THE MAT KIP AS A PROGRESSIVE STEP TOWARD THE PERFORMANCE OF THE GLIDE KIP ON THE UNEVEN PARALLEL BARS: A CINEMATOGRAPHIC STUDY

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN PHYSICAL EDUCATION IN THE GRADUATE SCHOOL OF THE TEXAS WOMAN'S UNIVERSITY

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CHAPTER I

ORIENTATION TO THE STUDY

Gymnastics is a popular physical education activity for both student and teacher. Both are attracted by the beauty and grace of the sport and enjoy the challenge and variety which the activity offers.

One stunt which is included in virtually every intermediate and advanced gymnastic routine on the uneven parallel bars is the glide kip. Unless a student is able to master this stunt, she cannot progress beyond the low intermediate level of performance.

The glide kip is one of the more difficult skills for physical educators to teach successfully. Many instructors do not understand the mechanics of the skill, and most are unable to demonstrate it. Even though there is a great deal of literature available to assist the teacher to choose the methods for teaching the glide kip, none of it appears to be substantiated by research. As a result, there is an overall lack of understanding of the stunt and the physical strength and timing which are required to perform it. With the increasing interest and participation of the schools and recreational clubs in gymnastics, further research in skill development and teaching methods is necessary.

Purpose of the Study

The purpose of this study is to contribute to the formulation of a progression which can be utilized in the teaching of gymnastics. Specifically the following question will be answered: Does the mat kip represent a valid step in the progression for learning the glide kip on the uneven parallel bars? In order to answer the question, a mechanical analysis of the mat kip and the glide kip which focused upon rotational parameters was completed. Parameters examined in detail were angular displacement, angular velocity, angular acceleration, and total body center of gravity.

Statement of the Problem

The study entailed a cinematographic investigation of the mat kip as a progressive skill for learning the glide kip on the uneven parallel bars. The investigation was delimited to four woman gymnasts from the University of Wisconsin Gymnastic Team at Madison, Wisconsin. The subjects were eighteen and nineteen years of age. Each subject was filmed while performing three trials of the mat kip and the glide kip on the uneven parallel bars. Composite diagrams and stick figures were made from the processed film. Manual plotting and data smoothing were used to obtain the rotational parameters. Parameters that were computed were angular displacement, angular velocity, and angular acceleration. The total body center of gravity was determined by computer analysis. A conclusion was drawn regarding the similarity of the mat kip to the glide kip on the uneven parallel bars in terms of rotational parameters. The value of the mat kip as a valid progressive skill to the learning of the glide kip was then determined.

Rationale for the Study

Certain experts[1] indicate that a gymnast who can perform a mat kip will learn the kip on the uneven parallel bars faster than a gymnast who cannot perform this skill. Therefore, the mat kip may be called the first stunt in the kip progression.[2] "The mechanics of the skill are basically the same regardless of whether the movement is done on the

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[1]See Eric Hughes, Gymnastics for Girls; A Competitive Approach for Teacher and Coach (New York: The Ronald Press Company, 1963), p. 176; Richard Ronald Spencer, "Ballistics in the Mat Kip," Research Quarterly 34 (May 1963): 213-18;

[2]Bruce A. Frederick, "Gymnastics Basic Seven for Girls and Women," Selected Gymnastic Articles, ed. Carolyn O. Bowers (New York: AAHPER, 1971), p. 86.

[2]Hughes, Gymnastics for Girls, p. 31.

mat, on the apparatus, as a single stunt, or in combination with other stunts."[1]

Even though experts profess that the mat kip is an important progressive skill, no research evidence appears to exist to verify their opinions. The investigator deems such verification to be essential to the overall development of gymnastics and therefore has selected the problem as the topic of this thesis.

Definitions and/or Explanation of Terms

For the purpose of clarification, the following definitions and/or explanations of terms have been established for use throughout the study.

Cinematography. "Cinematography is the study of human performance through the use of motion-picture film."[2]

Mat kip. The performer sits on the mat in a pike position. She rolls back, swings her legs back over her head, and places the hands, palms down, to the side of the head. The weight is now over and behind the head. The performer kicks her legs up and outward beyond the vertical,

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[1]Sherry Lynn Bovinet, "The Dynamics of the Kip on the Uneven Parallel Bars" (Ph.D. dissertation, University of Illinois, 1971), p. 21.

[2]John W. Northrip, Gene A. Logan, and Wayne C. McKinney, Introduction to Biomechanic Analysis of Sport (Dubuque, Iowa: Wm. C. Brown Company, Publishers, 1974), p. 221.

flexes the knees, tucks the feet toward her buttocks, and then snaps her head back as she pushes off the mat with the hands. In the leg thrust, the performer bends the knees so that the feet can be placed well back and under the body in order to enable her to come to an upright position.[1] (See figure 1.)

Uneven parallel bars.

> The uneven parallel bars are merely two horizontal bars, one two and a half feet above and approximately a foot and a half to the side of the other, but they are easier on the hands and softer to land on than the steel horizontal bars used by men because they are larger in diameter and have more "flex" or spring.[2]

"The height of the upper or high bar is 7 1/2 feet; height of the low bar is 5 feet."[3]

Glide kip. The glide kip is a stunt performed on the uneven parallel bars that is executed in the following manner: the performer stands behind the low bar. She jumps upward and grasps the low bar in an overhand grip, then pikes her hips to swing under the bar. As she glides forward, her feet are held just above the mat until a fully extended position is reached at the end of the swing. From

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[1] Spencer, "Ballistics in the Mat Kip," p. 214.

[2] Hughes, Gymnastics for Girls, p. 140.

[3] Blanche Jessen Drury, Andrea Bodo Schmid, and Patricia Thomson, Gymnastics for Women (Palo Alto, California: The National Press, 1968), p. 118.

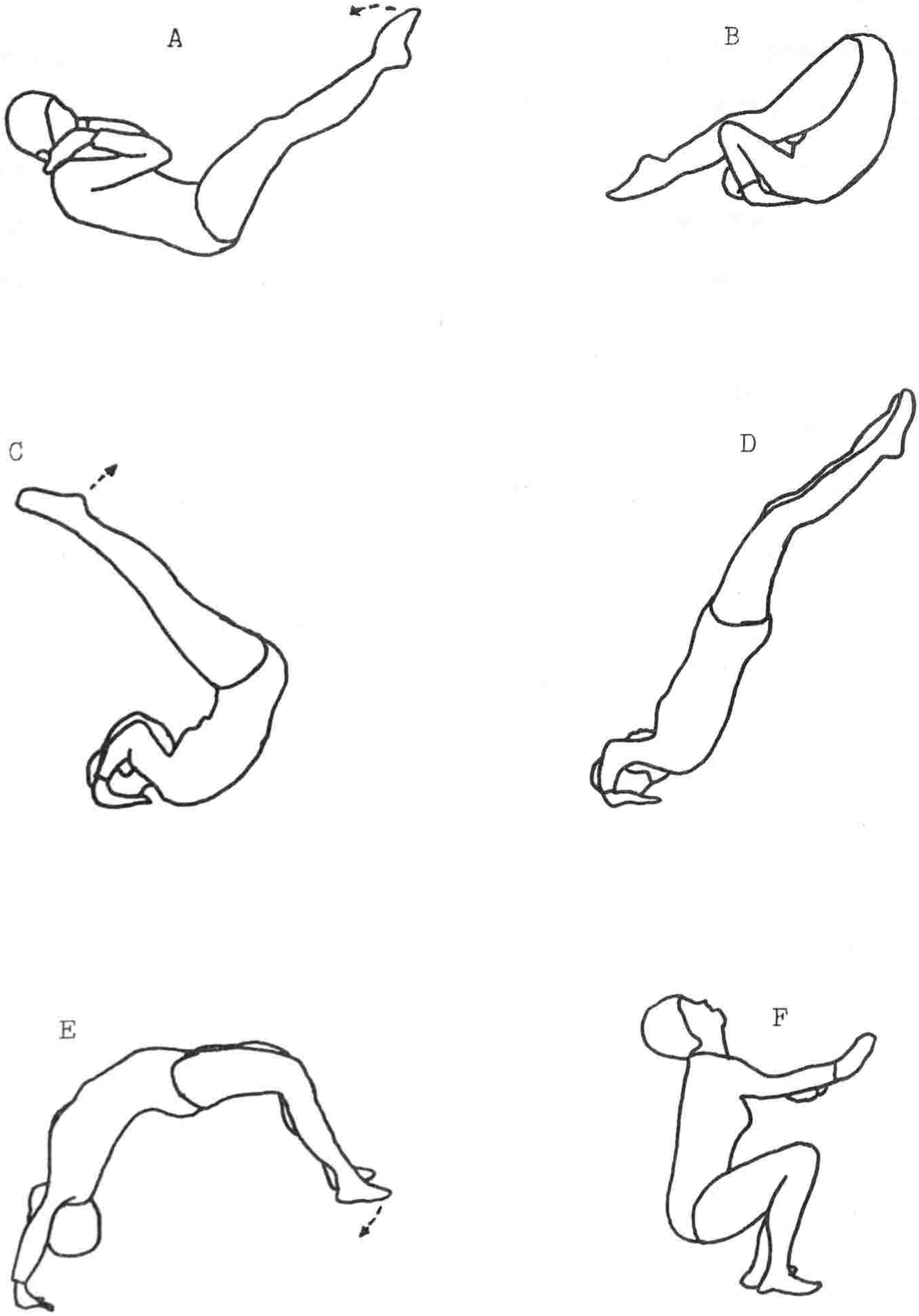

Fig. 1. Outline Drawing of the Mat Kip

this position, the hips are piked to bring the ankles to the bar. The performer then thrusts her hips upward and outward, extending her hips. This movement causes her body to rotate around the bar at the hips, and she finishes the stunt in a straight arm support on the bar.[1] (See figure 2.)

Forward grip or overgrip. The hands are placed on the bar with the back of the hands facing upward. The thumb may be either alongside the fingers or around the bar.[2]

Straight-arm support. A balance on the low bar in which the weight is supported by the arms and thighs. The arms and knees are straight, and the feet are plantar-flexed.[3]

Delimitations of the Study

This study was subject to the following delimitations:

1. Four female gymnasts eighteen or nineteen years of age who were members of the University of Winsconsin Gymnastic Team at Madison, Wisconsin.

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[1]Jo-Ann Garavaglia, "An Electromyographic-Electrogoniometric Analysis of the Action of Selected Trunk and Lower Extremity Muscles in the Glide Kip" (M.S. thesis, Brigham Young University, 1971), p. 3.

[2]Phyllis Cooper, Feminine Gymnastics (Minneapolis, Minnesota: Burgess Publishing Company, 1969), p. 109.

[3]Garavaglia, "An Electromyographic-Electrogoniometric Analysis," p. 3.

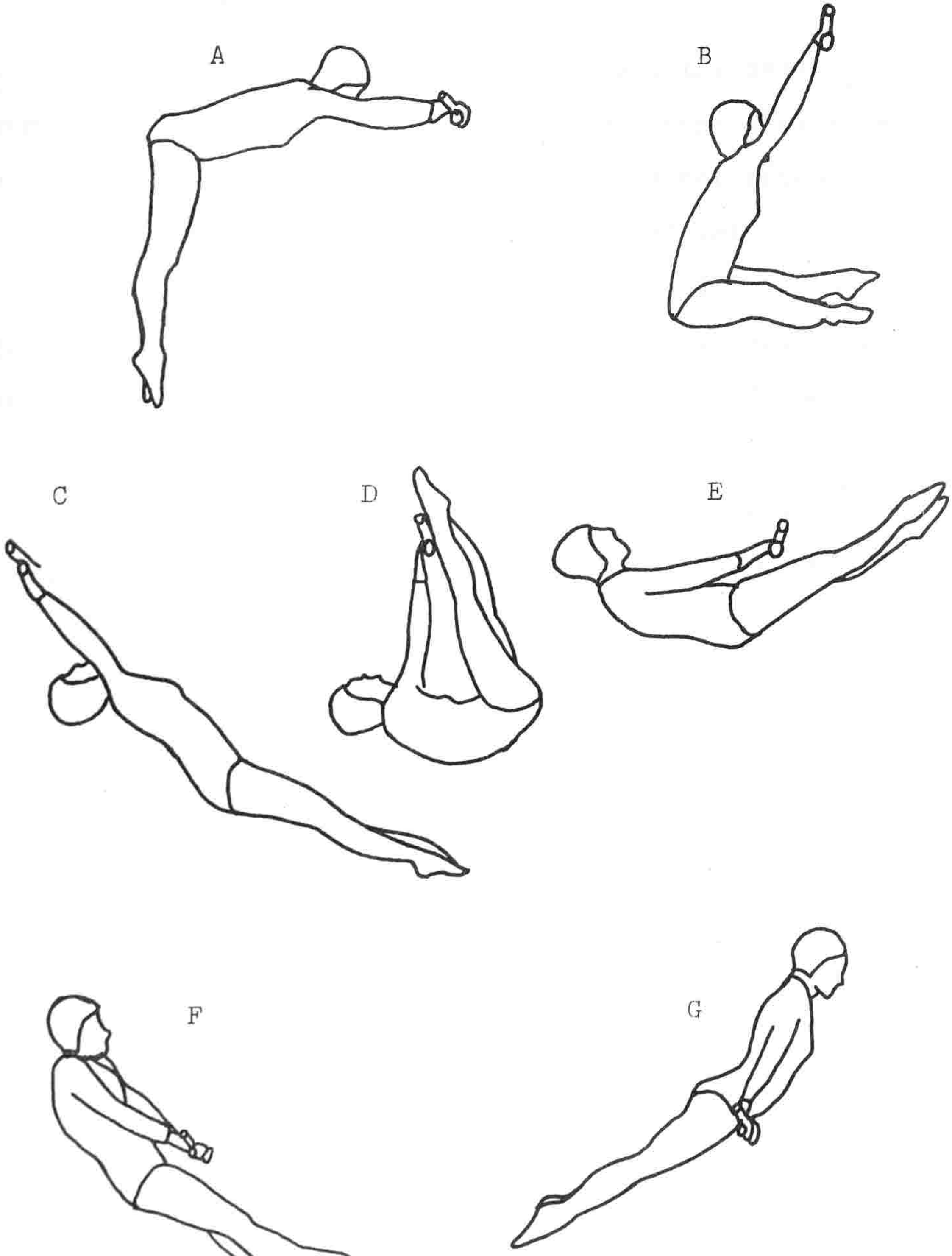

Fig. 2. Outline Drawing of the Glide Kip

2. The use of a Millikin pin register unit, sixteen millimeter camera with a shutter opening of seventy-two degrees and a film speed of 100 frames per second.

3. The use of a Recordak Film Analyzer.

4. The determination of absolute and relative angular displacement, angular velocity, and angular acceleration of the thighs and trunk as indicators of the similarity of the two kips.

5. The determination of the center of gravity as an indicator of translational similarities of the two stunts.

6. The use of symmetrical analysis.

CHAPTER II

REVIEW OF RELATED LITERATURE

No previous study has been undertaken which is identical with the present investigation. The review of literature was limited to selected studies which were of assistance to this investigator.

Bovinet undertook a study using cinematography to analyze the dynamics of the kip on the uneven parallel bars which involved four phases: obtaining required body segment parameters, identifying the timing and force factors which differentiated among performance levels, determining the relative significance of the kip from an analysis of a skilled performance.[1]

Bovinet photographed nine woman gymnasts from the McKinley Y.M.C.A. Gymnastic Club at Champaign, Illinois. The subjects were between eleven and twenty-two years of age. They were chosen by three judges using the Federation Internationale de Gymnastique rating scale. They were grouped in best, middle, and poorest groups which were called the excellent, good, and fair groups respectively.

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[1]Bovinet, "The Dynamics of the Kip on the Uneven Parallel Bars."

Three subjects comprised a group. Two trials of the glide kip and two trials of the arch kip on the uneven parallel bars were filmed with the best one being used for the analysis. One subject was dropped from the analysis because of incomplete data.

The standing and sitting height, weight, shoulder width, and hip width were recorded for each subject using standard measurement methods. A board and scale apparatus was used to determine the center of gravity of the total body. Specific strengths were measured at 30, 90, and 150 degrees of flexion and extension for the shoulder and at 90 degrees of flexion and extension for the trunk. The strength/weight ratio was calculated for each subject as an index of total body strength.

Direct measurement was used to determine the length of each body segment and the weight was calculated by multiplying the volume in cubic centimeters by the specific gravity. With an assumption of uniform mass, the mid-volume was taken as the center of gravity for the arm and leg. The center of gravity for the trunk was determined by a resolution of forces.

The moments of inertia for the upper and lower limbs were computed from the theoretical model for a truncated cone. The moment of inertia for the trunk was calculated by determining the moment of inertia of the total body from its period of oscillation as a pendulum and subtracting the combined moments of the arms and legs.

To obtain the absolute and relative velocities and accelerations, vertical and horizontal forces at the joint axes, the resultant force and the angles of projection of this force, moment of force, and the location of the center of gravity of the total body, a computer analysis was used.

The investigator's findings revealed that the strength and the data for the segment lengths and weights showed no differences among the groups or no appreciable differences between the results obtained and those reported from previous studies on women subjects. The center of gravity and radius of gyration data for the segments were well within acceptable limits. The trunk data showed inter-subject differences, and the author indicated that for these data to be useful the subjects should have been homogeneously grouped according to age, size, and somatotype. Based on the comparative analysis of the results, the methods used were valid techniques for approximation of body segment parameters _in vivo_ as concluded by the author.

The kinematic and kinetic analysis for both kips identified the critical factors of the kip which differentiated among performance levels as the extension before the pike to the bar and the timing of the leg thrust. The leg thrust affected the direction of the resultant vertical force in such a way as to increase the effectiveness of the muscle action, when timed correctly. The data revealed that approximately a 51 degree angle of projection was considered to be the most efficient, producing a smoother acceleration of the hips to the bar with sufficient momentum to complete the movement to a high front support position.

Spencer conducted a study to determine the range and angle of leg thrust in the performance of a successful gymnastic mat kip. He assumed for the study that a maximum angle of leg thrust had a direct relationship to success or failure and that, all other factors being equal, the angle of leg thrust should be the determining parameter for successful performance of the mat kip.[1] Twenty-eight male subjects who participated in the experiment were selected at random from two separate college classes of physical education majors at the University of California, Los Angeles. The investigation was conducted in the men's gymnasium during regular class periods. Standardized instructions were given to each class group. A pre-test demonstration illustrating common errors was given both classes by the same instructor. Only two warm-up trials were permitted

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[1]Spencer, "Ballistics in the Mat Kip."

prior to the three actual attempts of the mat kip. The third attempt was recorded on film.

A four by eight foot protractor was used to measure the ballistic movement of the leg thrust and to enable the instructor to determine the best range for judging success or failure. Three inch arabic numerals were stenciled on the protractor with black ink to measure the angle of leg thrust. Solid black lines marked the ten degree increments and broken lines marked the five degree increments. A five by ten foot gym mat was placed directly in front of the protractor and was bisected transversely at the five foot mark with three-fourth inch black masking tape. The mat line was placed in a direct line with the 90 degree vertical axis of the protractor.

The camera used for filming the subjects was a sixteen millimeter with a wide angle lens and a film speed of 64 frames per second. The developed film sequences were run through an animatic film strip projector which could be operated manually or automatically. The frames were moved manually to analyze one frame at a time. Any aberrations would be minimized.

To begin the kip pattern the instructor positioned the subject's acromion process of the shoulder area on the mid-point of the mat. Each subject performed the mat kip three times and the third attempt was recorded on film.

The processed film was projected directly onto a large piece of white hard surface cardboard on which a protractor was drawn. When the maximum point of leg thrust was reached, the film was projected one frame at a time. The projector was stopped and straight pins were inserted in the cardboard protractor at the degree of leg thrust. Then the projector was turned off and the line between the pins was recorded as the angle of maximum thrust.

The investigator's analysis of the leg thrust based on the means and standard deviations indicated that the angle of leg thrust for the successful group ranged from 45 to 70 degrees with a mean of 51 degrees and a standard deviation of 16.8. The investigator has a critical ratio of 2.31 per cent level of significance.

The author noted that sometimes the subject did obtain the proper angle of thrust but the mat kip was not successful. This would indicate that there were other involvements influencing success and failure that were not explored in this study. It was noted, also, that the successful performer kept the legs extended in the initial thrust but bent the knees abruptly in the final part of the thrust, maintaining an arched back. The successful performer sacrificed upward inertia in favor of the greater forward inertia needed to carry him to or beyond the balance position on the feet. The investigator concluded that "the fact that the mat kip may also be performed without using the hands suggests the importance of the angle of thrust in successful performance."[1]

The principal findings of the study showed that the angle of thrust when projecting the body was a determining factor in the successful performance of a mat kip, and that the performer has a better chance of attaining a higher level of skill if he does attain an angle of leg thrust higher than 30 degrees. A mean angle of leg thrust for a successful mat kip was determined for the experimental group.

Hough stated in her study of the glide kip that the most exciting gymnastics routines performed by women are those on the uneven parallel bars and that kipping moves constitute a major portion of the routines on this apparatus. Her study dealt with a film analysis of the glide kip mechanics and errors which resulted from improper execution of the skill.[2] Three woman gymnasts from the University of Tennessee and Knoxville area were selected as subjects.

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[1]Ibid., p. 218.

[2]Josephine Elizabeth Hough, "A Film Analysis of the Glide Kip" (Master's thesis, University of Tennessee, 1970).

One performer successfully performed the glide kip, one demonstrated a poor execution, and the other demonstrated the mechanics of the skill but was still unsuccessful and was not able to complete the skill.

A grid made of black electric tape was placed on the white gymnasium wall in one-foot squares. The size of the grid was eight feet high and approximately thirteen feet long. An orientation on the purpose and procedures of the study was given the subjects. They were allowed one warm-up glide kip on the uneven parallel bars. Subsequently the subjects were filmed on a third glide kip. All glide kips were performed with the legs in a straddled position.

A professional photographer from the University of Tennessee Photographic Center filmed the study with a sixteen millimeter, Bolex-rex movie camera using black and white Kodak 4-X 16 millimeter film. The film was processed, then reviewed on a sixteen millimeter movie projector. Thereafter, the film was critically reviewed on a 35 millimeter filmstrip projector with a special attachment for showing sixteen millimeter film frame-by-frame. The film was projected onto a glass plate covered by a sheet of graph paper on which traces were made for comparison of the different performers.

The body positions, initial velocity, and angle of elbow and hip flexion were determined and compared to each other from the film drawings and also to the ideal glide kip. The investigator concluded that failure to keep the chin tucked through the complete skill, insufficient leg thrust, and failure to keep the elbows straight were the most common causes for unsuccessful performance of the glide kip.

Garavaglia's study was directed toward the investigation of the actions of muscles that may flex or extend the hip joint and lower trunk during the glide kip on the uneven parallel bars by using electromyography and electrogoniometry. The muscles tested were the sartorius, semitendinosus, rectus femoris, external oblique, rectus abdominis, sacrospinales, gluteus maximus, and tensor fasciae latae. The specific sub-problems were to determine the contractual characteristics of the muscles involved, the angle or angles at which a muscle exhibited action potentials of the greatest amplitude, and the characteristics of an excellent glide kip. The investigator selected the glide kip because it is the one stunt which is included in almost every intermediate and advanced routine on the uneven parallel bars. Unless a girl is able to master the glide kip, she will not be able to progress beyond the low intermediate level of performance. The author stated that electromyographic research would increase a teacher's knowledge of which muscles contribute to the successful execution of the glide kip and at which time action potentials are the strongest. Electrogoniometric research would contribute much to the understanding of the timing of the stunt.[1]

The five woman subjects were selected from high school and college gymnastics teams in the Salt Lake City and Provo, Utah areas. Each subject demonstrated to the investigator a high level of technical execution of the glide kip. The study was conducted at the Brigham Young University Human Research Center. The data were recorded on six-inch wide Eastman Kodak Photographic paper by a Honeywell electronics system, paired surface silver disc electrodes, and hip and knee electrogoniometers were utilized. The subjects wore leotards with holes cut into them to allow the electrodes to be located on the skin. Eight sets of leads were applied for the electromyographic data involving eight muscles. Only two muscles could be tested at one time because of limited instrumentation capacity. Electrogoniometers were placed on the axis of the right hip and knee joints. Three glide kips were performed by each

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[1]Garavaglia, "An Electromyographic-Electrogoniometric Analysis."

subject with each set of electrodes. The tracings were examined for the purpose of comparing the same muscles and joints from each of the five subjects, so that the tracings could be analyzed to determine the similarities and/or differences that existed.

The investigator's findings showed that the hip and lower trunk flexors were active during hip flexion against the force of gravity and hip extension with the force of gravity. These electromyographic findings were expressed by the author in the following manner:

> The greatest amplitudes were recorded for these muscles during the pike to bring the ankles to the bar. The hip and lower trunk extensors were active during the thrust of the jump, the kipping action, and the arch to finish the stunt.[1]

The characteristics of an excellent glide kip according to Garavaglia included: (1) coming to a full extension at the end of the glide, (2) pausing at the end of the glide, (3) bringing the ankles all the way to the bar during the following pike, (4) extending the leg action upward and outward during the kip, and (5) keeping the knees straight throughout the stunt.

Frederick states that of all movements in gymnastics, the kip or kipping action is high on the list of primary stunts to be learned. He adds that all kips involve an

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[1]Ibid., Abstract.

explosive folding and unfolding of the body and are usually preceded by an extension of the body and claims there are two general classifications of the kip: a back lying position kip with hips flexed and a swinging kip.[1]

Frederick states also that the kip sires the headspring, handspring, and back extension roll, in addition to a wide variety of apparatus movements.[2] Frederick's method in teaching the kip involves starting with the mat kip and finishing with a bridge or handstand. If the student has problems getting the feel for the kipping action, he should use the trampoline to slow down the action of the kip. Next the performer moves on to the neckspring, headspring, and handspring. For the first apparatus kip work, Frederick has the student start on even parallel bars with rails a little below shoulder height, then jump to a piked inverted hang position and "ride" forward and back in the inverted hang. This kip is done on the "bounce" at the end of the backswing and finishes in an upper arm hang. Following the above kip, the student is ready to learn kips on the uneven parallel bars.

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[1]Frederick, "Gymnastics Basic Seven for Girls and Women, p. 86.

[2]A. Bruce Frederick, <u>Women's Gymnastics</u> (Dubuque, Iowa: Wm. G. Brown Company, Publishers, 1966), p. 27.

Hughes states that the mat kip is the first stunt in the kip progression and that a girl who can perform a good mat kip will learn the glide kip faster than one who cannot. Hughes states also that the performer should practice the kip on a low horizontal bar or parallel bar about chest height by jumping immediately into the pike position with the ankles close to the bar. This should be followed by practicing the walkout glide kips.[1]

Cochranie, too, claims that the kip movement is an essential part of work on the uneven parallel bars. The author says six or seven different kips may be included in a good performer's routine, and that body control, strength, and good kinesthetic sense are needed for a kip. Cochranie advises that the kipping action should be begun on the uneven parallel bars and should initiate with the single leg stem rise and progress to the stem rise, knee kip, kip to the high bar from the low bar, and then to the glide kip using the run under the bar method.[2]

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[1]Hughes, Gymnastics for Girls, p. 176.

[2]Tuovi Sappinen Cochranie, International Gymnastics for Girls and Women (Reading, Massachusetts: Addison-Wesley Publishing Company, 1969), p. 172.

CHAPTER III

METHODS AND PROCEDURES

The general problem of the study was to determine whether the mat kip is a valid progressive skill for learning the glide kip on the uneven parallel bars. The study was conducted on adult woman volunteers who were gymnasts of the University of Wisconsin Gymnastic Team at Madison, Wisconsin. This chapter consists of methods and procedures used in the attainment of the purpose of the study, including preliminary procedures, selection of instrument, selection of subjects, collection of data, and preparation of the final written report.

Preliminary Procedures

The investigator surveyed, studied, and assimilated information from all available documentary sources related to the aspects of the proposed study. This information was used in the formation of a tentative outline. Permission to conduct the study was secured from the Dean of the College of Health, Physical Education and Recreation and from the Human Research Review Committee of the Texas Woman's University.

The outline of the proposed study was developed by the investigator and approved by the members of the thesis committee. On April 6, 1976, the completed tentative outline of the thesis was presented at a Graduate Seminar. In accordance with suggestions offered by those participating, the outline was revised. A Prospectus of the approved study was then filed in the office of the Dean of Graduate Studies of the Texas Woman's University.

Selection of Instrument Procedures

The use of cinematography has been helpful in studying many sports skills. "The use of motion pictures is probably the best single technique for obtaining kinetic and kinematic data related to whole body motion."[1] Motion pictures allow one to study the positions of the body and executions of the movements. The film shows the plane in which the movement occurred, the relationship between the body parts, and the placement of the equipment.

A Milliken pin register movie camera was used to film the study. It was fitted with a twenty-five millimeter lens with a shutter opening of 72 degrees and a film speed of 100 frames per second. The f was set at 2.0.

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[1]Stanley C. Plagenhoef, "Gathering Kinesiological Data Using Modern Measuring Devices," Journal of Health, Physical Education and Recreation 39 (October 1968): 81.

A pilot study was conducted on February 18, 1976, at the University of Wisconsin Men's Gymnasium during which a subject was filmed performing a glide kip on the uneven parallel bars and a mat kip. Proper camera placement, lighting effects, and camera settings were determined. An outline of the pilot study and the check list used appear in appendix C.

Procedures Followed in Selection of Subjects

The subjects for the study were selected on the following criteria: (1) the subjects had to be female members of the University of Wisconsin Gymnastic Team at Madison, Wisconsin during the spring semester of 1976; (2) the subjects had to be of advanced skill level in gymnastics as determined by their participation in the 1976 National Gymnastics Championship held in Boone, North Carolina; and (3) each subject had to volunteer and sign a written consent form (see appendix A).

Procedures Followed in the Collection of Data

A personal data sheet was completed on each subject for the study. A copy of the personal data sheet appears in appendix A. Also to be found in appendix A is a copy of the data sheet developed to record the data yielded from the film analysis.

On April 27, 1976, four women from the University of Wisconsin Gymnastic Team were given a few minutes each to warm-up on the uneven parallel bars before they were filmed. Each subject performed three trials of the glide kip in succession, returning to the floor after each trial. The mat kip was filmed in the same manner performed on the gymnastic mat. Thomas W. Roberts, a research specialist at the University of Wisconsin, and the investigator implemented the setting up of equipment and the photography. The subjects placed the body markings on each other (supervised by the investigator) and took turns keeping the notice board correct.

The Milliken pin register movie camera was placed on a tripod perpendicular to the lateral plane of movement. The camera was set thirty-six feet from the subject for the filming of the glide kip on the uneven parallel bars. A thirty-two foot setting was used for the subject on the mat kip. Included in the photographic field was a two-second conical timer. The timer was built by Thomas W. Roberts at the University of Wisconsin patterned from Blievernicht's[1]

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[1]David L. Blievernicht, "A Multidimensional Timing Device for Cinematography," Research Quarterly 38 (March 1967): 146-48.

timer. Roberts improved the timer by rebuilding the fiber glass cone and using a thirty revolution per minute synchronous motor. The timer rotated once every two seconds, and had ten large divisions marking off ten intervals of 0.2 seconds each. There were two fixed pointers 90 degrees apart. The notice board in view displayed the date, the numbers of the subjects, the stunt, and the trial. A black card six inches square with a plus sign on it was used as a horizontal and vertical reference. A third plus card was placed four feet in front of the subject also to be used as a reference point. A meter stick was filmed at the place of performance.

The subject's body segments were marked with an X on a piece of one and one-half inch square adhesive tape. The tape was placed on each subject on the top of the head, the knuckles, the toe, and the axis of shoulder, elbow, wrist, hip, knee, and ankle. A photograph of the body markings appears in appendix C.

The 300 feet of exposed film was processed and a positive print was made for projection. The analysis equipment was then assembled and checked for working order.

Preparation of the Final Written Report

Upon the completion of the analysis of the data, the investigator organized and presented the data in appropriate illustrations, composite diagrams, stick figures, tables, and graphs. The data were summarized, and a conclusion was drawn based upon the problem of the study. A written report on the study was submitted which contained the findings and recommendations for future studies. A classified bibliography and appendixes were added in order to complete the written report.

CHAPTER IV

PRESENTATION OF THE FINDINGS OF THE STUDY

The purpose of this investigation was to determine whether the mat kip is a valid progressive skill for learning the glide kip on the uneven parallel bars. A pilot study to establish the proper camera placement, lighting effects, and camera settings was conducted. After the completion of the pilot study the investigation was continued using four female volunteers from the University of Wisconsin Gymnastic Team at Madison, Wisconsin. Presented in this chapter are:

1. The methods of analysis of the film
2. The collection of data on trunk and thigh angles and their presentation
3. The illustration of outline drawings
4. The preparation and illustration of the stick figures
5. The preparation of the center of gravity data of the total body and its presentation
6. The computation and presentation of angular parameters

7. The mechanical analysis of the mat kip
8. The mechanical analysis of the glide kip.

Analysis of the Film

All filmed trials were evaluated by using a Kodak Analyst Projector (L W Motion Analyzer 900) for sixteen millimeter film. Three trials for every glide kip and mat kip were filmed for each of the four subjects. The best trial of each stunt for each subject was selected by the investigator for the analysis.

The film was then projected through a Recordak P-40 microfilm reader with a magnification ratio of forty to one. By using the Recordak the investigator was able to check the speed calibration of the camera. This was accomplished by noting the elapse of ten frames for each tenth of a second on the conical timer.

Trunk and Thigh Data

A sheet of eight and a half by eleven inch graph paper was prepared with central vertical and horizontal axes drawn for emphasis. A 360 degree six-inch diameter protractor was taped with transparent tape to the graph paper such that its axes coincided with the axes drawn on the paper and the zero angle index coincident with the longitudinal axis. This assembly was placed on the viewing area of the Recordak with the zero angular index to the right. After the film was centered on the Recordak, the cross-over of the axes was placed at the hip body marking. The nearest lower line was made parallel with the lower film edge. A further check was provided by other horizontal references on the projected images. Angles were read off the protractor in the counterclockwise direction from the positive horizontal axis by extending the trunk and thigh angles to the periphery of the protractor by means of a transparent straight edge. The film was advanced at ten frame intervals and the thigh and trunk angles obtained in the above manner were recorded for the entire stunt for each subject for the glide kip. The thigh and trunk angles for the mat kip were only recorded to the point where each subject bent her legs at the end of the kipping action. This was done since once knee bending in excess of about fifteen degrees occurred the kipping action between the mat kip and the glide kip were considered no longer comparable.

Outline Drawings

The investigator placed tracing paper on the viewing field of the Recordak microfilm reader. The desired frame was selected and the paper was taped in place. A pencil was then used to trace the body outline of the gymnast. The sequence was drawn to illustrate the basic movements involved in performing the mat kip and the glide kip on the uneven parallel bars. The outline drawings were then reduced on a copying machine to 40 percent of their original size. The reduced outline drawings were subsequently placed on a lamp table and traced in sequence for thesis illustration. The horizontal and vertical axes were maintained during the entire procedure.

Composite Stick Figures

The film data were placed on a Recordak P-40 microfilm reader from which the base was removed and replaced with the digitizing platen of a Hewlett-Packard 9864A Digitizing System. The magnification was somewhat in excess of forty to one because the platen was lower than the original base. The free moving cursor and platen were connected to the main frame of the digitizer by cables. The digitizing surface acted as a receiver for low-frequency electromagnetic signals transmitted by the cursor. The resolution of the digitizing platen was accurate to the nearest .01 inch, with a rounding error of .005 inches. Beginning with the reference point the cursor was always moved in the same order to the following selected body markings and equipment:

1. For the mat kip: ankle, knee, hip, shoulder, top of the head, shoulder, elbow, and wrist.

2. For the glide kip: ankle, hip, shoulder, top of the head, shoulder, wrist, and bar.

When all points in a frame were completed the film was advanced ten frames and the process continued until the entire stunt was digitized.

The main frame of the digitizer converted the received information into coordinates that described the position of the center of the cursor's cross hairs on the platen. The Cartesian coordinate data of the selected frame points were then entered into the Hewlett-Packard 9810A Calculator.

The calculator program used for graphing the stick figure data from the Hewlett-Packard Calculator was "Cordang Stick" (coordinates and angles), written by Sally Phillips (1975--University of Wisconsin, Madison). The calculator tape output for this program included X and Y coordinates of each point, angles of inclinations of the segment, and calculated joint angles. A maximum of twelve data points plus the reference point for each frame could be utilized with this program.

The Cordang Stick Program was used only for the purpose of graphing the stick figures on the Hewlett-Packard

9862A Calculator Plotter. Also, a Graph Preparation Program was used which set the limit size of the graph, the number of frames, points, readings, and the lines to be omitted.

To summarize the synchronization of the above equipment using the frame and optics of the Recordak: The information was transmitted from the cursor and digitizing platen to the main frame of the digitizer which established the coordinate data of the selected frame points. The data were then entered into the calculator, which had been programed in advance. The calculator triggered the plotter to draw single lines from the original data received from the cursor in real time sequence. In this manner, the designated points were connected to form the stick figures.

Upon completion of the graphed stick figures a lamp table was used to collate the figures in their final form and the needed symbols were added to define the parts of the body and the sequence of action. These composite stick figures can be found in appendix E.

The Total Body Center of Gravity

To determine the total body center of gravity for each tenth frame the same digitizing order and procedure were followed as described for the composite stick figure sequence. The above program was adapted from a similar program written by Carol Widule, Purdue, and revised by Judy Spray (May, 1972--University of Arizona). Plotting capability and program revisions were introduced by Sally Phillips (1975--University of Wisconsin at Madison). The calculator tape output for this program included X and Y coordinates for each segment and also for the center of gravity of the total body of each frame digitized.

The program was used only for the purpose of plotting the total center of gravity for every tenth frame. The program also drew the connecting lines between the plots.

The completed graphs for the entire stunt and the kipping action for the mat kip and the glide kip were then placed on a lamp table and collated for entry into appendix H.

Presentation of the data for the total body center of gravity was as follows:

1. The graphs for the full stunt were plotted separately to avoid confusion and facilitate comparison.

2. The graphs for all individuals in the mat kip and glide kip were scaled identically. However, scales of the mat kip and glide kip were not identical because of differences in the relative camera distance. The distance for the glide kip was thirty-six feet while that of the mat kip was thirty-two feet.

3. The graphs for the kipping action were drawn as composites for all the participants but separately for each stunt. To avoid excessive overlap of data points the scale was increased by a factor of two, relative to the full stunt.

4. The zero reference point for the kipping action in the mat kip was chosen to be at the start of the backward motion of the trunk. These points were made coincident for all curves of the composite.

5. The zero reference for the kipping action of the glide kip was taken as the maximum extension before kipping. Again, these points were made coincident for all curves of the composite.

Drawing of the curves was accomplished by first noting the zero reference locations on each stunt and individual on the full stunt graphs. The individual new points were located by multiplying the X - Y displacements from the reference point on the original curves by two. These points were then used to plot the new curves.

Methods of Raw Angular Displacement Data Processing and Presentation

The time scale on the abscissa of the graphs was left in frames rather than reduced to seconds since it provided ready comparison to the stick figures and total body center of gravity data. This procedure also eliminated the need for using decimal seconds. Since the time scale was 0.01 seconds per frame, conversion was a rather simple matter.

Original plans called for the use of a trunk and thigh velocity and acceleration program in conjunction with a Hewlett-Packard 9862A Calculator. The program plotted the data point to point as a linear approximation. Because of the speed of the action and the fact that only every tenth frame was digitized and entered, results were rather poor even for the displacement data. The first and second time derivatives accentuated the previous irregularities. Thus, the plots of velocity and acceleration were of very questionable validity.

This plan was abandoned in favor of manual plotting and data smoothing. Graphic differentiation methods were applied subsequent to manual data smoothing. The detailed procedure used is explained in the next three sections.

Absolute and Relative Angular Displacement

The trunk and thigh angles obtained earlier in the study were used for graphing displacement of the trunk and thighs. In order to make angular measures continuous, avoid negative numbers, and permit direct comparison between thigh and trunk angles, the following data modifications were made:

1. For both stunts, 360 degrees were added to all trunk angles.

2. When the thighs crossed the reference axis in the counterclockwise direction, 360 degrees were added to the thigh angles. (In the glide kip the 360 degrees were added during the pike to the bar and the kipping action; in the mat kip the addition was made after the initial low frames.)

Once the data were placed on graph paper (one dot for every ten frames), French curves were used to link the points into smooth graphs. These plots were subsequently transferred to unlined paper using the lamp table. The resultant graphs are in appendixes F and G.

Methods of presentation of data for absolute and relative angular displacement follow:

1. The graphs for the full stunt were plotted as combined thigh and trunk composites for each stunt and each subject. Identical ordinates (80 degrees per inch) and abscissa scales (53 1/3 frames per inch equal to .533 seconds per inch) were used on all stunts to simplify comparison. Additionally, identical ordinate reference axes were used. No relative plots for the full stunt were developed.

2. The graphs depicting the displacement for the kipping action were treated somewhat differently. As in

the case of the kipping action for the total body center of gravity, the indices for the start of the action were taken at the beginning of the backward motion for the mat kip and the maximum extension before kipping for the glide kip. The graphs were compiled into groups of mat kip thigh, mat kip trunk, glide kip thigh, and glide kip trunk composites. As an additional reference, the point of maximum back rotation of the thighs in the case of the mat kip and the point of zero angular velocity of the thighs prior to kipping for the glide kip were indicated on each curve. These notations were also carried forward to the relative displacement as well as all relative velocity and acceleration curves.

Angular displacement curves of the thighs relative to the trunk were also drawn as composite groups for both the mat kip and glide kip. The data for the plots were obtained by subtracting the trunk displacement angle from the thigh displacement angle for each subject in each stunt at each ten frame interval.

Graphic scales of the kipping action and ordinate references were again made identical for both stunts for the thigh and the trunk but were expanded relative to the total stunt, the ordinates being 60 degrees per inch and twenty frames per inch (equivalent to .2 seconds per inch) was used for the abscissas. The ordinate references for the relative displacement in both mat kip and glide kip were adjusted to a different level from the absolute values but both were made identical to each other. The scales for the relative displacement were not altered on either axis from the graphs of absolute displacement. The abscissa scales were continued through the subsequent relative velocity and acceleration curves. The relatively large increase in the abscissa scale permitted easier and more reliable slope measurements for velocity and acceleration evaluation. Aside from providing easy comparison between the various curves, the equal scales on all graphs simplified velocity calculations.

Absolute and Relative Angular Velocity

All absolute angular velocities were obtained by graphic differentiation methods. Since angular velocity is the time rate of change of displacement, we may write:

$$\omega = \frac{d\theta}{dt} \qquad \triangleleft\ 1$$

Where:

ω is the angular velocity (degrees per second)

θ is the angular displacement (degrees)

t is the time (seconds)

For graphs where θ and t are plotted on identical scales, the tangent of the measured angle (ϕ) of the displacement curve is equal to the instantaneous angular velocity at the point where the angle is measured.

Therefore:

$$\tan \phi = \omega = \frac{d\theta}{dt} \qquad \triangleleft\ 2$$

If the scales are not identical, a correction factor must be applied.

Thus:

$$K \tan \phi = \omega = \frac{d\theta}{dt} \qquad \triangleleft\ 3$$

For 45 degrees $\tan \phi = 1$ and therefore:

$$K = \omega \Big|_{\phi = 45°} = \frac{d\theta}{dt} \Big|_{\phi = 45°} \qquad \triangleleft\ 4$$

Using equation 4 and the scale values of the displacement curves for the whole stunt the value of K for the whole stunt is:

$$K_1 = \omega \Big|_{\phi = 45°} = \frac{d\theta}{dt} = \frac{80°/\text{in}}{\left[53\ 1/3 \text{ frames X } \frac{1}{100} \frac{\text{sec.}}{\text{frame}}\right] \frac{1}{\text{in}}}$$

$$K_1 = 150°/\text{sec.}$$

Referring to the scales of the curve for the kipping action the value for K is:

$$K_2 = \frac{60°/\text{in}}{\left[20 \text{ frames X } \frac{1}{100} \frac{\text{sec.}}{\text{frame}}\right] \frac{1}{\text{in}}}$$

$$K_2 = 300°/\text{sec.}$$

The instantaneous values of angular velocity were calculated by equation 3 using the appropriate K value. For convenience the equation can be rewritten as:

$$\omega = K \tan \phi \quad \triangleleft\ 5$$

The slope angles ϕ on the original displacement curves (graph paper plots) were measured at ten degree frame intervals using a 360 degree six-inch KOH-I-MOOR #8220-6 protractor. The horizontal 0° - 180° axis was made tangent to the point on the curve to be measured and the angle read by first aligning the protractor center with one of the horizontal lines on the graph paper. The angle was obtained by reading its value at the intersection of the same line and the angular scale at the periphery of the protractor.

Additional points were taken by noting the maxima and minima of the displacement curve which provided the zero points on the velocity curves. The points of inflection were also measured and recorded. These gave the maxima and minima for the velocity curves.

The relative angular velocity data were obtained by subtracting the angular velocity of the trunk from the respective angular velocity of the thighs.

Presentation of the absolute and relative angular velocity data was as follows:

1. Once the values of angular velocity were calculated, they were plotted on graph paper first and then transferred to unlined paper by tracing them on a lamp table. The final graphs are included in appendixes F and G.

2. The collating of various graphs followed the exact procedure used for the displacement curves. The ordinate scale used throughout was 200 degrees per second per inch.

Absolute and Relative Angular Acceleration

As was the case with absolute angular velocities, all absolute angular accelerations were obtained by graphic differentiation methods. Since angular acceleration α is the time rate of change of angular velocity we may write:

$$\alpha = \frac{d\omega}{dt} \qquad \triangleleft\ 6$$

Where the parameters have the significance assigned above.

For graphs where ω and t are not plotted on identical scales the equation for angular velocity is given by:

$$C \tan \psi = \alpha = \frac{d\omega}{dt} \qquad \triangleleft\ 7$$

Where:

C is the proportionality constant (°/sec^2)

ψ is the instantaneous slope angle on the velocity curve.

At a 45 degree slope angle equation 7 reduces to:

$$C = \alpha\Big|_{\psi = 45°} = \frac{d\omega}{dt}\Big|_{\psi = 45°} \qquad \triangleleft\ 8$$

From equation 8 and the scale values of the velocity curves for the entire stunt, the value of the multiplication constant C is:

$$C_1 = \alpha\Big|_{\psi = 45°} = \frac{d\omega}{dt} = \frac{200°/\text{sec. in.}}{\left[160 \text{ frames X } \frac{1 \text{ sec.}}{100 \text{ frames}}\right] \frac{1}{\text{in.}}}$$

$$C_1 = 375°/\text{sec}^2$$

For the kipping action the value of the multiplication constant C is:

$$C_2 = \frac{200°/\text{sex. in.}}{\left[20 \text{ frames X } \frac{1 \text{ sec.}}{100 \text{ frames}}\right] \frac{1}{\text{in.}}}$$

$$C_2 = 1000°/\text{sec.}$$

The slope angles ψ on the original velocity curves were obtained in an identical manner as the velocity values ϕ were obtained from the displacement curves. The procedure of computing relative angular acceleration again involved the subtraction of the trunk from the thigh values.

The method followed throughout for presentation of the absolute and relative angular acceleration data was the same as for velocity as far as procedure, plotting, and collating are concerned. The ordinate scale was 1600 degrees per second squared per inch for all absolute accelerations and 1800 degrees per second squared per inch for the relative values. Because of lack of space the same scale could not be used on the latter. The graphs are included in appendixes F and G.

Mechanical Analysis of the Mat Kip

The mat kip consists in the first instance of raising the center of gravity of the body as high as possible by the rollback and then imparting translational dynamic forces such as the centrifugal force of lower body rotation, the force created by the straightening of the spine, and arm and head thrusts to further raise or project the center of gravity upward and maintain it at sufficiently high level to allow the rotational momentum of the lower body to carry the entire body to the vertical position.

This general description can be further detailed by segmenting the action into its basic components so that one can differentiate between the mat kip and other stunts which use kipping action.

Phase I: The ROLLBACK in mechanical terms raises the center of gravity of the entire body. The raising of the center of gravity is greater in women than in men since in the former its location is closer to the hips, thus less additional energy is required to complete the stunt. The rollback allows the placement of the hands and the balancing of the body in the piked back position (figure 3b). Again from the mechanistic point of view the timing of the rollback is of no particular consequence. This is also illustrated by the fact that in the subjects examined the angular displacement, velocity, and acceleration were vastly divergent as shown in the graphs of appendix G, figures 46 to 54, where the zero rotational velocity of the thighs shows the end of the rollback phase. The points of zero angular velocity of the thighs have also been plotted and listed on the total center of gravity graphs for the kipping action in appendix H, figure 69. The variability in the total center of gravity position noted in the above figures is either an indication of:

1. The lack of training of the subjects in the mat kip

2. The relative lack of importance of the starting position of the body for the subsequent action

Standard Symbols

β Angular displacement upper body
γ Angular displacement lower body
σ Relative angular displacement
ω Angular velocity
α Angular acceleration
v Linear velocity
a Linear acceleration
CG Center of gravity (mass center)
W Weight
M Mass
T Torque
F External reaction force
P Hip reaction force
r Radius of rotation from center of rotation to the center of mass
d Moment arm
Σ Summation symbol
I Moment of inertia

Subscripts and Superscripts

1 Upper body }
2 Lower body } except for moment arms
T Total body }
n Normal
\- CG reference
O Center of rotation reference
t Tangential

Note on force diagrams throughout this study: The imbalanced force resultants are shown in the normal manner to match the equations and not as reversed resultants (inertia forces or couples); i.e. the equilibrium system of the D'Alembert* principle was not applied.

