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A CINAMATOGRAPHIC COMPARISON OF A VOLLEYBALL SPIKE PERFORMED WITH AND WITHOUT ANKLE WEIGHTS

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A Thesis

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By

Dianne Lee Davis

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CHAPTER I

DEVELOPMENT OF THE PROBLEM

For years, advertisements for ankle weights have appeared in various sporting goods catalogues. Manufacturers claim that the use of ankle weights provides coaches with an easy method of conditioning athletes. Such an advertisement appears in the Wolverine Sports Supply 1966 catalogue:

> Weights employ the basic principle of 'overload training'.... They develop the actual muscles used in track, baseball, football, basketball and other sports by making them work harder during warm up practice.... Improve your athletes in less time and get more out of available training periods. (2, p. 40)

Some coaches have used these weights extensively in exercise programs, either for pre-season conditioning or in regular training programs.

There is much controversy among physical educators as to the value of wearable weights. The results of studies reported by physical educators do not indicate that these weights have significant value in developing such variables as leg strength, jumping ability, speed, and endurance. No research has been published by established manufacturers to substantiate the claims for using ankle weights to improve athletic training.

While there is no agreement as to their use in athletic training, there is a further controversy as to the effect of these weights on the performance of skills where timing and coordination are prime factors. Most physical educators feel that, while the wearing of the weights supposedly increases strength, the performer will vary his skill pattern to compensate for the additional weights. Thus, the athlete will practice an altered pattern rather than the desired sucessful pattern. The formulation of these opinions are the result of observation; there is no actual written research to substantiate these claims.

Since manufacturers continue to claim the value of their products as effective methods of conditioning athletes, and coaches and trainers continue to use weights, research was definitely needed to present objective results to indicate the effect of ankle weights on the performance of skill patterns.

Statement of the Problem

The purpose of this study was to compare a volleyball spike pattern performed without ankle weights with one performed while wearing a 2.5 pound ankle weight on each ankle.

Subproblems

The following subproblems were considered in this study:

1. Selection of the subject.
2. Obtaining anatomical data of the subject.
3. Selection of a method of skill analysis.
4. Collection of the data.
5. Analysis of the data.

Hypothesis

The following hypothesis was based upon completed research in the area of study: Ankle weights will cause alteration in the performance of a skill pattern; the skill pattern under analysis being the volleyball spike.

Basic Assumptions

The following fundamental assumptions were made by the experimenter:

1. Plagenhoef's method of kinetic analysis (17, p. 103) is a valid method of analyzing motion.

2. Ankle weights are used extensively throughout the United States in the training of athletes.

Definitions

Since various terms used throughout the study are either controversial or unclear, definitions of words used in this study are needed.

Ankle weights. Canvas belt approximately one foot in length, with pockets filled with fine lead shot. Worn by wrapping around the ankle and securing with large pins. Each weight weighs 2.5 pounds; each pair, a total of 5 pounds.

Overload principle. The strengthening of a muscle by loading it over and above previous requirements. This may be done by increasing the speed of the movement, or by adding weights to that portion of the body involved.

Kinetic analysis. An analysis of joint forces and moments of force for any position of a whole body motion through the use of slow motion photography, anatomical data, and mechanics.

Delimitations

The study was confined by the following delimitations :

1. The study was delimited to one subject, a female graduate student at the University of Massachusetts.

2. The volleyball spike was the skill pattern under consideration.

3. There was one set of 2.5 pound ankle weights added to the ankles of the subject.

Limitations

The experimenter recognizes the following limitations to the completed study:

1. The study was limited to one subject.

2. Psychological effects which might have influenced the subject were not taken into consideration.

3. The motivation of the subject was not controlled.

4. The physical condition of the subject at the time of performance was not considered.

5. The study was limited to the effects of one specific set of ankle weights which weighed 2.5 pounds each.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature related to this study is presented under two headings. The first section consists of literature concerning the alteration of skill patterns through the application of weights. The second section presents published research related to training through the use of ankle weights.

Alteration of Skill Patterns Through the Application of Weight

Physiologists have proposed that a muscle may be strengthened through the application of weights, and upon this assumption, trainers utilize various types of wearable weights and weighted implements in training for various types of activities. They can not actually agree upon how much weight for each activity, or when this weight should be applied. This controversy stems from their fear that the wearable weight will alter the skill pattern during practice, so that an altered pattern will be practiced, rather than the desired sucessful pattern.

Application of weights to the body. Winningham (21), while investigating the use of ankle weights in running, has definite statements concerning their effect on performance:

> Because the research has generally supported the view that skill development is specific in nature, weighting performers while they practice in a specific skill may, in fact, mean they are developing a different skill than the one desired. Repeated practice may bring a positive effect in performance only under the particular weighted condition applied. If this hypothesis were true, there remains the possibility that the use of weights could produce a negative effect in the efficiency of the actual desired performance. The stronger contractions required to move the weighted limb might still function for a period of time after the weights have been removed. (21, p. 5)

Whitley and Smith (19) have shown that an arm can move faster while empty than when holding a weight, and therefore, the speed of arm flexion depends on the weight held in the hand. Winningham (21) also noticed this reduction of speed in his study of running. He found that the group wearing 5 pound ankle weights ran slower than all other groups, and at the termination of his study, he had the following conclusions and recommendations:

> There were findings, however, that raised questions as to the value of wearing ankle weights while training for a team sport activity. When proper timing and coordination between players is the desired outcome of a practice session, a detrimental effect of such weights would seem a possible outcome. ... based on the findings of this study, the use of ankle weights while training for sports activities requiring intricate team play cannot be recommended. (21, pp. 90-92)

Morehouse and Miller (12) indicate that "during practice those objects and movements which will be employed in the final performance should be used." (12, p. 71)

Considering the physiological aspects of weights, Van Huss (20) has discussed the possibility that additional motor units recruited into action by the overload may actually enhance performance. He states:

> It may be that the effects were not warm up but neuromuscular in nature in that the motor units or the additional muscle fibers in a unit recruited by high intensity overload continued to function when the load was decreased. (20, p. 472)

Application of weighted implements. Overloading or weighting a warm up or practice movement through the use of a weighted implement prior to using that same movement in competition with a regulation implement has received little study. Morehouse (13) states that:

> The procedure of warming up with an implement heavier than that used in competition has been advocated on the theory that the lighter implement felt so much better that performance would be improved. (13, pp. 213-214)

Morehouse (13) goes on to say that performance is not improved through the practice of warming up with a heavier or lighter implement. The best performance is noted when athletes warm up with the same implement they are to use in competition.

Morehouse and Rasch (14) make specific statements concerning the effect of weights on the performance of a skill pattern. They state:

> Each athletic event makes specific demands in terms of its pattern of load, rate, repetition, and duration. The neurophysiological adjustments must be acquired. These adjustments are so

> precise that a slight change in the weight of a club or ball will affect the trained athletes' performance. A heavy shot or discus used as a special training device will train the athlete to use that particular implement. But, when the athlete transfers to the lighter, regulation shot or discus, he also tends to transfer the timing and coordination for the heavier implement which is improper for the lighter. Thus he starts again essentially from the beginning adjusting to the lighter implement. (14, pp. 29-30)

Scott and Crafts (4) recommend the use of weight training in women's track and field, but they disapprove of the use of a heavier shot in practice throws. They realize that the strength of the girl will be increased, but they feel that "either a heavier or lighter object produces a different technique than that required for official competition." (4, p. 158)

Van Huss (20) investigated the effect of overloading warm up on the velocity and accuracy of throwing in baseball. Utilizing a weighted ball, he found an increase in ball velocity, but a significant negative affect of accuracy of the throw.

Lindelburg and Hewitt (9) utilized a weighted basketball and found "no appreciable effect on the basketball skills of shooting and ball handling." (9, p. 164)

Kennison (10), in a study of various programs' effect on basketball skills, also utilized an overweight ball as one training method, and his findings indicated a shooting improvement in all groups except the one utilizing the weighted ball. He did notice that the weighted group increased in passing velocity and palmar flexion strength.

