UNIVERSITY OF ALBERTA

A BIOMECHANICAL ANALYSIS OF THE VOLLEYBALL SPIKE JUMP

by

John Pierre Baudin

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled, "A Biomechanical Analysis of the Volleyball Spike Jump," submitted by John Pierre Baudin in partial fulfilment of the requirements for the degree of Master of Science in Physical Education.

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DEDICATION

This thesis is dedicated to my wife Joan. Her unfaltering love, support and understanding during the good times and the bad made its' completion possible.

ABSTRACT

The purpose of this study was to determine the effect of selected kinematic variables on the height of a volleyball spike jump. A cinematographical analysis was done on 44 volleyball spike jumps performed by 22 elite female volleyball players. The variables examined were: the horizontal velocity of the center of mass, the vertical velocity of the center of mass, the angular velocity of the arm, the angular velocity at the knee, and the contact time with the floor during the jump phase.

The results of this study indicate that only contact time had high relationship to the height jumped. The pattern of armswing was identified and found to be biomechanically sound and had a temporal relationship to the angular velocity at the knee joint. Two patterns of leg extension were found when studying the angular velocity at the knee for the step-close approach. The close leg apparently demonstrated the ability to utilize the leg extension muscle's stored elastic energy better than the [illegible] leg.

[illegible] study indicates the need for more biomechanical research into the volleyball spike jump.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction.

The height to which a volleyball player is able jump when attacking the ball is of great concern to the coach. The higher a player is able to jump the more likely is success in attack because increasing the jump (a) increases the area of opposition court open to the attacker (Enoka, 1973) and (b) increases the time during which attack is possible.

The reasons for one athlete's ability to perform a volleyball spike jump more successfully than another are not generally obvious. The complexity of this skill demands the isolation of component variables which must then be evaluated as to (a) their contribution to the resulting jump and (b) the importance of this contribution. The lack of quantitative knowledge about this skill reveals a need for biomechanical research into the topic. This study has not attempted to examine all of the variables influencing the height of the volleyball spike jump, but has concentrated on selected kinematic factors.

Purpose of the Study.

The purpose of this study was to determine the influence of selected kinematic variables on the height of a volleyball spike jump. The variables studied were: (a) Horizontal velocity of the center of mass, (b) Vertical velocity of the center of mass, (c) Angular velocity of the right arm about the shoulder, (d) Angular velocity at the knee, and (e) Contact time with the floor.

Definition of Terms.

Volleyball spike jump - a vertical jump utilizing a two or three step running approach and jumping off two feet.

Horizontal velocity - the horizontal velocity of the center of mass of the subject during the volleyball spike jump.

Vertical velocity - the vertical velocity of the center of mass of the subject during the volleyball spike jump.

Angular velocity of arm - the angular velocity of the right arm about the shoulder joint of the subject during the volleyball spike jump.

Angular velocity at knee - the angular velocity at the knee of the subject during the volleyball spike jump.

Contact time - the time period in which there is foot contact with the floor during the jump phase of the volleyball spike jump.

Contact - the moment when the foot first makes contact with the floor at the end of the approach phase.

Jump phase - the period during which all vertical velocity is developed for the jump.

Approach phase - last step immediately prior to the jump phase.

Height of jump - the difference between the height from the floor of the center of mass when the subject is standing and when the highest point of the jump is reached.

Step-close approach - a volleyball spike jump approach in which the athlete steps out and brakes her approach momentum with one leg. The other leg then closes to the first and aids in the ensuing jump.

Hop approach - a volleyball spike jump approach in which the athlete drives out with the last step and while airborne brings both legs together. Both feet then contact the floor at the same time to brake the approach momentum in preparation for the ensuing jump.

Brake leg - that leg of the step-close approach which contacts the floor first at the end of the approach phase and brakes the athlete in preparation for the jump.

Close leg - that leg of the step-close approach which closes to the brake leg to aid in the jump.

CHAPTER II

REVIEW OF LITERATURE

The lack of literature directly related to the volleyball spike jump reflects the small role played by biomechanical research in this sport thus far.

The effect of horizontal velocity on the height jumped, when performing running vertical jumps has been examined by several researchers. Kinpara et al (1966) report velocities ranging from 2.4 m/sec. for a one (1) step approach to 6.1 m/sec. for a seven (7) step approach in the straddle high jump. In this instance the increase in horizontal velocity was accompanied by a corresponding increase in the height jumped. Chistyakov (1966) reports the approach velocity of former world record holder Valery Brummel at 7.5 m/sec.. Wasser and Nigg (1973) show a range of horizontal velocities from 3.9 to 7.1 m/sec. for a group of straddle and flop high jumpers. In this study no correlation was shown between the horizontal approach velocity and the height jumped. Hay (1973) believes that it is the athletes ability to utilize a horizontal speed increase, not the increase itself, which is of prime importance in increasing the height jumped. This concept is supported by the findings of Chistyakov (1966). Two studies report on horizontal velocities in the volleyball spike jump. Samson and Roy (1976) illustrate the horizontal velocity curve of the center of mass of the athlete during the approach and jump phases. A mean horizontal velocity of 2.88 m/sec. for twenty-two (22) male volleyball players is reported by Samson et al (1978). In neither of these studies was a relationship described between the horizontal velocity and height jumped.

The athletes vertical velocity at touch down, though deemed important to success in the high jump by Hay (1973), has not been examined in either the high jump or the volleyball spike jump.

The angular velocity of the arms about the shoulder has been examined by Samson et al (1978). They report a mean absolute angular velocity for the arms of 489 deg/sec.. In addition, they found a Pearson's product moment correlation of .617 between the maximum angular velocity of the arms and the height jumped.

Contact time with the ground during the jump phase has been discussed and studied by a number of researchers. It is only when the feet are in contact with the ground that vertical forces can be generated by the athlete. The time of vertical force application has a direct influence on the vertical impulse and thus the vertical velocity at takeoff. Kinpara et al (1966) report decreases in contact time for the height jumped. Kuhlow (1973) found that the contact time did increase for the height jumped in the straddle high jump but decreased for the height jumped in the flop. Hay (1974) reports contact times of .13 and.15 seconds for the flop and 118 and .22 seconds for the straddle. He believes that somehow floppers are able to generate greater vertical forces than the straddle jumpers thereby compensating for the decrease in time of force application. In a study of the volleyball spike jump Samson et al (1978) report a Pearson's product moment correlation of -.269 between the contact time and the height jumped. For his twenty-two (22) male subjects an average contact time of .35 seconds was found.

The increase in force output with shorter contact time may result from the storage of elastic energy in muscle during its' performance of negative work. This topic has been reported on by a number of researchers (Cavagna et al (1971), Asmussen and Bonde Petersen (1974)). Decreasing the amplitude and time of negative work appears to increase the elastic property in muscles, decreasing the time of positive work, and increase the force output (Cavagna 1977). The result is an increase in vertical impulse despite a loss in time of force application.

CHAPTER III

METHODS AND PROCEDURES

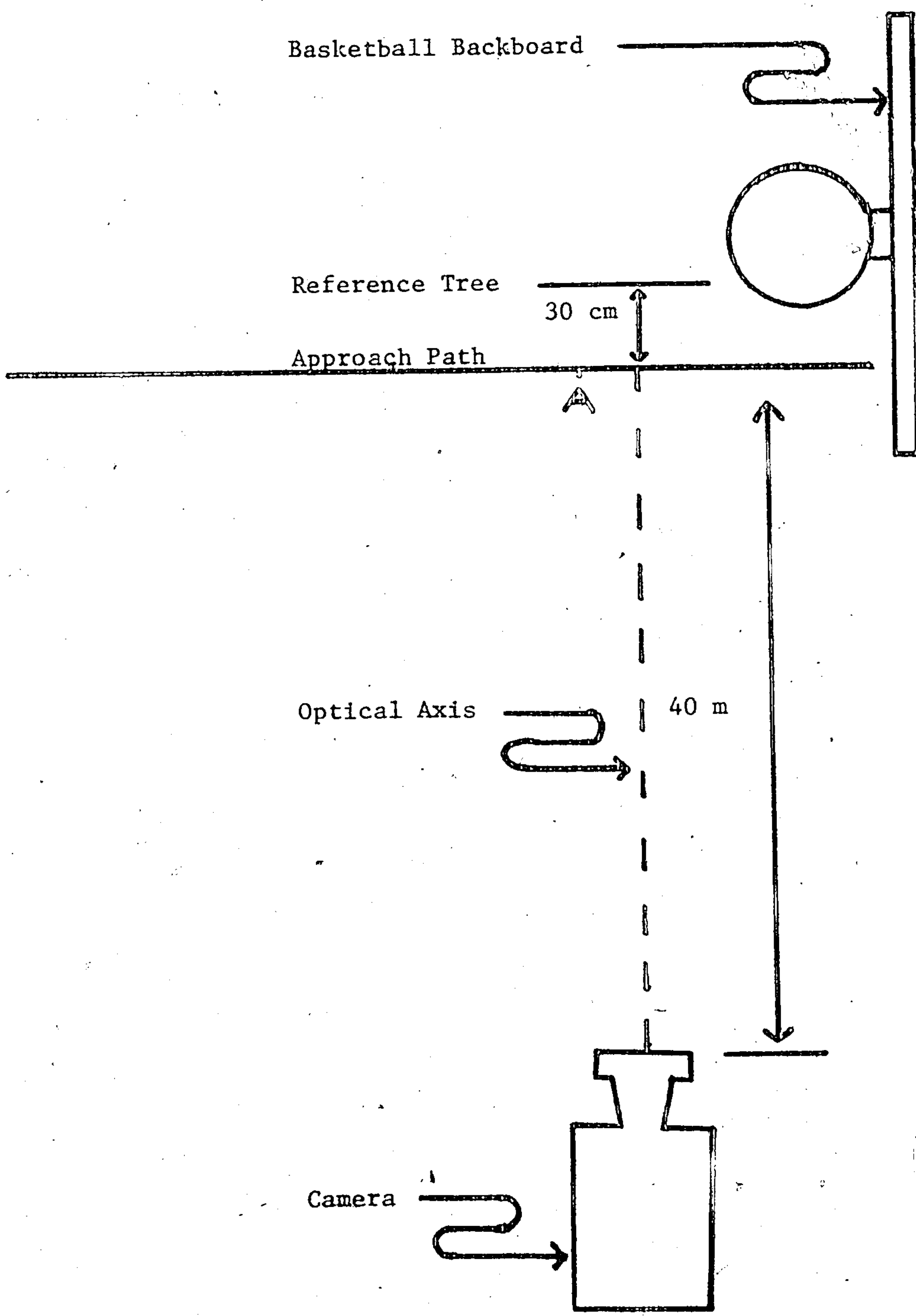
Twenty-two players from the Canadian and Dutch Junior National women's volleyball teams acted as subjects for the study prior to a normal morning training session. All wore standard volleyball shoes, shorts and tops. To ensure maximum visibility of the joints those with long sleeves were instructed to roll them up past the elbow.

First, the purpose of the study and then the testing procedure were explained to the entire group of subjects. All were familiar with this type of test as it is commonly used by volleyball coaches for evaluation. The only difference for this study was the use of cinematography for data collection. Warm ups, with the same focus, were next directed by the subjects respective coaching staffs. Each subject was then individually tested.

Placement of the equipment and the movement path of the subjects are shown in Figure 1. The subject was first directed to stand at point (A) facing the camera with her dominant hand fully extended overhead and the other resting at her side. While in this position she was filmed by the camera. Next, the subject was instructed to perform two volleyball spike jumps and touch as high as possible on the basketball backboard with the dominant hand. Each jump began when the researcher gave an audible command of "go" to the subject. The approach to the jump was along a designated path marked on the floor to ensure that the action remained, as much as possible, in the plane perpendicular to the optical axis of the camera. The approach in a volleyball spike jump is generally straight so this

Figure 1

Superior View of Equipment Layout and Approach Path



restriction presented no problem to any of the subjects. The starting point for each jump was not controlled but left to the individual subject's discretion. A reference tree placed 30 cm beyond this path was visible throughout the filming session.

All trials were filmed with a Photo-Sonics 1 PL 16mm camera equipped with a Photo-Sonics timing light generator set at 10 Hz. The camera was operated at 93.458 framed per second with a shutter angle of 140 degrees resulting in an exposure time of .00416 seconds. The f-stop was set at 2.2 and the camera was situated 40 meters from the path of each approach and jump. Ectochrome 7250 film (400 ASA) was used for all shots and pushed one full f-stop in developing.

The datafilm was projected onto a Bendix digitizing board by a TRIAD VR-100 film analyzer. It was then analyzed using an HP 9825A computer hardwired to an HP 9864A digitizer and the Bendix digitizing board. This system allows for the determination of cartesian coordinate points with an internal accuracy of .0056 cm. The resolution of the film and the skill of the operator determined the overall accuracy of the analysis. Relative errors of $\pm$ .05 cm were produced when repeated analysis was made by the researcher. The ratio of the real image to the image projected onto the digitizing board was 6.20 to 1.

The following twenty-two (22) points were digitized in each frame of film analyzed:

1. Proximal head and neck (midline between shoulder points).
2. Distal head and neck (top of head).
3. Proximal trunk (midline between hip joints).
4. Distal trunk (midline between shoulder joints).
5. Shoulder joints (right and left).
6. Elbow joints (right and left).
7. Wrist joints (right and left).
8. End of hand (right and left).
9. Hip joints (right and left).
10. Knee joints (right and left)
11. Ankle joints (right and left).
12. Proximal end of feet (heels, right and left).
13. Distal end of feet (toes, right and left).

The determination of these points results in a degree of subjective error dependent upon researchers knowledge of anatomy and the movement being analyzed.

The twenty frames analyzed for each jump performed are outlined below:

Frame 1. The subject when standing and reaching up with one arm.

Frames 2-16. Every fifth frame (.0536 seconds apart) throughout the last step of the approach and jump, up to and including the takeoff frame (the last frame where contact with the ground is observed).

Frame 17. The tenth frame (.107 seconds) prior to the highest point reached by the subject.

highest point reached by the subject.

Frame 18. The fifth frame (.0536 seconds) prior to the highest point reached by the subject.

Frame 19. The frame where the subject reached her highest point.

Frame 20. The fifth frame (.0536 seconds) after the highest point reached by the subject.

Programs for the HP 9825A computer stored the data points for all frames and calculated the following quantities for each trial for each subject: (a) The horizontal velocity of the center of mass from frames 2 to 16 determined by dividing horizontal displacement of the center of mass between adjacent digitized frames by the time period between frames of .0536 seconds, (b) The vertical velocity of the center of mass from frames 2 to 16 determined by dividing vertical displacement of the center of mass between the adjacent frames by the time period between of .0536 seconds, (c) The angular velocity of the right arm about the right shoulder from frames 2 to 16 determined dividing angular displacement of the right arm between adjacent digitized frames by the time period between frames of .0536 seconds, (d) The angular velocity at the knee joint from frames 2 to 16 determined by dividing the change in knee angle (given by the thigh and leg) between adjacent digitized frames by the time period between frames of .0536 seconds, (e) The contact time with the floor during the jump phase, and (f) The height jumped determined by the subtractive difference between the highest of the points reached by the center of mass from the floor in frames 17 to 20 and the height of the center of mass in frame 1. For each of frames 2 to 16 the velocities for all trials were averaged to produce a curve for: (a) The horizontal velocity of the center of mass, (b) The vertical velocity of the center of mass, (c) The angular velocity of the right arm about the right shoulder and (d) The angular velocity at the right knee. The total decrease in the angle at the knee after contact was measured for each trial.

Limitations of the Study.

Cinematographical analysis using one camera makes it impossible to make the measurements in more than the one plane filmed. Every attempt was made to take measurements only of motions which occur in that plane. Despite this, there is little doubt that a small amount of motion analyzed did not take place completely within the film plane resulting in some data error.

This study made no attempt to examine the possible affects psychological variables had on the results of this study. It can only be assumed that such variables were constant throughout the testing since the testing environment was not altered.

The use of select females as subjects for this study makes it impossible to draw conclusions which may be applied to the general volleyball playing population.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter will report and discuss the results under seven major headings: Height of jump, Horizontal velocity of the center of mass, Vertical velocity of the center of mass, Contact time, Angular velocity of the arm, Angular velocity at the knee, and General discussion.

Height of Jump.

The range, mean, and standard deviation of height jumped are reported in Table 1. The mean value found for the twenty-two (22) female subjects is 8.48 cm lower and 10.98 cm lower respectively than that reported by Samson and Roy (1976) 71.5 cm and Samson et al (1978) 74 cm. for male subjects.

Horizontal Velocity of the Center of Mass.

The mean horizontal velocity curve of the center of mass through the approach and jump phases for the volleyball spike jump for all trials is illustrated in Figure 2. The velocity remains constant until initial contact with the floor, beginning the jump phase, takes place. At this time the horizontal velocity starts a deceleration which continues until the moment of takeoff. Samson and Roy (1976) reported similar findings for eleven (11) male subjects. The range, mean, standard deviation, and correlation with height jumped for the horizontal velocity at contact are shown in Table 1. The mean value obtained in this study is only .25 m/sec. higher than the 2.88 m/sec. value reported by Samson et al (1978). The low correlation found between this horizontal velocity and height jumped indicates

TABLE 1

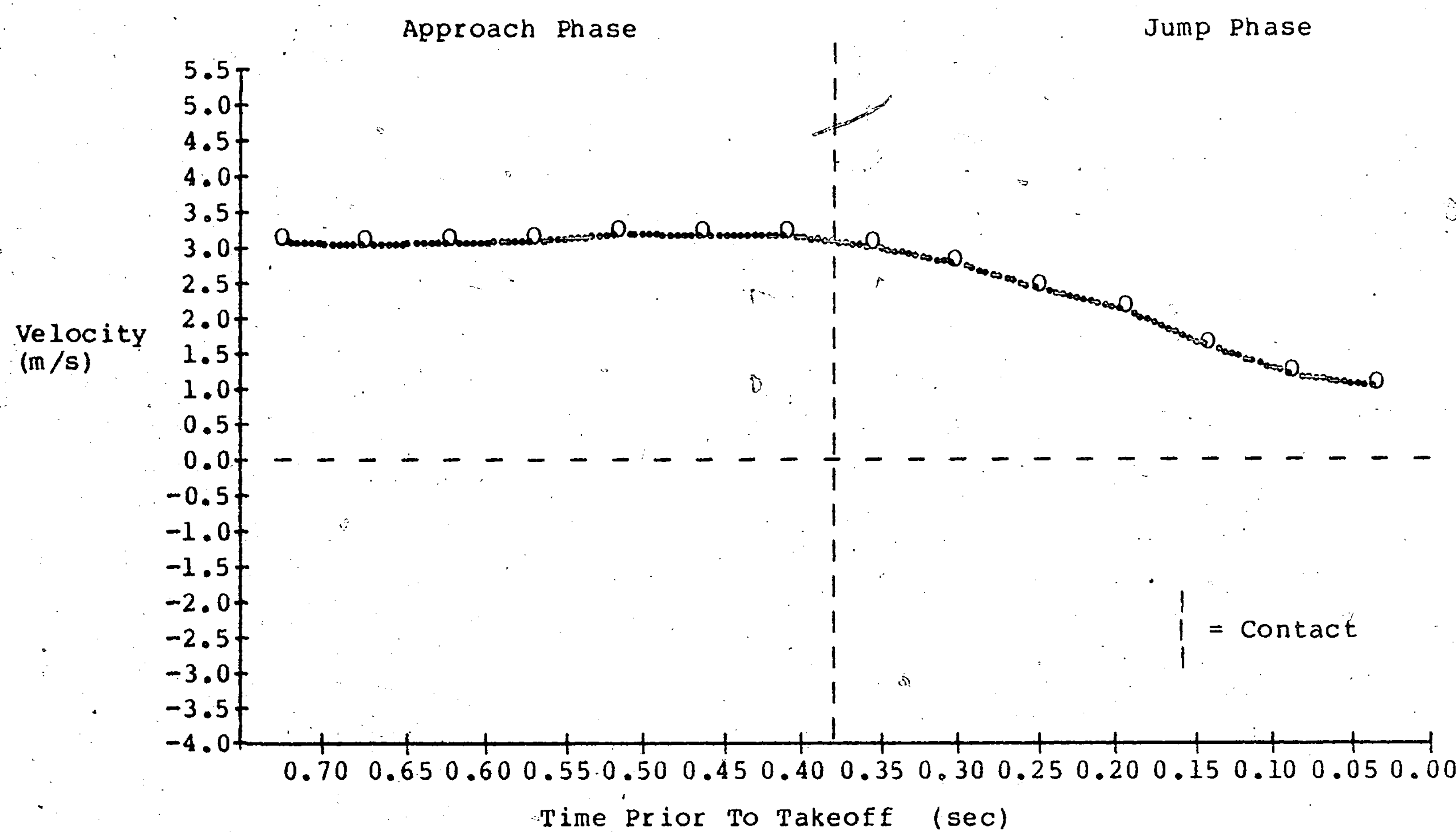
Range, Mean, Standard Deviation, and Correlation to Height Jumped for Selected Kinematic Variables.

(N=44)

	RANGE	MEAN	S.D.	r. TO JUMP
HEIGHT JUMPED	50.81-70.82	63.02	5.09	*
HORIZONTAL VELOCITY AT CONTACT m/sec.	2.33-3.80	3.13	.391	.132
VERTICAL VELOCITY AT CONTACT m/sec.	2.48-4.09	3.37	.404	.243
MAXIMUM ANGULAR VELOCITY OF UPPER RIGHT ARM deg/sec.	751.09-1493.69	975.99	155.78	.388
MAXIMUM ANGULAR VELOCITY AT BRAKE KNEE deg/sec.	259-1023	702	158	.298
MAXIMUM ANGULAR VELOCITY AT CLOSE KNEE deg/sec.	345-978	666	157	.115
CONTACT TIME sec.	.246-.492	.376	.059	-.520

Figure 2:

Mean Horizontal Velocity Curve for Center of Mass



that horizontal approach velocity is not highly related to the height of the spike jump for these subjects.

Vertical Velocity of the Center of Mass.

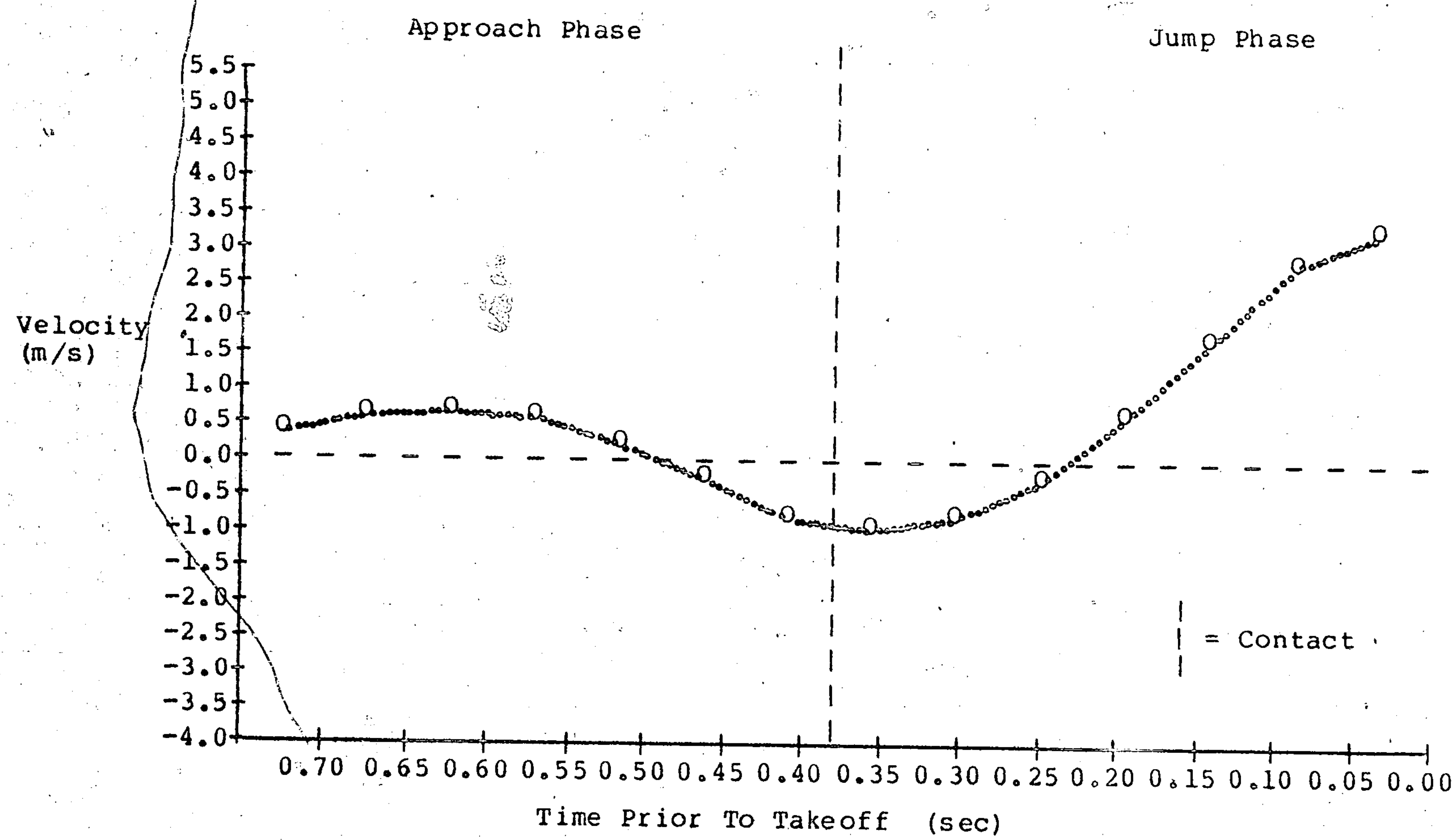
Illustrated in Figure 3 is the mean vertical velocity curve of the center of mass through the approach and jump phases of the volleyball spike jump for all trials. This curve is typefied by an initial increase in positive velocity caused by the upward drive during the last step. At the end of the thrust the body goes into a free fall situation affected only by gravitational forces. This is illustrated in the curve by a deceleration of positive vertical velocity. This acceleration in turn stops when contact is made with the floor at the beginning of the jump phase. A rapid deceleration of negative vertical velocity can now be seen preceeding a large acceleration in the positive velocity which continues until takeoff. This finding agrees with that of Samson and Roy (1976). The range, mean, standard deviation, and correlation of vertical velocity at contact to height jumped is reported in Table 1. The correlation of .234 appears to indicate that within the range of velocities found in this study the vertical velocity at contact is not highly related to the height jumped. This finding does not support the theory put forth by Hay (1974) for high jumping in which he suggests that minimum negative vertical velocities at contact will result in higher takeoff velocities.

Contact Time.

The range, mean, standard deviation, and correlation of contact time with the height jumped are reported in Table 1. The mean contact time found is in close agreement with that given by Samson and Roy

Figure 3:

Mean Vertical Velocity Curve for Center of Mass



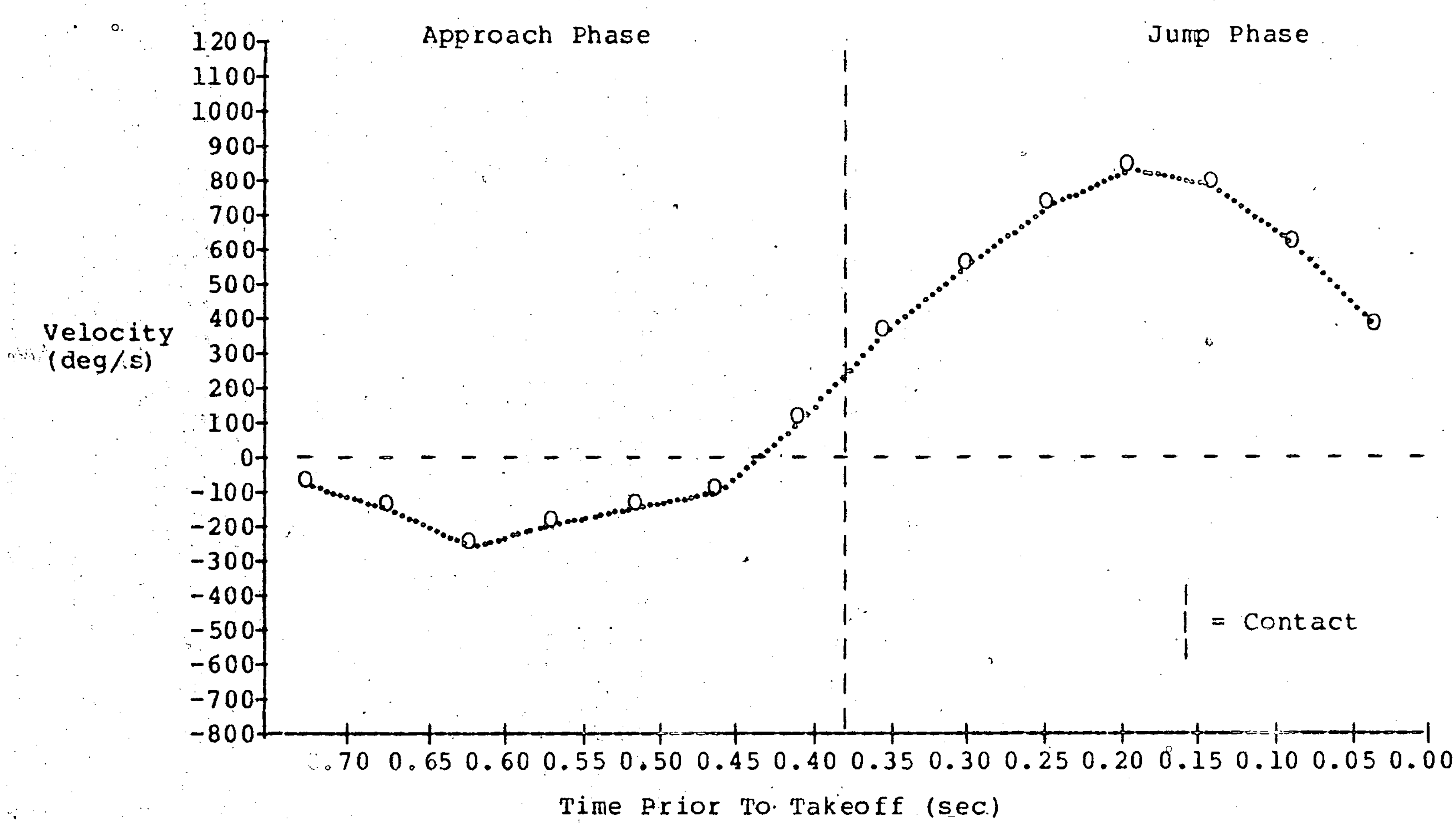
(1976) of .371 seconds for eleven (11) male subjects and .350 seconds reported by Samson et al (1978) for twenty-two (22) male subjects. Values for high jump reported by Hay (1974) and Kuhlow (1973) were considerably lower. The value of -.520 found for correlation of contact time to height jumped was considerably higher than the -.269 value reported by Samson et al (1978). In this study, contact time accounted for 27 percent of the variance in height jumped.

Angular Velocity of the Arm.

The mean velocity curve for the right arm is illustrated in Figure 4. The negative velocities found during the initial period of the approach phase indicate the movement of the arms to a hyper-extended position. Immediately prior to and after contact a smooth acceleration in this velocity is observed up to a maximum velocity which is immediately followed by deceleration until takeoff. The shape of this curve, although previously unreported, has a sound biomechanical base. The angular acceleration of the arms results in the application of a positive vertical force at any instant of $(mr\alpha)\cos\theta$ where; m = mass of the arm, r = distance from the shoulder to the center of mass of the arm, α = angular acceleration of the arm, and θ = angle of the arm with respect to the horizontal. This reduces the forces required to decelerate the center of mass of the subject to a zero negative vertical velocity. The subsequent deceleration of the arms up to takeoff results in a similar positive vertical force application thereby decreasing the negative forces against which the leg straightening takes place. The result should be a higher vertical velocity at takeoff. This acceleration-deceleration concept of the arm swing is in agreement

Figure 4:

Mean Angular Velocity Curve for Right Arm about Shoulder



with that put forth by Plagenhoef (1971)

The range, mean, standard deviation, and correlation of maximum angular velocity of the arm with the height jumped are reported in Table 1. The mean value found was 486.99 degrees per second higher than the 489 degrees per second reported by Samson et al (1978) for male subjects. In the same study a correlation of .617 was found between the maximum angular velocity and the height jumped which is considerably higher than that found in the present study.

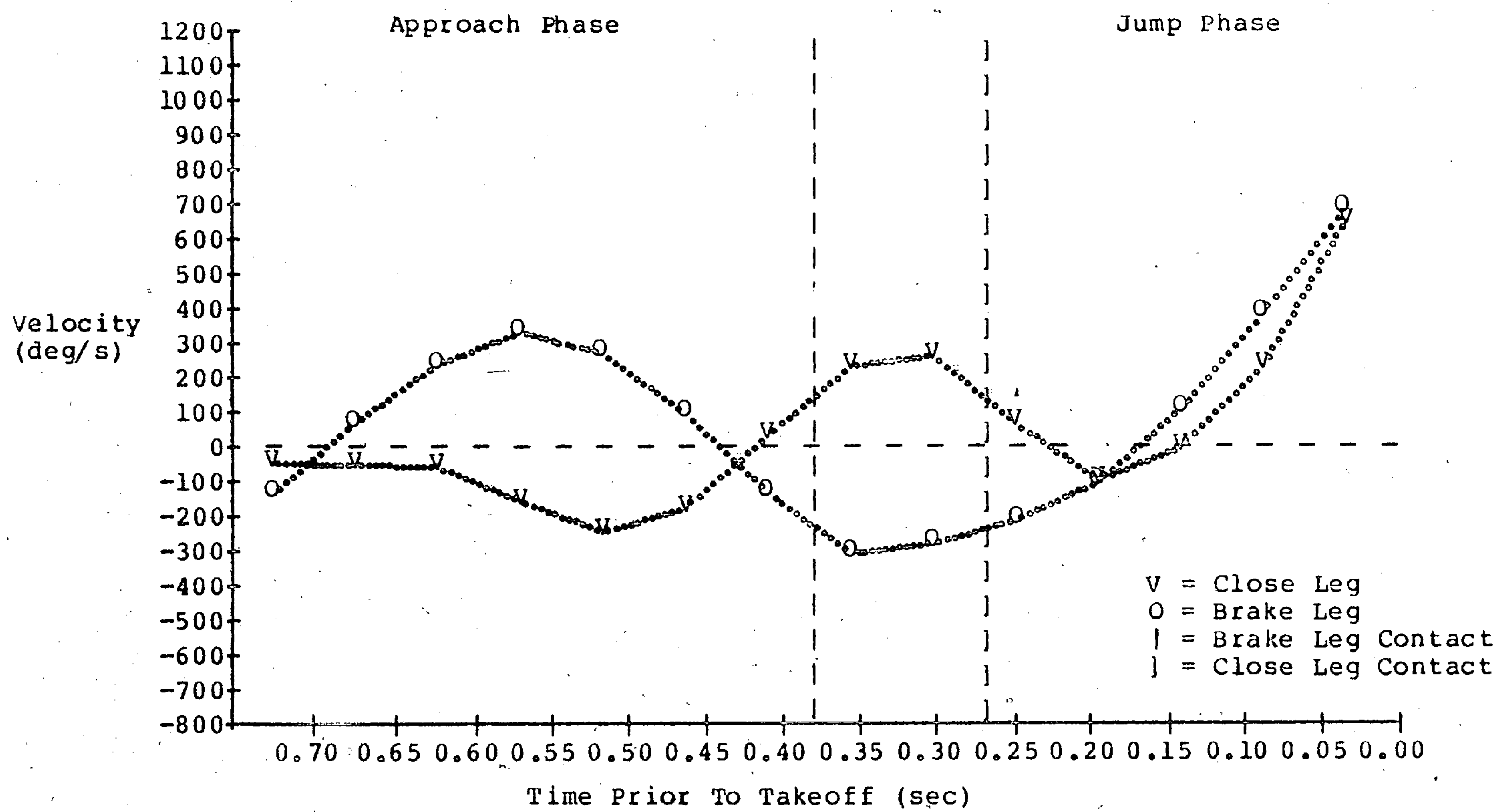
Angular Velocity at the Knee.

Examination of the angular velocity patterns at the knee was confined to those nineteen subjects which used a step-close approach. No study was done of these velocity patterns for the other three (3) subjects who used a hop approach because of insufficient data. Eight (8) of the subjects performed their jumps using a right brake leg, ten (10) subjects used a left brake leg and one (1) subject used a left brake leg on her first jump and a right brake leg on her second jump.

An examination of the angular velocity curves for the knees (Appendix C) revealed the existance of two distinctly different curves. The curve for the mean angular velocity at the knee of the brake leg is illustrated in Figure 5. This curve exhibits an increasing negative angular velocity of this knee immediately prior to contact. There is now a deceleration in the negative angular velocity followed by an acceleration in the positive velocity up to the moment of takeoff. Also seen in Figure 5 is the mean angular velocity curve for the knee of the close leg. It shows positive

Figure 5:

Mean Angular Velocity Curves at the Knee



angular velocity prior to its' contact with the floor. This positive angular velocity decreases after contact and is then followed by an increase in negative angular velocity up to a maximum. A deceleration of negative angular velocity is now observed followed by an acceleration in positive angular velocity up to takeoff.

The shape of the angular velocity curve at the knee fo the brake leg agrees with the findings of Samson and Roy (1976). No literature reviewed reports on an angular velocity curve for the knee shaped like that of the close leg.

The range, mean, standard deviation, and correlation to height jumped of maximum angular velocity of the knee for both the brake and close leg is shown in Table 1. For this group of subjects it would appear that maximum angular velocity at the knee for both the brake and close leg is not highly related to height jumped.

General Discussion.

The results indicate the existance of a temporal relationship between the velocity of the armswing and the velocity of leg extension. The velocity curves for arm swing and both knee extensions have two peaks of vertical force output as interpreted from observed maximum accelerations (positive or negative). As can be seen in Figures 4 and 5 these maximums are found after contact of the brake leg is made and just prior to takeoff. This allows for the summation of positive vertical forces at the two critical periods of the jump phase: (1) During the absorbtion of the body's free fall momentum created in the approach, and (2) During the propulsion of the body up to takeoff.

A closer examination of the different knee velocity patterns for the brake and close legs may reveal that the close leg better utilizes the storage of elastic energy for jumping than does the brake leg. Cavagna (1977) reported that decreasing the amplitude of negative work increases the utilization of stored elastic energy in positive work which immediately follows and decreases the time of this positive work. Table 2 shows a mean negative angular displacement, at the knee of the close leg, after contact which was 36.46 degrees less than that found for the brake leg. A further examination of the curves in Figure 5 shows that the time spent doing positive work is .025 seconds less for the close leg than for the brake leg. During this period of positive work the angular acceleration is greater for the close leg indicating a greater force output of the close leg's extension muscles. In this study, for the step-close approach, it would therefore appear that the close leg better utilizes the storage of elastic energy for jumping than does the brake leg.

TABLE 2

Total Negative Displacement at the Knee After Contact During Step-Close Approaches for the Brake and Close Leg.

Trial #	BRAKE LEG Total Negative Knee Displacement After Contact (deg)	CLOSE LEG Total Negative Knee Displacement After Contact (deg)
1	60.33	18.22
2	59.74	17.01
3	62.64	15.56
4	50.60	21.11
5	29.99	17.45
6	34.75	7.98
9	34.70	17.69
10	41.90	29.82
11	65.03	23.98
12	59.22	8.46
15	49.79	4.98
16	50.35	0.00
17	49.46	33.86
18	61.63	14.41
19	46.45	5.76
20	50.00	6.34
23	61.35	9.53
24	61.16	23.87
25	40.13	60.88
26	38.21	5.62
27	44.83	14.51
28	52.12	13.62
29	50.77	20.55
30	54.98	23.46
31	76.89	12.22
32	71.88	23.20
33	49.17	22.07
34	43.78	14.22
35	67.18	32.53
36	67.84	20.46
37	62.43	11.39
38	66.30	17.48
39	35.82	2.32
40	48.13	14.24
41	71.36	29.52
42	74.15	34.50
43	71.37	20.03
44	62.22	25.19
	$\bar{X}$ = 54.72	$\bar{X}$ = 18.26

CHAPTER V

SUMMARY AND RECOMMENDATIONS

Summary.

The purpose of this study was to determine the effect of selected kinematic variables on the height of a volleyball spike jump.

The relationship of the selected variables (horizontal velocity of the center of mass, vertical velocity of the center of mass, angular velocity of the arm, angular velocity at the knee, and contact time) to the height jumped was studied. Contact time, with a correlation to height jumped of -.520, accounted for 27 percent of the variance in the height jumped in this study. The other variables did not appear to have a high relationship to the height jumped.

A close examination of the variables did reveal some patterns not discussed in previous research. The angular velocity pattern of the arms was found to be biomechanically sound and had a temporal relationship to the angular velocity at the knee for the elite female athletes used as subjects. Patterns of angular velocity at the knee were identified for (1) The brake leg and (2) The close leg in a step-close approach. It would appear that the close leg is better able to utilize the stored elastic energy of the leg extension muscles than is the brake leg.

Findings.

Within its' limitations, this study resulted in the following findings for the volleyball spike jump:

1. Contact time had a correlation to height jumped of -.520.
2. The velocity pattern of armswing was biomechanically sound and had a temporal relationship to leg extension.

3. The brake and close legs exhibited different patterns of extension for the step-close approach.

Recommendations for Future Studies.

The variables in this study were examined in an inter-individual manner. As no large relationships to height jumped were found here a study should be done approaching the question from an intra-individual direction.

Future research should further examine the different patterns of leg extension as identified here. Should an athlete break with the right leg or the left leg when using the step-close approach? Is this choice natural or learned? Is one way superior? In addition, a study should be done examining only the hop style of approach.

Recommendations to Coaches and Teachers in Volleyball.

Results of this study would suggest that coaches and teachers should emphasize decreasing contact time of the jump when teaching the volleyball spike jump.

The concept of maximum acceleration and deceleration of the armswing during the jump phase of the skill must be thoroughly understood by all teachers and coaches. Instructional literature on the subject of volleyball (eg. Slaymaker and Brown (1970), Keller (1971), Scates (1972)) does not discuss this concept, omitting in particular the importance of arm deceleration prior to takeoff.

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APPENDIX

APPENDIX A

RAW DATA

TABLE 3

RAW DATA: Horizontal Velocities for Center of Mass (m/sec)

Between Frames	Subject 1 Trial 1	Subject 1 Trial 2	Subject 2 Trial 3	Subject 2 Trial 4	Subject 3 Trial 5	Subject 3 Trial 6	Subject 4 Trial 7	Subject 4 Trial 8
2 and 3	3.12	3.36	3.01	3.11	2.44	4.58	2.61	2.97
3 and 4	2.76	3.40	2.86	3.14	2.47	3.76	2.25	2.72
4 and 5	2.76	3.07	3.29	3.20	2.81	3.58	2.53	2.78
5 and 6	2.92	3.24	3.18	3.18	2.70	3.23	2.25	2.75
6 and 7	2.71	3.70	3.13	3.15	3.02	3.30	2.46	2.63
7 and 8	3.06	3.39	3.23	3.29	3.06	3.26	2.43	2.63
8 and 9	3.31	3.80	3.20	3.08	3.37	3.12	2.74	2.81
9 and 10	3.11	3.52	3.05	3.07	2.79	2.82	2.08	2.38
10 and 11	3.38	3.51	3.09	2.85	2.54	2.72	1.96	2.31
11 and 12	3.05	3.20	2.52	2.38	2.38	2.23	1.57	1.82
12 and 13	2.95	2.33	2.09	1.85	1.87	1.89	1.23	1.76
13 and 14	2.19	1.73	1.47	1.28	1.65	1.57	1.08	0.98
14 and 15	1.55	1.34	0.97	0.75	1.40	1.43	0.57	1.01
15 and 16	1.03	1.12	0.68	0.95	0.98	1.15	0.52	0.79

Between Frames	Subject 5 Trial 9	Subject 5 Trial 10	Subject 6 Trial 11	Subject 6 Trial 12	Subject 7 Trial 13	Subject 7 Trial 14	Subject 8 Trial 15	Subject 8 Trial 16
2 and 3	3.43	3.09	2.97	2.81	2.53	3.01	2.65	2.71
3 and 4	2.37	3.55	3.31	3.03	2.91	2.63	2.59	2.85
4 and 5	3.56	3.16	3.43	3.13	2.83	2.78	2.46	2.36
5 and 6	3.38	3.60	3.24	3.04	2.57	3.03	2.58	2.59
6 and 7	3.45	3.84	3.33	3.32	2.74	2.72	2.68	2.96
7 and 8	3.66	3.46	3.52	3.22	2.76	3.14	2.80	2.97
8 and 9	3.41	3.76	3.36	3.30	2.91	2.69	2.70	2.99
9 and 10	2.63	2.89	3.03	2.76	3.18	3.05	2.81	2.97
10 and 11	2.46	2.65	2.75	2.44	2.37	2.95	2.69	2.71
11 and 12	2.23	2.54	2.10	2.42	2.81	2.89	2.32	2.53
12 and 13	1.80	1.91	1.98	1.81	1.82	2.78	1.63	2.14
13 and 14	1.28	1.54	1.46	1.26	1.60	1.84	1.12	1.55
14 and 15	0.95	1.00	1.06	0.94	0.98	1.21	0.63	1.11
15 and 16	0.82	0.90	0.89	0.79	0.46	1.04	0.58	1.16

TABLE 3 continued:

Between Frames	Subject 9 Trial 17	Subject 9 Trial 18	Subject 10 Trial 19	Subject 10 Trial 20	Subject 11 Trial 21	Subject 11 Trial 22	Subject 12 Trial 23	Subject 12 Trial 24
2 and 3	5.40	3.50	2.48	2.31	4.27	3.48	2.91	3.15
3 and 4	4.47	3.92	2.41	2.64	3.99	3.22	3.32	3.26
4 and 5	4.40	3.57	2.28	2.47	3.62	3.26	3.19	3.14
5 and 6	4.35	3.49	2.74	2.85	3.51	3.63	3.47	3.08
6 and 7	4.21	3.63	3.05	3.11	3.55	3.31	3.25	3.55
7 and 8	3.92	3.60	3.05	2.88	3.55	3.35	2.97	2.70
8 and 9	3.65	3.57	2.91	3.00	3.67	3.94	2.61	3.14
9 and 10	3.54	3.54	2.79	3.09	3.66	3.74	2.00	2.27
10 and 11	3.24	3.00	2.78	2.47	3.65	3.82	1.86	1.73
11 and 12	2.99	2.61	2.07	2.09	3.41	3.42	1.41	1.79
12 and 13	2.41	2.24	2.04	1.65	3.32	3.09	1.23	1.36
13 and 14	2.02	1.79	1.56	1.63	2.01	2.22	1.28	0.89
14 and 15	1.60	1.66	0.96	1.22	1.24	1.33	0.71	0.67

Between Frames	Subject 13 Trial 25	Subject 13 Trial 26	Subject 14 Trial 27	Subject 14 Trial 28	Subject 15 Trial 29	Subject 15 Trial 30	Subject 16 Trial 31	Subject 16 Trial 32
1 and 2	3.06	3.05	2.37	1.89	2.43	2.55	3.08	3.01
3 and 4	2.76	2.54	2.33	2.40	2.62	2.72	2.88	3.41
4 and 5	3.14	2.68	2.43	2.31	2.65	2.75	3.19	3.08
5 and 6	2.78	2.90	2.74	2.75	2.68	2.52	3.02	3.13
6 and 7	3.17	2.95	2.69	2.88	2.61	2.90	3.19	3.41
7 and 8	3.04	3.35	3.00	2.78	2.64	2.78	3.19	3.20
8 and 9	3.10	2.99	2.73	2.89	2.48	2.57	3.27	3.40
9 and 10	3.29	3.11	2.48	2.49	2.73	2.54	3.40	3.30
10 and 11	2.77	3.08	2.43	2.18	2.18	2.18	3.22	3.11
11 and 12	2.44	2.11	1.82	1.87	2.09	2.05	2.76	2.72
12 and 13	2.19	2.56	1.73	1.60	1.61	1.82	1.88	2.06
13 and 14	1.70	1.91	1.30	1.12	1.11	1.55	1.57	1.75
14 and 15	1.66	1.63	1.11	0.91	1.69	1.97	1.12	1.14
15 and 16	1.68	1.21	0.76	0.34	0.51	1.23	0.69	0.86

TABLE 3 continued:

Between Frames	Subject 17 Trial 33	Subject 17 Trial 34	Subject 18 Trial 35	Subject 18 Trial 36	Subject 19 Trial 37	Subject 19 Trial 38
2 and 3	2.89	2.89	3.48	3.43	2.59	2.50
3 and 4	2.62	2.52	3.08	3.41	2.51	2.67
4 and 5	2.95	2.87	3.24	3.32	2.93	2.51
5 and 6	2.80	2.88	2.98	3.29	2.65	2.55
6 and 7	3.09	3.18	3.14	3.04	2.67	2.66
7 and 8	3.13	3.09	2.96	3.39	2.73	2.43
8 and 9	3.21	3.12	3.05	3.55	2.76	2.34
9 and 10	3.13	3.09	3.50	3.56	2.58	1.97
10 and 11	3.00	3.05	2.55	3.06	2.17	1.72
11 and 12	2.64	2.60	2.39	2.87	1.64	1.60
12 and 13	2.07	2.42	1.85	2.47	1.79	1.68
13 and 14	1.46	1.75	1.38	1.77	1.00	1.16
14 and 15	1.16	0.74	1.28	1.45	1.10	0.96
15 and 16	0.88	0.78	0.21	0.70	0.50	0.93

Between Frames	Subject 20 Trial 39	Subject 20 Trial 40	Subject 21 Trial 41	Subject 21 Trial 42	Subject 22 Trial 43	Subject 22 Trial 44
2 and 3	2.32	1.92	2.44	3.00	2.71	3.00
3 and 4	2.24	2.07	2.98	2.79	3.05	2.86
4 and 5	1.99	1.92	3.10	3.25	3.02	2.76
5 and 6	2.61	2.29	2.84	3.07	3.00	3.05
6 and 7	2.47	2.09	3.33	3.37	3.02	2.90
7 and 8	2.50	2.43	2.96	3.31	2.77	3.19
8 and 9	2.31	2.33	2.98	3.13	2.46	2.48
9 and 10	2.90	2.19	2.94	3.06	2.22	2.50
10 and 11	2.24	2.06	2.63	2.87	2.24	2.30
11 and 12	2.08	1.78	2.36	2.03	2.69	2.00
12 and 13	1.79	1.99	1.90	2.10	1.88	1.66
13 and 14	1.22	1.03	1.48	1.49	1.12	1.13
14 and 15	0.99	1.09	0.51	0.72	1.10	1.16
15 and 16	1.28	0.83	1.05	0.65	0.96	0.95

TABLE

RAW DATA: Vertical Velocities for Center of Mass (m/sec)

