39.0	42.0
10	.155	.135	.116	.155	.135	.155	.155	.135	.155
11	12.14	10.27	8.69	11.13	10.27	11.96	11.96	10.27	11.61
12	.431	.451	.393	.436	.456	.379	.480	.398	.446
13	.671	.623	.623	.537	.575	.556	.575	.633	.527
14	38.0	40.5	42.0	35.0	39.0	40.5	41.0	39.0	41.0
15	5.04	6.35	4.53	5.89	4.65	4.96	4.69	5.23	4.42
16	.251	.251	.271	.271	.270	.193	.271	.213	.271
17	19.67	19.10	20.31	19.46	20.62	14.90	20.92	16.21	20.31
18	44.0	47.5	53.0	48.5	45.0	36.5	44.0	42.5	43.0
19	107.0	111.5	108.0	111.0	105.5	110.0	110.0	108.0	109.0
20	63.0	64.0	55.0	62.5	60.5	73.5	66.0	65.5	66.0
21	122.5	137.0	131.0	133.0	141.0	134.5	131.5	128.0	133.5
22	60.5	83.5	88.0	69.5	81.0	88.5	60.0	60.5	66.5
23	62.0	53.5	43.0	63.5	61.0	46.0	71.5	67.5	67.0
24	180.0	175.0	180.0	173.0	188.0	172.0	180.0	173.0	180.0
25	180.0	165.0	144.0	168.0	192.0	134.0	161.0	173.0	156.0
26	0.0	10.0	36.0	5.0	-4.0	38.0	19.0	0.0	24.0
27	.302	.479	.431	.465	.431	.316	.398	.326	.431
28	.537	.642	.542	.575	.499	.499	.503	.441	.575
29	.235	.163	.111	.110	.068	.183	.105	.115	.144
30	.193	.213	.232	.193	.232	.193	.213	.193	.232
31	15.12	16.21	17.39	13.86	17.65	14.90	16.44	14.68	17.39
32	.710	.877	.815	.829	.714	.729	.757	.705	.815
33	.173	.235	.273	.254	.216	.230	.254	.264	.240
34	2.109	2.924	2.613	3.020	2.253	2.781	2.445	2.661	2.349
35	.677	.715	.715	.773	.677	.754	.657	.773	.677
36	53.05	54.41	53.59	55.53	51.52	58.22	50.73	58.82	50.74
37	99.5	84.5	90.0	82.0	78.5	70.0	78.5	76.0	71.5
38	143.5	139.0	137.0	137.0	153.0	157.0	160.0	145.5	156.5
39	116.0	72.5	104.5	83.0	94.0	97.0	115.0	101.5	99.0
40	1.276	1.314	1.334	1.392	1.314	1.295	1.295	1.314	1.334