The immediate sensation created by removing excess weight following training has been termed kinesthetic illusion or after-effect. Cratty and Hutton (5) have suggested that there may be some benefit in holding a heavier shot just before throwing a light one. Nelson and Nofsinger (15), in a study of effects of overload on speed of elbow flexion, also noticed this kinesthetic illusion of speed when the weights were removed, although increased speed was not actually evident.

Training Through the Use of Ankle Weights

Recently there has been some limited research concerning the use of ankle weights in the training of athletes, but the results have been controversial.

Winningham (21) investigated the effects of ankle weights on the running skill of college males. He utilized 5 pound, 2 pound, and no weights on three different groups. His results indicated that the 5-pound group actually ran a one hundred yard dash slower after training with the weights, and would, therefore, not recommend their use in athletic training.

Chambers (3) also studied the effect of ankle weights on running. He tested junior high school boys for improvement of running agility, and found that the weighted group improved significantly at the .001 level on all four agility tests, but the unweighted group improved significantly on three out of the four agility tests. He concluded, "The practice increased agility, but the ankle weights made little apparent difference." (3, p. 27)

A master's thesis by Anderson (1) investigated the use of a weighted ankle spat to improve the jumping performance, agility, and endurance of high school basketball players. The study utilized ten subjects who exercised for a seven-week period. The results indicated improvement in jumping performance and agility of both the unweighted and weighted groups. The improved jumping performance of the weighted group was the only improvement significant at the .05 level. The results also indicated improvement in endurance of the unweighted group, while the weighted group decreased in endurance.

Ranniger (18) studied the effect of ankle weights on the vertical jump ability, leg strength, and agility of male high school basketball players. He found, upon completion, that both the control and experimental groups improved in leg strength and agility at the .01 level of significance, but only the experimental group improved significantly in vertical jump ability. Based on his findings, Ranniger would still not recommend the use of the weights because he felt that they had a negative psychological effect on the basketball players using them.

A study directly related to ankle weights was made, utilizing a weighted training shoe. Lukas (11) investigated the effect of this weighted shoe on the jumping performance, agility, running speed, and endurance of college basketball players. He utilized three groups: a control group, a regular shoe group, and a weighted shoe group--- and found no significant difference between the weighted and the unweighted shoe groups. Although there was no significant difference, Lukas did state that the results indicated a trend which favored the weighted group.

Another investigation in which the results favored the weighted group, but in which there was no significant difference evident, was performed by Davis (7), who investigated the effect of 5 pound ankle weights on leg strength, speed, and general endurance of college women.

Summary

From the related literature presented, it is evident that there exists a dearth of actual research literature on the alteration of skill patterns through overweighting, through the use of wearable weights and weighted implements. It is evident, however, that here exists general opinion or fear that overweighting a performance will alter the skill pattern, although no actual research is available to support this.

Some research has indicated that ankle weights have improved some variables. This fact was observed in research performed by Lukas (11) and Ranniger (17), but the results are so inconsistant, that none of the researchers will actually recommend the general use of the weights.

Actual research is needed to indicate exactly if and how ankle weights alter skill patterns, and their effect on such physical variables as strength, endurance, jumping ability, and speed.

CHAPTER III

PROCEDURE

The procedure described in this chapter was used in the selection of a subject, selection of a method of analysis, collection of data, and methods employed in data analysis. This procedure was utilized in solving the problem of a comparison of a volleyball spike performed with and without ankle weights.

Selection of a Subject

The subject was a female graduate student at the University of Massachusetts, who was chosen for her ability to perform an acceptable volleyball spike.

Selection of a Method of Analysis

To compare volleyball spike patterns with and without ankle weights, the investigator employed a type of kinetic analysis that was developed by Plagenhoef (17). This method was chosen for its accurate and practical aspects in analyzing whole body motions in the actual athletic situation. A comparison of the motion performed with and without ankle weights was made possible by comparing maximum arm and leg velocities, moments of force, dominant muscle groups, and times of flight.

Collection of Data

In completing a kinetic analysis according to Plagenhoef's method, it was necessary to follow specfic steps as outlined in his article, "Methods for Obtaining Kinetic Data to Analyze Human Motions." (17, p. 103)

Determine the length of each body segment. The length of each body segment was determined through the measuring of three 8" X 10" somatotyping photographs taken with a 35 mm. camera. The three photographs consisted of a front, back, and side view, and included, in each, a meter stick to determine the proper scale.

Since the body segment length was measured from joint center to joint center, it was necessary to determine each of the joint centers. This was accomplished by the use of anatomical data provided by Dempster (8) as to the location of joint centers.

Determine the weight of each body segment. The weight of each body segment was determined by measuring the volume of each and multiplying it by the specific gravity of each segment. The average specific gravity as determined by Dempster (8) is:

Hand:	1.16
Upper Arm:	1.07
Shank:	1.09
Forearm:	1.13
Thigh:	1.05
Foot:	1.10

The volume of each segment was determined by immersing the extremities in water to a plane which was level with each joint center, and measuring the volume of water displaced.

Photograph the desired motion. The motion pictures of the volleyball spike were taken with a 16 mm. camera at 64 frames per second at $\frac{1}{4}$ open. They were taken in a gymnasium on a regulation volleyball court, with the volleyball net positioned at the correct height. The volleyball was a Japanese-made SV-5, inflated to regulation poundage.

The subject was filmed from the right side in a standing position, holding a meter stick which was later used to determine the scale. A clock was included to calculate the actual speed of the camera. The subject then performed several spikes without the ankle weights and several spikes while wearing 2.5 pound ankle weights on each ankle. She was given a target on the opposite side of the net, and a volleyball spike was considered "good" if it landed within this target area and if the subject felt that the movement was correct.

Method Employed in Data Analysis

Again, methods of data analysis were given in specific steps by Plagenhoef (17).

Composite tracings of the total movement. A 16 mm.

motion picture projector was used to project the film on tracing paper mounted on a wall. A horizontal and vertical reference line was marked on the paper to assure accurate tracing. The meter stick filmed with the subject was marked as a scale, and the clock was marked frame-by-frame to calculate the actual camera time.

Two volleyball spike pattern sequences were chosen for analysis--- one without ankle weights, and one with ankle weights. Frame-by-frame tracings were made of both sequences. The tracings were made by marking the joint centers and connecting them with lines. The lines indicated the segment lengths and positions. While tracing the motion, the time of flight of the subject in both the unweighted and weighted flights was calculated by counting the number of frames during flight.

Locate the center of gravity and radius of gyration of each segment. The location of the center of gravity and the radius of gyration for each segment is expressed in percentages in relation to the segment's length, and are calculated from either the proximal or distal end of the segment. Utilizing these percentages which were available from Dempster (8) and the corrected segment's length (measured from the tracings), it was possible to calculate the center of gravity and the radius of gyration for each segment in each instantaneous position.

A correction to the trunk center of gravity was necessary for greatest accuracy because shoulder movement was involved in the motion. The average weight of both shoulders is 5.5% of the total trunk weight, so a 1.8 cm. correction was made on the trunk center of gravity for every 10 cm. of shoulder joint motion in the direction of the change. This correction becomes increasingly important when the arms go over head and maximum shoulder elevation occurs.

Determine joint forces and moments of force. By utilizing the tracings of the two sequences, the angle of each segment at each joint was measured from the right horizontal counterclockwise to the segment for each instantaneous position desired. These angular measurements, the film time, and the number of positions were used to calculate the angular acceleration and velocity of each segment. These were calculated using a Control Data 3600-type computer and Computer Program No. 1 developed by Plagenhoef and Curtis (6).

Once this data was calculated, the angular velocity and acceleration, the corrected segments' length, the segments' weight, and the segments' center of gravity and radius of gyration were utilized through Computer Program No. 2 (6) to calculate joint forces, moments of force, center of gravity of the whole body, and the contribution of each segment to the total movement.

CHAPTER IV

ANALYSIS OF THE DATA

This chapter is concerned with analysis of data relevant to the purpose. The purpose of this study was to compare a volleyball spike pattern performed without ankle weights with one performed while wearing 2.5 pound ankle weights on each ankle.