Between Frames	Subject 1 Trial 1	Subject 1 Trial 2	Subject 2 Trial 3	Subject 2 Trial 4	Subject 3 Trial 5	Subject 3 Trial 6	Subject 4 Trial 7	Subject 4 Trial 8
2 and 3	0.06	0.20	0.70	0.62	0.04	-1.14	0.83	0.82
3 and 4	-0.01	0.52	1.05	1.19	-0.24	-0.01	1.21	0.80
4 and 5	1.23	1.07	1.17	1.26	0.85	0.37	0.61	0.70
5 and 6	0.72	1.10	0.61	0.08	0.63	0.80	0.22	2.70
6 and 7	1.00	0.50	0.22	-0.24	0.25	0.30	-0.08	0.09
7 and 8	0.65	0.61	-0.36	-0.06	-0.28	-0.31	-0.86	-0.89
8 and 9	0.15	-0.74	-1.23	-1.44	-0.62	-0.99	-1.49	-1.22
9 and 10	-0.35	-0.74	-1.47	-1.82	-0.76	-0.43	-1.71	-1.46
10 and 11	-0.75	-1.45	-1.93	-1.39	-0.75	-0.86	-0.98	-1.52
11 and 12	-0.88	-1.03	-0.61	-0.18	-0.08	-0.18	0.00	0.12
12 and 13	-1.30	-0.01	0.85	0.97	0.63	0.44	1.03	1.16
13 and 14	0.28	1.54	1.80	2.47	1.49	1.82	2.25	2.29
14 and 15	1.44	2.61	2.69	3.07	2.81	2.77	2.67	3.06
15 and 16	2.96	3.55	3.08	3.21	3.37	3.10	3.19	3.39

Between Frames	Subject 5 Trial 9	Subject 5 Trial 10	Subject 6 Trial 11	Subject 6 Trial 12	Subject 7 Trial 13	Subject 7 Trial 14	Subject 8 Trial 15	Subject 8 Trial 16
2 and 3	0.27	0.48	0.89	0.82	0.10	0.07	-0.09	-0.37
3 and 4	0.49	0.95	1.09	1.21	0.26	-0.07	0.01	0.35
4 and 5	0.84	0.49	0.88	0.67	0.71	0.28	0.32	0.14
5 and 6	-0.11	0.01	0.06	0.43	0.39	0.44	0.71	0.73
6 and 7	-0.42	0.22	-0.46	0.04	0.94	0.89	0.82	0.72
7 and 8	-0.51	-0.59	-0.96	-0.90	0.61	1.24	0.02	0.45
8 and 9	-1.14	-1.35	-1.77	-1.61	-0.28	-0.10	0.06	0.04
9 and 10	-1.37	-1.08	-0.87	-1.08	-0.42	-0.47	-0.70	-0.84
10 and 11	-0.15	-0.61	-1.08	-0.72	-1.34	-0.99	-0.68	-0.48
11 and 12	1.38	0.06	0.18	-0.13	-1.82	-1.13	-0.16	-0.73
12 and 13	1.08	1.20	0.91	0.52	-0.08	-1.19	0.62	0.53
13 and 14	1.87	2.10	1.84	1.89	1.23	0.36	1.18	1.49
14 and 15	2.64	2.91	2.65	2.71	2.60	2.59	2.54	2.77
15 and 16	3.34	3.10	2.84	3.28	3.29	3.21	3.04	3.08

TABLE 4 continued:

Between Frames	Subject 9		Subject 10		Subject 11		Subject 12	
	Trial 17	Trial 18	Trial 19	Trial 20	Trial 21	Trial 22	Trial 23	Trial 24
2 and 3	0.45	0.04	0.15	0.07	-0.27	0.17	1.02	0.66
3 and 4	-0.08	0.94	0.45	0.56	0.36	-0.22	0.54	0.84
4 and 5	0.65	0.75	0.21	0.86	0.65	0.73	0.14	0.13
5 and 6	0.93	0.24	0.86	0.54	1.20	1.04	-0.51	-0.39
6 and 7	0.21	-0.40	0.43	0.03	1.29	1.03	-1.05	-0.83
7 and 8	-0.23	-0.43	-0.30	-0.30	-0.07	0.65	-1.11	-1.64
8 and 9	-0.85	-0.93	-1.14	-1.11	-0.50	-0.53	-0.95	-0.89
9 and 10	-1.10	-1.18	-1.35	-1.21	-0.78	-0.81	-0.75	-0.64
10 and 11	-0.85	-0.92	-0.68	-0.56	-1.18	-0.83	-0.25	-0.46
11 and 12	-0.22	0.01	-0.01	-0.18	-1.69	-2.23	0.43	-0.27
12 and 13	0.71	1.17	0.60	0.60	-0.54	-0.96	1.06	1.44
13 and 14	1.73	1.74	2.22	1.90	0.67	1.18	2.33	1.79
14 and 15	2.56	2.61	2.48	3.09	2.88	2.63	2.57	2.48
15 and 16	2.99	3.03	3.08	3.14	3.76	3.71	2.89	3.12

Between Frames	Subject 13		Subject 14		Subject 15		Subject 16	
	Trial 25	Trial 26	Trial 27	Trial 28	Trial 29	Trial 30	Trial 31	Trial 32
2 and 3	-0.54	-0.63	-0.27	-0.14	1.24	0.79	0.44	0.79
3 and 4	-0.21	-0.29	0.25	0.61	1.40	1.44	0.68	0.95
4 and 5	0.30	0.48	0.21	0.25	0.40	0.56	0.89	0.99
5 and 6	0.32	0.57	0.76	0.39	-0.06	-0.58	0.84	0.64
6 and 7	0.63	0.62	-0.13	0.15	-0.70	-0.48	0.69	0.24
7 and 8	0.20	0.18	-0.45	-0.51	-0.77	-1.04	-0.31	-0.58
8 and 9	-0.93	-0.80	-1.05	-1.01	-1.82	-1.47	-0.92	-1.12
9 and 10	-0.80	-1.16	-0.73	-1.17	-1.35	-1.66	-1.45	-1.78
10 and 11	-0.80	-0.85	-0.39	-0.14	-1.25	-1.04	-1.13	-1.64
11 and 12	0.09	-0.16	-0.32	-0.43	-0.06	-0.51	-1.43	-1.13
12 and 13	0.32	0.47	0.78	0.59	0.62	0.90	0.43	0.58
13 and 14	1.36	0.84	1.93	1.45	1.80	1.70	1.28	1.80
14 and 15	2.67	2.63	3.14	3.03	2.55	2.63	3.17	2.53
15 and 16	3.37	3.34	3.15	3.02	3.46	2.83	3.04	2.86

TABLE 4 continued:

Between Frames	Subject 17 Trial 33	Subject 17 Trial 34	Subject 18 Trial 35	Subject 18 Trial 36	Subject 19 Trial 37	Subject 19 Trial 38
2 and 3	0.17	-0.05	0.03	-0.31	0.02	0.22
3 and 4	0.67	0.22	-0.13	0.24	0.17	0.59
4 and 5	1.25	0.78	0.22	0.00	0.51	0.17
5 and 6	0.86	1.01	0.21	0.75	0.52	-0.02
6 and 7	0.36	0.72	-0.51	0.50	-0.25	-0.91
7 and 8	-0.27	0.23	-0.08	0.02	-0.68	-1.14
8 and 9	-0.83	-0.45	-0.77	-0.51	-1.02	-1.27
9 and 10	-1.24	-1.06	-1.51	-1.20	-1.09	-0.73
10 and 11	-1.55	-1.50	-1.62	-1.40	-0.50	-0.64
11 and 12	-0.58	-0.80	-0.27	-0.63	-0.04	0.24
12 and 13	0.06	-0.47	0.99	0.47	0.71	1.44
13 and 14	1.25	1.33	2.26	1.59	1.75	1.86
14 and 15	2.99	2.88	2.76	2.91	2.50	2.61
15 and 16	3.46	3.70	3.10	3.16	3.17	2.82

Between Frames	Subject 20 Trial 39	Subject 20 Trial 40	Subject 21 Trial 41	Subject 21 Trial 42	Subject 22 Trial 43	Subject 22 Trial 44
2 and 3	-0.20	0.02	0.33	0.23	0.73	1.10
3 and 4	0.46	0.74	0.89	0.89	0.11	0.65
4 and 5	1.03	1.01	0.74	0.58	-0.45	0.11
5 and 6	0.61	0.92	0.30	0.66	-0.56	-0.66
6 and 7	0.70	0.21	-0.06	0.19	-1.72	-1.28
7 and 8	-0.10	-0.45	-0.49	-0.86	-1.46	-1.16
8 and 9	-0.61	-0.86	-1.29	-0.76	-0.83	-1.33
9 and 10	-1.34	-1.10	-0.83	-1.60	-0.93	-1.07
10 and 11	-0.95	-0.87	-0.84	-0.05	-0.38	-0.23
11 and 12	0.13	-0.19	0.41	-0.30	0.32	-0.36
12 and 13	0.26	0.65	0.65	0.30	0.97	1.00
13 and 14	1.33	1.60	1.40	1.71	1.61	1.51
14 and 15	2.46	2.55	3.10	2.90	2.68	2.62
15 and 16	3.28	3.01	3.14	3.32	2.88	3.17

TABLE 5

RAW DATA: Angular Velocities of the Right Arm about the Shoulder

Between Frames	Subject 1 Trial 1	Subject 1 Trial 2	Subject 2 Trial 3	Subject 2 Trial 4	Subject 3 Trial 5	Subject 3 Trial 6
2 and 3	281.86	569.48	-48.14	-153.12	-395.07	-465.44
3 and 4	290.69	608.52	-368.61	-284.76	-503.14	-723.86
4 and 5	445.03	520.83	-411.26	-424.26	-439.63	-671.79
5 and 6	495.31	674.83	-571.44	-724.23	-417.96	-421.57
6 and 7	1071.48	980.42	-410.40	-533.79	-276.95	-313.04
7 and 8	1436.31	958.94	-175.15	-142.65	-255.66	-245.75
8 and 9	667.40	546.64	108.98	226.29	-31.7	22.15
9 and 10	329.74	405.85	213.78	197.86	528.57	657.92
10 and 11	285.37	431.94	674.41	741.14	540.11	427.29
11 and 12	342.56	602.30	706.96	911.84	595.17	555.50
12 and 13	590.10	1013.60	780.52	896.78	678.33	711.22
13 and 14	766.13	763.39	745.24	860.67	928.91	726.43
14 and 15	902.74	645.43	713.60	638.60	978.82	1079.80
15 and 16	635.45	473.53	551.19	443.41	422.14	243.88

Between Frames	Subject 4 Trial 7	Subject 4 Trial 8	Subject 5 Trial 9	Subject 5 Trial 10	Subject 6 Trial 11	Subject 6 Trial 12
2 and 3	-101.54	-121.72	500.54	206.42	-494.56	-417.40
3 and 4	-248.31	-98.95	244.24	315.82	-393.35	-448.11
4 and 5	-336.60	-214.68	349.68	184.31	-470.15	-375.90
5 and 6	-272.92	-294.83	167.73	340.85	-201.01	-365.99
6 and 7	-244.47	-333.50	543.08	426.64	-26.29	-206.80
7 and 8	-152.03	-108.85	-944.87	-1471.45	69.47	8.78
8 and 9	86.41	1.47	385.25	577.68	228.78	81.22
9 and 10	296.58	194.87	447.86	639.27	516.76	473.37
10 and 11	704.96	558.03	516.06	521.89	835.30	757.04
11 and 12	801.18	854.72	589.28	533.57	648.09	795.08
12 and 13	748.41	780.31	723.69	869.17	765.33	887.40
13 and 14	689.90	842.52	568.39	651.51	1097.13	862.24
14 and 15	503.29	430.50	413.68	421.47	453.18	712.31
15 and 16	281.34	256.28	266.04	217.54	188.62	-5.45

TABLE 5 continued:

Between Frames	Subject 7 Trial 13	Subject 7 Trial 14	Subject 8 Trial 15	Subject 8 Trial 16	Subject 9 Trial 17	Subject 9 Trial 18
2 and 3	240.48	195.15	-450.11	-370.17	466.77	528.38
3 and 4	271.99	85.38	-422.46	-536.15	340.79	687.18
4 and 5	245.02	132.31	-606.83	-496.33	1476.12	-1618.34
5 and 6	-1195.11	1589.77	-85.07	-223.45	273.22	334.44
8 and 9	540.84	-484.10	164.85	132.67	255.84	396.30
9 and 10	247.85	315.09	431.12	248.25	438.33	442.52
10 and 11	521.03	311.56	583.89	493.95	533.94	539.25
11 and 12	553.13	549.02	873.90	847.14	562.46	717.17
12 and 13	828130	929.14	920.54	933.39	790.50	781.37
13 and 14	713.87	614.20	770.30	888.80	868.19	764.29
14 and 15	517.26	260.03	572.25	585.64	1073.69	767.22
15 and 16	699.25	559.46	268.95	494.49	476.42	264.58

Between Frames	Subject 10 Trial 19	Subject 10 Trial 20	Subject 11 Trial 21	Subject 11 Trial 22	Subject 12 Trial 23	Subject 12 Trial 24
2 and 3	-166.10	21.98	280.11	160.43	-339.54	96.79
3 and 4	-194.49	3.22	410.57	379.35	-371.47	-7.87
4 and 5	-1366.62	335.35	357.99	404.45	-348.21	-203.45
5 and 6	-119.58	438.19	433.28	425.83	-200.29	316.94
6 and 7	197.30	282.54	429.90	517.12	-164.08	365.89
7 and 8	216.04	320.22	648.63	405.93	147.15	379.63
8 and 9	322.33	278.14	-1466.62	1493.70	359.22	907.13
9 and 10	688.27	364.37	769.73	1146.28	528.68	899.15
10 and 11	887.39	660.57	603.44	801.16	640.97	523.19
11 and 12	1099.34	930.50	708.72	646.31	751.09	381.26
12 and 13	774.15	1039.25	757.63	885.73	678.01	431.77
13 and 14	562.62	612.18	824.87	765.45	508.44	853.03
14 and 15	283.08	597.25	585.95	603.50	695.32	666.81
15 and 16	36.14	393.84	412.37	508.98	490.82	496.58

TABLE 5 continued:

Between Frames	Subject 13 Trial 25	Subject 13 Trial 26	Subject 14 Trial 27	Subject 14 Trial 28	Subject 15 Trial 29	Subject 15 Trial 30
2 and 3	282.53	-218.48	-289.76	-198.80	-408.91	-289.48
3 and 4	-435.85	-374.35	-415.82	-461.26	-440.81	-349.6
4 and 5	-485.10	-487.62	-381.27	-510.65	-366.74	-270.89
5 and 6	-352.03	-518.74	-423.58	-559.63	-372.01	-413.27
6 and 7	-500.43	-332.93	-580.39	-351.37	-330.27	-321.82
7 and 8	-389.03	-336.98	-195.08	-157.47	-167.56	-295.47
8 and 9	58.68	45.68	3.77	-29.09	134.01	-116.23
9 and 10	259.01	217.97	363.67	440.10	387.91	262.39
10 and 11	514.13	550.80	523.45	599.66	792.06	461.76
11 and 12	916.94	650.69	873.71	837.27	936.12	894.09
12 and 13	805.15	845.10	1017.43	1155.57	899.56	788.88
13 and 14	804.21	841.14	727.21	723.70	1082.39	885.31
14 and 15	350.12	526.46	593.08	590.48	466.73	1105.40

Between Frames	Subject 16 Trial 31	Subject 16 Trial 32	Subject 17 Trial 33	Subject 17 Trial 34	Subject 18 Trial 35	Subject 18 Trial 36
2 and 3	71.94	163.15	-187.14	-247.94	187.73	254.04
3 and 4	-213.19	146.77	-103.93	-378.67	144.18	227.37
4 and 5	-437.00	-325.51	-333.97	-160.79	-97.07	28.14
5 and 6	-678.67	-340.09	-315.47	-286.90	-438.04	-239.54
6 and 7	-275.92	1625.44	-625.07	-454.60	-595.60	-542.86
7 and 8	-214.07	-322.27	-401.47	-480.81	-277.92	-521.74
8 and 9	-17.27	111.06	-199.40	-421.32	37.11	-124.60
9 and 10	203.12	356.15	36.91	18.23	398.24	-12.04
10 and 11	478.79	553.45	357.89	220.72	593.83	528.70
11 and 12	733.03	765.32	691.23	696.54	750.55	711.51
12 and 13	1073.62	1044.59	1129.42	953.09	874.70	1029.78
13 and 14	764.00	708.34	919.56	911.76	933.14	1085.41
14 and 15	630.71	609.38	713.93	975.32	861.90	538.54
15 and 16	495.72	543.89	396.66	325.44	74.57	120.12

TABLE 5 continued:

Between Frames	Subject 19 Trial 37	Subject 19 Trial 38	Subject 20 Trial 39	Subject 20 Trial 40
2 and 3	-249.60	-110.42	-147.58	-200.20
3 and 4	-225.54	-394.01	-318.29	-319.11
4 and 5	-437.58	-752.61	-308.00	-407.25
5 and 6	-677.62	-993.98	-281.06	-248.09
6 and 7	379.37	-343.55	-318.83	-412.35
7 and 8	-383.12	-67.70	-340.98	-188.27
8 and 9	23.40	192.62	-260.31	-12.25
9 and 10	314.94	486.40	112.43	193.77
10 and 11	495.87	707.66	495.60	450.89
11 and 12	852.84	884.94	756.93	837.47
12 and 13	904.55	836.92	784.49	762.93
13 and 14	734.81	508.60	902.89	697.14
14 and 15	439.79	304.73	725.15	977.35
15 and 16	381.02	370.26	531.85	428.63

Between Frames	Subject 21 Trial 41	Subject 21 Trial 42	Subject 22 Trial 43	Subject 22 Trial 44
2 and 3	-195.99	-86.25	-126.38	-115.47
3 and 4	-327.12	-236.14	-185.95	-212.33
4 and 5	-459.49	-500.04	-196.26	-261.14
5 and 6	-870.39	-356.41	-161.32	-245.47
6 and 7	-364.99	-786.34	-136.15	-153.51
7 and 8	-74.30	-151.86	-257.31	-162.29
8 and 9	29.11	56.63	-55.33	49.77
9 and 10	467.69	113.27	256.73	186.98
10 and 11	780.28	714.69	640.51	510.78
11 and 12	874.00	889.90	703.21	758.60
12 and 13	1047.38	1110.11	591.44	665.52
13 and 14	981.44	1012.47	898.41	846.49
14 and 15	487.08	600.38	489.81	554.96
15 and 15	320.45	365.83	436.28	568.98

TABLE 6

RAW DATA: Angular Velocities at Knee of Close Leg.

Between Frames	Subject 1 Trial 1	Subject 1 Trial 2	Subject 2 Trial 3	Subject 2 Trial 4	Subject 3 Trial 5	Subject 3 Trial 6	Subject 5 Trial 9	Subject 5 Trial 10
2 and 3	-309	-206	121	-150	22	39	95	67
3 and 4	-134	-2	-133	-72	-11	-86	119	193
4 and 5	-11	142	158	-34	222	116	268	173
5 and 6	-19	173	-297	-252	212	84	-46	80
6 and 7	130	-58	-274	-45	-427	-304	-545	-552
7 and 8	71	-294	158	222	-392	-483	-538	-524
8 and 9	-198	=162	429	592	=298	-129	-204	-337
9 and 10	-207	161	381	56	471	420	181	124
10 and 11	-63	319	147	9	473	364	530	559
11 and 12	240	82	-101	-310	52	53	447	712
12 and 13	284	-317	-140	-82	9	158	-125	-219
13 and 14	-276	16	-47	99	-26	-19	197	97
14 and 15	26	366	237	306	203	256	81	255
15 and 16	396	765	424	602	524	559	681	599

Between Frames	Subject 6 Trial 11	Subject 6 Trial 12	Subject 8 Trial 15	Subject 8 Trial 16	Subject 9 Trial 17	Subject 9 Trial 18	Subject 10 Trial 19	Subject 10 Trial 20
2 and 3	293	181	-60	-111	14	91	-158	-44
3 and 4	293	401	-38	-27	74	13	152	95
4 and 5	-514	-255	-133	61	78	202	281	229
5 and 6	-617	-561	-63	-20	285	264	103	65
6 and 7	-300	-516	-42	-89	217	-375	-459	-482
7 and 8	81	-81	-329	-284	-730	-624	-585	-488
8 and 9	315	119	-26	-311	-698	-439	-356	-385
9 and 10	590	481	39	35	-372	71	293	270
10 and 11	280	467	427	302	401	721	594	651
11 and 12	-208	76	289	287	946	395	37	-50
12 and 13	-238	-157	-92	64	477	-221	-107	-67
13 and 14	51	87	58	149	-258	-47	77	144
14 and 15	180	286	275	251	144	216	474	316
15 and 16	611	479	631	779	698	827	770	818

TABLE 6 continued:

Between Frames	Subject 12 Trial 23	Subject 12 Trial 24	Subject 13 Trial 25	Subject 13 Trial 26	Subject 14 Trial 27	Subject 14 Trial 28	Subject 15 Trial 29	Subject 15 Trial 29
2 and 3	87	185	-217	-151	30	776	103	245
3 and 4	-382	-204	-77	-33	71	200	-244	-211
4 and 5	-449	-490	86	28	79	-48	-396	-639
5 and 6	-388	-454	-130	15	-360	-365	-56	-73
6 and 7	25	-347	-236	-222	-417	-455	138	215
7 and 8	139	-99	-353	-387	-345	-215	409	294
8 and 9	162	577	-174	-314	161	242	368	508
9 and 10	261	745	168	-104	445	400	21	73
10 and 11	-56	654	464	279	144	130	-50	-111
11 and 12	-106	143	479	422	-210	-155	-79	-54
12 and 13	-14	-316	82	543	-60	-98	-241	-267
13 and 14	231	-34	-85	55	49	43	-12	-5
14 and 15	396	128	174	22	378	332	219	95
15 and 16	703	345	449	528	894	888	710	630

Between Frames	Subject 16 Trial 31	Subject 16 Trial 32	Subject 17 Trial 33	Subject 17 Trial 34	Subject 18 Trial 35	Subject 18 Trial 36	Subject 19 Trial 37	Subject 19 Trial 38
2 and 3	108	119	-51	-143	-40	-298	-97	83
3 and 4	135	110	185	146	-356	-135	-51	-252
4 and 5	118	-13	123	18	-63	-166	-87	-227
5 and 6	-235	-390	-333	83	-298	-99	-276	-287
6 and 7	-368	-216	-305	-424	-252	-133	-301	-32
7 and 8	-168	8	-223	291	-121	-295	-255	1
8 and 9	97	340	333	74	348	264	27	365
9 and 10	615	389	594	533	318	404	278	-174
10 and 11	148	101	223	466	-200	152	325	-25
11 and 12	-65	-67	-81	721	-344	-155	-118	-125
12 and 13	-47	-311	-191	-108	-62	-226	-93	92
13 and 14	-114	-53	-138	-156	76	17	193	177
14 and 15	277	168	399	301	387	240	238	398
15 and 16	683	714	642	653	978	796	849	825

TABLE 6 continued:

Between Frames	Subject 20 Trial 39	Subject 20 Trial 40	Subject 21 Trial 41	Subject 21 Trial 42	Subject 22 Trial 43	Subject 22 Trial 44
2 and 3	69	216	-6	-26	-630	-419
3 and 4	35	417	141	114	-596	-752
4 and 5	75	-100	161	202	-318	-252
5 and 6	-183	-91	-81	-323	-12	-211
6 and 7	-220	-248	-549	-474	313	63
7 and 8	-243	23	-237	-413	532	417
8 and 9	-28	-3	-258	-330	682	707
9 and 10	142	331	298	319	137	416
10 and 11	402	313	502	664	-97	94
11 and 12	285	-227	220	445	-180	-303
12 and 13	-43	4	-240	-315	-95	-166
13 and 14	21	-34	-52	86	70	18
14 and 15	265	318	352	277	157	92
15 and 16	397	621	855	791	579	597

TABLE 7

RAW DATA: Angular Velocities at Knee of Brake Leg

Between Frames	Subject 1 Trial 1	Subject 1 Trial 2	Subject 2 Trial 3	Subject 2 Trial 4	Subject 3 Trial 5	Subject 3 Trial 6	Subject 5 Trial 9	Subject 5 Trial 10
2 and 3	-517	-409	169	261	-166	-623	-166	-255
3 and 4	-306	221	327	429	157	-63	211	94
4 and 5	-204	270	430	343	368	232	317	364
5 and 6	240	410	241	245	458	497	506	579
6 and 7	398	563	285	38	206	145	595	501
7 and 8	548	350	95	51	3	42	-83	73
8 and 9	385	54	-121	-248	-78	-157	-35	161
9 and 10	219	41	-400	-436	-252	-195	-348	-530
10 and 11	-285	-212	-440	-320	-158	-176	-264	-210
11 and 12	-171	-623	-253	-179	-46	-81	173	-40
12 and 13	-423	-278	-74	-7	-23	-36	62	77
13 and 14	-245	53	83	151	34	63	117	139
14 and 15	69	277	570	513	301	325	259	269
15 and 16	450	760	636	828	685	633	259	392

Between Frames	Subject 6 Trial 11	Subject 6 Trial 12	Subject 8 Trial 15	Subject 8 Trial 16	Subject 9 Trial 17	Subject 9 Trial 18	Subject 10 Trial 19	Subject 10 Trial 20
2 and 3	225	81	-499	-446	-536	-598	-18	-8
3 and 4	205	218	-339	-335	-672	39	184	136
4 and 5	448	356	71	168	-124	246	381	413
5 and 6	545	415	297	497	352	452	463	518
6 and 7	409	446	579	402	418	534	456	470
7 and 8	-28	282	489	325	612	311	-159	-133
8 and 9	-238	-208	122	139	10	-156	-237	-137
9 and 10	-446	-439	-169	-136	-[illegible]	-391	-325	-411
10 and 11	-335	-286	-353	-305	-34[illegible]	-303	-317	-341
11 and 12	-187	-159	-329	-442	205	-182	134	-181
12 and 13	-5	-11	-77	-54	-137	-115	-224	43
13 and 14	236	223	91	38	-56	88	310	306
14 and 15	487	463	229	356	396	521	168	227
15 and 16	662	557	719	815	654	725	835	856

TABLE 7 continued:

Between Frames	Subject 12 Trial 23	Subject 12 Trial 24	Subject 13 Trial 25	Subject 13 Trial 26	Subject 14 Trial 27	Subject 14 Trial 28	Subject 15 Trial 29	Subject 15 Trial 30
2 and 3	208	204	-341	-260	109	32	127	68
3 and 4	348	495	-181	-32	204	157	238	317
4 and 5	491	568	31	232	267	346	191	254
5 and 6	205	241	354	391	378	386	227	456
6 and 7	-46	-90	426	500	209	236	233	136
7 and 8	-240	-432	377	153	-177	-163	31	388
8 and 9	-399	-280	-202	-182	-213	-191	1	-53
9 and 10	-132	-102	-259	-197	-433	-256	-481	-452
10 and 11	-67	-105	-134	-409	-62	-140	-341	-274
11 and 12	-273	-220	-247	101	-15	-284	-122	-109
12 and 13	-20	177	-106	-73	-111	-99	-3	-136
13 and 14	98	211	446	-133	29	65	133	266
14 and 15	515	353	434	232	505	363	535	551
15 and 16	683	425	669	665	750	749	766	714

Between Frames	Subject 16 Trial 31	Subject 16 Trial 32	Subject 17 Trial 33	Subject 17 Trial 34	Subject 18 Trial 35	Subject 18 Trial 36	Subject 19 Trial 37	Subject 19 Trial 38
2 and 3	-468	-302	-73	-208	-205	-417	-15	234
3 and 4	-23	104	241	116	-542	-469	151	328
4 and 5	99	122	191	291	-121	42	521	552
5 and 6	375	476	325	220	188	238	504	352
6 and 7	453	425	192	317	288	370	273	-46
7 and 8	336	41	271	246	428	534	-187	-288
8 and 9	76	-145	131	205	175	307	-432	-591
9 and 10	-419	-417	-197	-186	-275	-202	-274	-216
10 and 11	-342	-351	-262	-317	-487	-553	-181	-60
11 and 12	-299	-365	-370	-386	-373	-435	-71	-35
12 and 13	-373	-206	-285	-110	-129	-74	-203	4
13 and 14	277	149	204	148	144	279	127	149
14 and 15	322	511	417	514	339	188	336	75
15 and 16	861	846	875	631	1023	784	683	737

TABLE 7 continued:

Between Frames	Subject 20 Trial 39	Subject 20 Trial 40	Subject 21 Trial 41	Subject 21 Trial 42	Subject 22 Trial 43	Subject 22 Trial 44
2 and 3	28	29	-240	-32	342	397
3 and 4	155	215	107	169	504	292
4 and 5	357	257	312	428	57	194
5 and 6	338	328	284	402	-69	127
6 and 7	298	140	489	391	-317	-161
7 and 8	201	170	199	171	-225	-197
8 and 9	-167	-47	-254	-301	-423	-499
9 and 10	-234	-387	-445	-541	-160	-228
10 and 11	-182	-189	-208	-162	-178	-174
11 and 12	-134	-181	-376	-240	-26	-23
12 and 13	-101	-91	96	-137	106	-37
13 and 14	-15	251	-143	66	200	332
14 and 15	536	421	704	576	513	412
15 and 16	576	591	948	989	629	616