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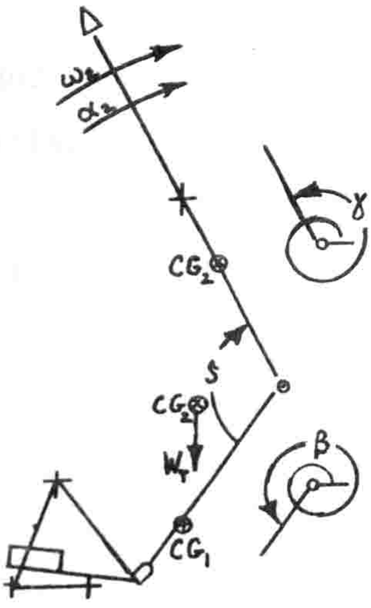
*Seely and Ensign, Analytical Mechanics for Engineers, article 112, pp. 256-58.



a Total body diagram

b Lower body "free body diagram

c Upper body "free body" diagram

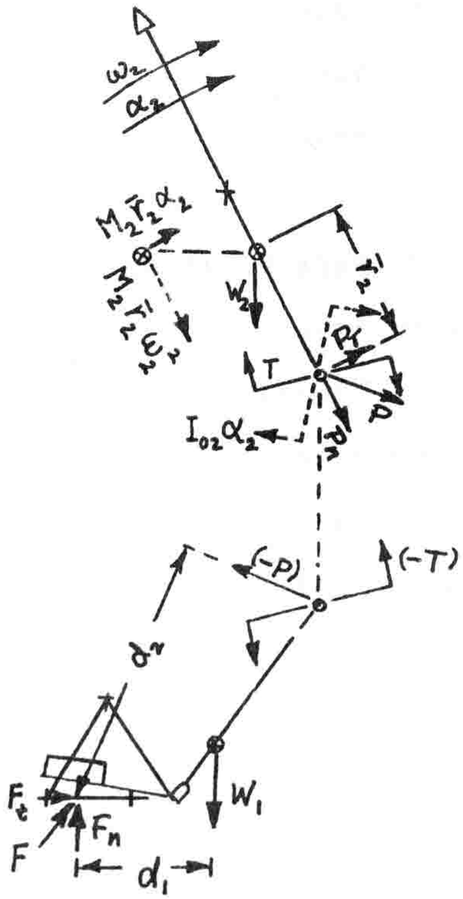


Fig. 3. Force diagram during the forward thigh rotation in the mat kip and list of standard symbols used in the text.

3. The large diversity of methods, which can be used to execute the stunt requiring different starting conditions for the beginning of the kipping action

4. The lack of a formalized training or evaluation methods, or

5. A combination of any of the above factors.

If one transfers the zero angular thigh velocity frames to the stick figures in appendix E, figures 14 to 17, and compares individual body positions at zero angular thigh velocity the diversity of body position becomes even more striking.

Phase II: The FORWARD THIGH ROTATION shall be specified as starting with beginning of forward thigh rotation and ending at the moment of shoulder lift-off. Figure 3a is a stick figure showing the body in the upper range of the forward thigh rotation action sector. The displacement angle references are matched to those of the graphs in appendix F, figures 22 to 25, and appendix G, figures 46 and 47, to allow ready comparison. Also shown are the "free body" diagrams of the lower and upper body segments to clarify the motion analysis. In the interest of simplicity the hips are assumed to be stationary for the action segment discussed here.

The dynamic equations of motion applying to a rotating "rigid body" with a "fixed" axis of rotation not at the mass center[1] are given by:

$$\Sigma F_n = M\bar{r}\omega^2 \qquad \triangleleft\ 9$$

$$\Sigma F_t = M\bar{r}\alpha \qquad \triangleleft\ 10$$

$$\Sigma T_o = I_o\alpha \qquad \triangleleft\ 11$$

If these equations are applied to the conditions shown in the "free body" diagram of figure 3c the following result[2] will be obtained:

$$\Sigma F_{2n} = P_n - W_2 \sin\gamma = M_2\bar{r}_2\omega_2^2 \qquad \triangleleft\ 12$$

$$\Sigma F_{2t} = P_t - W_2 \cos\gamma = M_2\bar{r}_2\alpha_2 \qquad \triangleleft\ 13$$

$$\Sigma T_{20} = T + \bar{r}_2W_2 \cos\gamma = I_{02}\alpha_2 \qquad \triangleleft\ 14$$

Where:

$$P = P_t + P_n \qquad \triangleleft\ 15$$

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[1]Fred B. Seely and Newton E. Ensign, Analytical Mechanics for Engineers (New York: John Wiley and Sons, Inc., 1944), article 111, pp. 249-56. Unless otherwise stated, symbols once clarified will retain their meaning and will not again be defined. Symbols with self evident subscripts will not be noted separately. No special notations are used to designate a quantity as a vector.

[2]In all equations here and subsequently used, normal mathematical conventions regarding signs are used. All forces, angles, etc. are symbolically written as positive and their actual direction in a particular computational case determined by the application. This excludes the weight W in force equations only to avoid confusion since W is always a negative force.

Since the hips are considered to be stationary, the "free body" diagram of figure 3b can be considered as a statically balanced system for which the following equations apply:

$$\Sigma F = 0 \qquad \triangleleft\ 16$$

$$\Sigma T = 0 \qquad \triangleleft\ 17$$

If these equations are applied to the specific conditions given the following is obtained:

$$\Sigma F_1 = F - W_1 + (-P) = 0 \qquad \triangleleft\ 18$$

$$\Sigma T_{10} = (-T) + d_1 W_1 + d_2(-P) = 0 \qquad \triangleleft\ 19$$

Under the conditions of equations 12, 13, and 14 all parameters except P_n, P_t, and T are to some extent measurable or can be estimated. Thus, the reaction vectors of the hip on the upper body which are equal and opposite to the force vectors on the hip are readily calculable.

If α goes to zero only the normal force system of equation 12 remains. This is approximately the condition at the end of the leg rotation. Again assuming stationary hips, then it will be noted from figure 3b that the force moment d_1W_1 provides the stabilizing torque against the moment $d_2(-P)$ and the thigh torque reaction (-T).

When the thighs are first starting to move, P_n due to the low angular velocity of the lower body is small, while P_t resulting from high angular acceleration is large. This, in combination with the thigh angle γ, will cause (-P) to be nearly in line with the upper body and the hips will remain relatively stationary. As motion continues, (-P) will act more at right angles and tend to force the hips to move over the head. By dropping the hips somewhat during the early stages of thigh rotation or maintaining them at a lower level, the moment of force d_1W_1 increases counteracting the tendency to roll backward and allows an increase in acceleration at later stages of the thigh rotation with a consequent increase in both lift-off energy and rotational speed during flight. These translational motions coupled with the straightening of the back will to some degree modify the simplified force system assumed above.

An examination of the stick figures in appendix E, figures 14 to 17, and the trunk angular displacement curves in appendix G, figure 47, show that the drop back of the hips was absent in subjects one and two and quite pronounced in subjects three and four. For subject three the drop back started after maximum back rotation of the thighs, while in the case of subject four the onset preceded the completion of back rotation and continued during the initial phases of forward thigh rotation. The characteristic loops in the total center of gravity graphs (appendix H, figure 69) also emphasize the characteristic hip drop of subjects three and four.

Considerable differences in the angle of maximum back rotation of the thighs (55 degrees) can be noted on the subjects by an examination of appendix G, figure 46. The values obtained varied from 510 degrees (30 degrees above the horizontal) for subject two to 565 degrees (25 degrees below the horizontal) for subject three.

Phase III: The LIFT-OFF is a transitory stage and overlaps the thigh rotation and the subsequent flight. For the purpose of the analysis, the investigator has considered the action to begin as the shoulders cleared and end as the hands left the mat. During the lift-off sector the following sequence of actions occurs:

1. The independent lower body rotation becomes transitional as the upper body starts to lock into the rotational system at lift-off. This may be described as gradual momentum transfer.

2. The hip thrust caused by the straightening of the back and the arm push (to some degree reinforced by the push of the head against the mat) assist the centrifugal force and body rotation due to momentum transfer as developed by the leg rotation to cause the entire body to lift off the floor. Additionally this thrust adds to the angular momentum.

3. Body arching and the dropping of the legs prevent excessive reduction in rotational velocity caused by the momentum transfer noted in number one above by keeping the moment of inertia of the total system low.

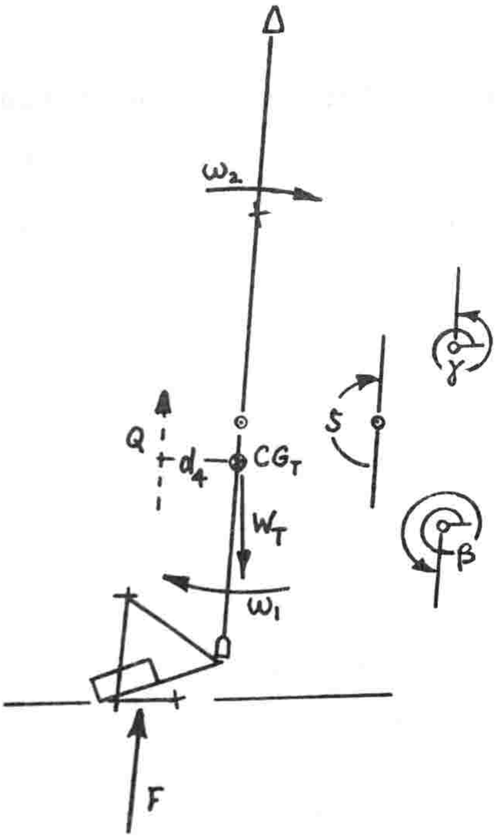
The stick figure in figure 4 illustrates conditions at the start of the lift-off phase. The system again is not statically balanced and is non-rigid. Neither the net imbalanced force Q nor its line of action is constant. The position of the center or centers of rotation and consequently the moment arms of force d_4 are not readily determinable.

If the angular momentum imparted to the lower body at the end of the initial leg rotation sector is given by $I_{i2}\omega_{i2}$ then by conservation of momentum:

$$I_{i2}\omega_{i2} + \text{lift-off momentum} = I_{01}\omega_1 + I_{02}\omega_2 \quad \triangleleft\ 20$$

Initially ω_1 will be relatively small but as transfer continues its value increases until $\omega_1 \doteq \omega_2$ at the end of the lift-off. It should, however, be noted that all parameters in the right hand side of equation 20 are variables. At completion of momentum transfer and start of flight one may write:

$$I_{i2}\omega_{i2} + \int_{t_1}^{t_2} Qd_4dt = I_T\omega_T \quad \triangleleft\ 21$$



Q is the instantaneous unbalanced force acting with moment arm d_4 on the assumed center of rotation CG_T.

Fig. 4. Simplified force diagram during the initial phases of lift-off in the mat kip.

Where the second term represents the additional rotational momentum introduced by the force moment consisting of the unbalancing force Q multiplied by its moment arm d_4 both of which are functions of time. The product is integrated over the total time of the lift-off sector. Although the magnitude of Q and its direction are not known, it can be deduced from the conditions of figures 4 and 5 that the rotational moment is clockwise and will therefore increase the clockwise angular momentum. $\bar{I}_T\omega_T$ is the total rotational momentum at the end of lift-off. Here $\bar{I}_T$ is determined relative to the center of mass of the body which can be considered as the instantaneous center of rotation.

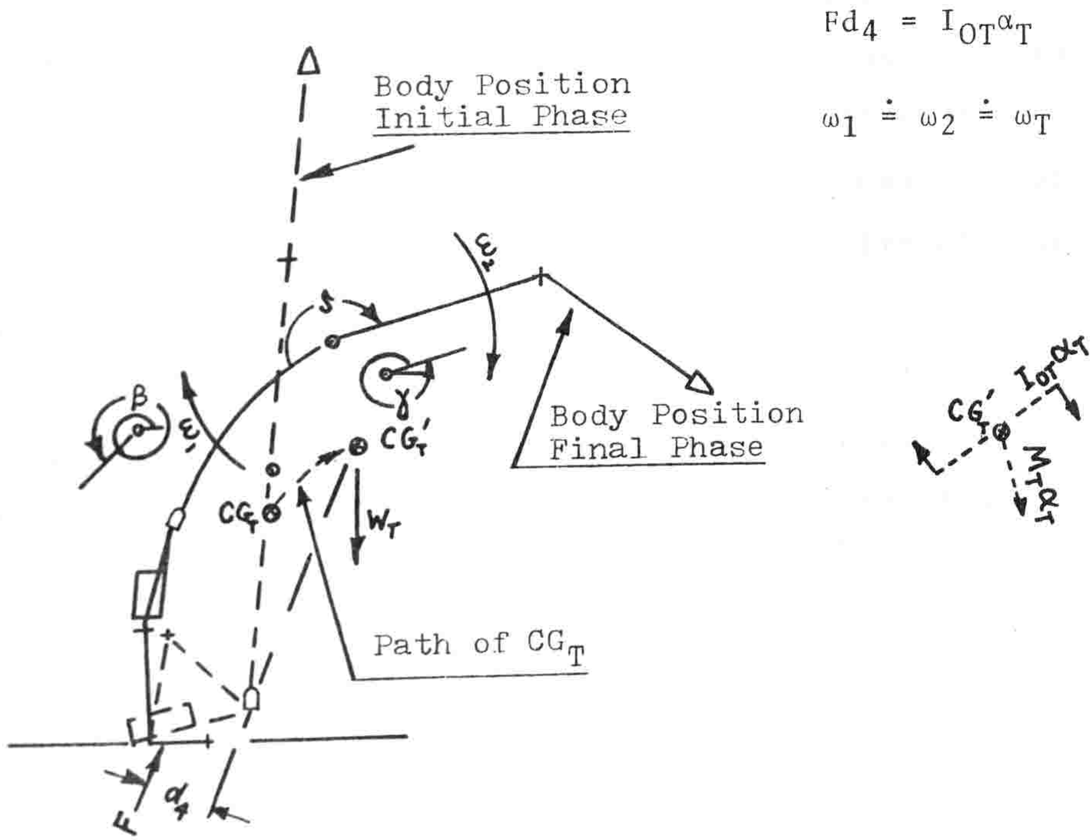


Fig. 5. Simplified force diagram for the mat kip during the initial and final phases of lift-off.

From the stick figures of the actual subjects studied (appendix E, figures 14 to 17), it is noted that there appears to be no drastic difference between ω_{i2} and ω_T. This can only be if the new moment of inertia I_T is reasonably identical to the moment of inertia of the lower body I_{02} (referenced to the hip). If the body is well arched so that the extremities come closer to the center of rotation such conditions can exist. Some increase probably still occurs since the mass involved is more than doubled. This condition can of course be compensated for by an additional increase in momentum during lift-off (see equation 21).

So far the rotational factors during lift-off have been described. To obtain an overall view the translational parameters must also be examined. Figures 4 and 5 and the stick figures in appendix E, figure 16, and to some extent the graphs of total body center of gravity in appendix H, figure 64, show the translational changes. In figure 64 subject two, from frame 150 to frame 170, shows the motion of the center of gravity during the lift-off period. As the lower body swing continues from the pike to the layout configuration, the center of gravity tends to remain stationary as described in Newton's First Law (law of inertia--every body continues in a state of rest or of uniform motion in a straight line unless it is compelled by external forces to change that state).[1] Since the motion of the center of gravity is at least in the perpendicular direction relatively unopposed by external forces, the hips tend to flex from back to front while the center of gravity has only a slight motion to the back. The latter is due to the couple Qd_4 discussed above. In the in-line direction the center of gravity is raised by the following combination of forces: (1) the centrifugal force of the lower body, (2) the straightening of the back, (3) the arm push, and (4) to a minor degree the head push.

The upper body rotation due to momentum transfer helps to raise the shoulders off the ground but does not contribute to raising the center of gravity. In order to complete the stunt in the layout position, the center of gravity must be raised as high as possible during the lift-off and preferably continue to increase during flight. To accomplish this the sum of the translational forces must be directed as vertically as possible and must be of sufficient magnitude to cause a vertical upward momentum component Mv_y.

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[1]John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs, N. J.: Prentice-Hall, 1972), p. 8.

The reference points for the division of the stunt into the various action sectors discussed here for the performers tested are shown in appendix H, figure 64. The same figure shows that subjects one, two, and three all attained fairly high center of gravity levels just prior to flight, as compared to subject four. The latter performer did not raise her center of gravity at all during the lift-off phase.

Because observations on angular displacement were terminated (in retrospect, wrongfully so) after knee bending, the thigh data for angular displacement, velocity, and acceleration for the entire stunt (appendix F, figures 22 to 33) ended in the general area of the end of lift-off. On subjects three and four the data extended slightly further. The reversal of the trunk rotation after momentum interchange is just barely visible in figure 24. The other angular displacement data during this sector provide little useful input and are nonexistent for the remainder of the stunt. One must, thus, rely on the stick figures and the total body center of gravity graphs for supporting data.

Phase IV: The start and termination of the FLIGHT are self evident. The force diagram, figure 6, illustrates the kinetic parameters of flight. In analyzing this stage the investigator shall make the reasonable assumption that for a well executed stunt the arched layout position attained at the end of lift-off will be continued until the feet touch the ground.

$\omega_T = \omega_T'$ for a constant arch rotation about the CG

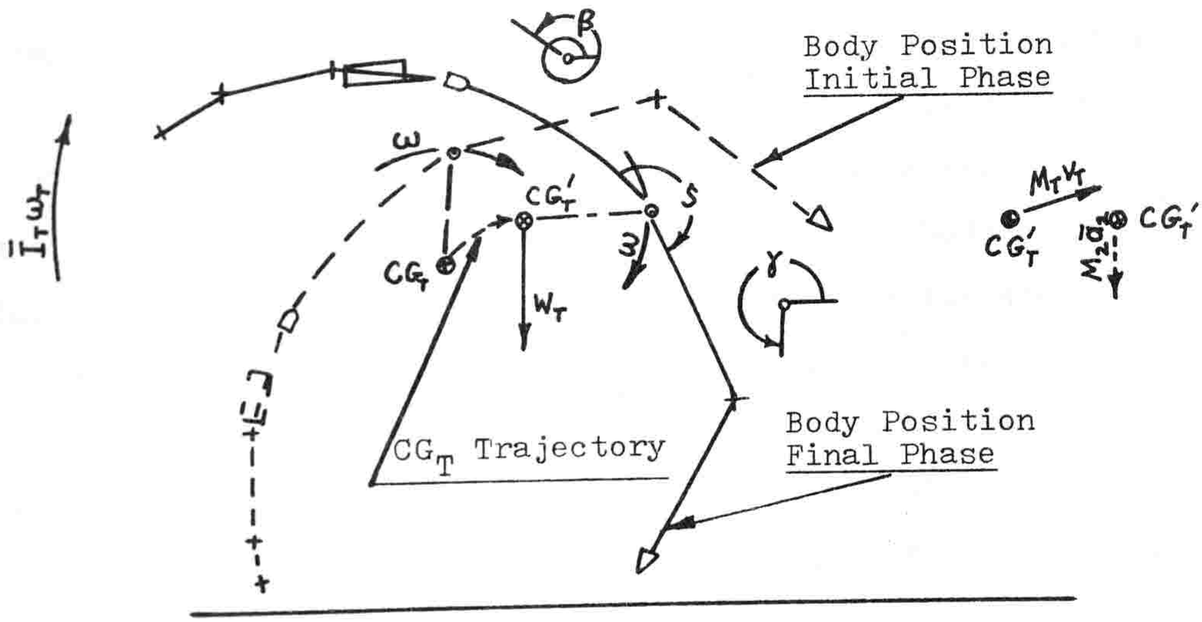

Fig. 6. Simplified force diagram for the mat kip at the initial and final phases of the flight sector.

The rotation for a well-executed stunt must be completed before the translational trajectory has reached its maximum position; otherwise, the loss in height of the center of gravity must subsequently be "made up" after touchdown. The center of rotation of the body in free flight is the center of gravity, which is located within the arch of the body. In a "rigid" body all elements of the body will rotate in equal angular increments in any given time period. For a given momentum input prior to flight, the rotation will be faster for a well arched body (small value of $\bar{I}_T$ as previously noted) thus successful completion of rotation before the center of gravity reaches its maximum depends to a large extent on the degree of body arch. For a given arch the rotational speed depends primarily on the rotational velocity of the lower body during initial leg rotation and to a lesser extent on the additional rotational momentum imparted during lift-off.

The translational trajectory is parabolic similar to a missile or a shot being put in the shot put event. On the subjects examined the initial trajectory angle varied between twenty and thirty degrees, except for subject four for whom the angle was less than horizontal and flight never really occurred (appendix H, figure 64). This fact alone is of no great significance since the speed of rotation and the ultimate height of the center of gravity seems to be more important in determining the success or failure in completing or doing the mat kip properly. The study by Spencer indicated a mean angle of "leg thrust" of 51 degrees with a range of 45 to 70 degrees.[1] The measurement was made at what is here referred to as the start of flight. Success or failure as defined in Spencer's study appeared to be determined solely by the ability of the subject to stand regardless of whether completion was by layout or a deep knee bend. Since it is demonstrated here that the motion is not a pure thrust but a thrust combined with rotation, the accurate measurement of "thrust" in the above study depended on the fortuitous coincidence of the angle of rotation and the real angle of thrust or projection of the translational trajectory. If one examines figure 64 (in appendix H) and the stick figures in appendix E, figures 22 to 25, it will be seen that only subject two performed the mat kip in essentially an ideal fashion. Subject one showed a drop in the center of gravity due to inadequate angular velocity which apparently resulted from insufficient arching and low angular momentum. The same appears to be true of subject three, but to a larger extent. Although subject four had little center of gravity drop, extension was too flat and "flight" never occurred.

Phase V: LANDING comprises the completion phase of the stunt beginning with foot contact with the ground and terminating with the body in the vertical position.

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[1]Spencer, "Ballistics in the Mat Kip," pp. 213-18.

Figure 7 illustrates both the start and completion of this phase for the ideal performance.

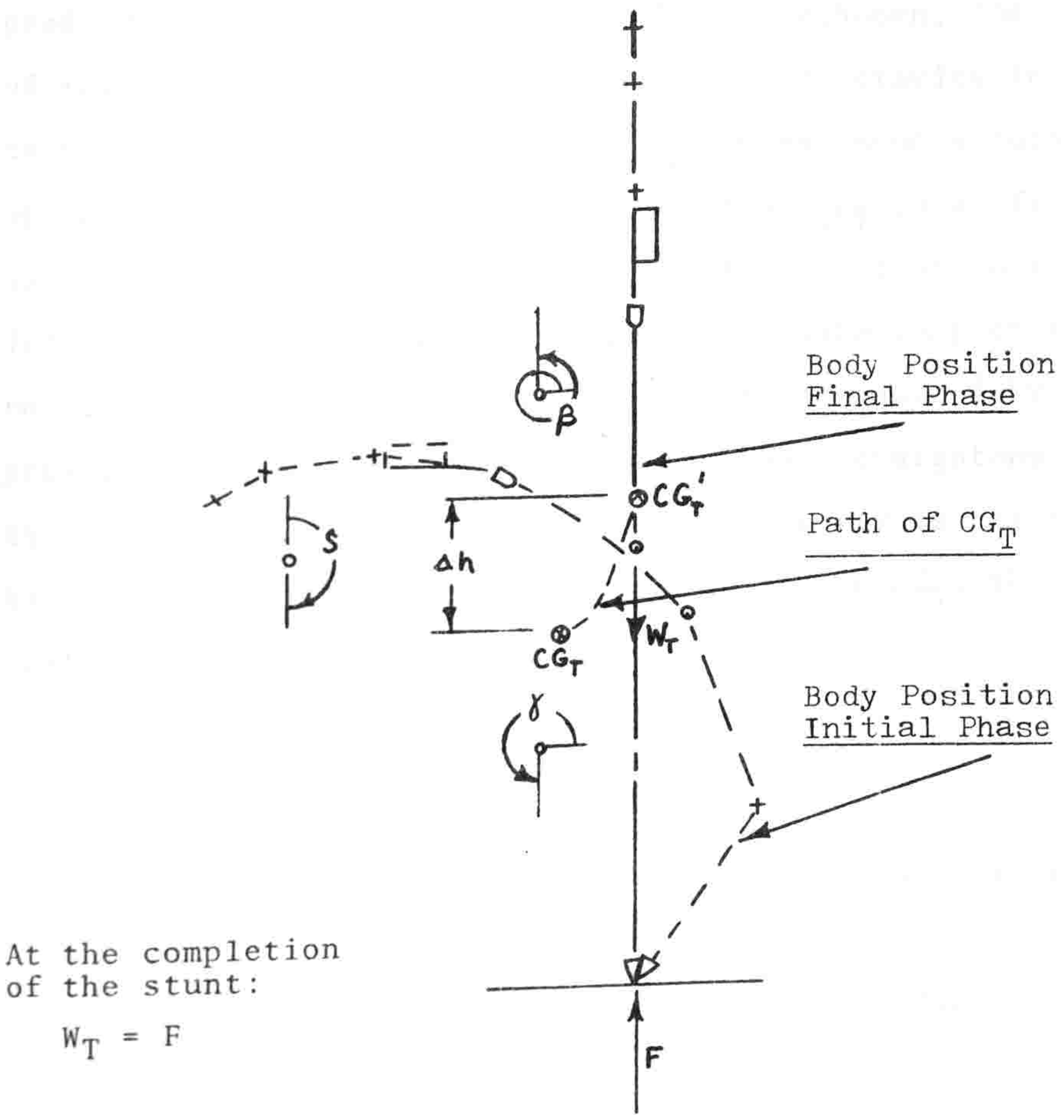

Fig. 7. Simplified force diagram for the mat kip at the initial and final phases of the landing sector.

Here the center of gravity is at the top of the parabola where no translational force has to be absorbed by the lower body. There is, however, the energy of rotation that will produce pressure against the mat. At touchdown, the center of rotation will change from the center of gravity to the point of foot contact. Except for the momentum absorbed by initial contact, the flight momentum $I_T\omega_T$ is at first unaltered. Since the moment of inertia relative to the foot is several times larger than it is with respect to the center of gravity, the angular velocity is reduced by approximately the same factor. As the body straightens out, this slowing continues. The remaining energy is absorbed by raising the center of gravity from CG_T to CG'_T, thus, the following energy equation applies:

$$\frac{1}{2}\bar{I}_T\omega_T^2 = \frac{1}{2}I_{OT}\omega_T^2 - E - \Delta hW \qquad \triangleleft\ 22$$

Where:

$\frac{1}{2}\bar{I}_T\omega_I^2$ is the rotational energy just prior to landing.

$\frac{1}{2}I_{OT}\omega_T^2$ is the rotational energy during the landing phase (variable).

E is the energy absorbed on impact.

ΔhW is the increase in potential energy of the body due to the increase of the height of the center of gravity.

If the rotation is too slow because of insufficient angular momentum or an excessive drop in the center of gravity during flight, the automatic response is to flex the knees and hips. This decreases I_{OT} thereby increasing ω_T, while at the same time allowing more time for rotation to bring the body to a vertical position. Additional energy must then be imparted to the lower body to raise the center of gravity to the normal standing position. Subject three is a good example in point (see appendix E, figure 16, and Appendix H, figure 64). Subjects one and four resorted to a step backward to regain balance (see appendix E, figures 14 and 17); this is an alternative to dropping the center of gravity. Subject two's performance is ideal since she never dropped her center of gravity either during flight or in the landing sector.

In summary, the mechanical analysis of the mat kip shows that:

1. The roll back is not important in the mechanical analysis.

2. A variety of factors individually under the control of the performer determines the rotational and translational components of flight.

3. Many combinations of rotational and translational components can lead to the "ideal" completion of the

stunt; thus generally a larger translational thrust will permit slower rotation and vice versa.

4. The above factors lead to a variety of ways of executing the stunt; i.e. there are a relatively large number of "degrees of freedom" available to the performer.

5. The ideal performance depends on the subject's ability to disallow the total center of gravity of the body to drop after lift-off is initiated.

Mechanical Analysis of the Glide Kip

This stunt consist of raising the center of gravity of the body as high as possible in the initial pike position, transferring the potential energy gained into kinetic energy during the glide, and stopping trunk rotation by piking and bringing the ankles to the bar. The kipping action in conjunction with arm torque translates the hip to the bar, and the angular momentum transfer from the thighs, legs, and feet to the composite body produces the rotation to the vertical. This general description is now further detailed by segmenting the total action into basic components for closer analysis and comparison with the mat kip or other stunts using a kipping action.

Phase I: The INITIAL PIKING phase permits the center of gravity to be raised as high and as far away from the bar as possible to supply the major part of the input energy necessary to complete the stunt. The initial and final energy levels for the glide kip are not very different as evidenced by the relatively small increase in height of the center of gravity after completion of the stunt (see appendix H, figures 65 to 68). We shall define this sector as terminating at the highest position of the center of gravity. The completion of the piking is well illustrated by the initial maxima in the graphs of the total body center of gravity, appendix H, figures 65 to 68. This is also demonstrated roughly by the initial minima in the angular displacement curves (appendix F, figures 34 to 37), and of course the corresponding zero angular velocity points on graphs in appendix F, figures 38 to 41.

Phase II: The GLIDE sector shall be denoted as starting from the maximum vertical center of gravity position of the initial pike and terminating at the extension just at the point where the relative angle between the thigh and trunk decreases. This is characterized by the crossover of the thigh and trunk velocity graphs in appendix F, figure 38 near frame 75, and in figures 39 to 41 near frame 110. The relative angular displacement of the thigh and the trunk should be near 180 degrees. In this investigation this angle was found to be precisely 185 degrees for all subjects. During the glide sector the potential energy of the initial pike is translated into kinetic energy. The relative motion of the thigh, trunk, and arms will not only add to or deduct from the appearance of the stunt but can also materially affect the efficiency of potential to kinetic energy transfer at extension if extension occurs at the same point. There is essentially a compound pendulum where, at the instant of extension, the energy is mostly rotational. This can be stated somewhat more precisely as:

$$E_P = E_K + E_L \tag{23}$$

Where:

E_P is the potential energy.

E_K is the kinetic energy differential between the highest total body center of gravity level and its relative height at extension.

E_L is the energy loss resulting from abrupt motions and decreases in the radius of the total center of gravity relative to the bar in terms of the fully extended radius.

Therefore:

$$W_T \Delta h = \tfrac{1}{2} I_{OT} \omega_T^2 + E_L \tag{24}$$

Where:

Δh is the center of gravity height change from the initial maximum.

I_{OT} is the total body moment of inertia relative to the bar.

Since the thighs must be lifted to clear the floor, the total body center of gravity must be held closer to the bar in the initial phases; thus, a certain amount of loss of potential energy is inherent during this portion of the stunt. For identical bar height taller subjects are additionally penalized. This, to some degree, also explains the greater ease of performing a kip on the men's horizontal bar. To minimize the loss the hips and thighs must, at their highest position, be extended as far away from the bar as possible. The purpose of this is not to "establish momentum," as noted by Garavaglia,[1] but to prevent the loss of potential energy which can be transformed into kinetic energy ($\frac{1}{2} I_{OT}\omega_T^2$) or angular momentum ($I_{OT}\omega_T$) at extension. The moment of inertia of the total body at extension, I_{OT}, of a given performer does not change regardless of the path of the total center of gravity; therefore the major difference noted will be the magnitude of the angular velocity of the center of gravity.

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[1]Garavaglia, "An Electromyographic-Electrogoniometric Analysis," p. 63.

The energy loss E_L is heat loss due to excessive flexing of the bar and internal body losses resulting from additional stretching. An extreme example of such loss can be demonstrated by having a performer drop from a straight arm support on a high bar vertically down to a hanging position. Although the kinetic energy equals the potential energy just prior to the application of the force on the arms, the net kinetic energy shortly thereafter is zero (if the performer is able to hang on to the bar).

Thus:

$$W_T \Delta h = E_L \qquad \triangleleft\ 25$$

On the other hand, if the body was extended at the same center of gravity height and then allowed to rotate E_L would be negligible and:

$$W_T \Delta h = \frac{1}{2} I_{OT} \omega_T^2 \qquad \triangleleft\ 26$$

The general force system near extension is shown in figure 8.

During the execution of this sector, the angular displacement of the trunk by the subjects tested in the study increases monotonically to a value of about 510 to 515 degrees as plotted in appendix F, figures 34 to 37 or to about 30 to 25 degrees below the horizontal. This is also readily observable from the stick figures in appendix E, figures 18 to 21. It is interesting to note the rather small range of deviation of this angle among performers.

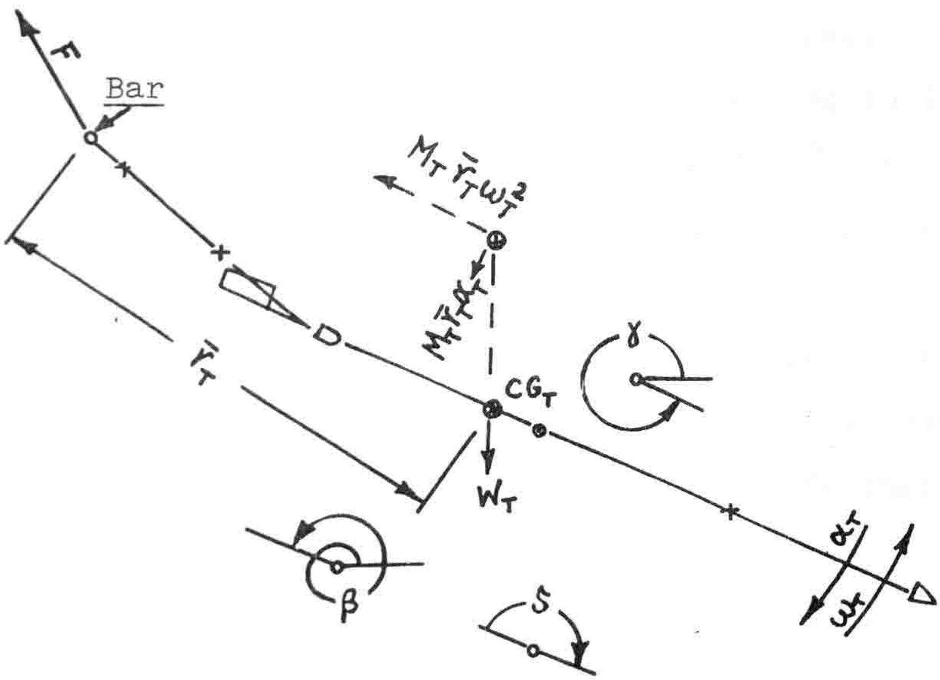

Fig. 8. Simplified force diagram during the final phase of the glide sector in the glide kip.

This may well indicate a generally, although empirical, critical value. Since the thigh velocities at this point are not zero, the performers could have forcibly prolonged the time to reach extension and thus attained a higher extension angle. This action would have to be initiated earlier by slowing down the acceleration of the thighs relative to the trunk. Extension is, therefore, not at the highest level of trunk angle attainable, as implied by Garavaglia,[1] since this would require the total dissipation of all kinetic energy at extension.

The dip in the angular displacement curves of the thigh during the sector (appendix F, figures 34 to 37) is due to the piking necessary to clear the floor. Since extension is occurring during the up-swing of the "pendulum" and the trunk's angular displacement is at a maximum, the angular acceleration of the trunk reaches a negative maximum. The fact that trunk and thigh velocities at extension are identical (appendix F, figures 38 to 41) further justifies the use of equation 24.

Phase III: The PIKE TO THE BAR portion of the action will be defined as ending at the time of zero angular velocity of the thighs (see appendix F, figures 38 to 41). This occurred at about frames 120, 150, 160, and 160 for subjects one through four, respectively. During this period the thigh angle continued to increase to a maximum of 460 to 470 degrees, or ten to twenty degrees past the vertical on the subjects tested; again a rather small range. The angular velocity of the thighs was greatest past extension and represented a smooth continuation of the velocity in the

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[1] Ibid.

glide sector as can be noted by examining figures 38 to 41 in appendix F.

Concurrently, the trunk was rotationally relatively stationary and reached a stable level at 530 to 535 degrees or ten to five degrees below the horizontal, respectively. This is shown by the nearly constant angular displacement in appendix F, figures 34 to 37, and the low angular velocity in the piking sector as seen in figures 38 to 41. Additionally, it should be noted that there is little translational motion of the hip during the first two-thirds of piking. The residual hip motion was, in all cases except for subject two, small. This can be observed from the stick figures in appendix E, figures 18 to 21. The movement was directed downward and backward toward the shoulders. This latter movement was mainly due to the rounding of the back during this phase of the kip and, to a lesser degree, due to an initial swing back of the shoulders. With the assumption of zero hip translation and zero trunk rotation during the first two-thirds of the pike sector, a simplified kinetic diagram (figure 9) can readily be constructed.

The total sector is also quite precisely defined (within a few frames) by the start and end of the negative slope of acceleration of the thighs in that time range.

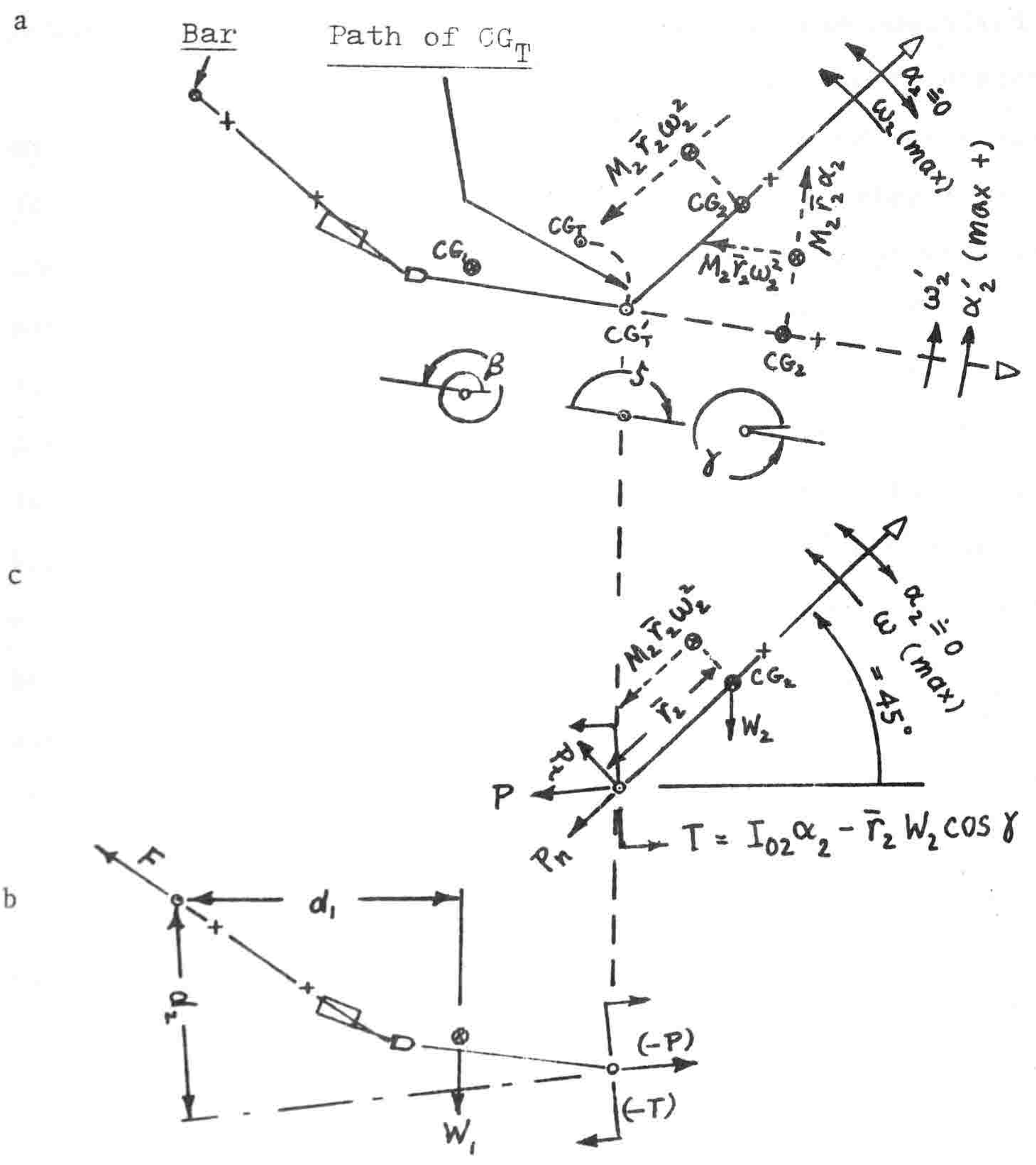

Fig. 9. Simplified force diagram for the pike to the bar. The "free body" diagrams show the mid-point of the piking sector. The slight drop of the upper body and its shortening due to upper body flexing are omitted in the sequence from extension shown.

At the end, this is due to the definition of the sector boundary where zero angular thigh velocity was specified.

The stick figure in figure 9a shows the reference systems for angles used in the graphs of appendixes F and G for the glide kip, the directions of angular velocity ω and acceleration of the thighs, and their initial and maximum velocity positions during the piking sector. The initial and the maximum thigh velocities, center of gravity positions, and paths of the center of gravity are also indicated. Since it has been assumed that the trunk and hips are essentially stationary, all parts of the body above the hip can be considered as a "free body" in static balance (figure 9b) as has been done in figure 3 for the mat kip. The lower body is, again, a dynamically balanced "rigid" system rotating about an axis which is not its mass center. Equations 9 through 19 are thus totally applicable to this system for the sector under discussion. The differences between the two applications are the direction and magnitudes of the various parameters. It must also be kept in mind that we are discussing here the piking sector while figure 3 and equations 9 to 19 were applied to the actual kipping action.

The weight of the upper body W_1, because of its horizontal distance from the bar and by virtue of its force moment d_1W_1, tends to rotate the trunk in the clockwise direction. The reaction to the rotational torque exerted on the legs by the hips (-T) produces a further clockwise moment on the upper body. Since the hips are stationary, an additional force (-P) is required to act in conjunction with moment arm d_2 to maintain the equilibrium of moments for the static condition imposed by equation 9 (with $\omega_1 = 0$) and equation 19.

This force (-P) must be supplied by the dynamic force system residing in the lower body. In examining this system (figure 9), the following will be noted. Both the torque due to the weight of the lower body (d_1W_1) and that due to the thigh reaction (-T) are in the clockwise direction; a counterclockwise balancing torque is required so that the net torque at the bar will be zero. The hip reaction torque (-T) is required to be clockwise since a counterclockwise torque must be applied to the lower body to induce piking. The force (-P) and its reaction P must balance all translational forces in the upper and lower body, respectively. The translational forces in the upper body are the bar reaction, F, and the upper body weight, W_1. The translational forces in the lower body involve the lower body weight W_2, the reaction to decreasing angular acceleration of the lower body, $M_2\bar{r}_2\alpha_2$, and the centrifugal force due to the thigh rotation about the hips, $M_2 r_2 \omega_2^2$. All these forces except weights W_1 and W_2 change both in direction and magnitude as lower body rotation progresses.

At the point where trunk rotation was definitely zero, all subjects exhibited maximum angular thigh velocity (see appendix F, figures 38 to 41). By checking the frame number of zero trunk velocity against the thigh angular displacement, it was found that zero trunk angular velocity and maximum thigh angular velocity occurred simultaneously and almost exactly at 45 degrees above the horizontal. Evaluation of the force system at this point will show that the centrifugal force from thigh rotation is at a maximum, and since its rate of change is zero, the angular acceleration and thus the tangential force are also zero.

Because of the addition of the gravitational force vector W_2, the net force operative in maintaining the equilibrium of the upper body $(-P) = W_2 + M_2 \bar{r}_2 \omega_2^2$ lies clockwise from 45 degrees above the horizontal. Also, since the centrifugal force $M_2 r_2 \omega_2^2$ is counteracting all other forces and moments in the entire system, it must, at this point, be considerably larger than W_2 and therefore the resultant force P is not expected to act above the horizontal. The average value for ω_{Max} of the thighs for the study group was about 410 degrees per second or 7.16 radians per second. Since $\bar{r}_2$ is approximately 1.2 feet, a close estimate of the centrifugal force in terms of the lower body weight would be:

$$M_2\bar{r}_2\omega_2^2 = \frac{W_2}{g}\,\bar{r}_2\omega_2^2 \qquad \triangleleft\ 27$$

$$= \frac{W_2}{32} \times 1.2' \times 7.16^2$$

$$= 1.92\ W_2\ \text{lb.}$$

Under these conditions the calculated resultant hip reaction (-P) would be 1.41 W_2 at an angle of about fifteen degrees above the horizontal.

The maximum average angular accelerations of the thighs in the piking sector for the group were:

$$+\ \alpha_{2max.} = 2000°/sec.^2 = 34.91\ rad./sec.^2$$

$$-\ \alpha_{2max.} = 2300°/sec.^2 = -40.25\ rad./sec.^2$$

Thus the maximum tangential forces on the hips in terms of the lower body weight W_2 can be found from:

$$P_t = M_2\bar{r}_2\alpha_2 \qquad \triangleleft\ 28$$

This results in:

$$+P_{t\ max} = 1.31\ W_2\ \text{lb.}$$

$$-P_{t\ max} = -1.51\ W_2\ \text{lb.}$$

Since the maximum positive acceleration occurs at the start of piking, this tangential force requires an upward directed hip reaction to maintain the hips at a constant level. At the forty-five degree position the tangential force goes to zero and the body position is entirely maintained by the centrifugal force. At the end of the pike, the negative acceleration produces a very sizable tangential force towards the bar driving the entire body backward. The normal inertial force on the lower body is at this time zero since the lower body angular acceleration is zero. In order to prevent excessive dropping of the total center of gravity during the piking stage, the kipping action must be instituted immediately. Because of the rapidly dropping lifting force due to the decreasing angular velocity of the thighs near the completion of the pike, a slight drop in the center of gravity occurs. This is clearly shown in appendix H, figures 65-68 and 70. Subject two showed both a larger drop in the center of gravity (figure 66) and a greater simultaneous hip drop (appendix E, figure 27c). This phenomenon appears to be related to that subject's lower height at the initial pike (figure 66) which resulted in lower angular velocity at extension (zero relative frame value in appendix G, figure 57). The associated delay in piking (figure 55) extended the time over which gravity acted resulting in the noted drop of the hips. The reduced velocity is vividly illustrated by the shift to the right of all kipping action curves for subject two (figures 55 to 60).

It is also of interest to establish an approximate level of centrifugal force at layout for the subjects tested. The average angular velocity of the trunk and thighs was nearly 185 degrees per second, or 3.23 radians per second, with a range of about five degrees per second. Assuming a radius of rotation for the total body center of gravity $\bar{r}_T$ of three feet, the total centrifugal force relative to the total body weight W_T would be:

$$M_T \bar{r}_T \omega_T^2 = \frac{W_T}{g} \bar{r}_T \omega_T^2 \qquad \triangleleft\ 29$$

$$= \frac{W_T}{32} \times 3.0 \times 3.23^2 \text{ lb.}$$

$$= .98\ W_T \text{ lb.}$$

It would also be helpful to have some knowledge of the residual kinetic energy at layout. Unfortunately the total body inertia moments of the subjects relative to the total bar were not obtained. The increase in height of the total body center of gravity from the extension to the zero thigh velocity in the total center of gravity diagrams (appendix H, figures 65 to 68) represents the re-transfer of kinetic energy to potential energy during the piking phase. The path of the center of gravity which forms a bulb shape shall hereafter be referred to as the bulb. The difference in horizontal level between the top of the bulb in these diagrams and the final zero thigh velocity point represents a reconversion to kinetic energy due to the return swing of the hips (rounding of the back) and the shoulders at the final phases of the kipping action. Since no significant "external force" was applied to the system as a whole, "loss" of total energy during the stunt to this point is approximately equal to the difference in height between the total center of gravity at the initial pike (start of the glide) and the highest part of the bulb in the total center of gravity diagrams (figures 65 to 68).