The analysis included comparison of the mean time of flight for all unweighted and weighted performances, maximum angular velocity of the leg, maximum angular velocity of the arm, maximum moments of force, and the dominant muscle group during each performance. The analysis was performed utilizing the right side of the body; the subject being right handed.

Since the unweighted performance was .15 seconds longer in execution and included 10 more frame positions than the weighted performance, it was necessary to divide the analysis of the performance of the volleyball spike into three distinct phases (Figure 1). Phase I included the positions from the maximum leg flexion to the actual take off of the foot from the floor surface. This phase included positions 1 through 23 for the unweighted performance and positions 1 through 19 for the weighted

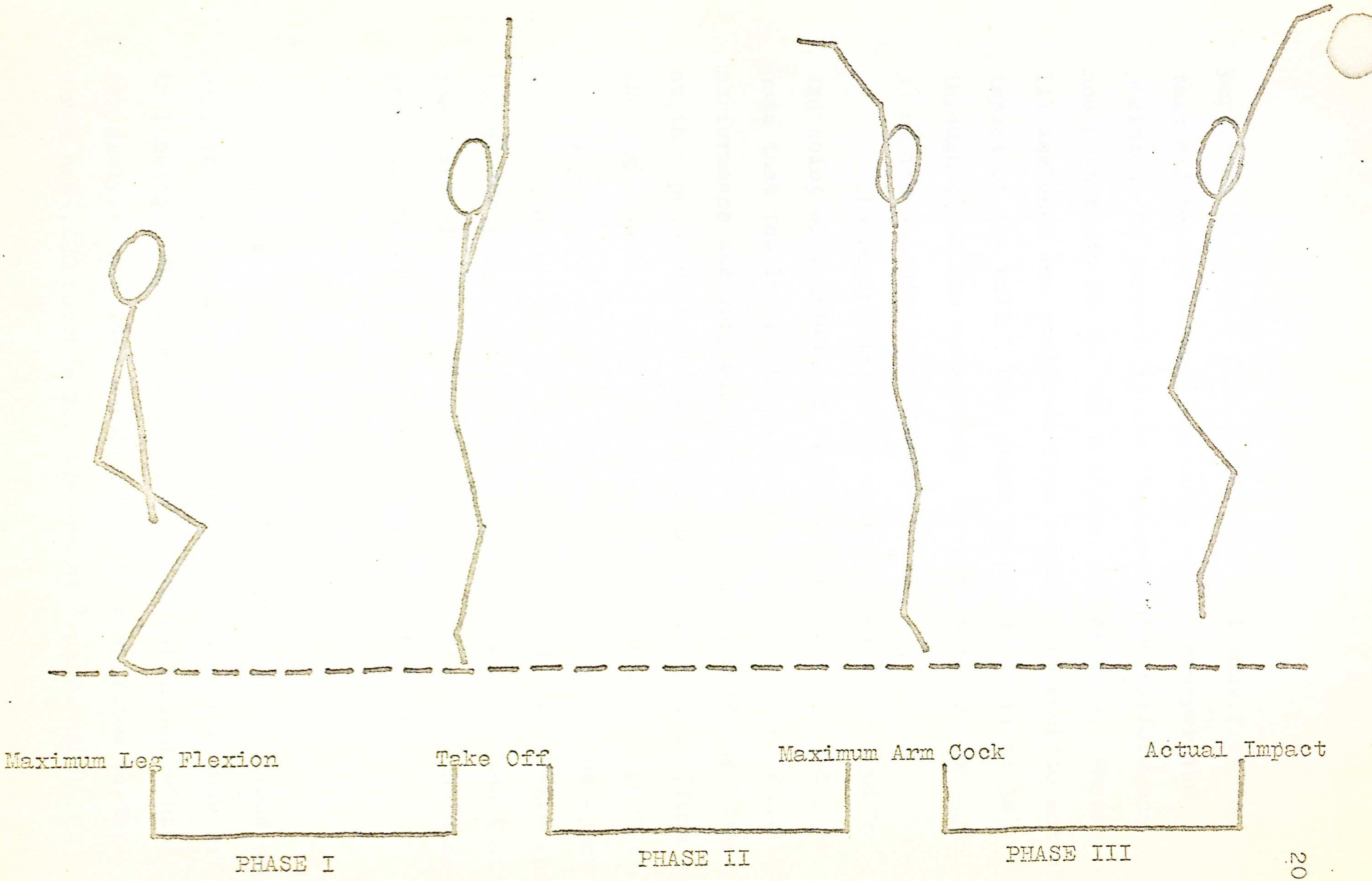


Fig. 1.--Three Phases of the Volleyball Spike Pattern

performance. Phase II included the positions from the take off to the maximum arm cock, which incorporated positions 24 through 33 for the unweighted performance and 20 through 26 for the weighted performance. Phase III included the positions from maximum arm cock to actual impact of the ball. This phase involved positions 34 through 43 of the unweighted performance and 27 through 33 of the weighted performance.

The beginning of the analysis was determined by the point of maximum leg flexion. It was interesting to note that the leg position for the unweighted and weighted performance was very similar. The position of the lower leg at this point of maximum leg flexion was measured (from the right horizontal) as 26.8° for the unweighted performance, and 28.8° for the weighted performance. The upper leg position was 105.8° for the unweighted performance and 109.6° for the weighted performance. This indicated that the point of maximum leg flexion was practically the same for both the unweighted and weighted performance.

Time of Flight

The time of flight for all performances filmed was calculated by counting the number of frames from take off to landing. The time of flight of the performances used for analysis was .525 seconds for the unweighted performance and .420 seconds for the weighted performance.

Of the performances which were filmed the mean of the four unweighted performances filmed was .491 seconds, and the mean of the seven weighted performances filmed was .411 seconds. The time of flight for all performances are included in Appendix A.

Angular Velocity of the Leg

Utilizing the speed of the film and the angles measured from the right horizontal at each of the instantaneous positions, the angular velocity of the performances was calculated for the lower and the upper leg (Figures 2 and 3). The exact values are included in Appendix C. The velocity of the segments was compared utilizing the maximum velocity of each distinct phase.

Angular velocity is expressed in radians per second (one radian = 57.3°). The mathematical negative and positive signs preceding the numerical value indicate direction in relation to the original direction of motion, not a negative or positive value.

Phase I - Maximum Leg Flexion to Take Off

Lower leg. The maximum angular velocity for the lower leg during this phase was 216.9 radians per second for the unweighted performance and 455.9 radians per second for the weighted performance (Table I).

Upper leg. The maximum angular velocity for the upper leg during this phase was -414.9 radians per second