APPENDIX B

INTERCORRELATIONS BETWEEN VARIABLES

INTERCORRELATIONS BETWEEN VARIABLES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
S	-.20	.28	-.28	-.20	.01	.09	-.19	.19	.50	.53	.49	-.16	.13	.21	-.17	.02	.08	-.64	.45	.66
1		.15	-.29	-.18	.10	-.16	.10	-.22	-.19	-.12	-.18	-.44	-.01	.18	.10	.05	-.01	.24	.12	-.68
2			-.08	-.48	.34	-.02	-.08	-.06	.00	.30	.18	.12	-.25	-.06	.09	.26	.21	-.05	.08	.08
3				.19	-.22	-.10	.20	.01	-.15	-.39	-.31	.24	.09	-.23	.32	-.15	-.08	.26	-.56	-.51
4.					-.60	.04	.26	.38	.09	-.26	-.09	-.16	.36	-.06	.25	-.62	-.53	-.20	-.36	-.10
5						.65	-.09	-.08	.00	.44	.34	.24	-.32	.05	.07	.37	.31	.00	.20	.12
6							.17	.38	.13	.40	.41	.43	.18	.28	-.01	.26	.28	-.08	-.02	.04
7								.09	-.65	-.43	-.36	.22	.43	.35	.13	.04	.08	.52	-.50	-.63
8									.69	.63	.71	-.02	.29	.00	-.07	-.23	-.20	-.40	-.03	.22
9										.79	.83	-.26	-.08	-.24	-.16	-.22	-.22	-.67	.29	.58
10											.97	-.01	-.20	-.01	-.21	.12	0.08	-.54	.42	.59
11												-.02	-.20	-.03	-.22	-.01	-.01	-.59	.32	.57
12													.14	.26	-.08			.42	-.16	-.34
13														.46	-.07	.19		.26	-.17	-.26
14															-.35	.46		.28	.03	-.14
15																-.30	-.33	-.04	-.06	-.02
16																	.98	-.12	.12	-.24
17																		.53	.04	.30
18																			-.33	-.80
19																				.82
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21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
.67	-.21	.56	.07	.52		.33	.12	-.37	.05	-.02	.54	.68	-.60	-.12	-.23	-.11	-.09	-.59	.23
-.20	.34	-.42	.03	-.14		-.26	.02	.35	-.11	.00	-.32	-.48	.14	.18	.07	.26	-.03	.25	.22
.10	-.10	.14	.01	.15		.21	.02	-.29	-.38	-.47	.17	.18	.04	.24	.01	-.09	-.14	-.20	.49
-.23	.07	-.20	.31	-.06		.08	-.05	-.17	-.27	-.13	.00	.07	.25	.04	.23	-.12	-.08	-.21	-.40
-.37	-.07	-.15	-.28	-.10		-.45	-.35	.32	-.45	-.24	-.30	-.07	.10	.22	.54	.01	.07	.09	-.70
.21	-.12	.22	-.03	.15		.26	.15	-.23	.07	-.05	.02	-.14	.12	-.12	-.33	-.27	.21	-.08	.44
.12	-.04	.11	.01	.20		.15	.03	-.18	-.15	-.15	-.07	-.18	-.10	-.27	-.29	-.25	.27	-.09	.01
-.77	.02	-.46	.11	-.47		-.45	-.35	.32	.02	.06	-.59	-.55	.22	-.02	.06	-.01	.10	.53	-.17
.04	-.32	.30	-.27	.29		-.07	.05	.15	-.50	-.40	.07	.06	-.23	-.04	.08	.00	-.02	-.25	-.24
.58	-.27	.57	-.30	.57		.25	.26	-.11	-.37	-.33	.47	.45	-.33	.00	.02	-.01	-.06	-.57	-.05
.55	-.36	.64	-.02	.52		.30	.29	-.22	-.42	-.31	.38	.21	-.34	-.16	-.30	-.15	.10	-.48	.24
.47	-.44	.65	-.14	.53		.20	.22	-.07	-.30	-.27	.30	.23	-.43	-.23	-.23	-.14	.19	-.39	-.01
.08	.11	-.04	.40	.00		.42	.22	-.41	.07	.11	.11	-.17	-.07	-.56	-.59	.03	-.03	.01	.03
-.26	.00	-.15	.08	.04		-.01	-.07	-.09	-.07	.05	-.01	.04	-.27	-.27	-.17	.44	-.40	-.00	-.22
.06	.22	-.16	.28	-.11		.17	.05	-.20	[illegible]	.44	-.05	-.17	-.24	-.50	-.55	-.20	.13	-.02	.14
-.18	-.08	-.04	-.38	-.04		-.12	.09	.26	-.40	[illegible]	.01	-.06	.56	.54	.50	.11	-.33	-.21	.07
.30	.29	-.08	.44	.11		.61	.51	-.42	.32	.24	.35	-.13	-.24	-.60	-.86	.25	-.22	-.07	.54
.24	.26	-.09	.53	.12		.57	.47	-.38	.40	[illegible]	.31	-.13	-.31	-.71	-.88	.27	-.15	-.02	.37
-.41	.40	-.59	.27	-.35		.20	.20	-.09	[illegible]	.16	-.14	-.43	.40	-.18	-.26	.25	-.25	.31	.18
.57	.17	.18	-.02	.12		.31	.51	[illegible]	.17	[illegible]	.46	.20	-.14	.06	-.16	.20	-.26	-.25	.10
.60	-.13	.46	-.16	.29		.08	.20	.09	-.03	-.05	.36	.39	.00	.15	.06	-.03	-.01	-.35	.19
	.11	.47	.10	.54		.64	.49	-.45	.20	.07	.67	.44	-.32	-.14	-.38	-.12	-.14	-.67	.42
		-.82	.32	-.46		.18	.38	.12	.17	.07	.14	-.24	.31	.06	-.07	.11	-.11	.13	.30
			-.22	.72		.20	-.06	-.37	[illegible]	[illegible]	.26	.47	-.46	-.16	-.16	-.17	.02	[illegible]	[illegible]
				.02		.11	.01	-.15	.32	.34	[illegible]	-.14	-.09	-.58	-.51	.03	.30	.18	-.18
						.49	.19	-.54	[illegible]	[illegible]	.41	.45	-.48	-.12	-.15	.00	-.16	-.69	.04
							.73	-.75	-.05	-.13	[illegible]	.45	-.04	-.24	-.44	-.02	-.40	-.72	.45
								-.09	-.04	-.13	.76	.08	.10	-.16	-.37	.32	-.25	-.47	.50
									-.05	.06	-.46	-.62	.16	.15	.28	.35	.10	.59	[illegible]
											-.17	-.29	-.31	-.68	-.68	-.02	.23	.25	-.07
											-.24	-.25	-.35	-.61	-.56	-.02	.25	.30	-.08
												.69	-.08	-.04	-.23	.12	-.47	-.72	.45
													-.21	.15	.13	-.17	-.20	-.63	.06
														.66	.55	-.16	-.19	.07	.24
															.90	-.13	-.26	-.11	.24
																-.15	-.07	.01	-.24
																	-.65	.20	.03
																		.39	-.42
																			-.27