The piking phase is also characterized by the highest positive angular thigh velocity. This can be viewed as being basically due to the momentum transfer from the whole body to the lower body which has much less inertia and must, because of the law of conservation of momentum,[1] make up for this deficiency by increased

[1] Seely and Ensign, <u>Analytical Mechanics for Engineers</u>, Article 149, pp. 330-331.

angular velocity:

$$\text{Momentum} = I_{OT}\omega_T = I_{02}\omega_2 \quad ◁ 30$$

Where:

I_{OT} is the total body inertia relative to the bar at the instant of transfer.

I_{02} is the lower body inertia relative to the hips.

This is a somewhat oversimplified view since losses of momentum occur between extension and maximum angular velocity because of the decrease in kinetic energy; hence, ω_2 will be lower than indicated by equation 30. Also, transfer is a gradual and not an abrupt condition. A more precise but less obvious relationship applicable to any lower body angle would be:

$$I_{OT}(\omega_{T1} - \Delta\omega_T) = I_{01}\omega_1 + I_{02}\omega_2 \quad ◁ 31$$

Where:

ω_{T1} is the total body angular velocity at extension.

$\Delta\omega_T$ is the change (loss) in angular velocity of the total body center of gravity due to the decrease in kinetic energy.

After completion of momentum transfer ($\omega_1 = 0$) the term $I_{01}\omega_1$ will go to zero.

At the final third of the piking sector, the assumption of zero translatory motion of the upper body no longer holds as was previously indicated. Figure 10 shows the simplified force diagram depicting conditions during the transition from piking to kipping. After the maximum angular velocity of the lower body has been attained at a thigh angle of about forty-five degrees above the horizontal (figure 9), the centrifugal force decreases and acts in a less favorable angle to maintain the initial extension of the upper body. This change with the simultaneous increase in the tangential reaction force created by the negative maximum acceleration α_2 noted before, the upper body force F and the torque T_F initiate the rapid backward translation of the trunk. The details will be further elaborated in the discussion of the kipping action relative to figure 10. This translation also allows the legs to drop back to the bar before the start of the kipping action.

Phase IV: The KIPPING ACTION sector will be defined as beginning with the point of zero thigh rotational velocity after piking and ending with the horizontal layout before rotation. The terminal point of this phase is somewhat obscure since no definite horizontal layout position exists and the momentum transfer from the lower body to the whole body is gradual and cannot be well defined. The cutoff point was chosen by visual observation of the stick figures in appendix E, figures 18 to 21.

The stick figures (figures 18 to 21) as well as the angular displacement curves and angular velocity curves (appendix F, figures 34 to 41, and appendix G, figures 56 and 58) show that the angular displacement of the trunk for the subjects tested remained relatively constant at 525 degrees or about 15 degrees below the horizontal for all performers tested. This is nearly the same angle which was maintained through the latter part of the pike. The rapid backward and upward translation of the trunk initiated in the final phases of piking continues to be augmented by the increasing shoulder torque T_F. Figures 10 and 11 show force diagrams describing the kipping sector. In the interest of simplification, the small effect of rotation of the trunk was omitted. The curvature of the path of motion of the upper body toward the terminal portion of this sector is, however, not a negligible effect. The overall stick figure was, for convenience of analysis, split into a lower body sector separated at the hips; and the arms were separated from the upper body segment at the shoulders. Again, to simplify matters, the effects of arm weight were considered as part of the upper body weight W_1, and the a Total body diagram

c Lower body "free body" diagram

d Arm "free body" diagram

b Upper body "free body" diagram

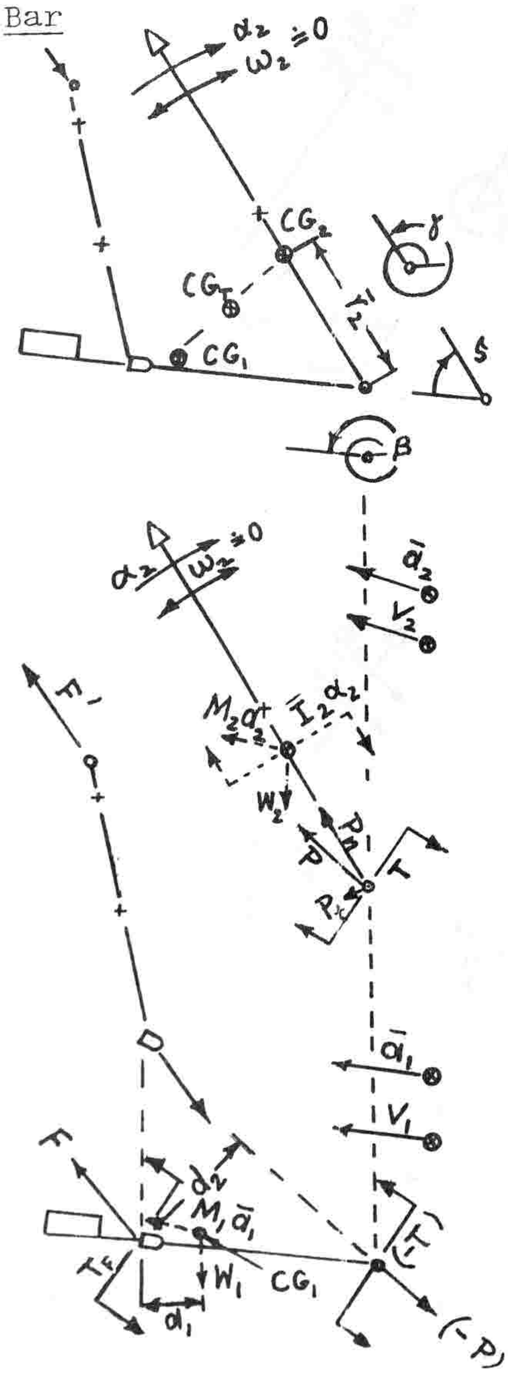

Fig. 10. Simplified force diagram at the final phase of the piking sector and the start of the kipping sector.

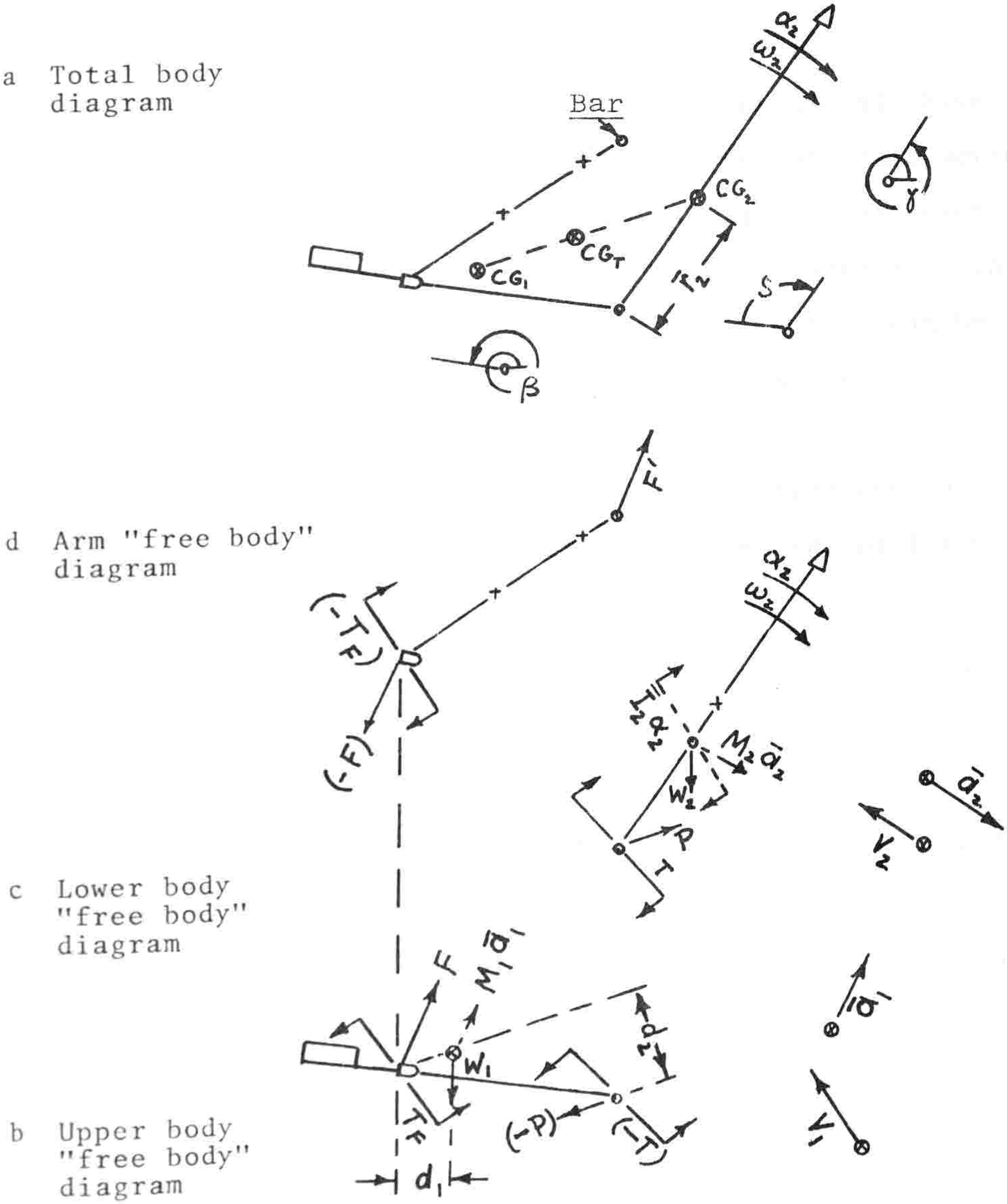

Fig. 11. Simplified force diagram just after the mid-point of the kipping sector.

rotational velocity and acceleration influence of the arms were considered to be minor.

The motion of the upper body in the initial phases of the kipping sector is predominantly translational, moving in a slightly curved path backward and upward. The lower body has both translational and rotational components. The instantaneous center of rotation of the lower body can be chosen at will provided the same point is also used to describe the translation of the system.[1]

If, additionally, the center of rotation chosen is also the center of gravity, the following set of force equations applies to plane motion:[2]

$$\Sigma F_x = M\bar{a}_x \qquad \triangleleft\ 32$$

$$\Sigma F_y = M\bar{a}_y \qquad \triangleleft\ 33$$

$$\bar{\Sigma}\bar{T} = \bar{I}\alpha \qquad \triangleleft\ 34$$

The above can be restated for application to the lower body motion of figures 10 and 11 as:

$$\Sigma F_2 = M_2\bar{a}_2 \qquad \triangleleft\ 35$$

$$\bar{\Sigma}\bar{T}_2 = \bar{I}_2\alpha_2 \qquad \triangleleft\ 36$$

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[1] Ibid., article 96, p. 220; article 114, pp. 264-73.

[2] Ibid., article 114, pp. 264-73.

Through substitution of the forces and torques from figures 10c and 11c, the following was obtained:

$$\Sigma F_2 = -W_2 + P = M_2\bar{a}_2 \qquad 37$$

$$\Sigma \bar{T}_2 = T + r_2P_t = \bar{I}_2\alpha_2 \qquad 38$$

The force equations applying to the upper body which has been simplified into the plain translational system of a "rigid" body are:

$$\Sigma F_1 = M_1\bar{a}_1 \qquad 39$$

$$\Sigma T_{01} = 0 \qquad 40$$

Substitution of forces and torques from figures 10b and 11b results in:

$$F_1 = F + (-P) - W_1 = M_1\bar{a}_1 \qquad 41$$

$$T_{01} = (-T) + T_F + d_2(-P) + d_1W_1 = 0 \qquad 42$$

A knowledge of the linear acceleration, $\bar{a}_2$, and the weight of the lower body, W_2, will permit the evaluation of the hip reaction force vector, P, by equation 37. The value of moment of inertia, $\bar{I}_2$, and the vector, P, in conjunction with the rotational acceleration, α_2, permit the calculation of the hip torque, T, by equation 38.

In the final phases of the piking (figure 9a), it has been noted that the maximum negative angular velocity produces a reaction force $-M_2\bar{r}_2\alpha_2$ acting to rapidly translate the upper body backward. This inertial force (which, because of the new rotational reference system of figure 10c, now substantially resides in the $\bar{I}_2\alpha_2$ term of equation 38 but is assisted by the shoulder torque, T_F, and the pendulum action of the upper body) continues the rapid backward movement of the upper body that is typically taken to mark the end of piking. This is very evident in the stick figures (appendix E, figures 18 to 21). A superposition of the stick figures for the piking and kipping sectors may have provided a better view of the start of the rapid backward translation of the trunk during piking and its continuation during kipping. Under these conditions, however, rather crowded diagrams would have resulted.

Because the upper and lower body are both subject to dynamic forces, even a cursory mechanical analysis of this sector will require the translational parameters of displacement, velocity, and acceleration for an assessment of the direction and magnitudes of hip, shoulder, and arm forces and torques. Some tentative conclusions can, however, be arrived at by observation of the stick figures and other available data.

A close examination of the stick figures (appendix E, figures 18 to 21) shows that the center of gravity of the lower body moves from a relative stationary position (at approximately two-thirds through the piking action) backward and upward to about twenty-five to thirty-five degrees from the horizontal on the subjects tested. Hence, the initial linear accelerations must also be in the same general direction as shown in figure 10. During the later phases, the translational velocity of the center of gravity tends to slow down as the bar reaction force F' changes direction and the rotational forces of the lower body become more dominant. These forces oppose backward translation. Linear horizontal acceleration thus reverses as shown in figure 11. From appendix H, figures 65 to 68, it can be observed that in this region of the sector distances decrease between successive ten-frame data points of the total center of gravity. This, in turn, indicates a decrease in velocity and, therefore, a reversal in acceleration not only along the horizontal but also along the path of motion. Conversely, vertical velocity and acceleration increased (see figures 65 to 68 and appendix E, figures 18 to 21).

A study of figure 10b and equation 42 indicates that the torques, (-T) and T, tend to raise the hips while the torques, $d_2(-P)$ and d_1W_1, have the opposite effect. Since there is little rotation of the upper body these two sets of torques must be reasonably balanced.

Equation 41 and figure 10, in conjunction with the stick figures, also provide some further insight into the translatory motion of the upper body at the start of the kipping action. The force vector F (opposed by -P) acts in a direction to induce a translatory acceleration backward and upward. The weight W_1 has only a vertical component and tends to retard upward motion only. The center of gravity CG_2 shows increasing initial acceleration backward and upward at about ten to fifteen degrees above the horizontal. This is evident from the fact that the thighs in figures 18 to 21 (appendix E) move in this direction during the initial transitional phases from piking to kipping action. Since CG_1 is moving faster than CG_2, the initial upper body translatory acceleration $\bar{a}_1$ is greater than that of the lower body. Additionally the force causing translation $M\bar{a}$ is greater for CG_1 than for CG_2 because of its greater acceleration and the somewhat larger magnitude of M_1.

Figure 11 illustrates conditions at just past the midpoint of the kipping action. A description of the major differences between this stage and the start of the kipping sector follows in the paragraphs below.

The horizontal component of the translational acceleration $\bar{a}_2$ of the lower body center of gravity is now reversed (figure 10c). This causes the horizontal force components of P and (-P) to reverse and act to increase the backward horizontal force component. The inertial force of the lower body rotation is now pushing the upper body backward instead of pulling it.

The bar reaction F' which by previous assumption is equal to the shoulder force F tends to slow the horizontal velocity, but increases the vertical component. F and T_F are now also at a more favorable angle for the application of increased shoulder action. The effect of this increase in force is quite noticeable in the stick figures for all subjects.

Since the translatory motion is now more vertical, the shoulder force F and the torque T_F are larger and, because the upper body angle remains at about the same inclination, the force (-P) must act toward the back and more vertically. The couple (-T) must increase to maintain the balance of equations 41 and 42.

The increasing differences in the distances between successive positions of the upper body in the stick figures (appendix E, figures 18 to 21) in the vertical direction indicate an increase in vertical acceleration. There is, therefore, an increase in the shoulder force F' and the associated torque T_F.

As noted above, slowing of the horizontal velocity reverses the horizontal acceleration component of the upper body. This, together with the increasing vertical acceleration, causes the new $M_1\bar{a}_1$ vector to be directed forward and upward (figure 11b).

It should be noted that the kipping action itself does not raise the total center of gravity during kipping. Throughout kipping the hips move upward more rapidly than the total center of gravity, which even shows a slight initial drop due to the pendulum motion of the body explained previously. The hips by flexing simply rise toward the total body center of gravity, while the center of gravity of the lower body drops relative to the upper body. The force applied by the arms provides the translational energy necessary to increase the total center of gravity level above the starting value at the top of the "bulb" on the total center of gravity plots (appendix H, figures 65 to 68 and 70) and compensates for energy losses during the stunt. The final force conditions of the body in the kipping action will be described in the rotational phase.

Phase V: The BODY ROTATION is defined here as terminating in the straight arm support with the body in the vertical position. Figure 12a is a stick figure in the initial position of this sector at the start of rotational momentum transfer. At this stage the following conditions were noted from subject test data (rotational plots, stick figures, and total body center of gravity graphs):

1. The translational motion of the body is strictly vertical, as shown in appendix H, figures 65 to 68.

2. The trunk angular velocity ω_1 crossed the zero axis and began its clockwise (negative) rotation (appendix F, figures 38 to 41).

3. The lower body angular velocity ω_2 was near its negative maximum. Subject two showed an anomaly (figure 39) which may have resulted from recovery attempts by premature locking of the hips to rectify her excessive center of gravity and hip drop during kipping (appendix E, figure 19c and appendix H, figures 66 and 70).

4. Total body center of gravity movement was vertically upward (appendix H, figures 65 and 68).

The following additional factors in connection with figure 12 are noteworthy for the instant of time indicated:

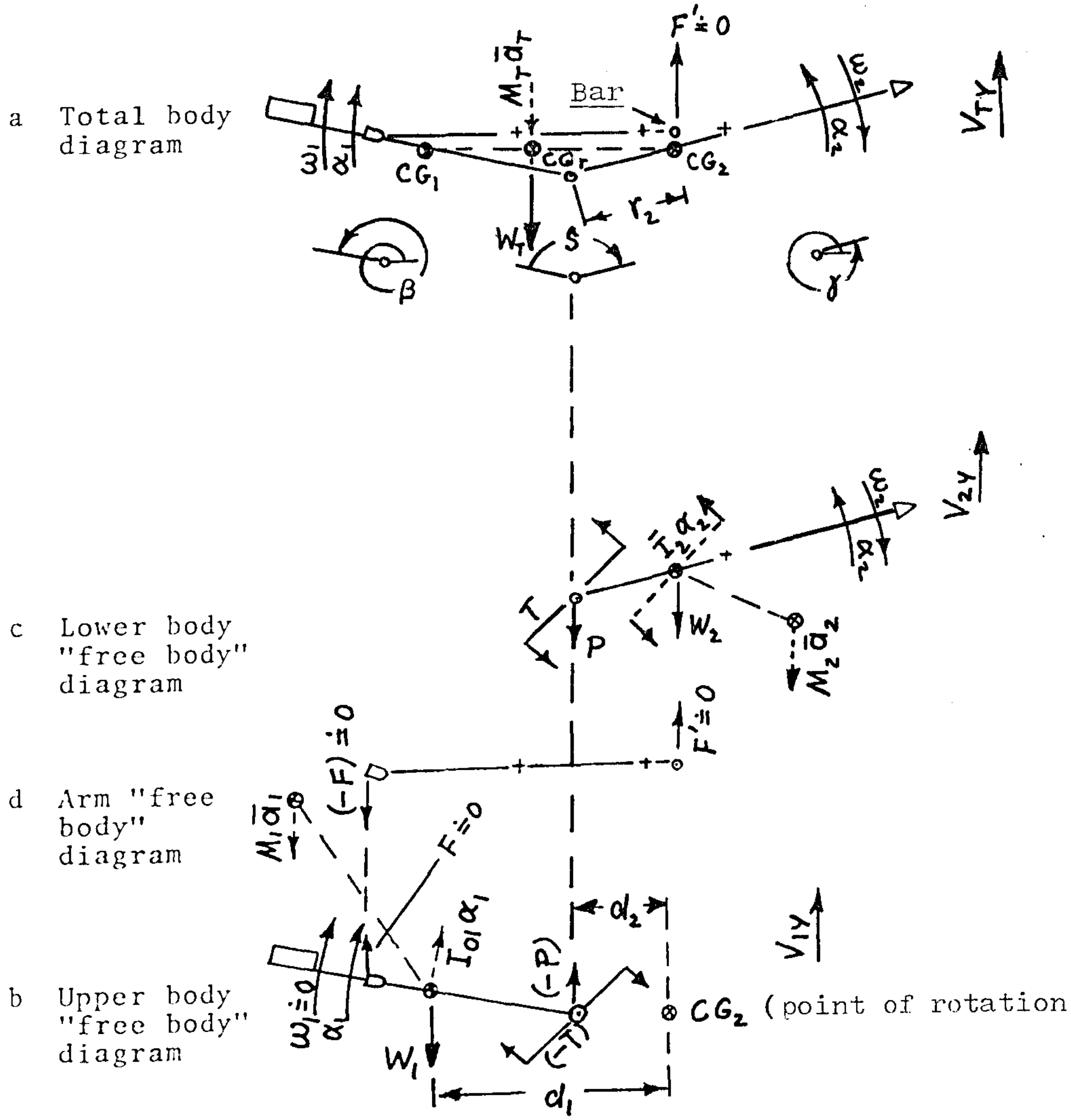


Fig. 12. Simplified force diagram at the instant of "weightlessness" (wrist rotation) at the start of the rotation sector.

Note: The translational momentum ($M_T v_y$) tends to hold the body momentarily "suspended" against the force of gravity. Initial rotational effects due to this momentum if the thighs should strike the bar have been omitted.

1. The bar reaction force F' is essentially zero as is evidenced by the successful wrist rotation of the performers at this stage.

2. Negligible shoulder force and torque exist and vertical translatory acceleration becomes negative although the vertical momentum of the total center of gravity $M_T v_y$ momentarily continues. This momentum tends to resist the gravitational force W_T and also produces some initial rotation about the bar if the thighs strike the bar.

3. In order not to have any large net horizontal forces, all force vectors in figure 12b must be reasonably vertical. The only large translational force aside from (-P) is W_1 which must be vertical, thus, (-P) and, as a result, P must also be close to vertical. Since ω_1 as noted above is essentially zero, no significant centrifugal force is present in the free body segment shown in figure 12b.

4. Similarly, in order not to produce any sizable horizontal forces in the lower body, the point of leg rotation O must be nearly coincident with the lower body mass center CG_2. If rotation occurs at any other point a net centrifugal force colinear with the lower body will exist. The above logic can be further reinforced by noting that the arms in the position shown (figure 12a) are just about

at the center of gravity of the lower body CG_2; and since the thighs should be against the bar at that time, rotation will have to occur at that point.

5. The initial locking of the joints of the lower extremities reverses the direction of the vertical components of vectors P and (-P) (compare figure 12b and c with figure 11b and c) and gives rise to the reversal of the couple pair, T and (-T); the negative angular acceleration, α_1; and the resultant tangential force $I_{01}\alpha_1$ (figure 12b).

The force and torque summations for the "free body" diagrams of figure 12 at the instant of weightlessness may be written as follows:

1. Figure 12b:

$$\Sigma F_1 = (-P) - W_1 = M_1\bar{a}_1 \doteq 0 \qquad \triangleleft\ 43$$

$$\Sigma T_1 = (-T) + d_1W_1 = I_{01}\alpha_1 \qquad \triangleleft\ 44$$

2. Figure 12c:

$$\Sigma F_2 = P - W_2 = M_2\bar{a}_2 \qquad \triangleleft\ 45$$

$$\Sigma T_2 = r_2P_n + T = I_2\alpha_2 \qquad \triangleleft\ 46$$

The methods for establishing the formulas follow the same basic procedure previously explained.

If the lower and upper body rotation became fully locked in, then ω_1, and ω_2, and α_1, and α_2 would be identical. This is actually never fully achievable. According to the data of appendix F, figures 38 to 41, the conditions within the rotational sector which lead to the quality of ω_1 and ω_2 either occurred twice (subjects one, two, and four) or was only approached (subject three). Equality of acceleration (figures 42 to 45) was equally irregular for the subjects examined. Because precise conditions and timing of momentum transfer are not too important in completing the stunt, more "degrees of freedom" are available to the performer.

For the sake of simplifying the theoretical discussion, it was assumed that ideal conditions of equal angular velocity and acceleration applied and that the upper and lower body sectors were in line. The force diagram for the action is shown in figure 13. The conditions during the half rotation point are depicted. For this purpose the entire body was assumed to be a "rigid body" rotating about the bar. The general force equations 9, 10, and 11 apply. Specifically:

$$F_n = -W_{Tn} + F_n' = M_T \bar{r}_T \omega_T^2 \quad \triangleleft\ 47$$

$$F_t = -W_{Tt} + F_t' = M_T \bar{r}_T \alpha_T \quad \triangleleft\ 48$$

$$T_O = d_1 W_T = I_{OT} \alpha_T \quad \triangleleft\ 49$$

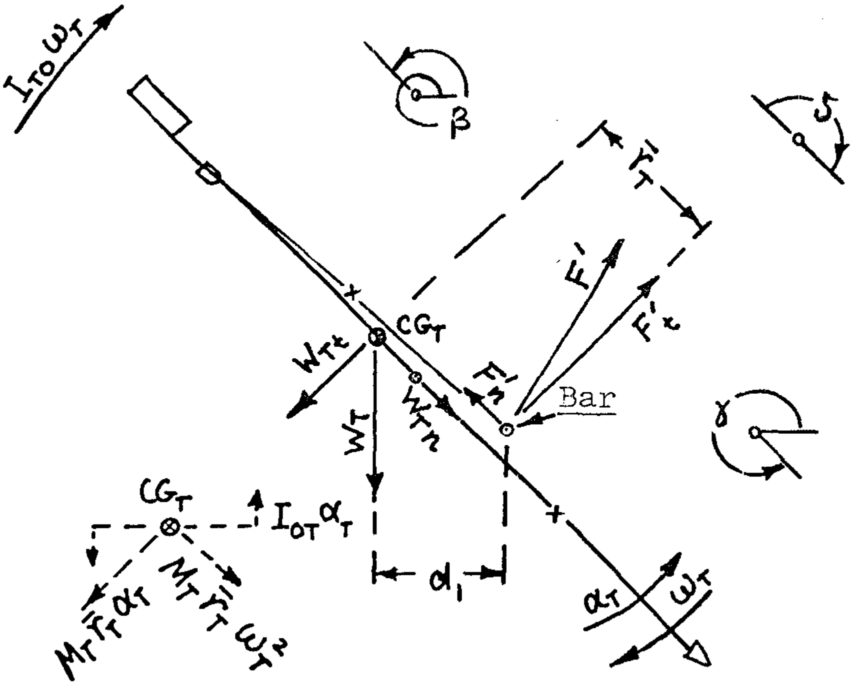


Fig. 13. Simplified force diagram near the halfway point of the rotation sector of the glide kip.

The increase in potential energy level during this phase is supplied by the loss in kinetic energy from the rotation of the lower body. The energy is first transferred from the lower body to the entire body, which then provides the necessary "work" to raise the center of gravity. Any residual energy at the end of the stunt has to be dissipated either by allowing the whole body or legs to swing back away from the bar, or by applying a resisting torque to the bar with the hands, or both.

The momentum transfer, if it is assumed to be total and to have occurred at the initial point of totation (figure 12), would satisfy the following equation:

$$I_2\omega_2 = I_{OT}\omega_T \qquad \triangleleft\ 50$$

Since I_{OT} is greater than I_2, ω_T will be less than ω_2. This is evident by an examination of the stick figures in appendix E, figures 18 to 21, and the velocity reduction of the thighs (lower body) at the point where the upper body begins to lock-in (ω_1 becomes negative) (see appendix F, figures 38 to 41).

Equation 50 is again somewhat oversimplified since momentum transfer in the practical case was not instantaneous and the transfer of kinetic to potential energy affects ω_T and ω_2. In order to obtain more precise results, equation 31 can also be applied here.

In summary, the mechanical analysis of the glide kip indicates that:

1. The glide kip requires precise timing in both the kipping sector in the preparatory phases (the initiation of the pike to the bar and the start of the kipping action).

2. Preparatory phases must be executed precisely in terms of certain critical positions and timing. The angular displacement of the trunk and thigh angles at the

end of the pike to the bar, the thigh angle at maximum thigh velocity and the lack of trunk velocity during piking are but a few examples.

3. The exchanges of kinetic and potential energy levels require precise budgeting.

4. The number of "degrees of freedom" in the performance of the stunt are quite limited as evidenced by the close conformance of the rotational data and the total body center of gravity curves as well as the mechanical requirements based on theoretical considerations of the mechanical analysis. The main exception to this appears to be the final rotation where any residual energy, if present, must be dissipated.

5. The actual kipping action is mainly responsible for supplying rotational energy and the translational energy to lift the center of gravity from below the bar at the start of the rotation sector to the straight arm support. The remaining energy necessary to perform the stunt is primarily due to the potential energy level attained at the initial pike and the arm torque applied during kipping.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDIES

The purpose of this study was to determine whether the mat kip represents a valid step in the progression for learning the glide kip on the uneven parallel bars. Parameters examined in detail were angular displacement, angular velocity, angular acceleration, and total body center of gravity. Through analysis the controversy among specialists in this subject was investigated. The study was delimited to four woman volunteers eighteen and nineteen years of age from the University of Wisconsin Gymnastic Team at Madison, Wisconsin.

A review of literature indicated that the present study did not duplicate any previous investigations. Bovinet, Frederick, Hughes, and Spencer all stated that the mat kip and any swinging kip were mechanically similar and, therefore, the mat kip could be considered a lead-up skill to the learning of the glide kip on the uneven parallel bars.

Spencer's study of the mat kip and Bovinet's study of the glide kip on the uneven parallel bars both determined that approximately a fifty-one degree angle of projection of the thighs during the kipping action was considered to be the most efficient for a successful performance in their respective studies. Spencer's male subjects indicated the angle of leg thrust for a successful mat kip ranged from forty-five to seventy degrees with a mean of fifty-one degrees. On the other hand, Bovinet's female performers revealed that an approximate fifty-one degree angle of projection produced a smooth acceleration of the hips to the bar with sufficient momentum to complete the glide kip to a high straight arm support position.

Hough, in her study, found that the most common causes for unsuccessful performance of the glide kip were failure to keep the chin tucked in to the chest through the complete skill, insufficient leg thrust, and failure to keep the elbows straight.

The Garavaglia study of the glide kip concluded that an excellent glide kip should include the following characteristics: (1) coming to a full extension at the end of the glide, (2) pausing at the end of the glide, (3) bringing the ankles all the way to the bar during the following pike, (4) extending the leg action upward and outward during the kip, and (5) keeping the knees straight throughout the stunt.

Frederick's article, "Gymnastics' Basic Seven for Girls and Women," claimed there are two general classifications of the kip: a back lying position kip with hips flexed and a swinging kip. Hughes, Spencer, and Frederick indicated in their writings that a gymnast who can perform a mat kip will learn the kip on the uneven parallel bars faster than a gymnast who cannot perform this skill. While Cochranie agrees that the kip movement is an essential part of work on the uneven parallel bars, he states that the kip should be initiated with the single leg stem rise on the uneven parallel bars.

Through the use of cinematography a mechanical analysis of the mat kip and the glide kip which focused mainly upon rotational parameters was pursued. The parameters examined in detail were angular displacement, angular velocity, angular acceleration, and total body center of gravity. Four woman gymnasts volunteered to participate in the study. The subjects were photographed performing the mat kip and the glide kip on the uneven parallel bars. The best of the three trials of each subject was analyzed.

The methods of analysis used were:

1. The collection of data on trunk and thigh angles and center of gravity of the total body.

2. Illustration of outline drawings and composite stick figures.

3. The computation of absolute and relative angular displacements, velocities, and acceleration of the trunk and thighs and their graphical and tabular presentation.

4. Mechanical analysis of the mat kip and the glide kip.

From the analysis the similarities and dissimilarities of the mat kip and the glide kip were determined.

Results of the Study

The results of this study can be summarized as follows:

Similarities

1. Both stunts involve a basic kipping action which is defined as a momentum transfer from the lower body (thighs, legs, and feet in an extended state) to the total body.

Dissimilarities

1. A thrust action appears in the mat kip. No similar phenomenon occurs in the glide kip.

2. Preparatory sectors for the kipping action are of little consequence in the mat kip but are of extreme importance in the glide kip.

3. In the mat kip the translational forces caused by the kipping action of the legs prior to lift off are

absorbed by the shoulders and arms. In the glide kip the translational forces are utilized to translate the body backward and upward against the underside of the bar.

4. In the mat kip a variety of factors individually under the control of the performer determine the rotational and translational components of flight. On the other hand, the glide kip requires precise timing in both the kipping sector and the preparatory phases such as the initiation of the pike to the bar and the start of the kipping action.

5. The ability of the performer to interchange rotational with translational factors to obtain a successful mat kip allows the gymnast a larger number of "degrees of freedom" than in the glide kip. In the latter the exchanges of kinetic and potential energy levels and timing require precise budgeting.

6. In addition to the above-stated differences, the mechanical analysis and the resultant mathematical models show absolutely no similarities except for the fact that momentum transfer does occur in both kips.

Conclusion of the Study

The similarities and dissimilarities of the mat kip and the glide kip led to the conclusion that, except for a basic momentum transfer mechanism, the two stunts are not comparable.

Spencer and Bovinet stated in their respective studies that a fifty-one degree angle of projection of the thighs during the kipping action was considered most efficient for a successful kip. This study reveals no projection to exist in the glide kip. The initial translatory trajectory angle of the mat kip after lift off (thrust) was noted to be twenty to thirty degrees on the subjects studied. Spencer's observations on the mat kip did not differentiate between rotation and translation. Bovinet only noted a projection angle of fifty-one degrees in the conclusion of her study on the glide kip, but no support or definition was provided in the text.

The results of this study agree with those of Frederick that two general classifications of the kip exist: (1) a kip from a fixed reference surface which restricts hip motion and (2) a swinging or dynamic kip.

Discussion

This study provided an adequate data base to justify the conclusions obtained. However, additional data would have been useful in simplifying the task of analysis, for providing background material for a more exhaustive study of both stunts, and to establish a broader base for future theses. Such modifications would include:

1. The processing of every second frame for rotational data to eliminate the rather laborious manual methods of evaluation and plotting.

2. Rotational data acquisition over the entire mat kip rather than terminating prematurely as was done in this study.

3. The addition of all translational parameters for the upper, lower, and total body centers of gravity.

4. The measurement of moments of inertia of the total body and certain body sectors relative to selected axes of rotation.

The rather extensive mechanical analysis was found necessary to ascertain the scientific basis of the study. The methods applied and the manner of establishing simplified mathematical models should be useful in other biomechanical studies. The few sample benchmark solutions of force equations only provide examples of what is possible. The first step in any exhaustive study of body motion should be a thorough mechanical analysis of the type noted here so that internal and external forces not directly measurable can be realistically estimated. Other evaluations of these stunts such as the electromyographic and electrogoniometric studies by Garavaglia on the glide kip could then be more securely based.

The concept of defining the stunts into action sectors to assist analysis and simplify the set-up of mathematical models proved to be very useful and can be applied to most physical activities. It is, however, necessary to separate the important factors and eliminate minor actions and perturbations.

Through this study, it was established that any kip will provide the performer the basic skill of momentum transfer from the lower body to the entire body. A basic rollback from a seated position followed by a leg kip back to the seated position should be as good an introductory exercise as the mat kip.

In order to acquire the more complex skills of timing and coordination of the glide kip, a dynamic or swinging kip must be used, as Cochranie has pointed out. A good beginning swing kip would be the uprise or bar kip done on the men's horizontal bar. This would provide the following advantages:

1. Less skill would be required by eliminating the necessity of piking to clear the floor.

2. The performer would be able to use multiple swings and build up momentum in order to reach the proper position for extension and piking to the bar.

3. The gymnast would experience some feeling regarding the amount of potential energy required to reach proper extension, that is, to obtain adequate height of the body center of gravity on the backswing. This is similar to the proper initial pike height in the glide kip.

Recommendations for Further Studies

Since this study conclusively showed that the mat kip is not a lead up skill to the glide kip, further studies on this subject are not recommended. Extension of the analysis of both stunts could establish more insight into improved methods of performing the mat kip and the glide kip. The following areas give some examples of what could be explored thoroughly:

1. The extension of the numerical analysis of the forces at various sectors of the stunts.

2. Measurement of moments of inertia and additional translational parameters to permit the total solution of the equations of force.

APPENDIX A

1. Investigation Form
2. Personal Data Sheet
3. Thigh and Trunk Data
4. Summary of Subject Personal Data

INVESTIGATION FORM

As a subject in this investigation you will be filmed doing a mat kip and a glide kip on the uneven parallel bars. You may withdraw from the above investigation any time you wish. You will be asked to progress only within your own limits.

Name: ______________________________ Age: __________

Address: ______________________________

____

Telephone Number: ____________________

I have read the above regarding the investigation. I willingly agree to volunteer for the investigation titled: "The Mat Kip as a Progressive Step Toward the Performance of the Glide Kip on the Uneven Parallel Bars," conducted by Mrs. Darlene J. Oess. I do not consider that my rights as a human being are infringed upon in any way.

______________________________ Date: __________
Signature of volunteer

PERSONAL DATA SHEET

Name ____
(First) (Middle) (Last)

Birthdate ____
(Month) (Day) (Year)

Subject Filming Number ____________

Subject Height ________________ Weight __________

Are you a student at the University of Wisconsin? ________

If not, where? ______________________________

How long have you participated in gymnastics of any type?

____

How long have you been a member of the University of

Wisconsin Gymnastic Team? ____________________

Did you qualify for the National Gymnastics Championships

in 1976? Yes ________ No ________

THIGH AND TRUNK DATA

Subject Number ____________ Stunt ______________________

FRAME	THIGH	TRUNK	FRAME
0			0
10			10
20			20
30			30
40			40
50			50
60			60
70			70
80			80
90			90
100			100
110			110
120			120
130			130
140			140
150			150
160			160
170			170
180			180
190			190
200			200
210			210
220			220

SUMMARY OF SUBJECT PERSONAL DATA

The gymnasts had been active in gymnastics from five to eight years. Most of the performers had been on the University of Wisconsin Gymnastic Team for one year. Subject two was on the team for two years prior to the study.

The following were the weight and height of each subject:

Subject One

Weight: 95 pounds

Height: 4 feet 11 inches

Subject Two

Weight: 136 pounds

Height: 5 feet 3 3/4 inches

Subject Three

Weight: 121 pounds

Height: 5 feet 4 inches

Subject Four

Weight: 129 pounds

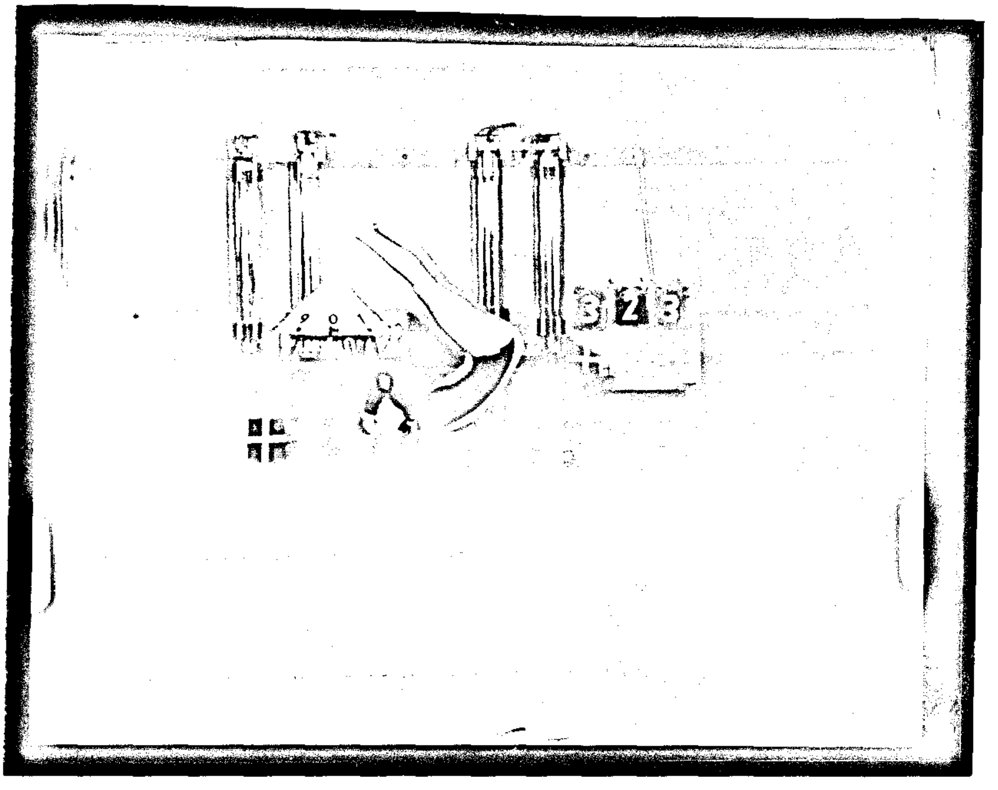
Height: 5 feet 7 1/2 inches

APPENDIX B

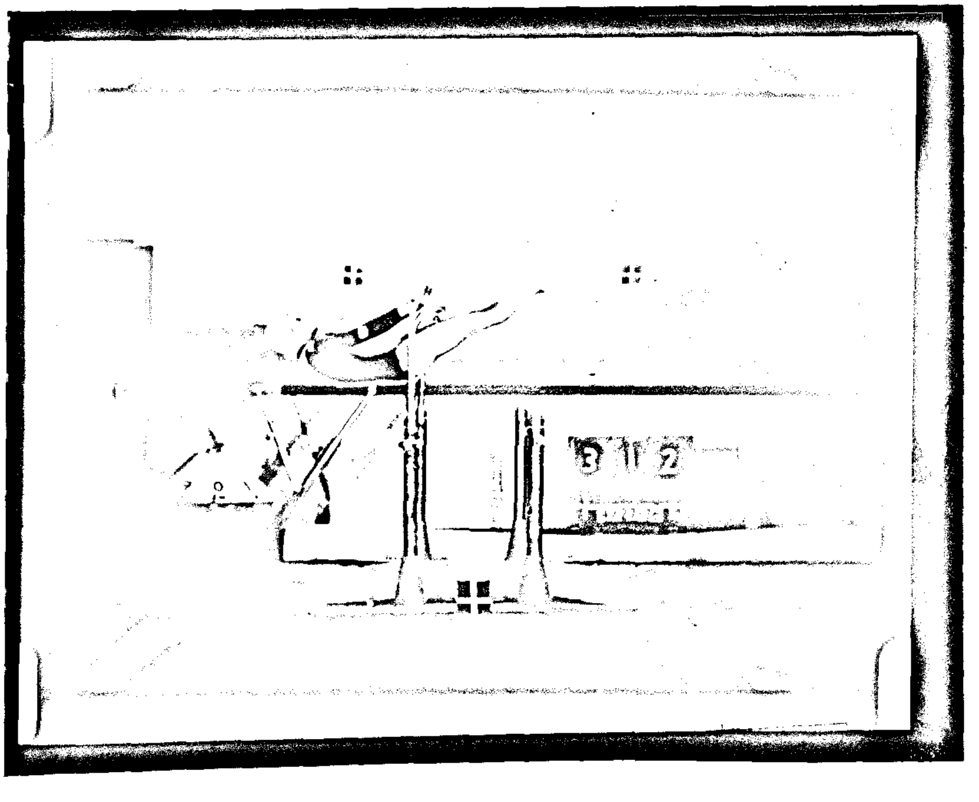
1. Camera View of Equipment and Subject
2. Equipment in Camera Field of View
3. Data Analyzing Equipment

CAMERA VIEW OF EQUIPMENT AND SUBJECT

Mat
Kip



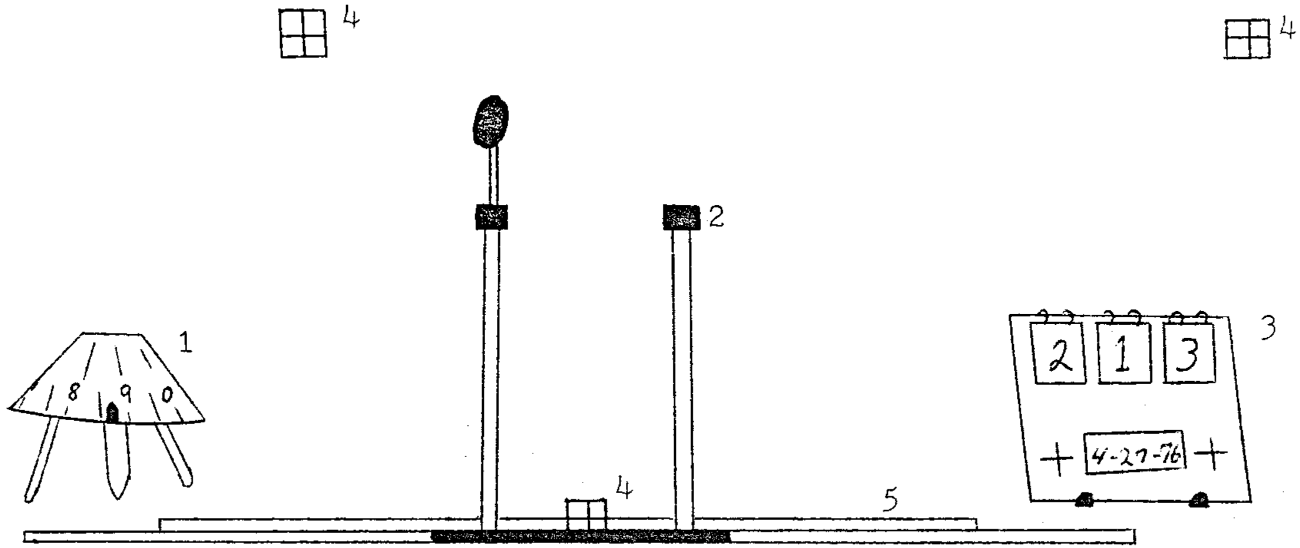
Glide
Kip



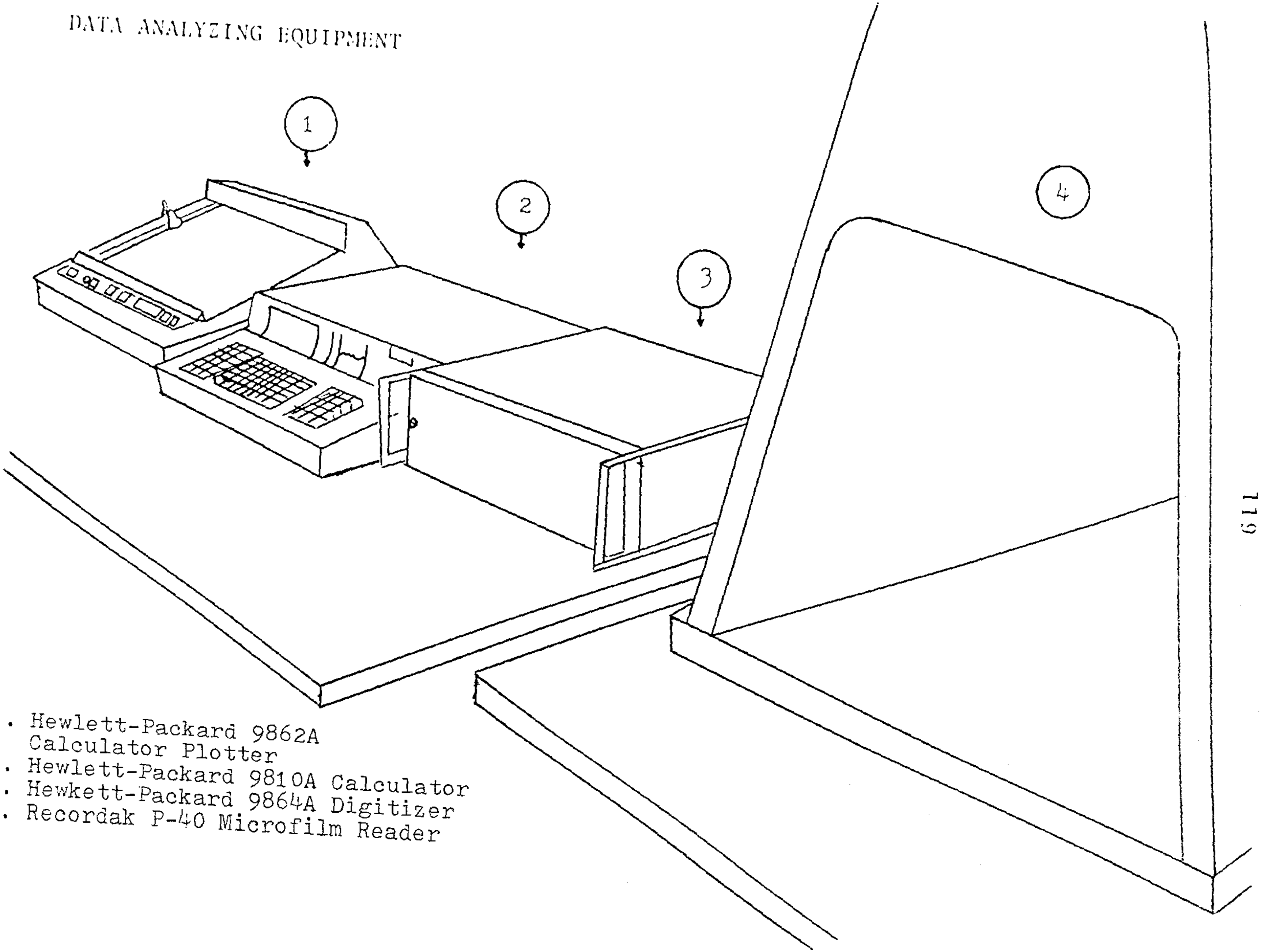
EQUIPMENT IN CAMERA FIELD OF VIEW

KEY

1. Conical Clock
2. Parallel Bars
3. Notice Board
4. Reference Points
5. Gymnastic Mats



DATA ANALYZING EQUIPMENT



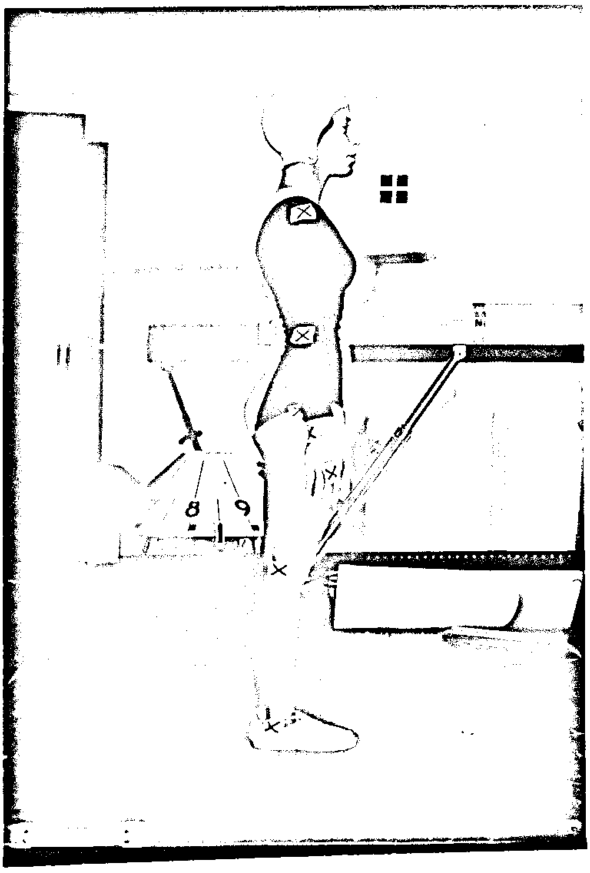
1. Hewlett-Packard 9862A Calculator Plotter
2. Hewlett-Packard 9810A Calculator
3. Hewkett-Packard 9864A Digitizer
4. Recordak P-40 Microfilm Reader

APPENDIX C

1. Subject Body Marking
2. Pilot Study
3. Check List

SUBJECT BODY MARKINGS

The subjects' body parts were marked with an X on a piece of one and one-half inch square adhesive tape. The tape was placed on each subject on the top of the head, the knuckles, the toe, and the axis of shoulder, elbow, wrist, hip, knee, and ankle.