Fig. 2.—Angular Velocity: Lower Leg

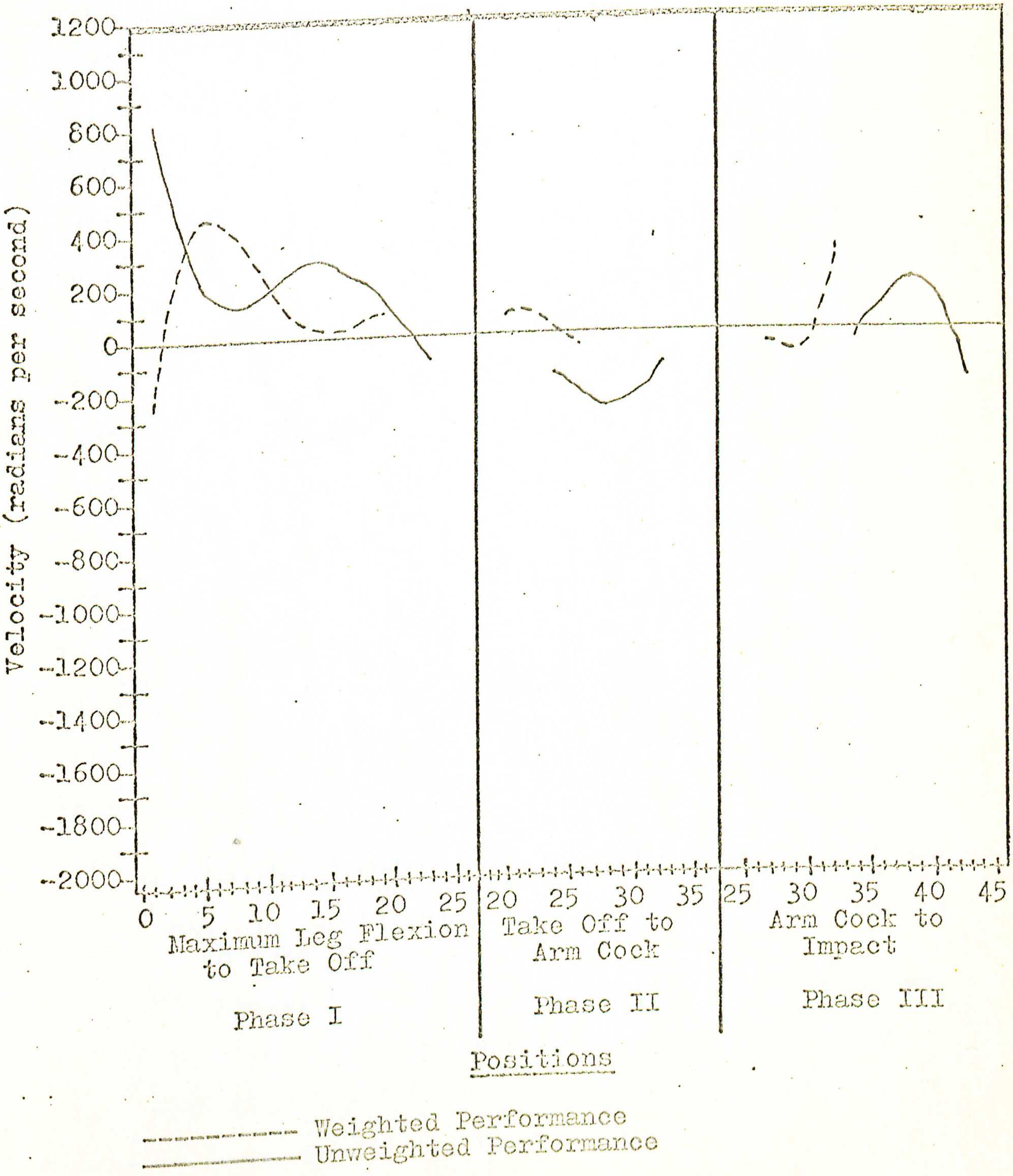
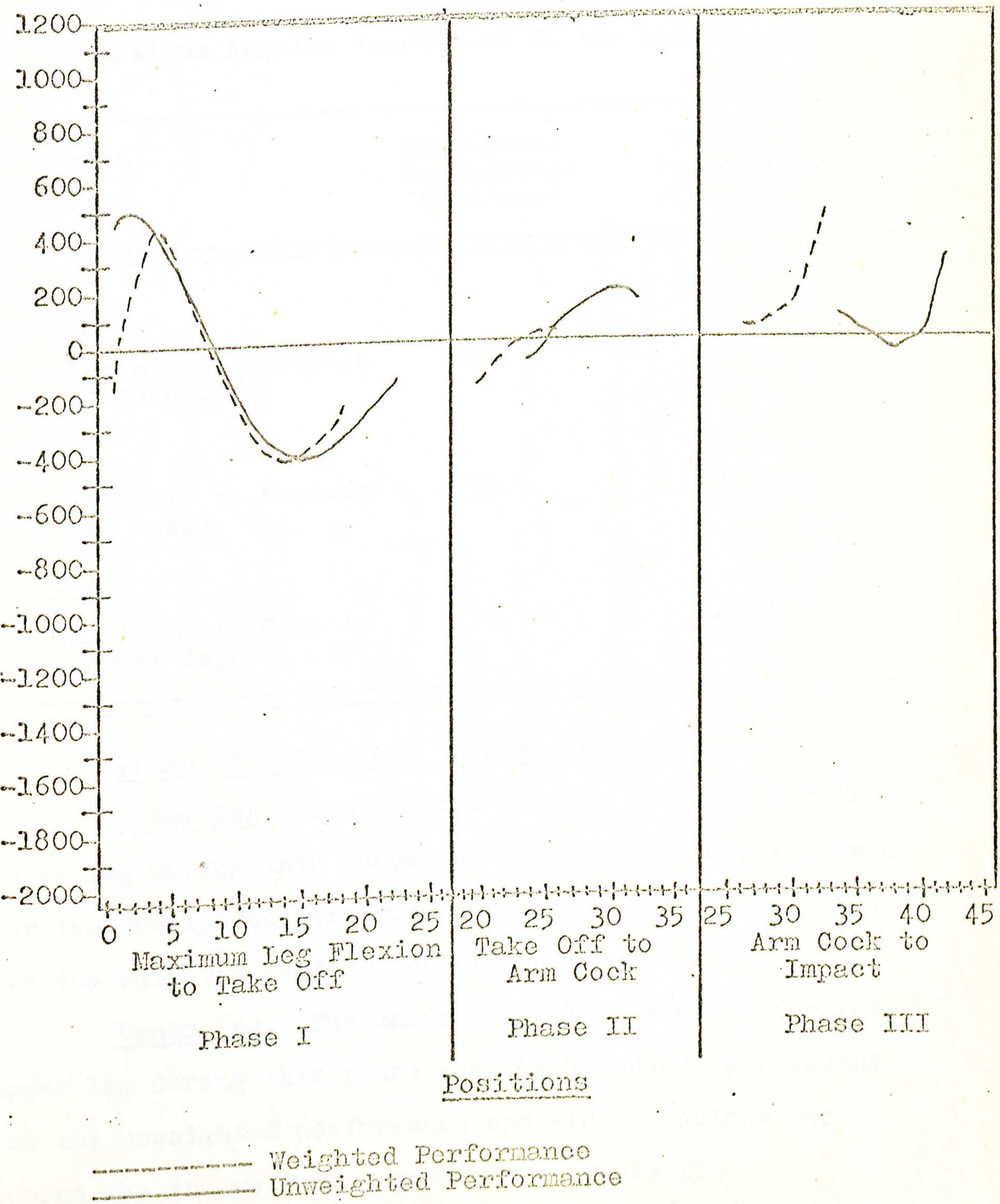


Fig. 3.—Angular Velocity: Upper Leg



for the unweighted performance and -422.9 radians per second for the weighted performance (Table II).

TABLE I

Maximum Angular Velocities of the Lower Leg

Phase	Unweighted Performance (rad/sec)	Weighted Performance (rad/sec)
PHASE I (Maximum Leg Flexion to Take Off)	216.9	455.9
PHASE II (Take Off to Maximum Arm Cock)	-238.9	54.3
PHASE III (Maximum Arm Cock to Actual Impact)	175.5	-95.5

Phase II - Take Off to Maximum Arm Cock

Lower leg. The maximum angular velocity for the lower leg during this phase was -238.9 radians per second for the unweighted performance and 54.3 radians per second for the weighted performance (Table I).

Upper leg. The maximum angular velocity for the upper leg during this phase was 154.7 radians per second for the unweighted performance and -185.2 radians per second for the weighted performance (Table II).

TABLE II

Maximum Angular Velocities of the Upper Leg

Phase	Unweighted Performance (rad/sec)	Weighted Performance (rad/sec)
PHASE I		
(Maximum Leg Flexion to Take Off)	-414.9	-422.9
PHASE II		
(Take Off to Maximum Arm Cock)	154.7	-185.2
PHASE III		
(Maximum Arm Cock to Actual Impact)	102.8	129.1

Phase III - Maximum Arm Cock to Actual Impact

Lower leg. The maximum angular velocity for the lower leg during this phase was 175.5 radians per second for the unweighted performance and -95.5 radians per second for the weighted performance (Table I).

Upper leg. The maximum angular velocity for the upper leg during this phase was +102.8 radians per second for the unweighted performance and 129.1 radians per second for the weighted performance (Table II).