APPENDIX B

Horizontal and Vertical Velocity Curves for Center of Mass

Figure A1: Subject 1, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

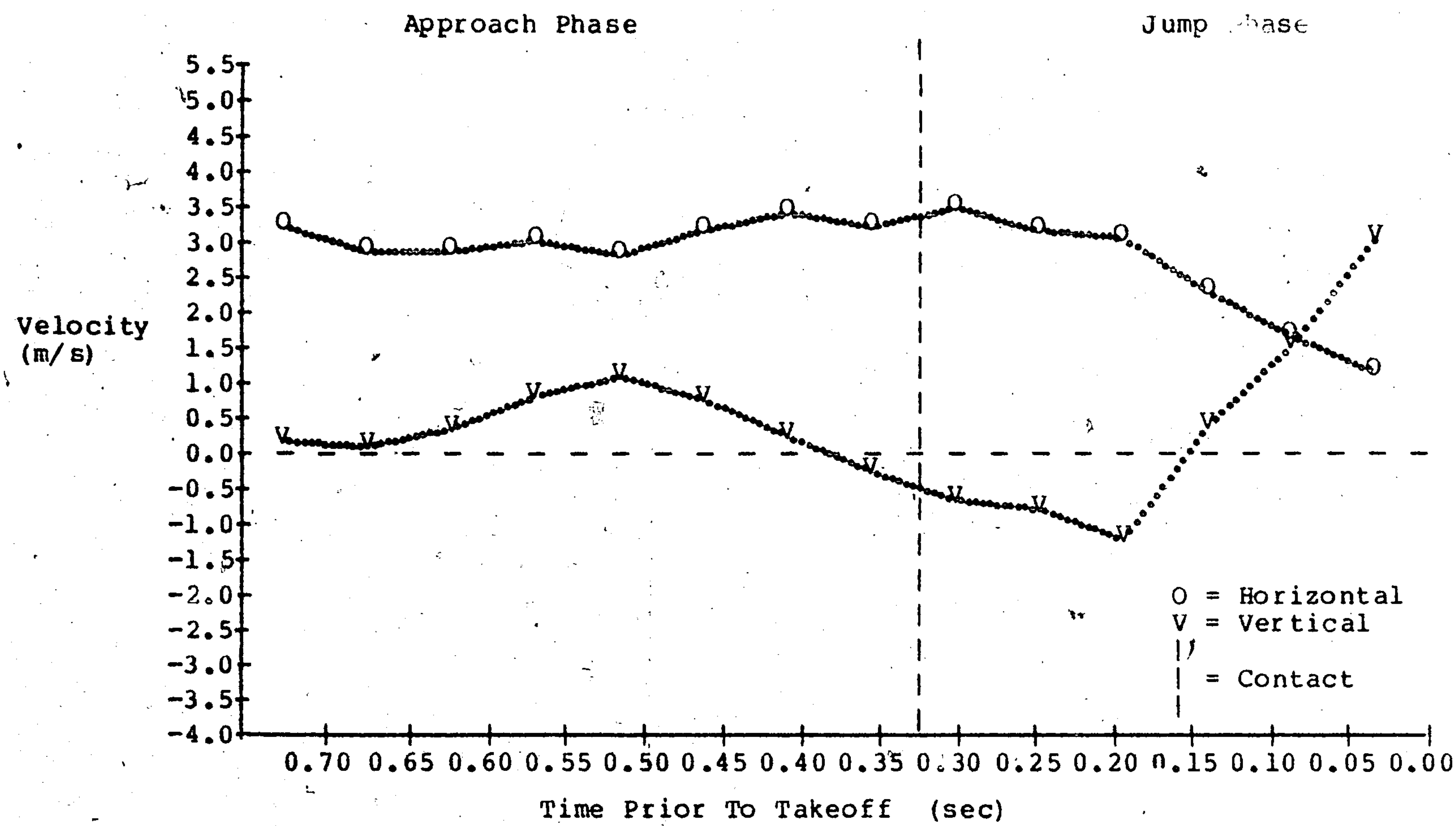


Figure A2: Subject 1, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

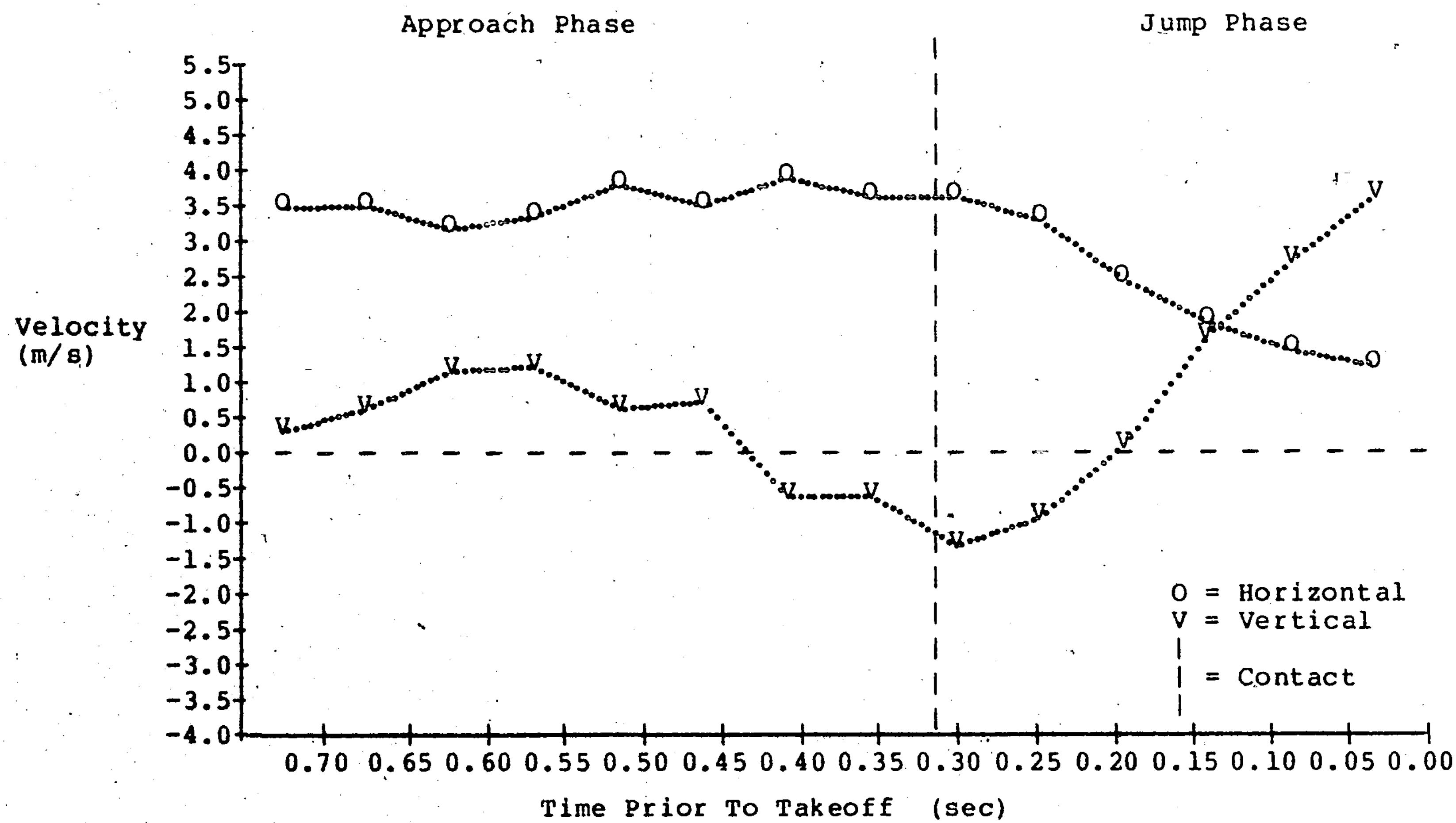


Figure A3: Subject 2, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

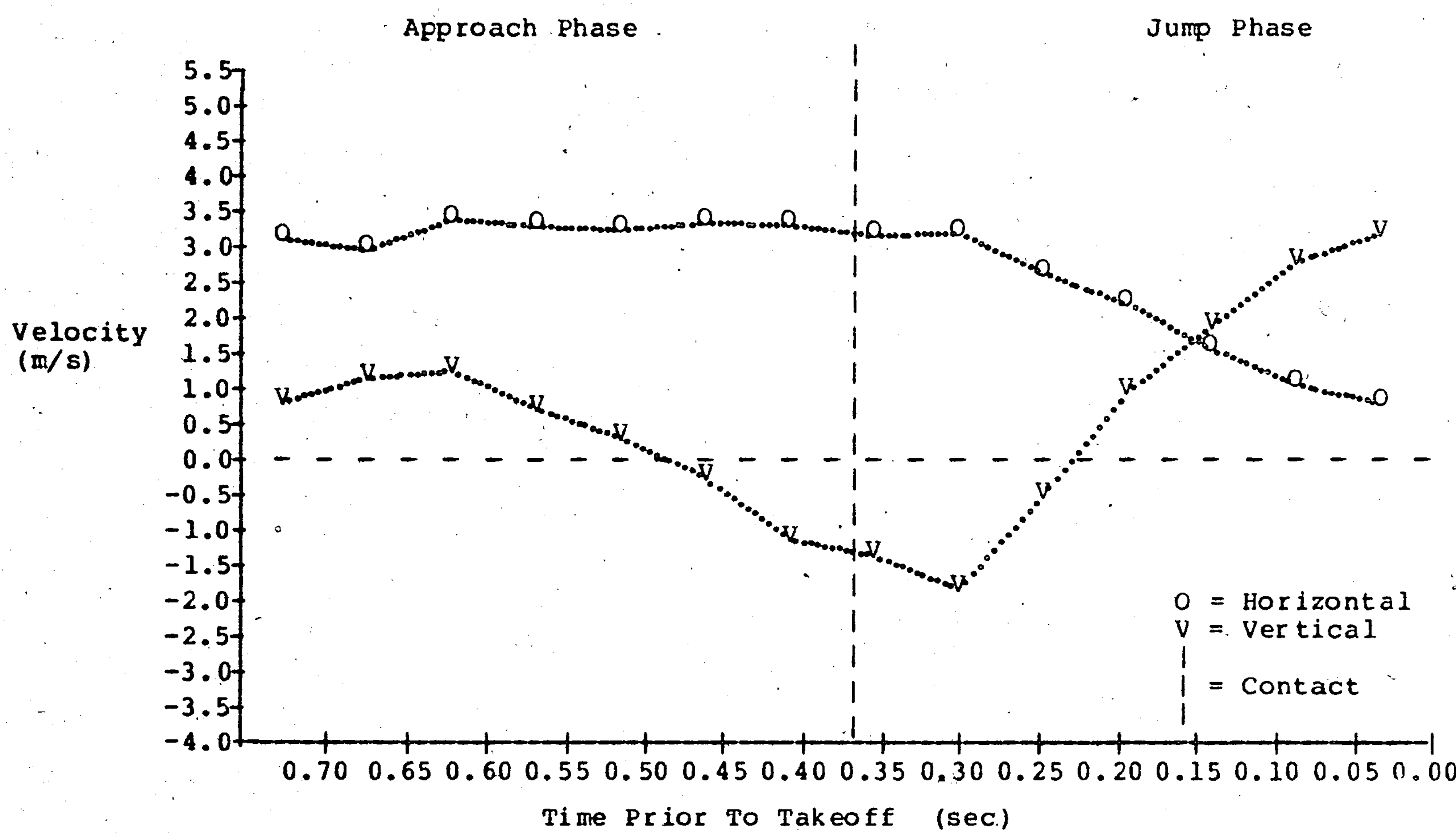


Figure A4: Subject 2, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

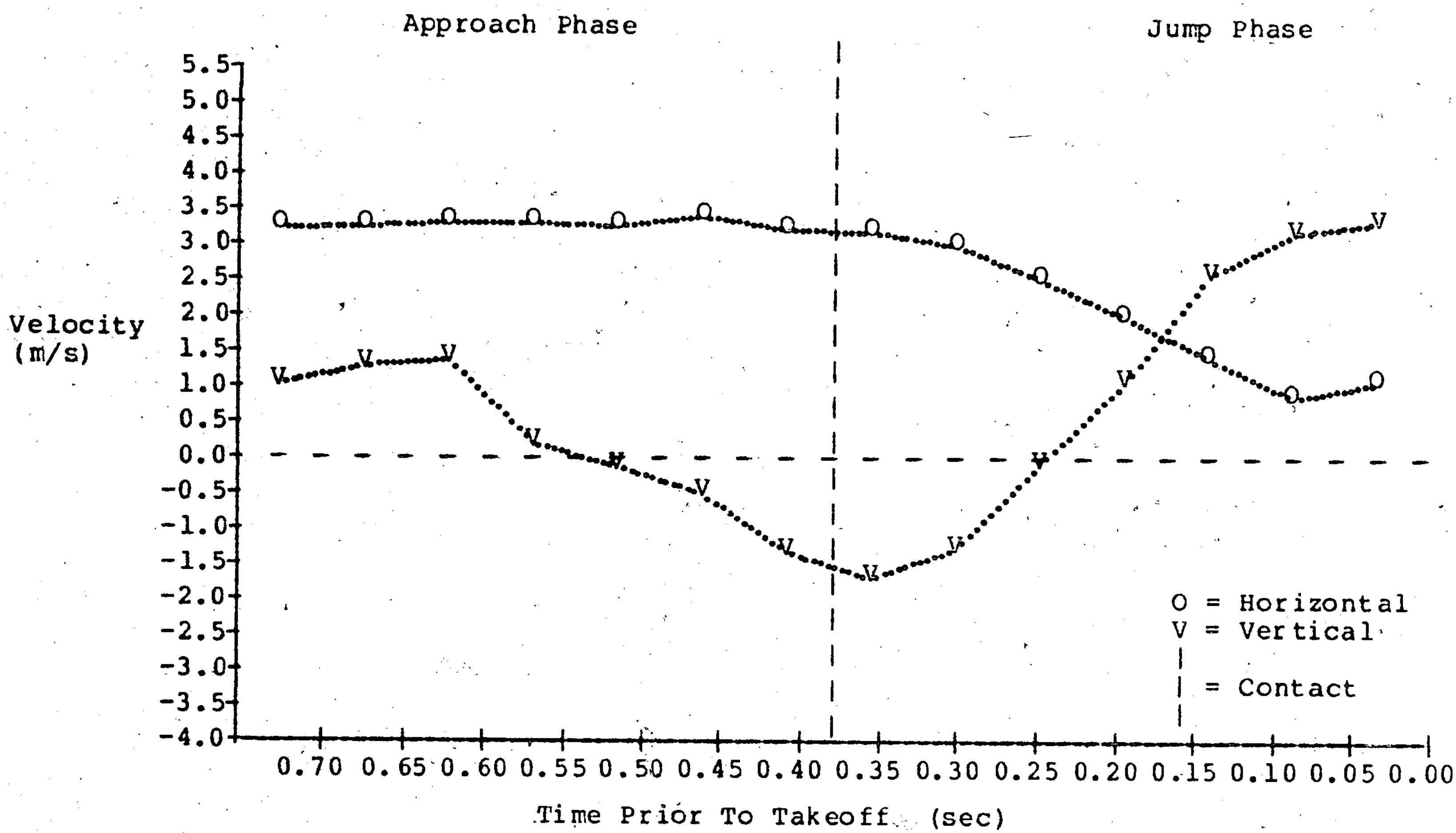


Figure A5: Subject 3, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

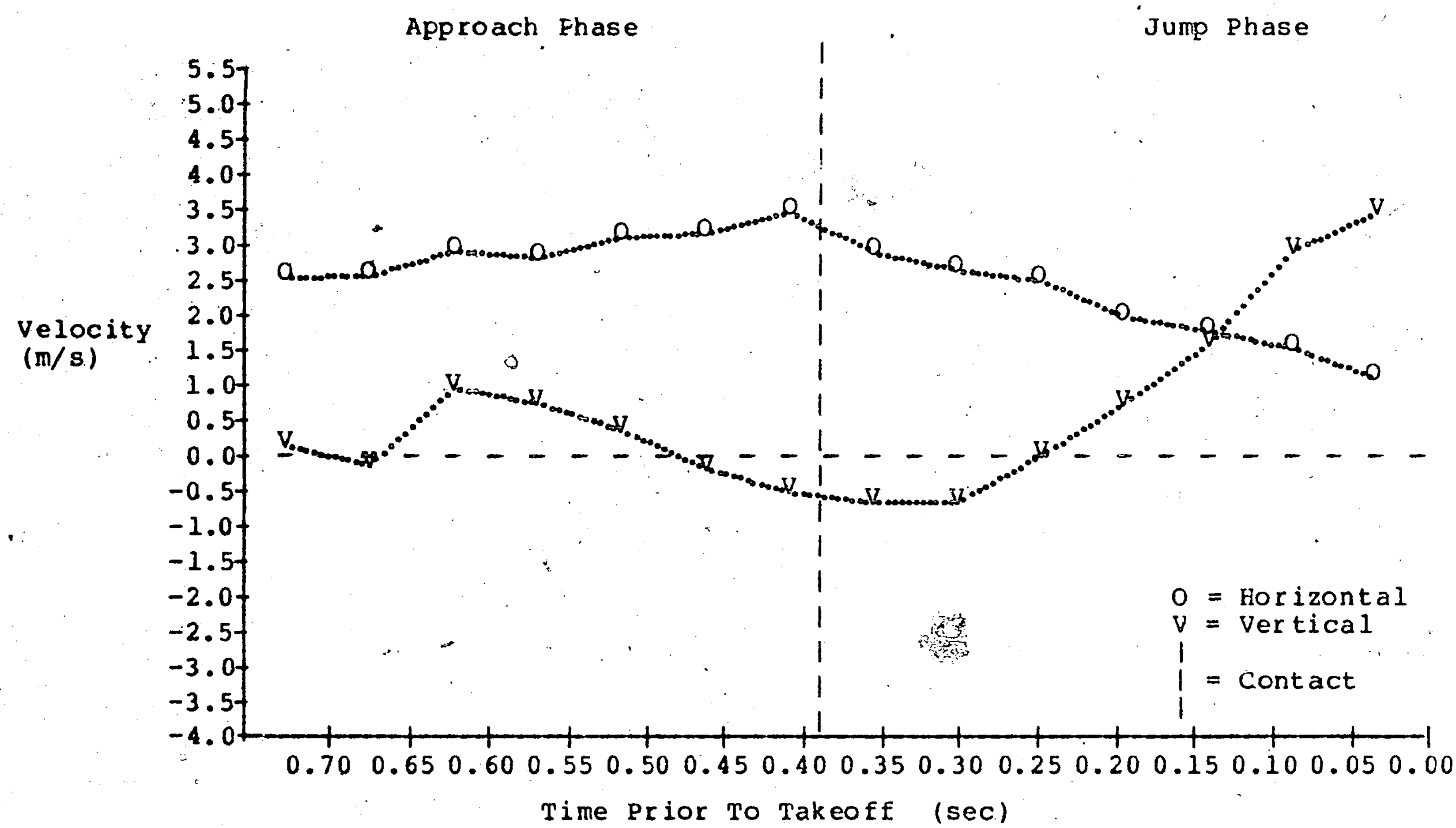


Figure A6: Subject 3, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

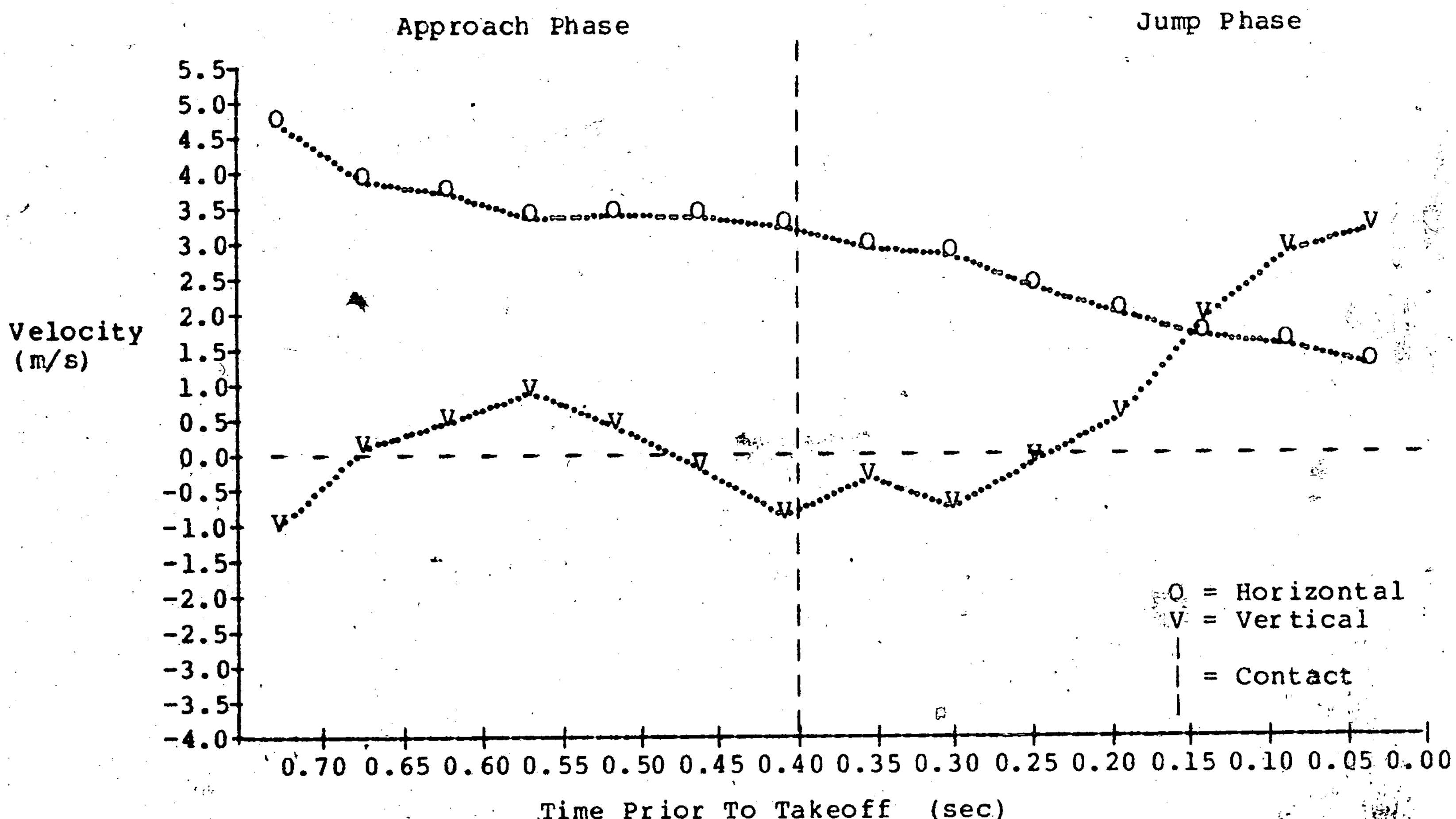


Figure A7: Subject 4, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

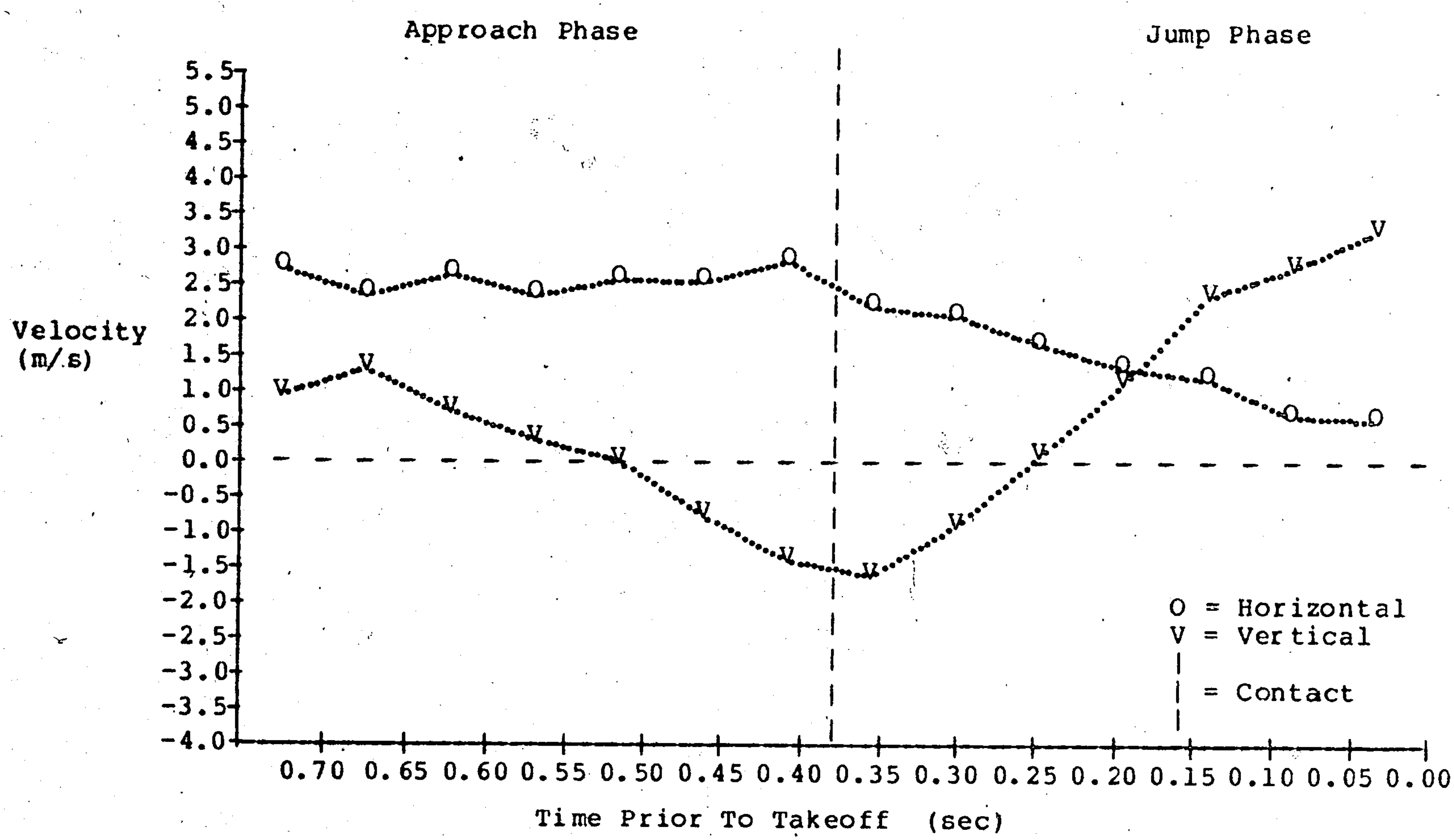


Figure A8: Subje 4, Jump 2

H'rizontal and Ver cal Velocity Curves for Center of Mass

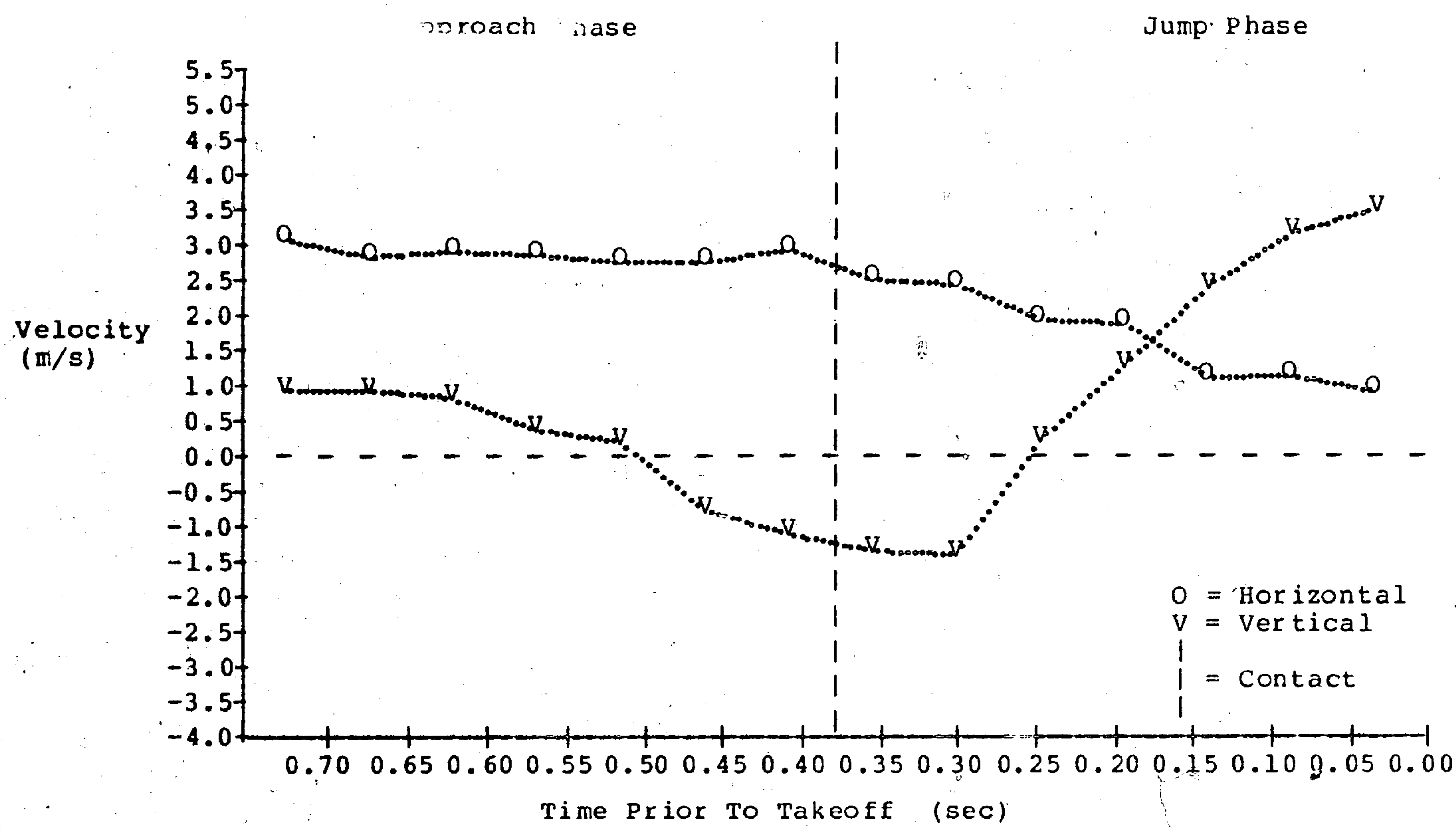


Figure A9: Subject 5, Jump 1

Horizontal and Vertical Velocity Curves for Center of Ma

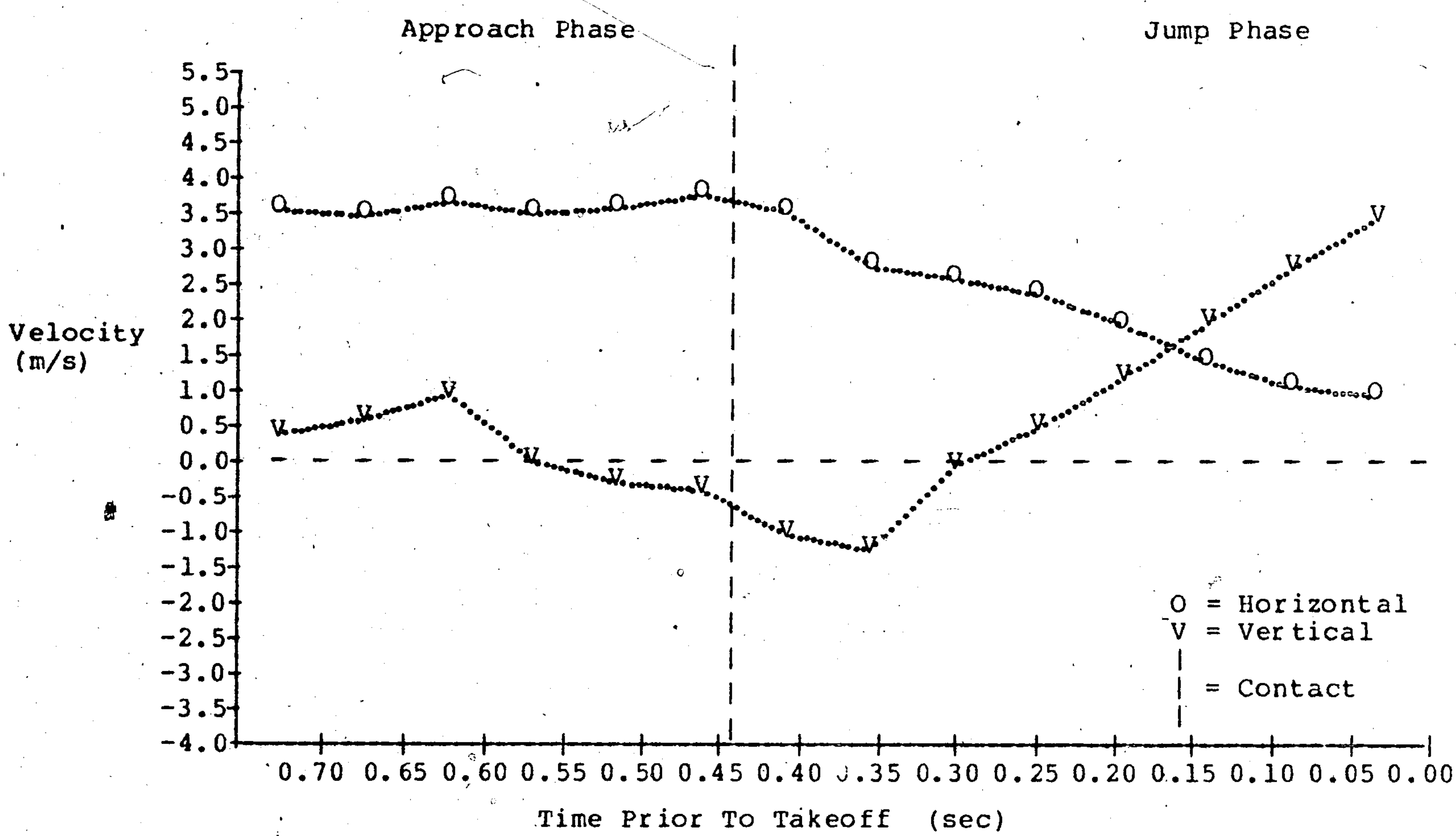


Figure A10: Subject 5, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

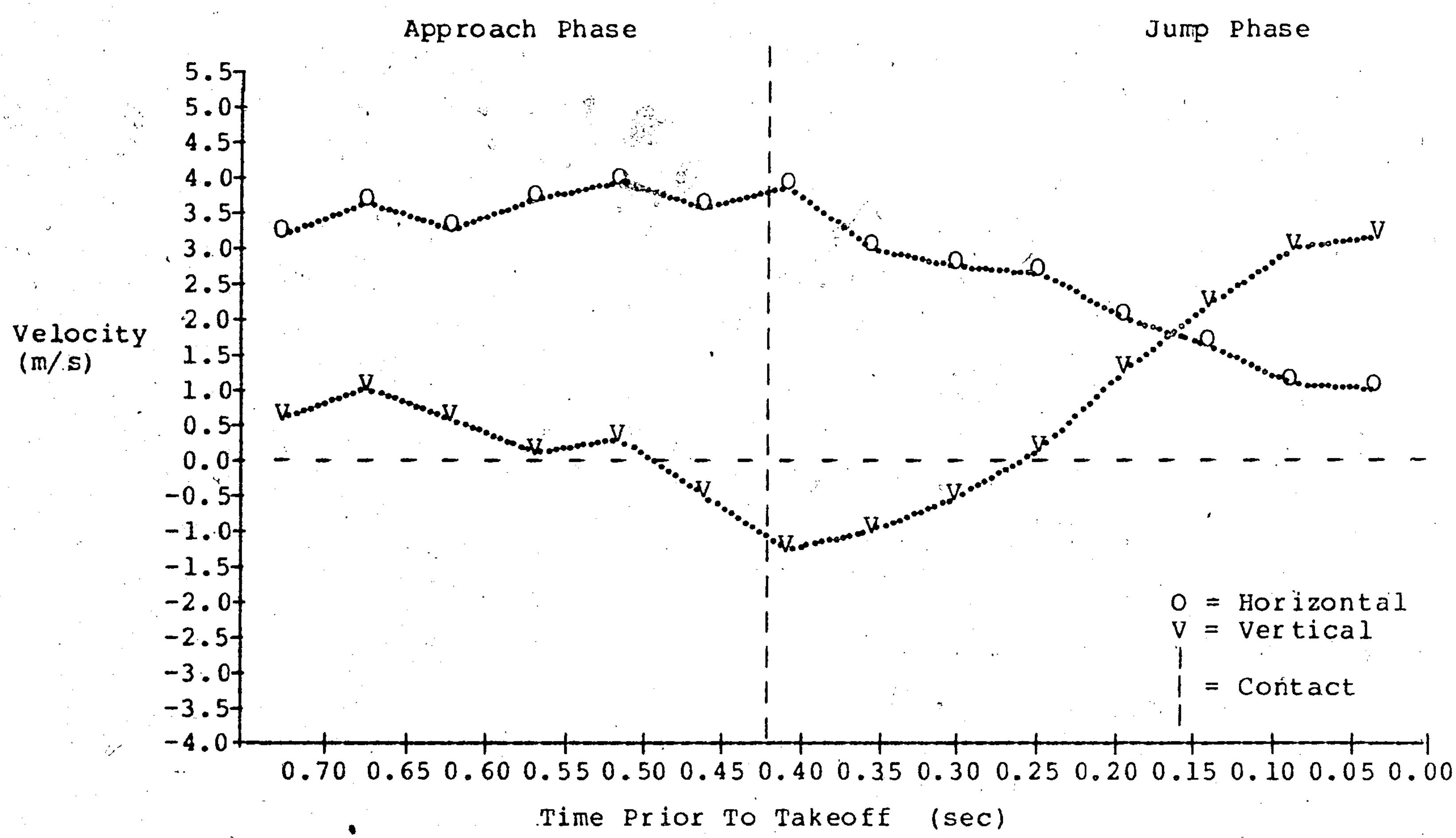


Figure All: Subject 6, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

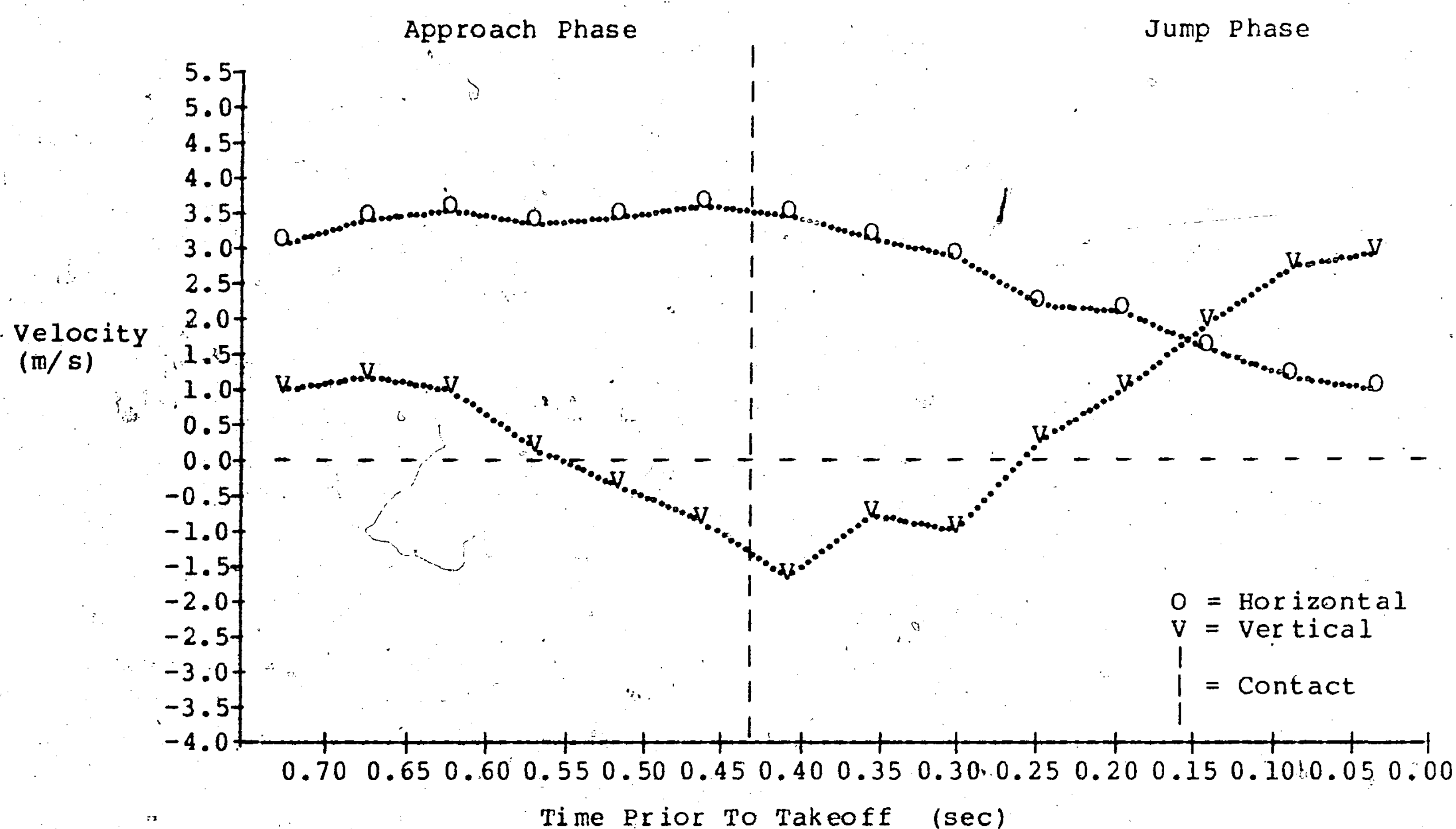


Figure A12: Subject 6, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

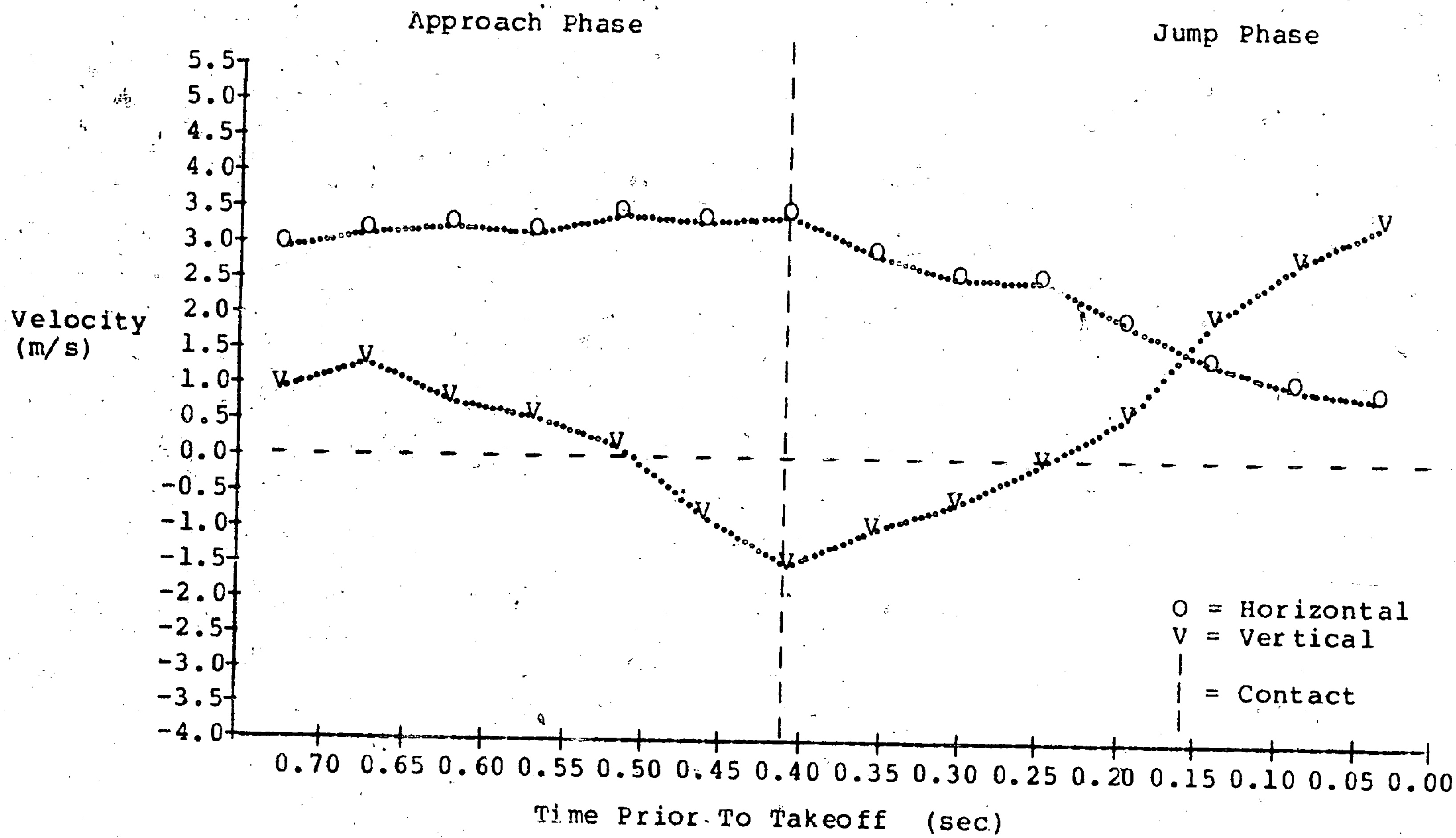


Figure A13: Subject 7, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

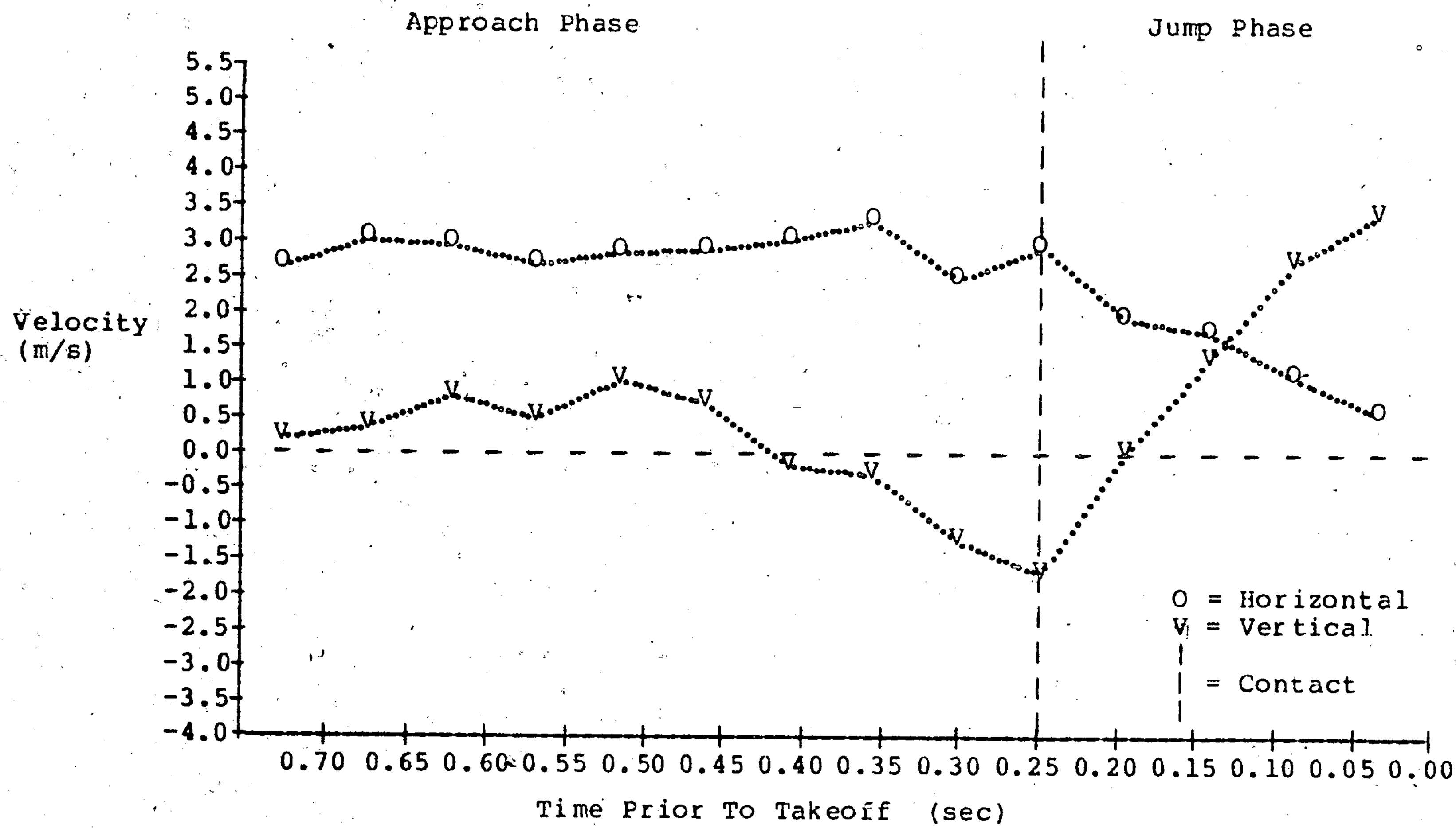


Figure A14: Subject 7, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

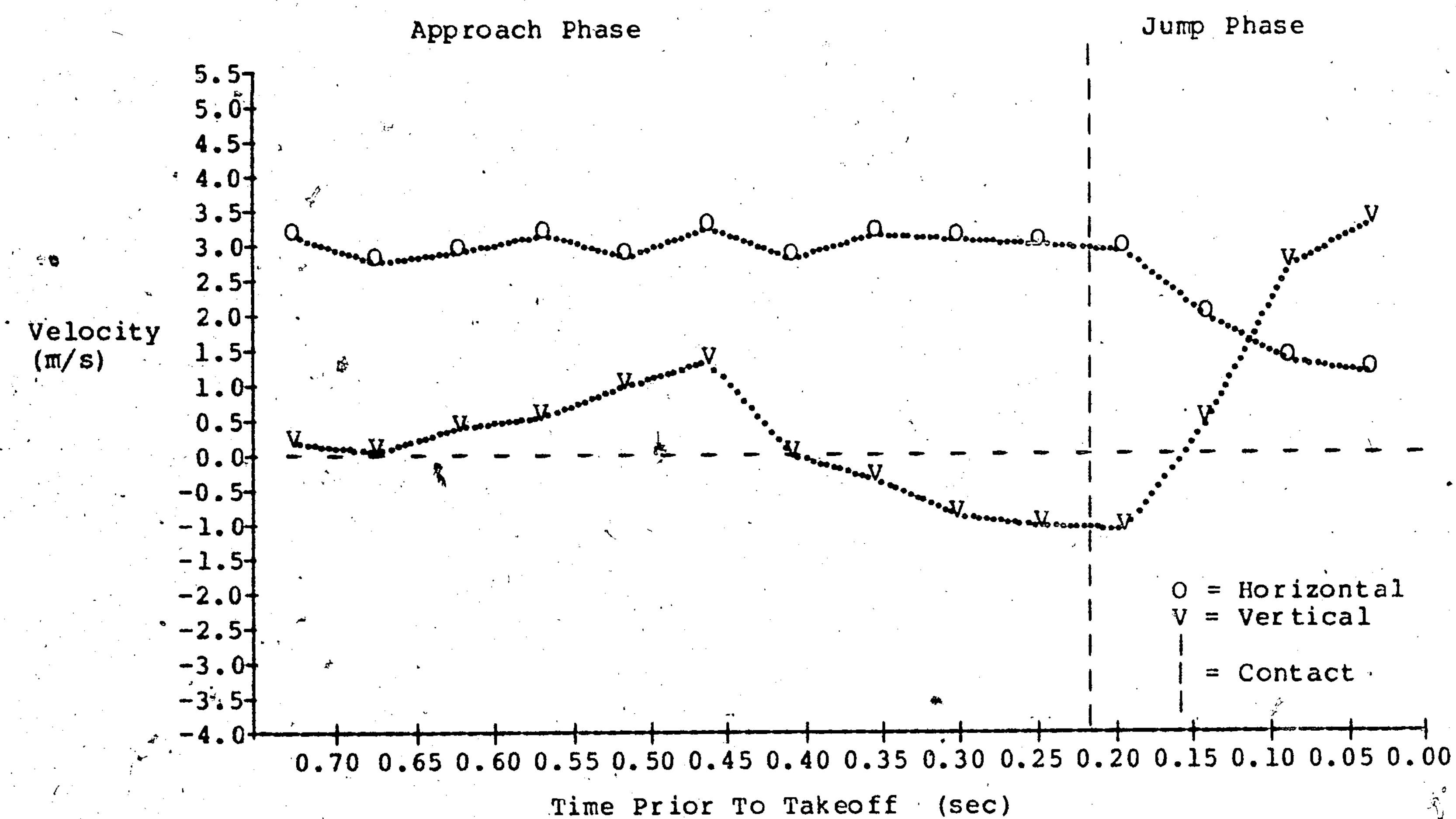


Figure A15: Subject 8, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