PILOT STUDY

On February 18, 1976, at the University of Wisconsin Men's Gymnasium, Mr. Thomas W. Roberts and the investigator filmed an eleven-year-old female gymnast volunteer performing a glide kip on the uneven parallel bars and a mat kip. The setting up and filming was done from 6:00 p.m. to 8:30 p.m.

Equipment Used:

1. Milliken pin register movie camera with a twenty-five millimeter lens, shutter speed 72 degrees, frame rate 100, f stop 2.0. The camera was placed on a tripod 36 feet from the subject.

2. The film used was black and white 4-X reversal Kodak sixteen millimeter movie film.

3. The lighting was two quartz lights, set up seven feet in front of the camera, ten feet to the side of the camera, at an angle of 40 degrees from the subject. Light height was five feet.

4. The other equipment used included: a conical clock, measuring stick (one meter), tape measure, adhesive tape for body markings, bathing cap, light meter, gray card, and four extension cords.

Filming of the Glide Kip: Camera lens height 42 inches. Three glide kips were filmed.

Filming of the Mat Kip: Camera lens height 33 1/2 inches. The tape body markings were placed on the subject. A three inch long tape was placed on the mat for the subject to line up her shoulders for each mat kip performed. Three mat kips were filmed.

Amount of film footage used was 86 feet.

Filming Schedule:

1. Transport: 30 minutes

2. Set up equipment: 60 minutes

3. Filming: 20 minutes

4. Pack equipment and transport: 40 minutes

Comments: The tape body markings were not placed on the subject for the filming of the glide kip, so a check list was made and used during filming procedures for the study.

CHECK LIST

I. Forms Filled Out
  - A. Investigation Form
  - B. Personal Data Sheet

II. Equipment Used
  - A. Camera, Milliken pin register unit
    1. Shutter opening 72 degrees
    2. Frame rate 100
    3. f stop 2.0
    4. Lens 25 mm.
    5. Camera distance from subject 36 feet for the glide kip, 32 feet for the mat kip
    6. Camera height was five feet
  - B. Film
    1. Black and white 4-X reversal Kodak type 16 mm. movie film
    2. ASA 320
  - C. Two quartz lights
    1. Height five feet
    2. Angle 40 degrees
    3. Distance from the subject was 29 feet
  - D. Conical Clock
  - E. Vertical and horizontal references, a plumb line, wall paneling, and the 6 x 6 inch plus sign cards were placed on the wall and floor.
  - F. Notice board displayed: date, number of subject, stunt, and trial.
  - G. Body marking tape placed on subject's toe, top of the head, the knuckles, and the axis of shoulder, elbow, wrist, hip, knee, and ankle (nine markings).
  - H. Other equipment included: measuring stick, tape measure, level, masking tape, marking pencil, bathing cap, light meter, gray card, and four extension cords.

III. Checks made before camera rolled

A. Subjects' markers are in place

B. Notice board is correct

C. Camera ready

D. Subject ready

IV. Filming Order

A. Stick

B. Glide kip

C. Mat kip

V. Subject Information

A. Name

B. Number for the study

APPENDIX D

TABLES

TABLE 1

ANGULAR DISPLACEMENT DATA FOR THE THIGH IN THE MAT KIP

Time in Frame No.	Displacement in Degrees			
	Subject 1	Subject 2	Subject 3	Subject 4
0	357	356	357	354
10	355	356	353	354
20	356	356	355	359
30	360	360	360	373
40	371	377	374	397
50	392	392	398	428
60	428	414	426	460
70	467	439	455	485
80	500	465	485	503
90	525	486	508	514
100	540	500	528	521
110	543	504	546	523
120	538	493	558	527
130	504	460	562	534
140	473	404	557	541
150	422		542	533
160			522	504
170			486	458
180			439	400
190			391	

TABLE 2

ANGULAR DISPLACEMENT DATA FOR THE TRUNK IN THE MAT KIP

Time in Frame No.	Displacement in Degrees			
	Subject 1	Subject 2	Subject 3	Subject 4
0	450	475	448	488
10	465	493	464	504
20	489	509	487	516
30	509	521	502	525
40	520	527	513	532
50	530	532	519	537
60	538	538	529	542
70	546	541	536	548
80	554	545	548	558
90	567	550	558	575
100	579	557	572	591
110	586	567	585	603
120	590	575	595	605
130	598	584	597	603
140	607	595	596	595
150	610		588	584
160			590	581
170			595	584
180			605	592
190			594	

TABLE 3

ANGULAR VELOCITY DATA FOR THE THIGH IN THE MAT KIP

Time in Frame No.	Velocity in Degrees Per Second			
	Subject 1	Subject 2	Subject 3	Subject 4
0	- 13	- 8	- 58	0
10	- 5	- 5	- 16	18
13,15,13	0	0	0	
20	26	10	40	67
30	83	87	94	155
40	161	150	155	322
50	260	206	270	371
60	353	250	322	308
70	391	260	322	206
80	294	250	260	145
90	214	192	222	94
100	117	80	199	32
107	0	0	0	
110	0	- 52	150	24
120	-206	-185	97	67
130	-371	-391	0	90
140	-412	-601	- 94	24
141				0
150	-462		-192	-222
160			-282	-391
170			-412	-523
180			-462	-602
190			-462	

TABLE 4

ANGULAR VELOCITY DATA FOR THE TRUNK IN THE MAT KIP

Time in Frame No.	Velocity in Degrees Per Second			
	Subject 1	Subject 2	Subject 3	Subject 4
0	161	179	206	150
10	206	173	206	130
20	206	150	192	101
30	161	87	135	80
40	97	40	90	58
50	76	52	67	55
60	87	58	80	64
70	87	37	83	73
80	105	35	97	105
90	121	58	121	167
100	97	73	126	167
110	49	90	126	73
120	70	94	64	0
130	80	101	0	- 61
140	61	109	- 52	-101
150	43		- 32	- 58
			0	
154			46	0
160			80	55
170			40	80
180			0	
182			-214	
190				

TABLE 5

ANGULAR ACCELERATION DATA FOR THE THIGH IN THE MAT KIP

Time in Frame No.	Acceleration in Degrees Per Second Squared			
	Subject 1	Subject 2	Subject 3	Subject 4
0	159	46	463	122
10	208	144	498	304
20	463	556	536	600
30	736	705	624	1504
40	928	624	928	1154
50	978	536	883	0
60	842	304	234	-883
67,65	0		0	
70	-677	0	-253	-804
80	-769	-338	-624	-600
90	-928	-928	-326	-536
100	-978	-1227	-304	-350
107				0
110	-1400	-1504	-431	191
120	-2368	-1764	-600	498
130	-736	-2127	-705	0
140	-402	-2127	-842	-2368
150	-388		-928	-1929
160			-1089	-1504
170			-1089	-1089
180			-304	-677
185			0	
190			175	

TABLE 6

ANGULAR ACCELERATION DATA FOR THE TRUNK IN THE MAT KIP

Time in Frame No.	Acceleration in Degrees Per Second Squared			
	Subject 1	Subject 2	Subject 3	Subject 4
0	480	- 80	26	- 217
10	260	- 136	0	- 244
14	0			
20	- 283	- 375	- 338	- 263
30	- 705	- 577	- 536	- 253
40	- 447	- 577	- 388	- 144
43		0		
50	0	480	0	0
55		0		
60	108	- 263	73	87
70	108	- 253	159	209
75		0		
80	108	253	159	402
90	53	159	159	600
92, 95	0			0
100	- 842	108	159	- 498
107			0	
110	0	108	- 447	-1089
120	362	108	- 624	-1089
129	0			
130	- 33	108	- 624	- 577
140	- 87	108	- 388	0
143			0	
150	- 159		926	557
160			600	577
170			0	402
180			-1400	263
190			-3054	

TABLE 7

ANGULAR DISPLACEMENT DATA FOR THE THIGH IN THE GLIDE KIP

Time in Frame No.	Displacement in Degrees			
	Subject 1	Subject 2	Subject 3	Subject 4
0	259	271	260	265
10	246	267	261	267
20	255	268	260	269
30	275	269	262	272
40	309	291	277	280
50	317	308	302	298
60	311	328	331	323
70	310	328	352	344
80	339	322	350	349
90	383	315	346	338
100	424	321	340	327
110	458	338	336	325
120	470	363	351	335
130	457	408	382	364
140	423	440	419	406
150	383	467	457	446
160	347	462	477	471
170	317	423	466	472
180	292	381	433	444
190	278	351	396	404
200	267	327	360	366
210	257	298	328	331
220	248	268	298	304
230	238	224	270	279
240	231	193	248	256
250	227	171	227	235
260	222	158	211	219
270	216	155	202	209

TABLE 8

ANGULAR DISPLACEMENT DATA FOR THE TRUNK IN THE GLIDE KIP

Time in Frame No.	Displacement in Degrees			
	Subject 1	Subject 2	Subject 3	Subject 4
0	406	400	415	417
10	394	387	400	400
20	385	375	390	391
30	400	375	383	389
40	428	487	383	389
50	456	403	397	396
60	486	423	415	411
70	510	446	432	426
80	523	468	450	445
90	528	484	469	466
100	527	506	493	485
110	523	522	512	501
120	531	535	526	516
130	538	534	533	525
140	537	526	534	522
150	526	528	531	513
160	505	533	533	518
170	485	538	541	532
180	461	533	535	536
190	443	508	523	534
200	429	471	503	521
210	423	443	475	500
220	425	420	452	470
230	426	408	437	449
240	424	392	429	442
250	424	379	423	434
260	423	369	415	427
270	425	363	412	422

TABLE 9

ANGULAR VELOCITY DATA FOR THE THIGH IN THE GLIDE KIP

Time in Frame	No.	Velocity in Degrees Per Second: Subject 1	Subject 2	Subject 3	Subject 4
0		-145	- 37	0	8
10		- 90	- 21	0	10
	13, 15	0	0		
20		214	13	8	24
30		308	140	49	58
40		214	214	126	150
	47	0			
50		- 32	199	271	214
60		- 70	76	271	260
	67, 65	0	0		
70		87	- 49	87	161
	75, 77			0	0
80		412	- 64	- 37	- 58
90		491	- 21	- 64	-150
	92		0		
100		412	121	- 67	- 80
	107,105			0	0
110		250	206	55	37
	119	0			
120		- 18	322	222	173
130		-271	412	337	353
140		-371	391	412	462
150		-391	117	337	353
	152		0		
160		-353	-240	21	83
	162,163			0	0
170		-282	-412	-222	-150
180		-192	-371	-337	-308
190		-126	-294	-337	-371
200		- 90	-282	-322	-371
210		- 90	-308	-308	-308
220		- 80	-337	-294	-260
230		- 80	-353	-260	-240
240		- 70	-337	-231	-206
250		- 55		-192	-192
260		- 52		-117	-135
270		- 52		- 35	- 64

TABLE 10

ANGULAR VELOCITY DATA FOR THE TRUNK IN THE GLIDE KIP

Time in Frame No.	Velocity in Degrees Per Second			
	Subject 1	Subject 2	Subject 3	Subject 4
0	-126	-135	-140	-161
10	-109	-135	-130	-130
20	0	- 87	- 83	- 67
27		0		
30	214	46	- 10	- 8
33,34			0	0
40	294	150	61	29
50	322	199	126	109
60	294	222	173	155
70	214	214	199	185
80	97	206	214	199
90	0	199	206	199
100	- 49	192	214	185
107	0			
110	13	150	173	155
120	73	49	105	109
125		0		
130	32	- 46	49	40
135,138,133	0		0	0
140	- 58	- 35	- 16	- 37
145		0		
150	-150	29	- 26	- 32
153,153			0	0
160	-214	67	52	70
170	-231	10	24	76
171,173		0	0	
180	-199	-105	- 87	10
182				0
190	-167	-412	-173	- 58
200	-101	-308	-282	-179
210	- 26	-240	-260	-337
220	0	-180	-179	-222
230	0	-167	-109	-121
240	0	-155	- 70	- 87
250	0		- 64	- 70
260	0		- 49	- 52
270	0		- 40	- 46

TABLE 11

ANGULAR ACCELERATION DATA FOR THE THIGH IN THE GLIDE KIP

Time in Frame No.	Acceleration in Degrees Per Second Squared			
	Subject 1	Subject 2	Subject 3	Subject 4
0	402	122	0	59
10	977	208	59	80
20	2668	624	100	175
30	0	1227	536	556
40	- 199	600	1308	1086
45		0		
50	- 199	-1030	1030	650
55,53			0	0
60	0	-1504	-1227	-1764
70	3054	-1227	-2127	-2668
80	2127	0	-1227	-1764
90	0	842	- 402	0
94			0	
100	-1154	977	431	1154
110	-2127	977	1504	1764
120	-2668	977	2127	1624
130	-2127	577	1624	1929
133,138		0		0
140	- 480	-1400	0	- 363
148	0			
150	53	-3568	-1929	-2127
160	498	-2668	-3054	-2668
170	928	- 362	-1764	-1929
172		0		
180	977	736	- 536	-1030
185			0	
190	650	804	263	- 272
195,195		0		0
200	39	- 167	87	108
210	33	- 315	144	624
220	33	- 217	175	304
230	73	0	338	263
240	87	234	416	244
250	73		556	293
260	26		883	677
270	7		842	769

TABLE 12

ANGULAR ACCELERATION DATA FOR THE TRUNK IN THE GLIDE KIP

Time in Frame No.	Acceleration in Degrees Per Second Squared			
	Subject 1	Subject 2	Subject 3	Subject 4
0	108	- 26	136	263
5		0		
10	315	208	244	362
20	2127	205	402	498
30	1400	1340	804	577
40	556	1030	705	650
50	0	326	577	650
58		0		
60	- 480	- 46	338	375
70	- 977	- 80	183	175
80	-1089	- 108	375	26
90	- 769	- 122	0	0
99	0			
100	159	- 108	- 183	- 159
110	677	- 650	- 536	- 338
120	253	-1089	- 624	- 624
122	0			
130	- 804	- 375	- 624	- 842
134		0		
140	- 977	536	- 536	- 463
148,145			0	0
150	- 804	624	463	769
160	- 326	0	463	804
162,166			0	0
170	0	- 978	-1030	- 416
180	375	-2368	-1089	- 769
190	498	-4286	-1030	-1227
193		0		
200	769	1764	- 928	-1227
203			0	
210	447	677	705	0
220	94	234	883	1624
230	0	129	624	600
240	0	59	144	234
250	0		122	159
260	0		115	144
270	0		100	87

APPENDIX E

STICK FIGURES

Key for Stick Figure Diagrams

Head ------ □

Shoulder -- U

Hip ------- ○

Ankle ----- ▽

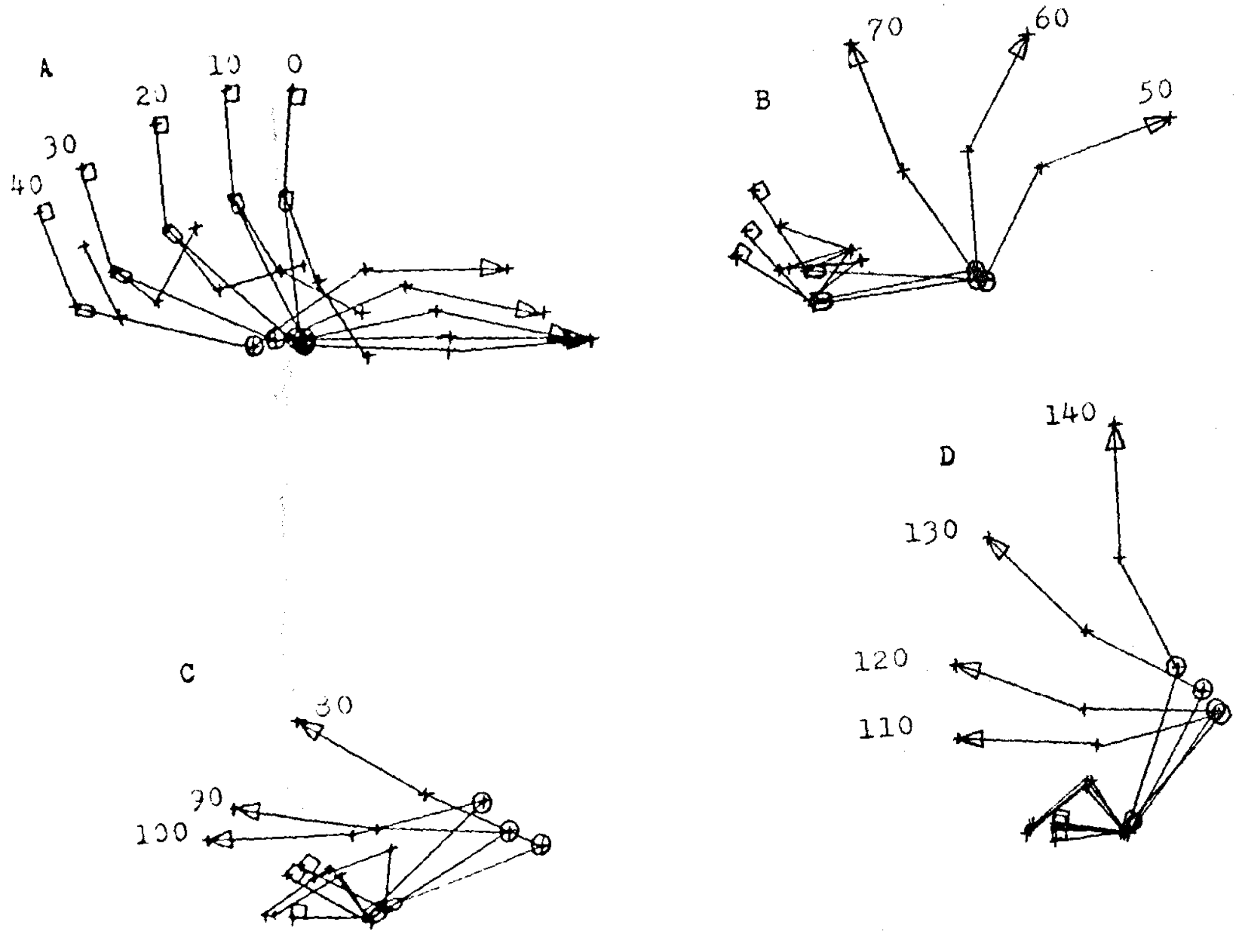


Fig. 14. Mat kip stick figure of subject one.

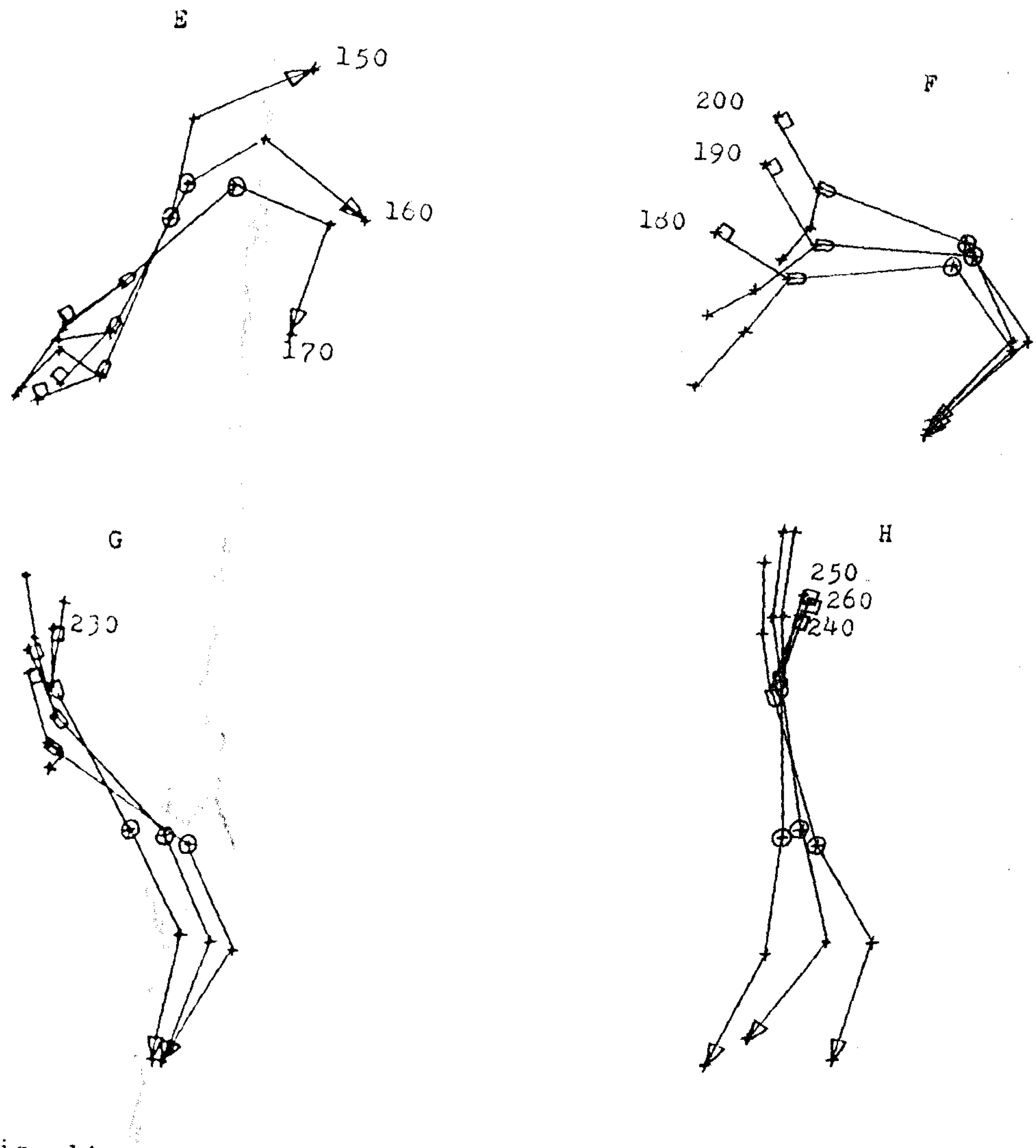


Fig. 14. Continued

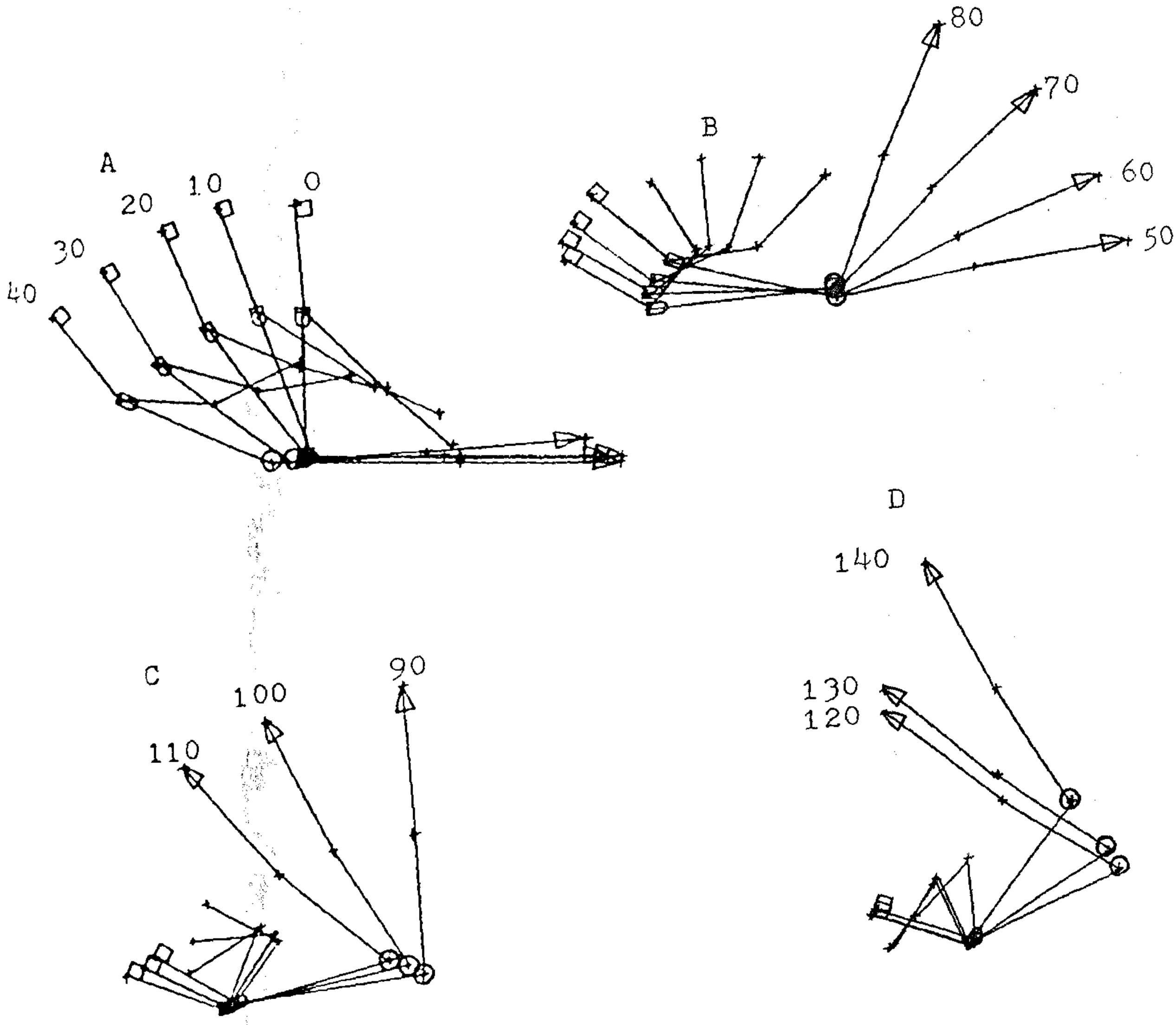


Fig. 15. Mat kip stick figure of subject two.

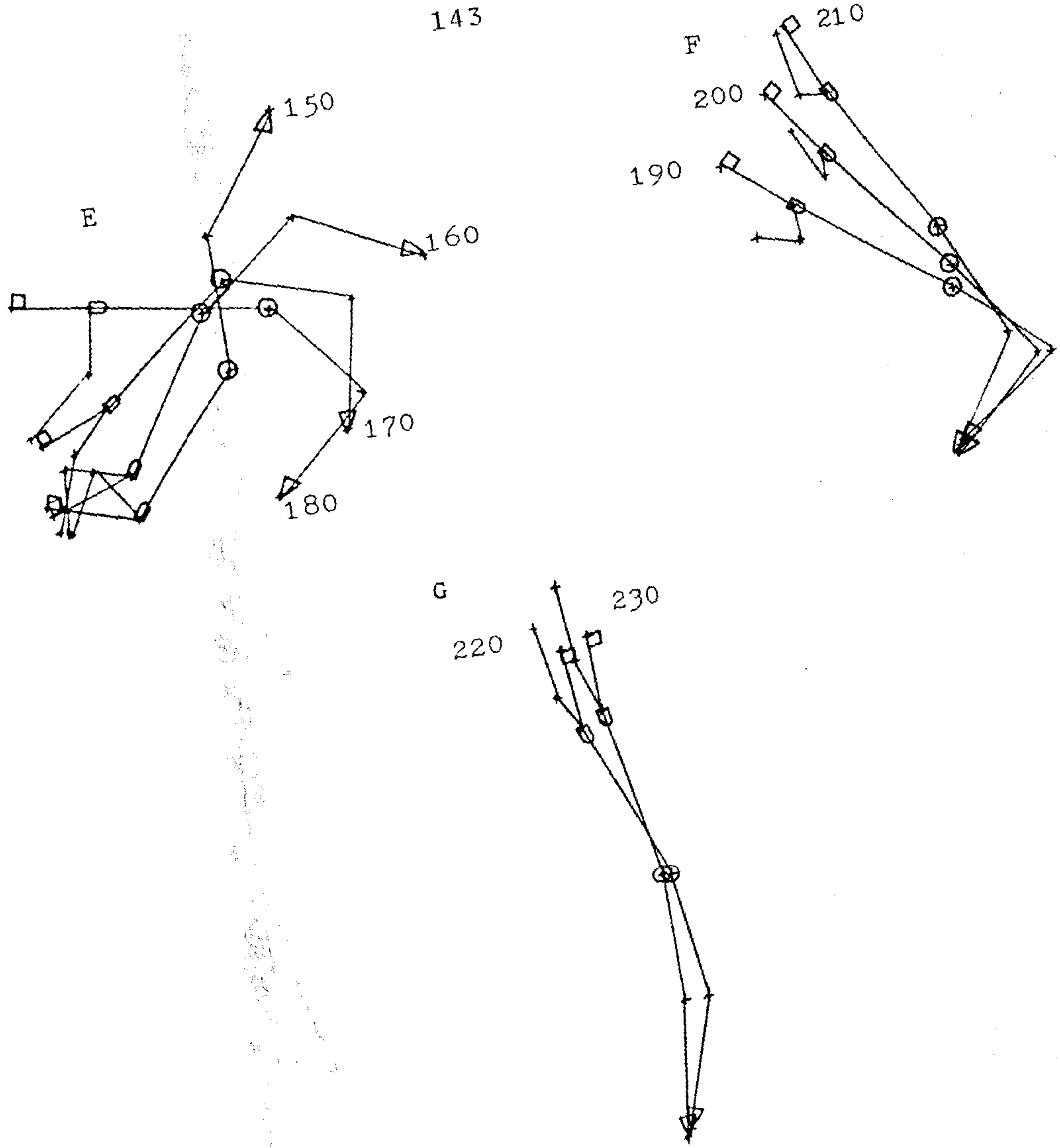


Fig. 15. Continued

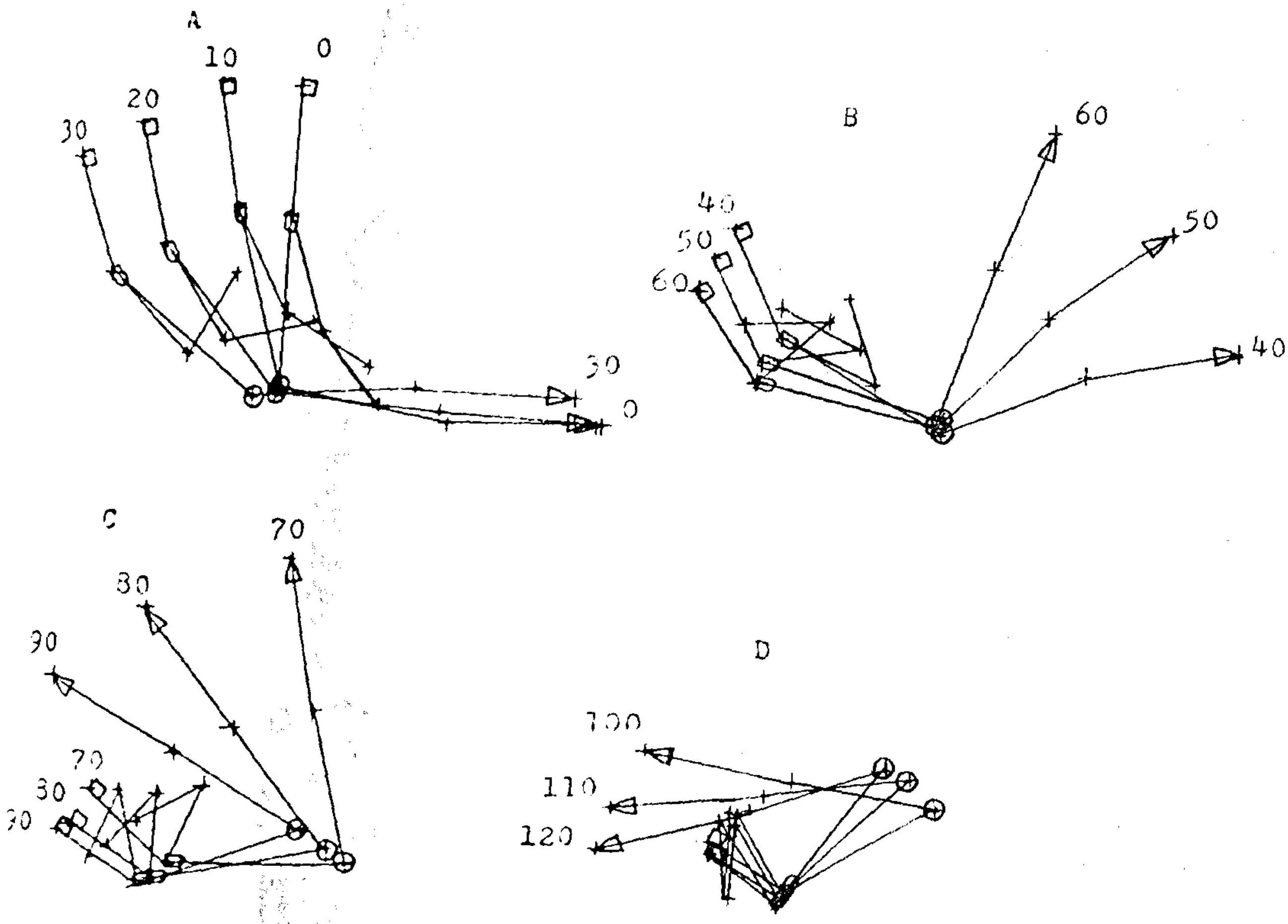


Fig. 16. Mat kip stick figure of subject three.

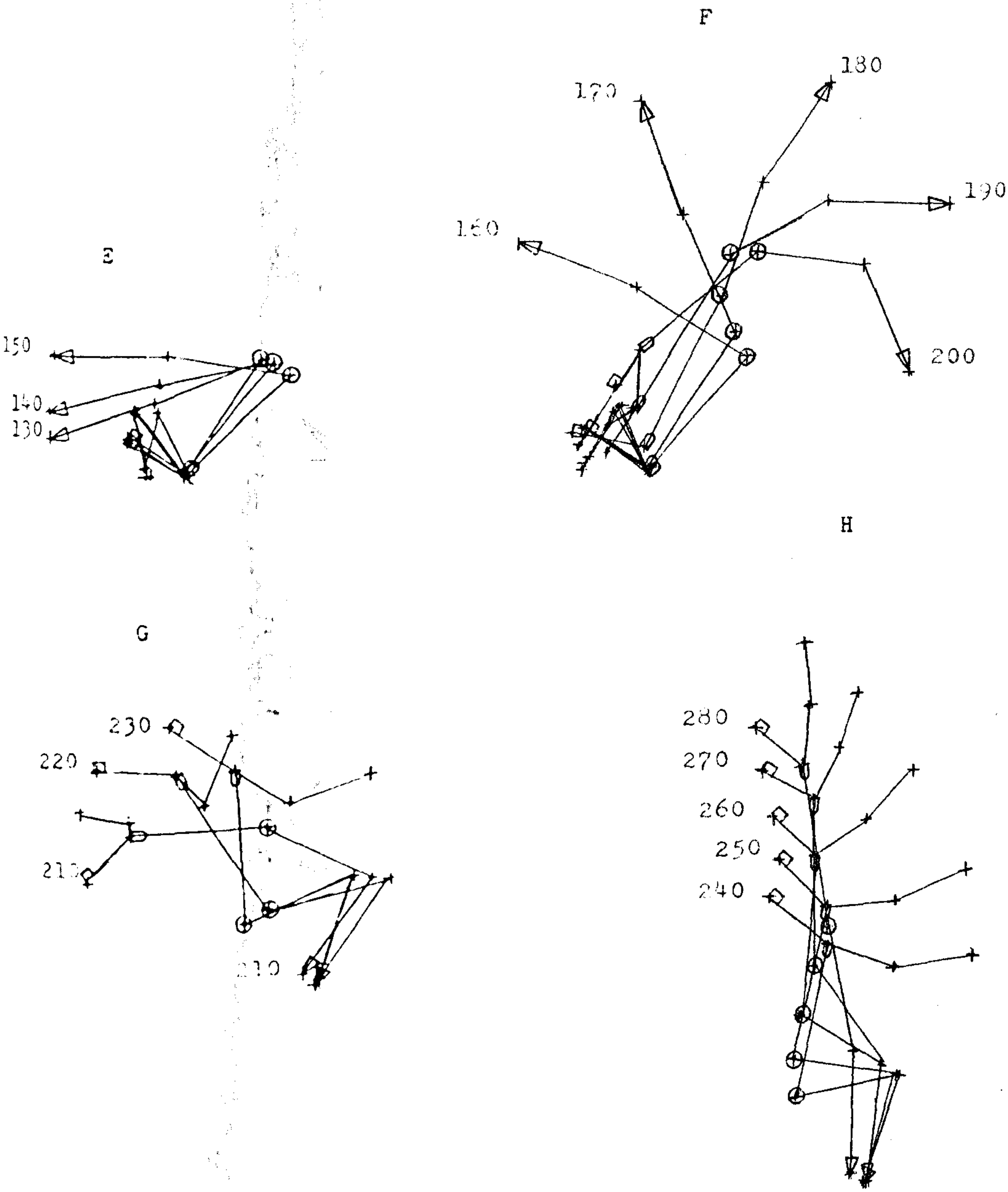


Fig. 16. Continued

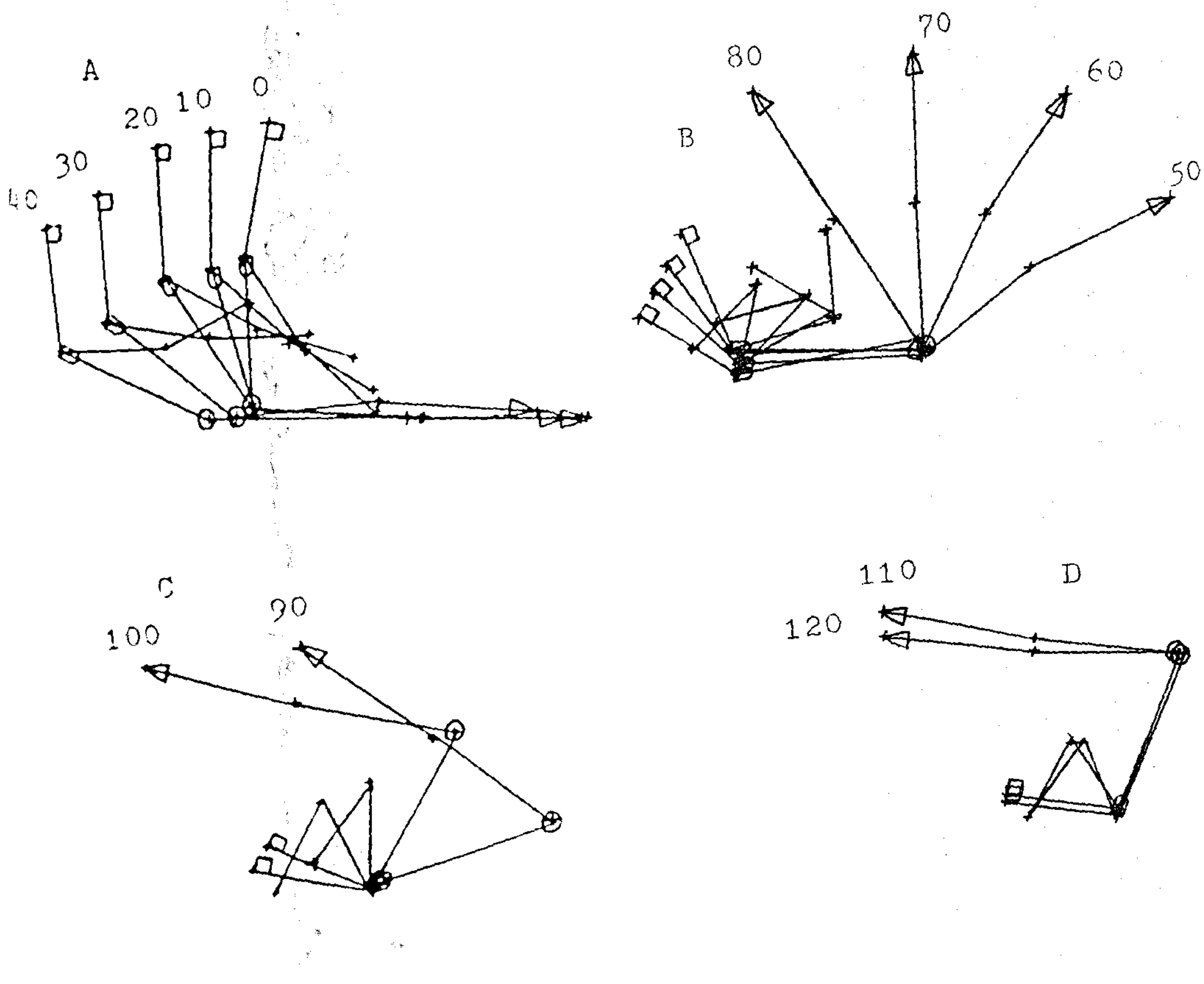


Fig. 17. Mat kip stick figure of subject four.