Angular Velocity of the Arm

The angular velocity of the arm of the performances was calculated for the upper and lower arm, and the hand (Figures 4, 5, and 6). The velocity of the segments was compared utilizing the maximum velocity of each distinct phase. The maximum velocity of the upper and lower arm, and the hand in each of the distinct phases was representative of the effect of the ankle weights on the arm velocity during the total motion.

The weights were not expected to have as much effect on the angular velocity of the arm as they had on the angular velocity of the leg, but in most of the phases, there was a definite difference in the maximum angular velocity of the arm for the unweighted and the weighted performances.

Phase I - Maximum Leg Flexion to Take Off

Upper arm. The maximum angular velocity for the upper arm during this phase was 857.1 radians per second for the unweighted performance and 1025.4 radians per second for the weighted performance (Table III).

Lower arm. The maximum angular velocity of the lower arm during this phase was 823.3 radians per second for the unweighted performance and 440.2 radians per second for the weighted performance.(Table IV).

Fig. 4.—Angular Velocity: Upper Arm

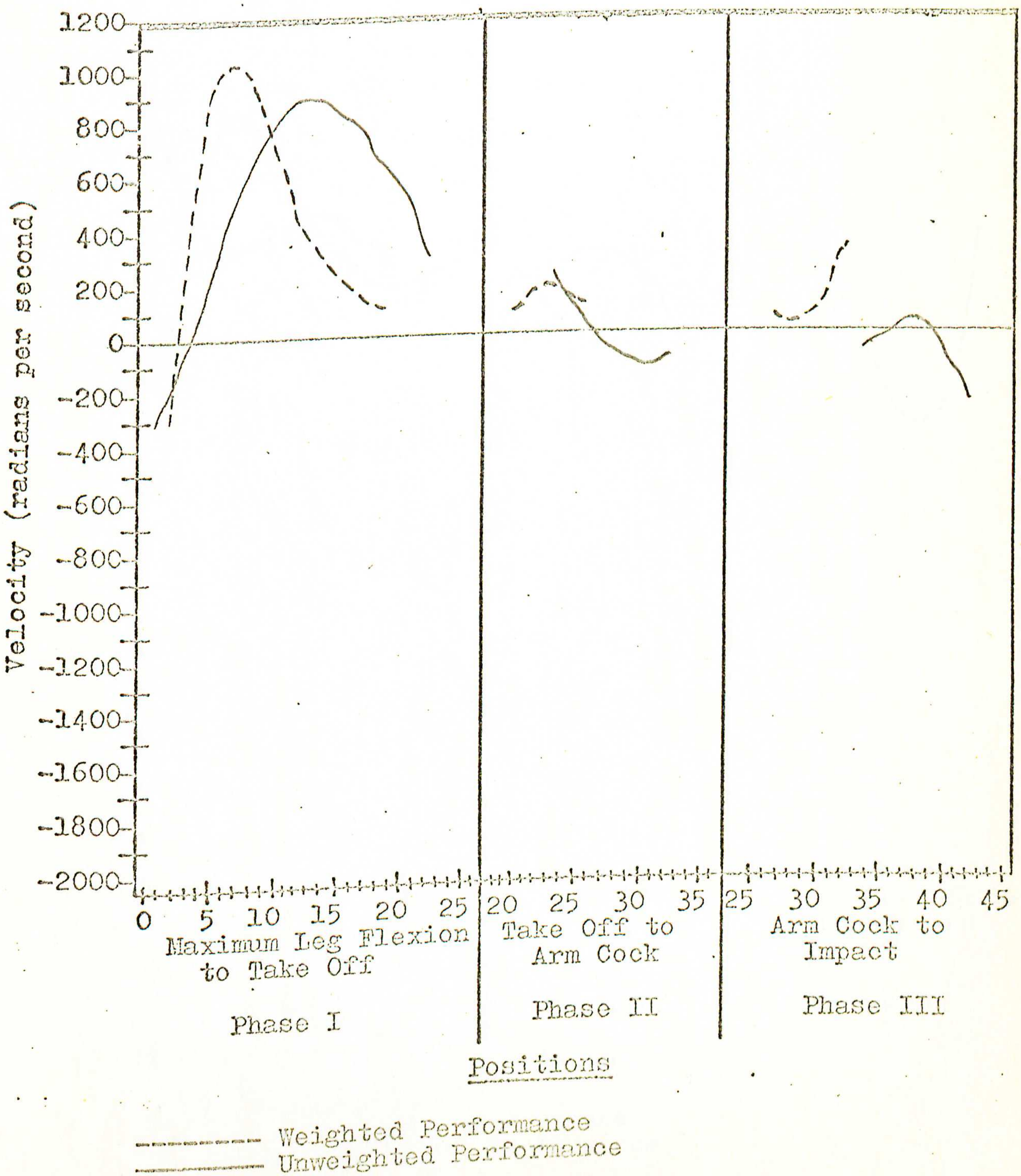


Fig. 5.--Angular Velocity: Lower Arm

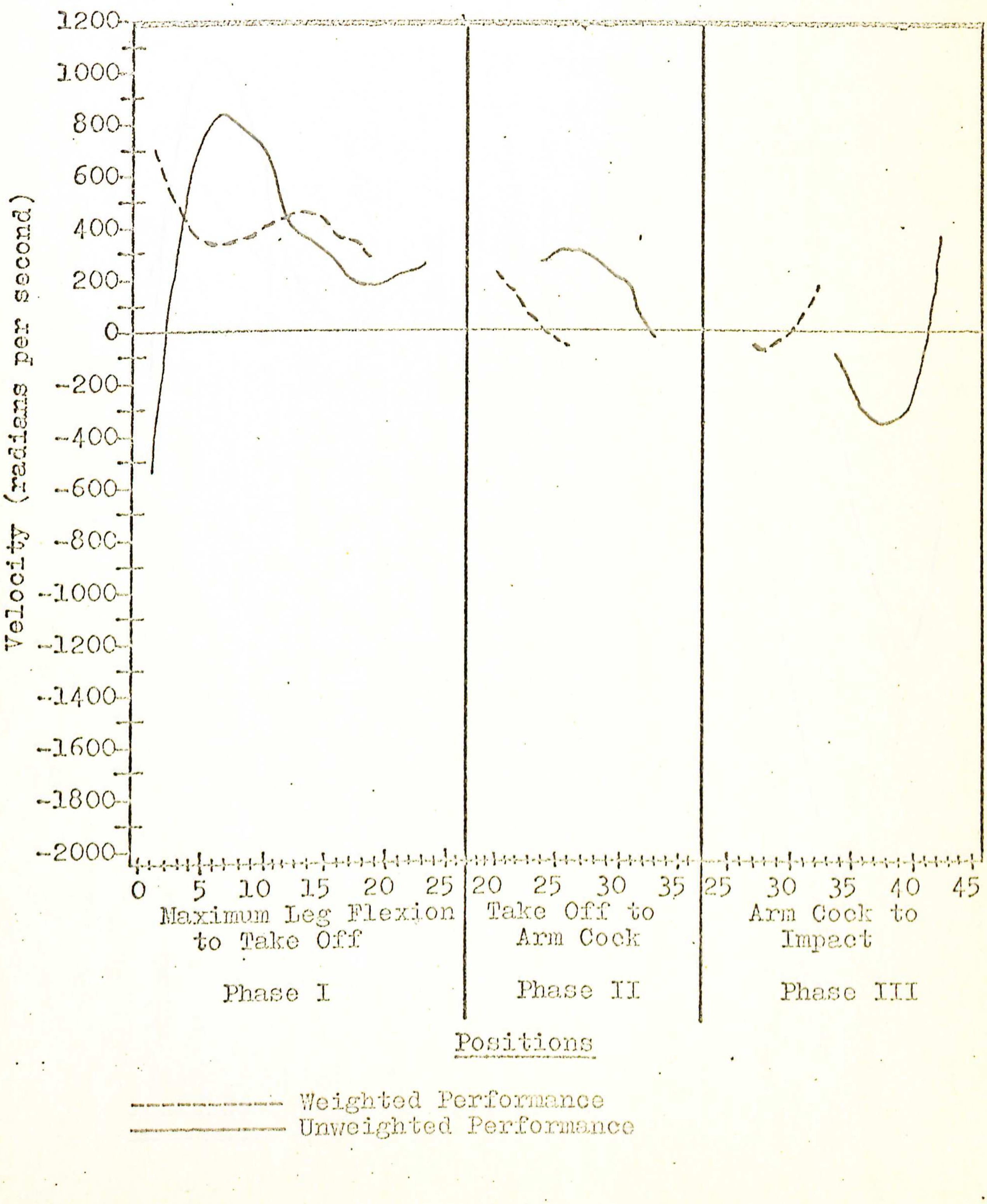


Fig. 6.--Angular Velocity: Hand

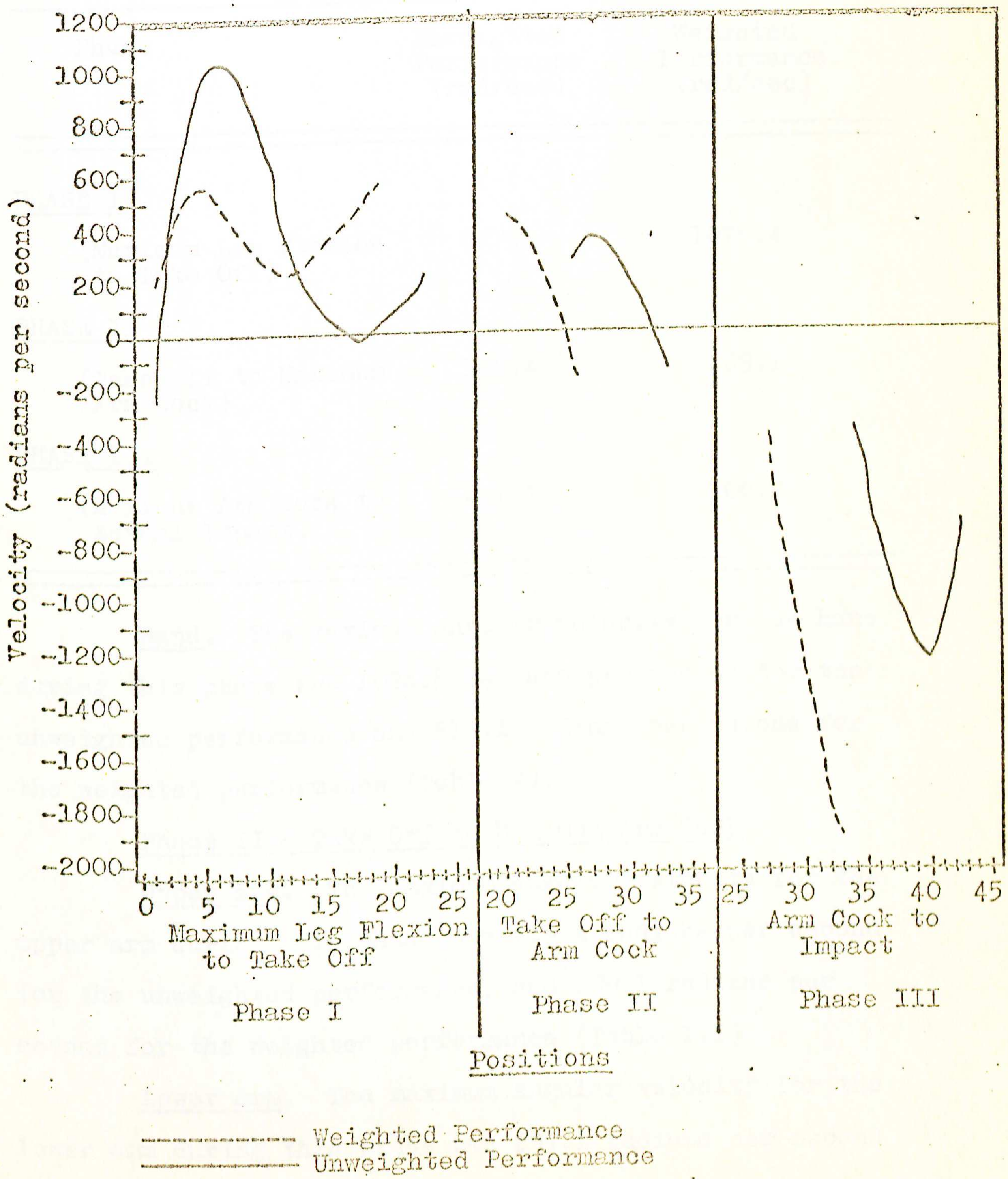


TABLE III

Maximum Angular Velocities of the Upper Arm

Phase	Unweighted Performance (rad/sec)	Weighted Performance (rad/sec)
PHASE I		
(Maximum Leg Flexion to Take Off)	857.1	1025.4
PHASE II		
(Take Off to Maximum Arm Cock)	189.4	109.1
PHASE III		
(Maximum Arm Cock to Actual Impact)	-71.7	100.7

Hand. The maximum angular velocity for the hand during this phase was 1028.8 radians per second for the unweighted performance and 512.1 radians per second for the weighted performance (Table V).

Phase II - Take Off to Maximum Arm Cock

Upper arm. The maximum angular velocity for the upper arm during this phase was 189.4 radians per second for the unweighted performance, and 109.1 radians per second for the weighted performance (Table III).

Lower arm. The maximum angular velocity for the lower arm during this phase was 297.1 radians per second for the unweighted performance and 227.4 radians per second for the weighted performance (Table IV).

TABLE IV

Maximum Angular Velocities of the Lower Arm

Phase	Unweighted Performance (rad/sec)	Weighted Performance (rad/sec)
PHASE I		