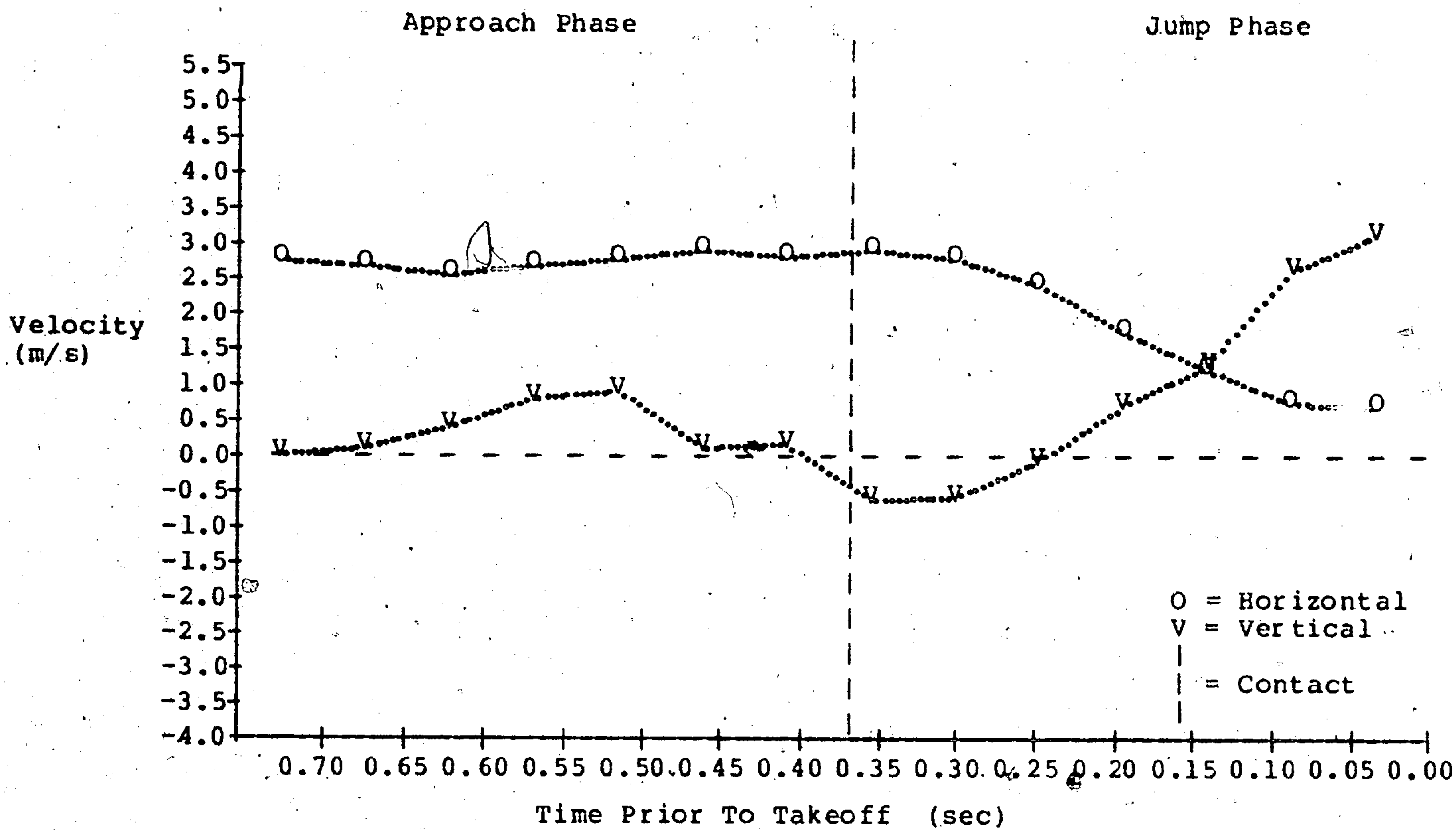


Figure A16: Subject 8, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

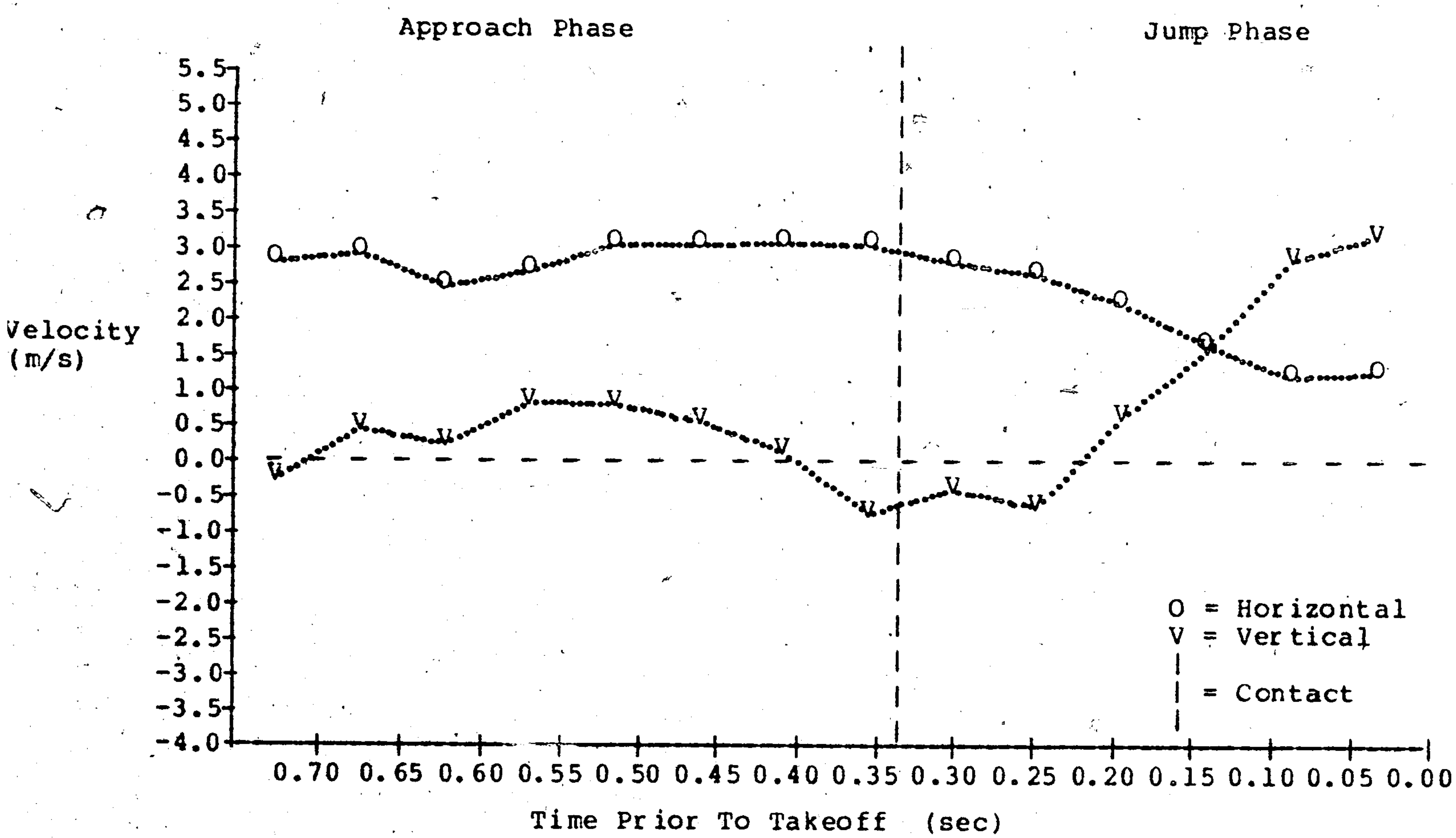


Figure A17: Subject 9, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

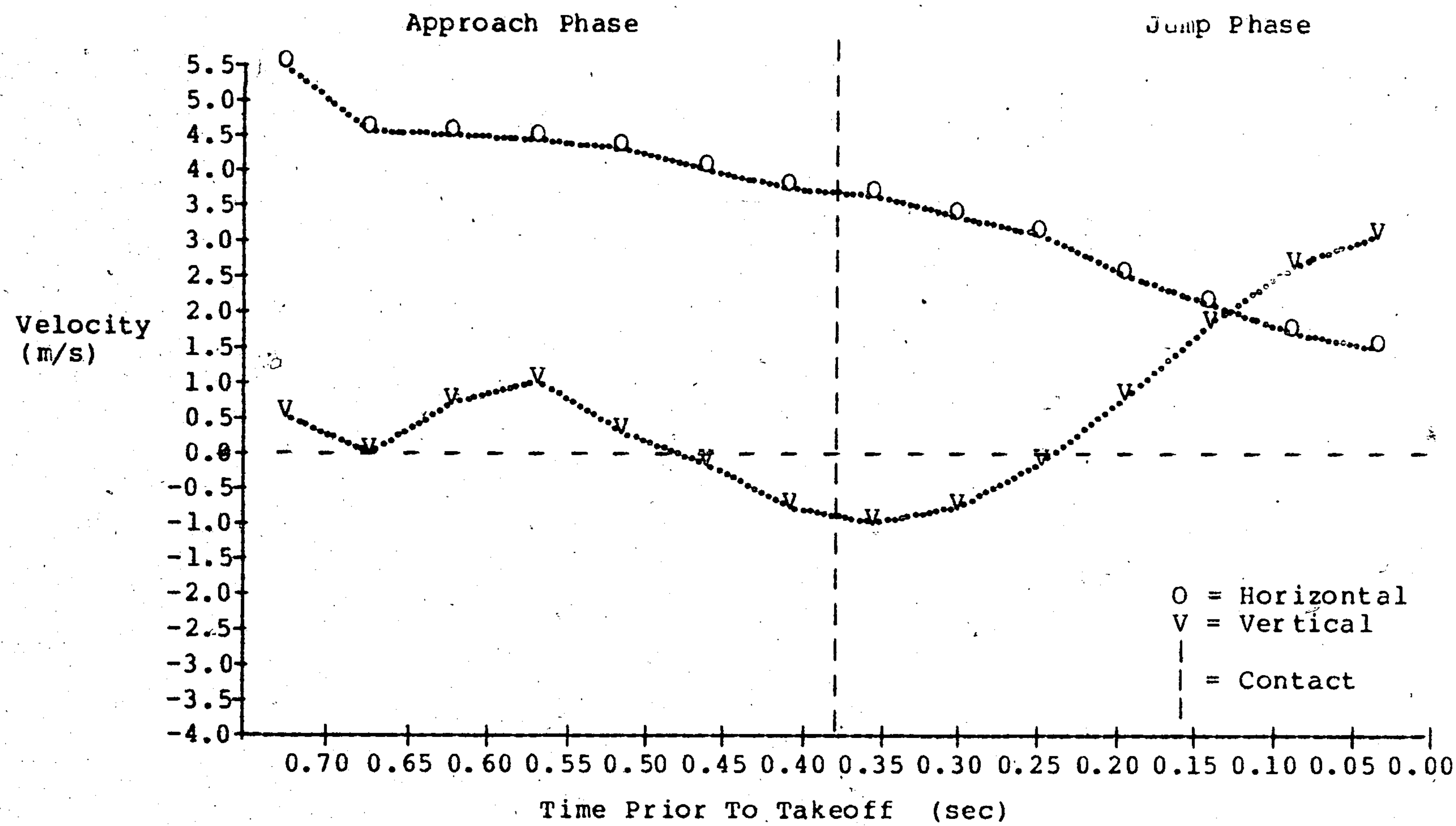


Figure A18: Subject 9, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

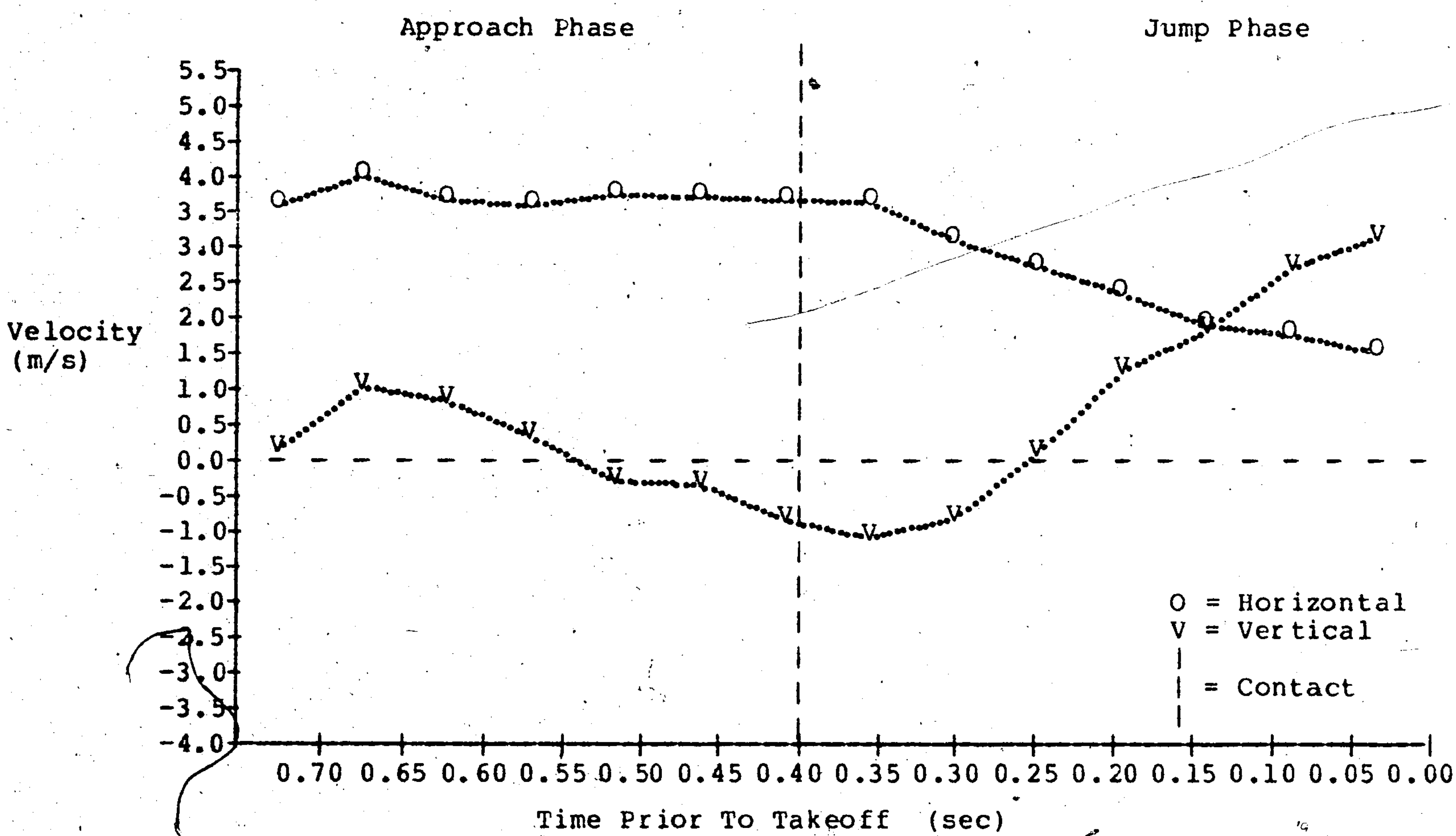


Figure A19: Subject 10, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

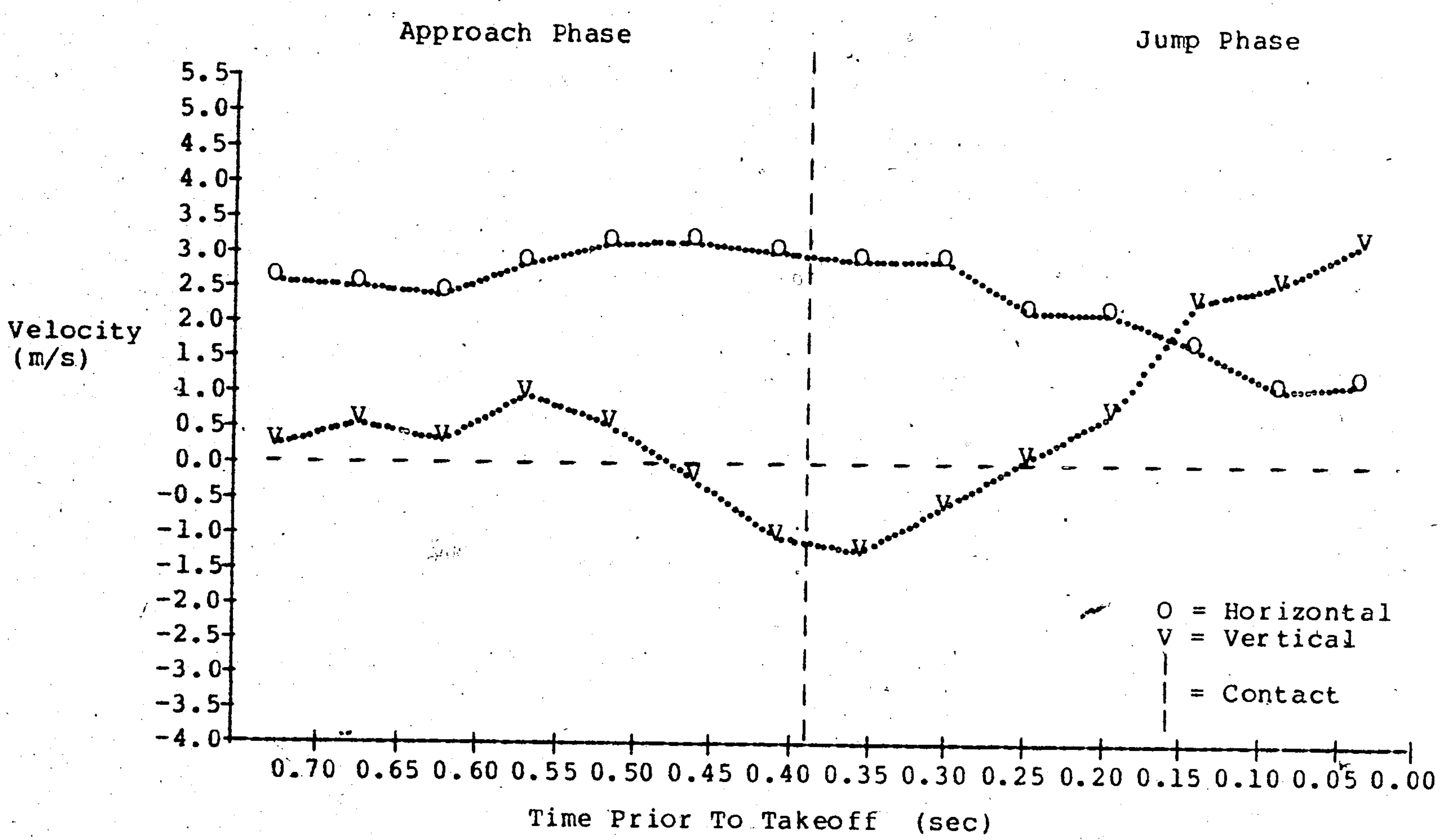


Figure A20: Subject 10, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

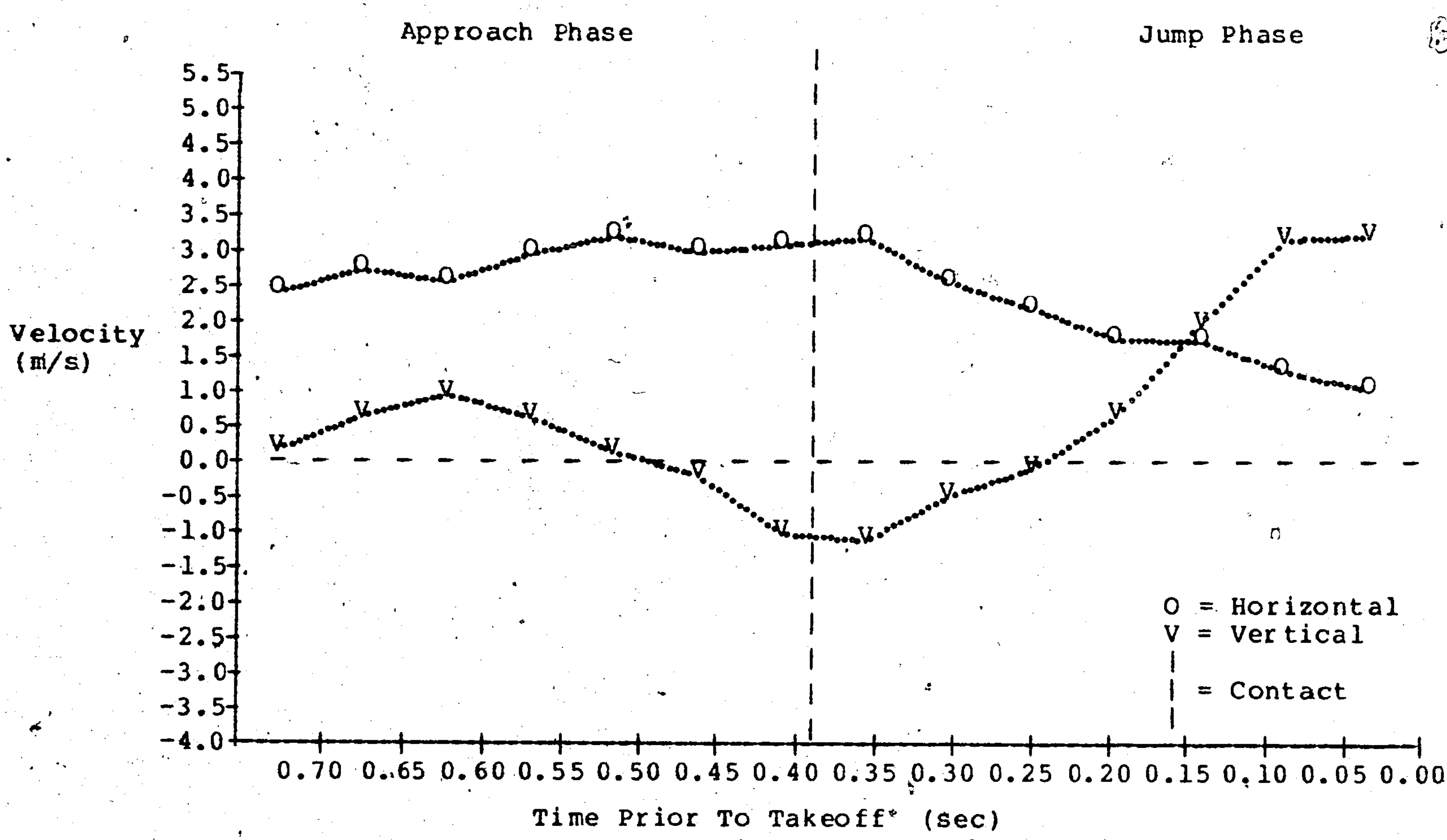


Figure A21: Subject 11, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

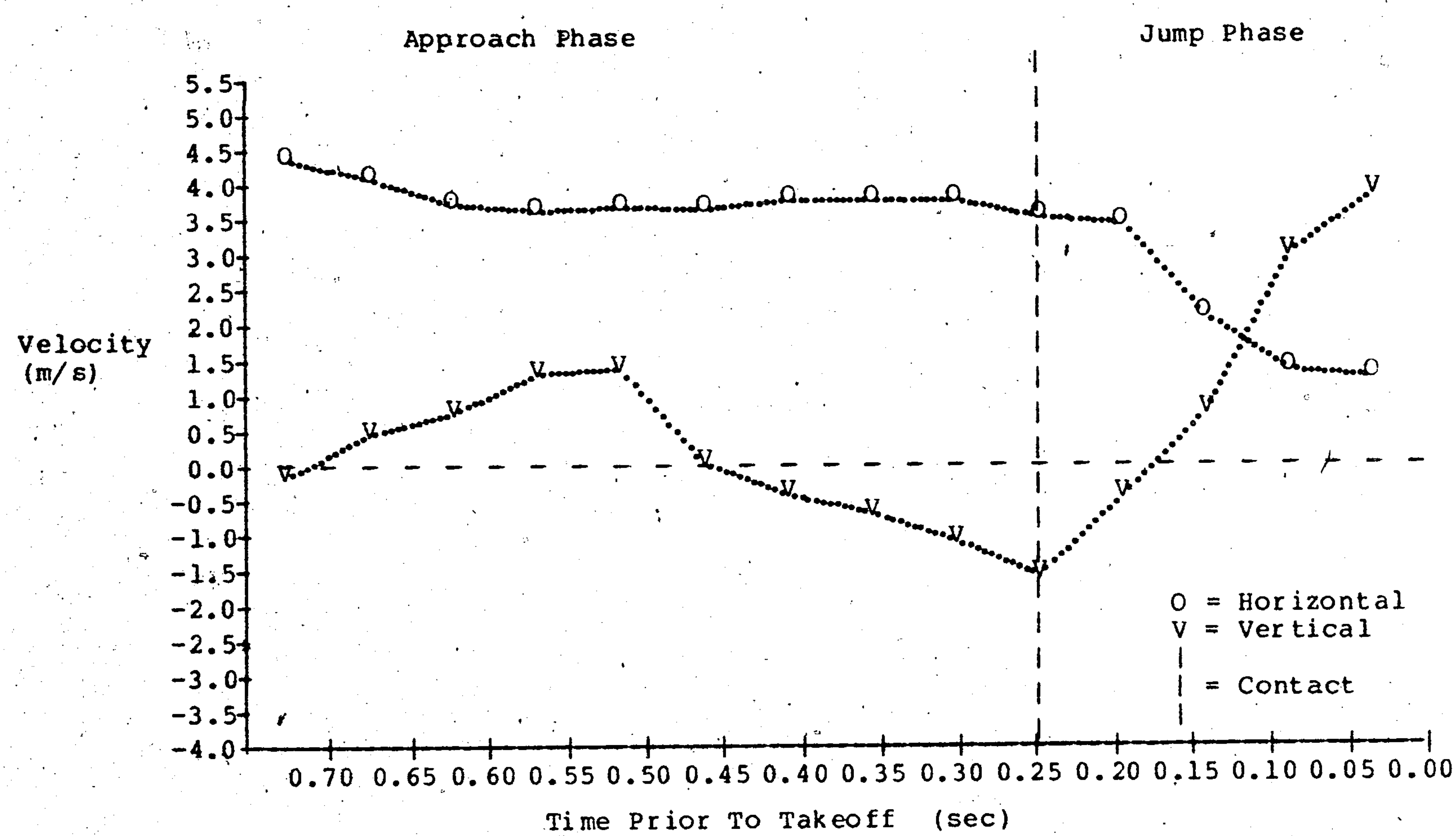


Figure A22: Subject 11, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

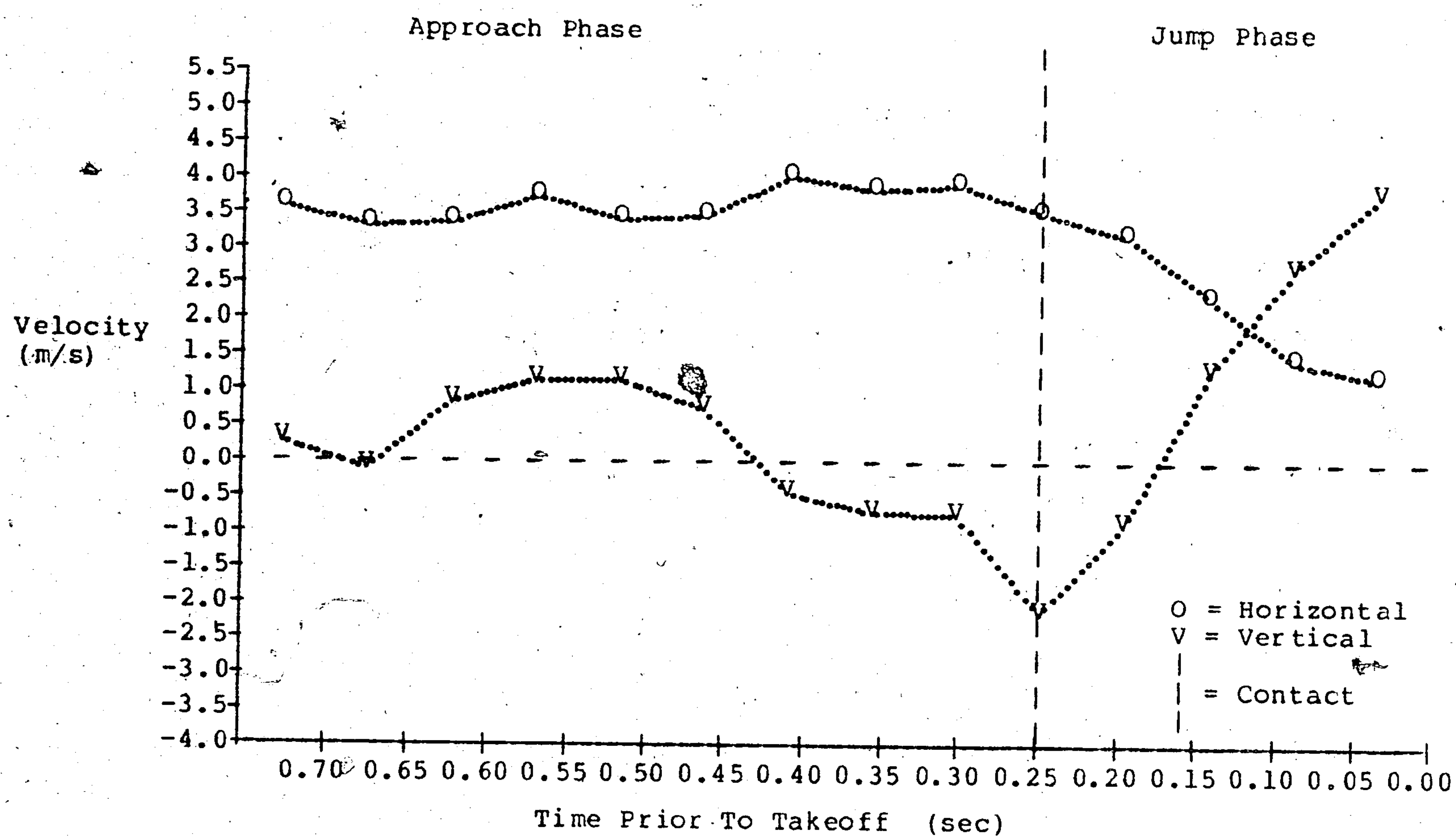


Figure A23: Subject 12, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

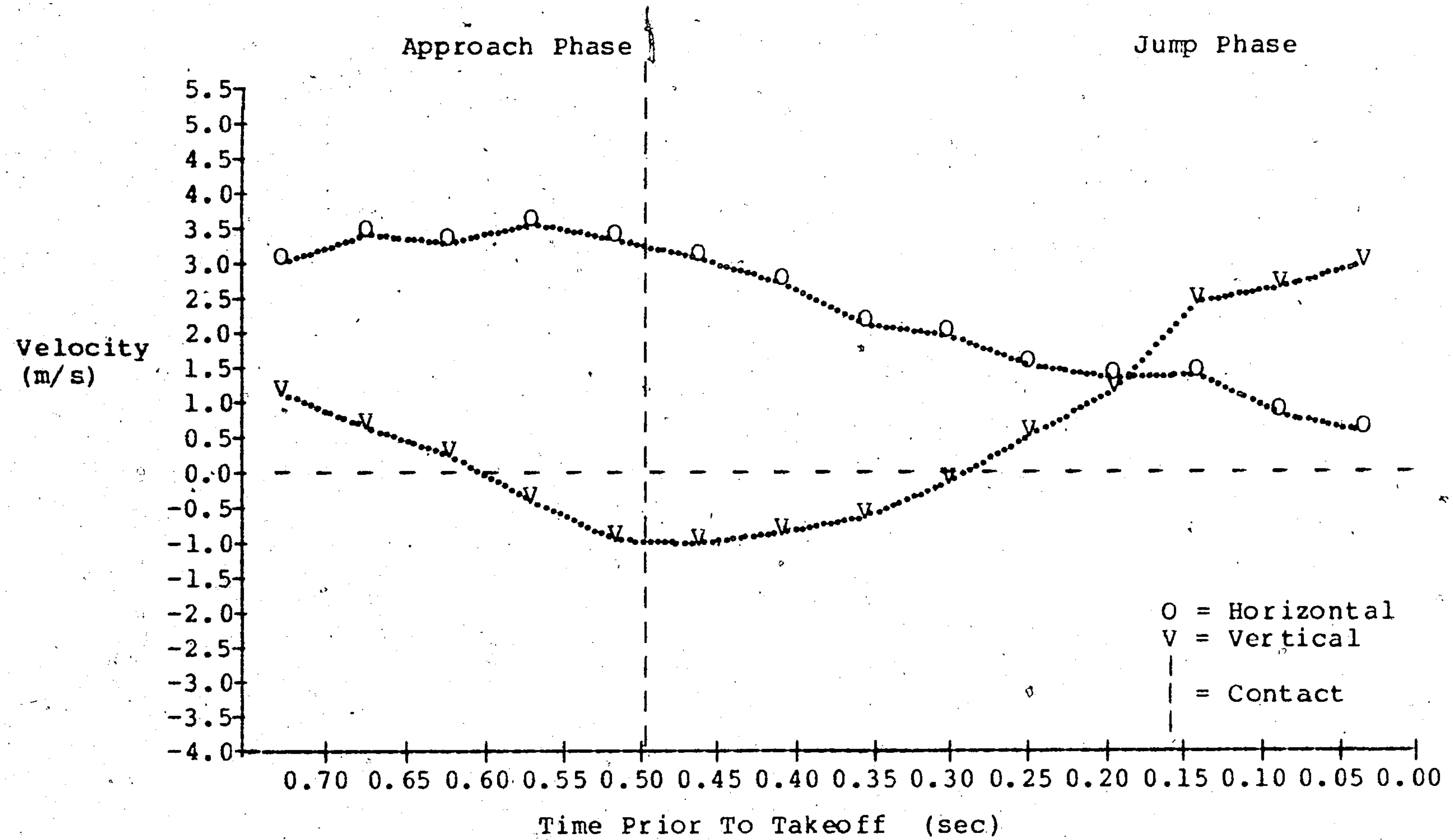


Figure A24: Subject 12, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

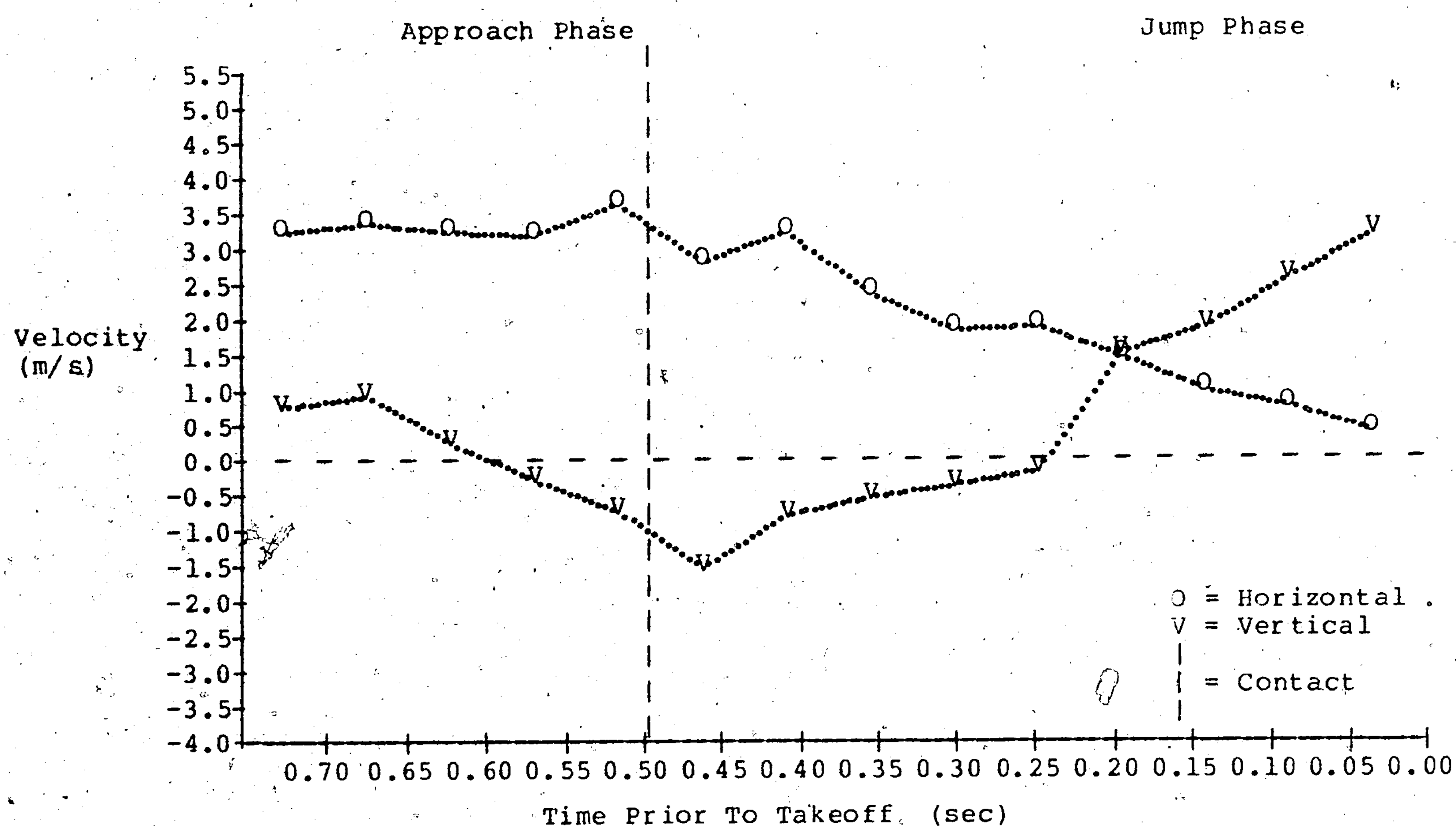


Figure A25: Subject 13, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

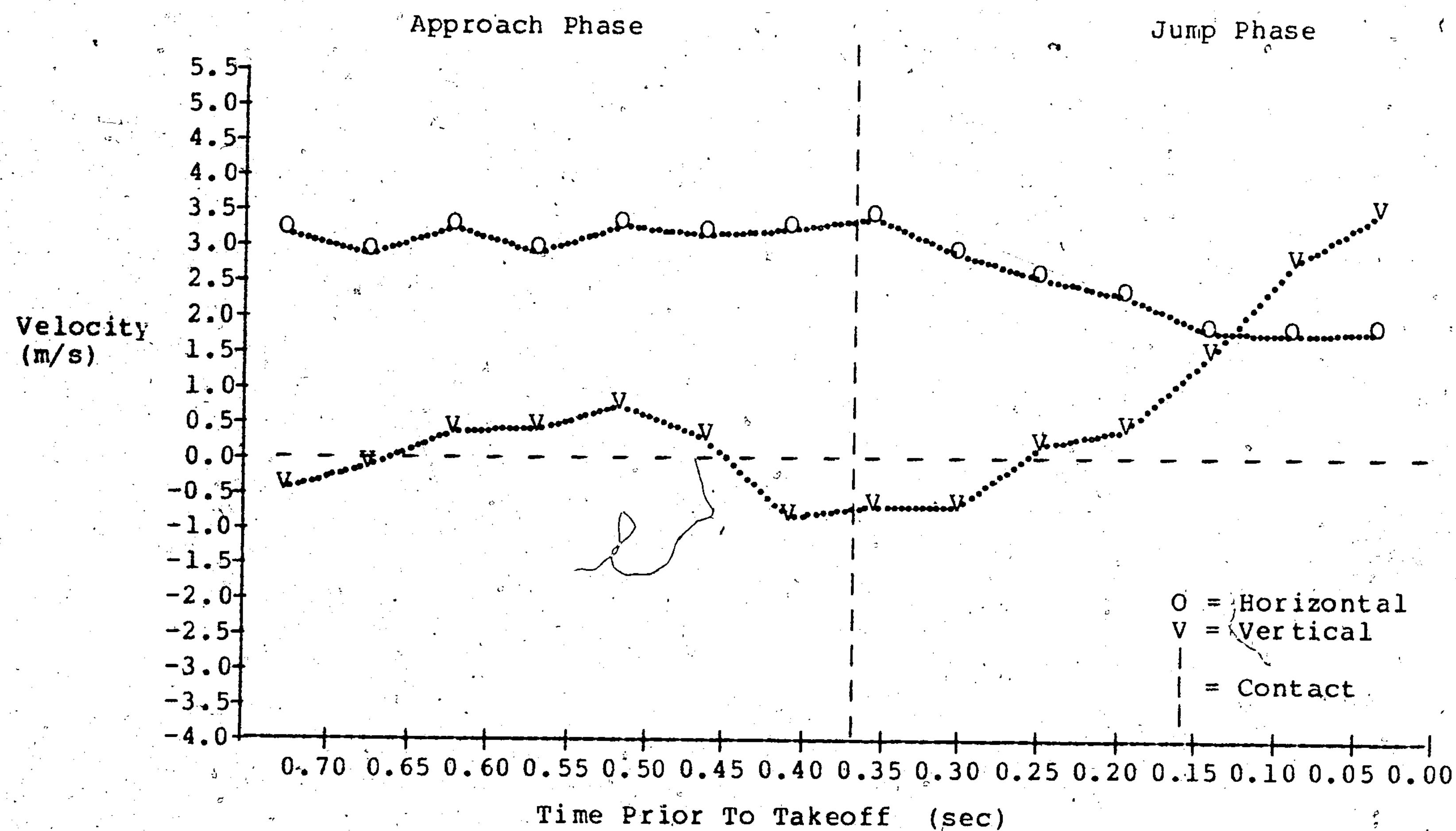


Figure A26: Subject 13, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

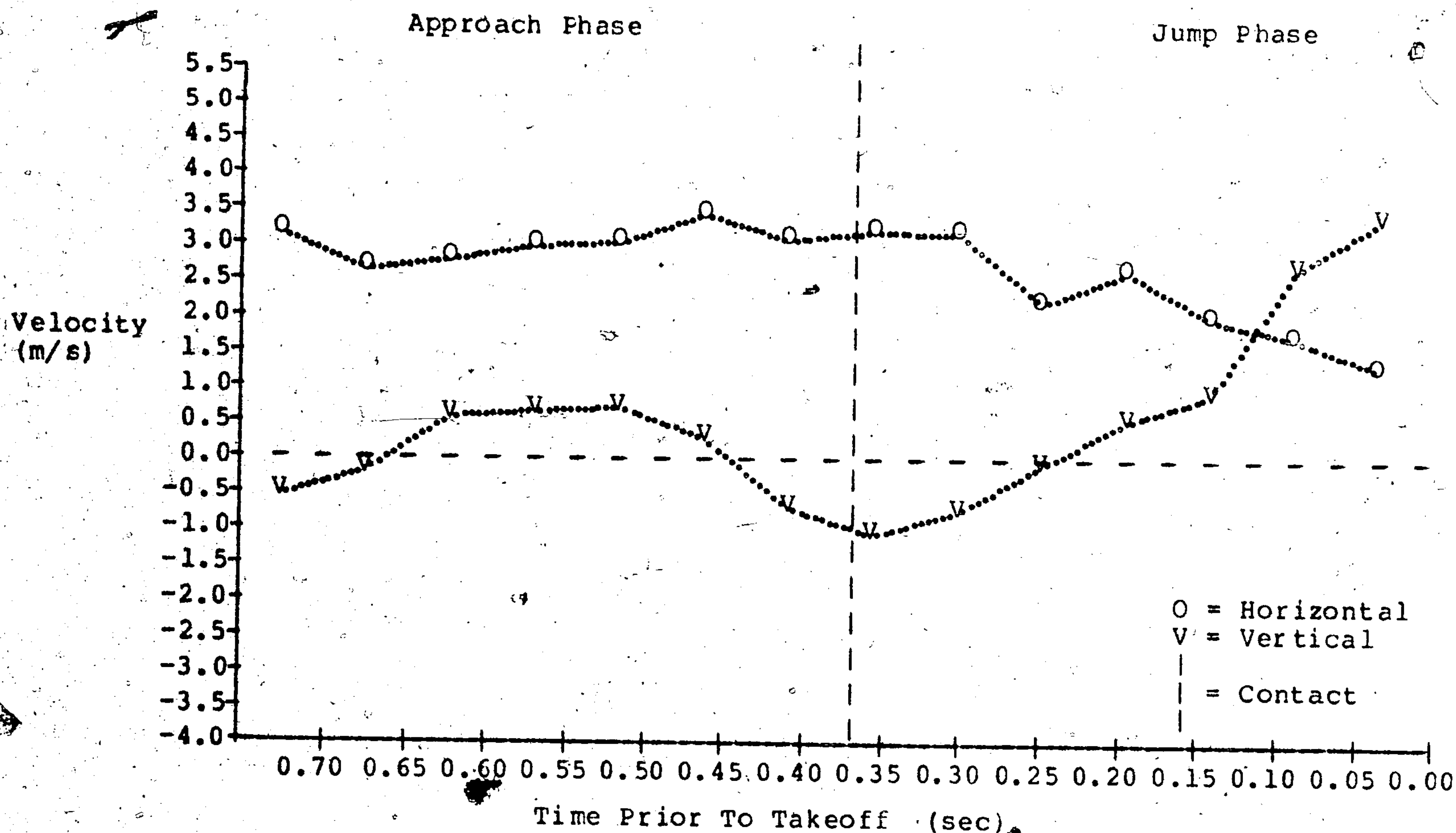


Figure A27: Subject 14, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

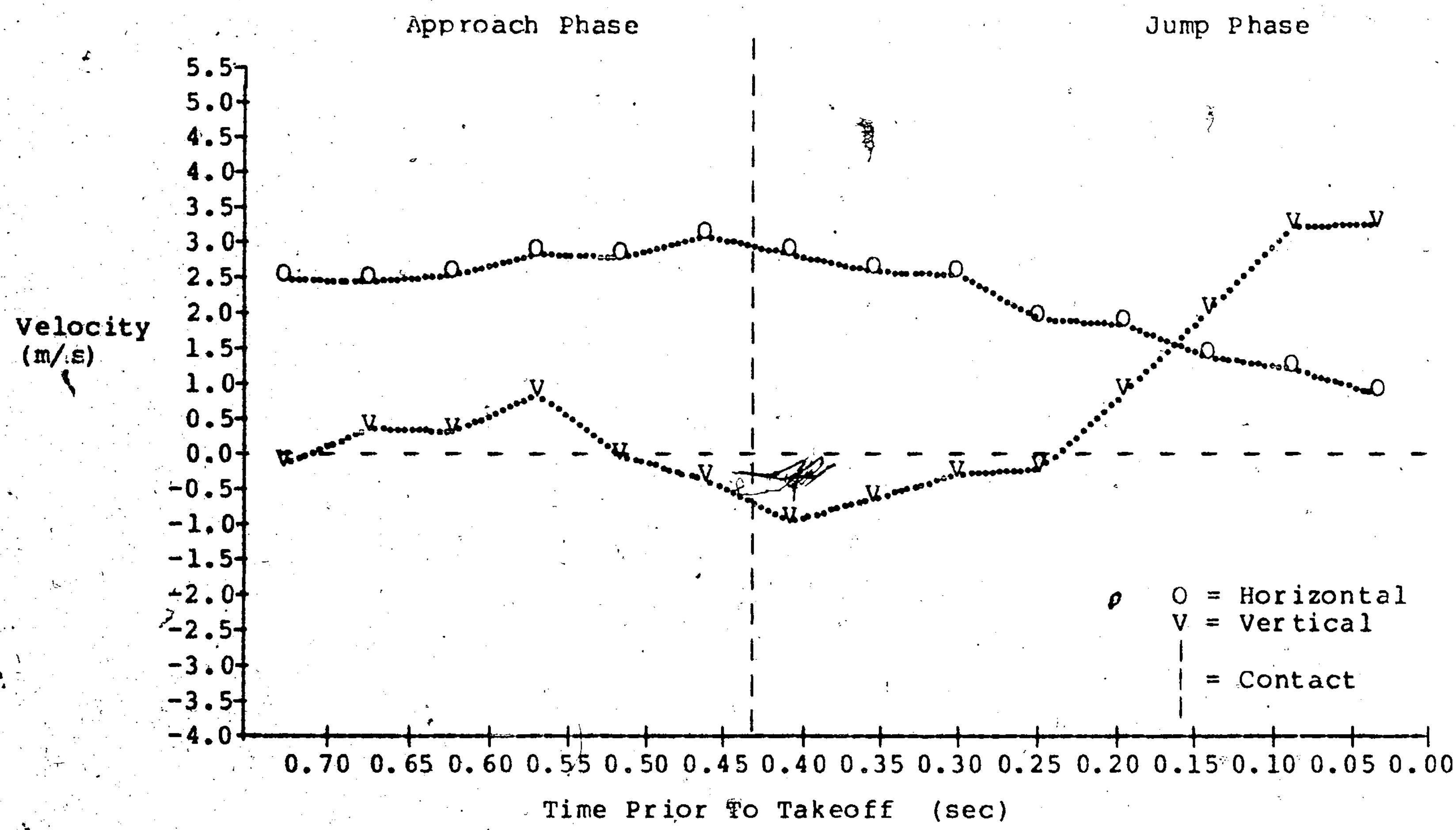


Figure A28: Subject 14, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

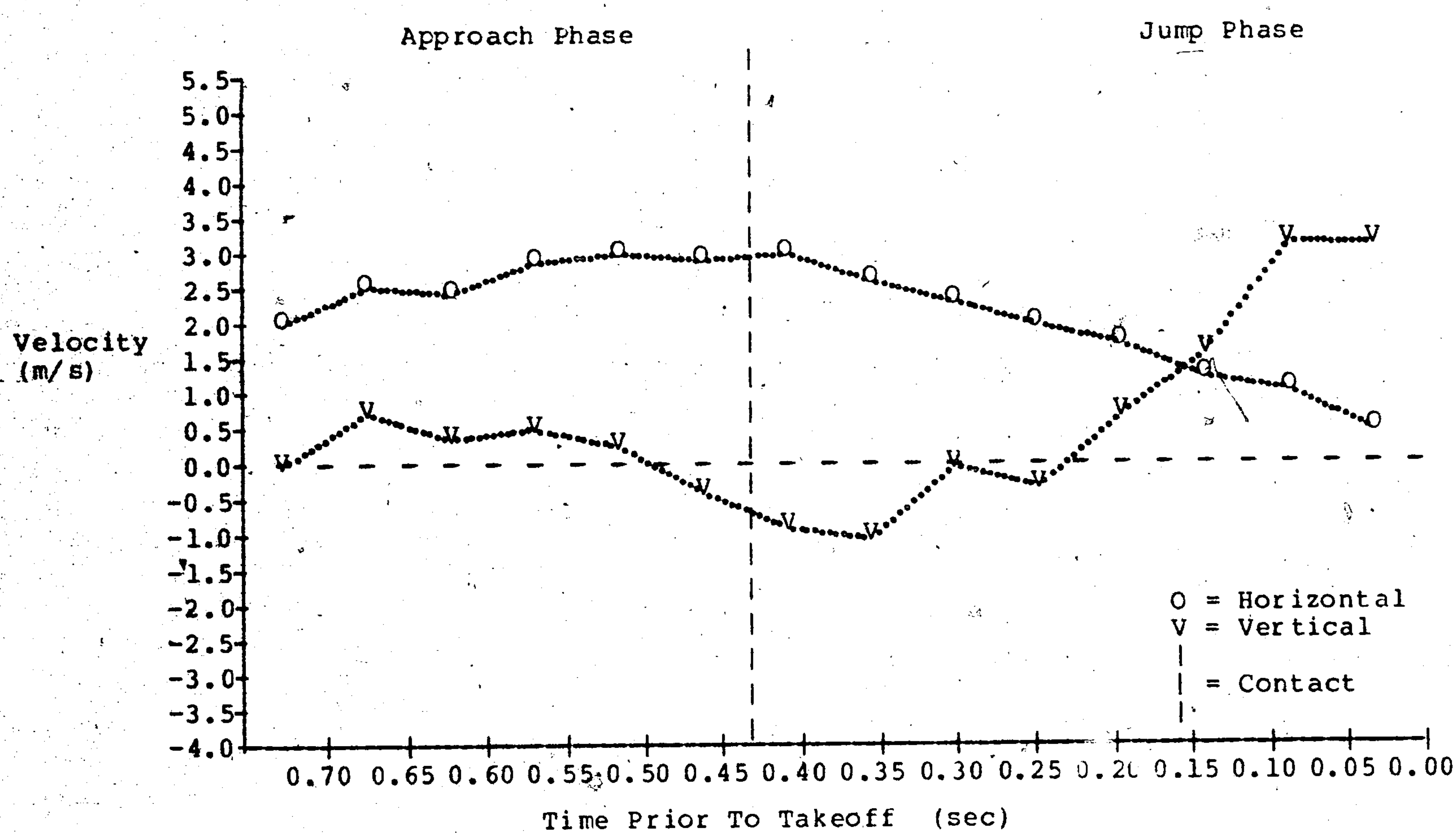


Figure A29: Subject 15, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

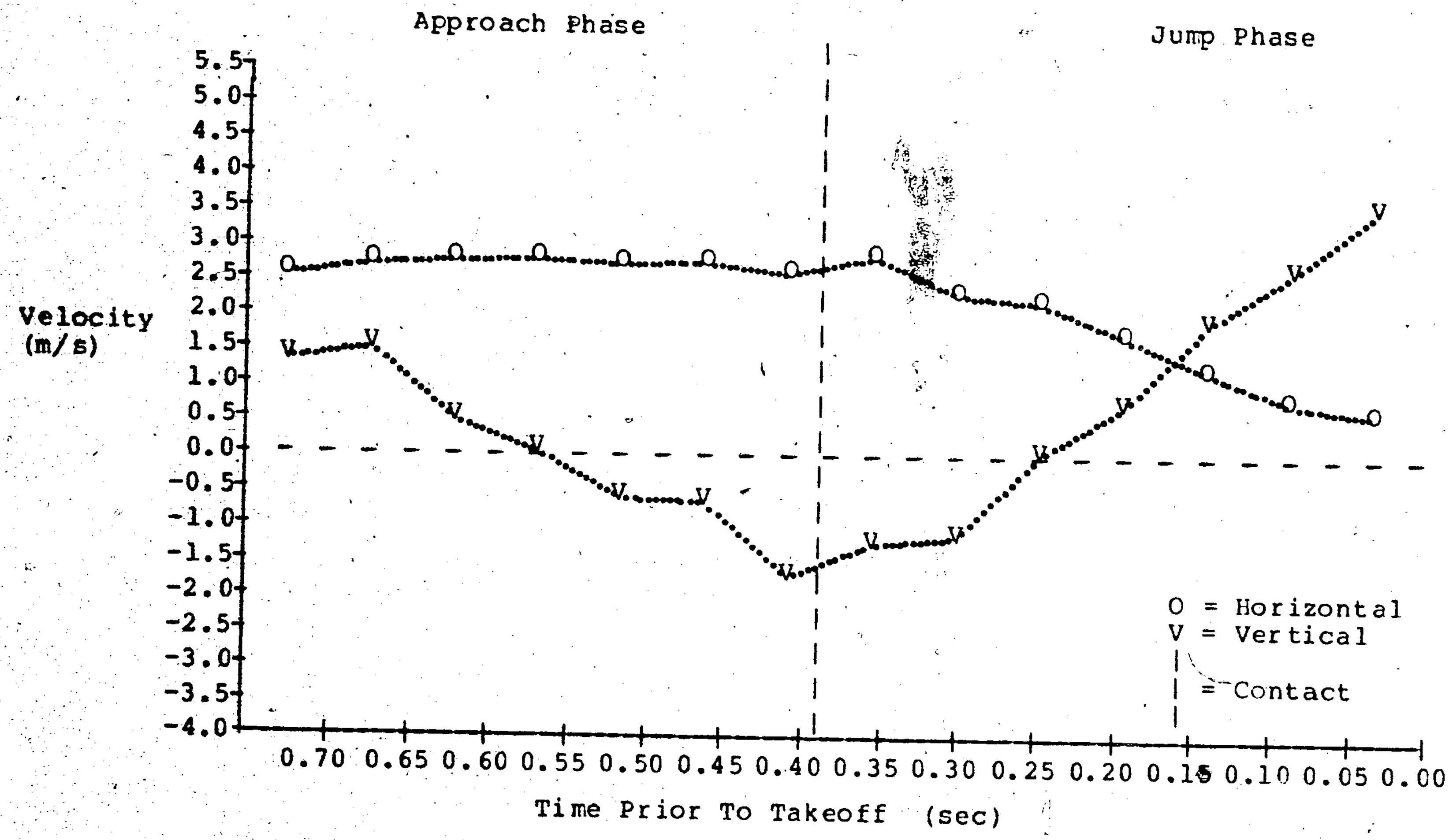


Figure A30: Subject 15, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