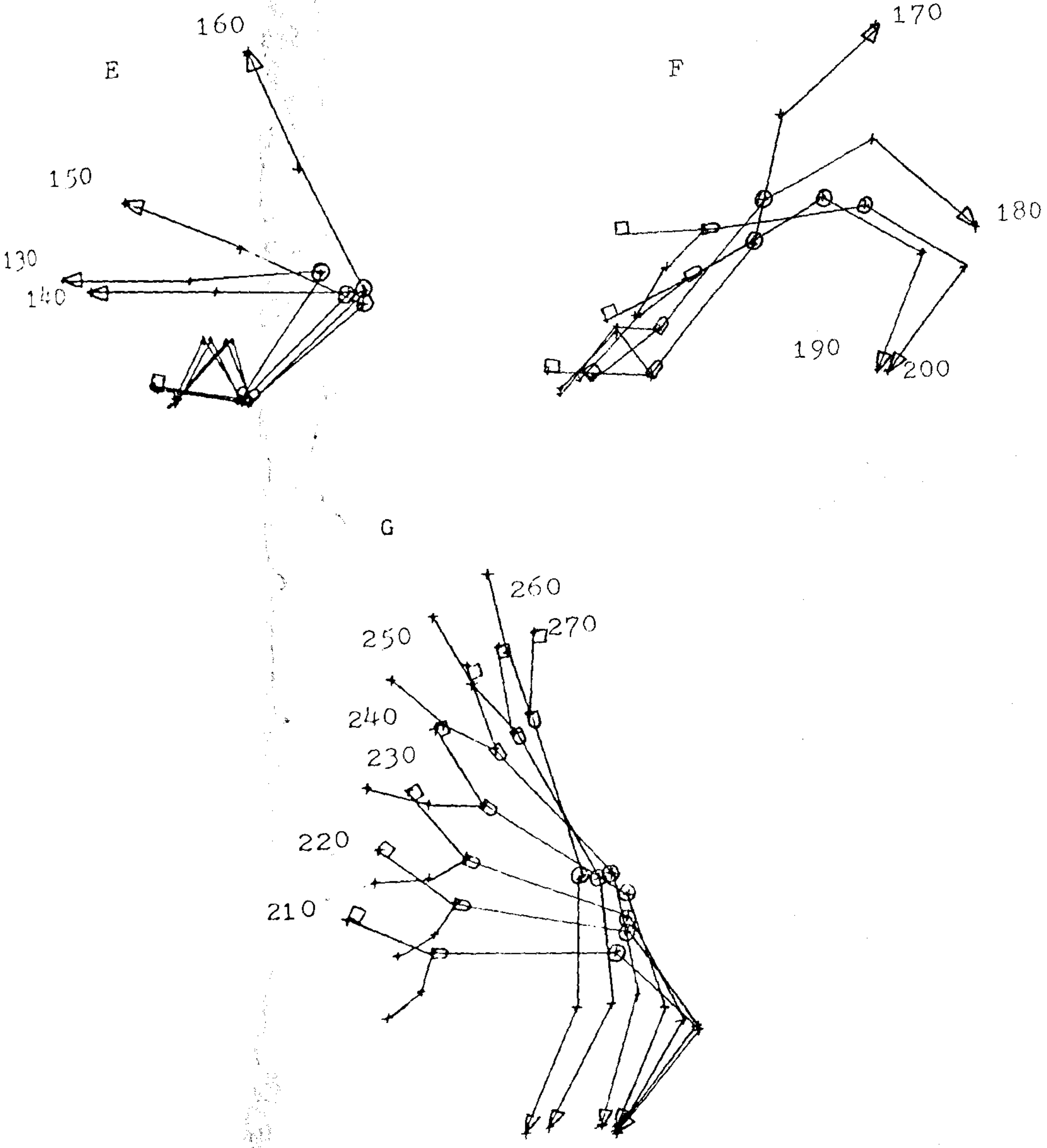


Fig. 17. Continued

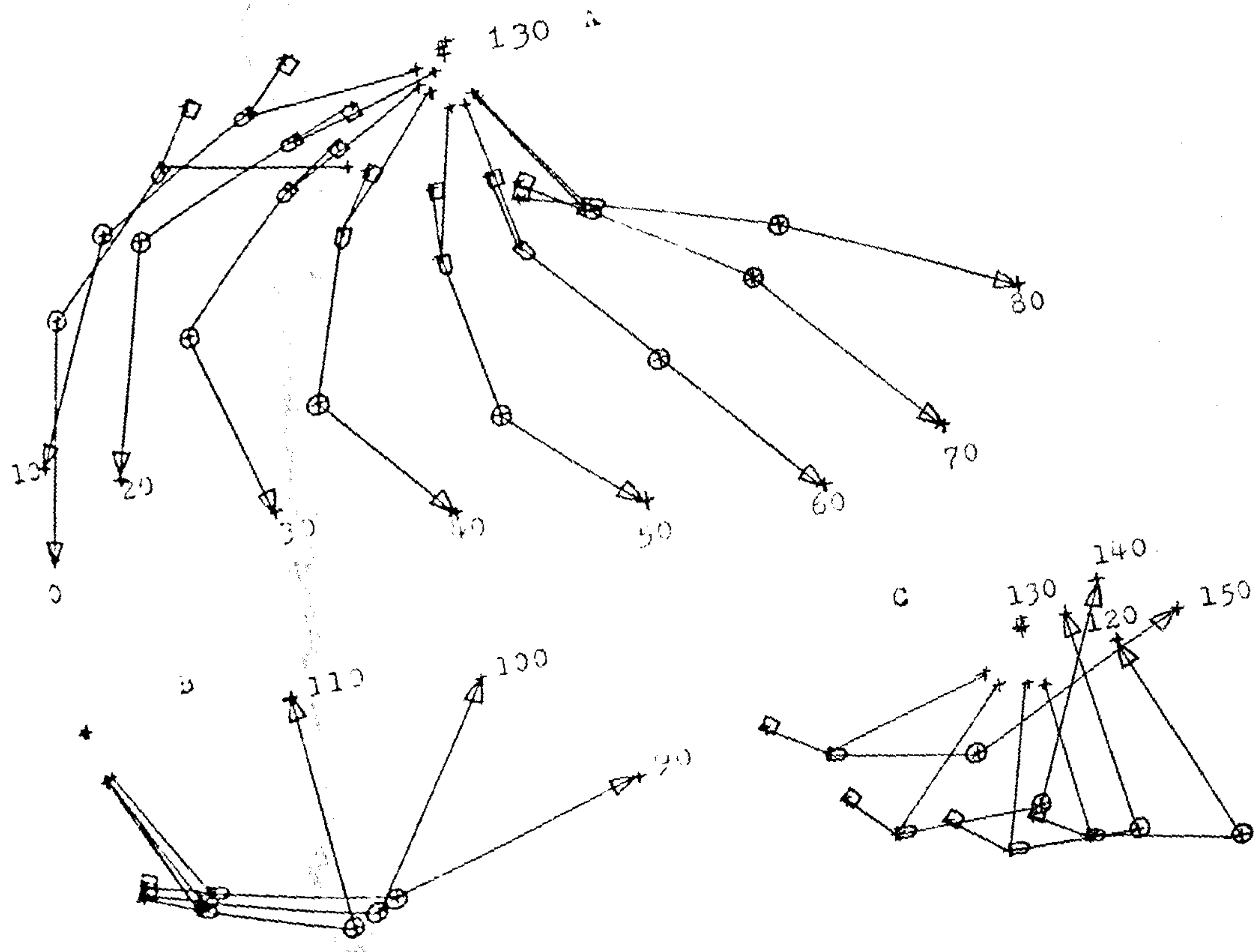
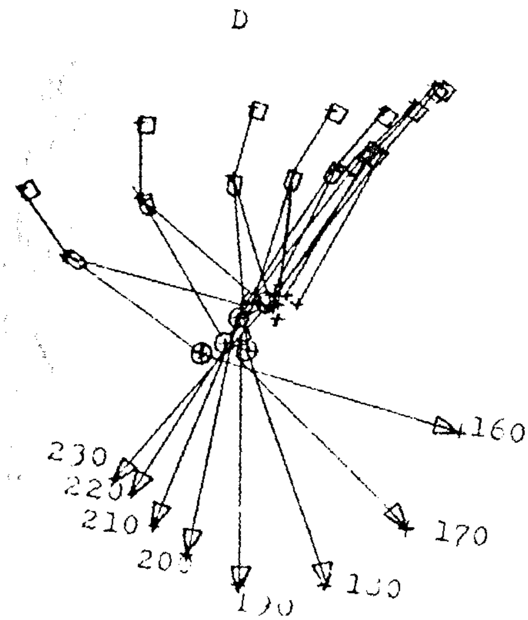


Fig. 18. Glide kip stick figure of subject one.



g. 18. Continued

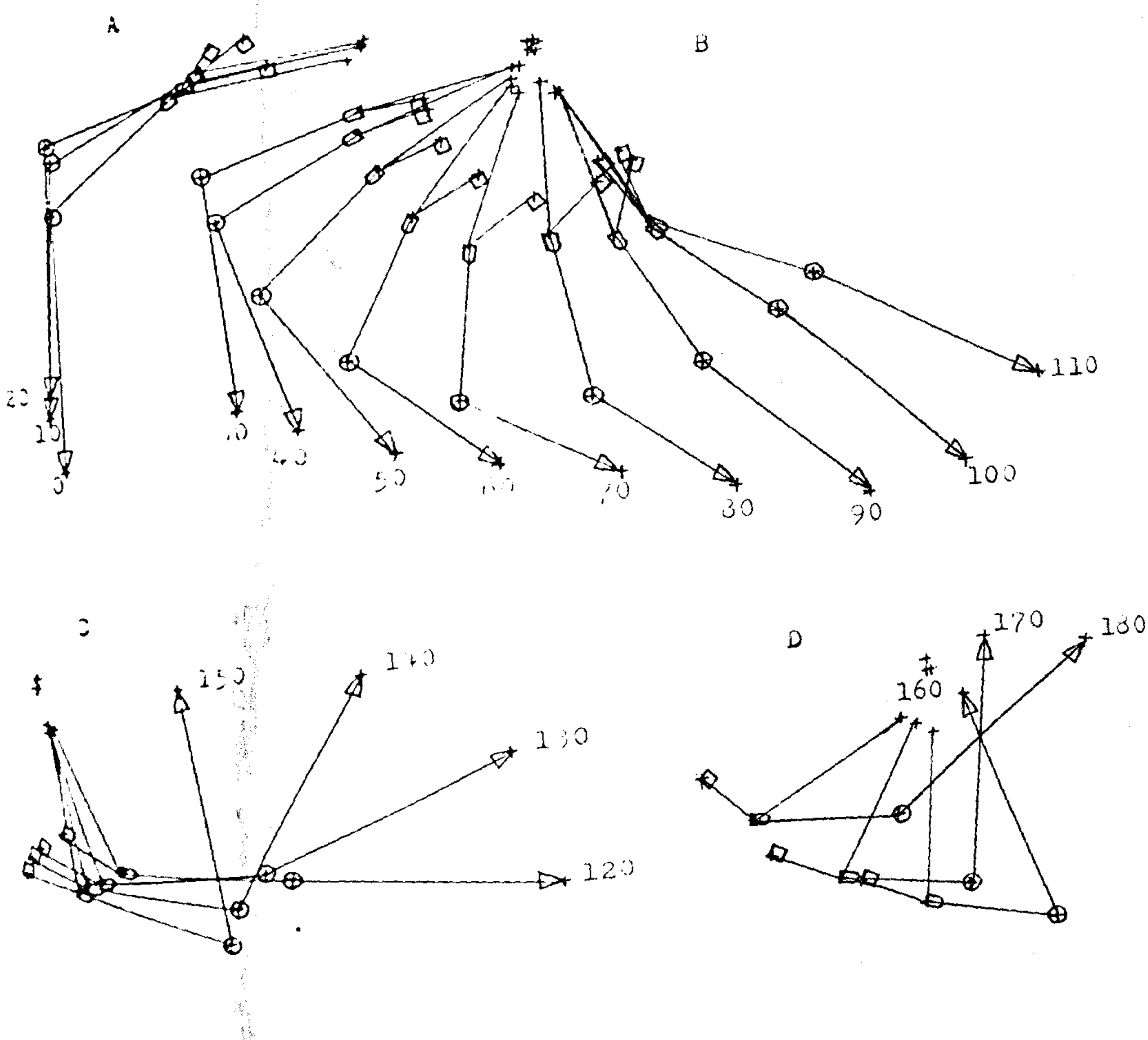


Fig. 19. Glide kip stick figure of subject two.

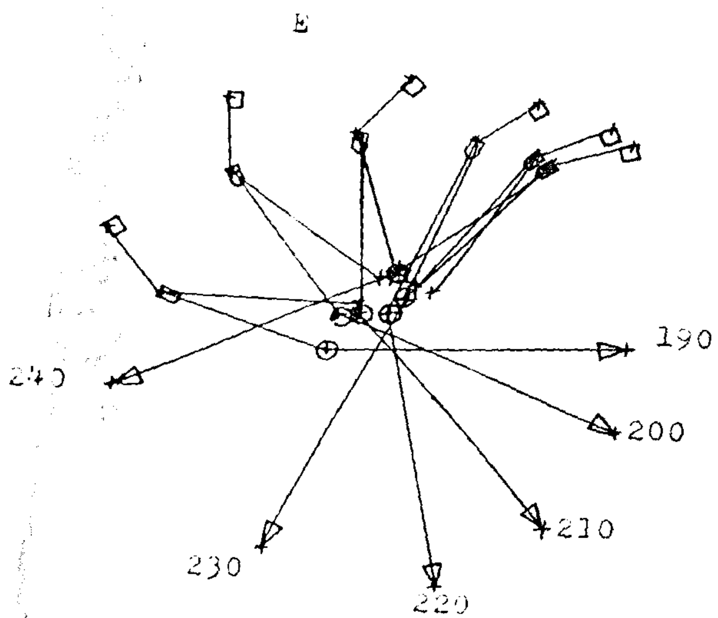


Fig. 19. Continued

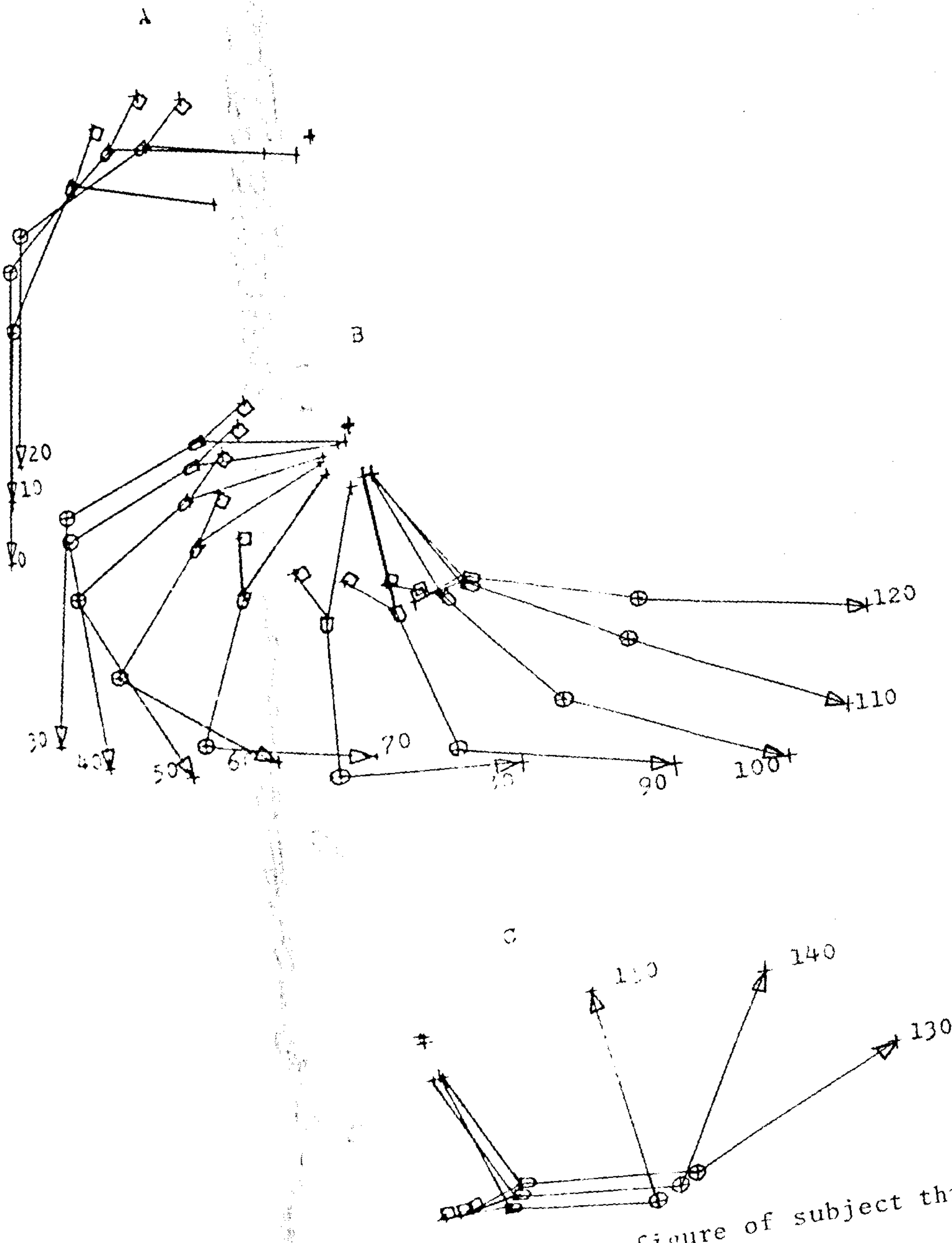
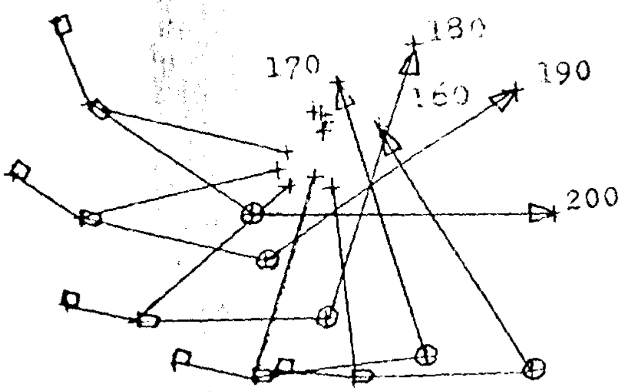


Fig. 20. Glide kip stick figure of subject three.

D



E

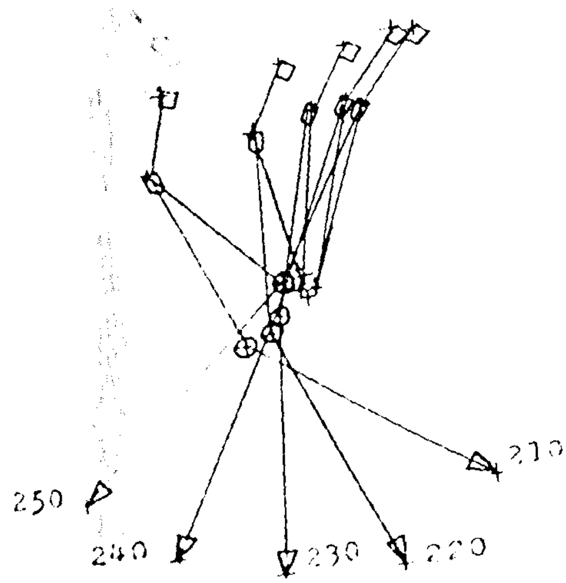


Fig. 20. Continued

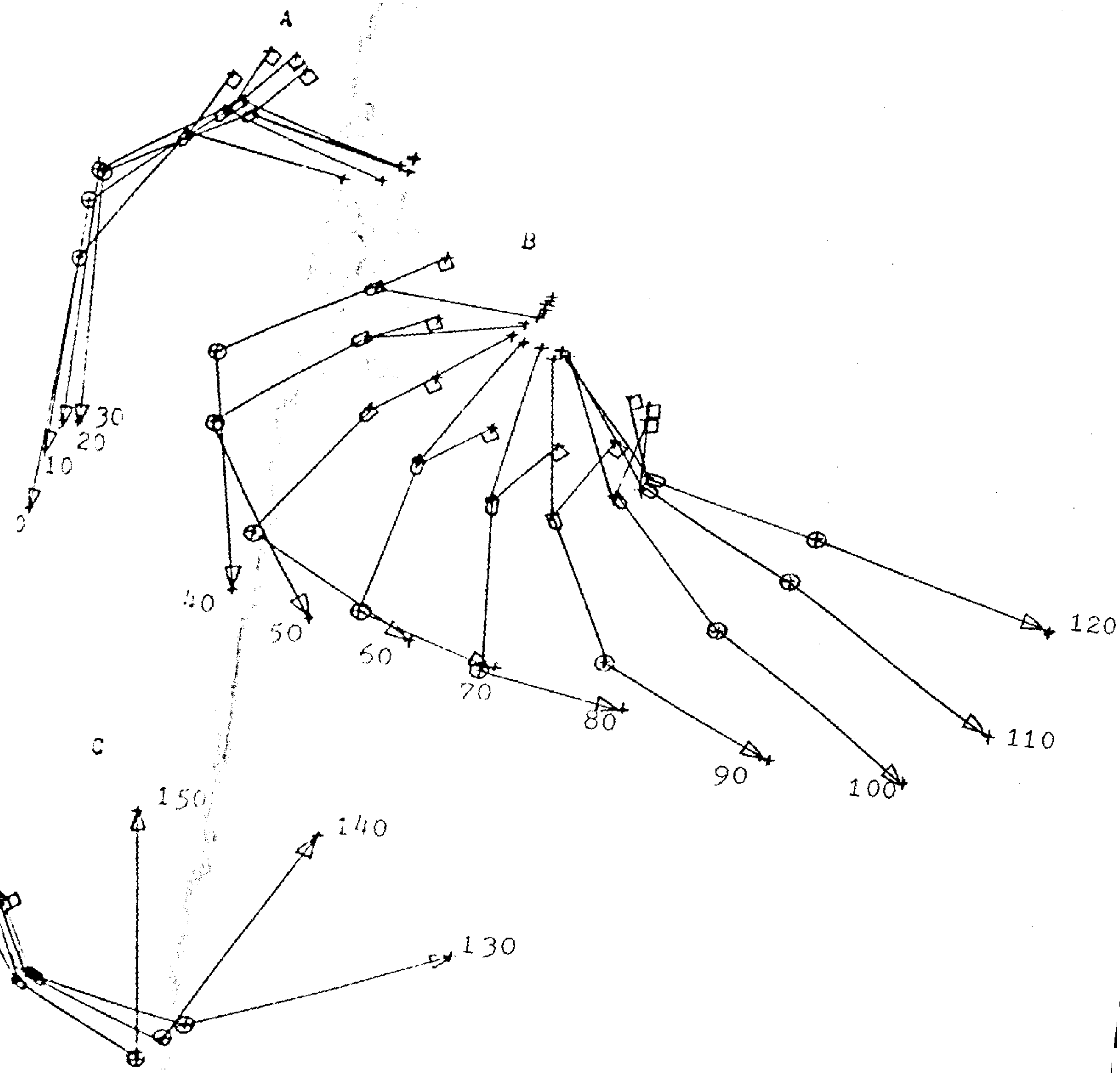


Fig. 21. Glide kip stick figure of subject four.

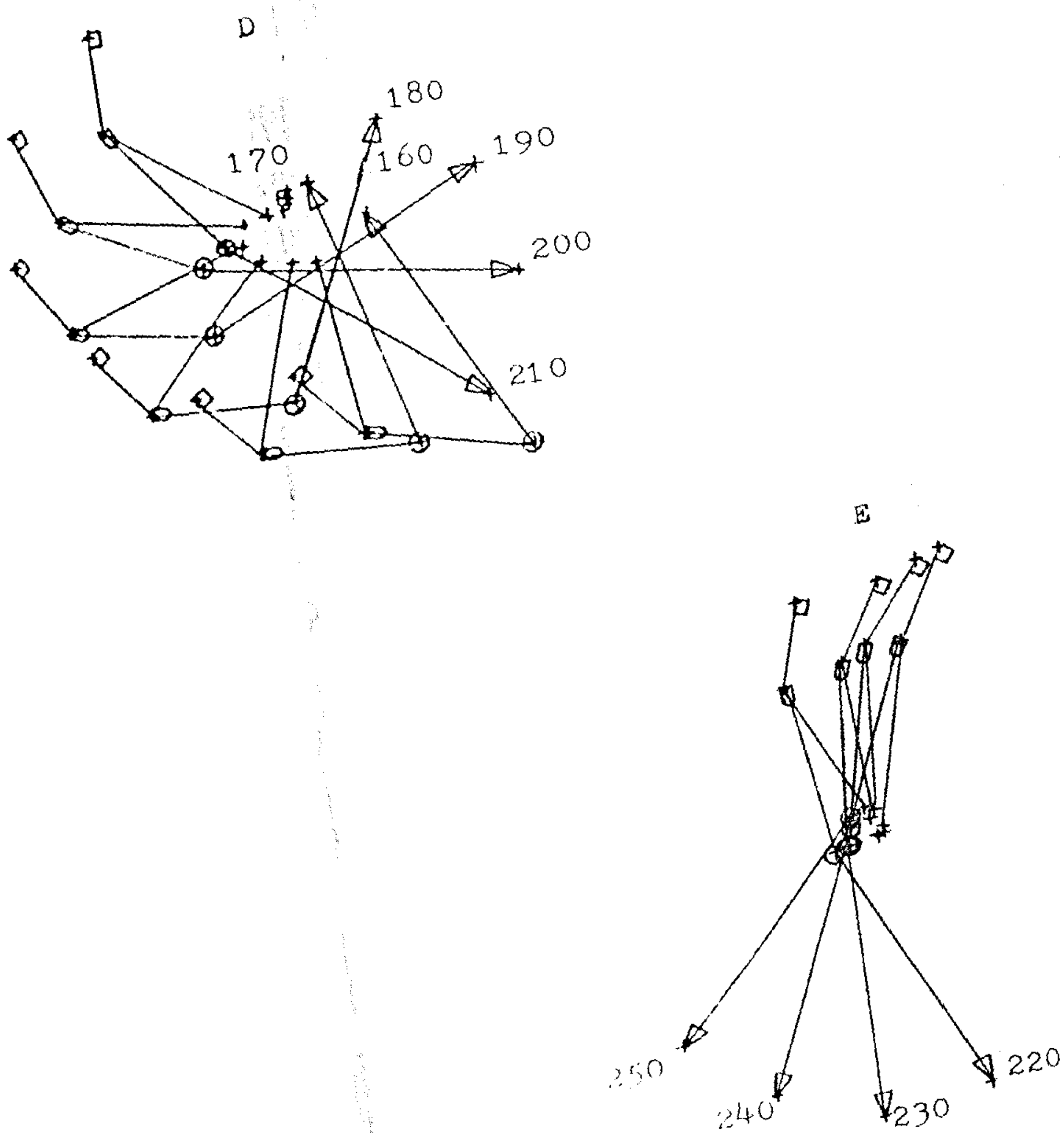


Fig. 21. Continued

APPENDIX F

SUBJECT GRAPHS

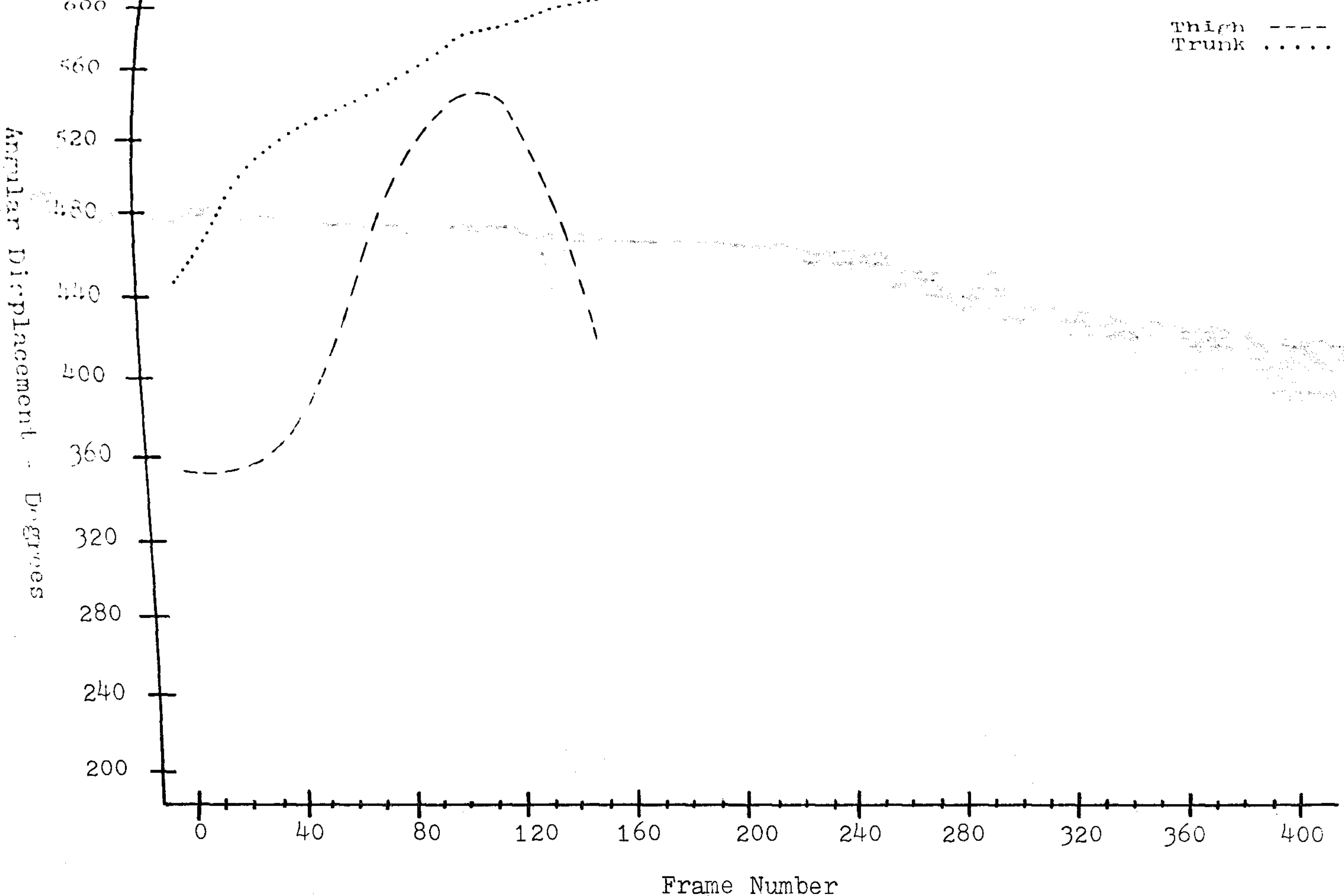


Fig. 22. Subject one angular displacement of the thigh and trunk for the mat kip.

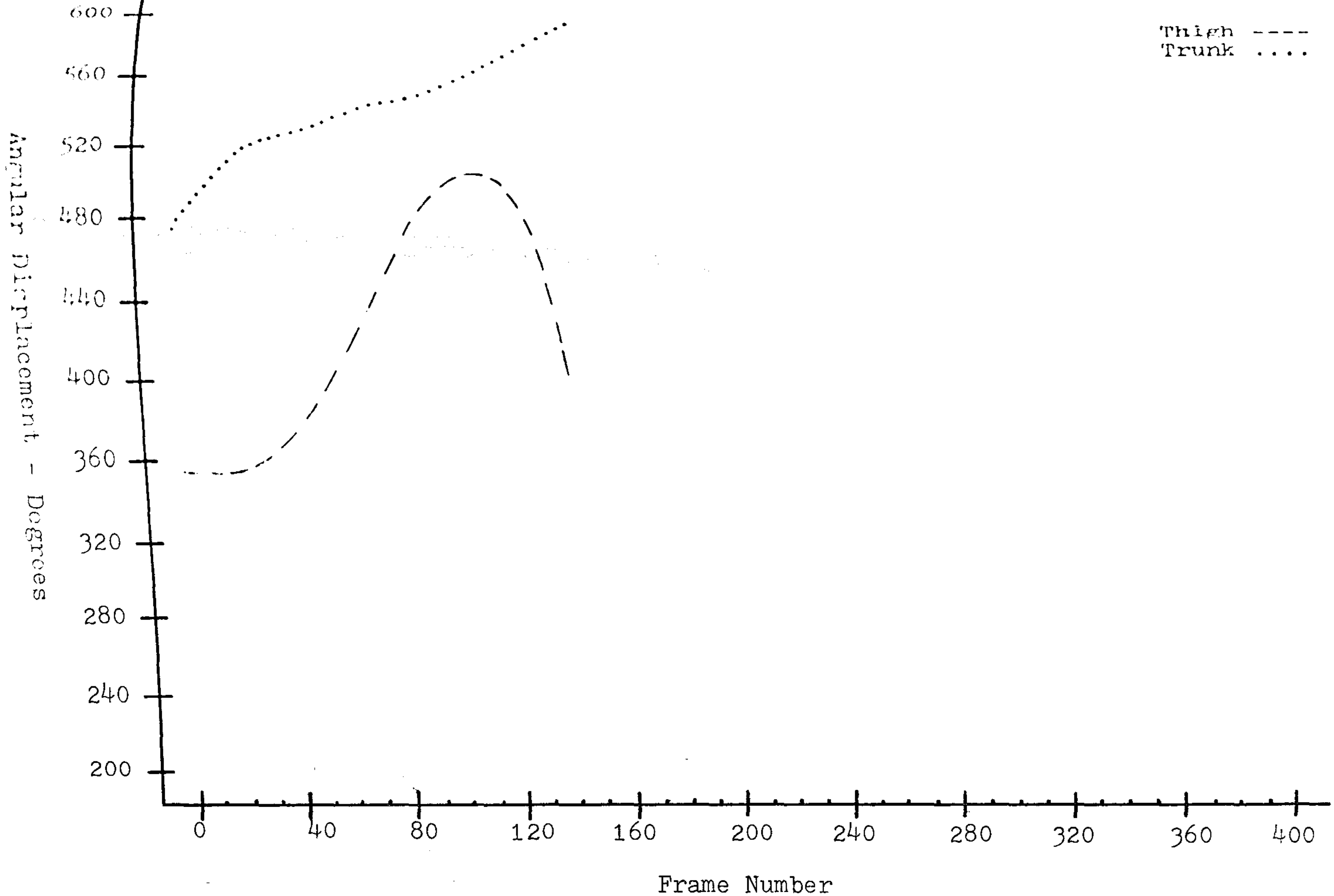


Fig. 23. Subject two angular displacement of the thigh and trunk for the mat kip.

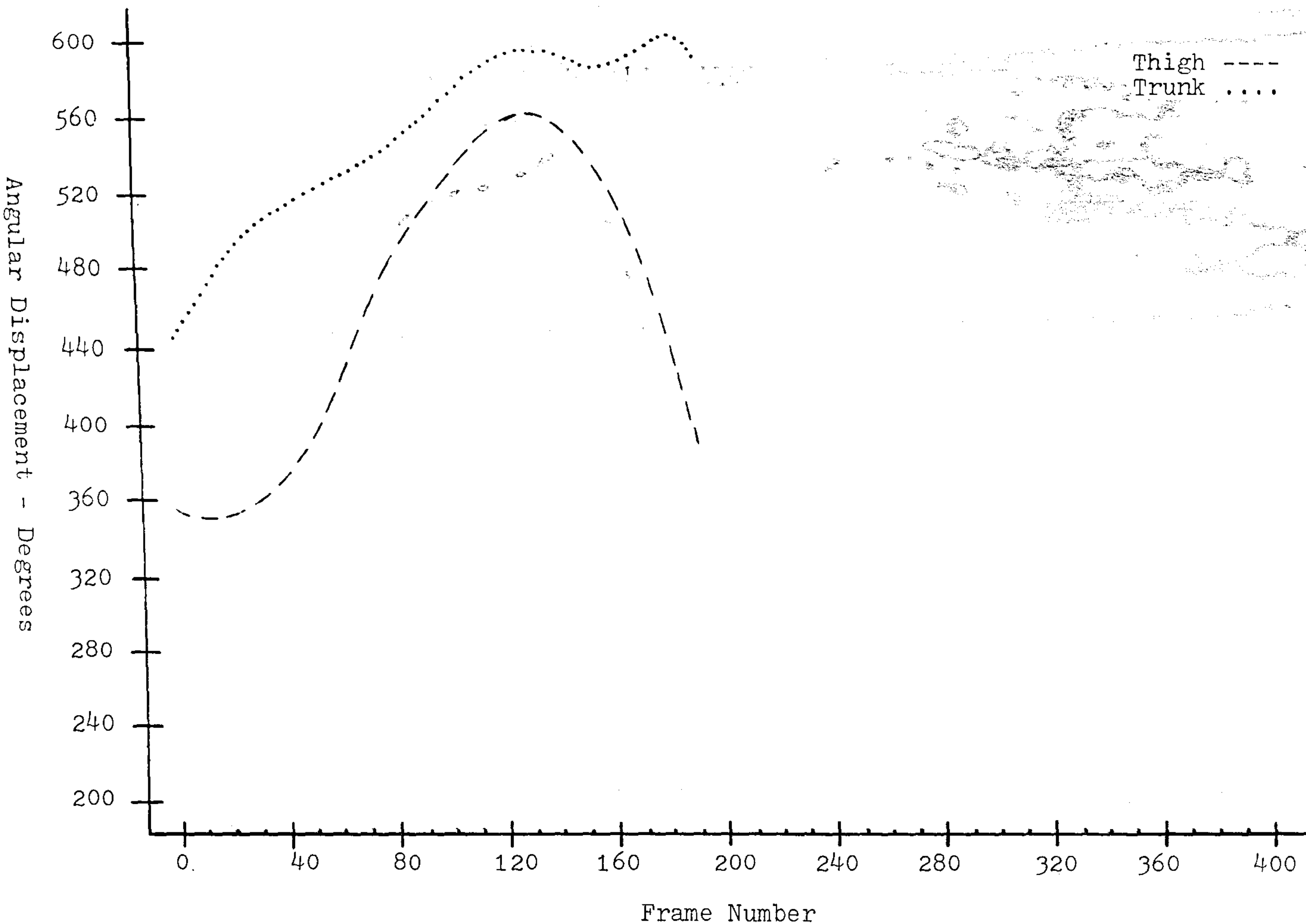


Fig. 24. Subject three angular displacement of the thigh and trunk for the mat kip.

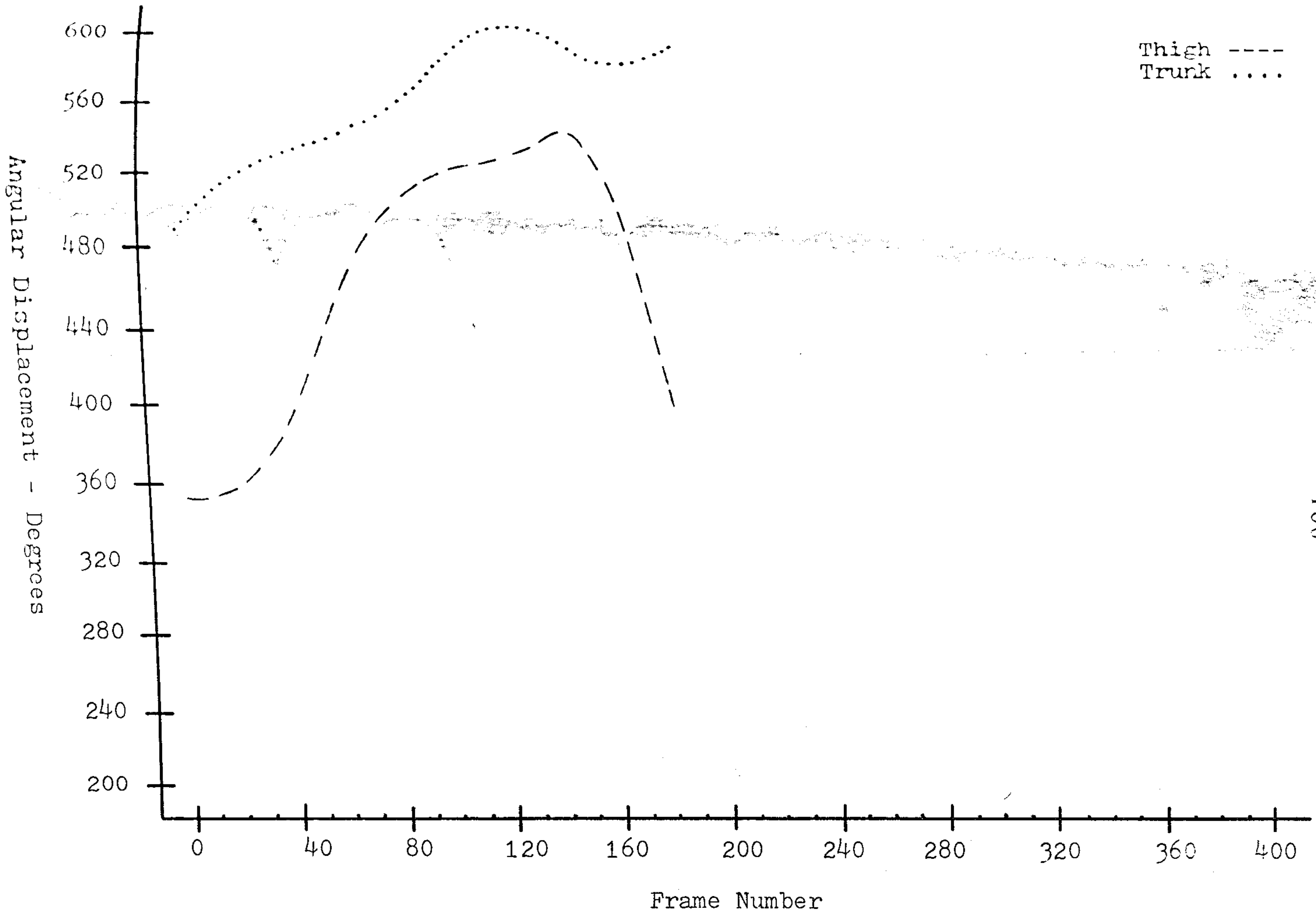


Fig. 25. Subject four angular displacement of the thigh and trunk for the mat kip.

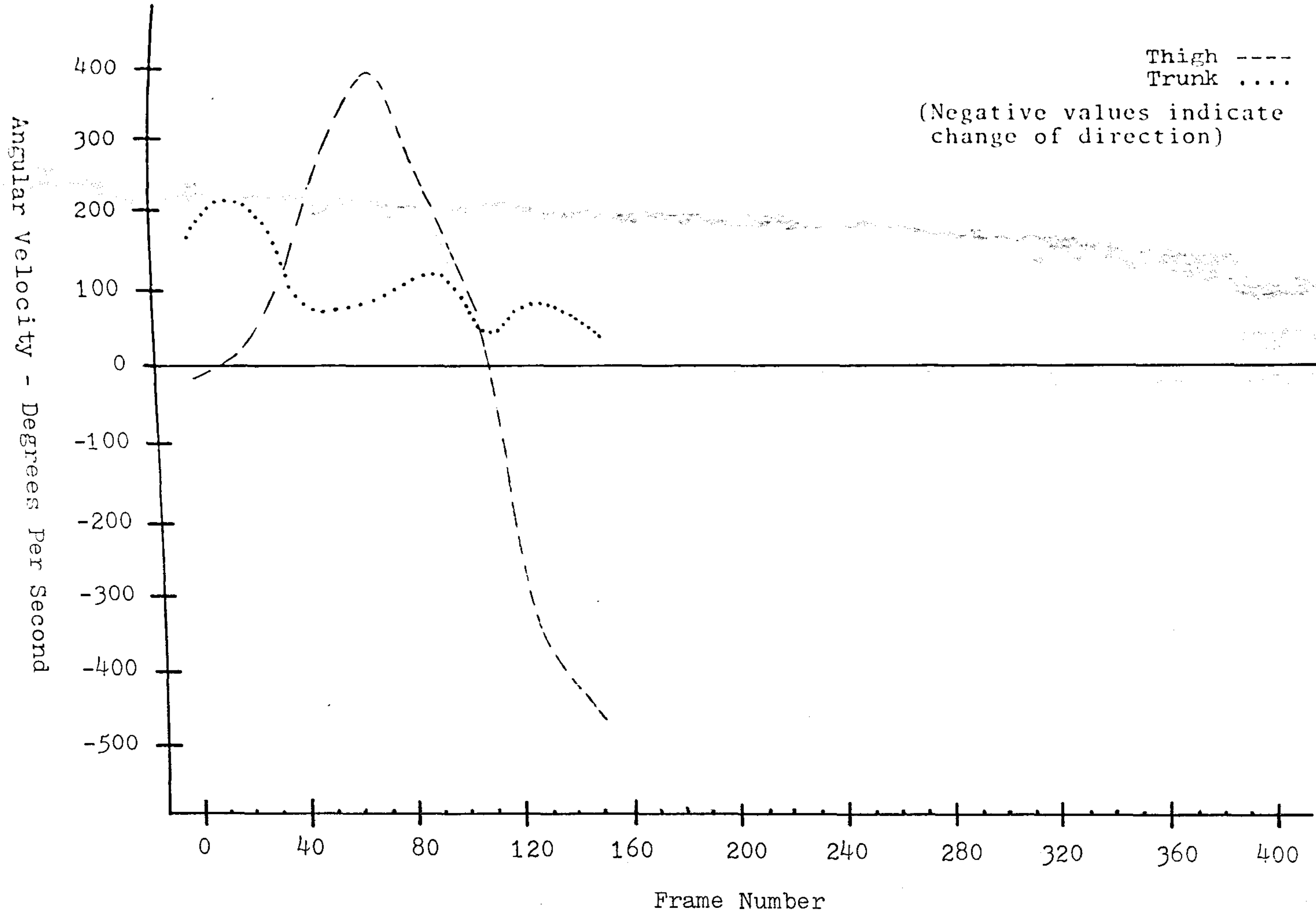


Fig. 26. Subject one angular velocity of the thigh and trunk for the mat kip.

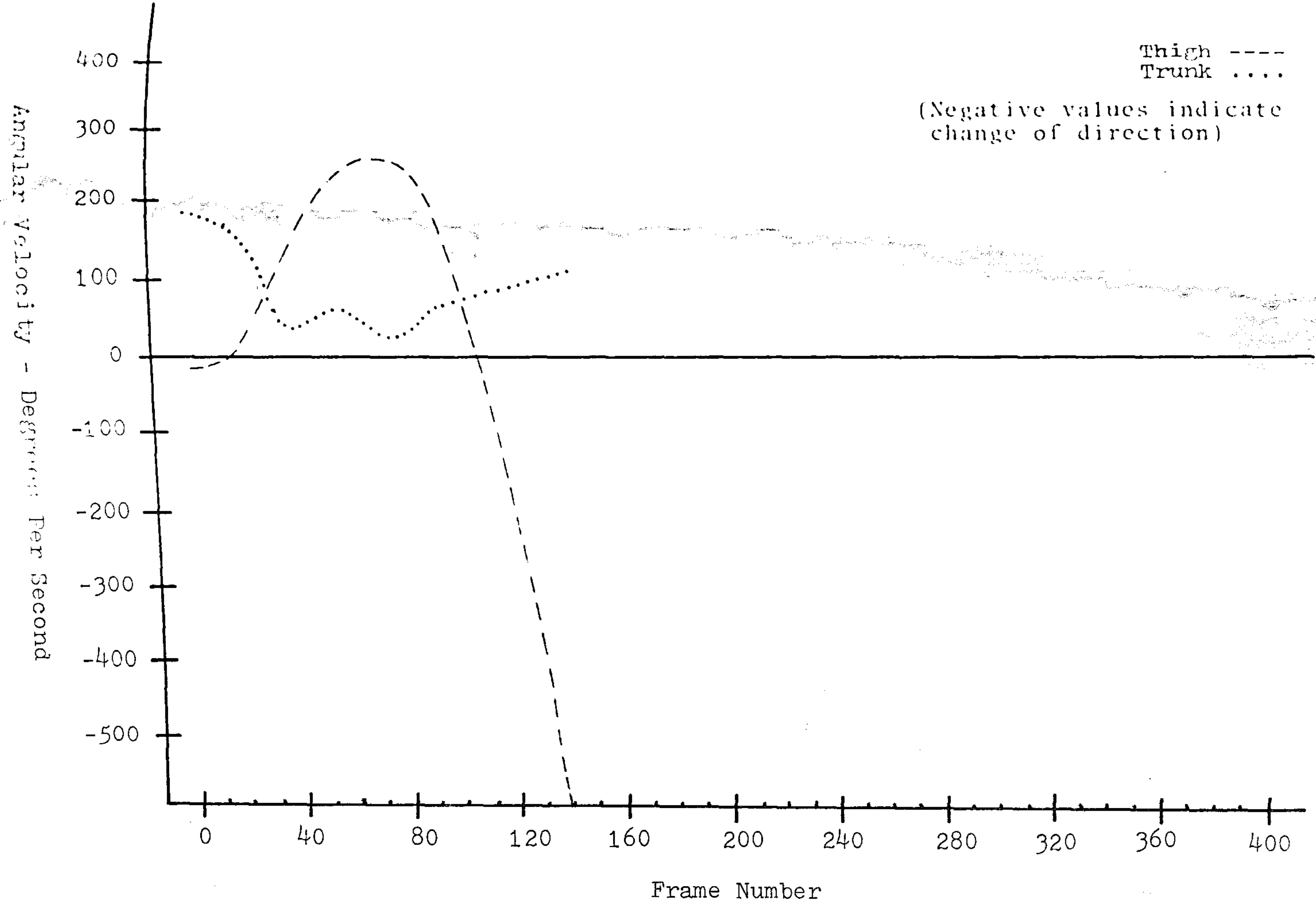


Fig. 27. Subject two angular velocity of the thigh and trunk for the mat kip.

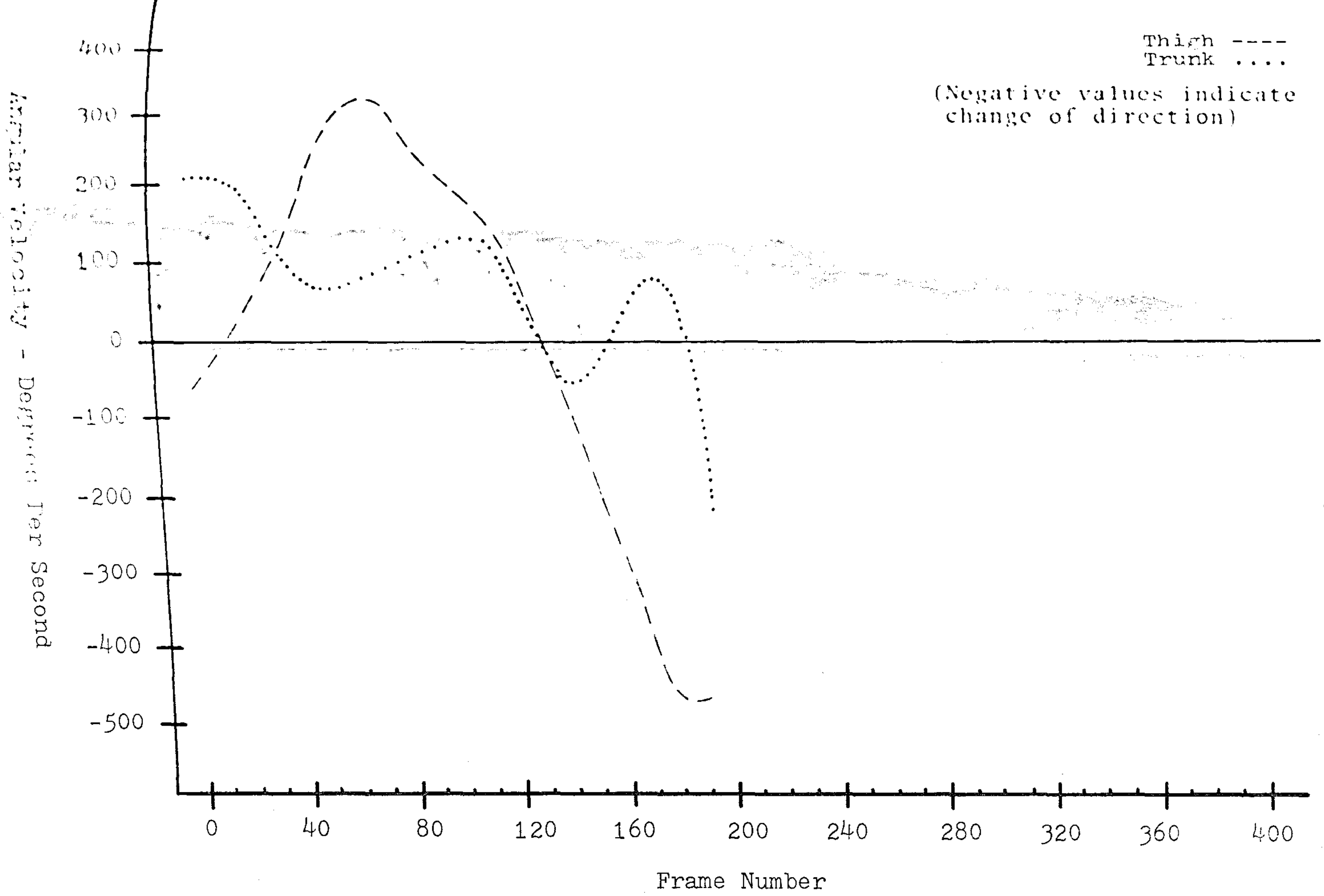


Fig. 28. Subject three angular velocity of the thigh and trunk for the mat kip.