(Maximum Leg Flexion to Take Off)	823.3	440.2
PHASE II		
(Take Off to Maximum Arm Cock)	297.1	227.4
PHASE III		
(Maximum Arm Cock to Actual Impact)	-372.2	-50.3

Hand. The maximum angular velocity for the hand during this phase was 360.2 radians per second for the unweighted performance and 474.4 radians per second for the weighted performance (Table V).

Phase III - Maximum Arm Cock to Actual Impact

Upper arm. The maximum angular velocity for the upper arm during this phase was -71.7 radians per second for the unweighted performance and 100.7 radians per second for the weighted performance (Table III).

TABLE V

Maximum Angular Velocities of the Hand

Phase	Unweighted Performance (rad/sec)	Weighted Performance (rad/sec)
<u>PHASE I</u>		
(Maximum Leg Flexion to Take Off)	1028.8	512.1
<u>PHASE II</u>		
(Take Off to Maximum Arm Cock)	360.2	474.4
<u>PHASE III</u>		
(Maximum Arm Cock to Actual Impact)	-1240.3	-1554.1

<u>Lower arm</u>. The maximum angular velocity for the lower arm during this phase was -372.2 radians per second for the unweighted performance and -50.3 radians per second for the weighted performance (Table IV).

<u>Hand</u>. The maximum angular velocity for the hand during this phase was -1240.3 radians per second for the unweighted performance and -1554.1 radians per second for the weighted performance (Table V).

Moments of Force

Through the use of the procedure given in Chapter III it was possible to obtain the moments of force of each segment at each instantaneous position for both the unweighted and the weighted performances (Figures 7 - 12). A moment of force is defined as the force applied through muscular contraction on a segment at the joint around which the segment rotates. The moments of force are the significant data for interpreting body motion (17), since they represent the dominant muscle force at each joint at the given instantaneous position.

The moments of force are indicated numerically in units of gram-centimeters, and the dominant muscle group is indicated by the mathematical negative and positive signs preceding the numerical value. A negative sign (-) indicates clockwise moments, and a positive sign (+) indicates counter-clockwise moments. As an example refer to Figure 13, and let us say that the moment of force is $+.30 \times 10^5$ gram-centimeters for the right lower leg. This is translated as meaning that the dominant muscle group for this position was the extensors of the lower leg, and the moment of force was 30,000.00 gram-centimeters.