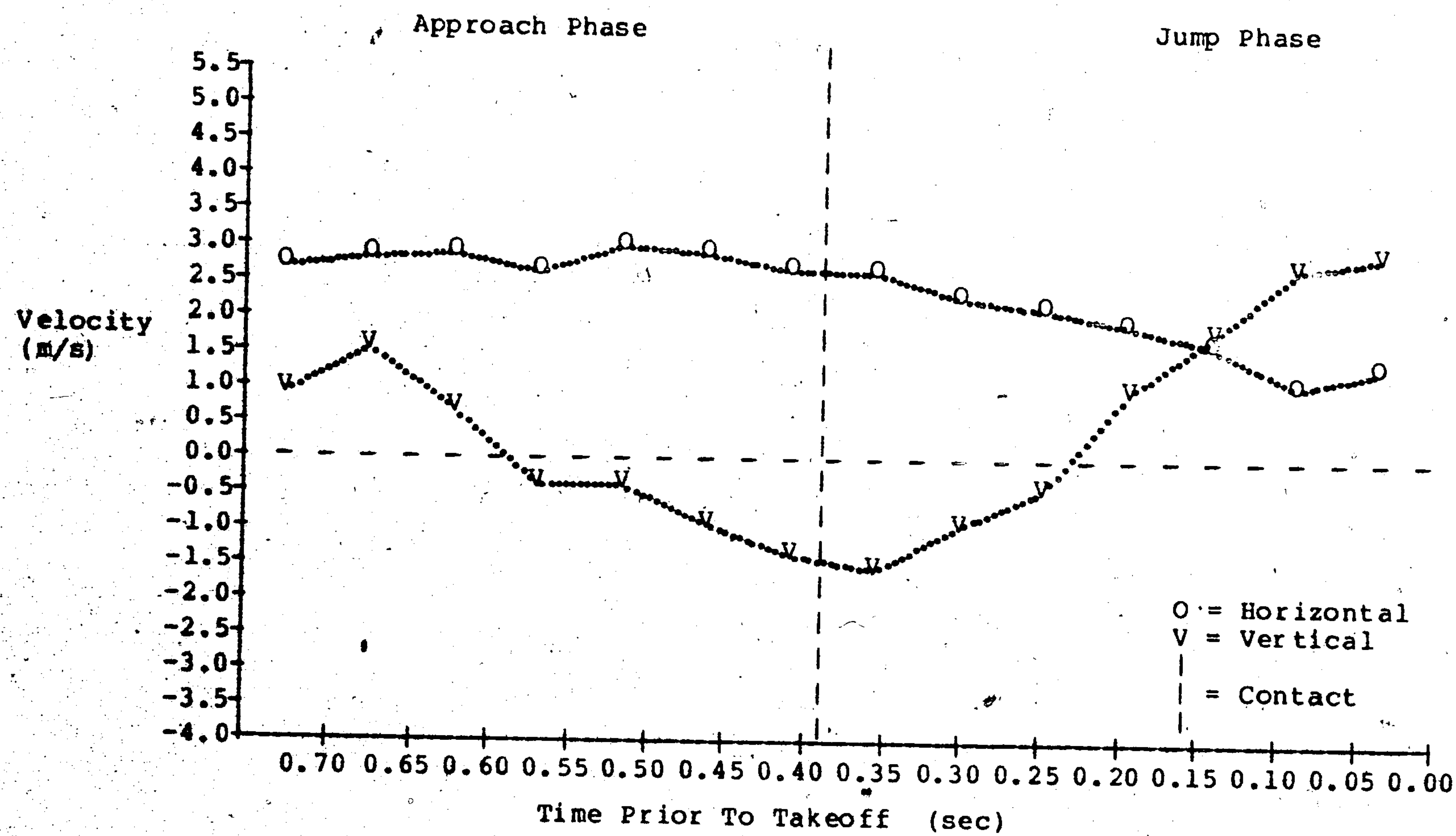


Figure A31: Subject 16, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

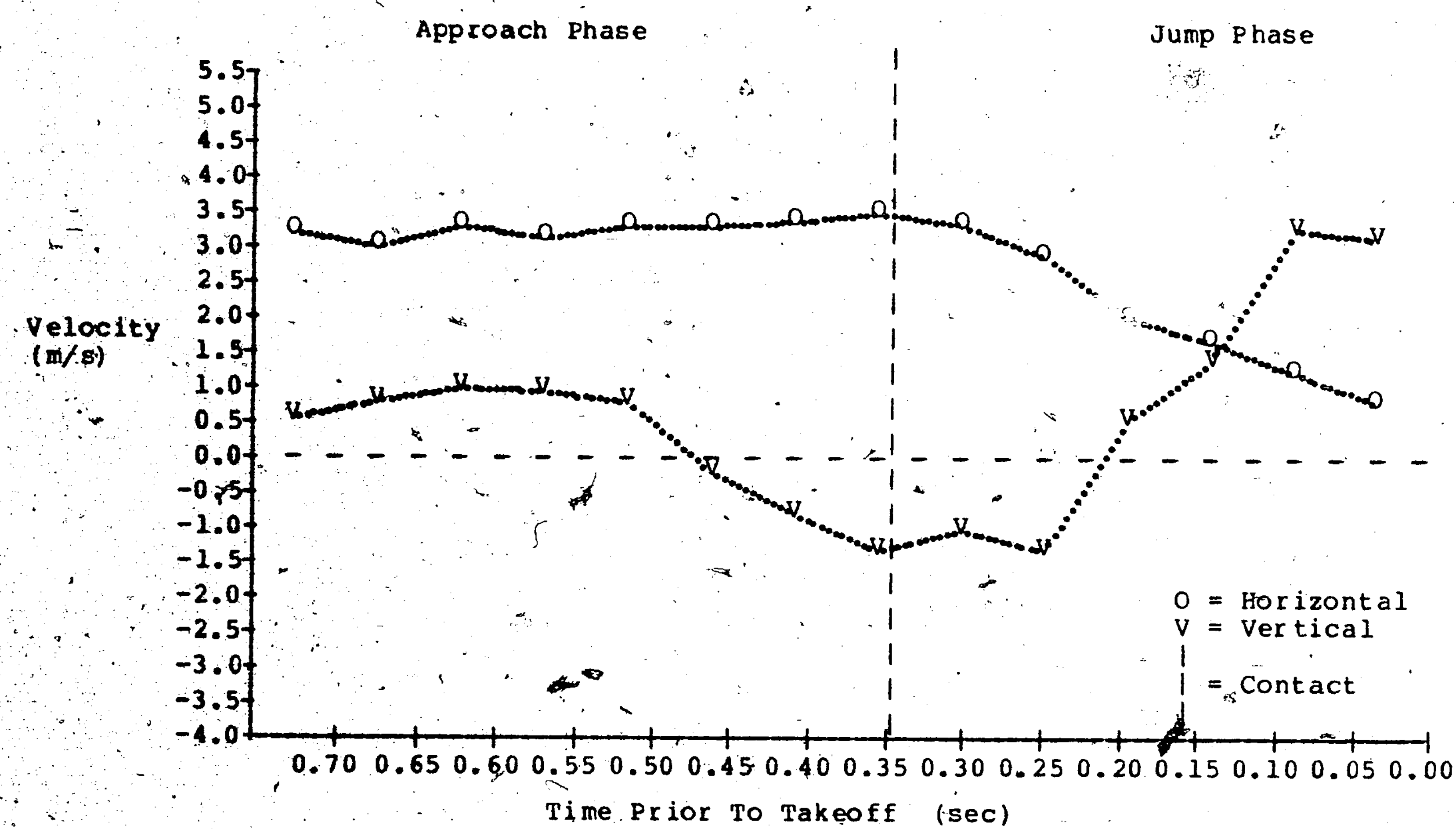


Figure A32: Subject 16, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

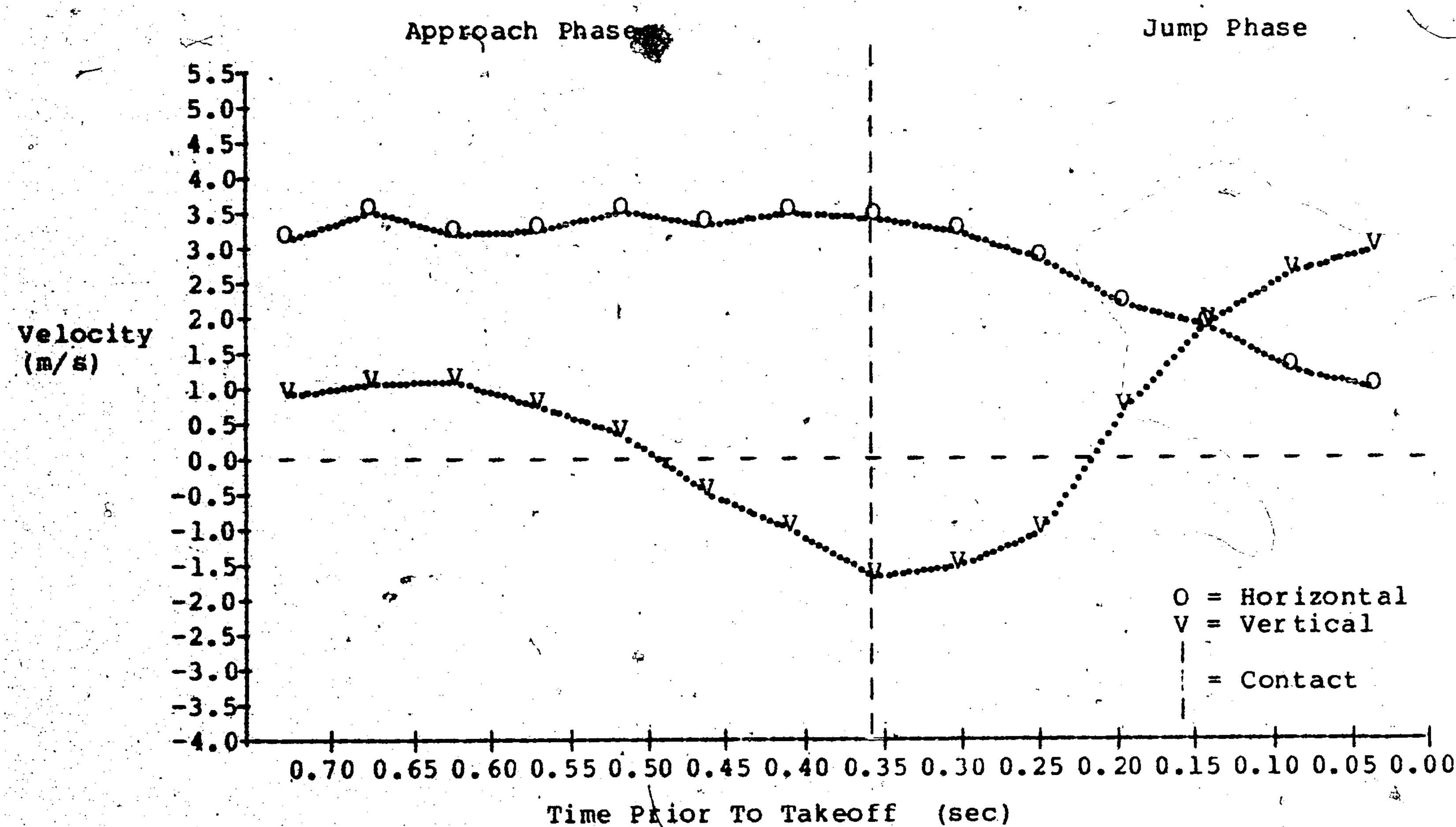


Figure A33: Subject 17, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

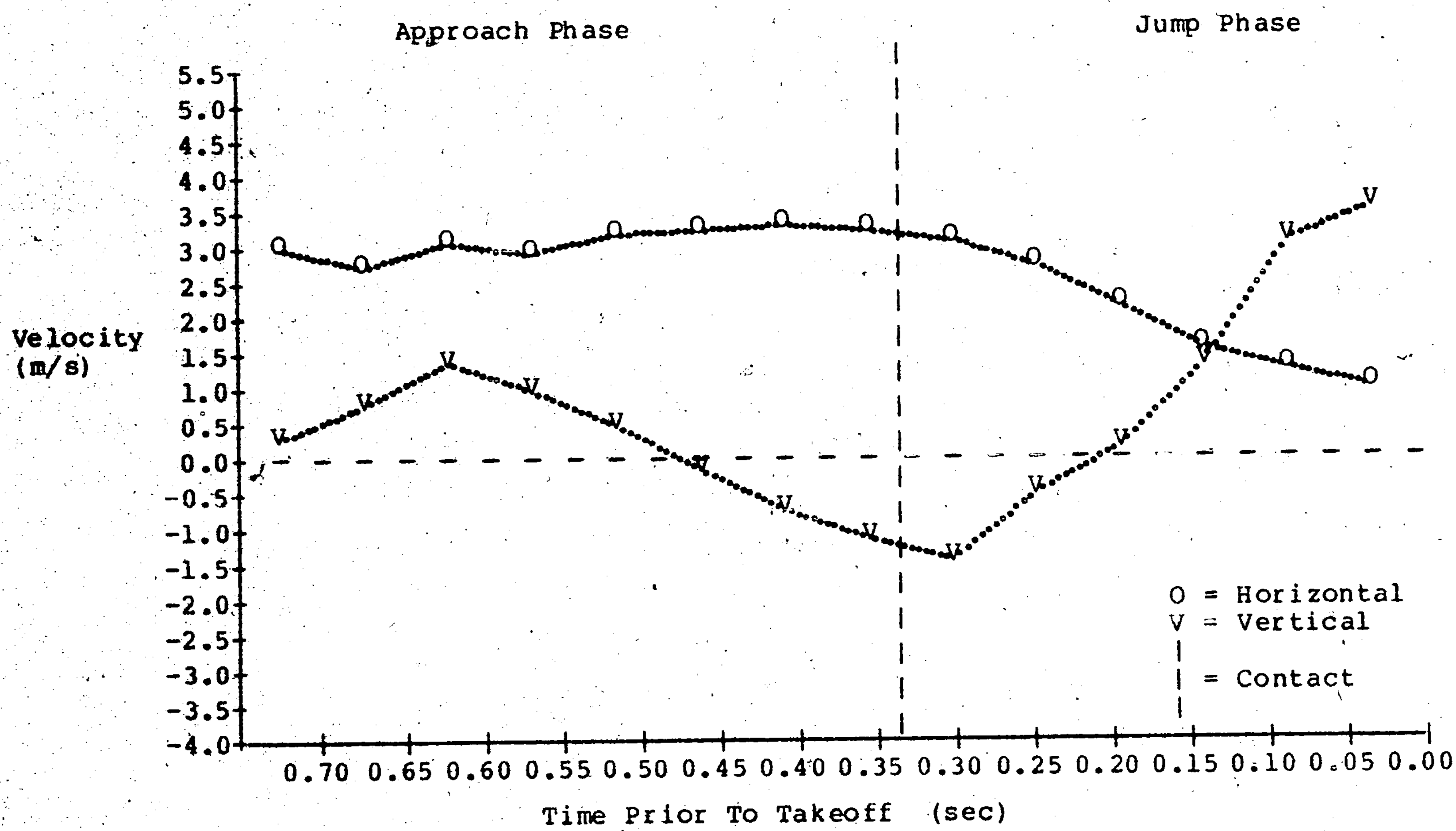


Figure A34: Subject 17, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

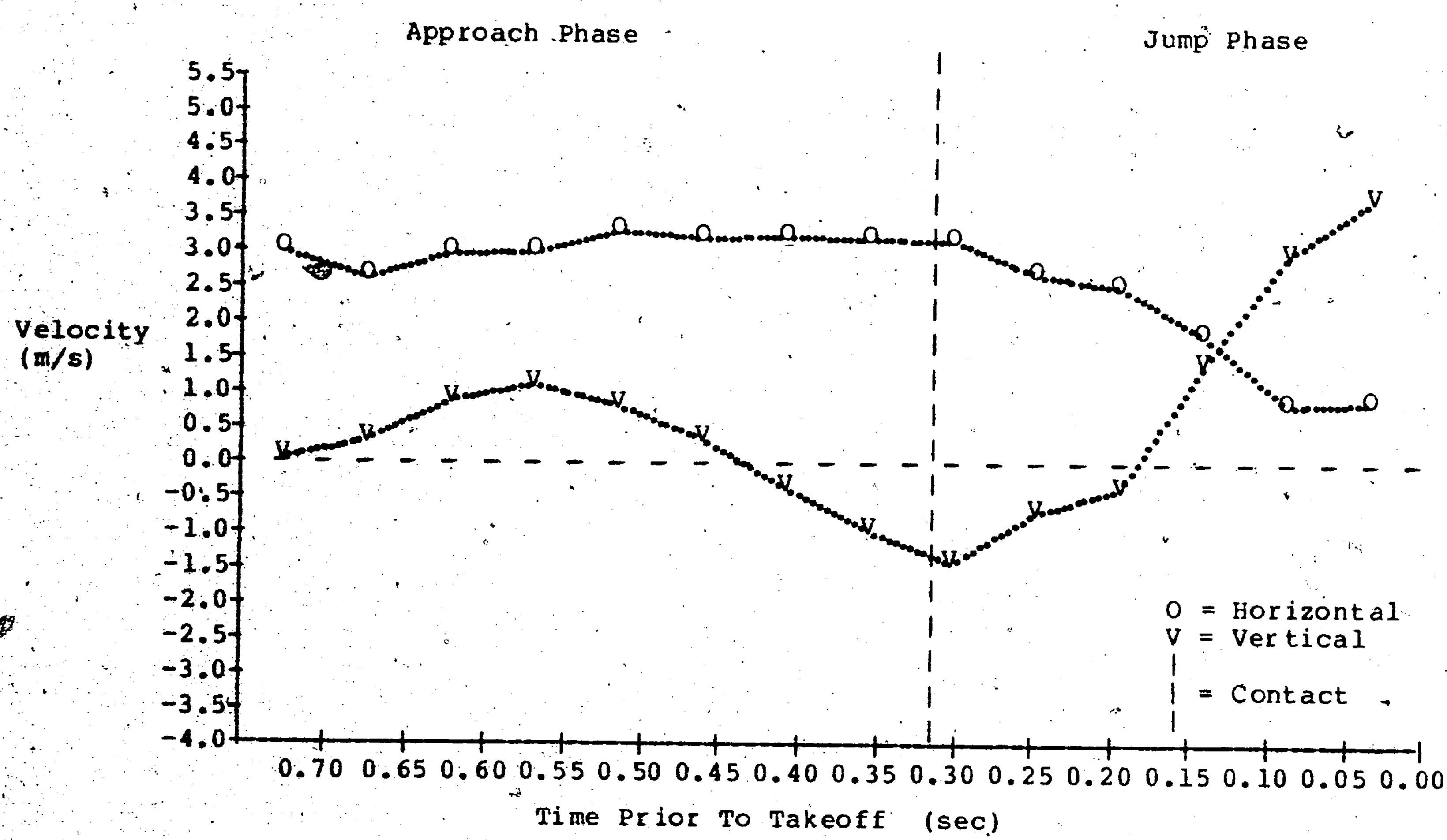


Figure A35: Subject 18, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

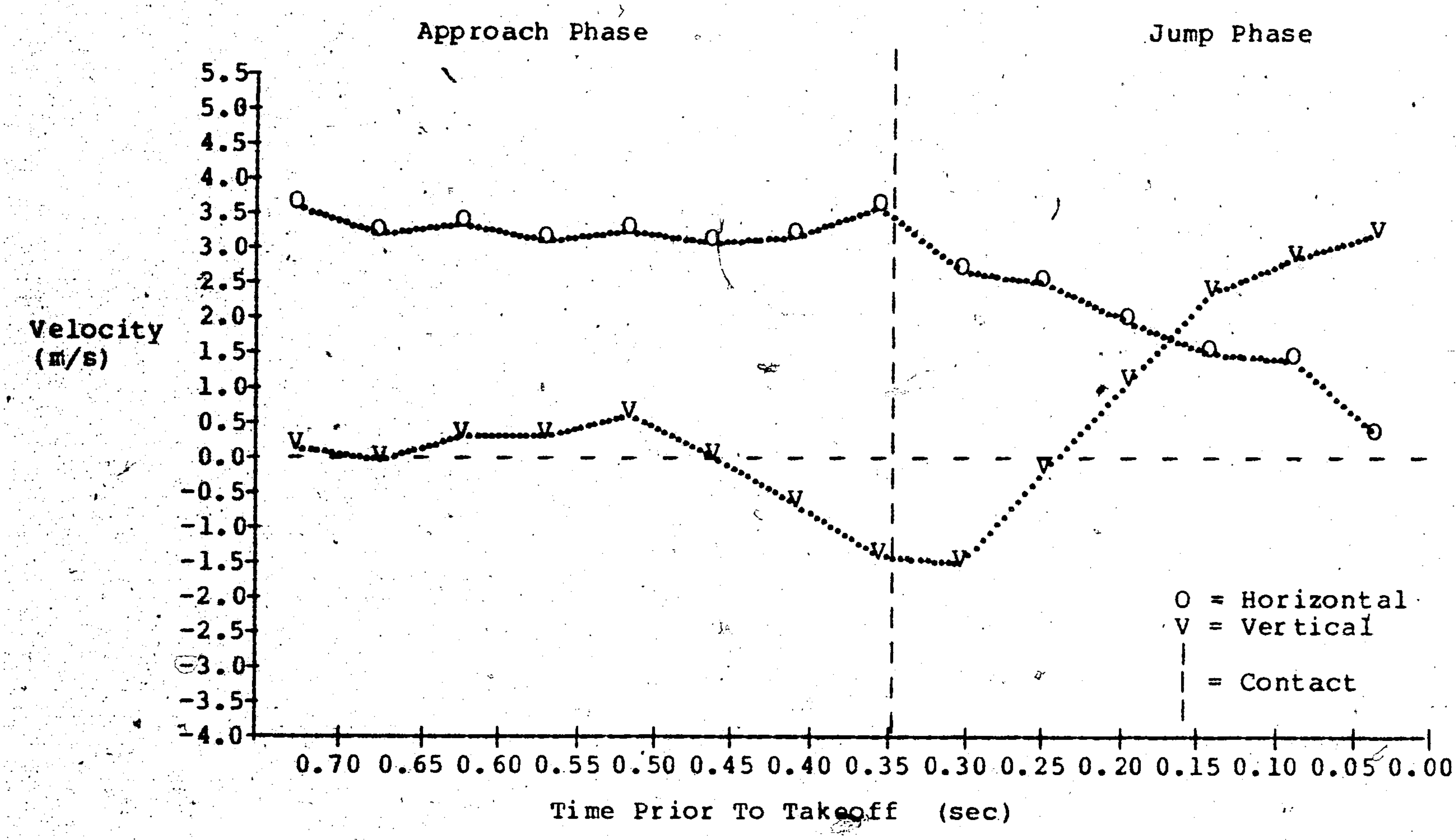


Figure A36: Subject 18, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

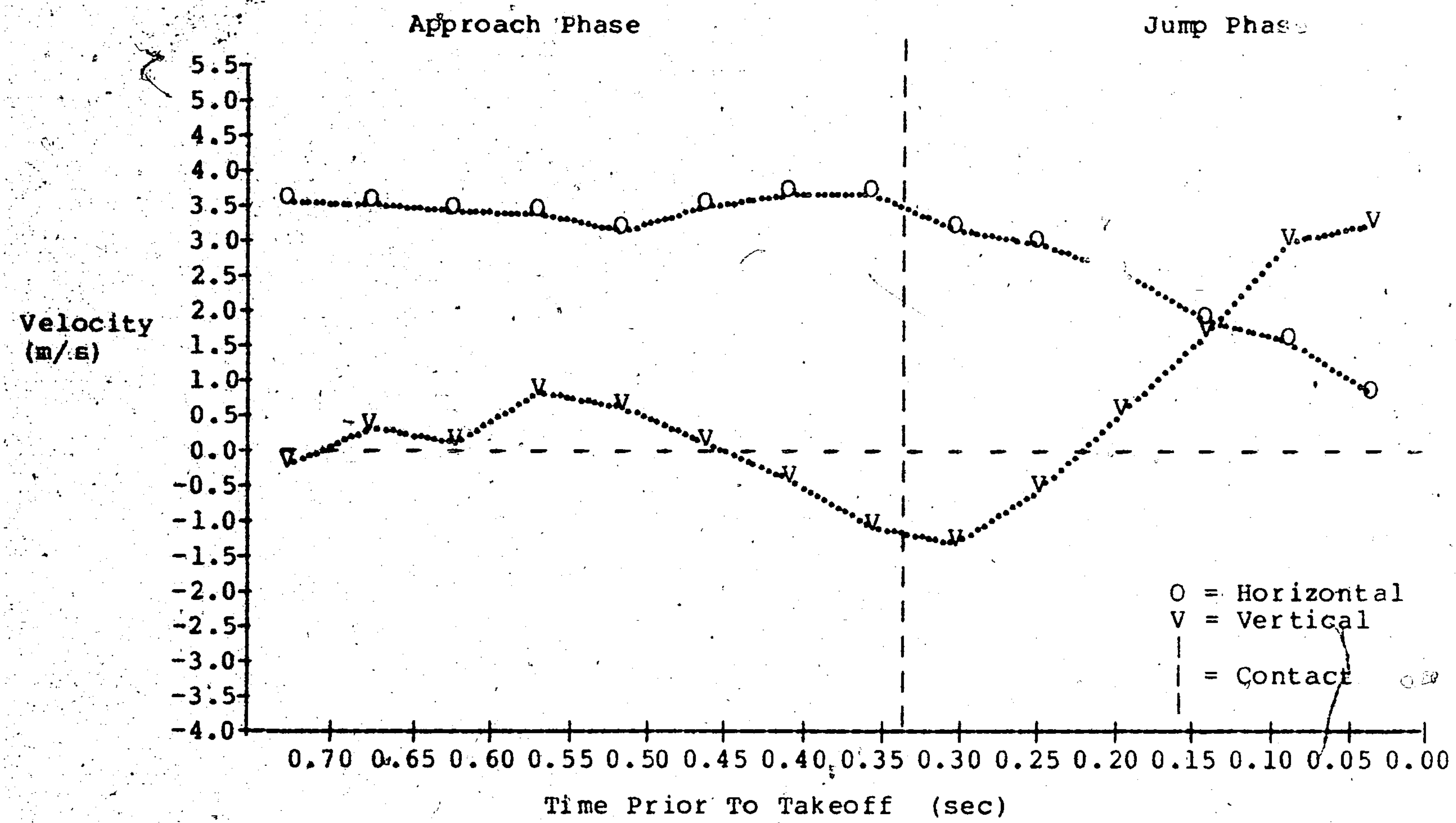


Figure A37: Subject 19, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

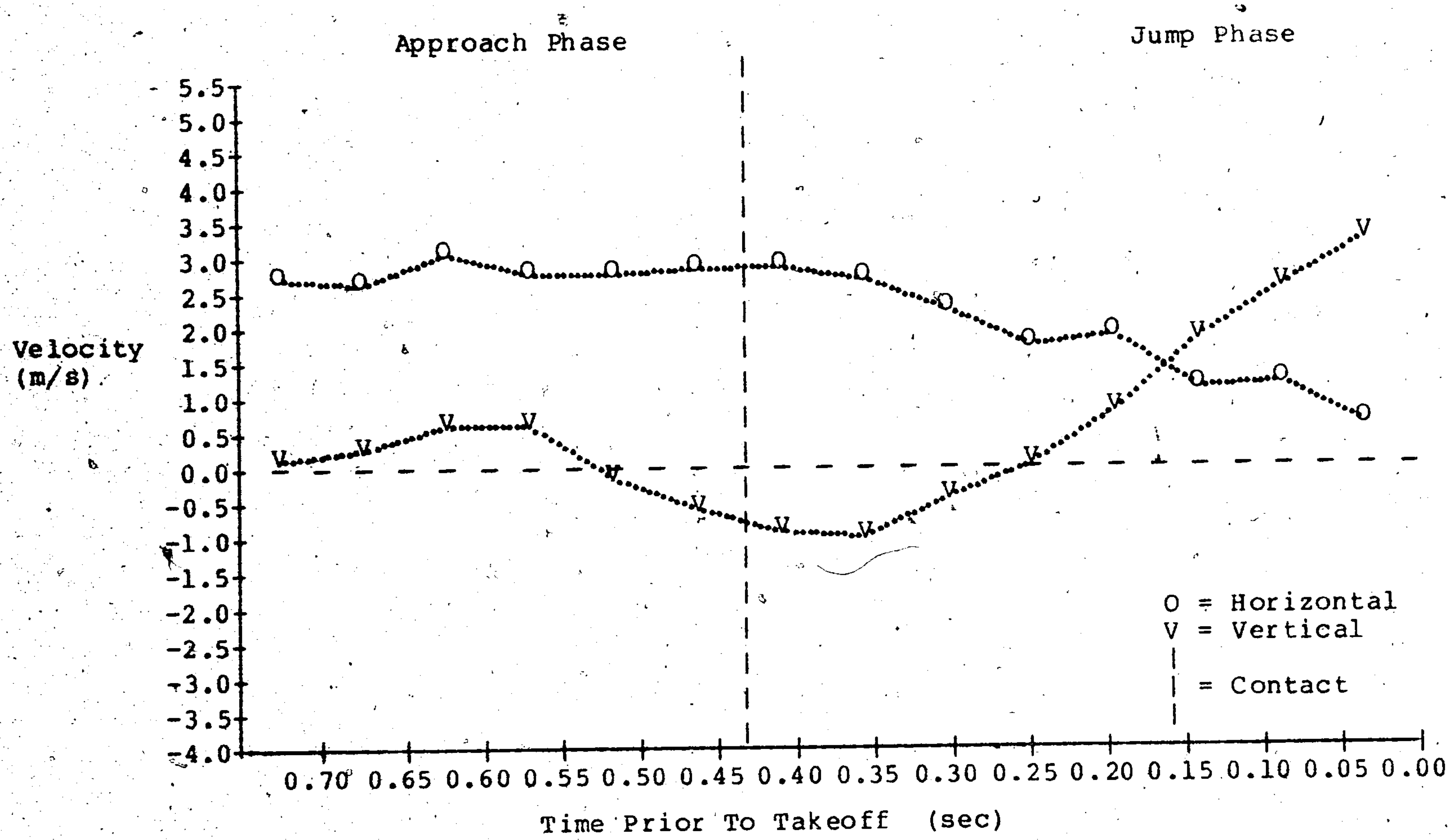


Figure A38: Subject 19, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

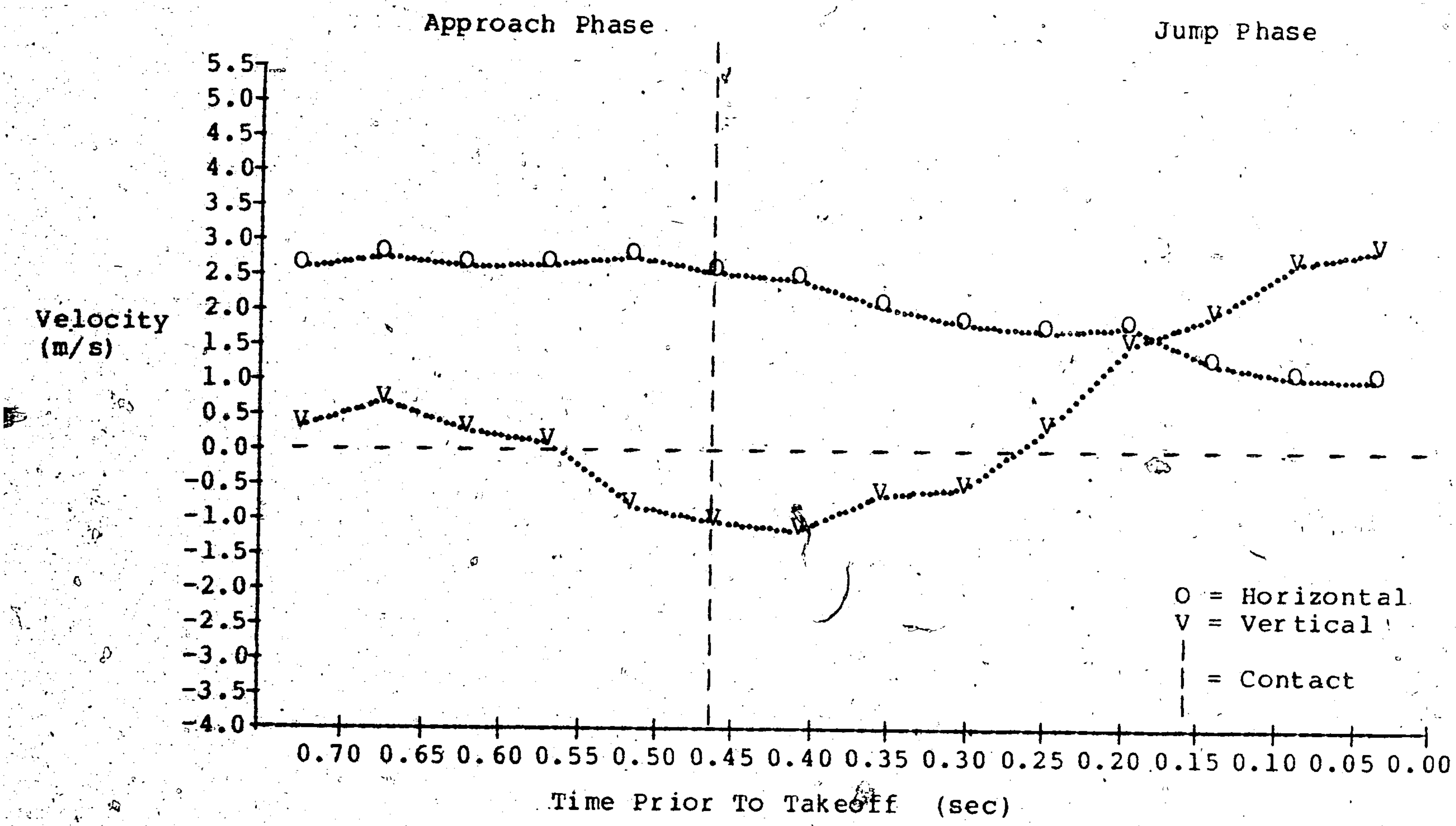


Figure A39: Subject 20, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

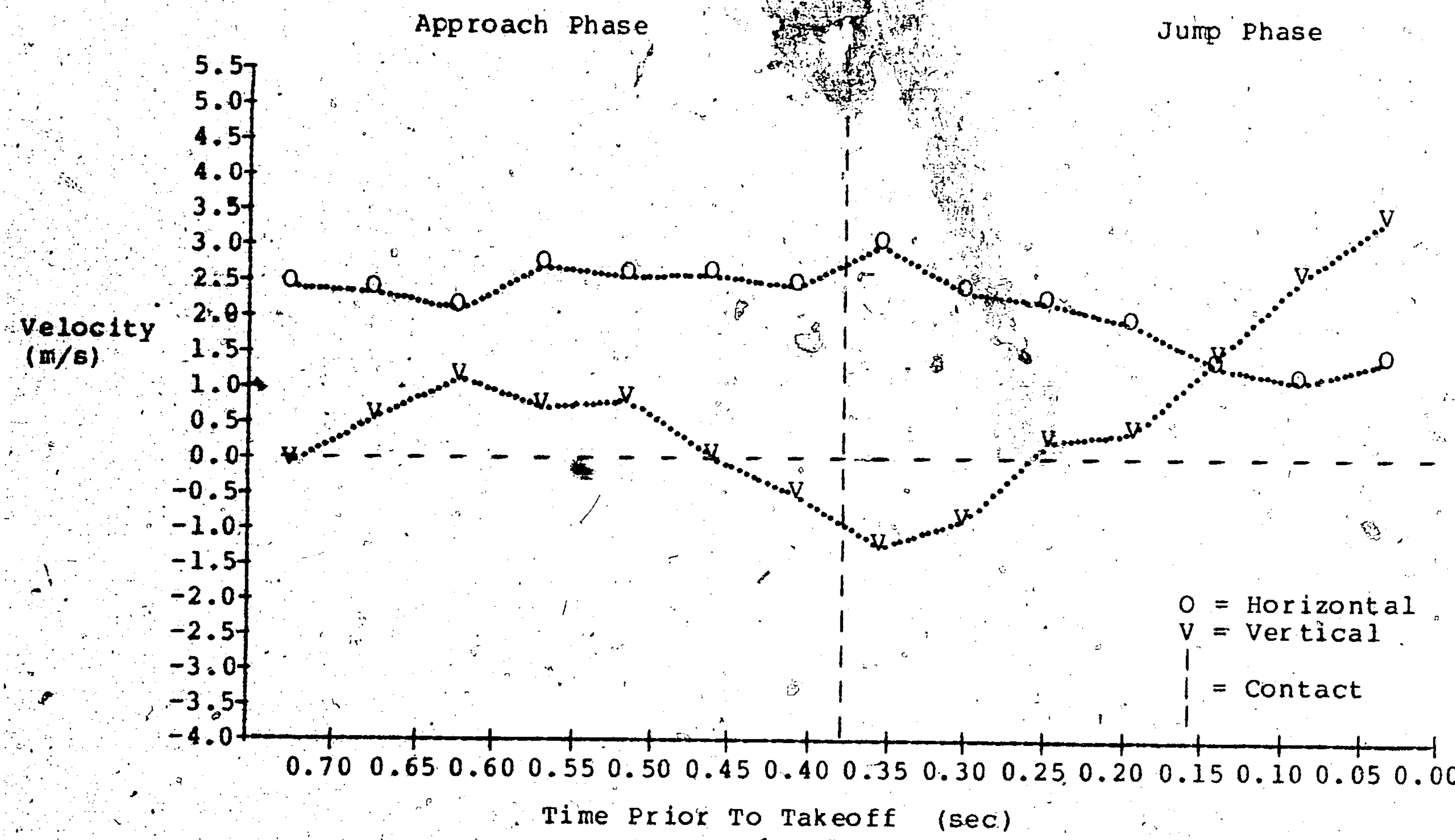


Figure A40: Subject 20, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

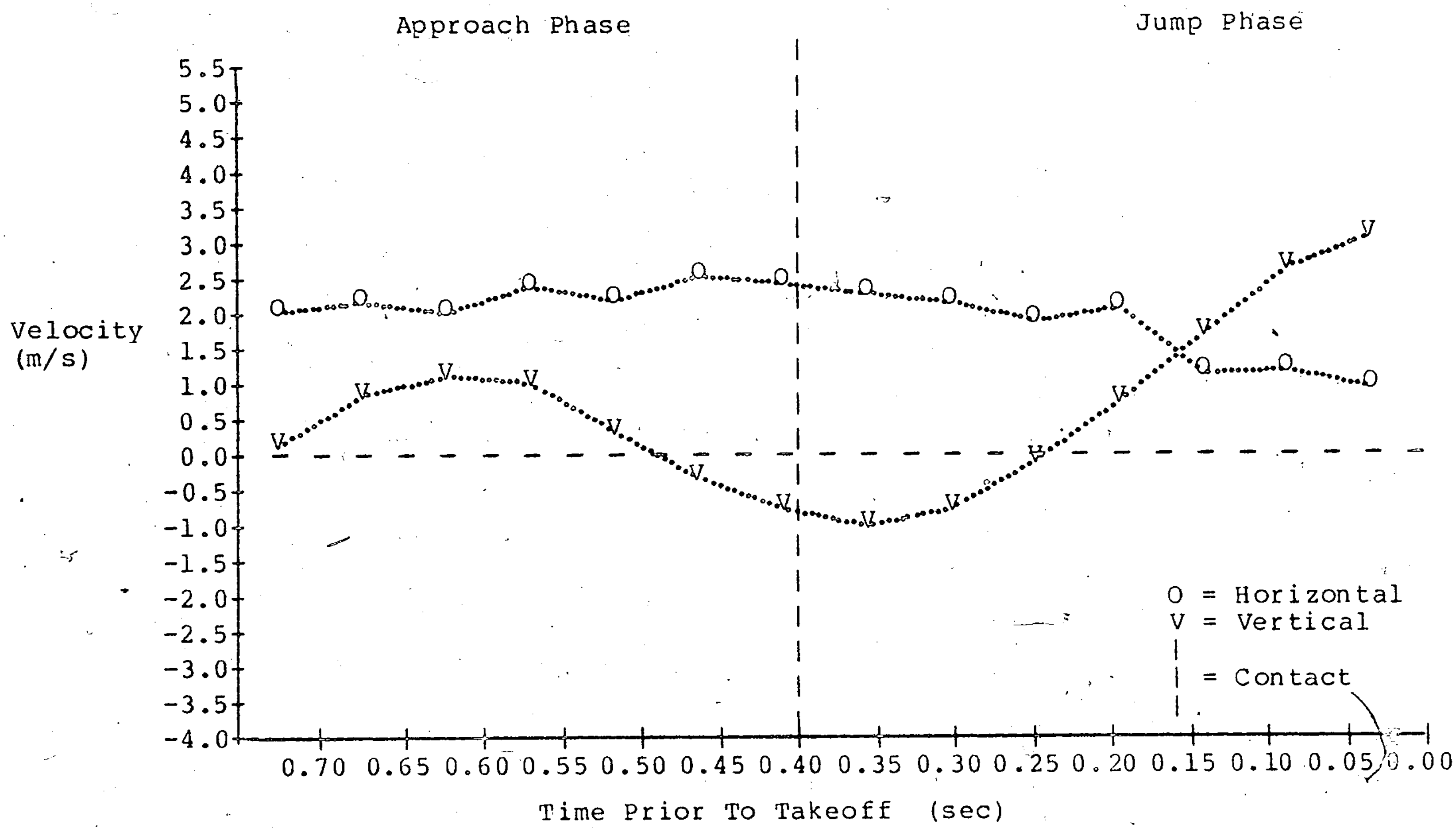


Figure A41: Subject 21, Jump

Horizontal and Vertical Velocity Curves for Center of Mass

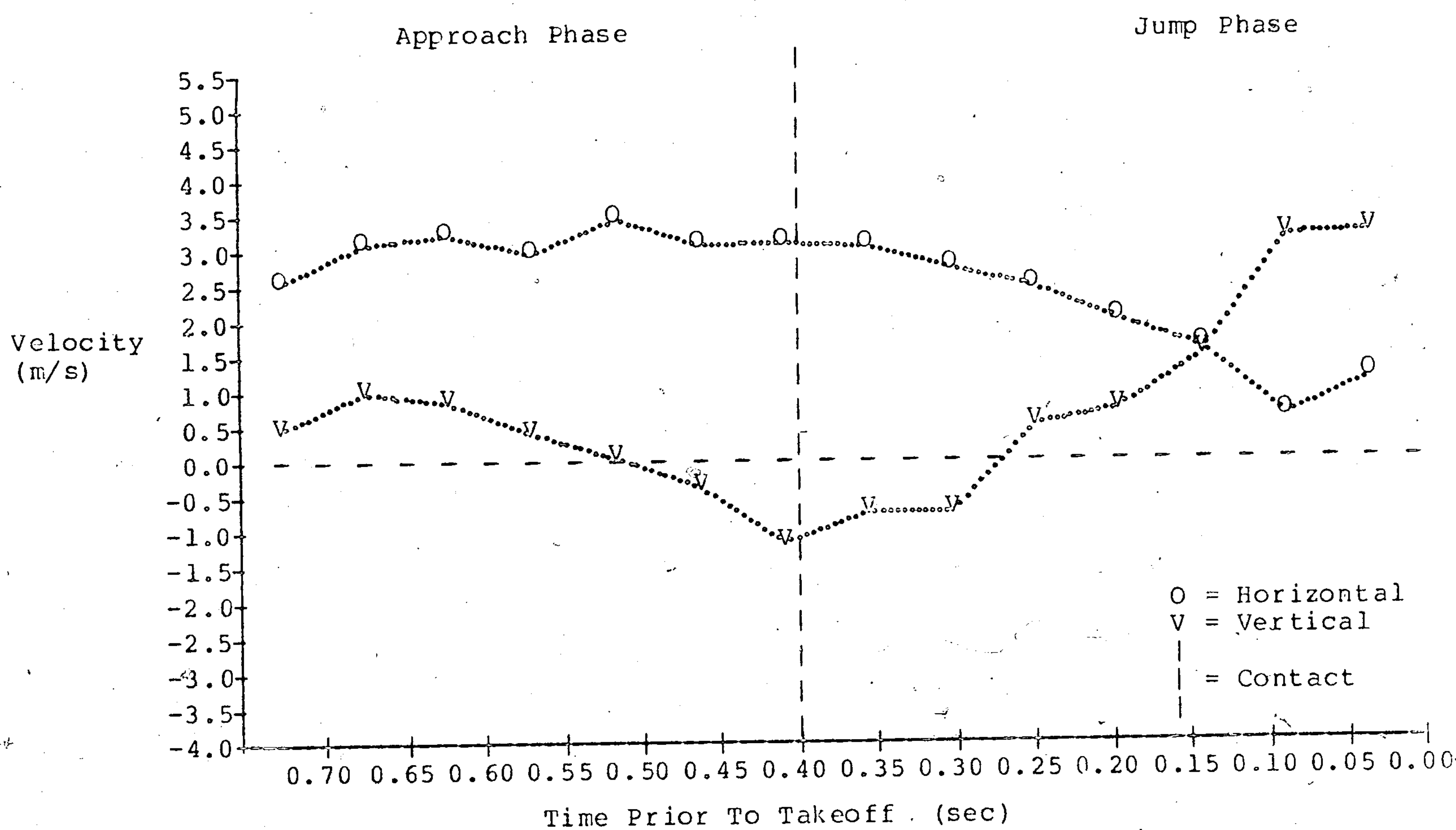


Figure A42: Subject 21, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass

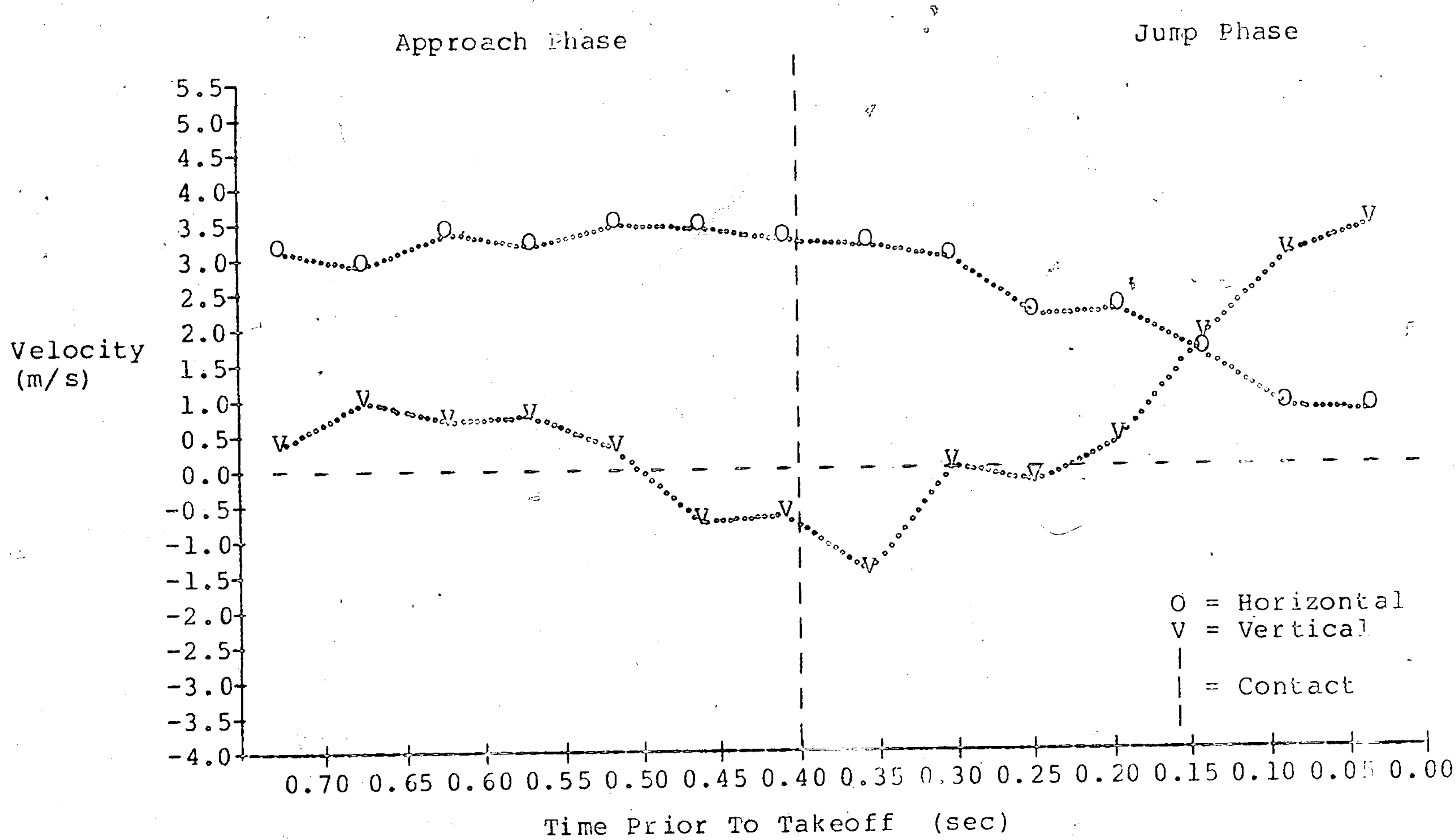


Figure A43: Subject 22, Jump 1

Horizontal and Vertical Velocity Curves for Center of Mass

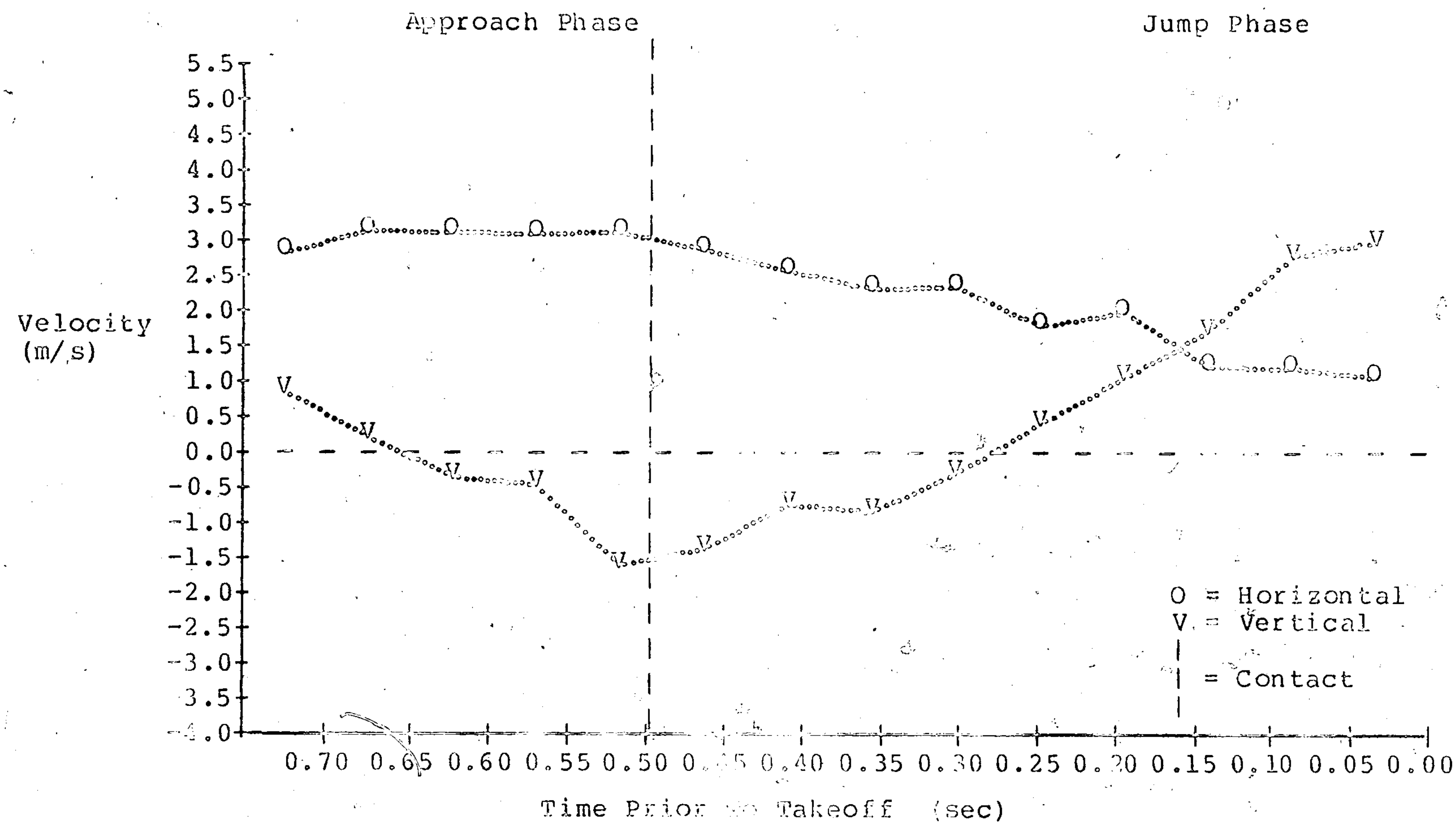
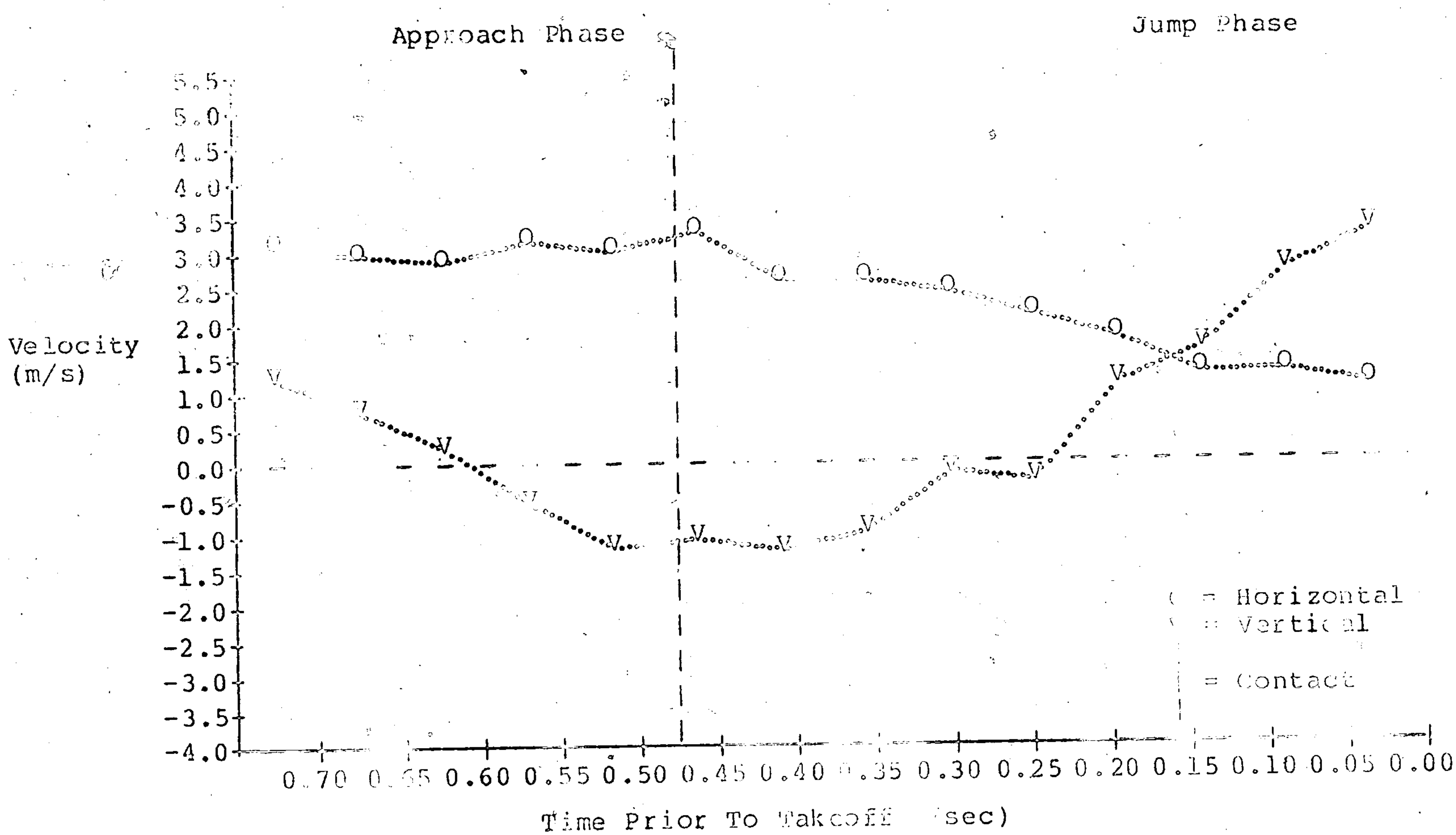


Figure A44: Subject 22, Jump 2

Horizontal and Vertical Velocity Curves for Center of Mass



APPENDIX C

Angular Velocity Curves for:

1) Right Arm

2) Right Knee

3) Left Knee

Figure B1: Subject 1, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

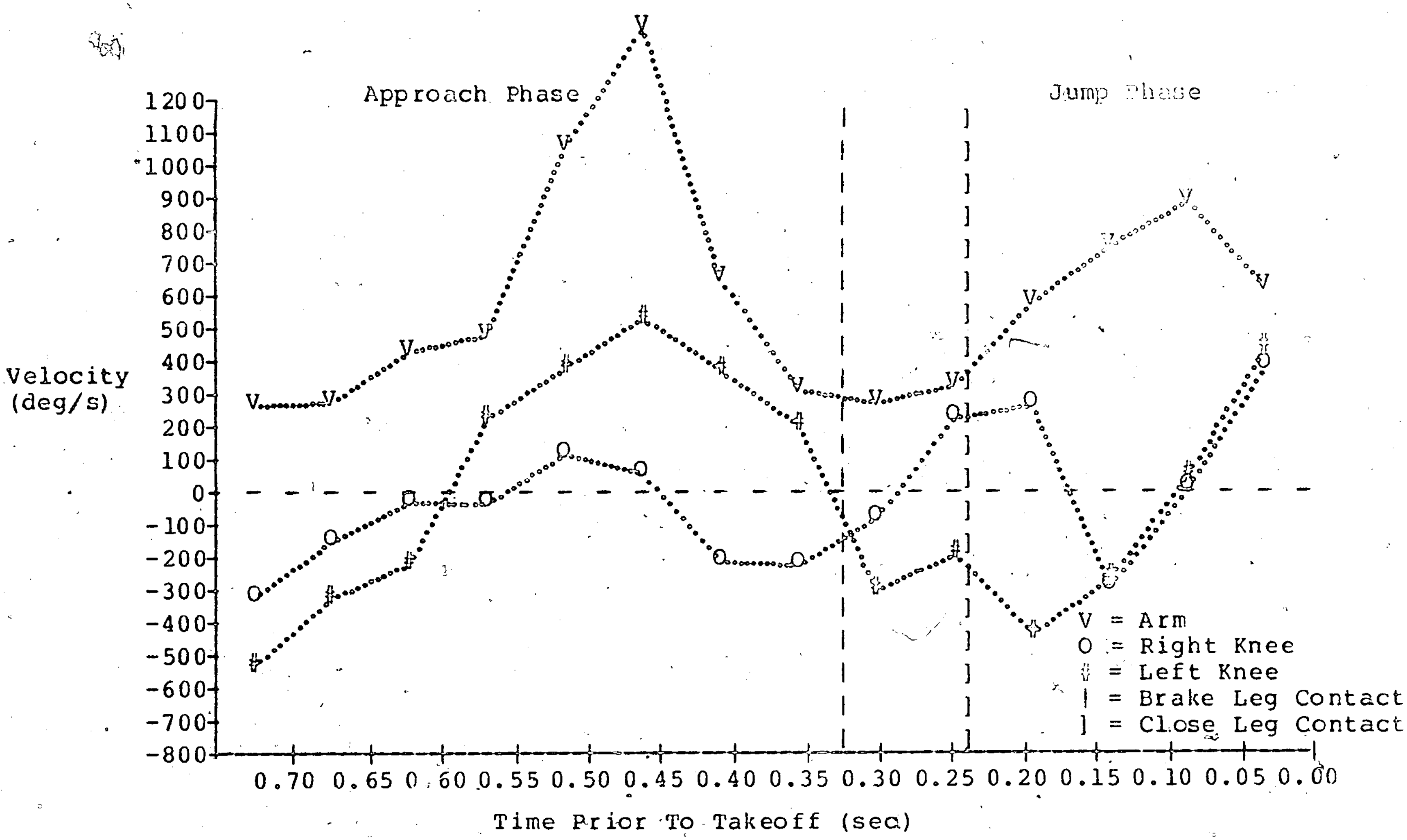


Figure B2: Subject 1, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

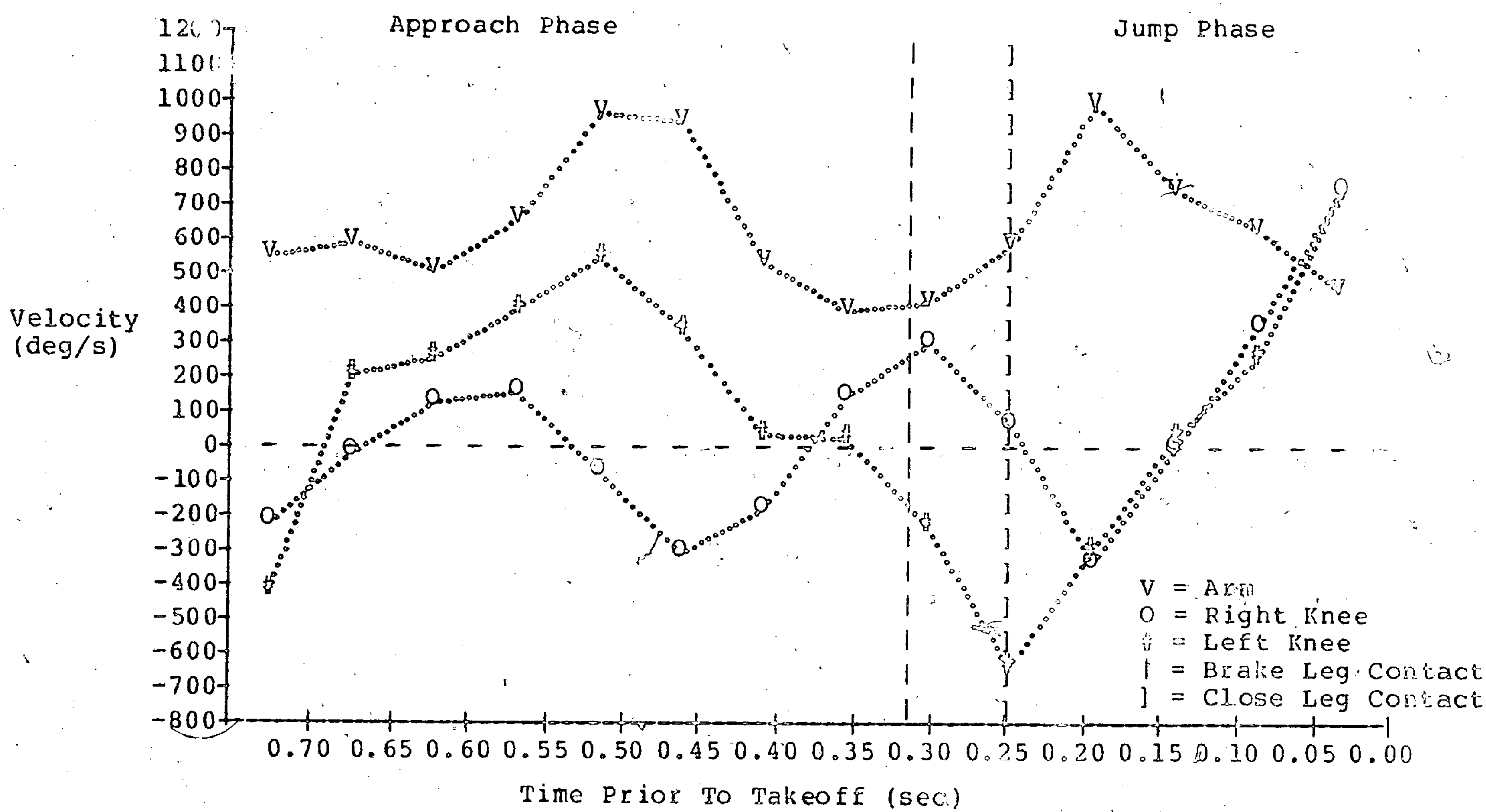


Figure B3: Subject 2, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

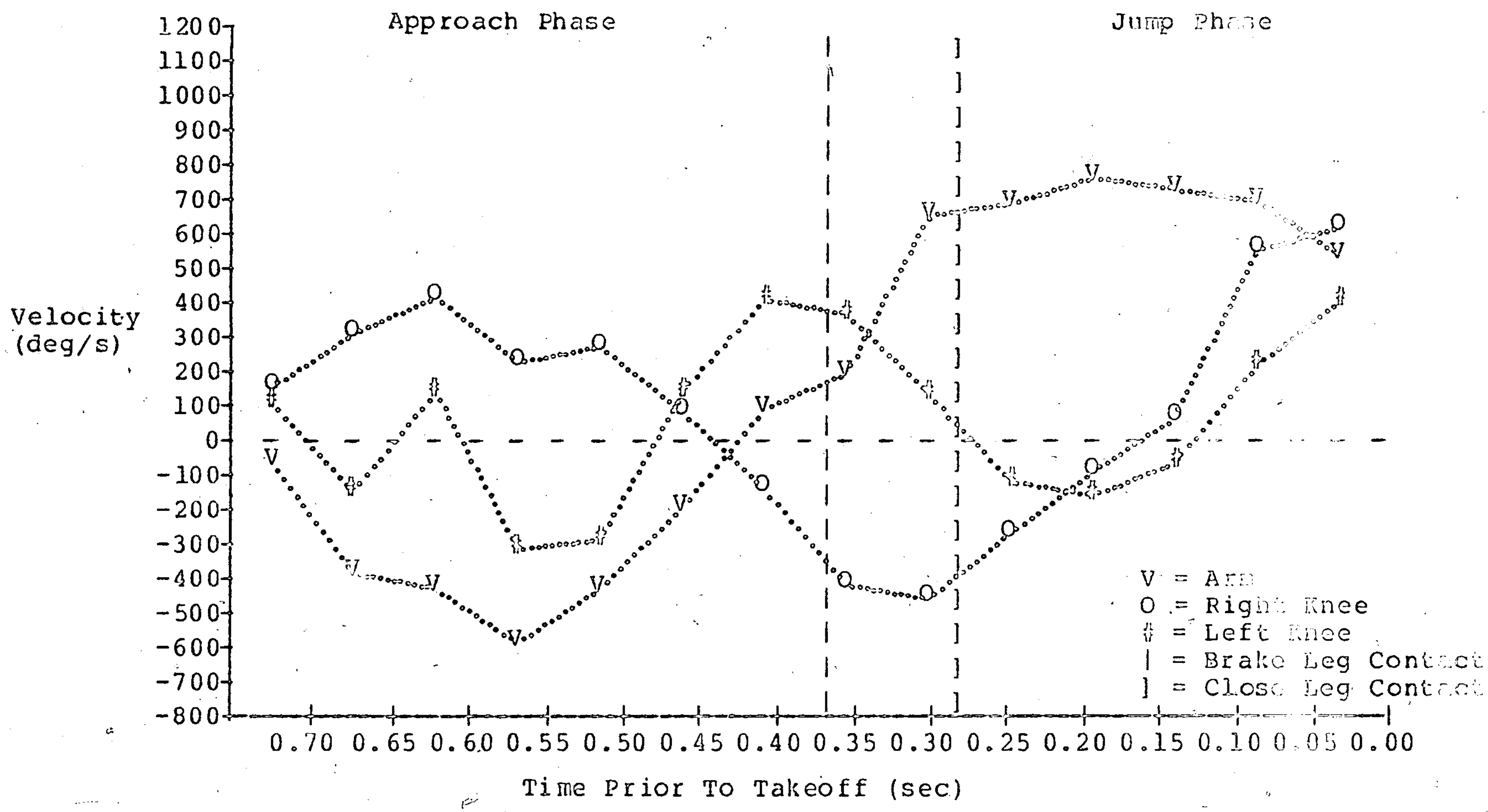


Figure B4: Subject 2, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

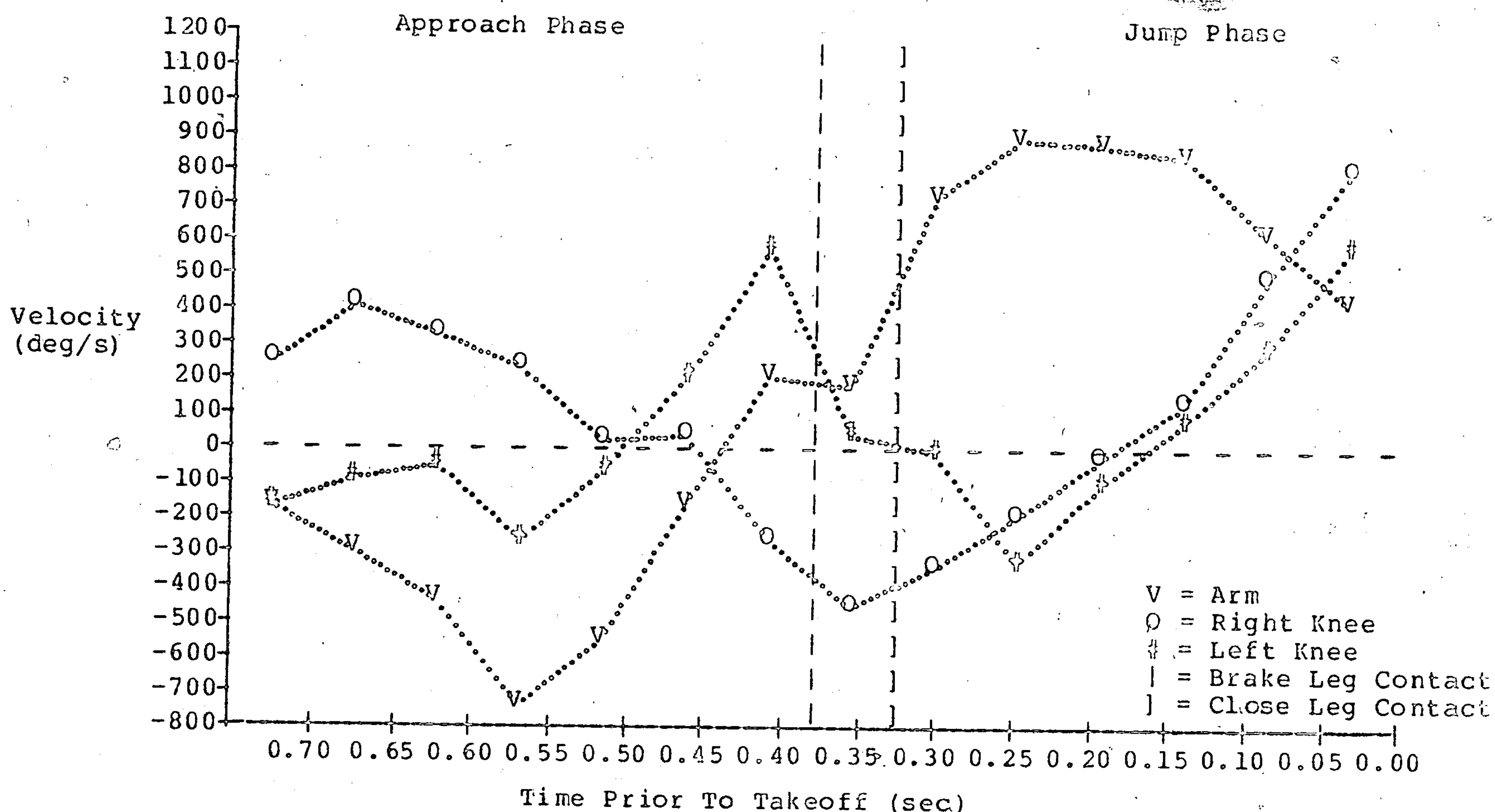


Figure B5: Subject 3, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

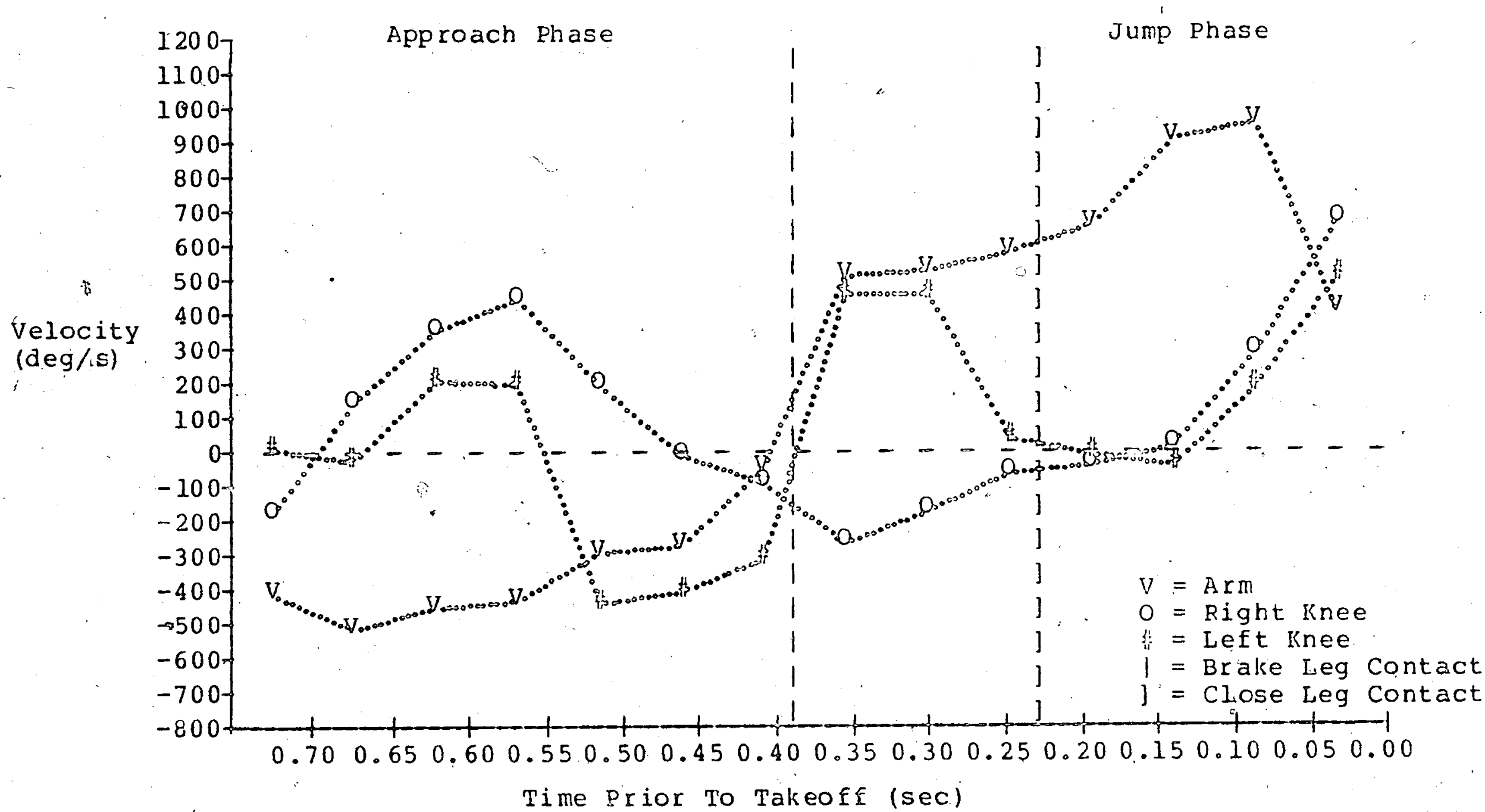


Figure B6: Subject 3, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

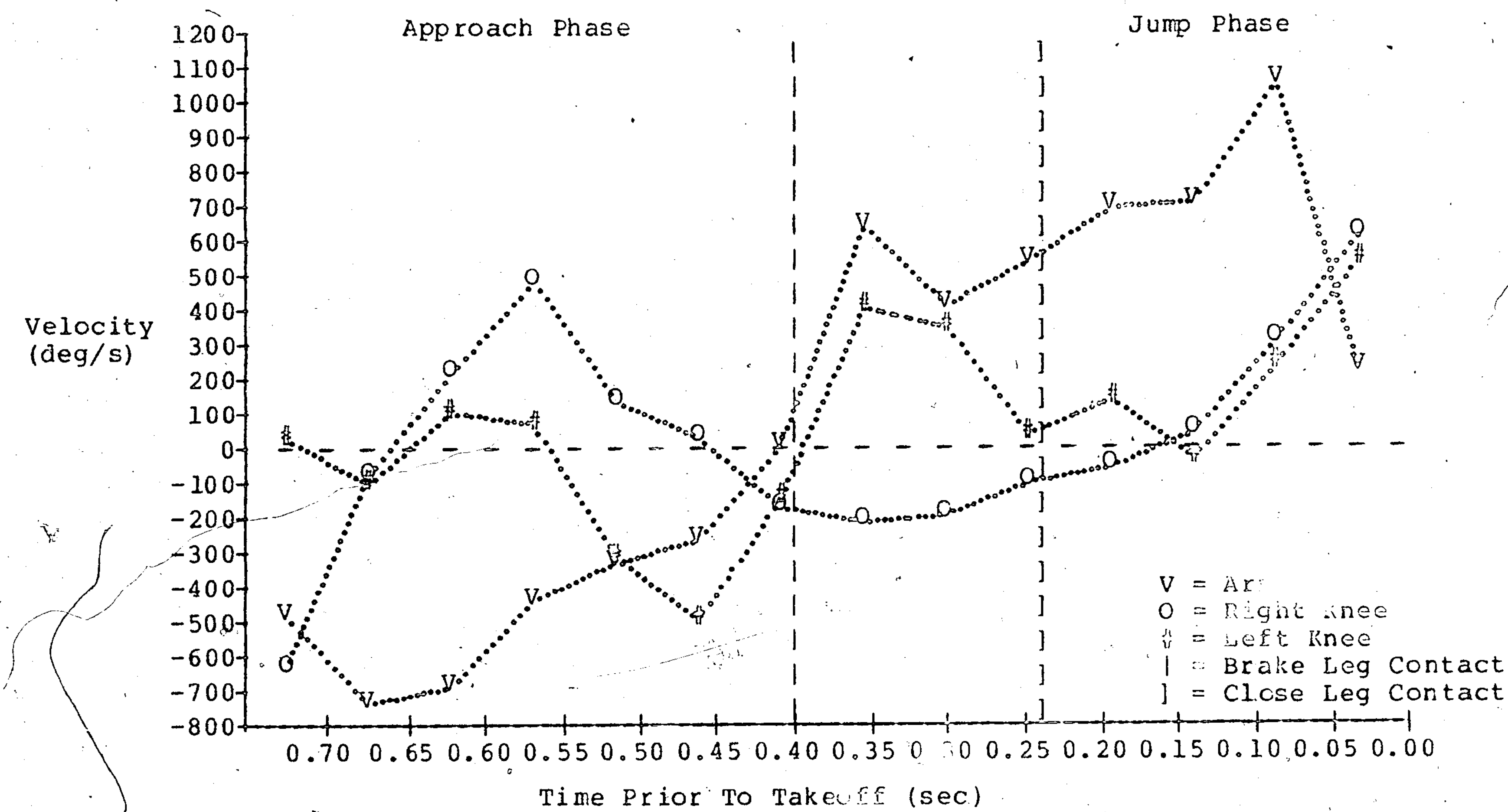


Figure B7: Subject 4, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

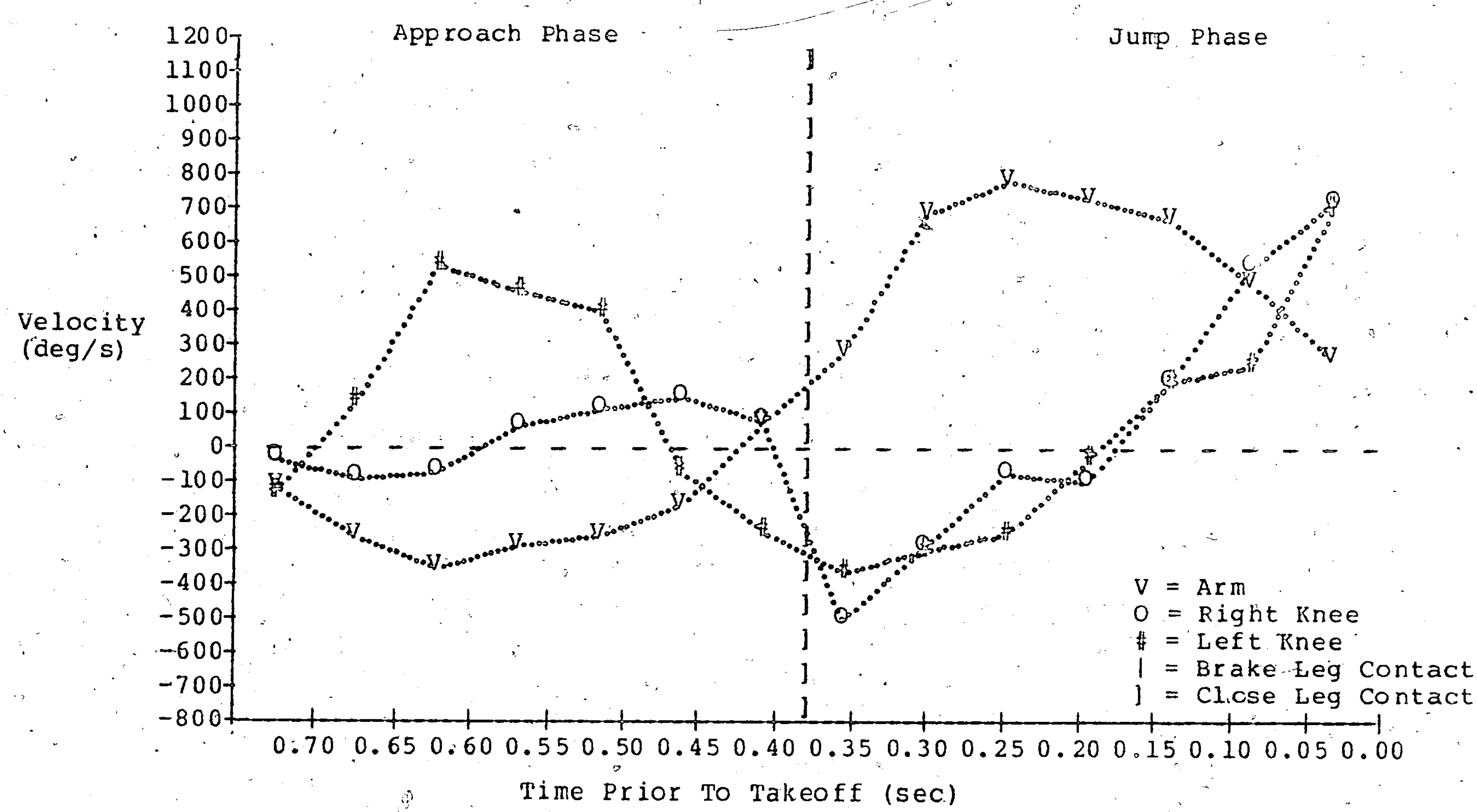


Figure B8: Subject 4, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

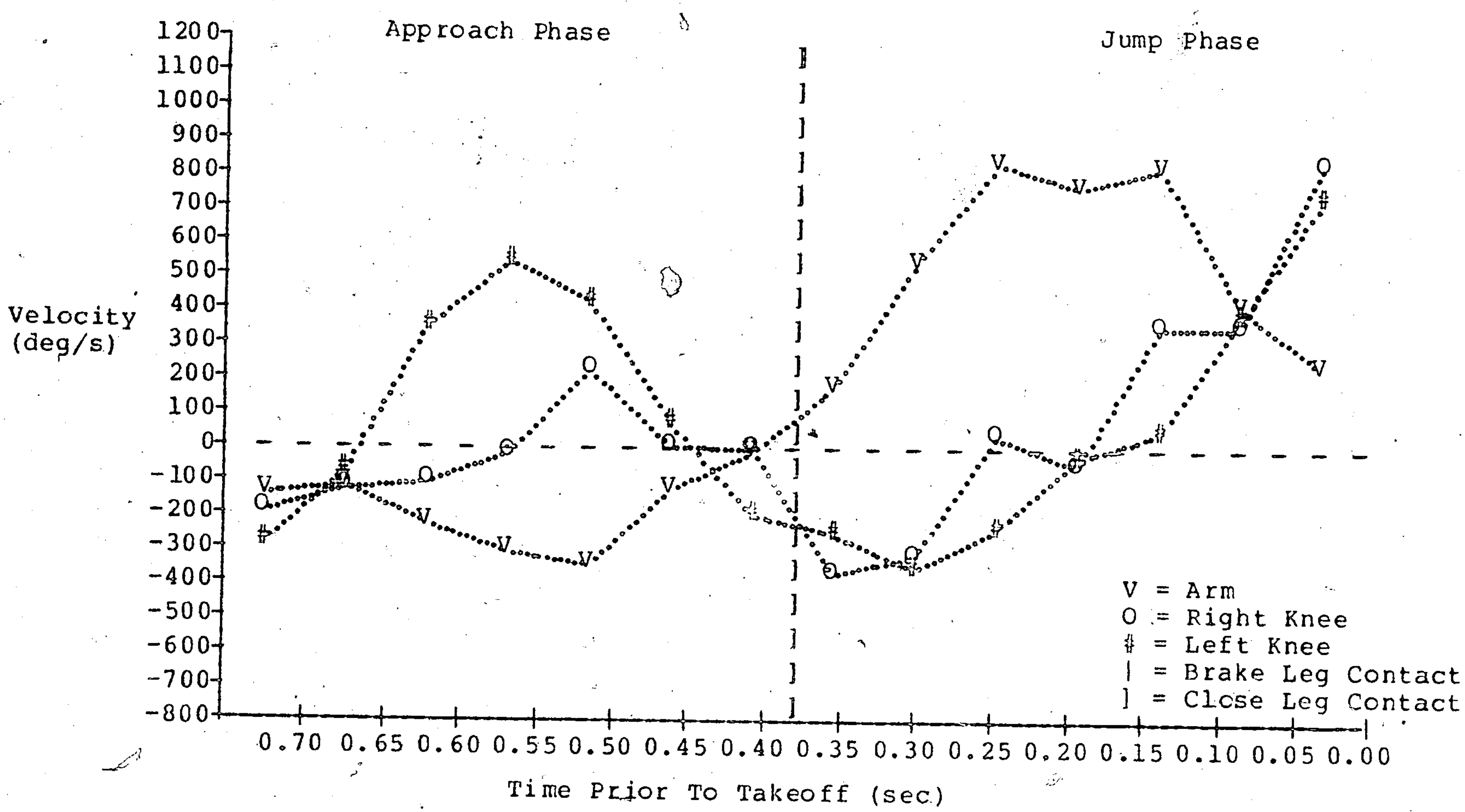


Figure B9: Subject 5, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

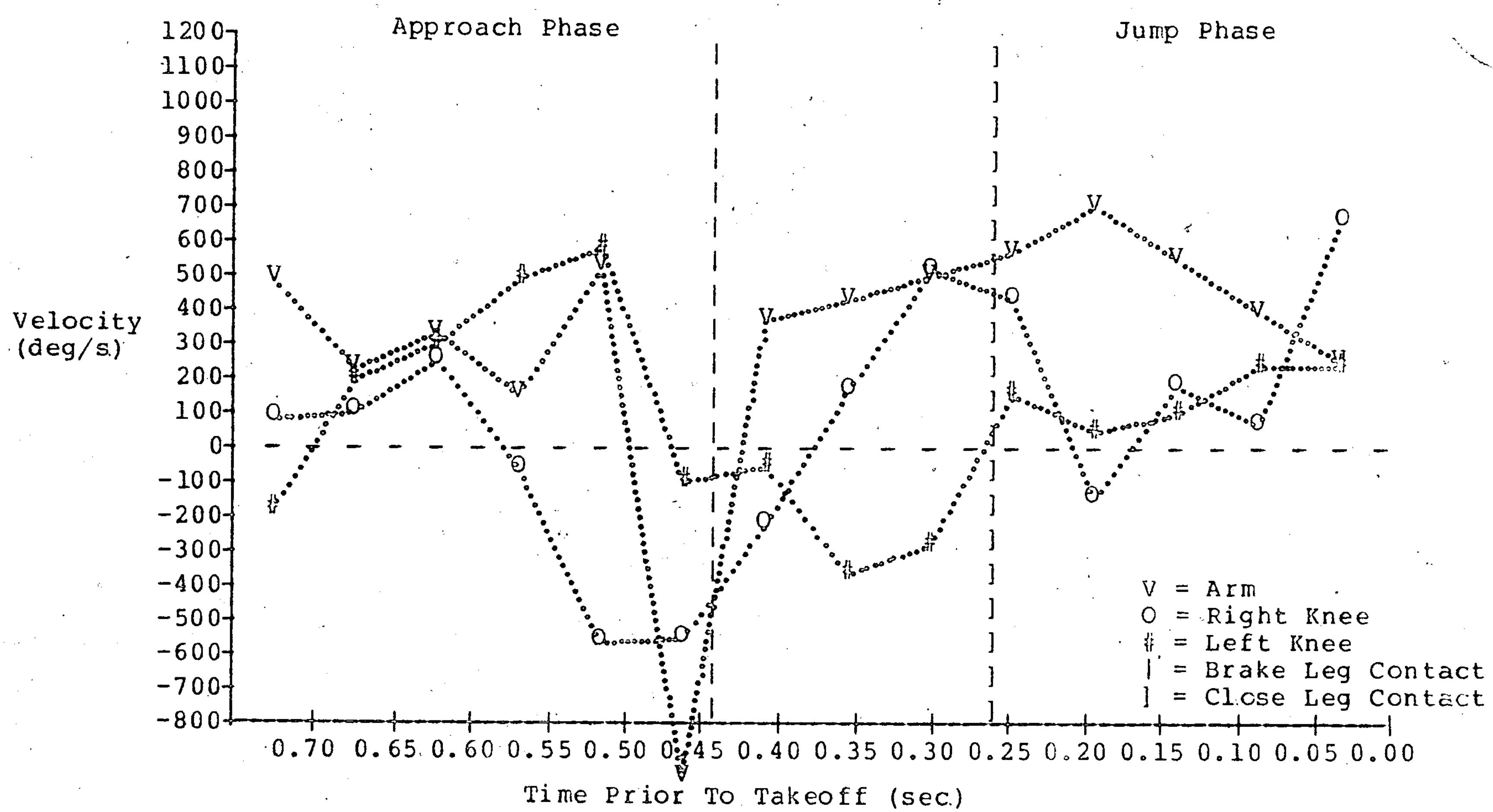


Figure B10: Subject 5, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

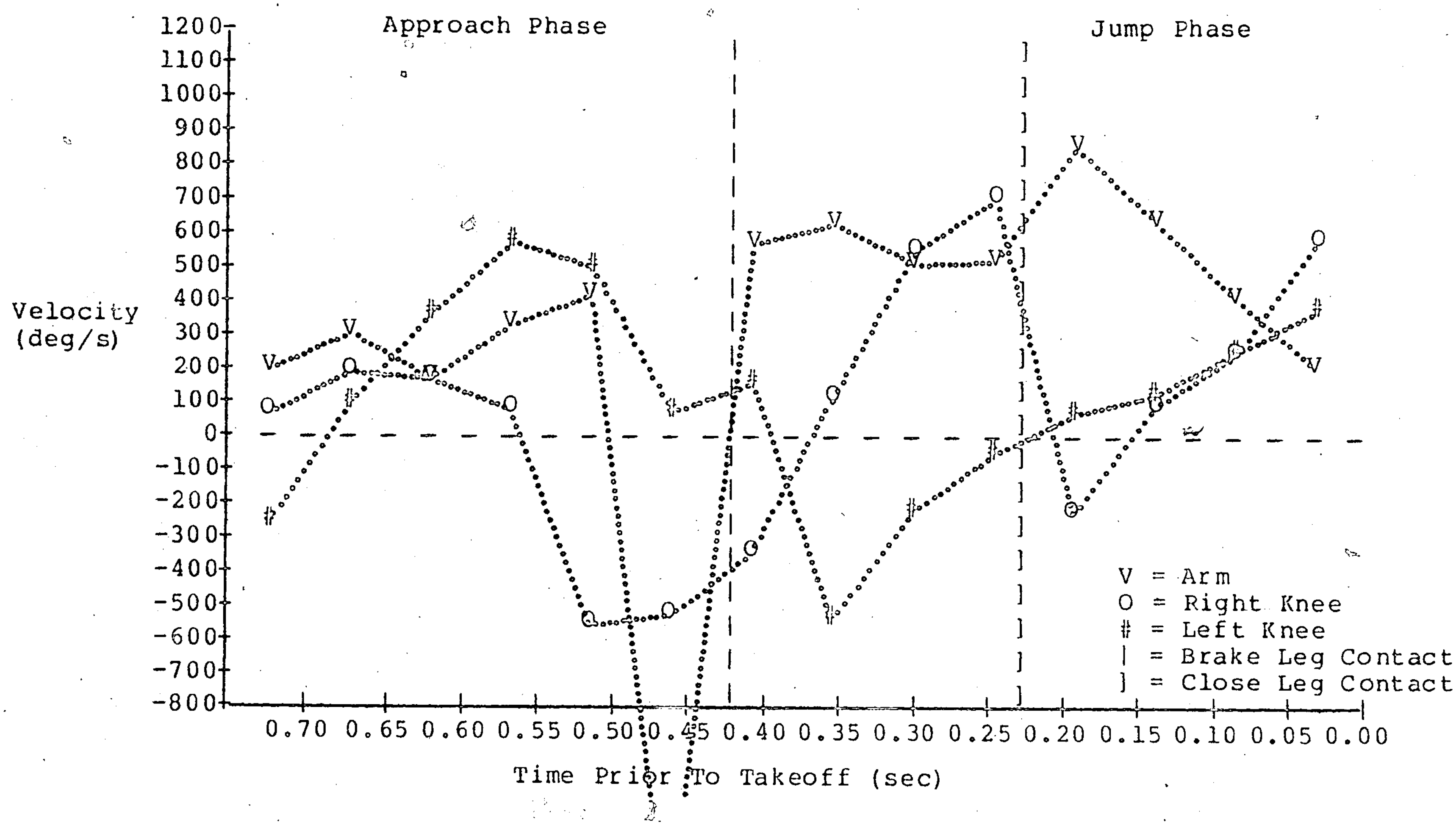


Figure B11: Subject 6, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

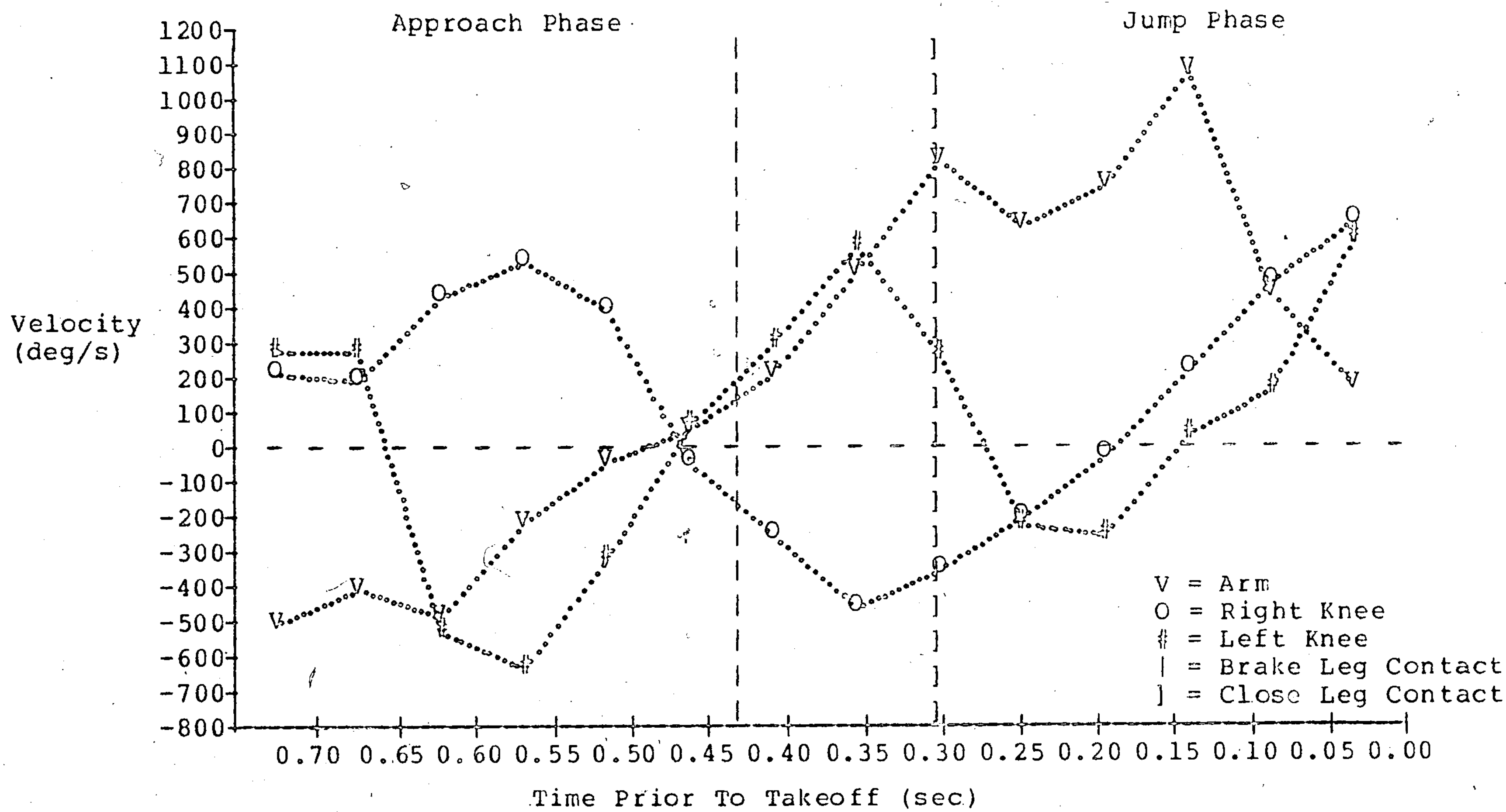


Figure B12: Subject 6, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

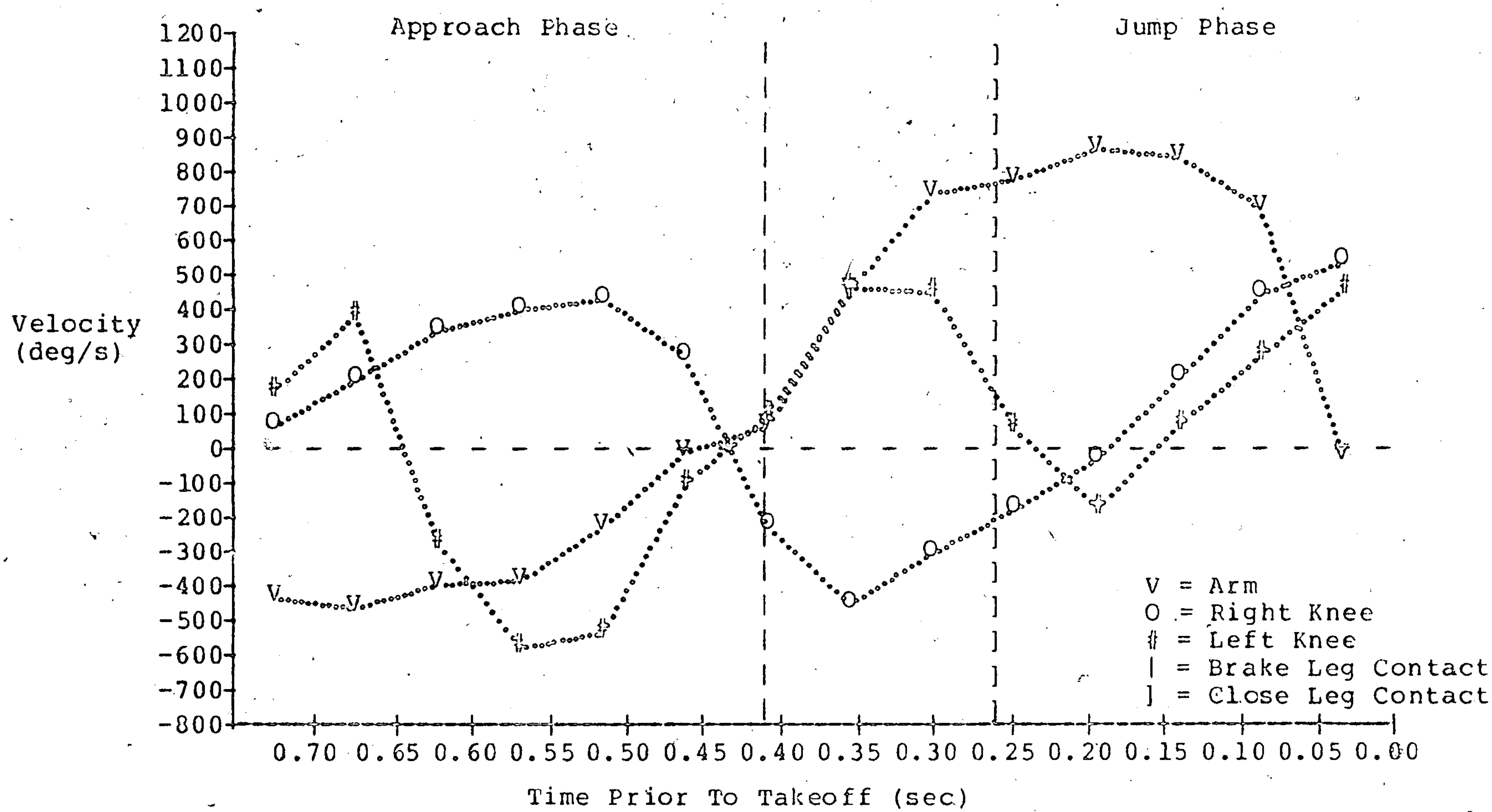


Figure B13: Subject 7, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

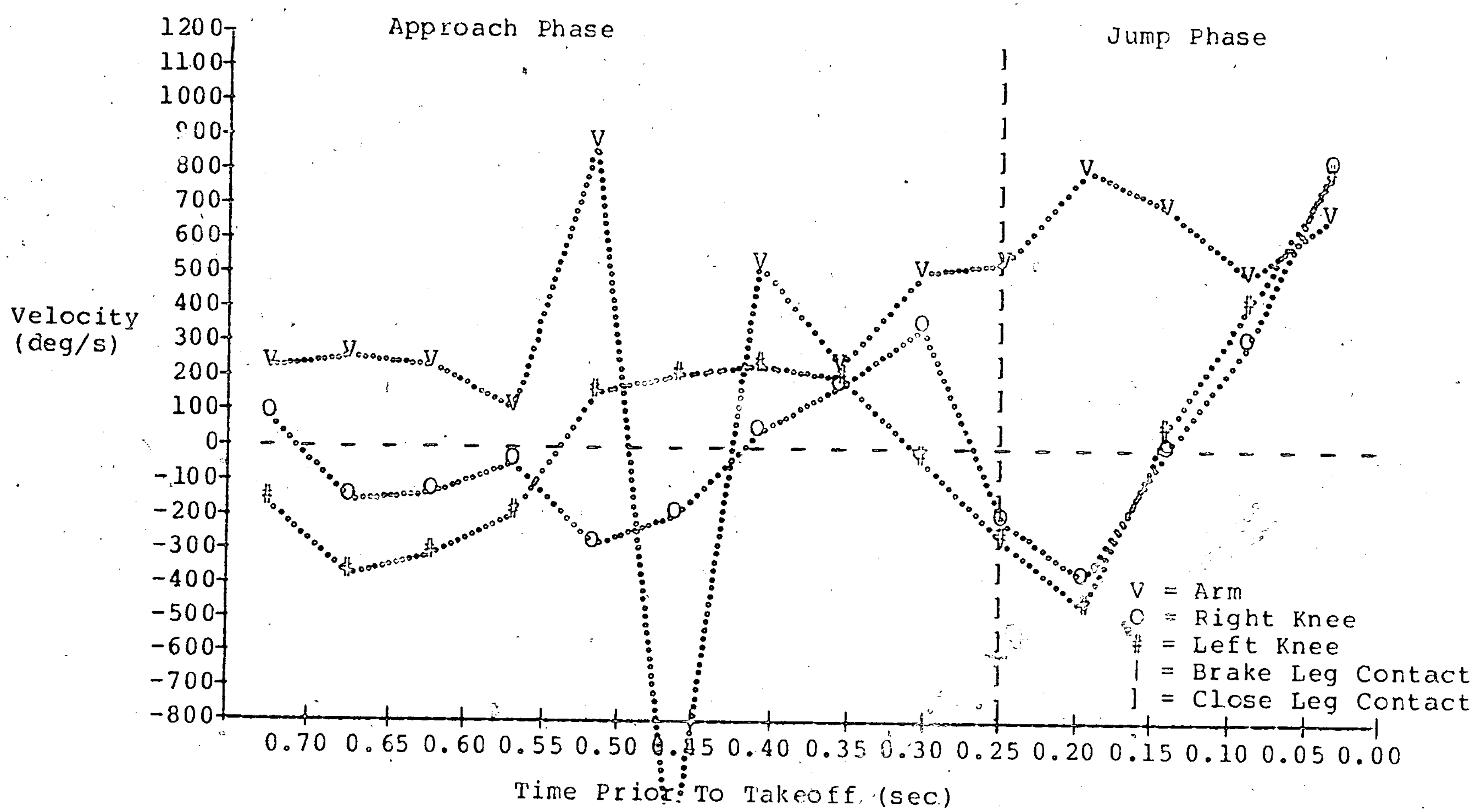


Figure B14: Subject 7, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

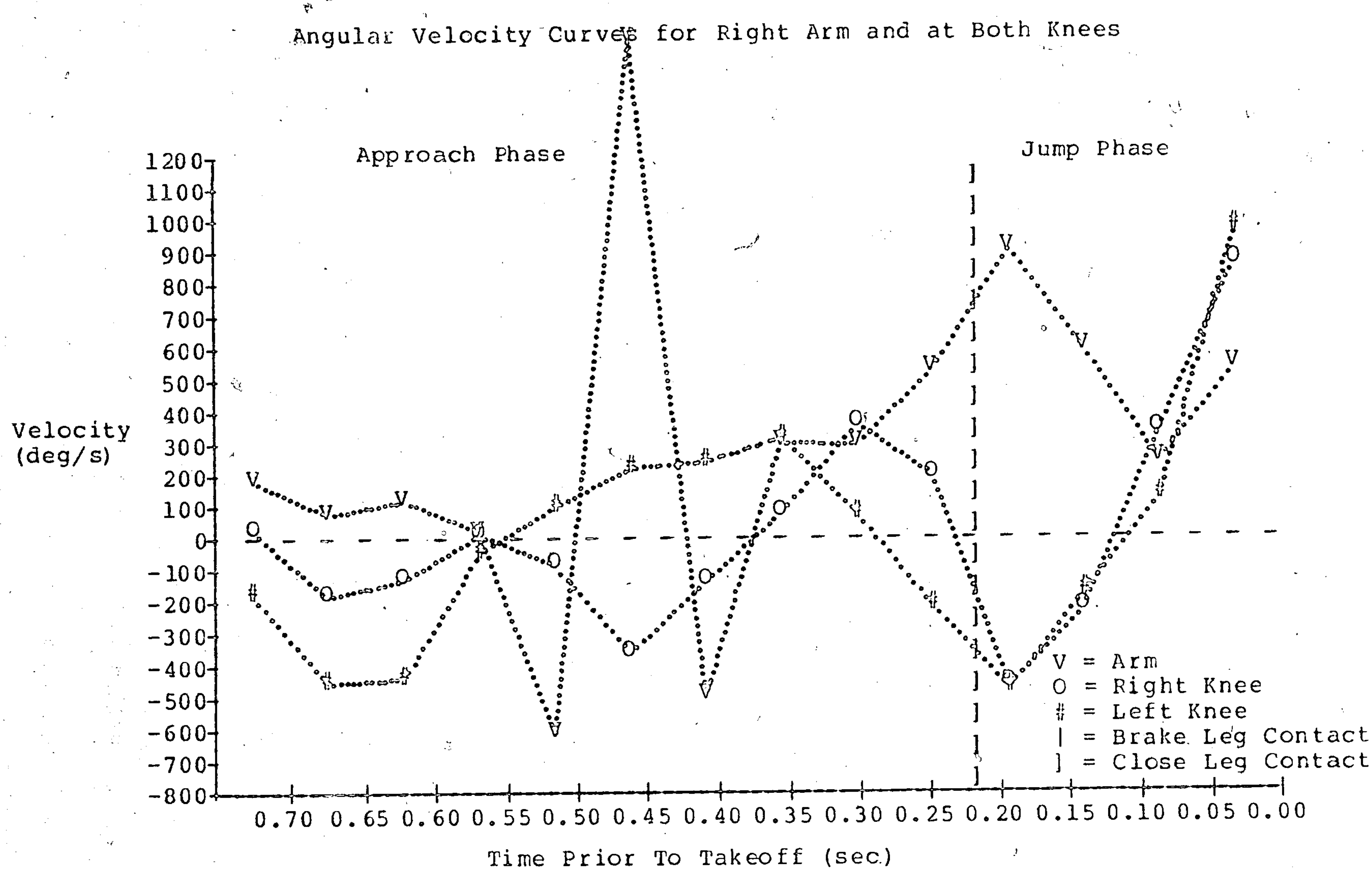


Figure B15: Subject 8, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