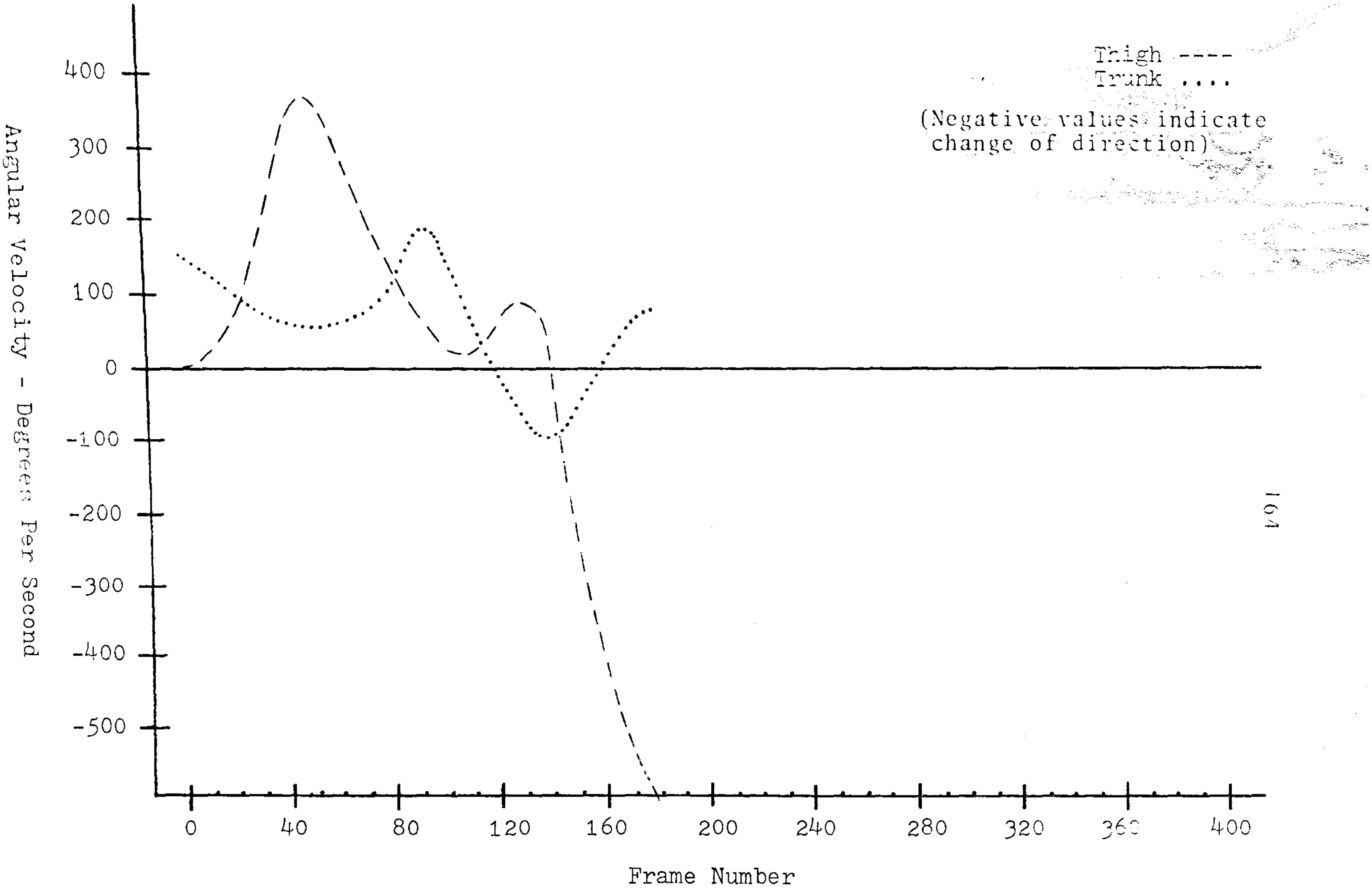


Fig. 29. Subject four angular velocity of the thigh and trunk for the mat kip.

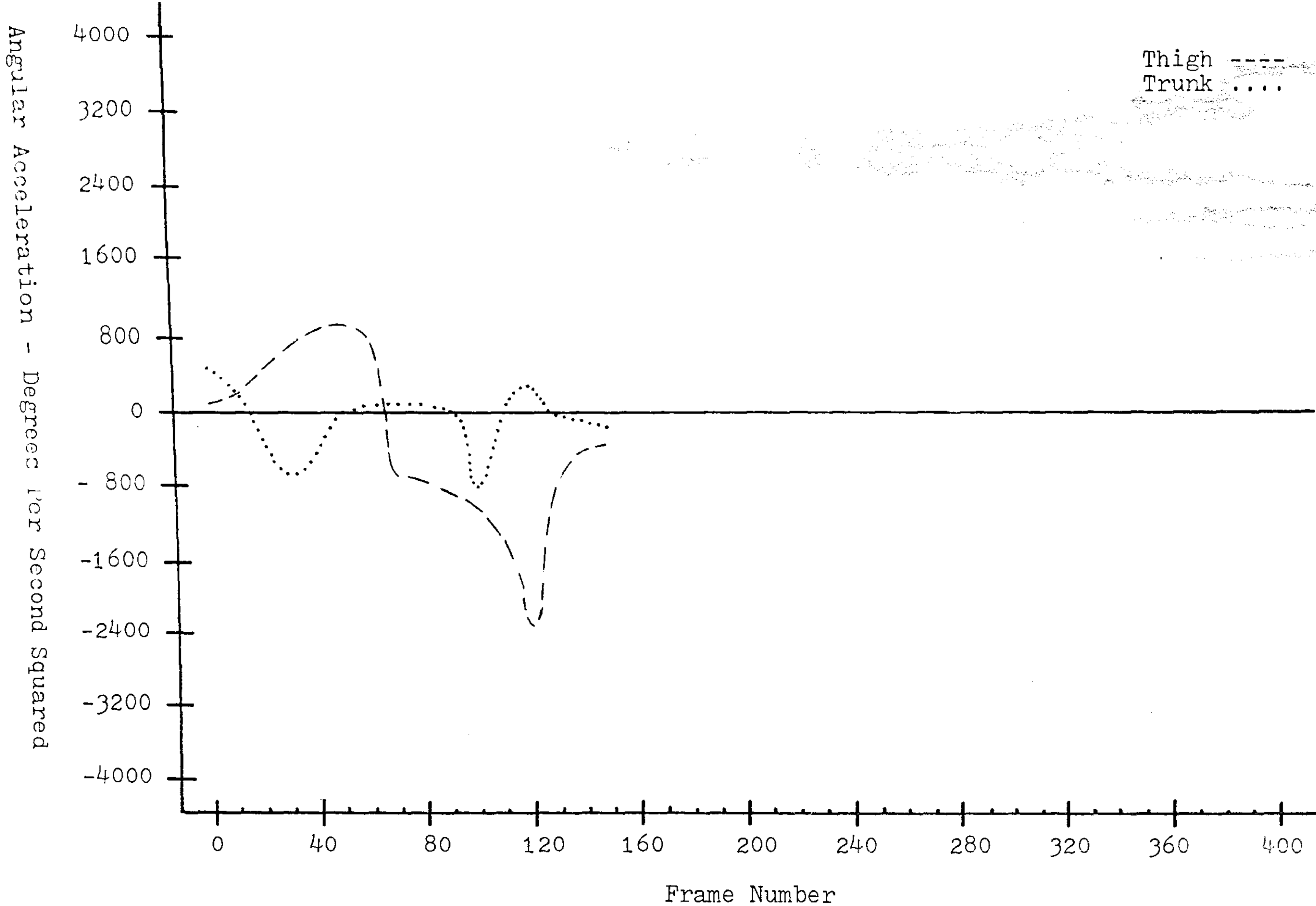


Fig. 30. Subject one angular acceleration of the thigh and trunk for the mat kip.

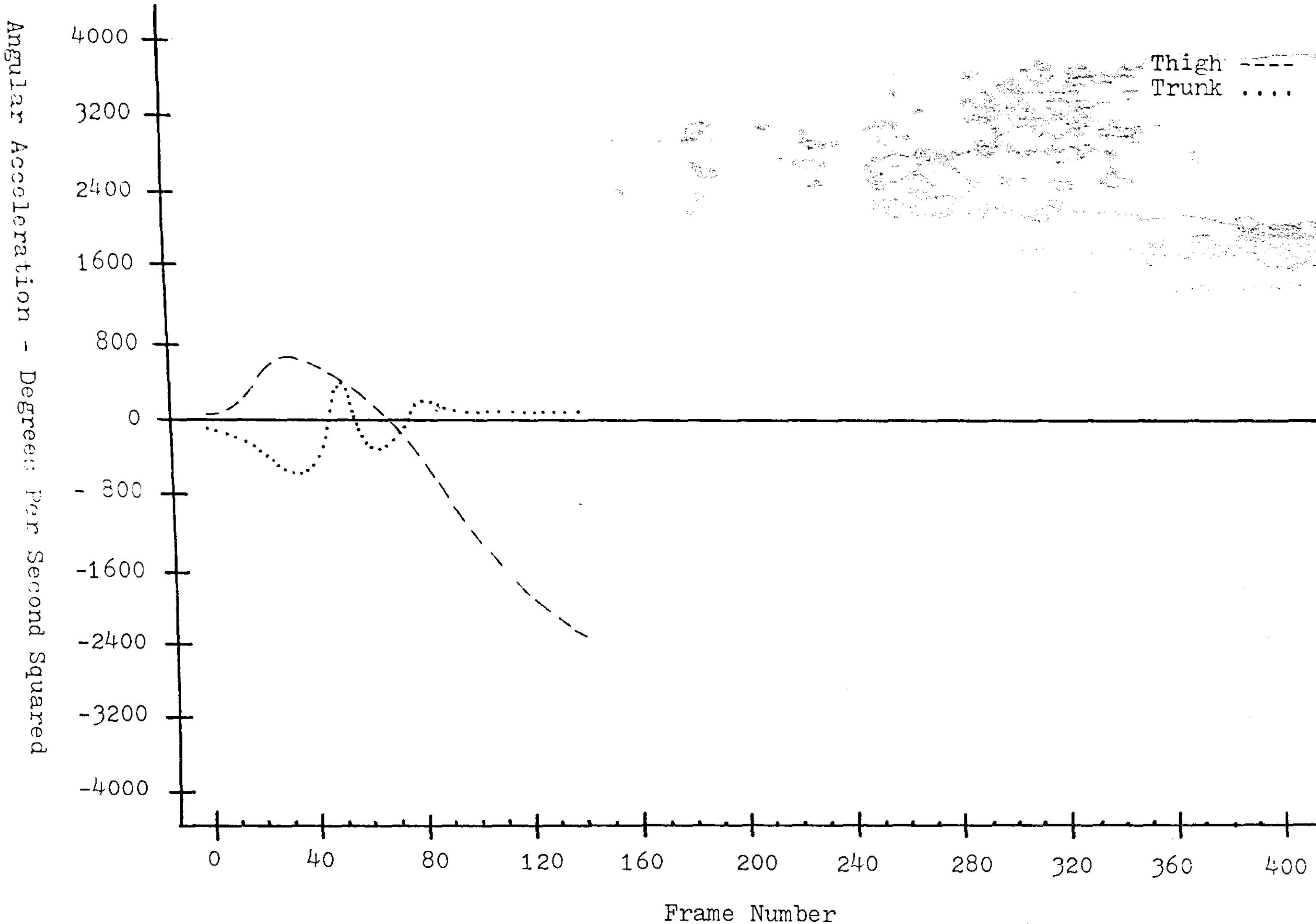


Fig. 31. Subject two angular acceleration of the thigh and trunk for the mat kip.

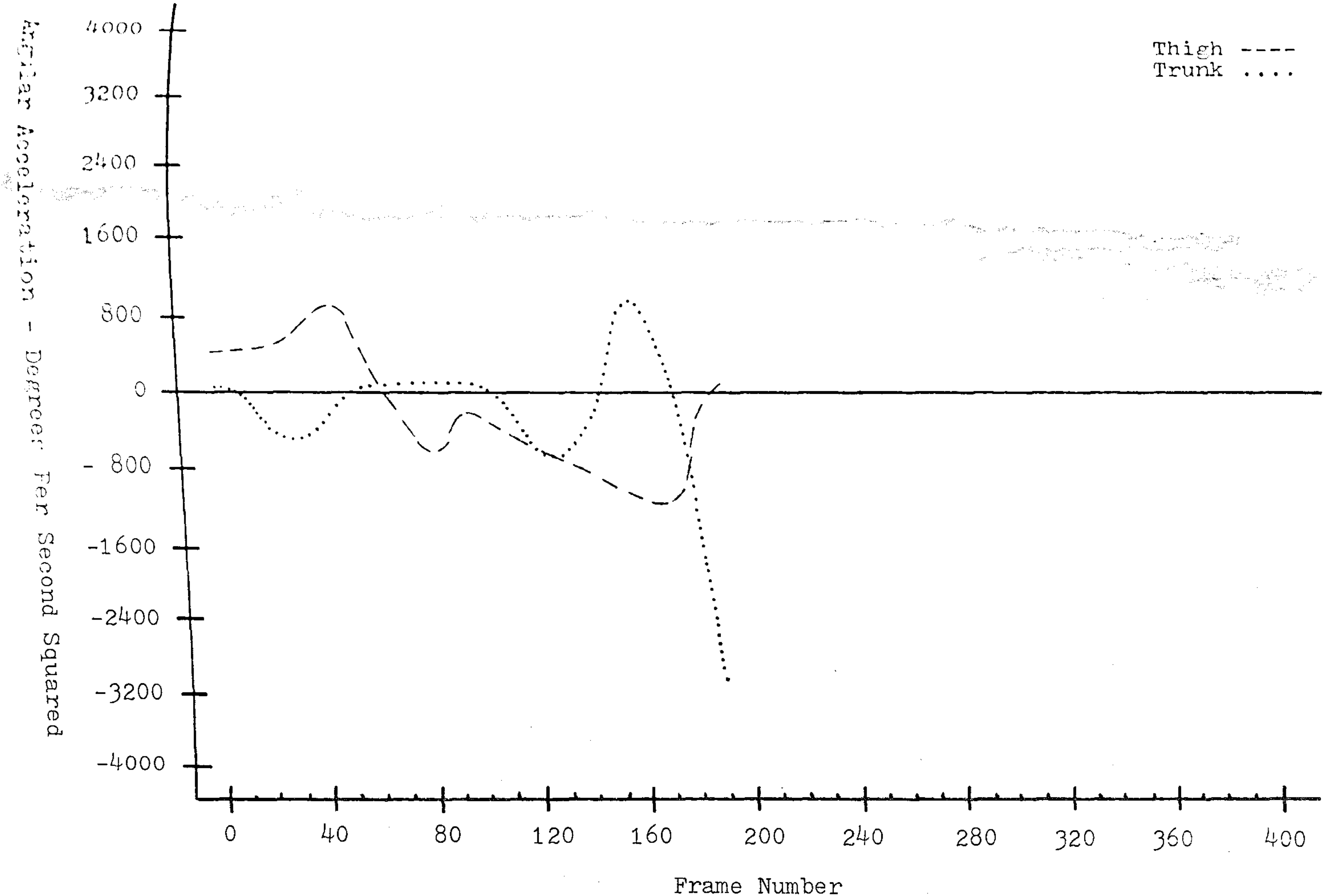


Fig. 32. Subject three angular acceleration of the thigh and trunk for the mat kip.

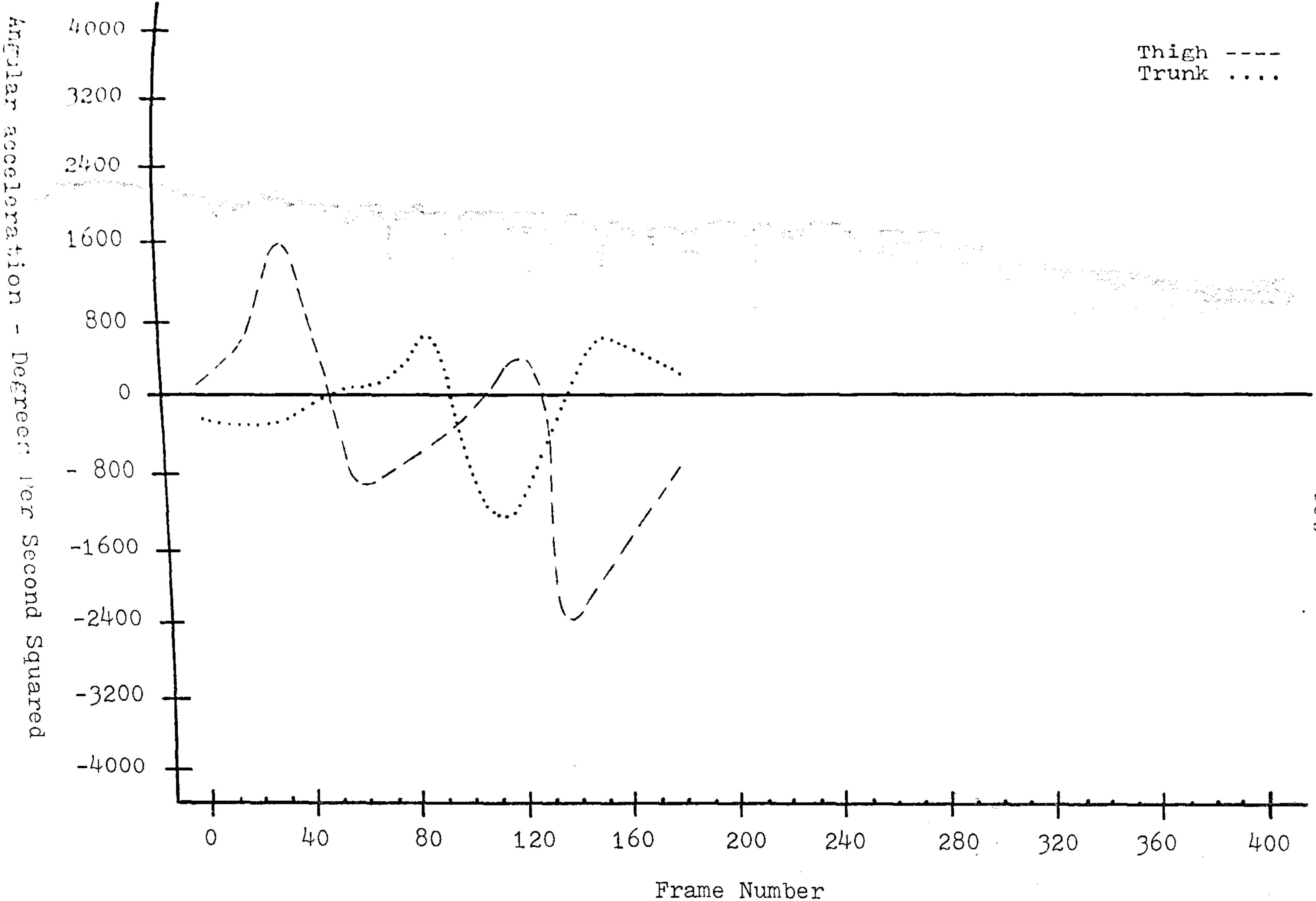


Fig. 33. Subject four angular acceleration of the thigh and trunk for the mat kip.

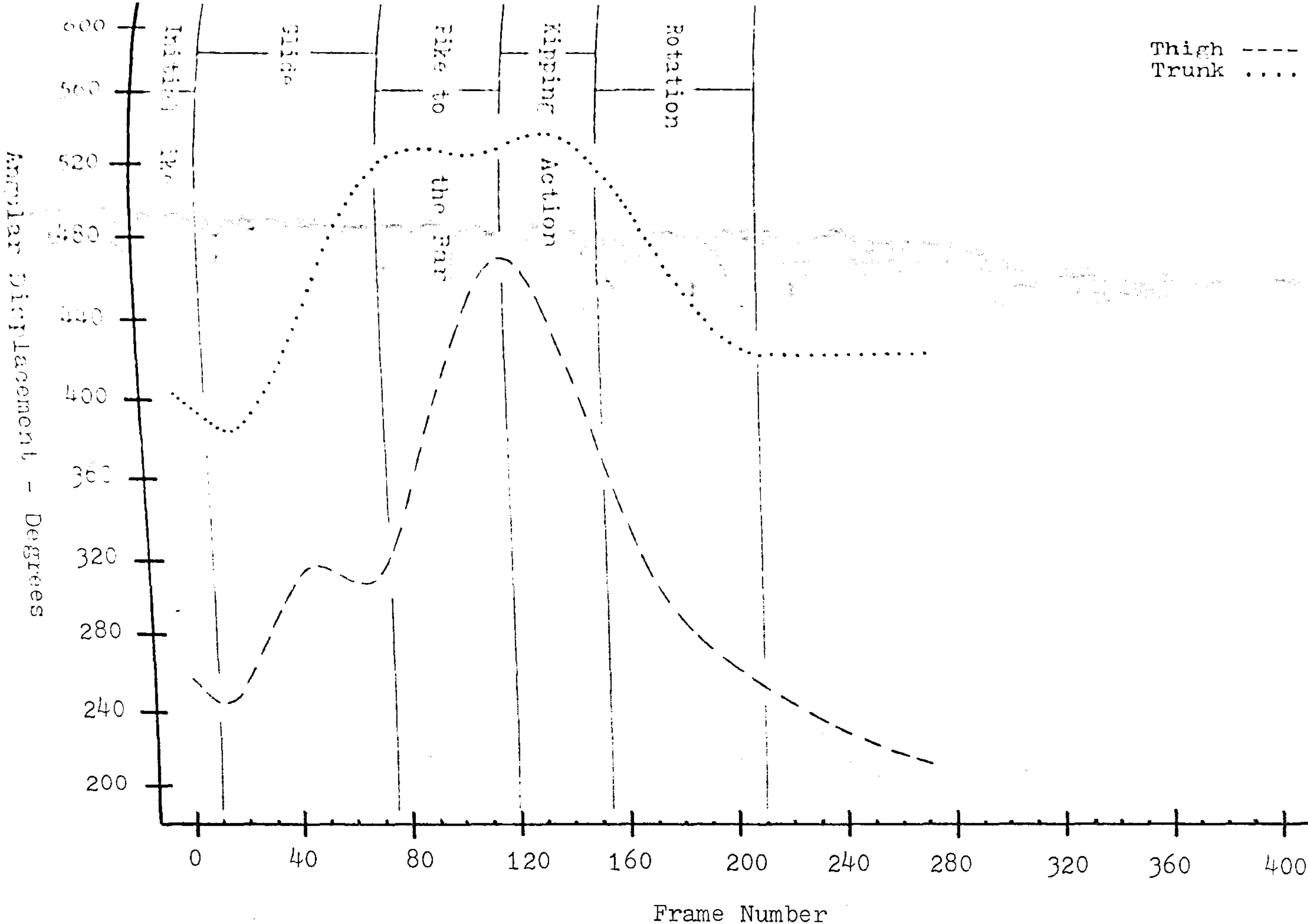


Fig. 34. Subject one angular displacement of the thigh and trunk for the glide kip.

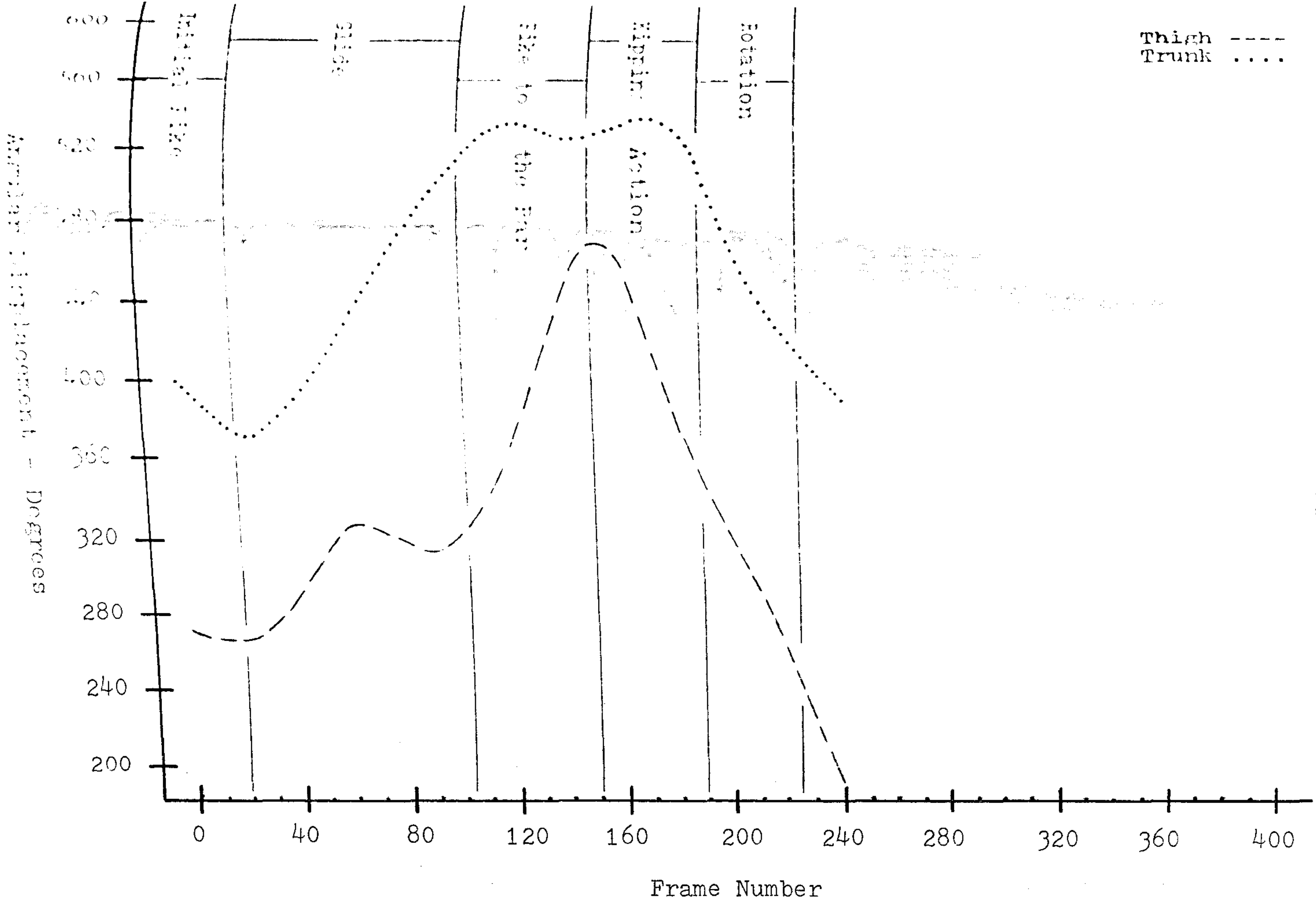


Fig. 35. Subject two angular displacement of the thigh and trunk for the glide kip.

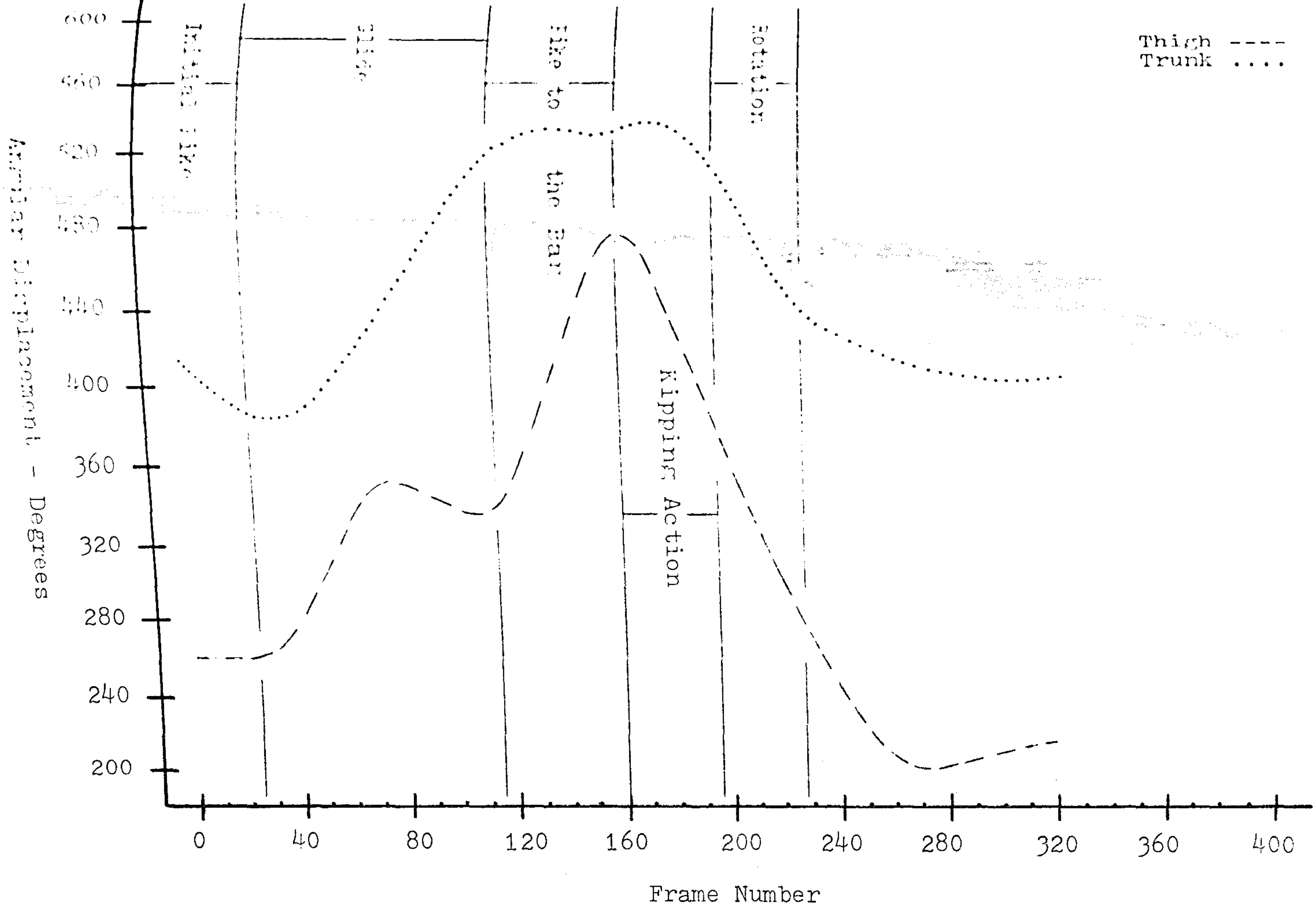


Fig. 36. Subject three angular displacement of the thigh and trunk for the glide kip.

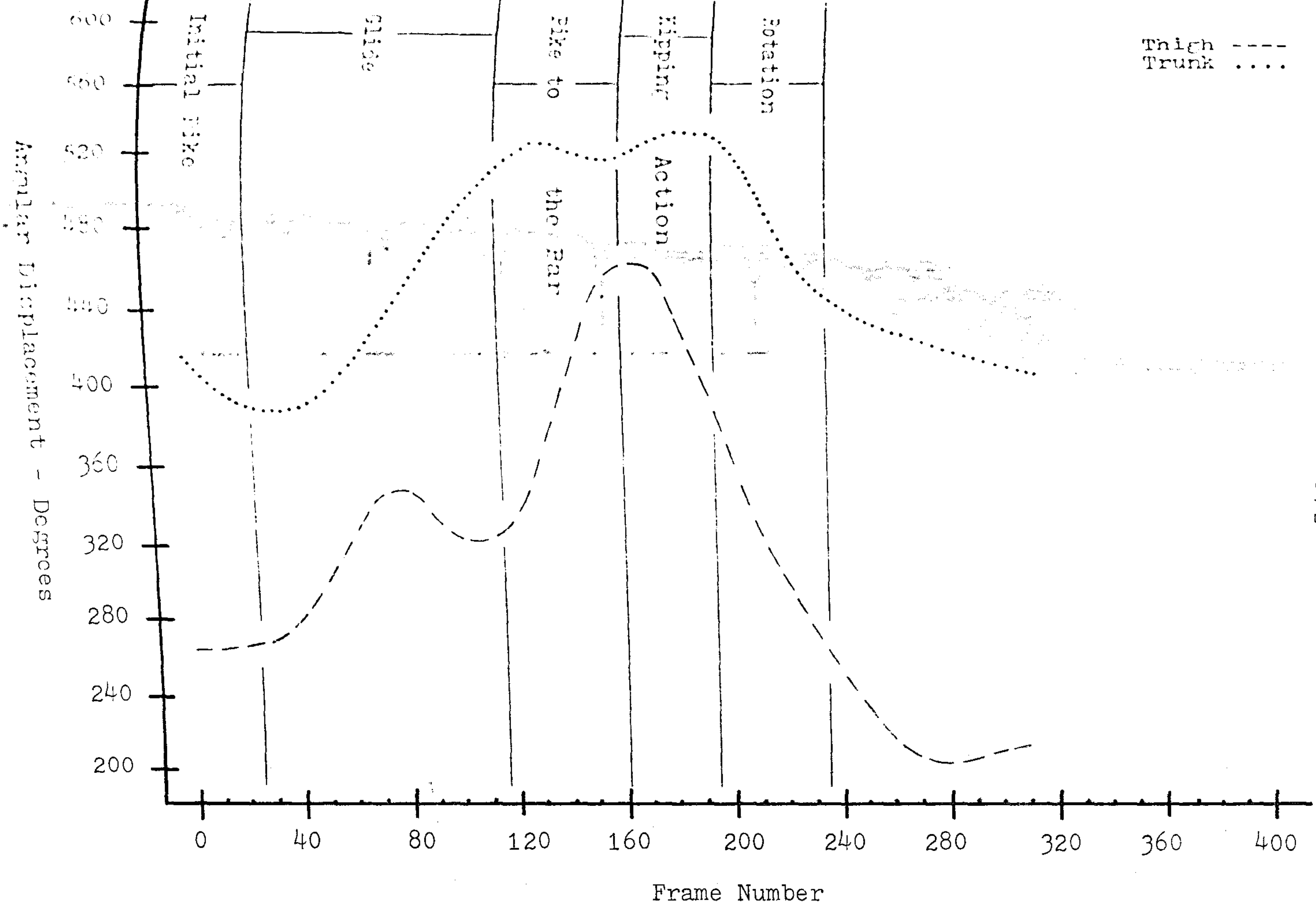


Fig. 37. Subject four angular displacement of the thigh and trunk for the glide kip.

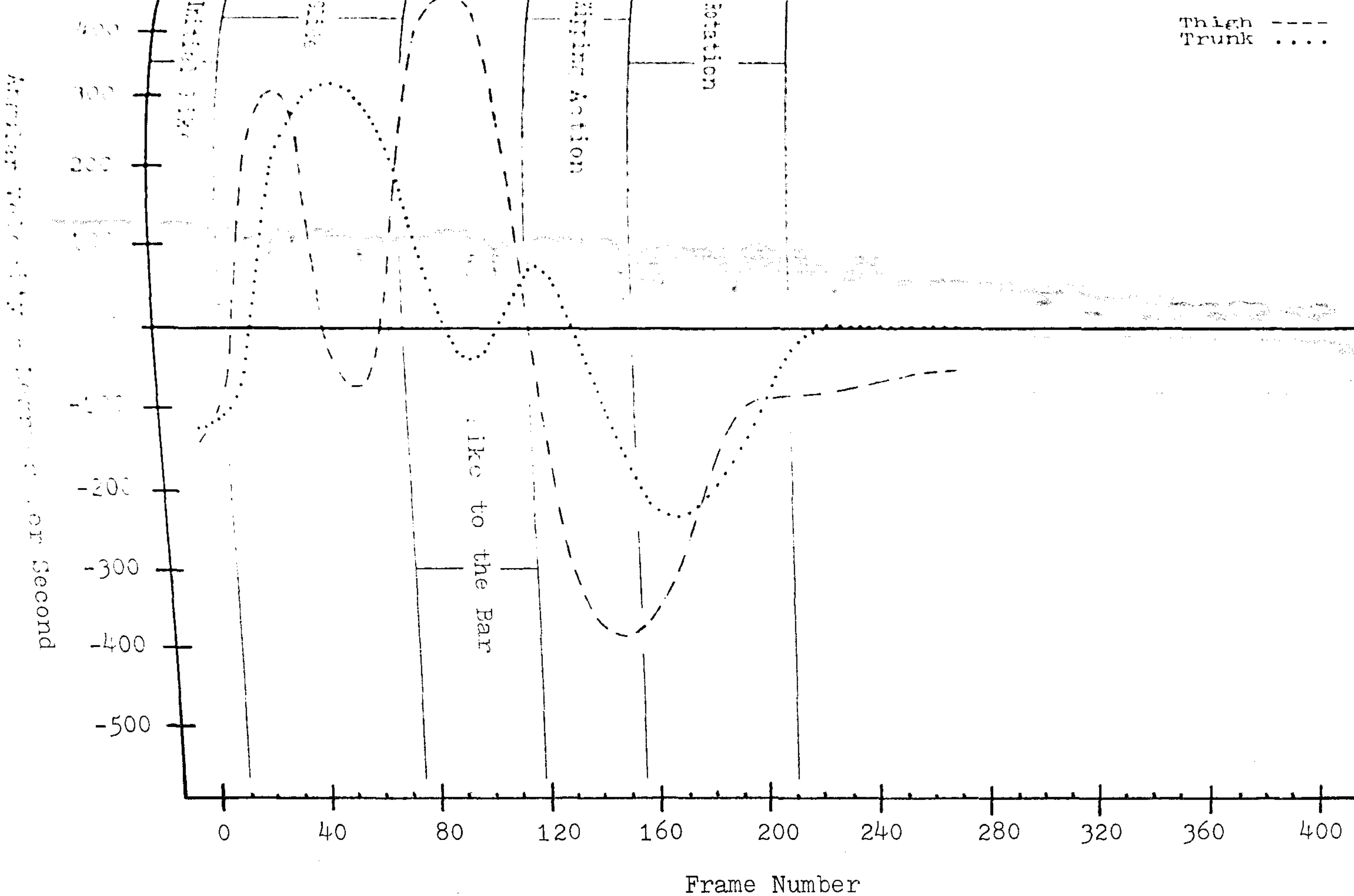


Fig. 38. Subject one angular velocity of the thigh and trunk for the glide kip.

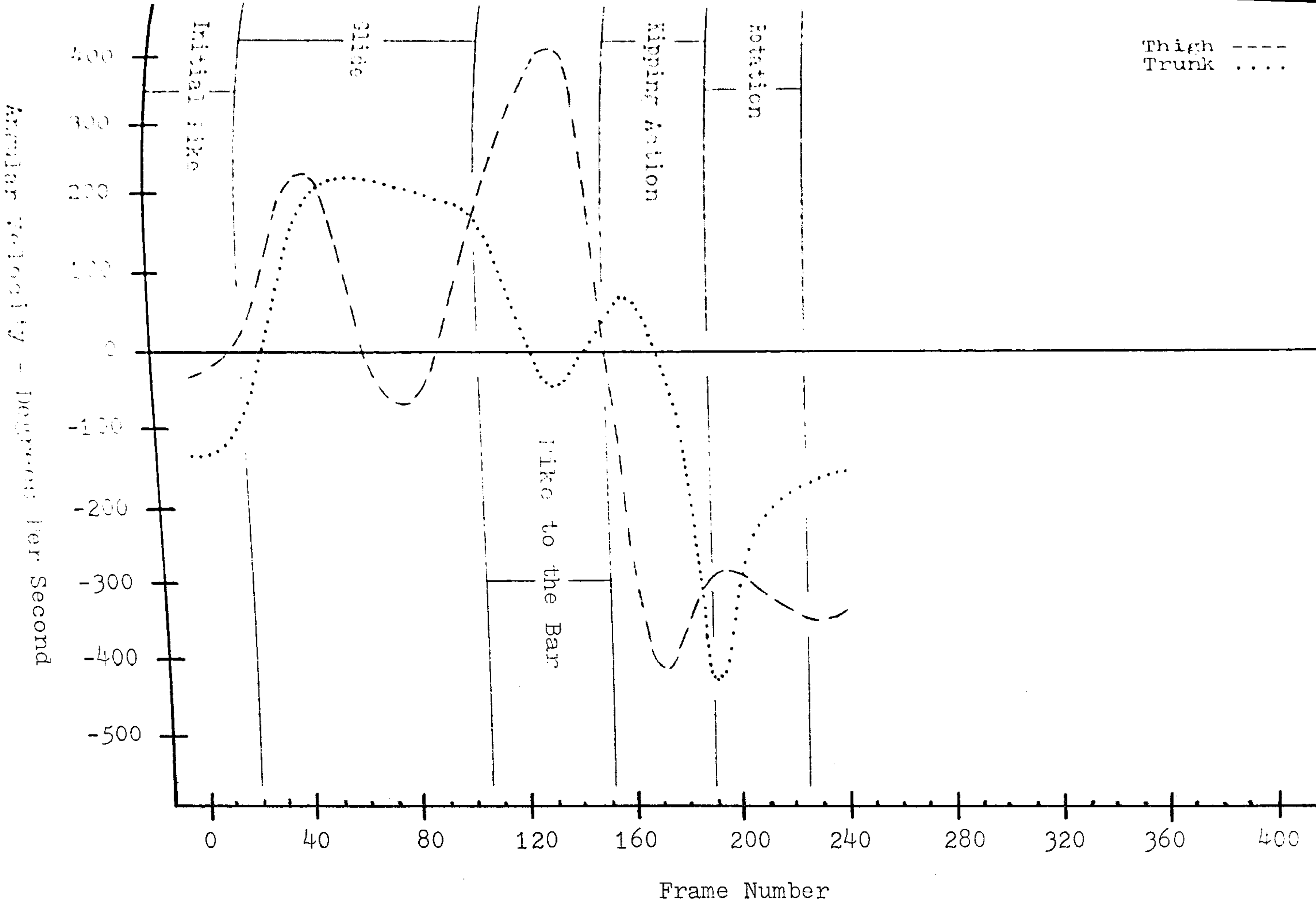


Fig. 39. Subject two angular velocity of the thigh and trunk for the glide kip.

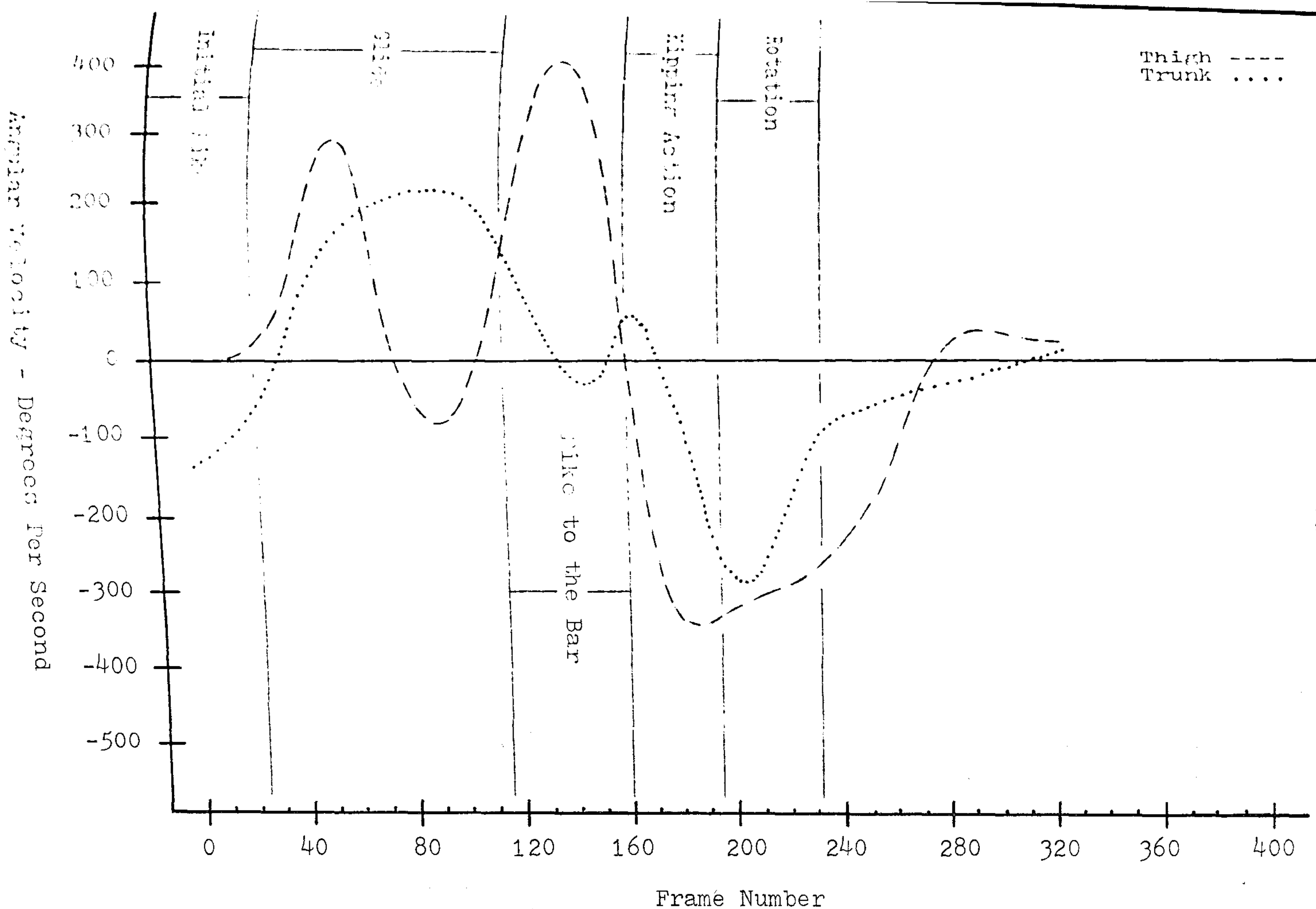


Fig. 40. Subject three angular velocity of the thigh and trunk for the glide kip.

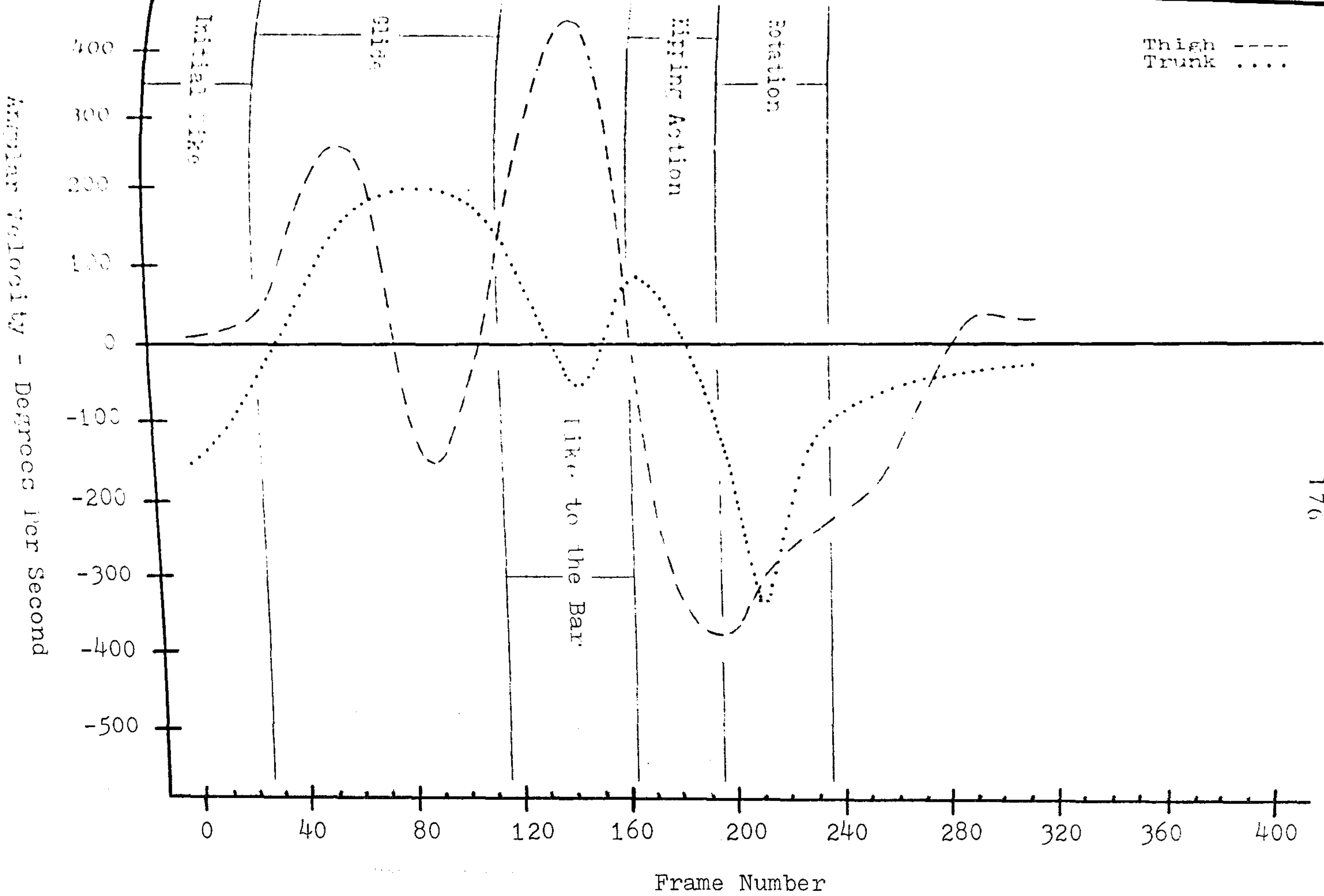


Fig. 41. Subject four angular velocity of the thigh and trunk for the glide kip.