Fig. 13.--Example: Moments of Force of Lower Leg

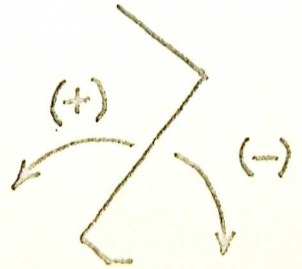


Fig. 7.—Moments of Force: Lower Leg

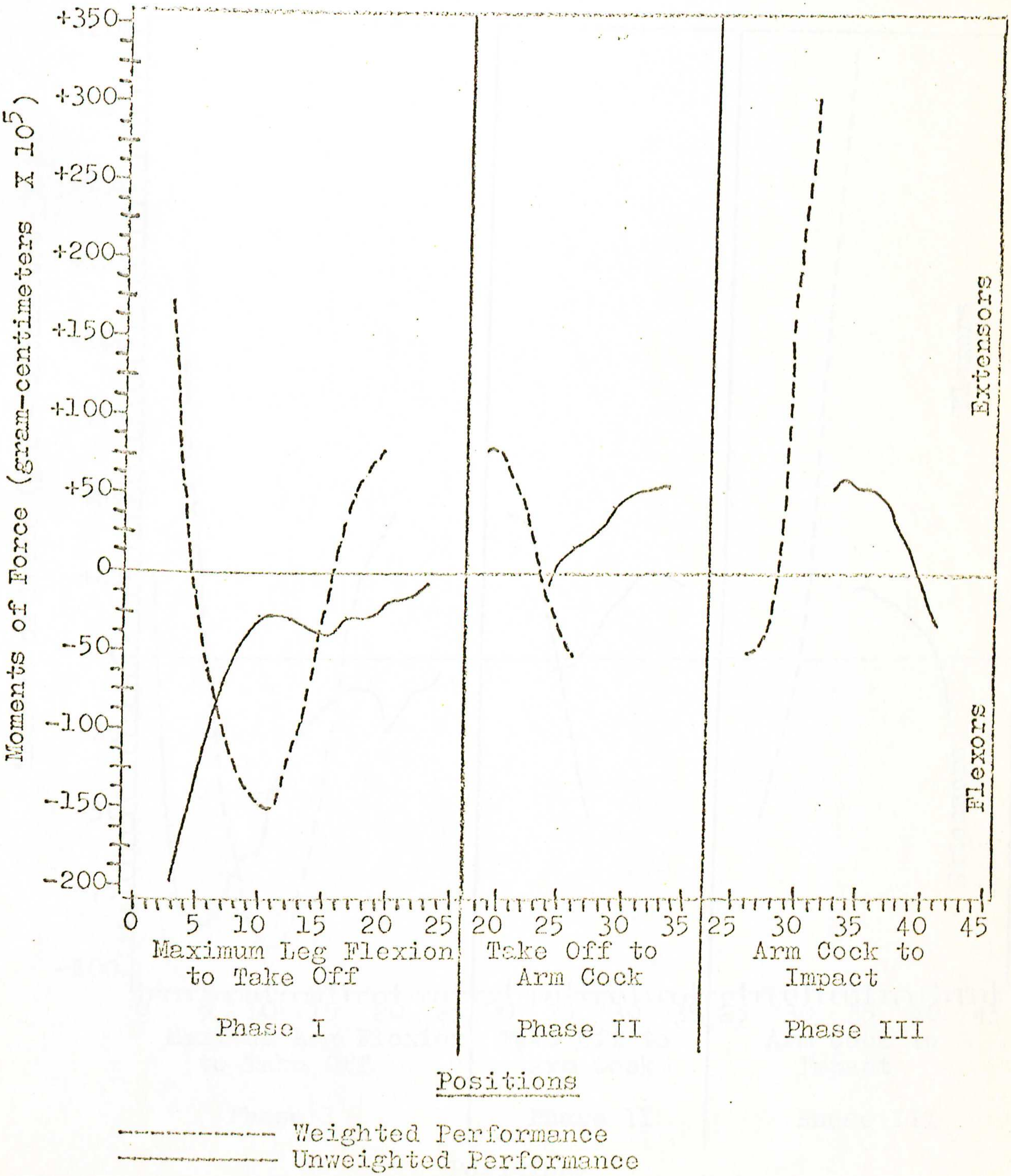


Fig. 8.—Moments of Force: Upper Leg