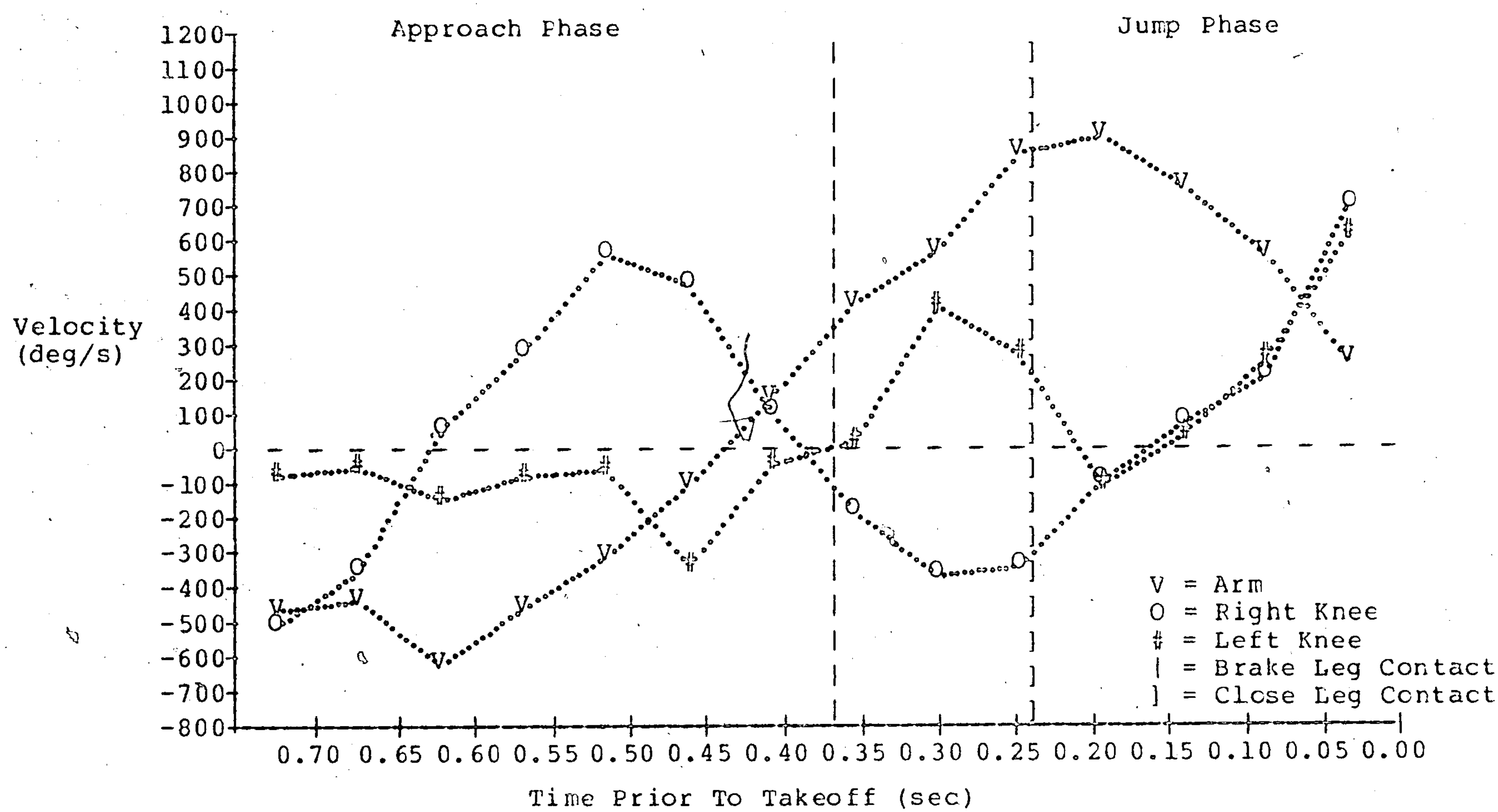


Figure B16: Subject 8, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

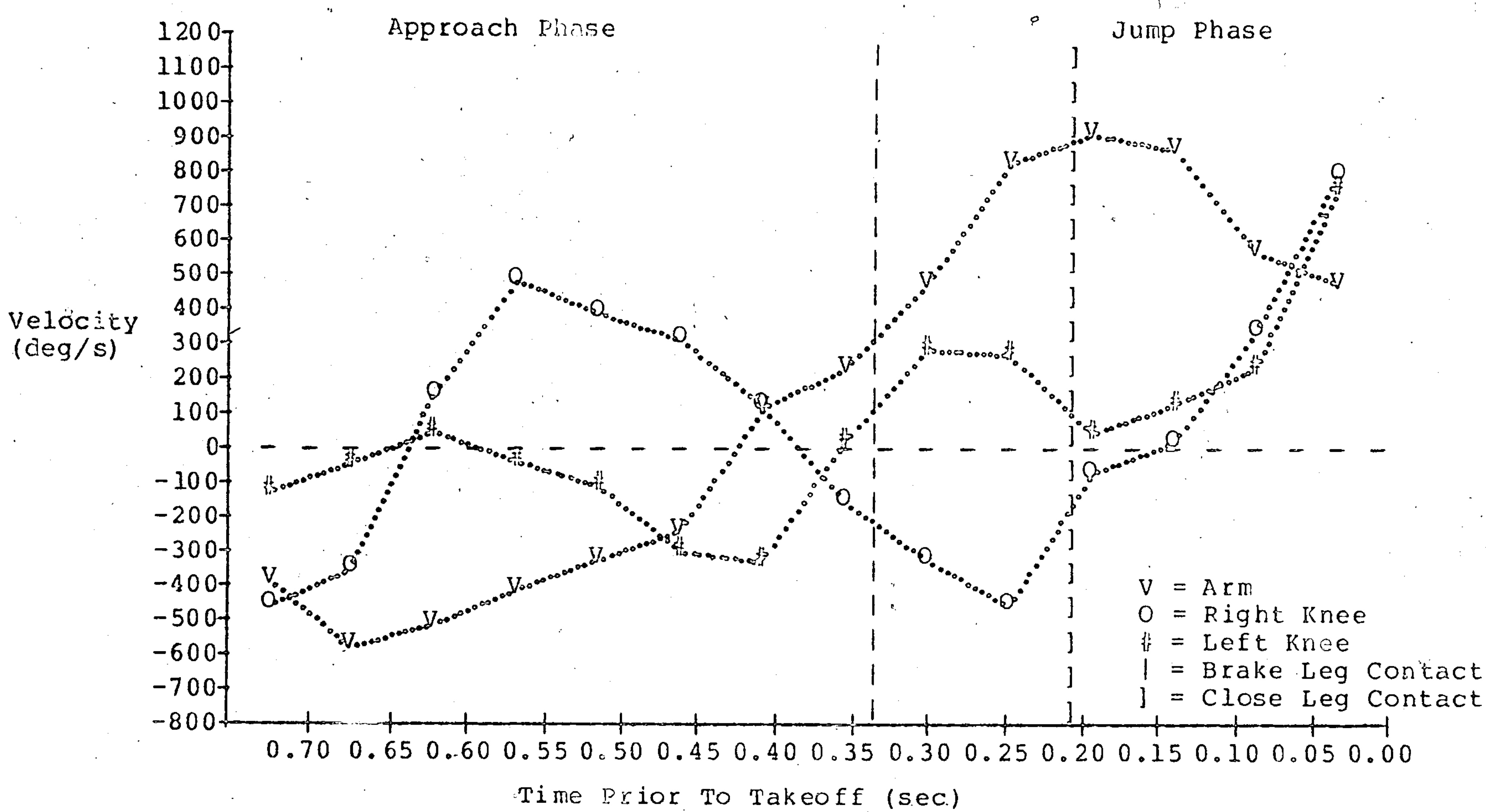


Figure B17: Subject 9, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

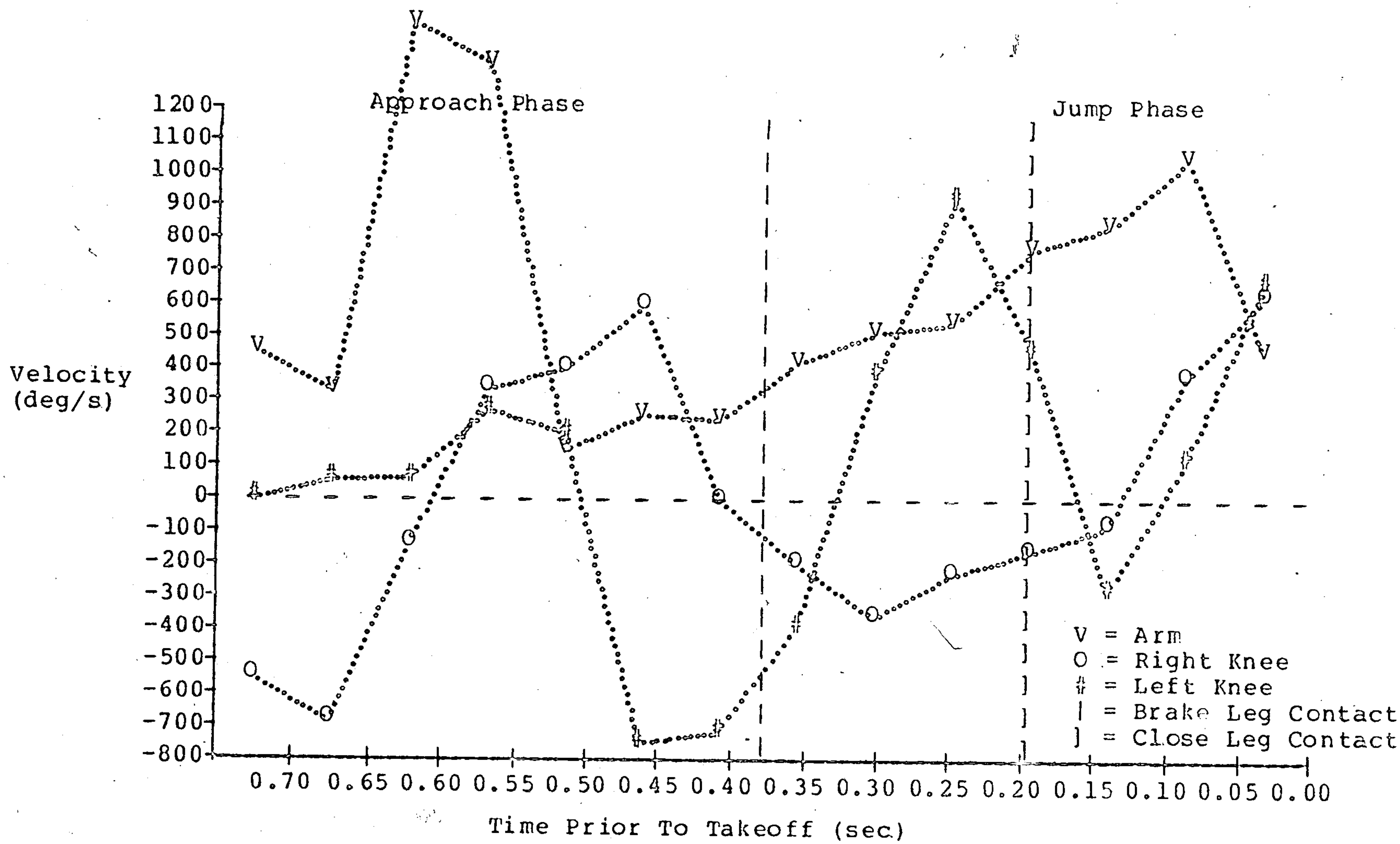


Figure B18: Subject 9, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

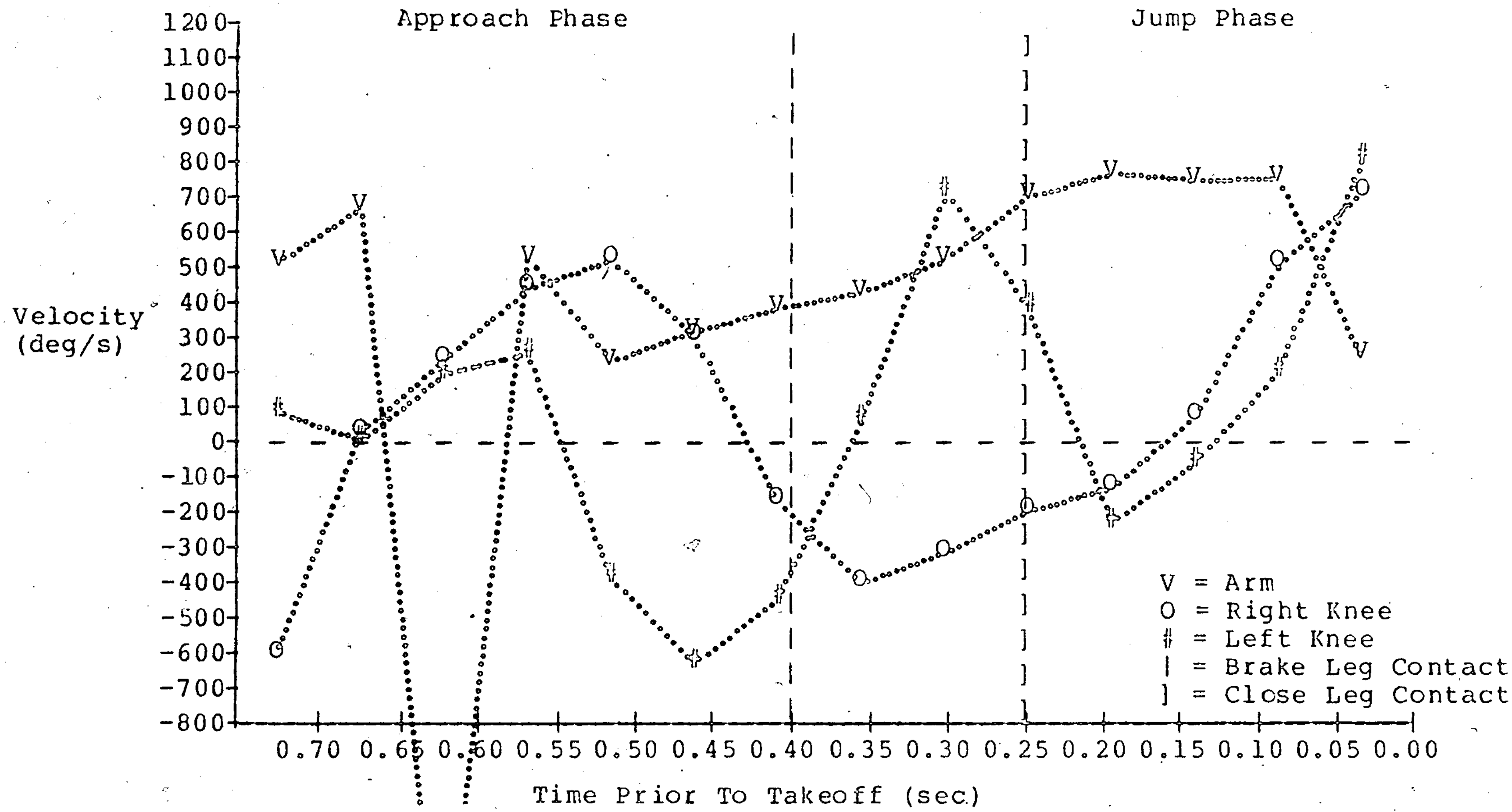


Figure B19: Subject 10, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

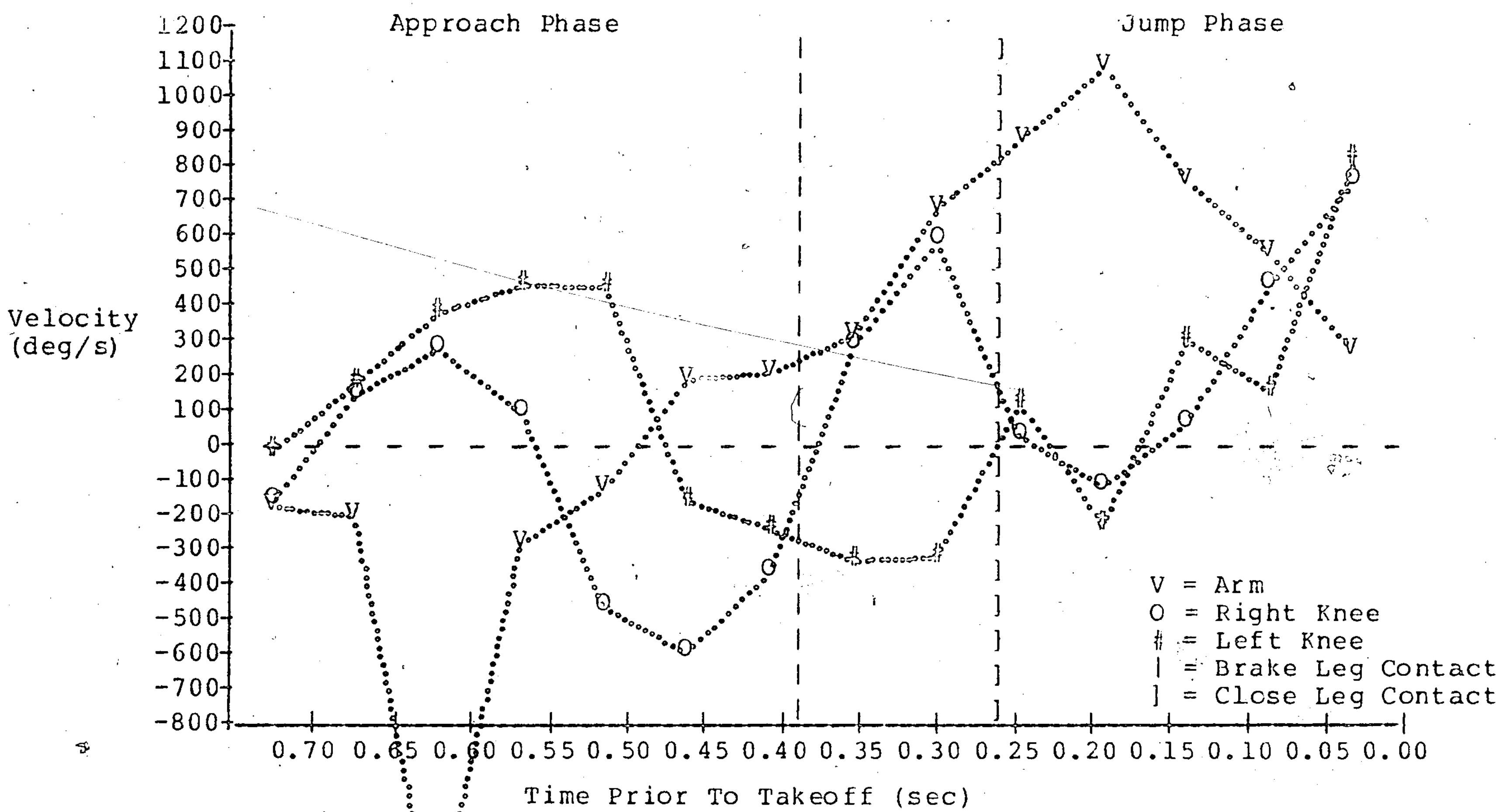


Figure B20: Subject 10, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

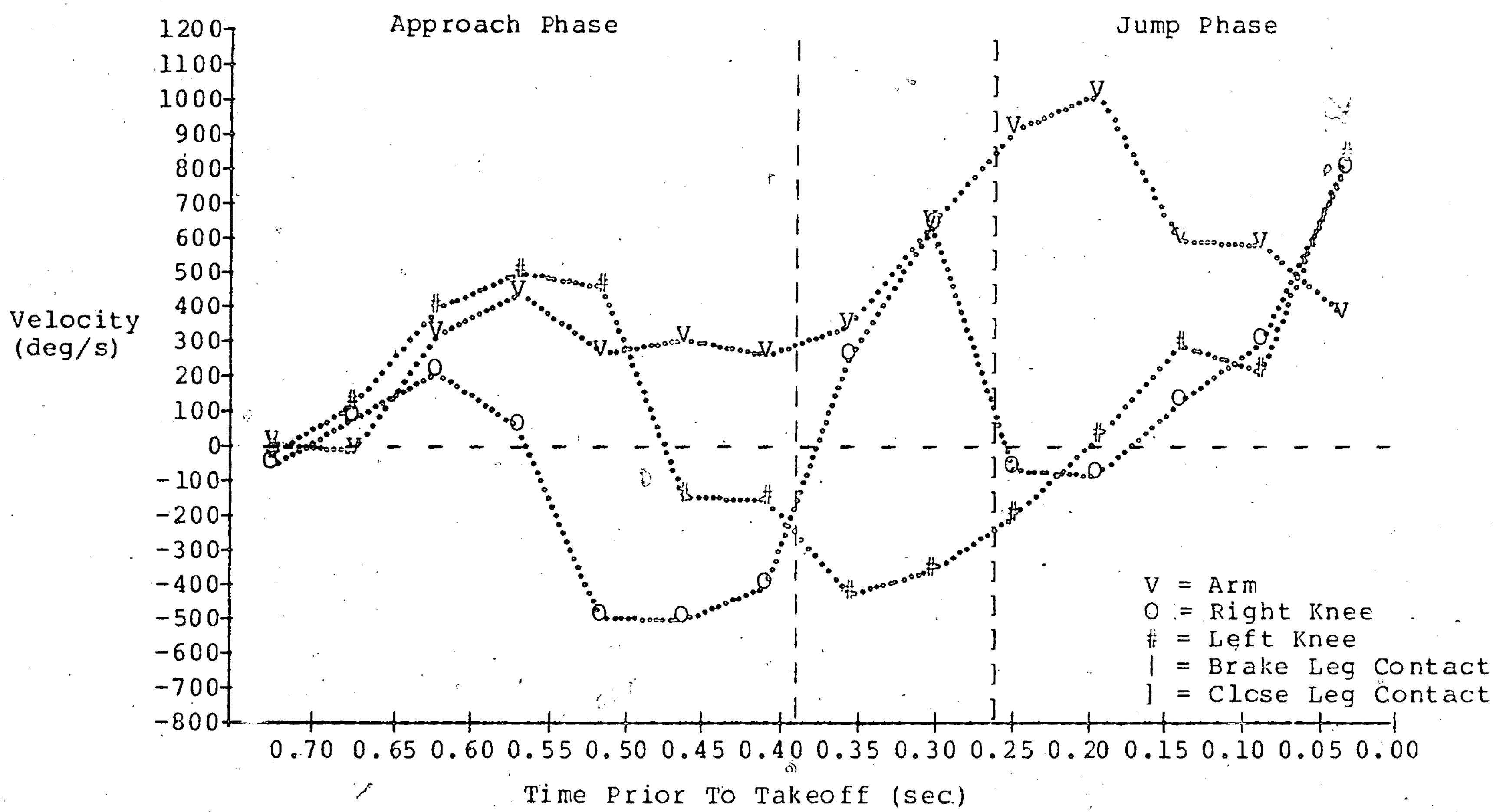


Figure B21: Subject 11, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

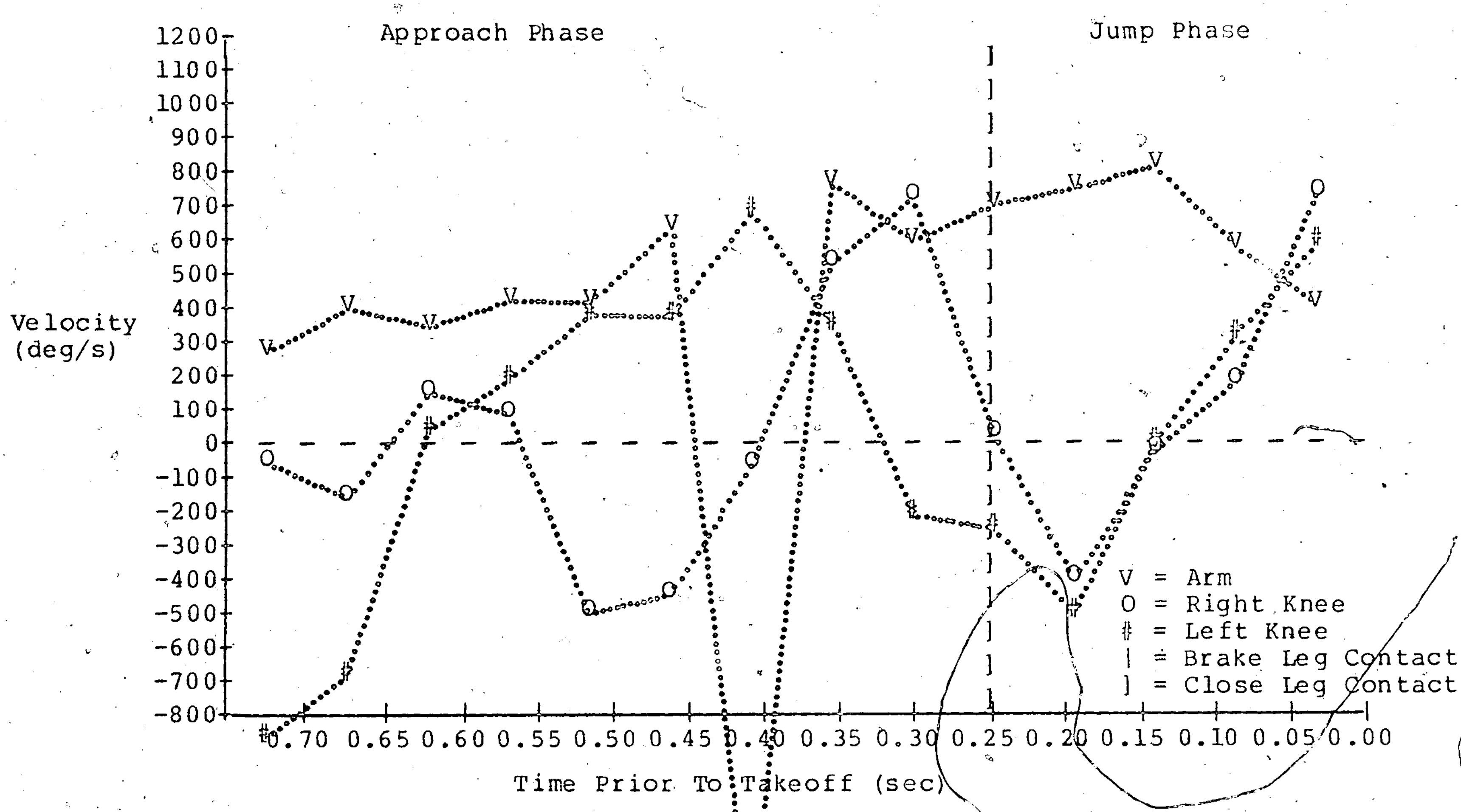


Figure B22: Subject 11, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

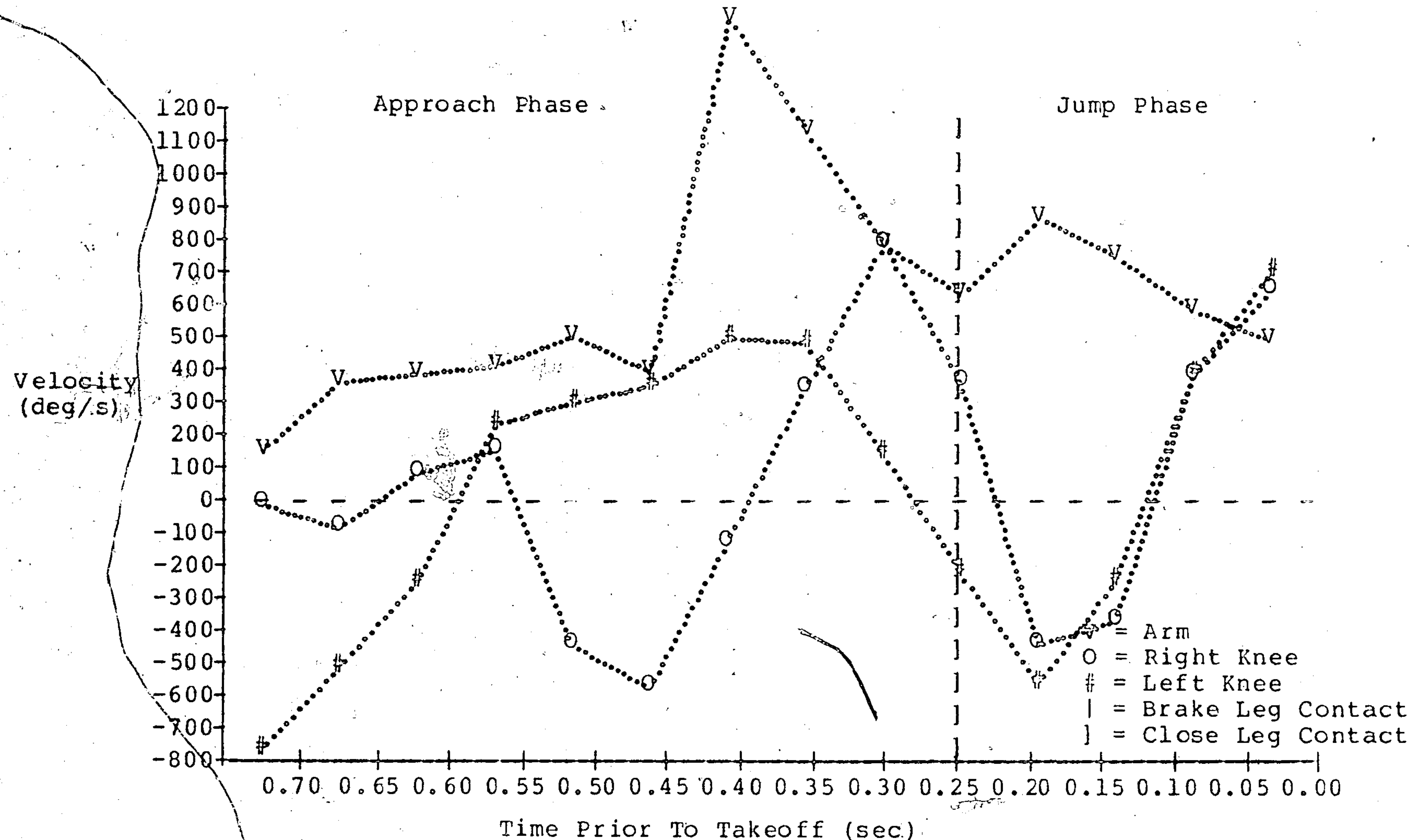


Figure B23: Subject 12, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

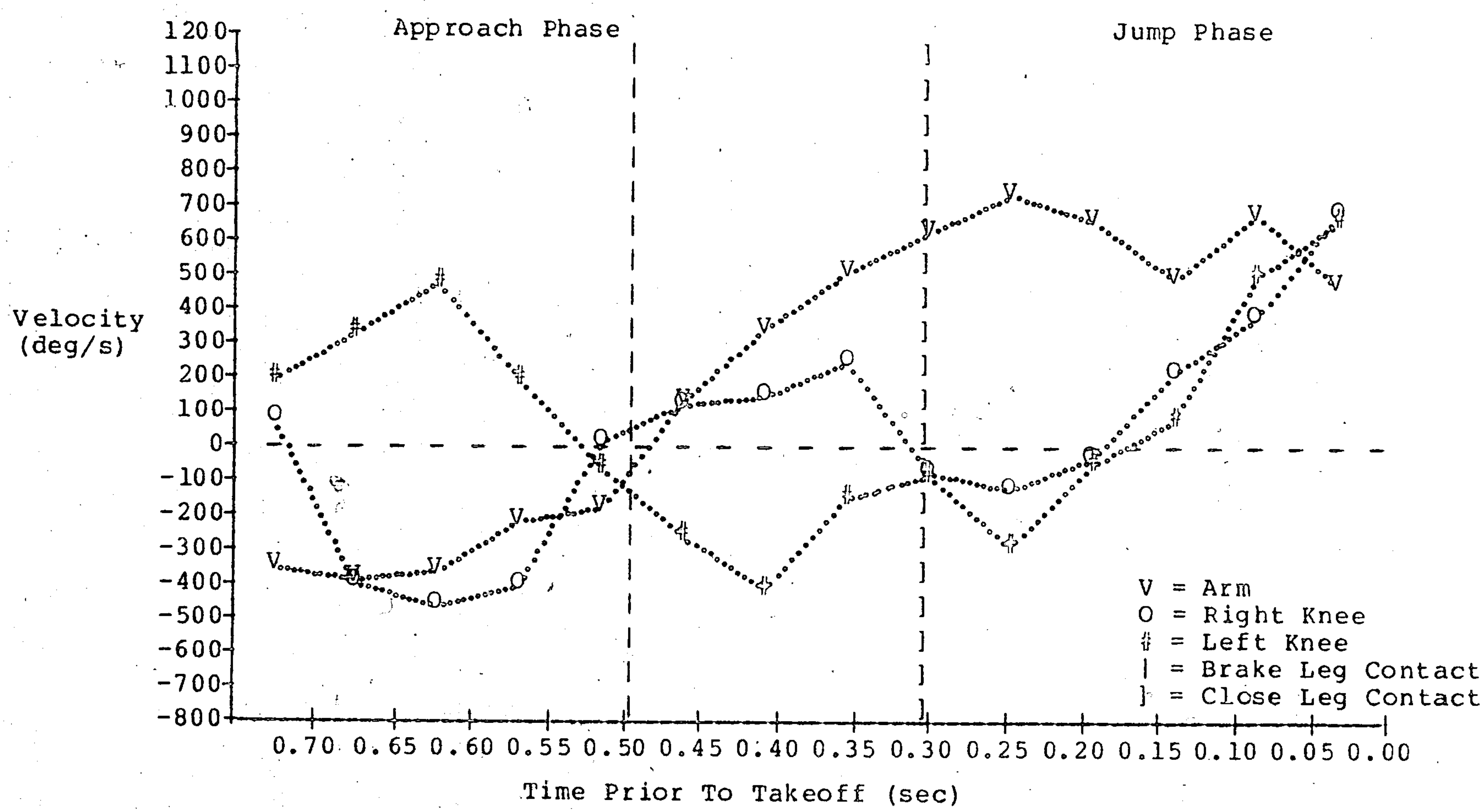


Figure B24: Subject 12, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

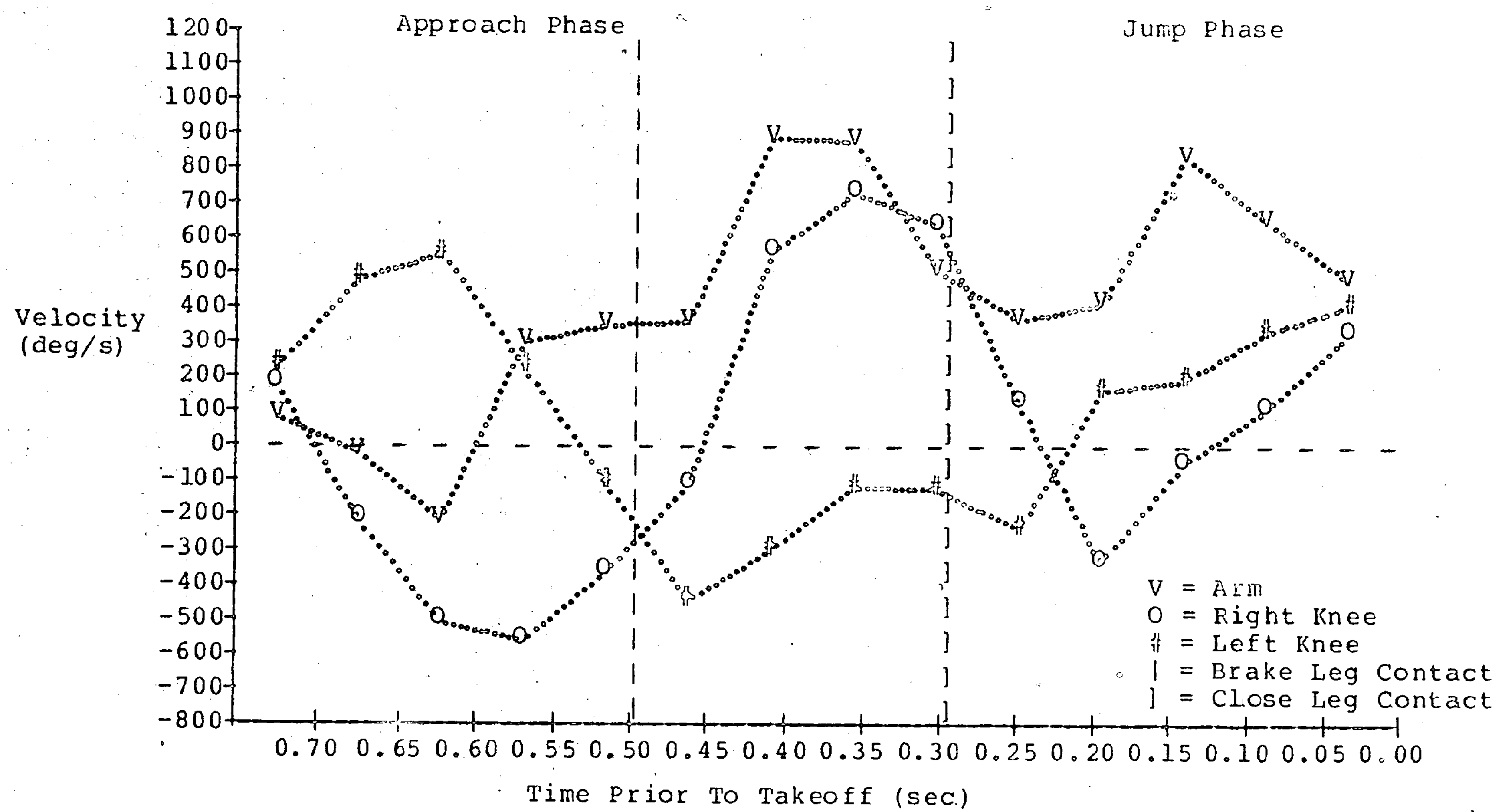


Figure B25: Subject 13, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

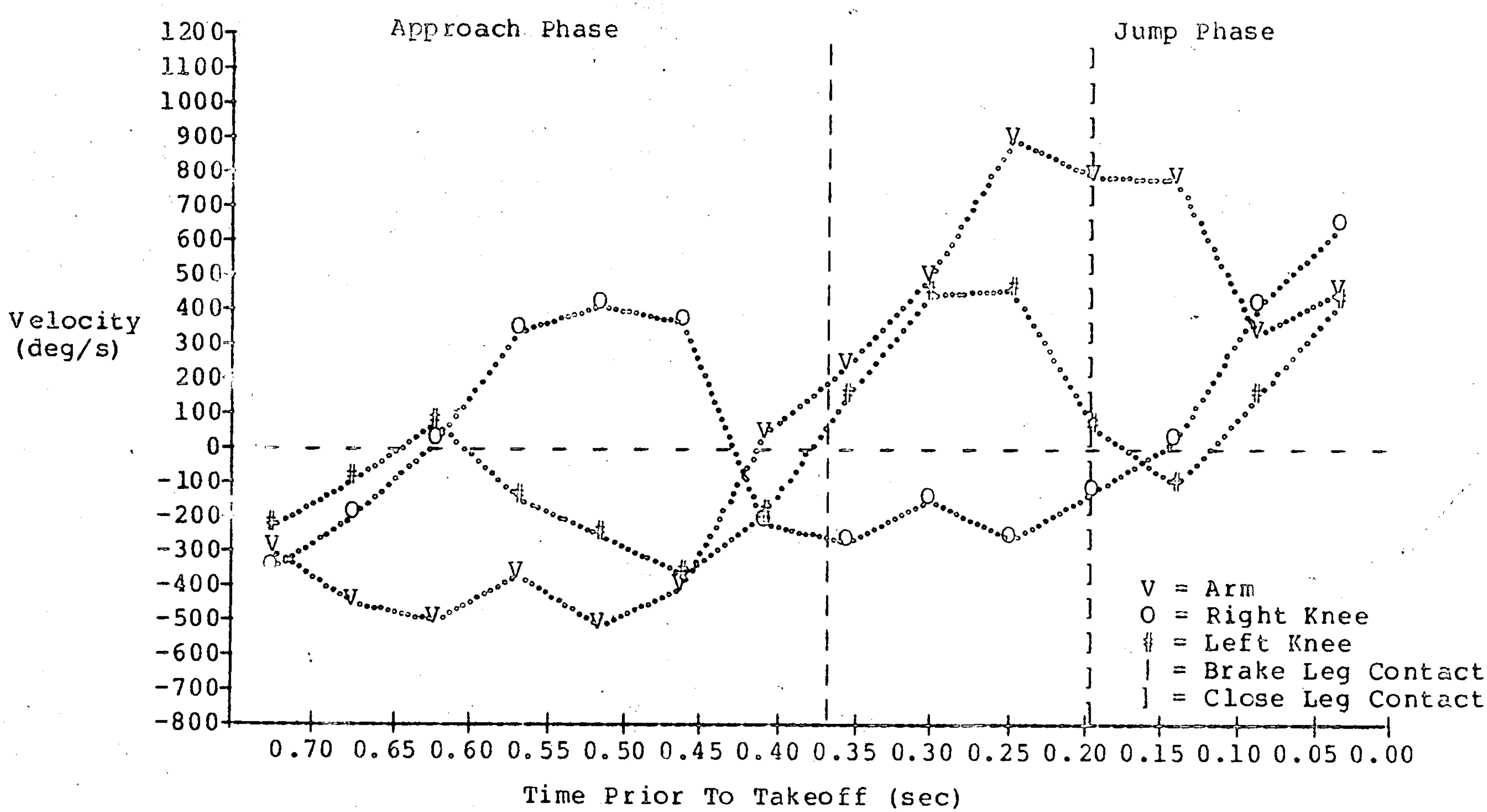


Figure B26: Subject 13, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

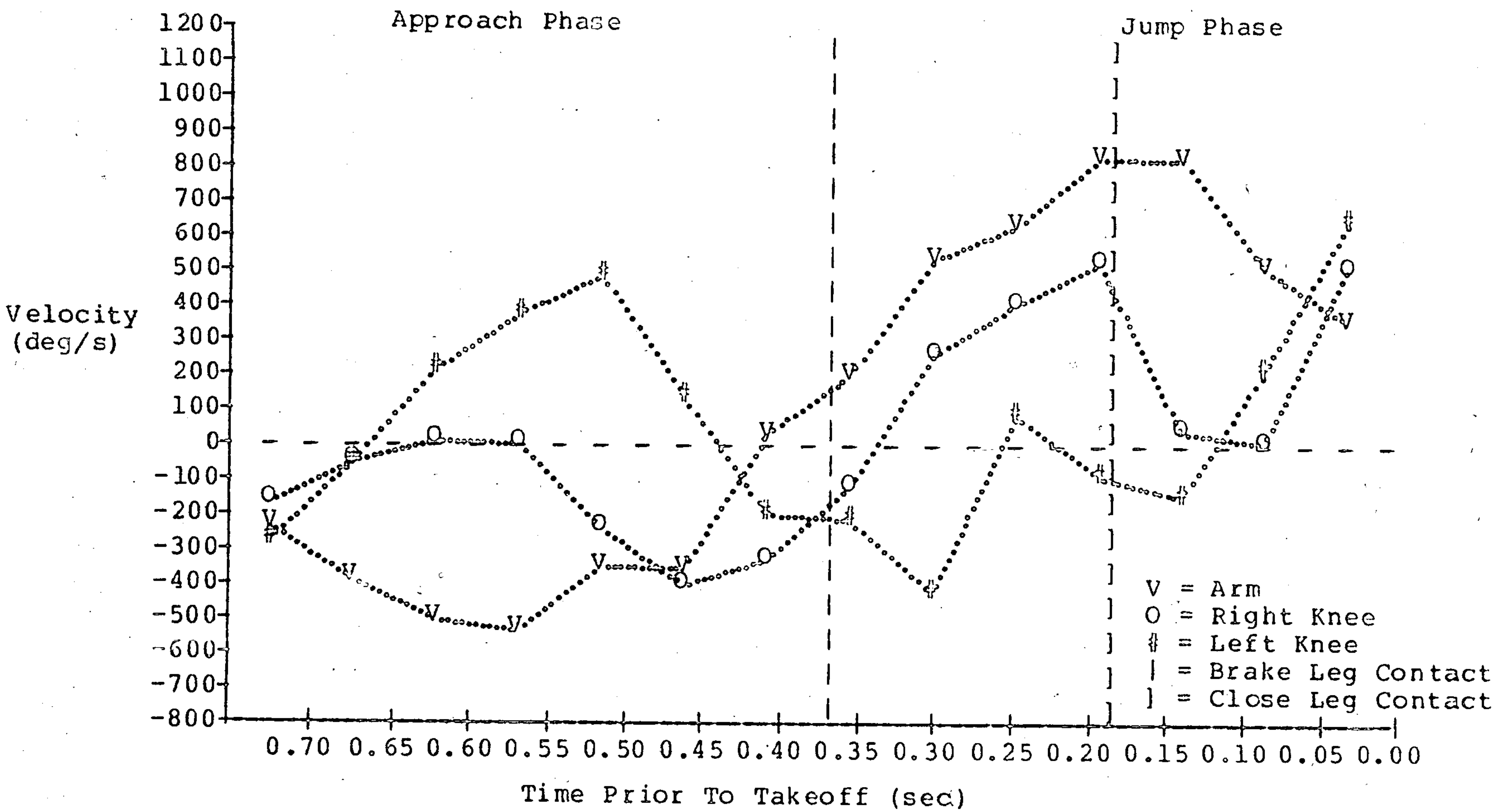


Figure B27: Subject 14, Jump 1

Angular Velocity Curves for Right Arm and Both Knees

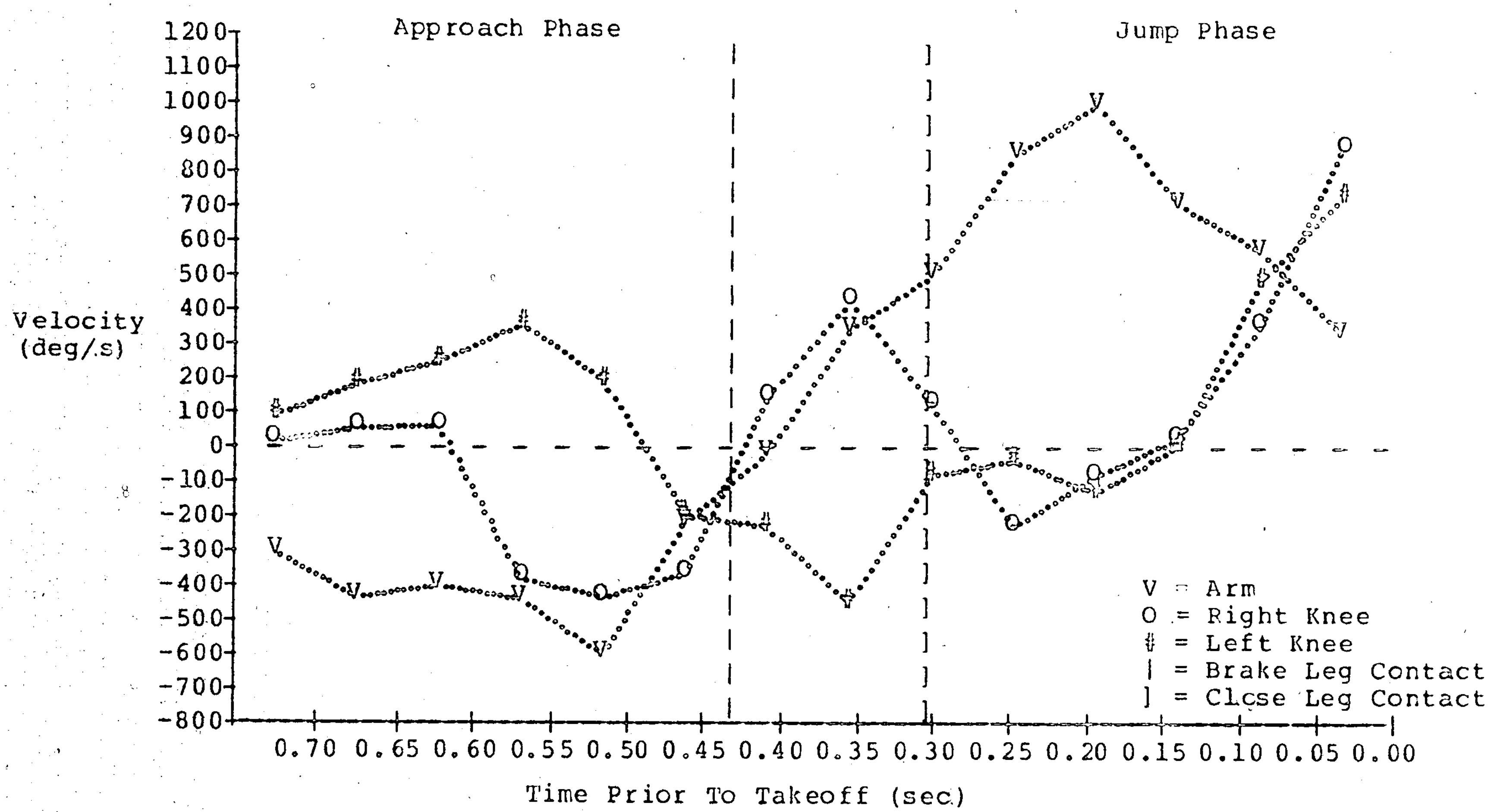


Figure B28: Subject 14, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

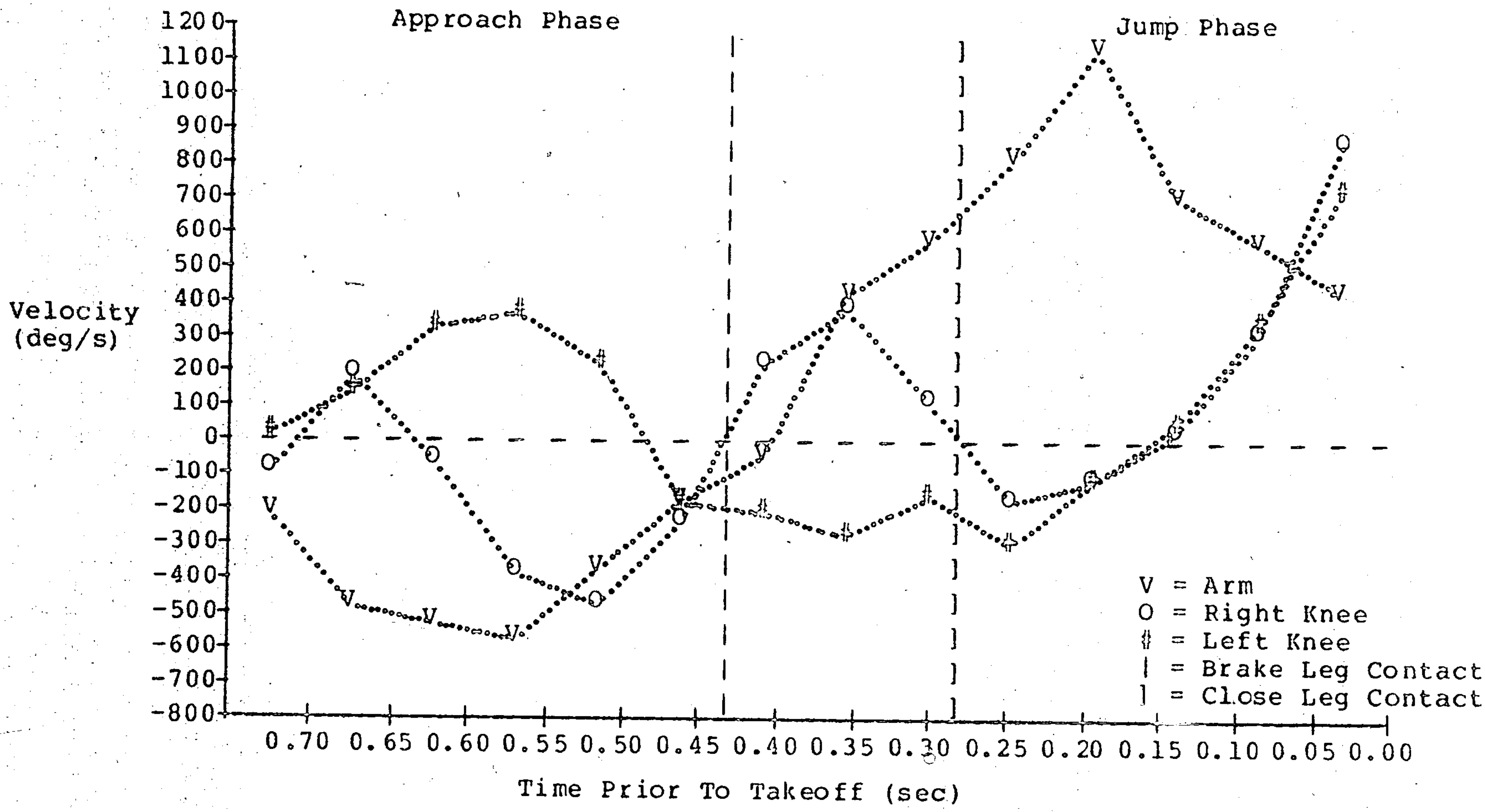


Figure B29: Subject 15, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

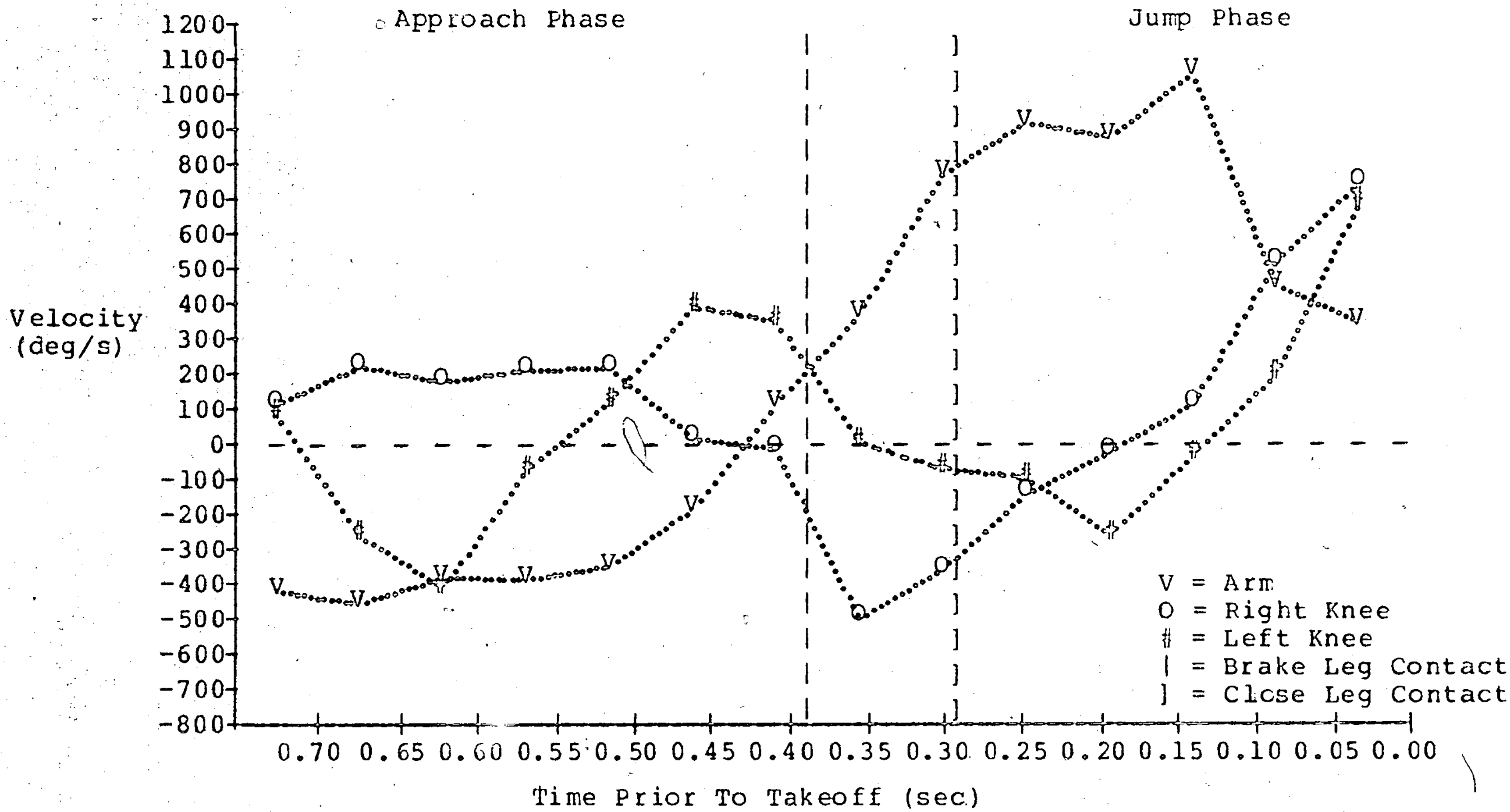