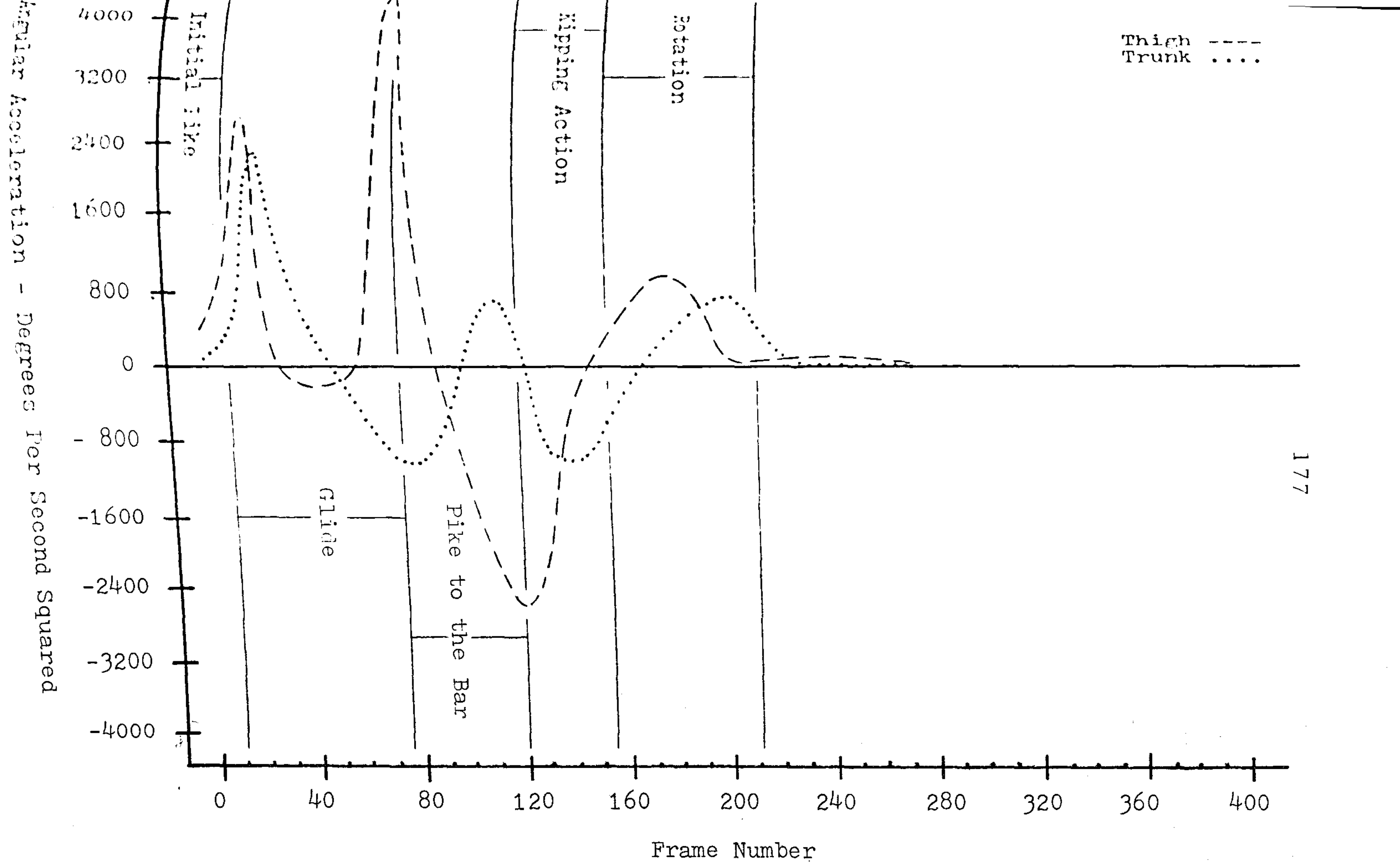


Fig. 42. Subject one angular acceleration of the thigh and trunk for the glide kip.

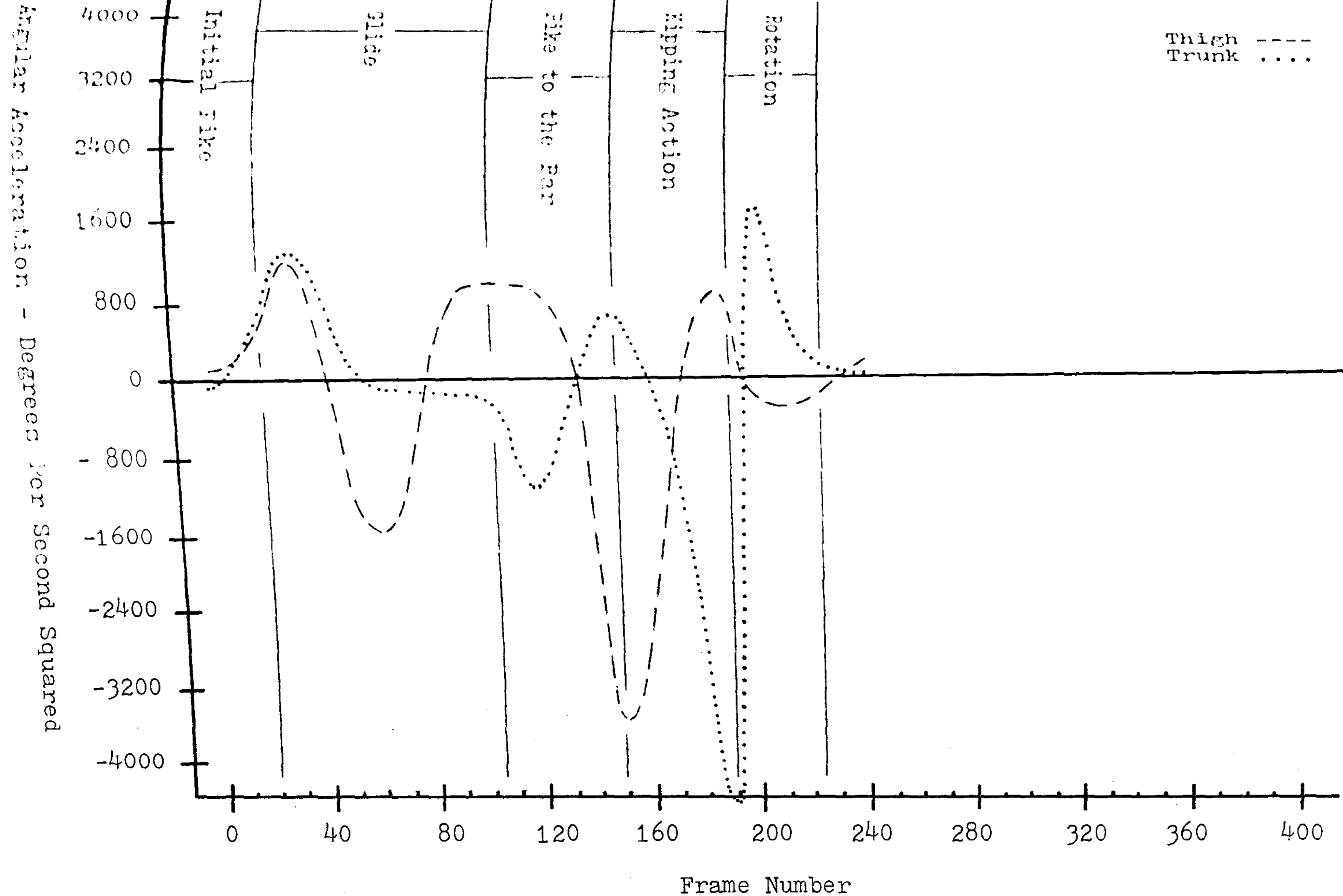


Fig. 43. Subject two angular acceleration of the thigh and trunk for the glide kip.

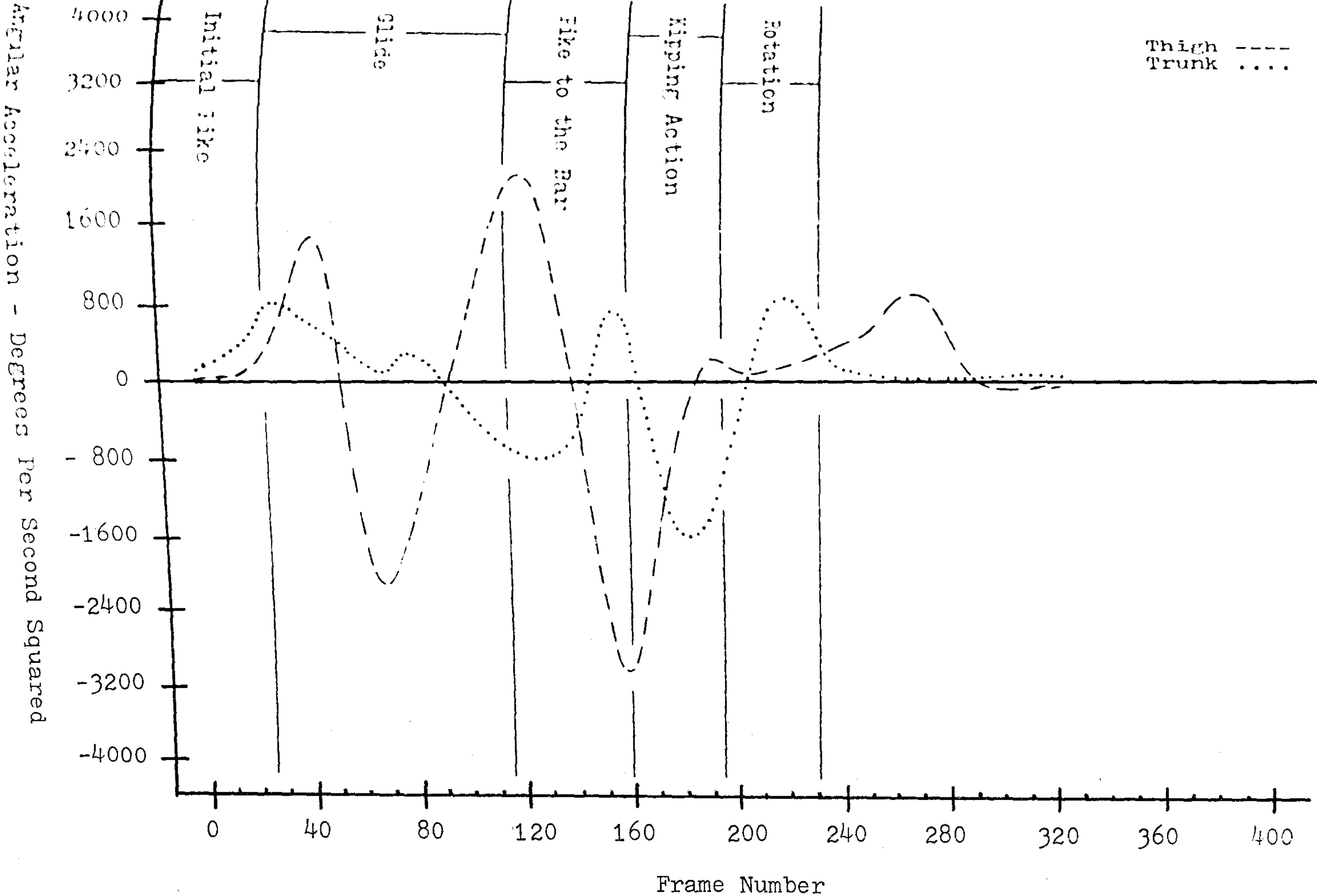


Fig. 44. Subject three angular acceleration of the thigh and trunk for the glide kip.

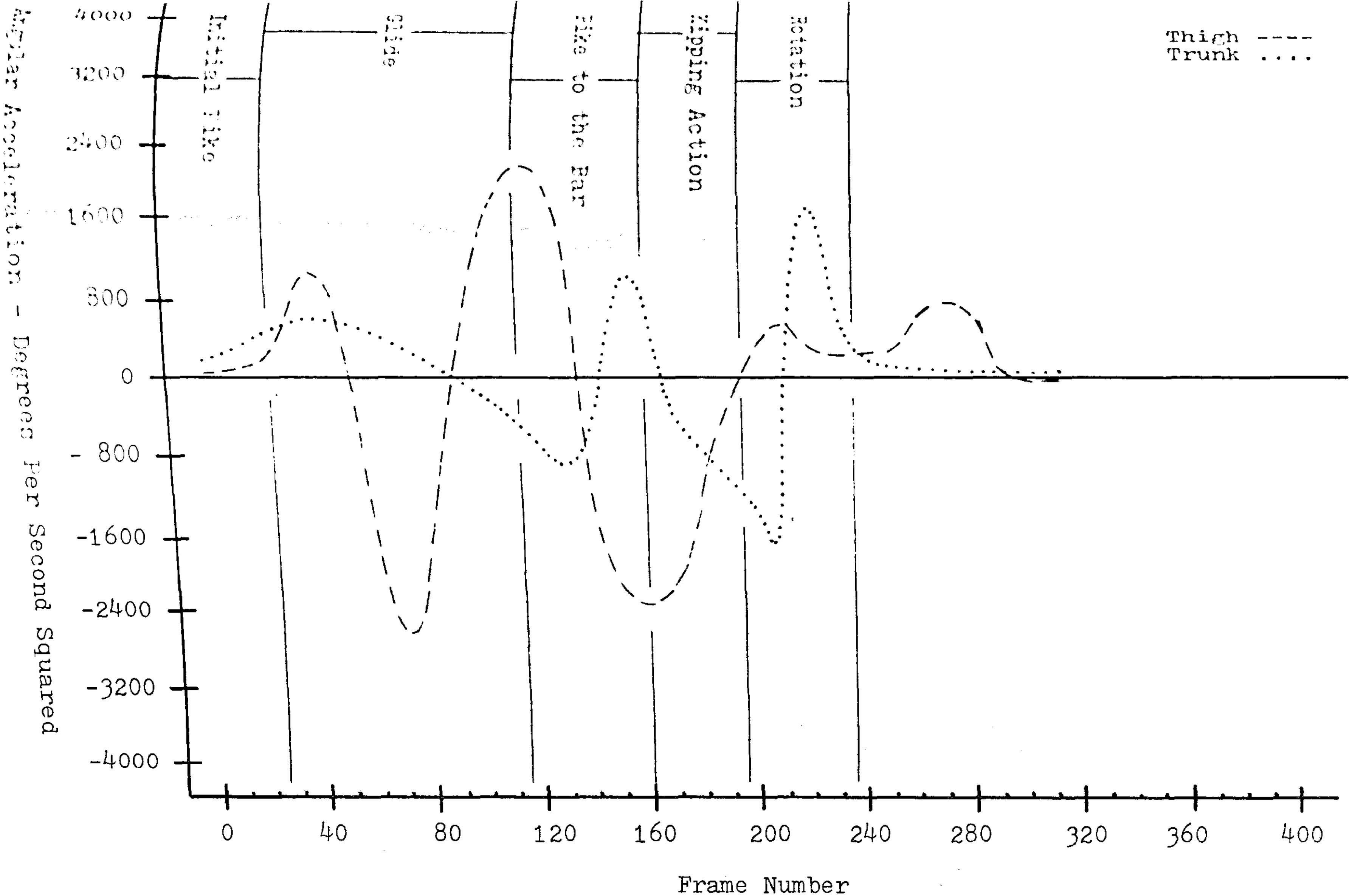


Fig. 45. Subject four angular acceleration of the thigh and trunk for the glide kip.

APPENDIX G

GRAPHS OF THE KIPPING ACTION

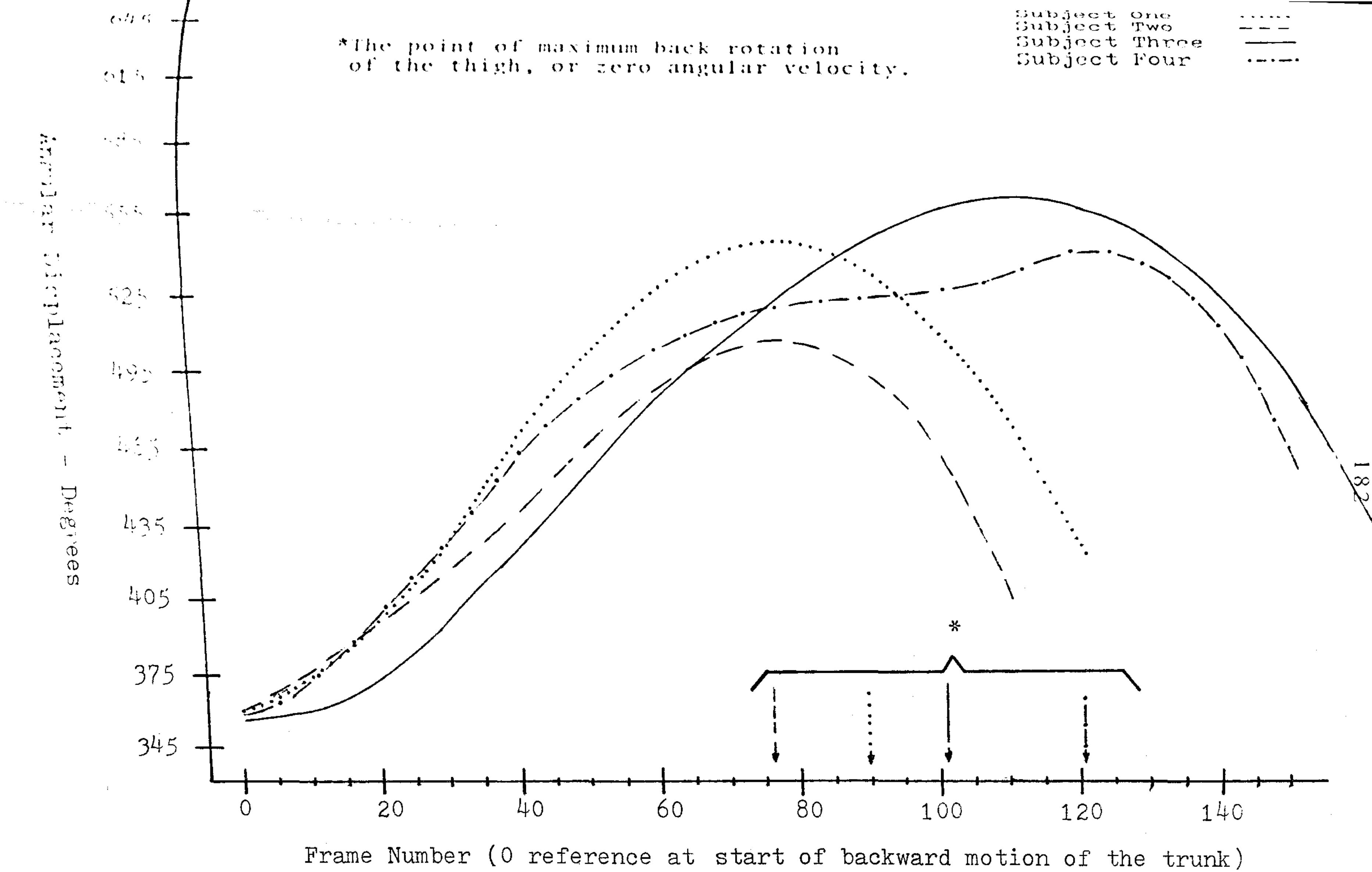


Fig. 46. Angular displacement of the thigh in the mat kip for the kipping action.

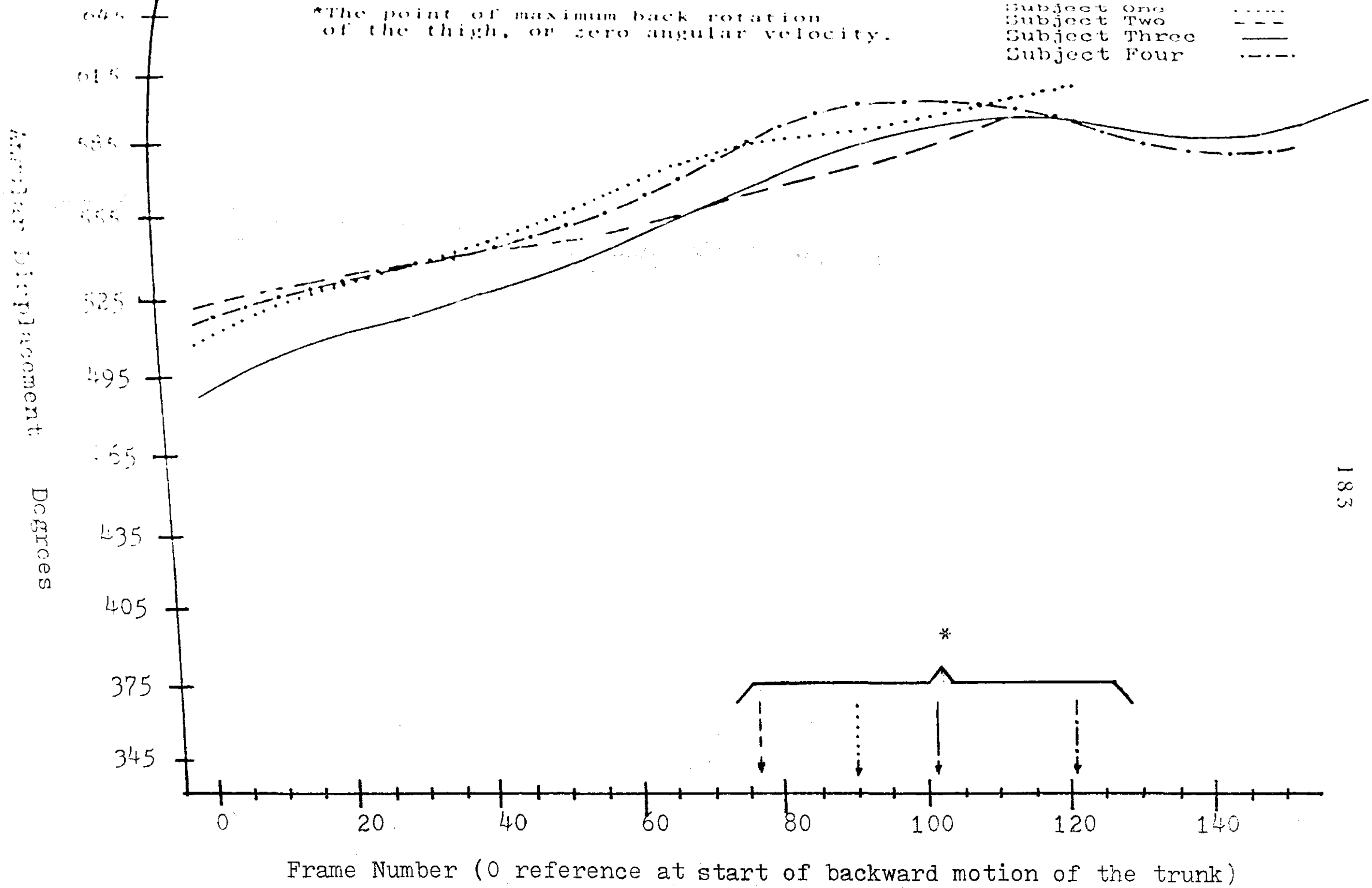


Fig. 47. Angular displacement of the trunk in the mat kip for the kipping action.

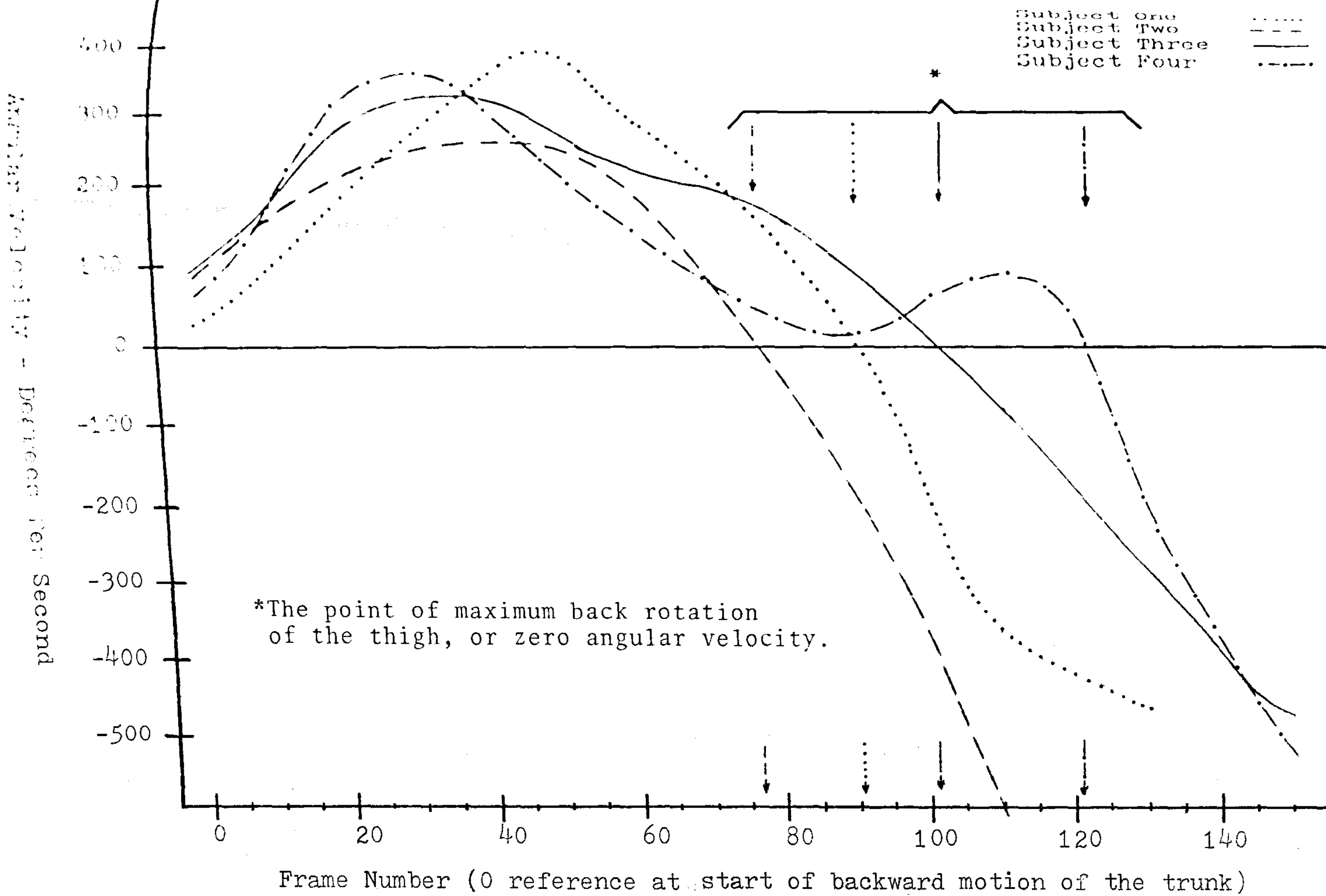


Fig. 48. Angular velocity of the thigh in the mat kip for the kipping action.

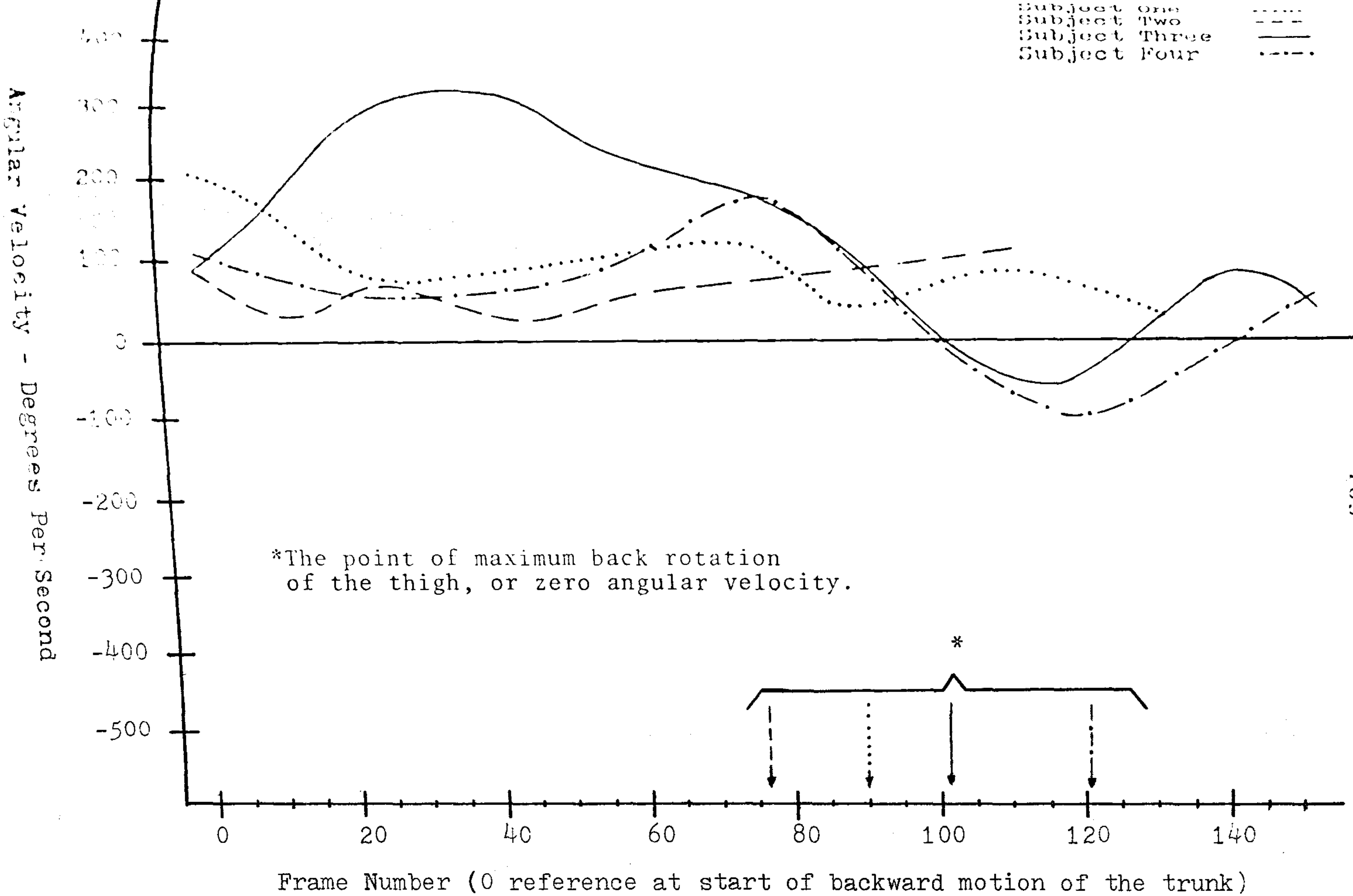


Fig. 49. Angular velocity of the trunk in the mat kip for the kipping action.

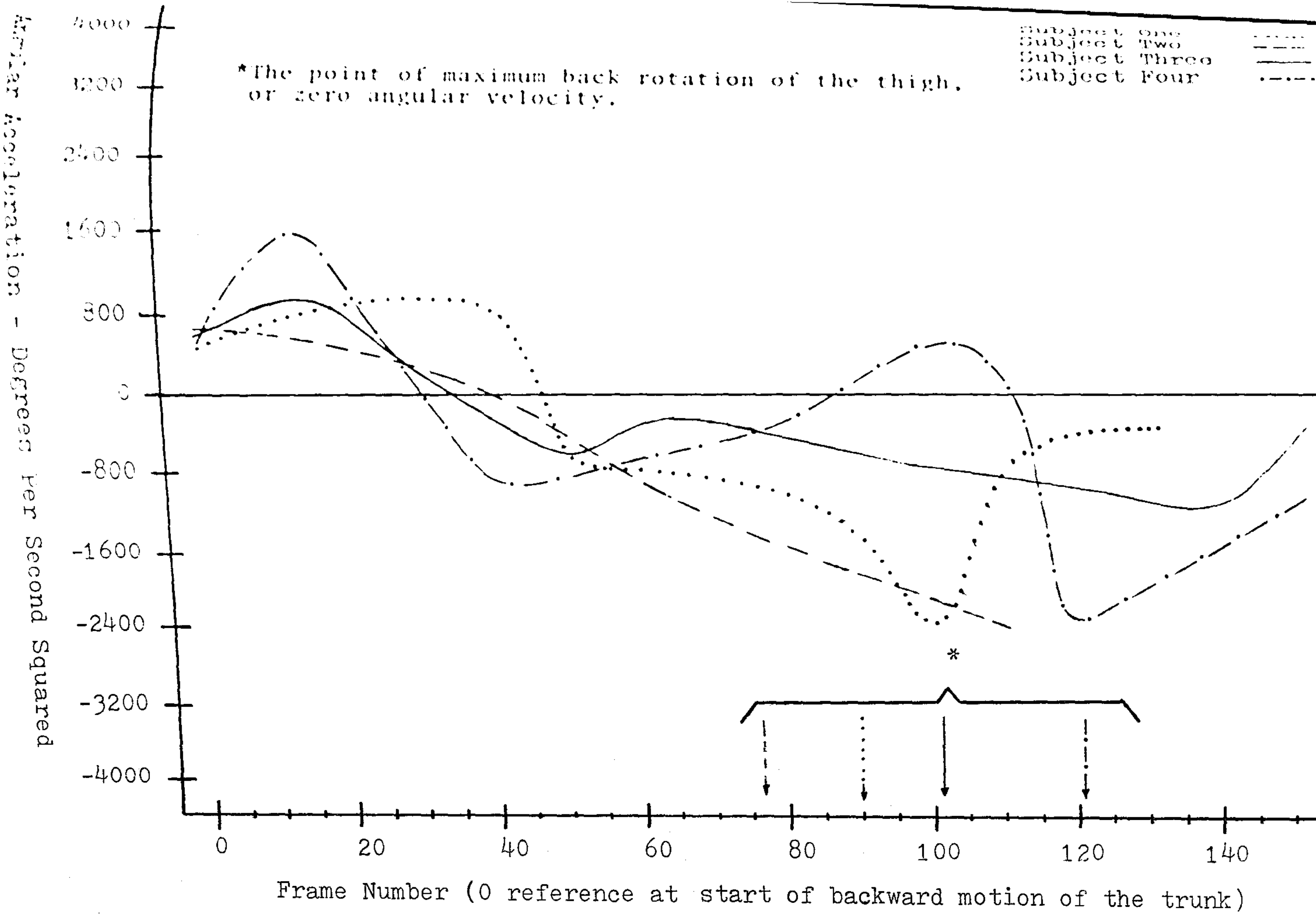


Fig. 50. Angular acceleration of the thigh in the mat kip for the kipping action.

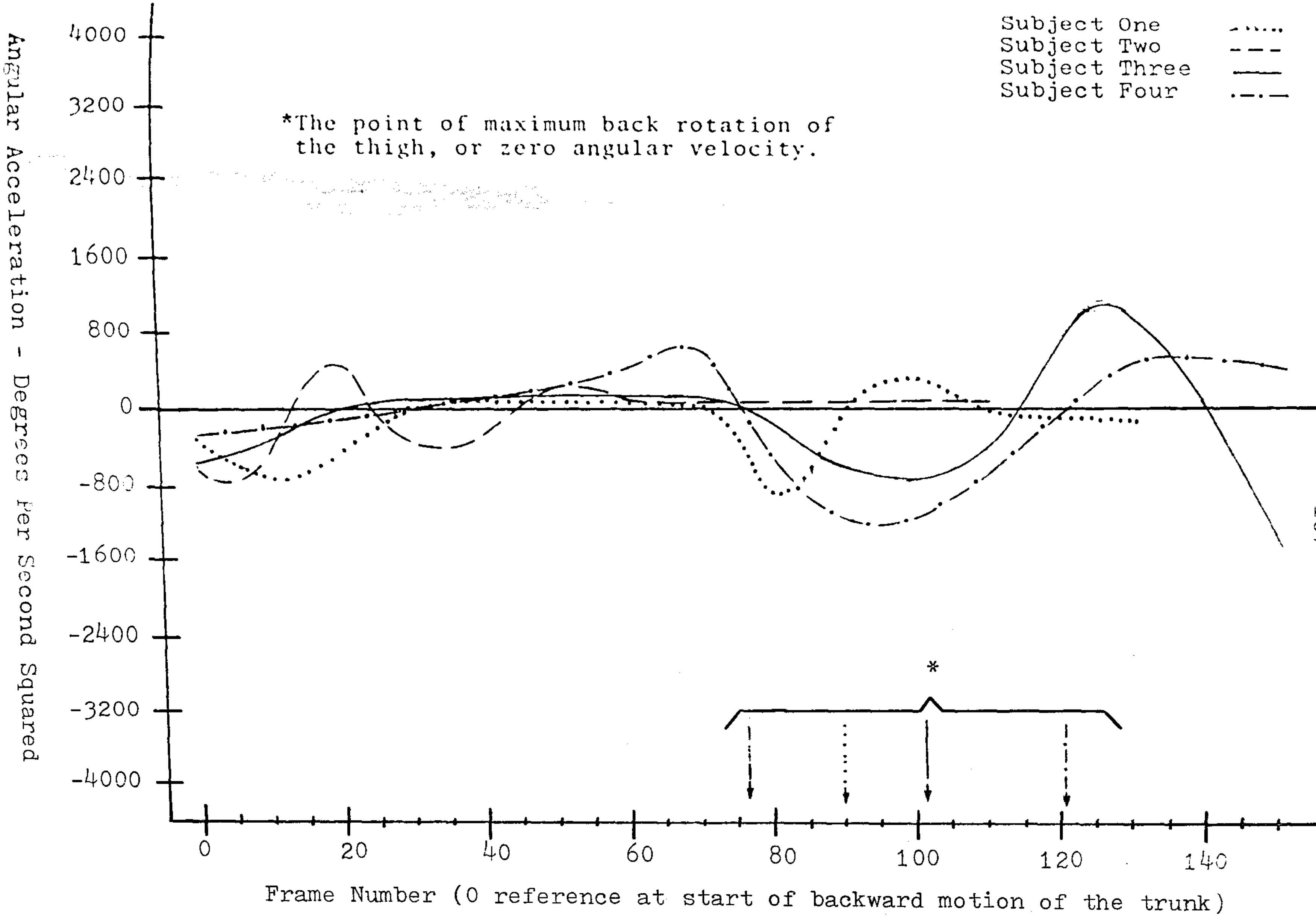


Fig. 51. Angular acceleration of the trunk in the mat kip for the kipping action.

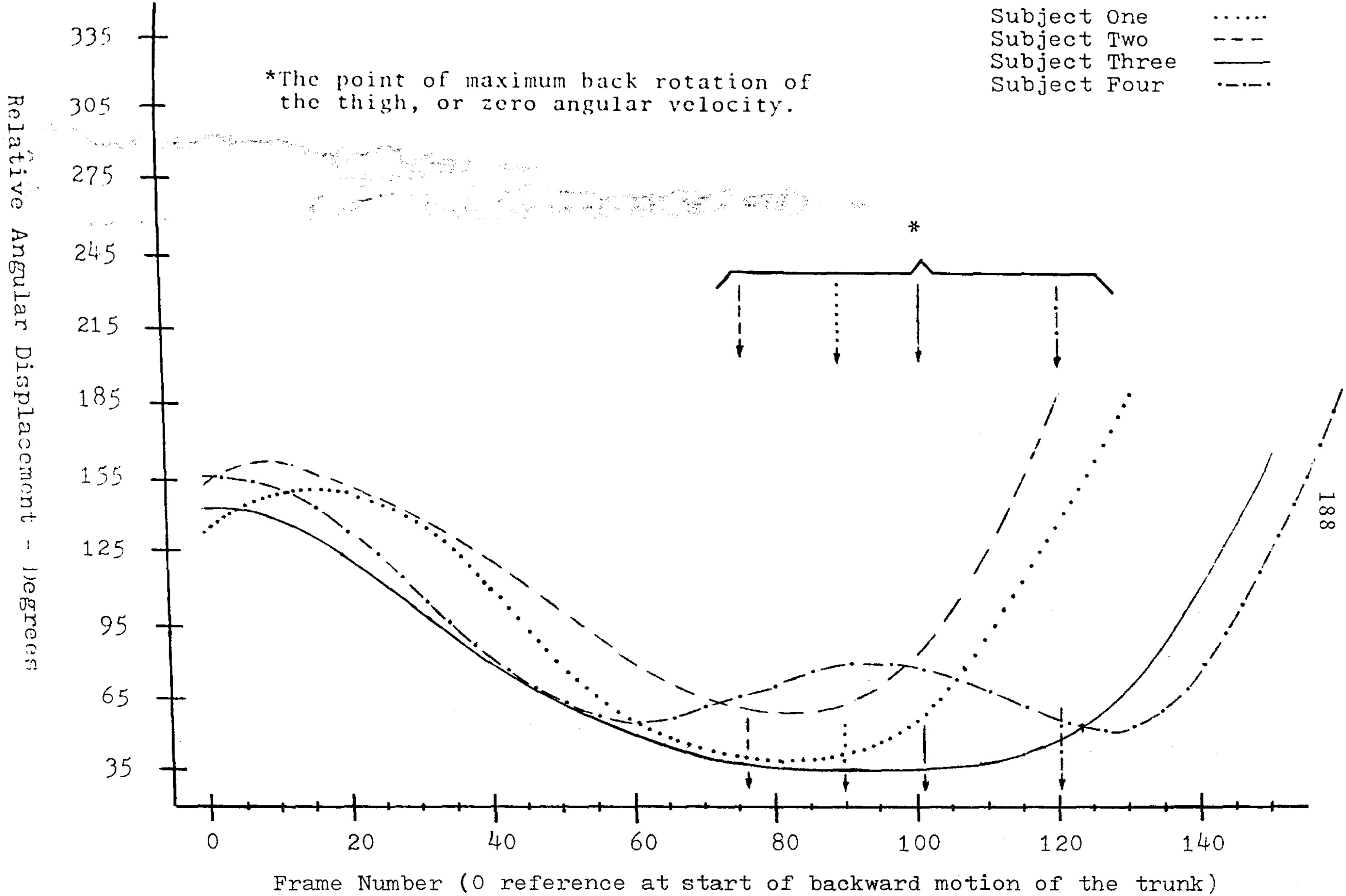


Fig. 52. Relative angular displacement in the mat kip for the kipping action.

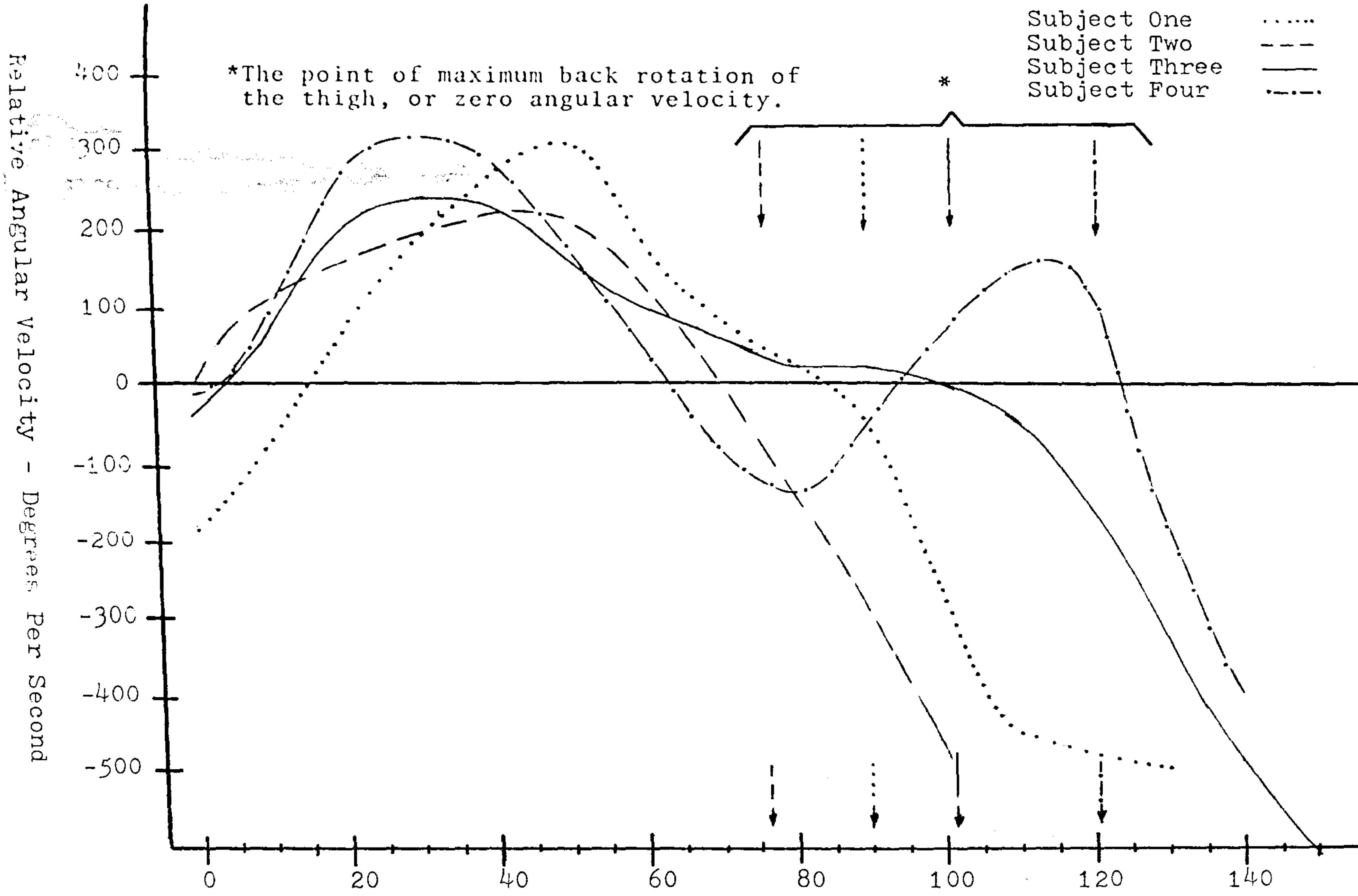


Fig. 53. Relative angular velocity in the mat kip for the kipping action.

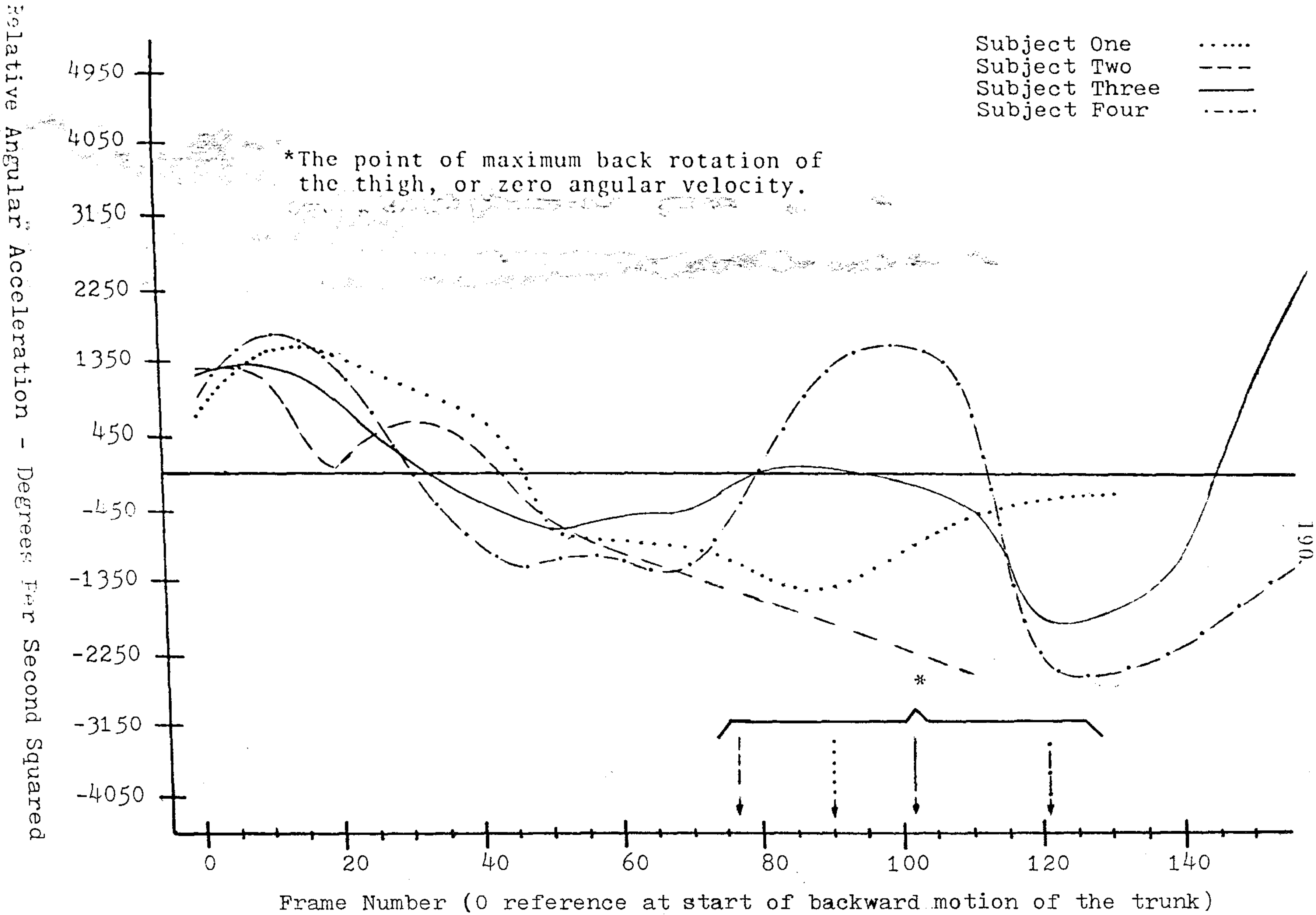


Fig. 54. Relative angular acceleration in the mat kip for the kipping action.

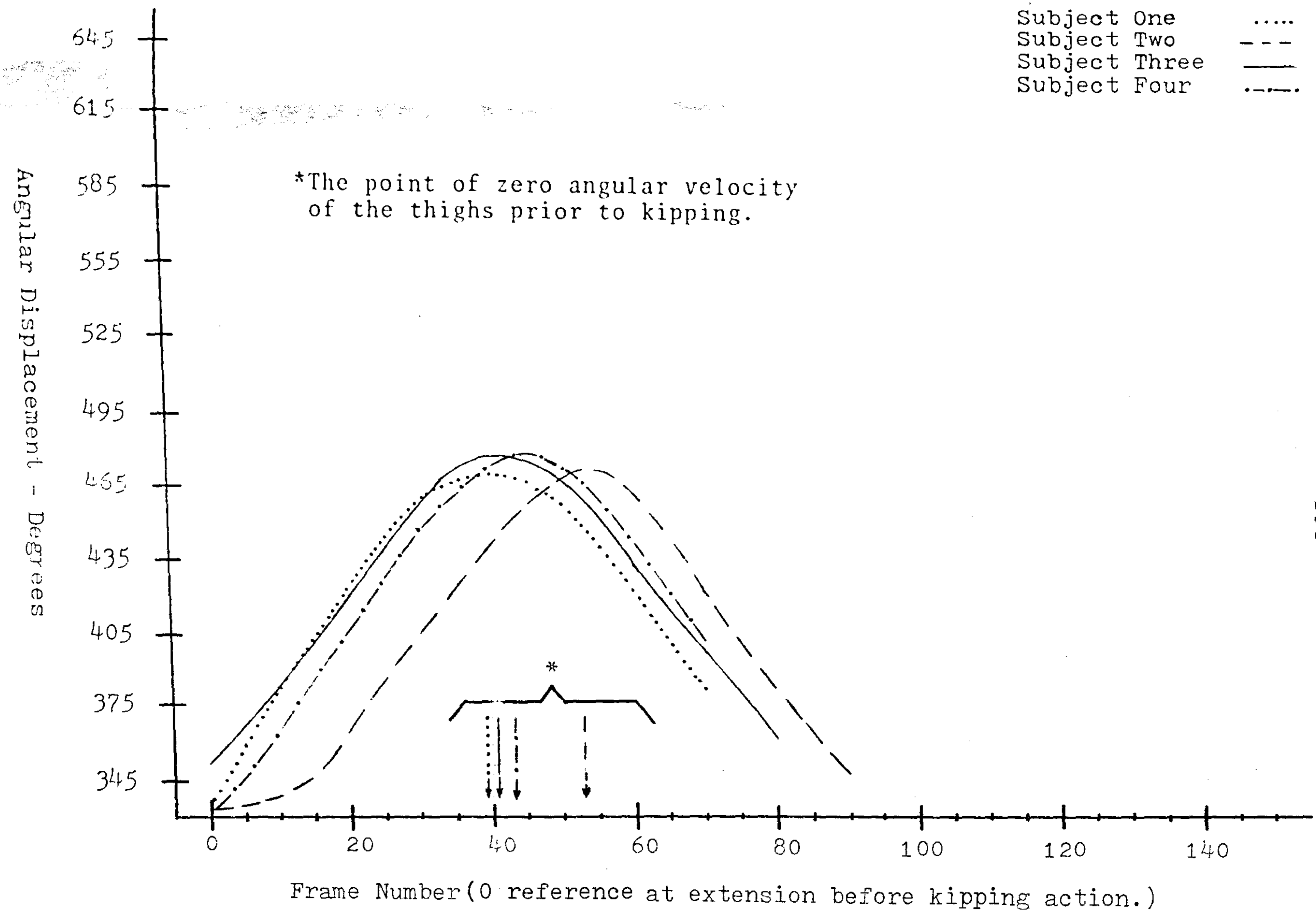


Fig. 55. Angular displacement of the thigh in the glide kip for the kipping action.

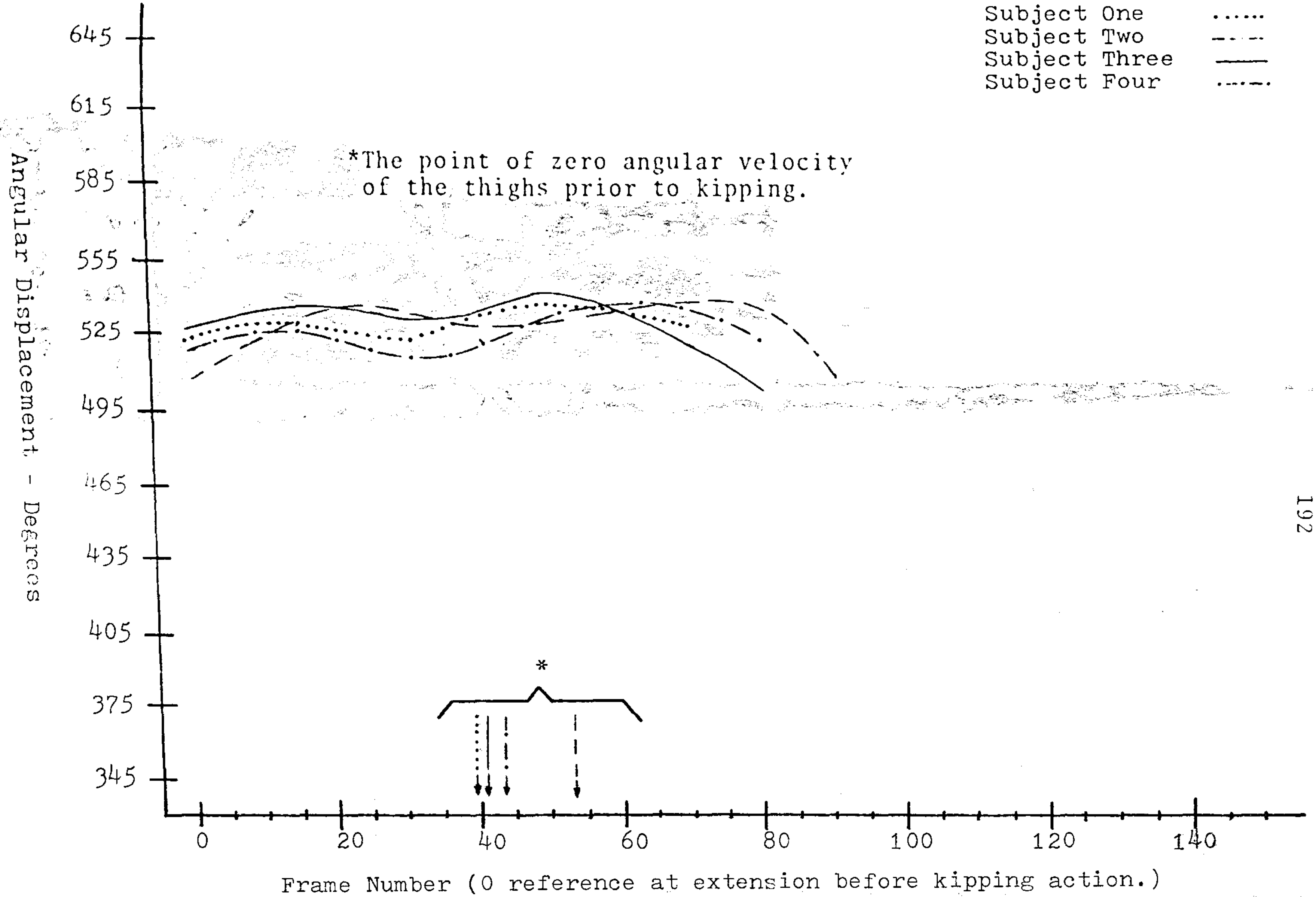


Fig. 56. Angular displacement of the trunk in the glide kip for the kipping action.

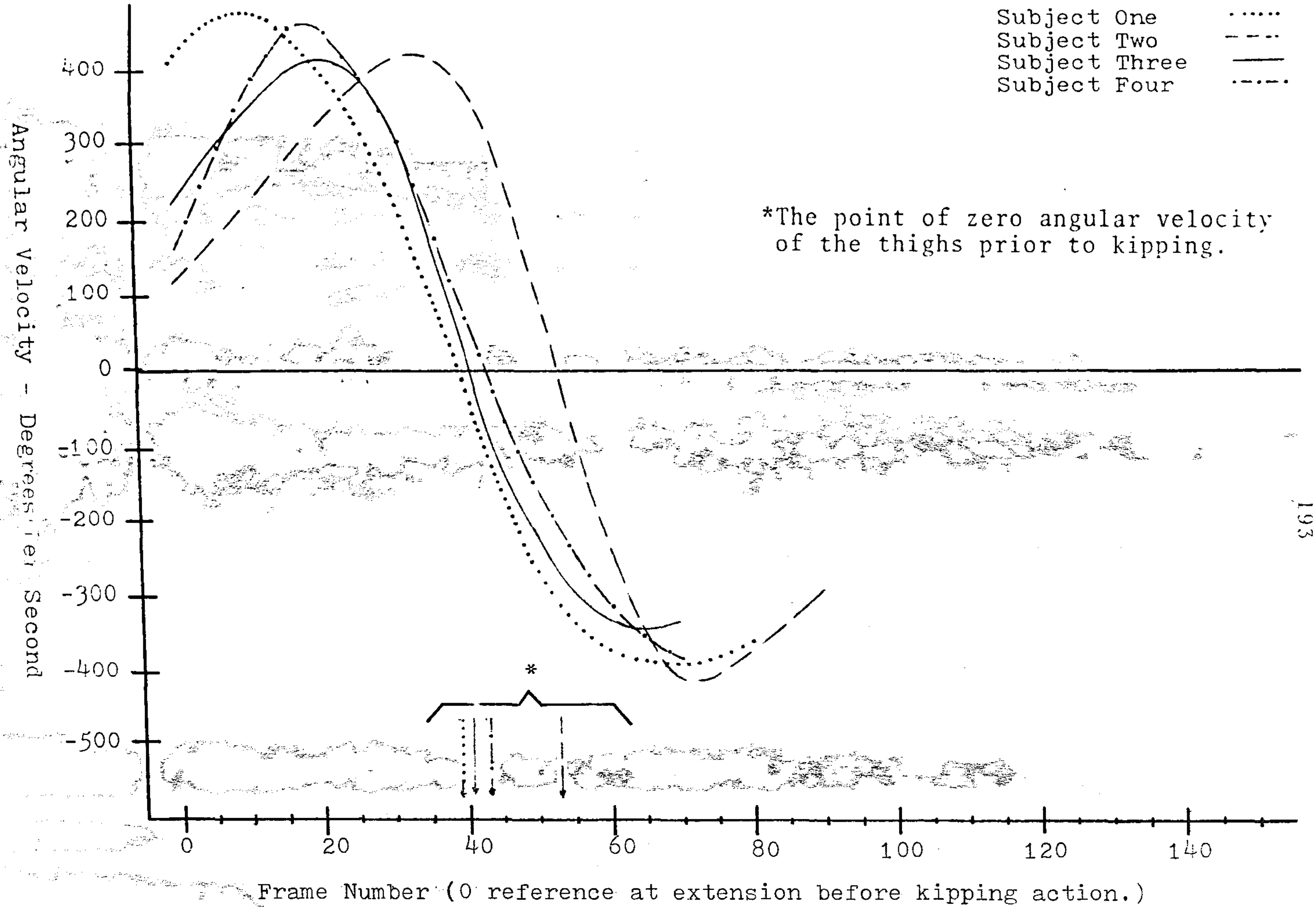


Fig. 57. Angular velocity of the thigh in the glide kip for the kipping action.

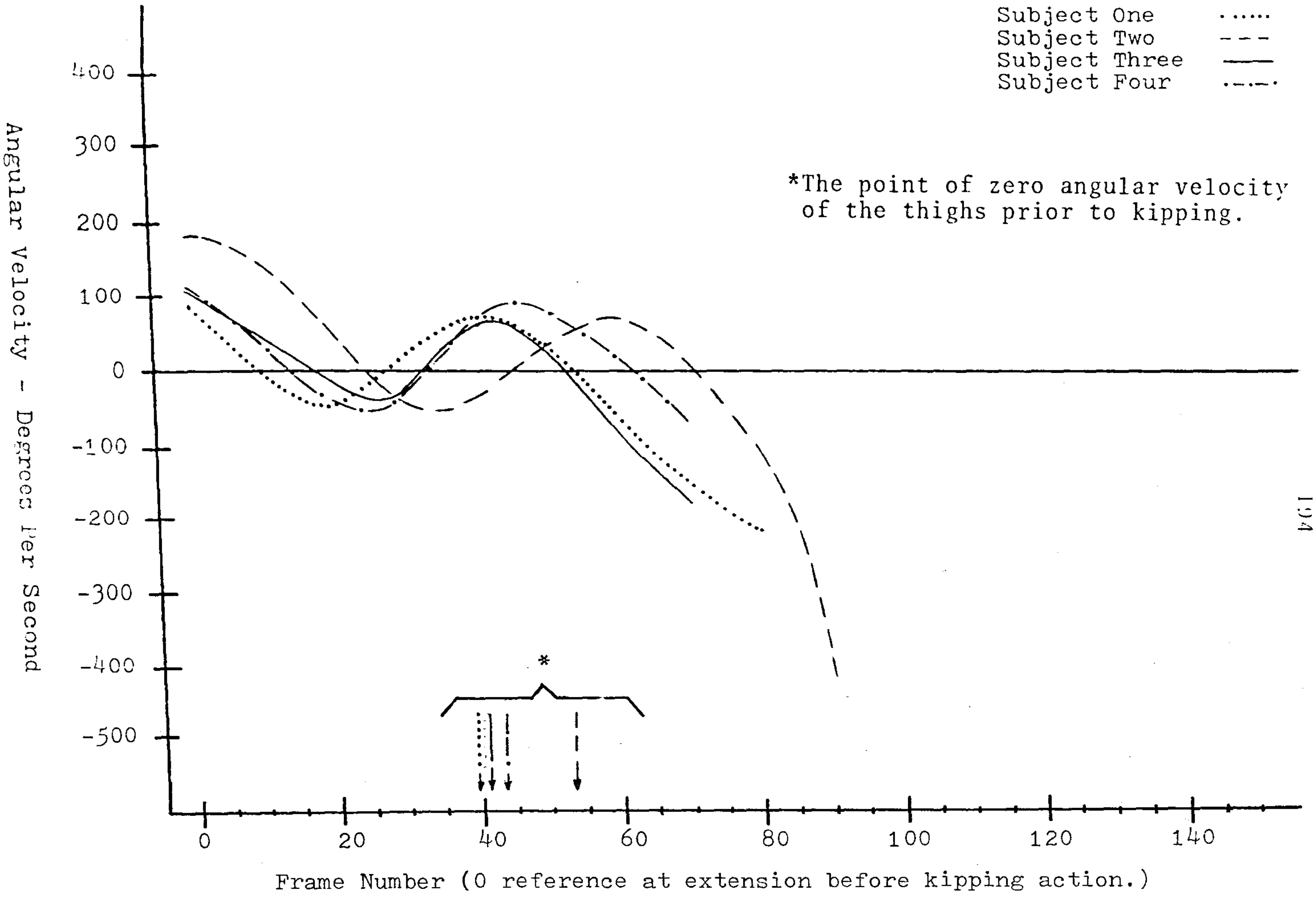


Fig. 58. Angular velocity of the trunk in the glide kip for the kipping action.

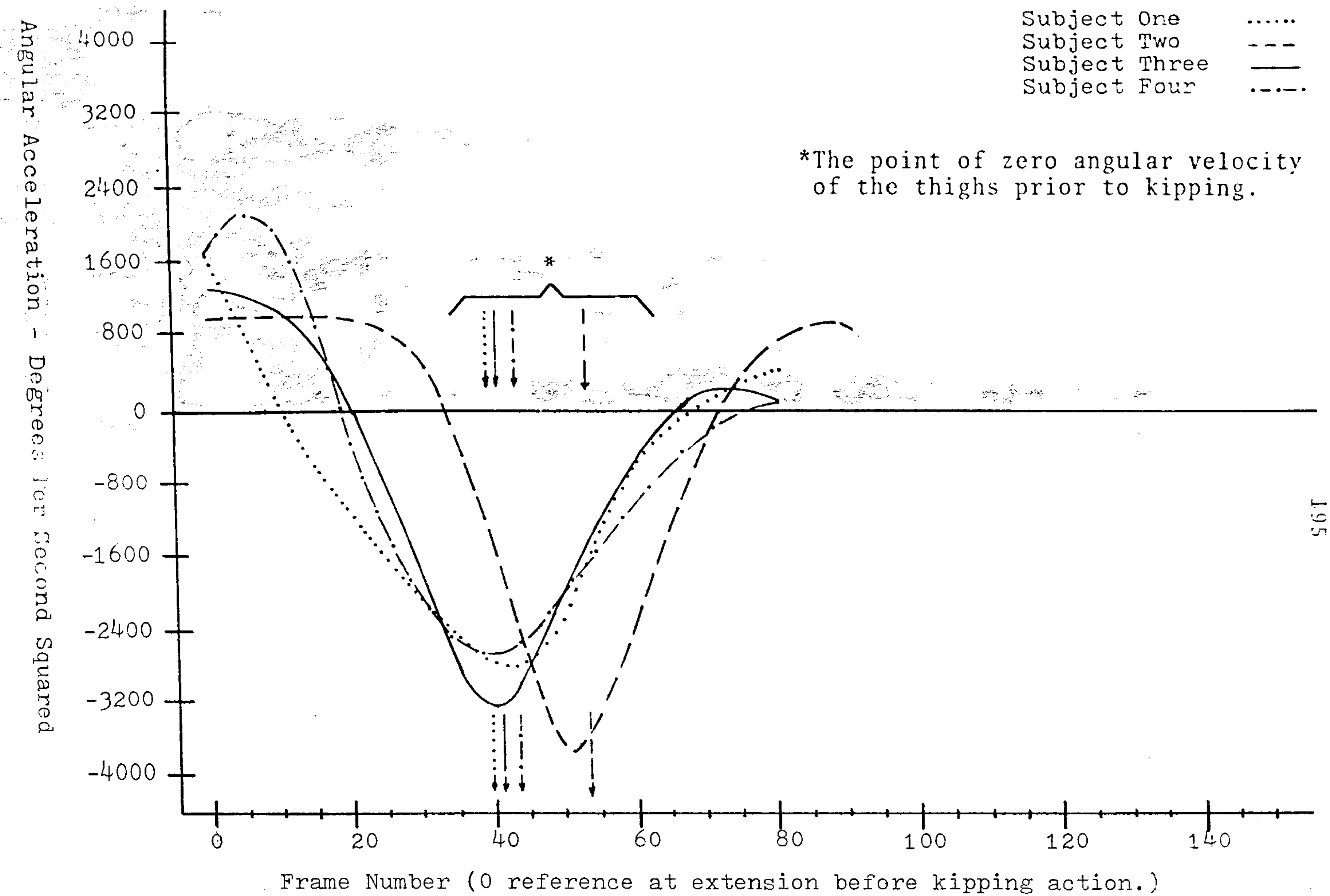


Fig. 59. Angular acceleration of the thigh in the glide kip for the kipping action.

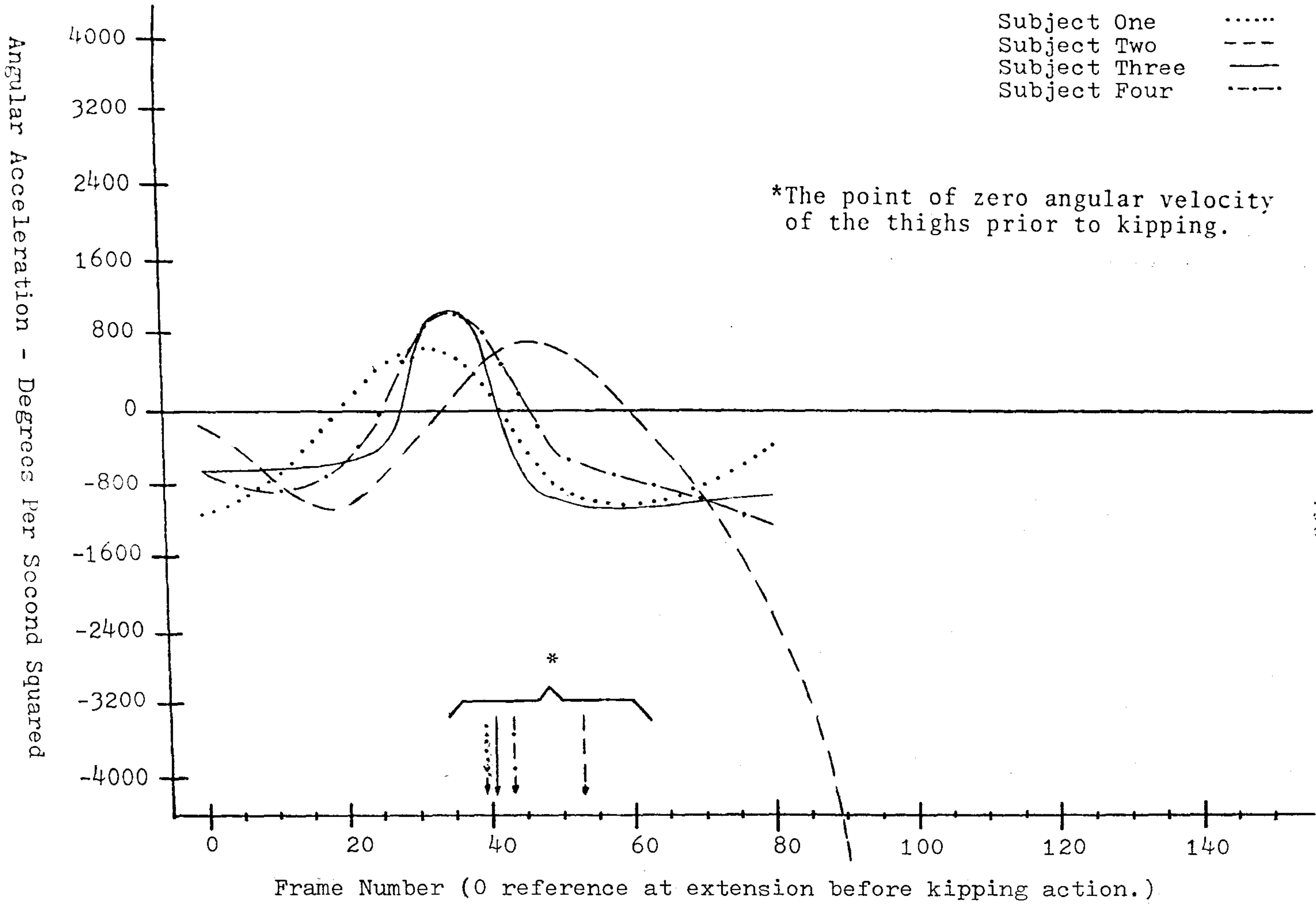


Fig. 60. Angular acceleration of the trunk in the glide kip for the kipping action.

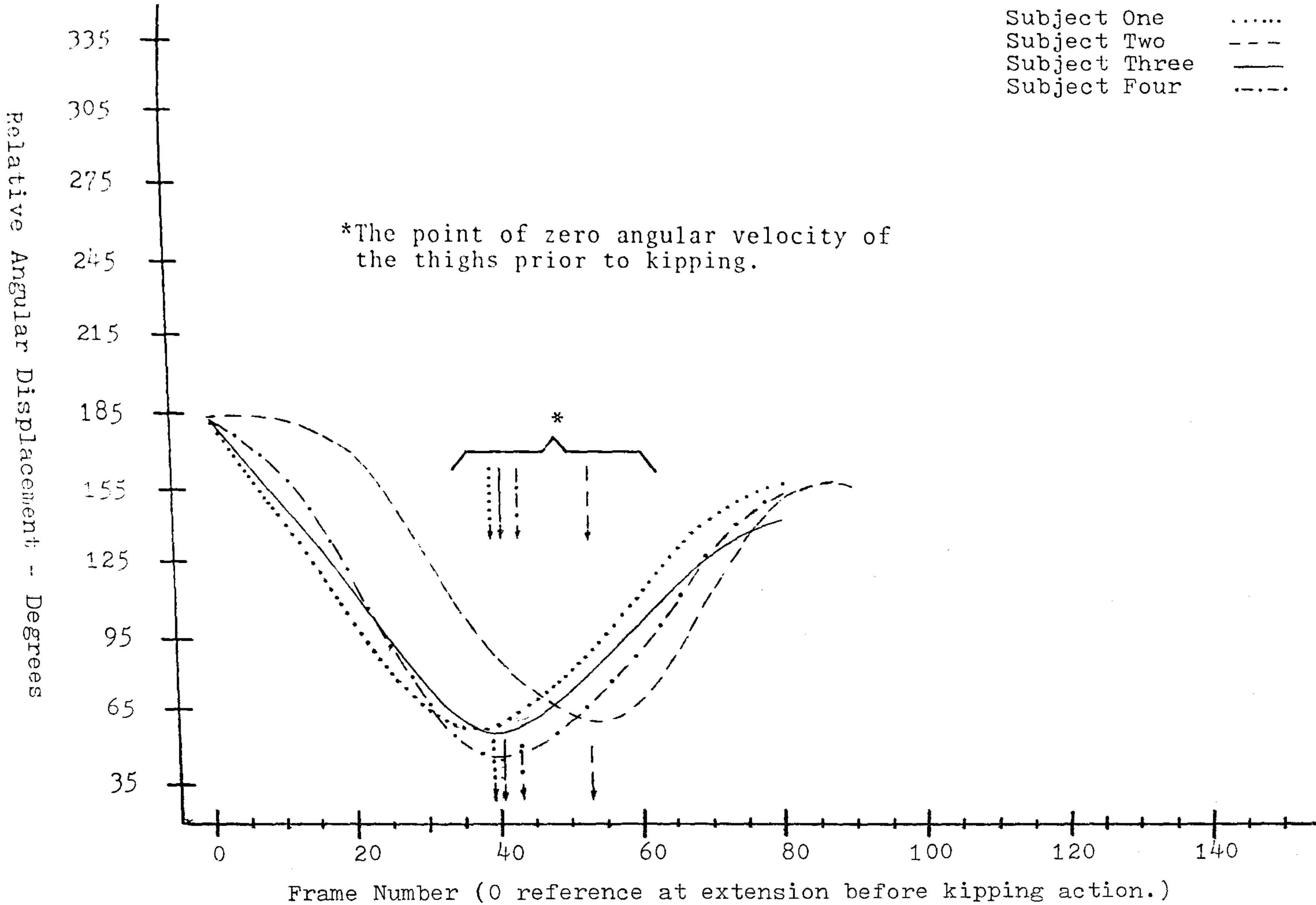


Fig. 61. Relative angular displacement in the glide kip for the kipping action.

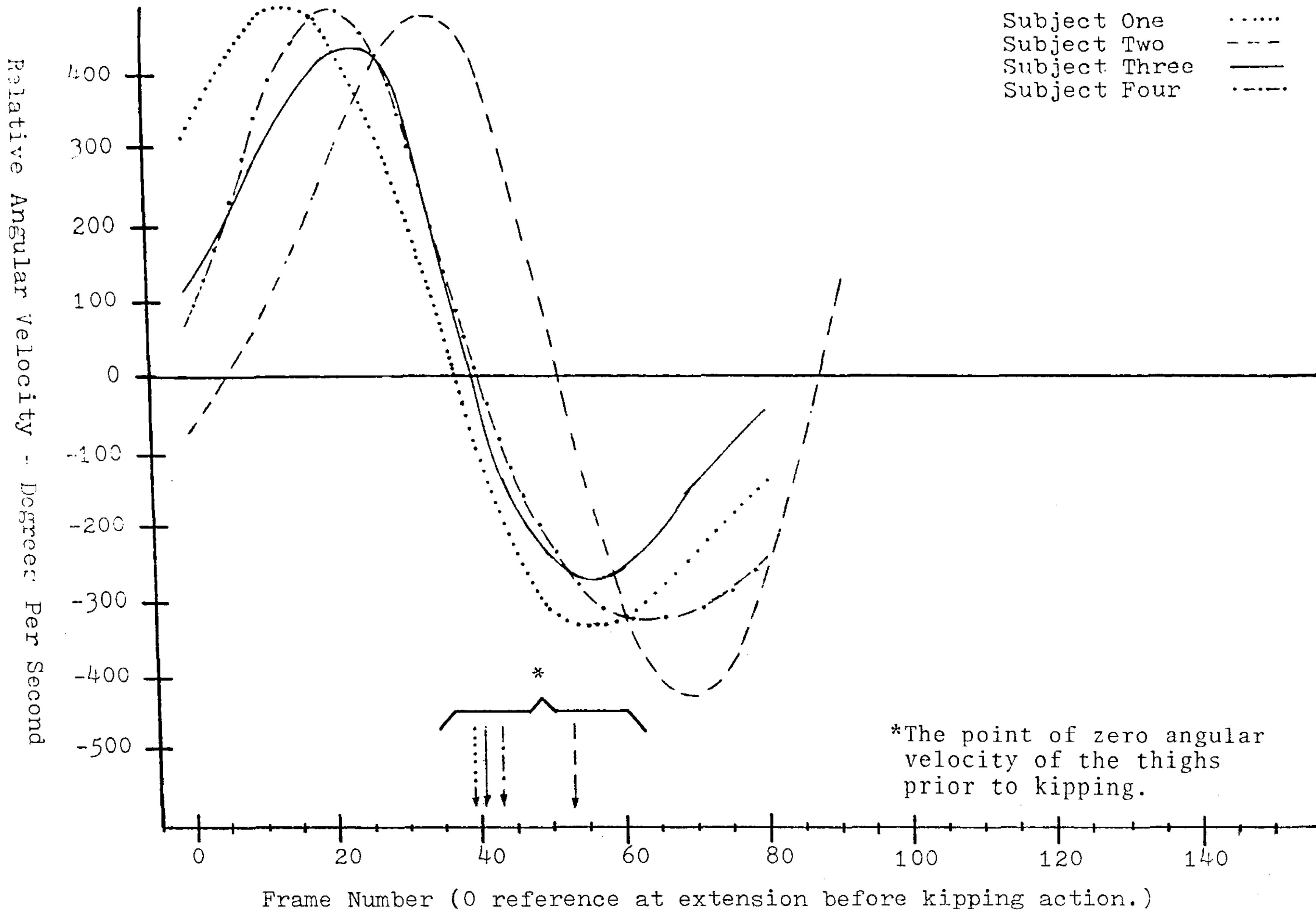


Fig. 62. Relative angular velocity in the glide kip for the kipping action.

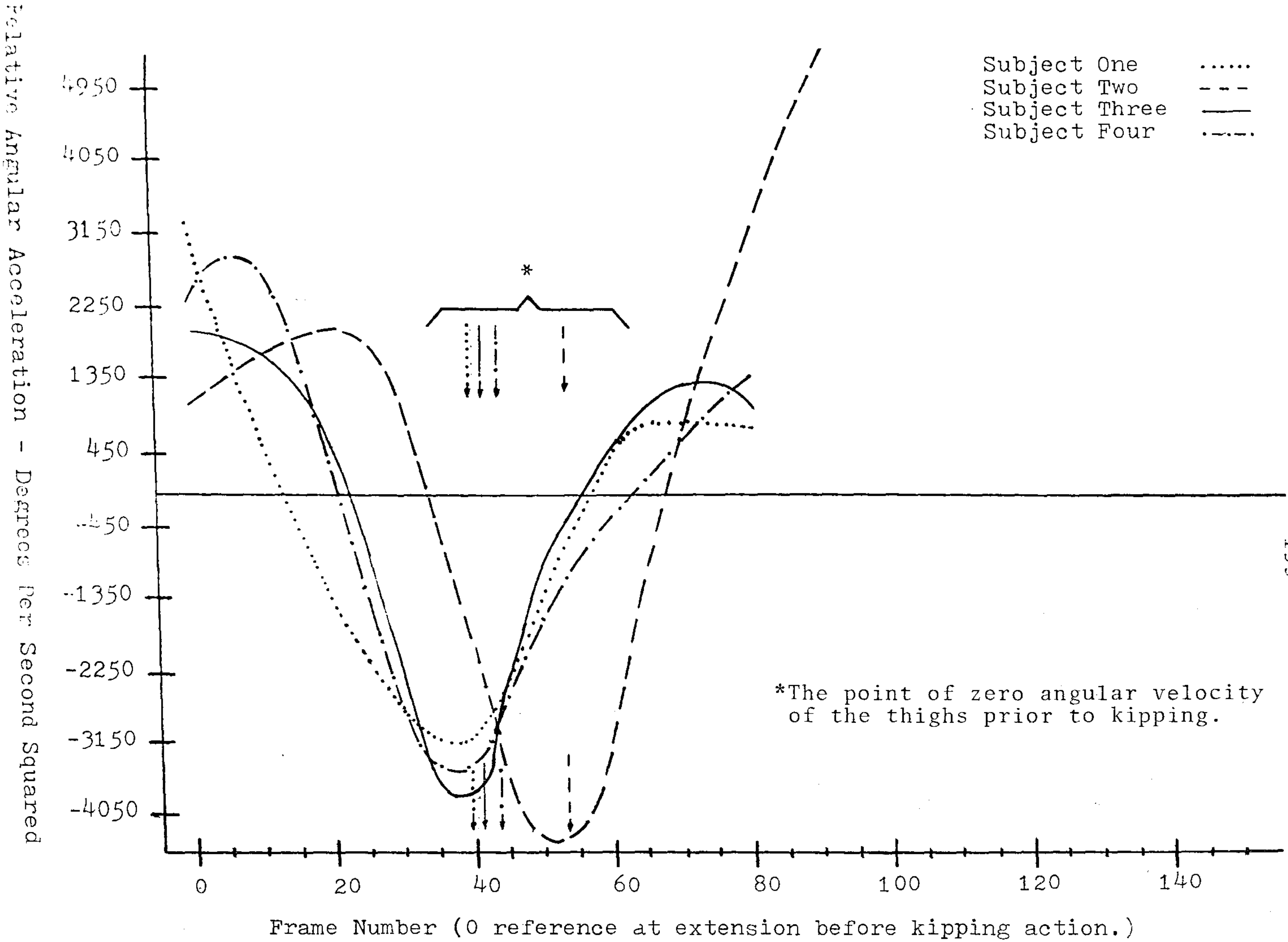
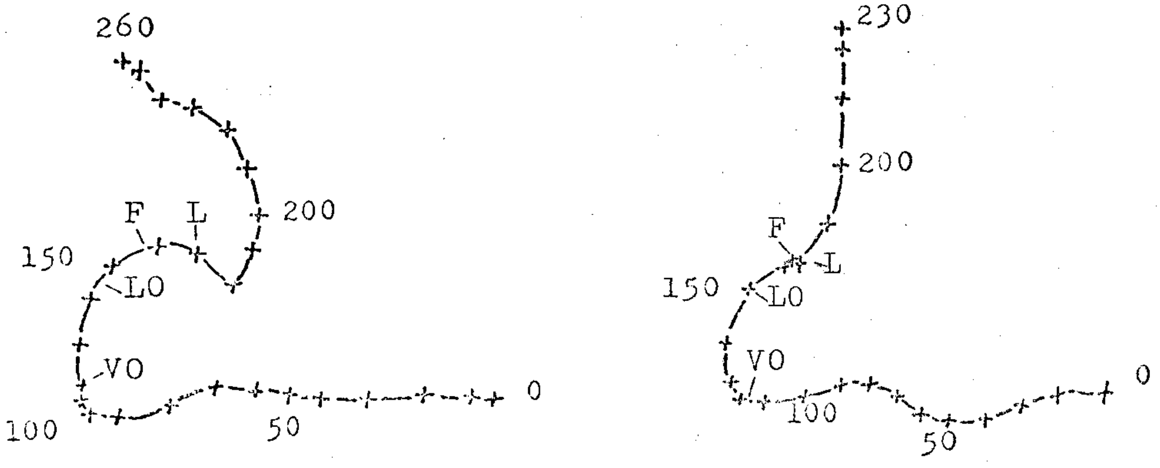


Fig. 63. Relative angular acceleration in the glide kip for the kipping action.

APPENDIX H

TOTAL BODY CENTER OF GRAVITY



Subject one

Subject two

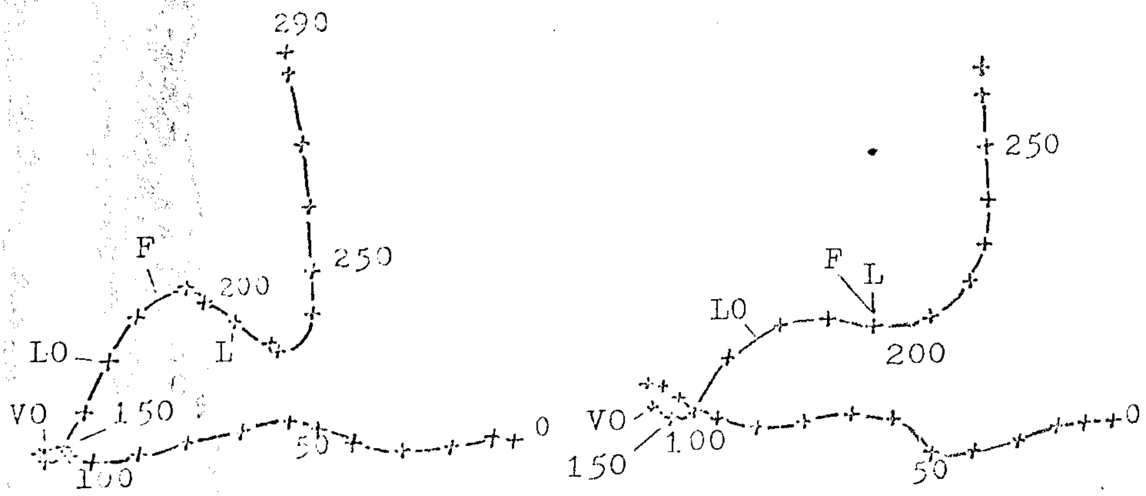
Key

VO = Zero Angular Thigh Velocity

LO = Lift-Off of Shoulders

F = Flight

L = Landing



Subject three

Subject four

Fig. 64. The mat kip, path of the total body center of gravity.

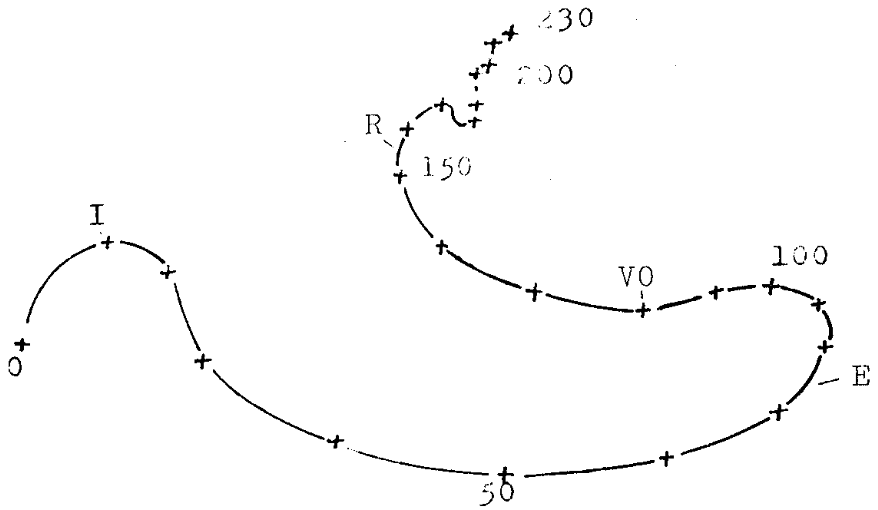


Fig. 65. Subject one performance of the glide kip. Path of the total body center of gravity.

Key

I = Initial Pike
E = Extension
VO = Zero Angular Thigh Velocity
R = The Beginning of Rotation

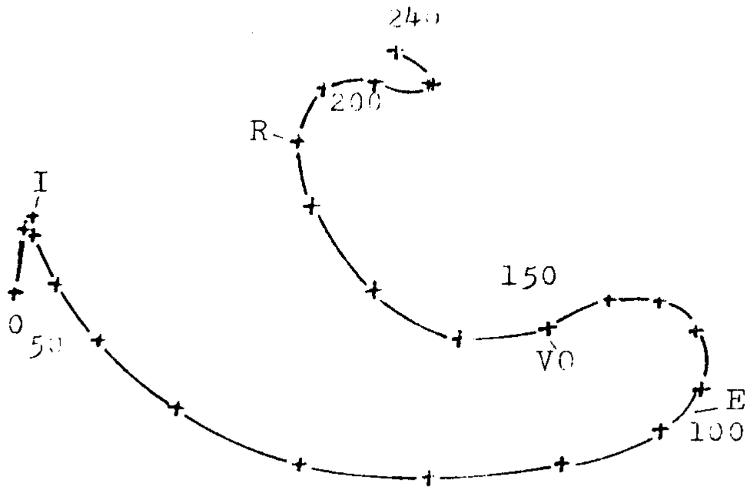


Fig. 66. Subject two performance of the glide kip. Path of the total body center of gravity.

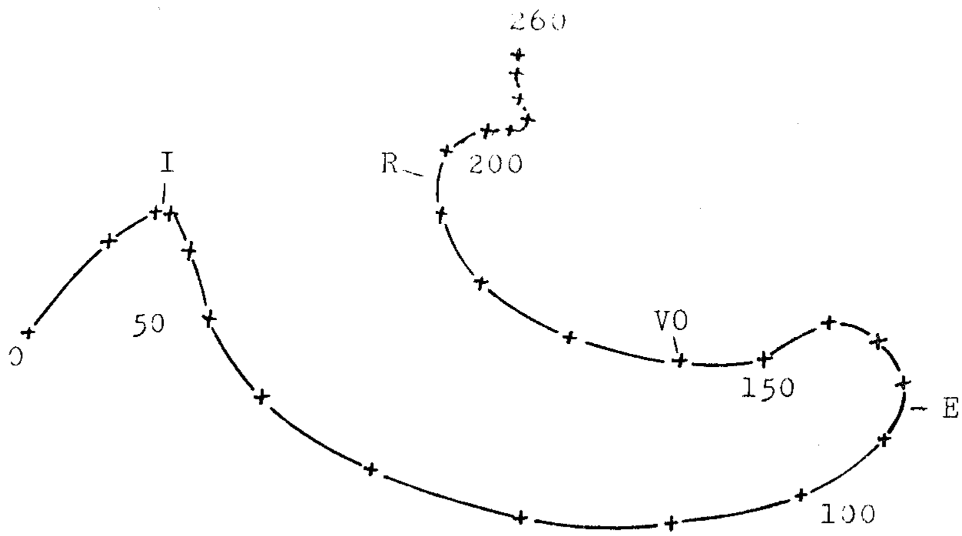


Fig. 67. Subject three performance of the glide kip. Path of the total body center of gravity.

Key

I = Initial Pike
E = Extension
VO= Zero Angular Thigh Velocity
R = The BEginning of Rotation

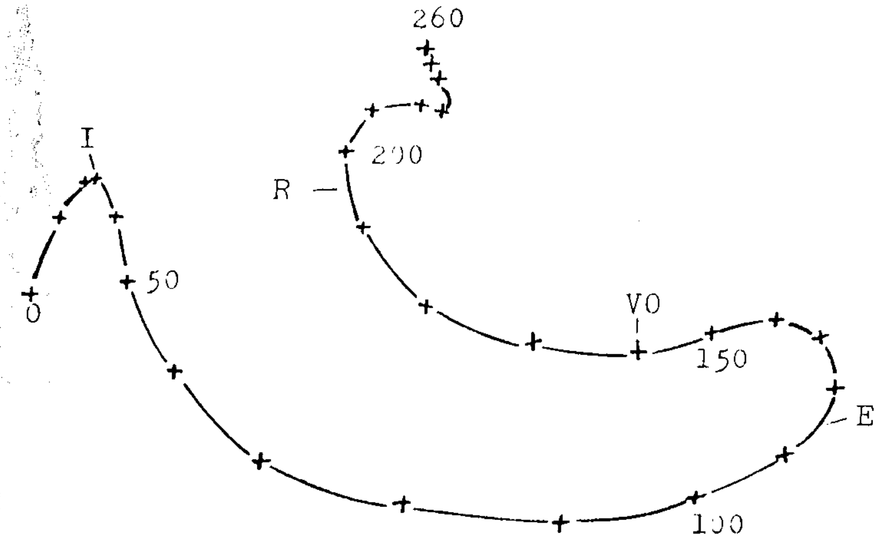


Fig. 68. Subject four performance of the glide kip. Path of the total body center of gravity.

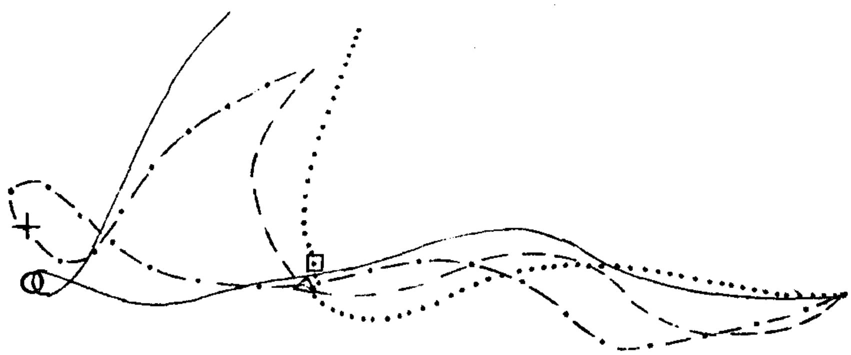


Fig. 69. Path of the total body center of gravity for the kipping action in the mat kip.

Index for the Start of the Kipping Action

Subject	Mat Kip Frame No.	Glide Kip Frame No.	Symbol*	Key
One	120	128	◻	. . . . .
Two	120	150	△	— — —
Three	130	160	○	———
Four	141	160	+	·—·—·

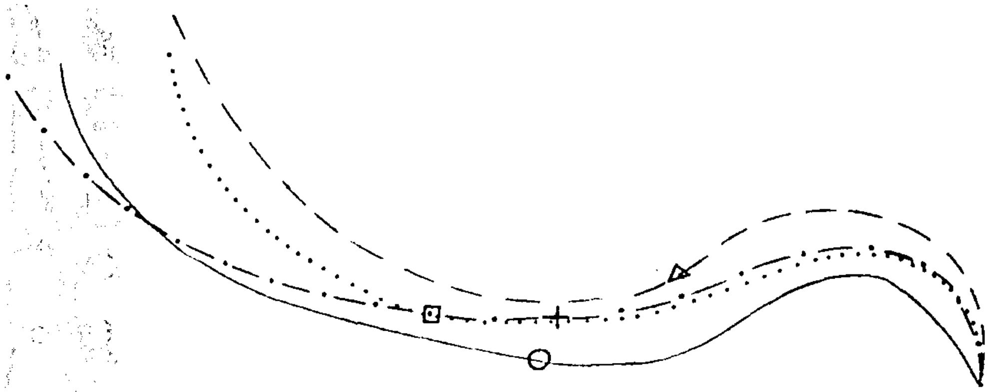


Fig. 70. Path of the total body center of gravity for the kipping action in the glide kip.

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