Figure B30: Subject 15, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

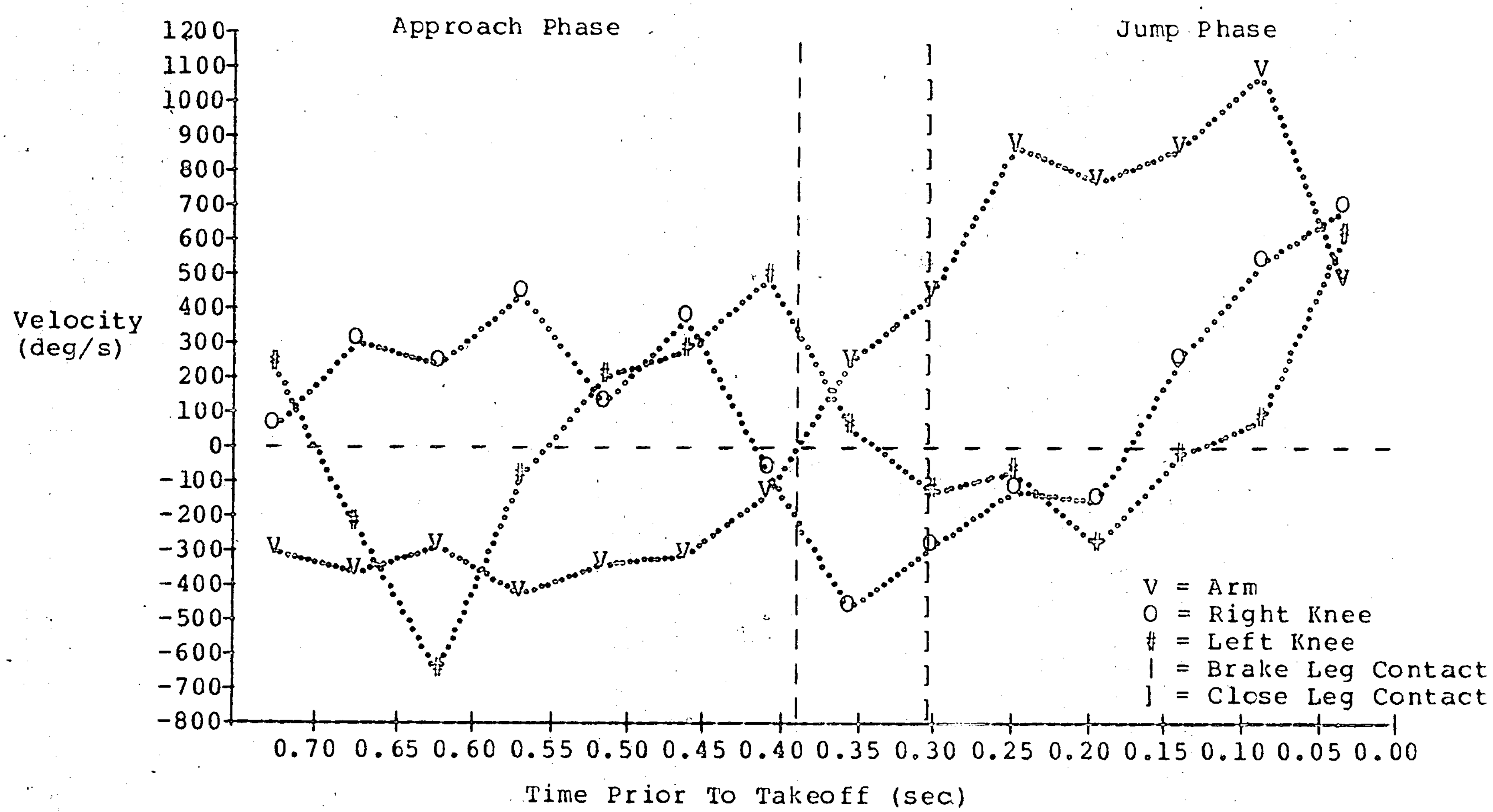


Figure B31: Subject 16, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

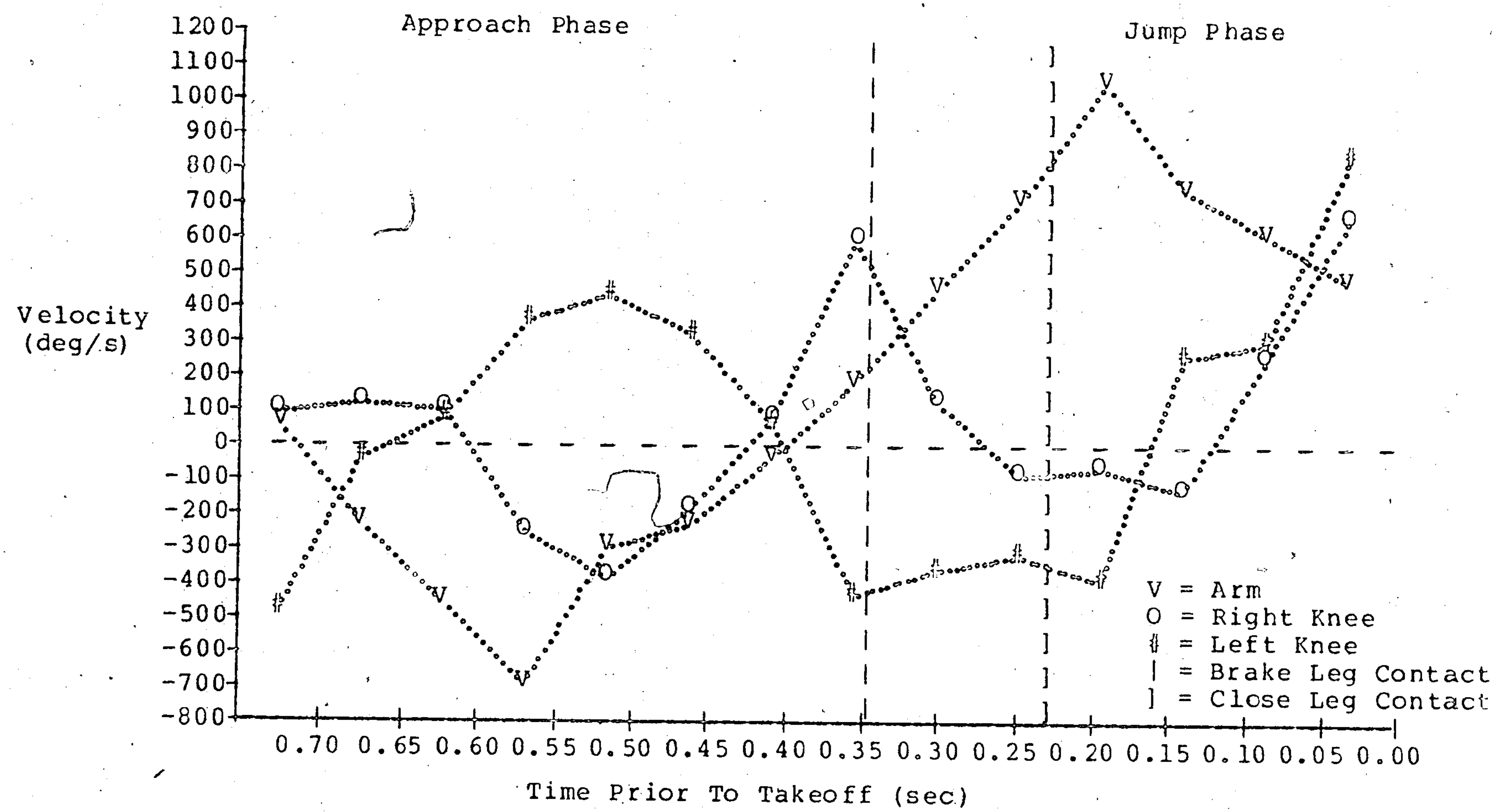


Figure B32: Subject 16, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

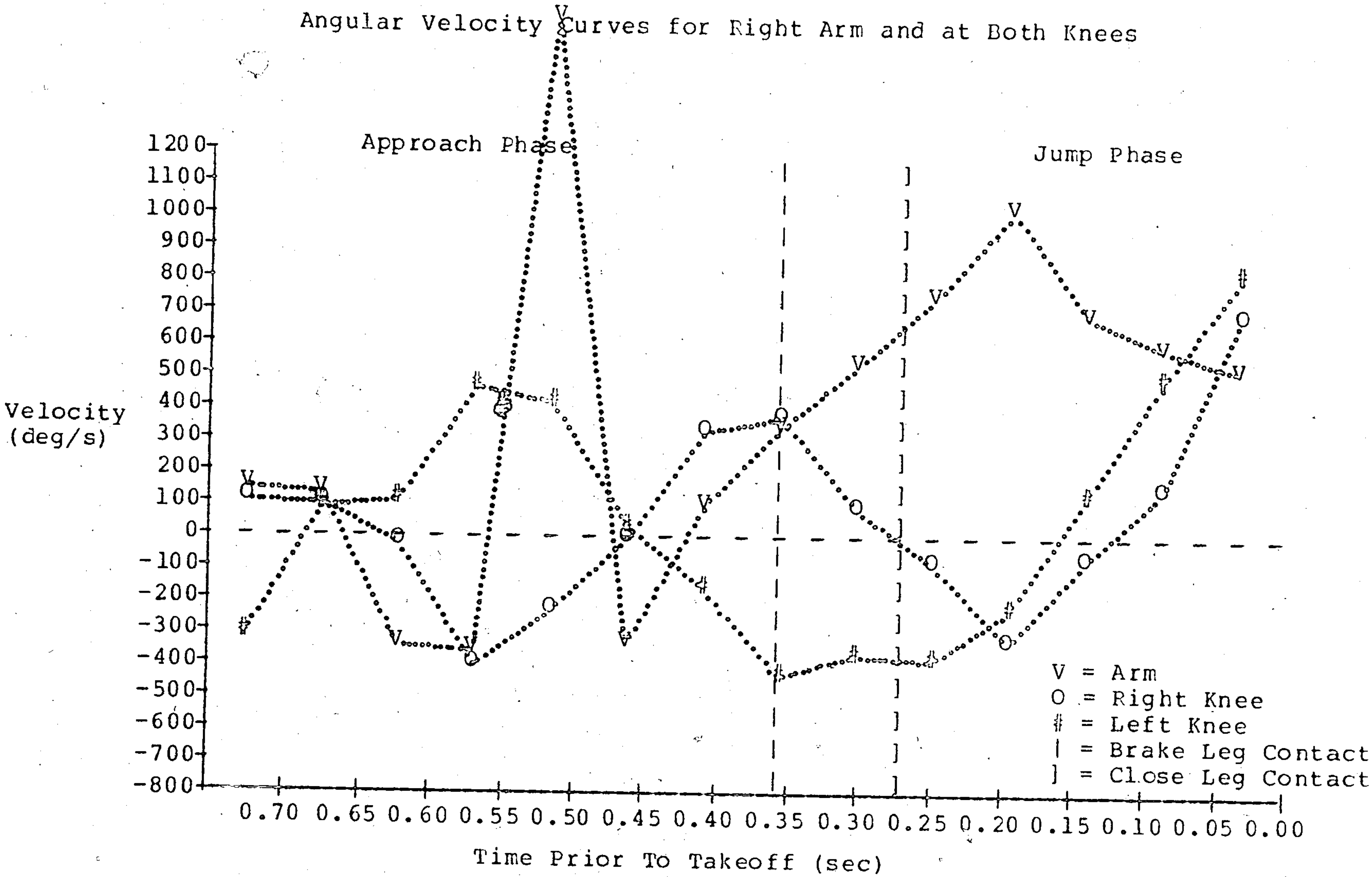


Figure B33: Subject 17, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

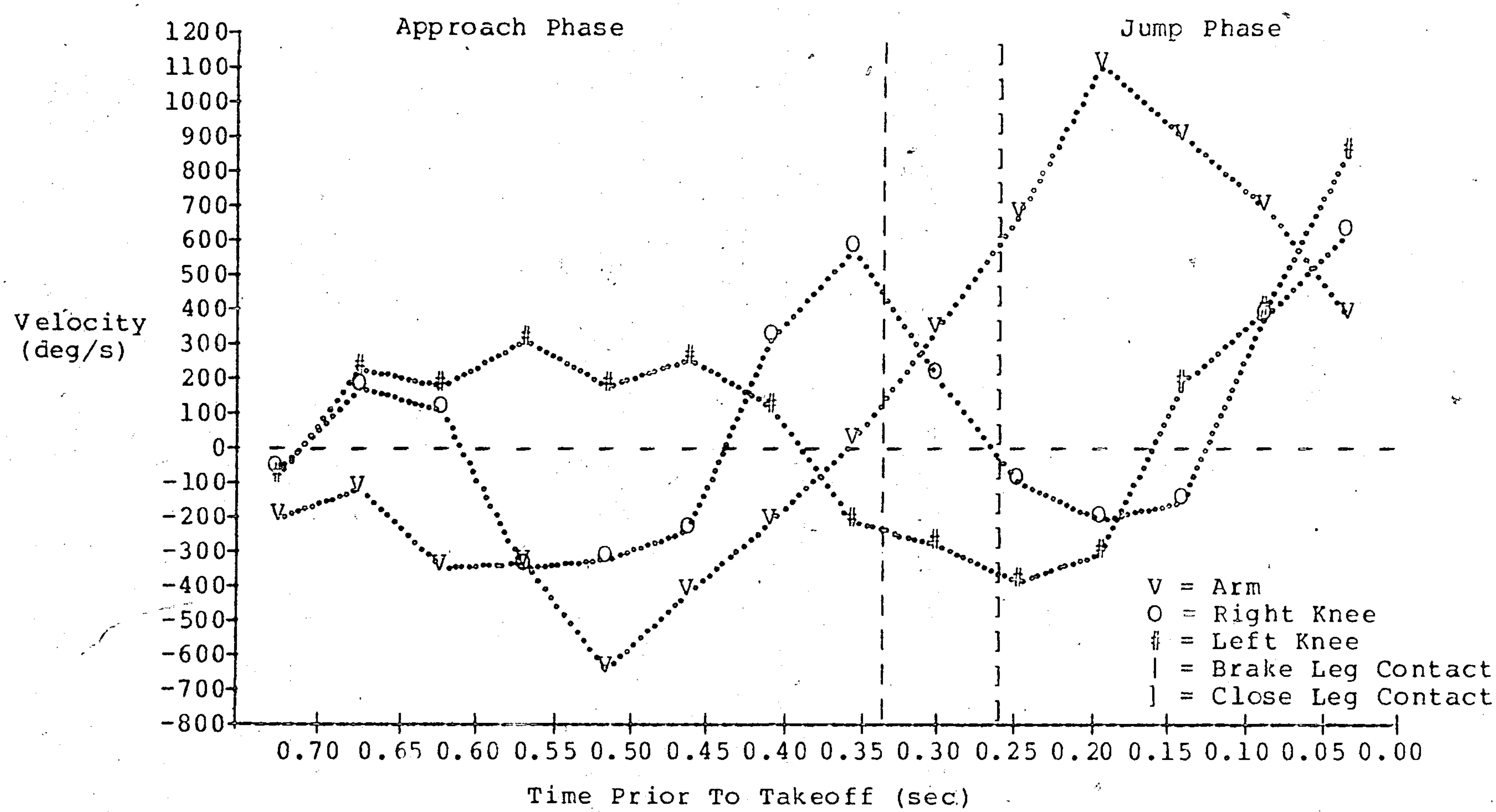


Figure B34: Subject 7, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

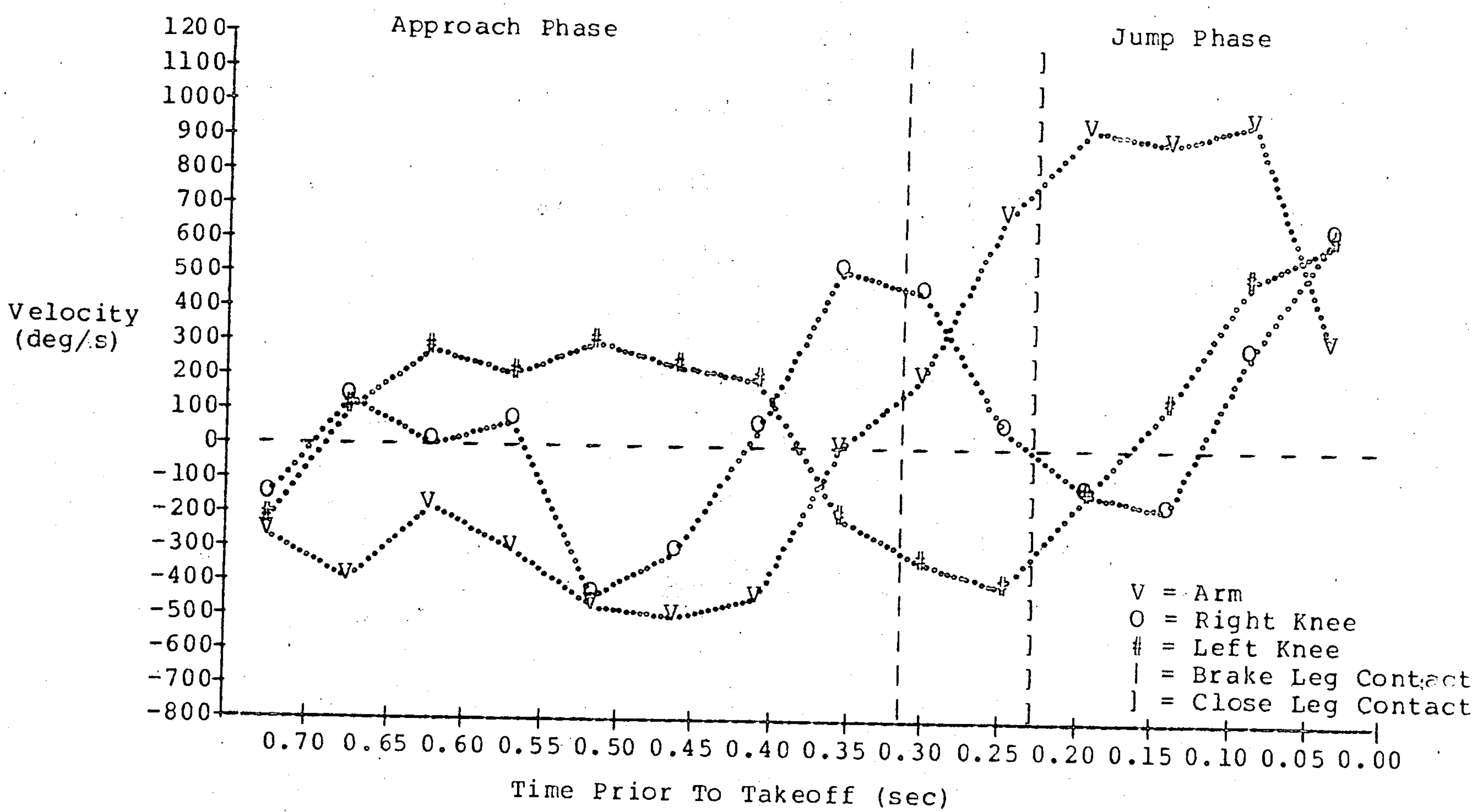


Figure B35: Subject 18, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

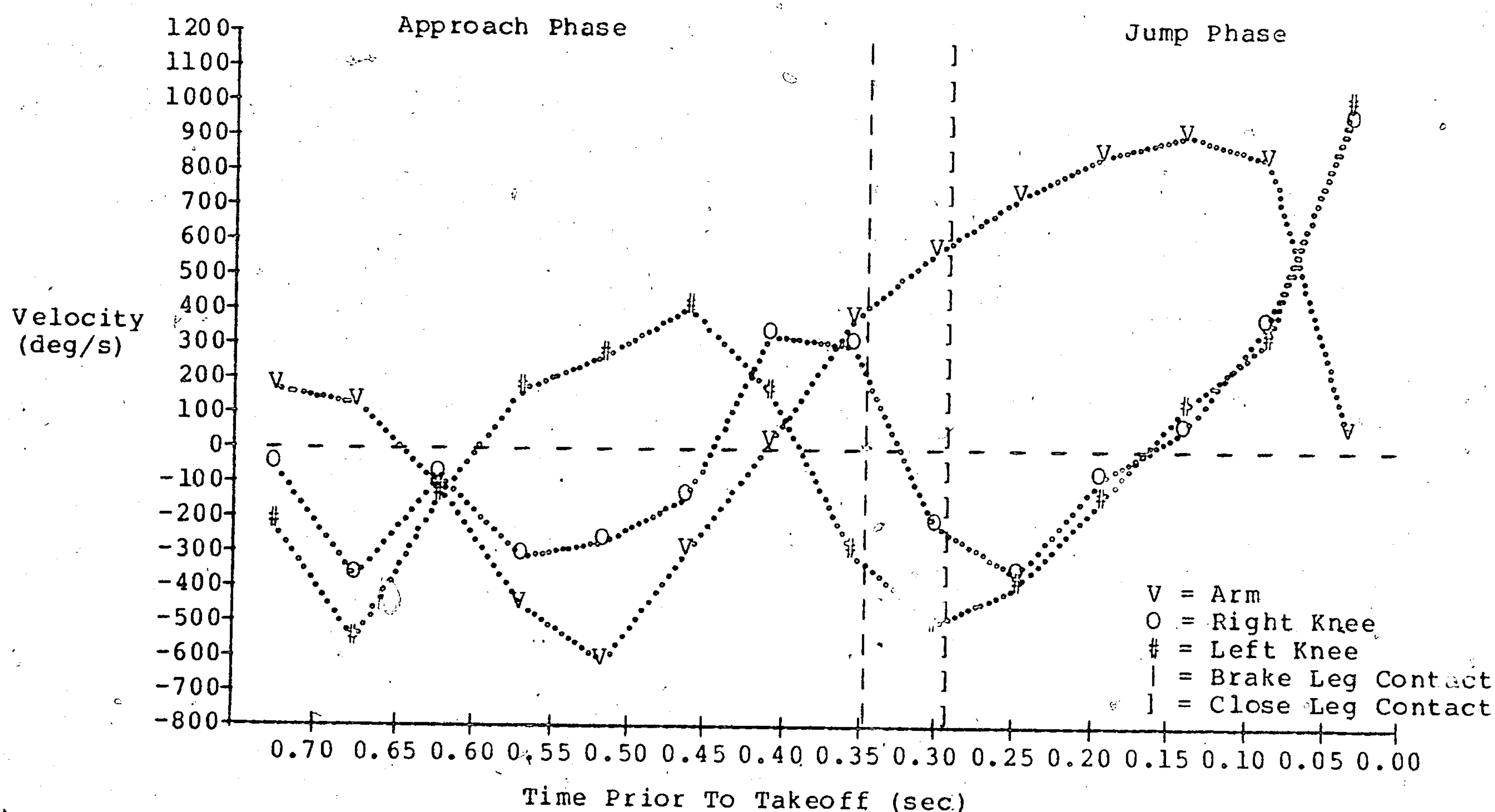


Figure B36: Subject 18, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

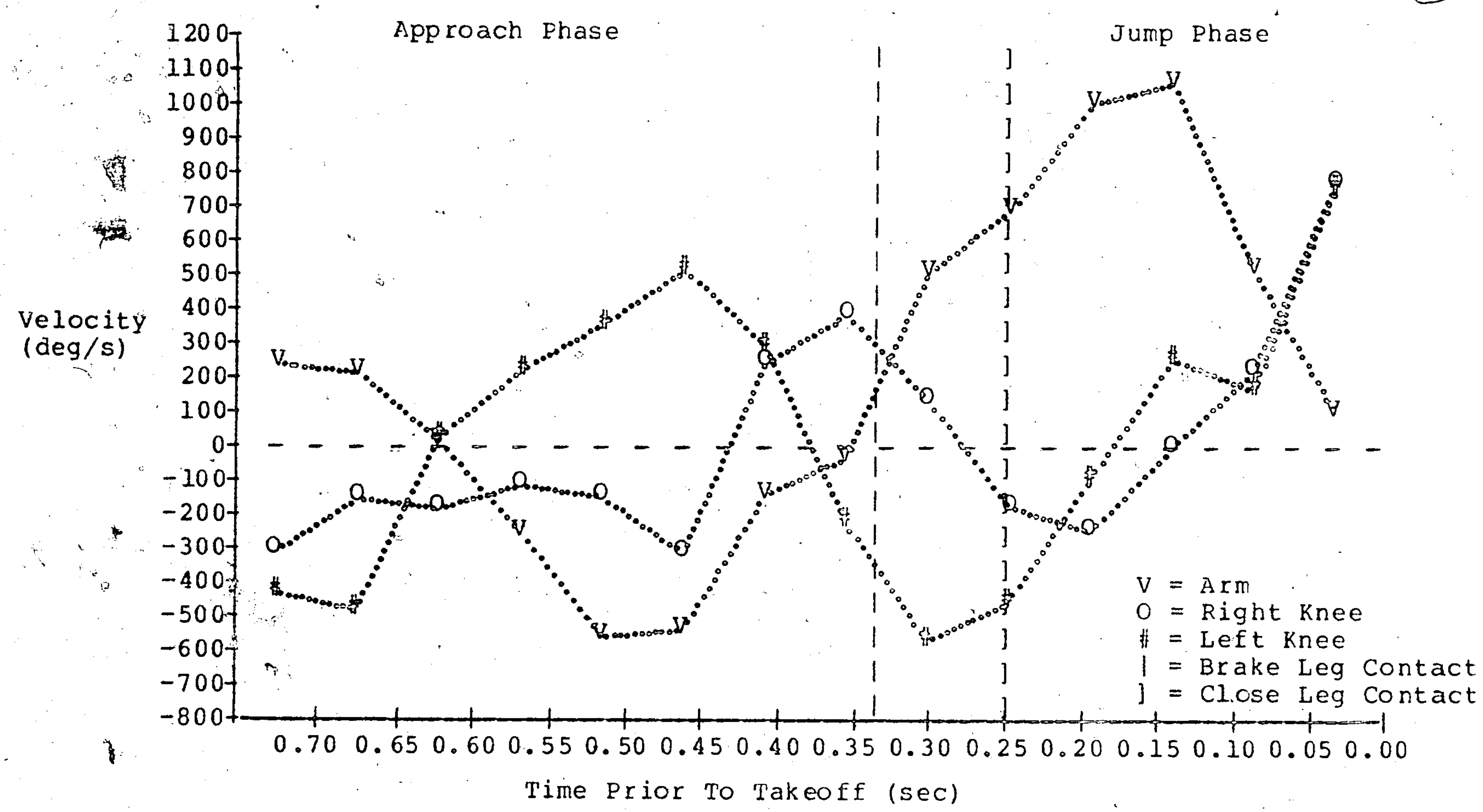


Figure B37: Subject 19, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

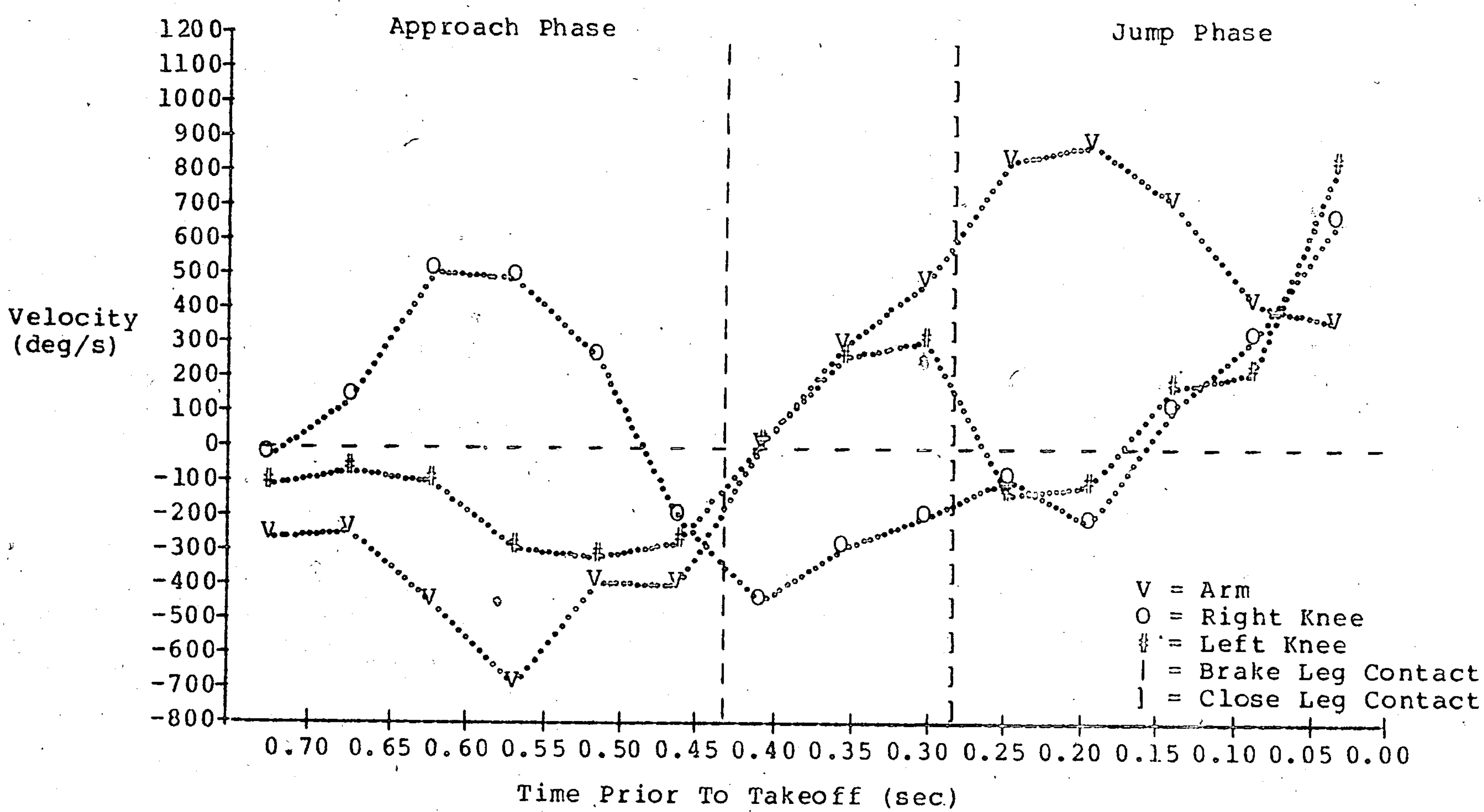


Figure B38: Subject 19, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

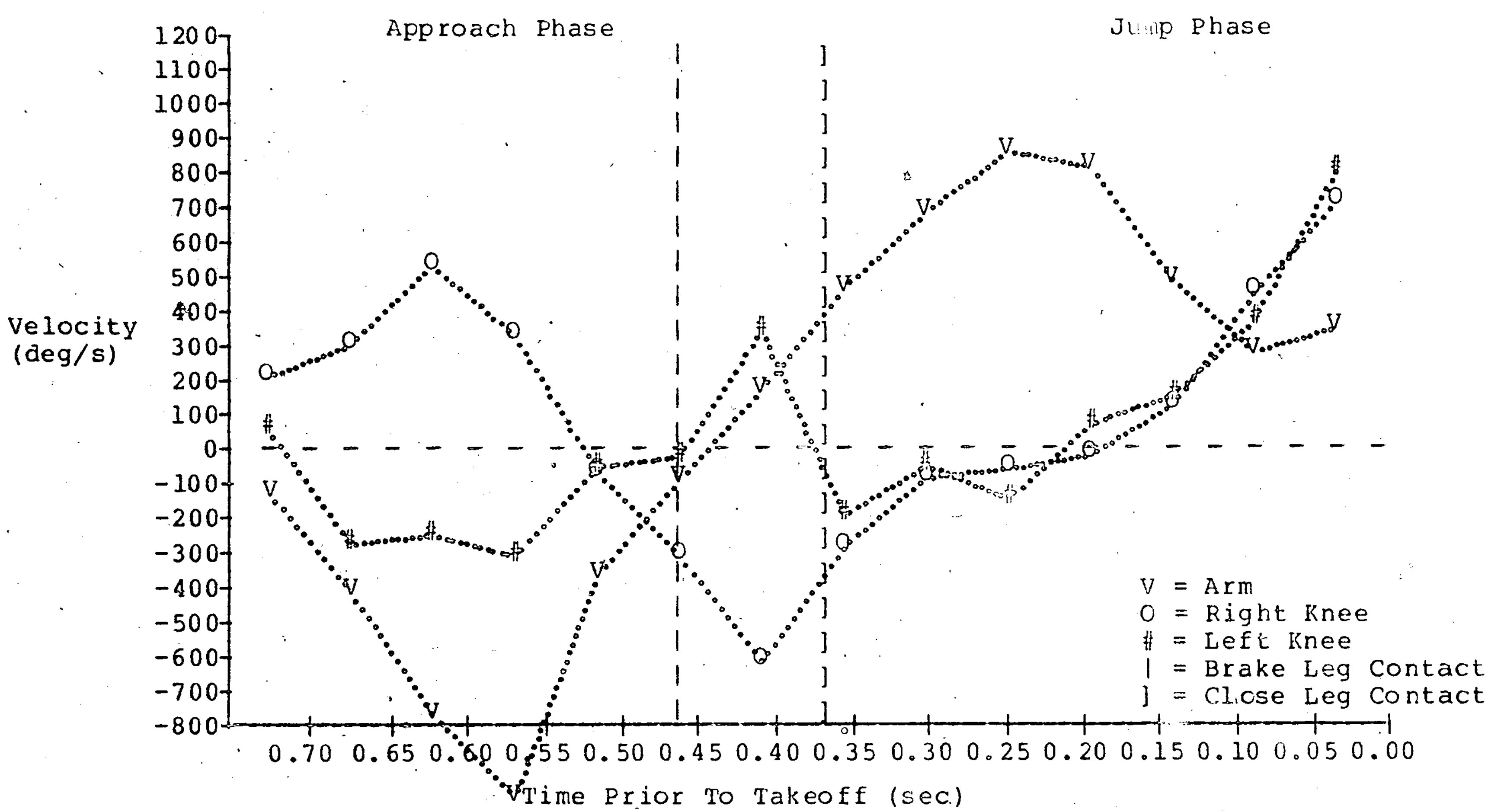


Figure B39: Subject 20, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

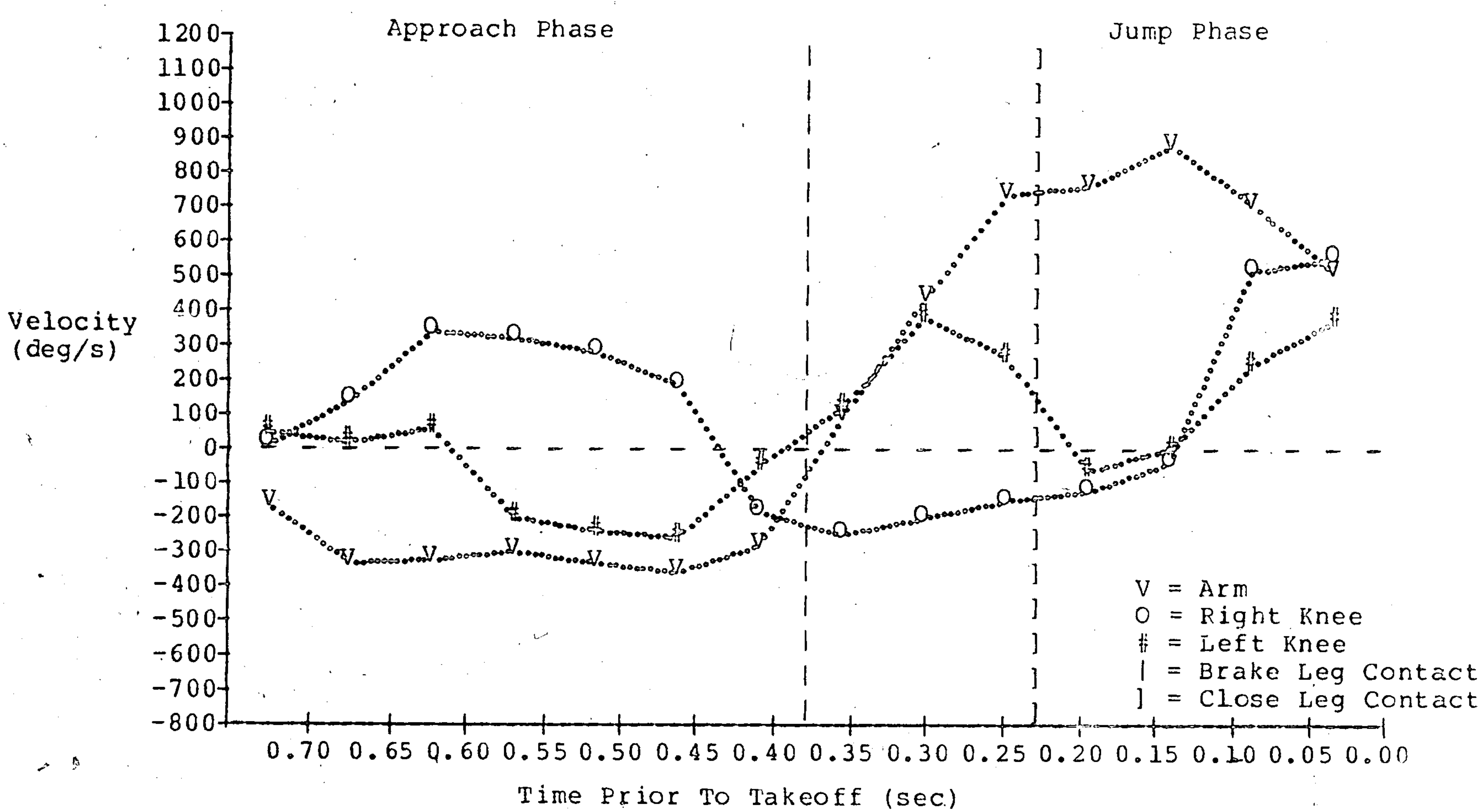


Figure B40: Subject 20, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

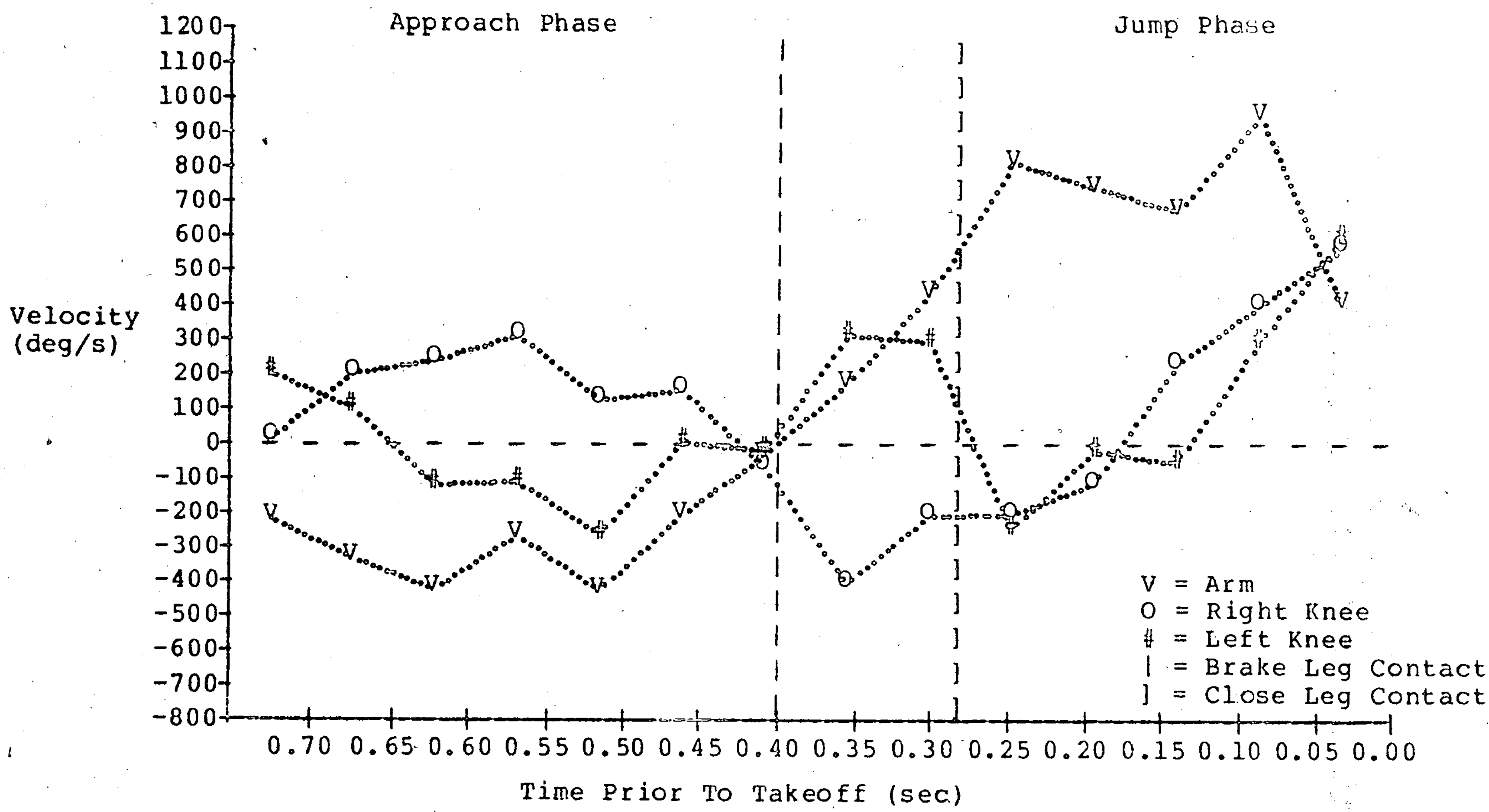


Figure B41: Subject 21, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

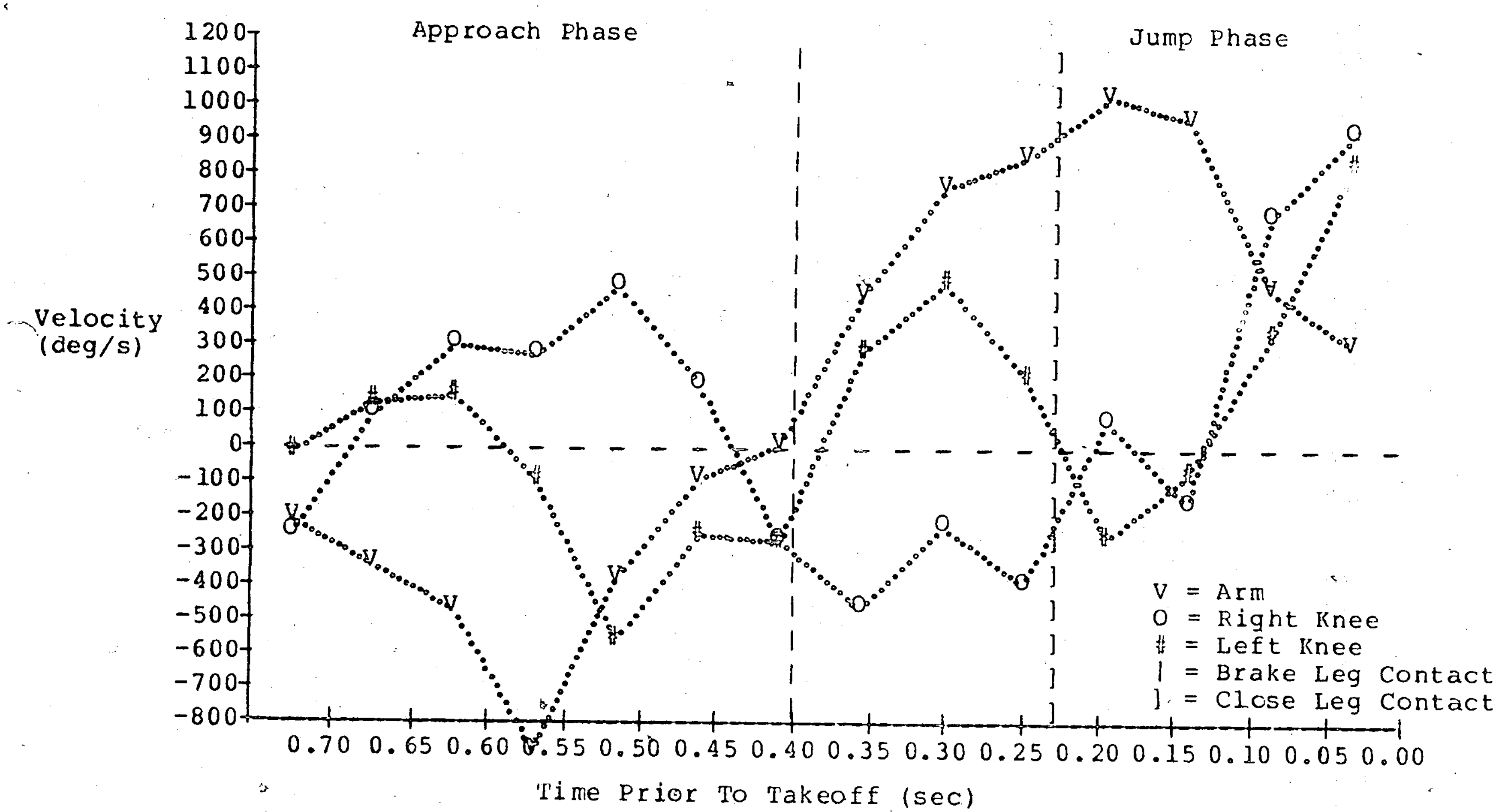


Figure B42: Subject 21, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees

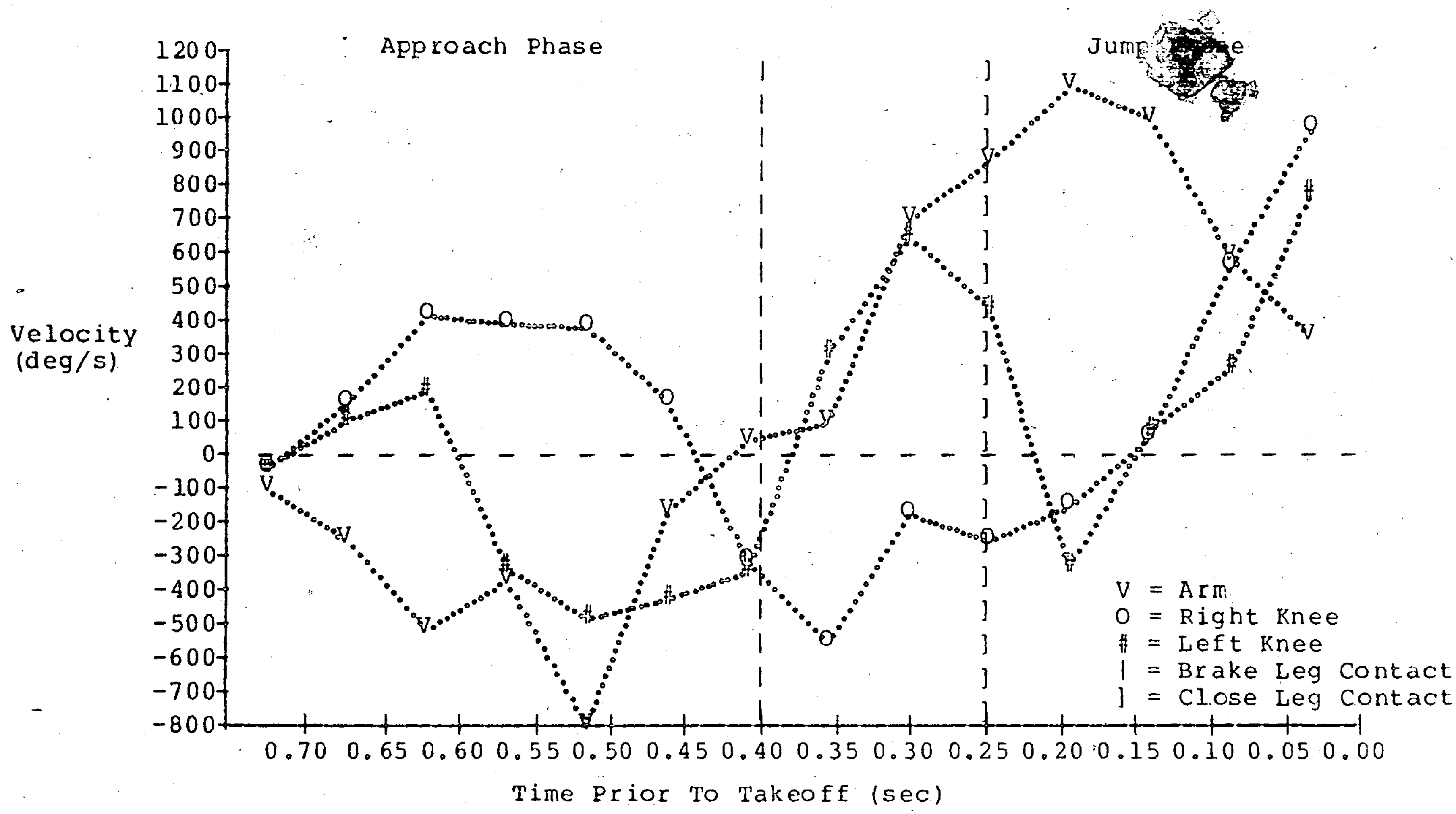


Figure B43: Subject 22, Jump 1

Angular Velocity Curves for Right Arm and at Both Knees

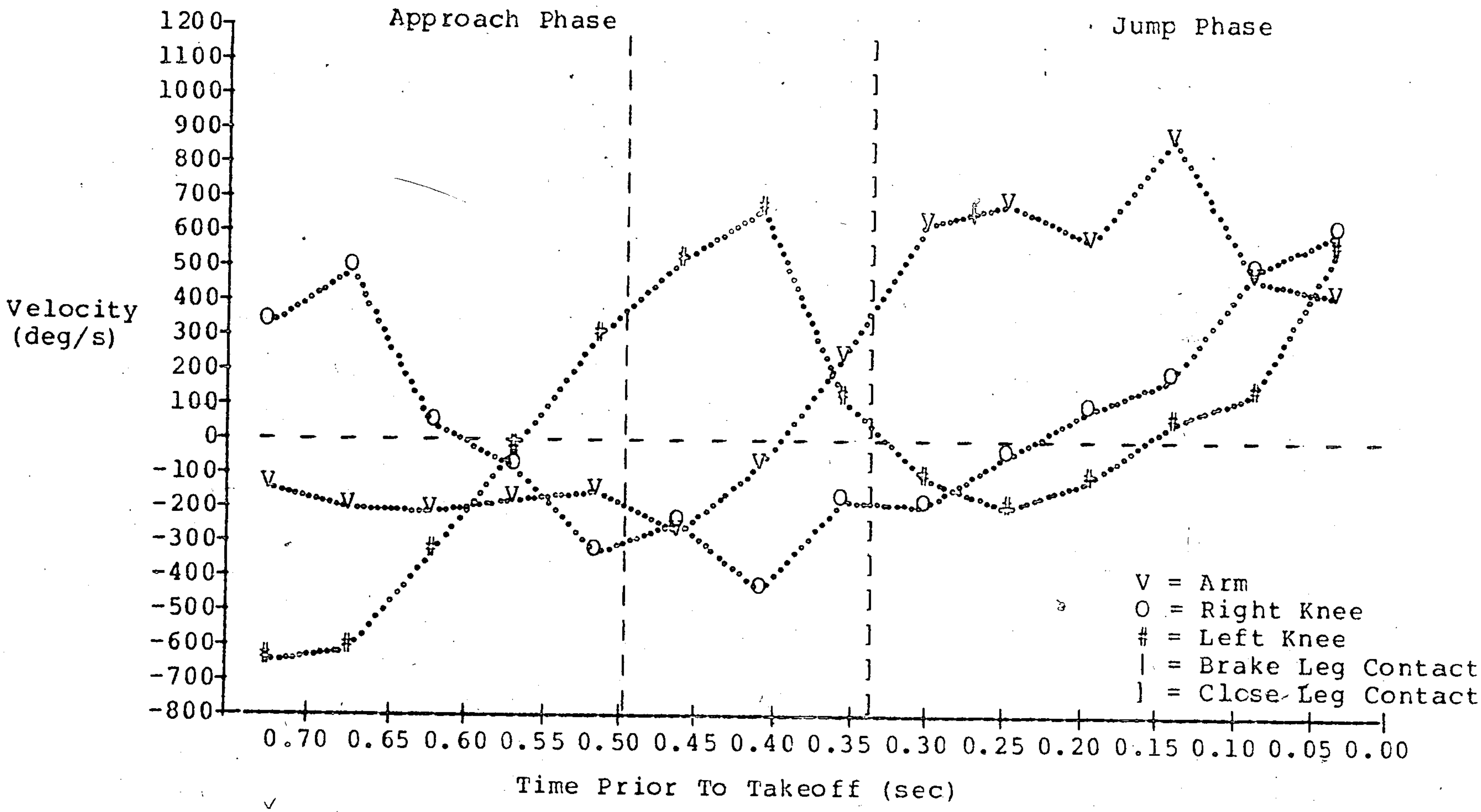


Figure B44: Subject 22, Jump 2

Angular Velocity Curves for Right Arm and at Both Knees