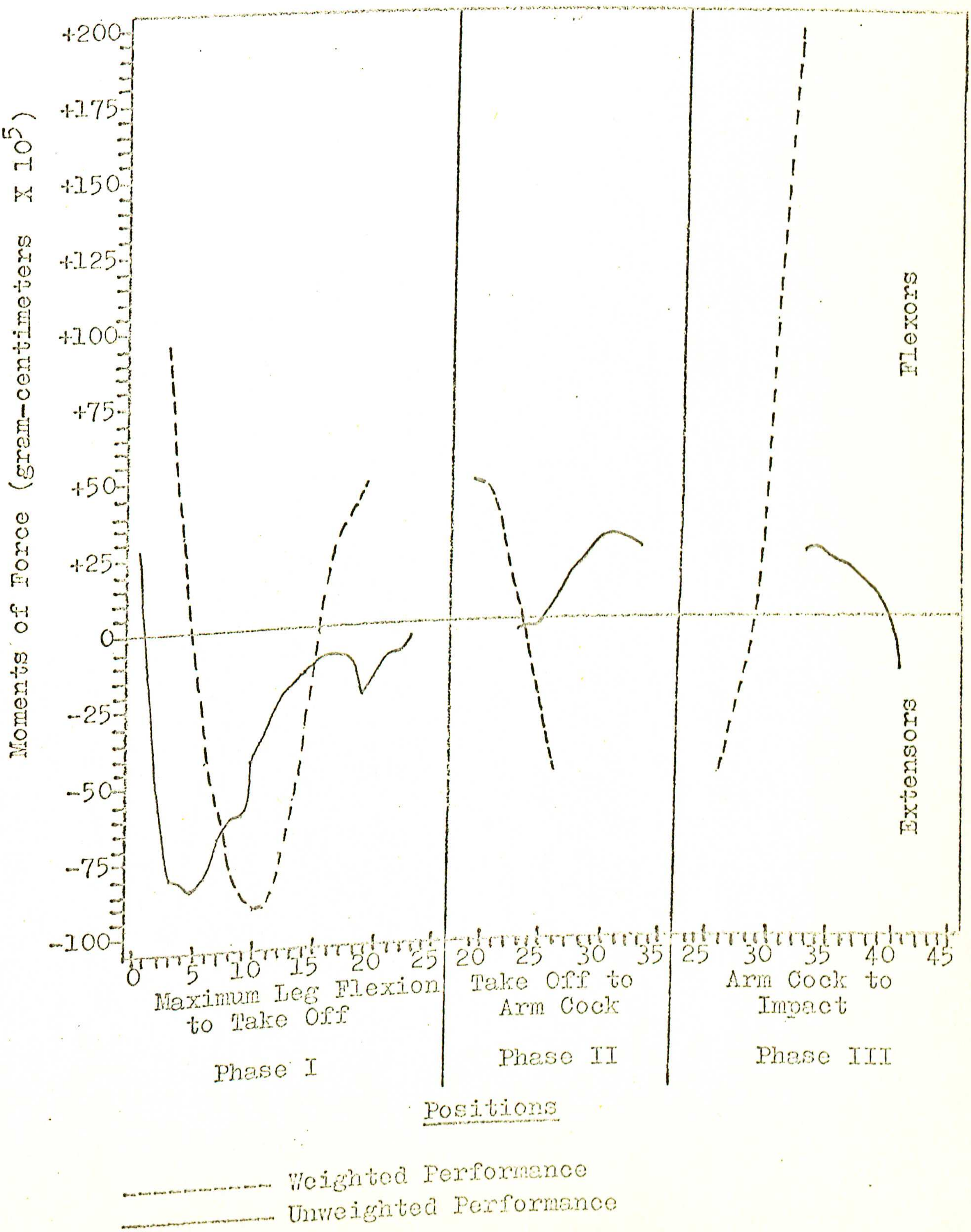


Fig. 9.--Moments of Force: Trunk

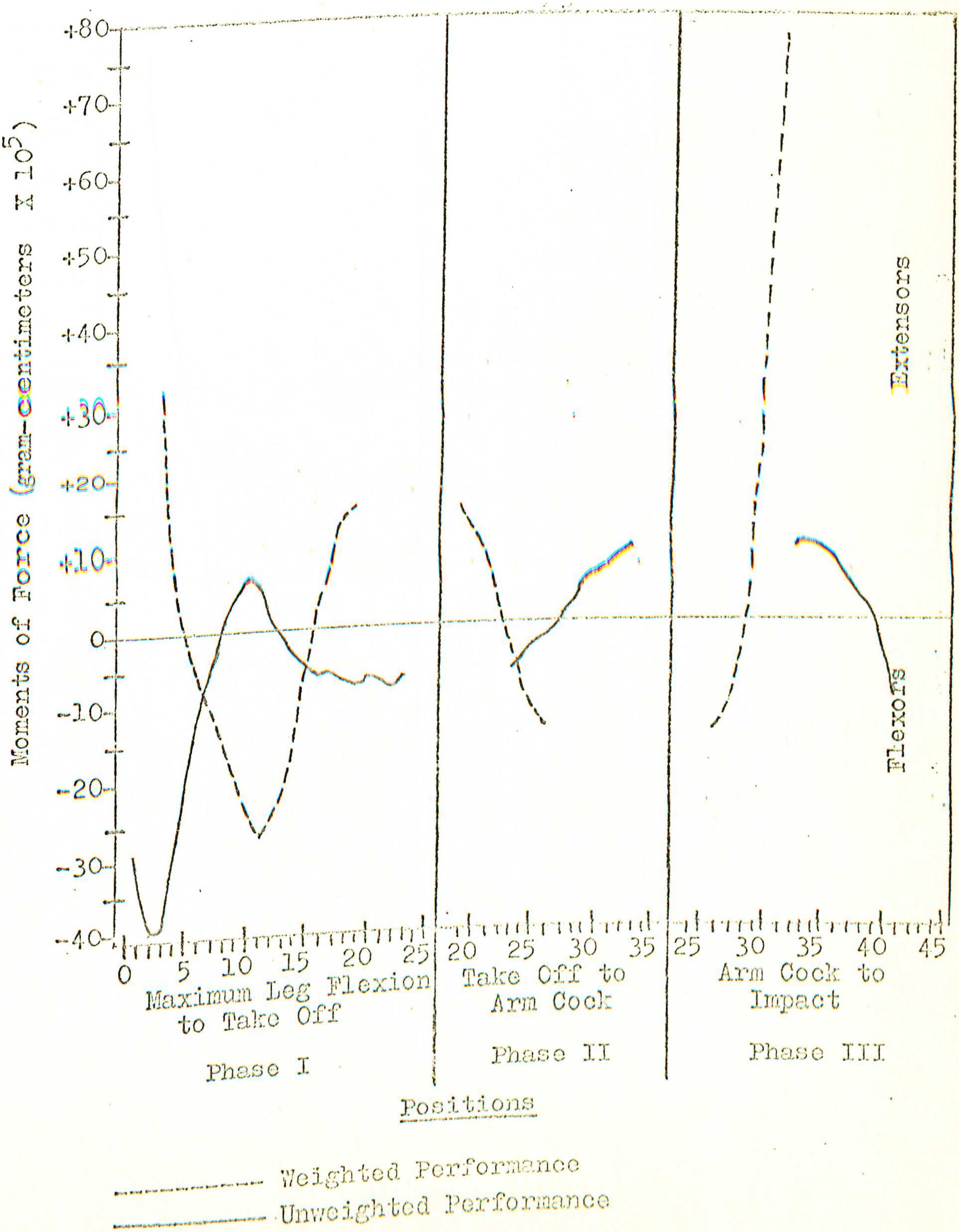


Fig. 10.---Moments of Force: Upper Arm

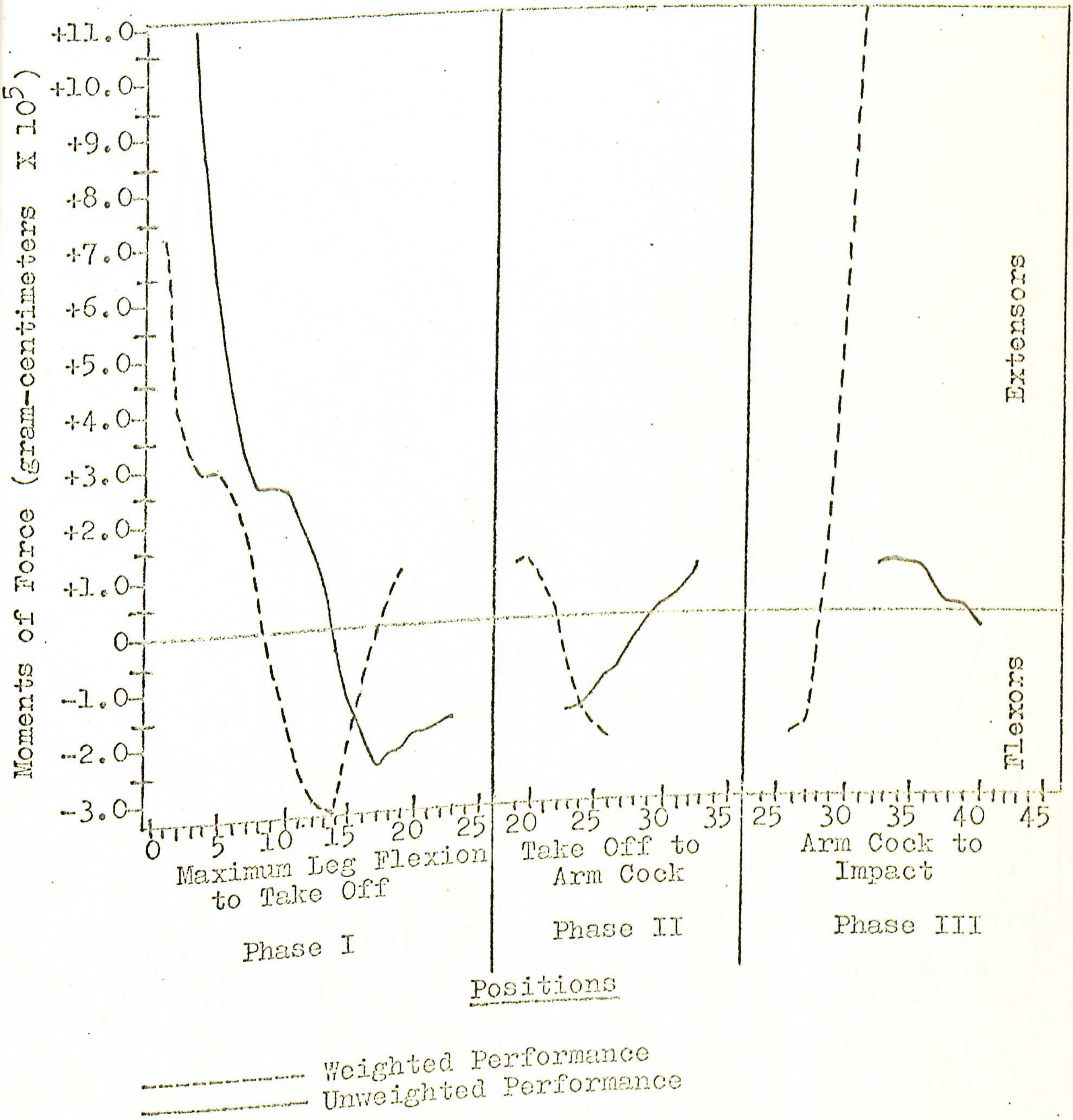


Fig. 11.--Moments of Force: Lower Arm

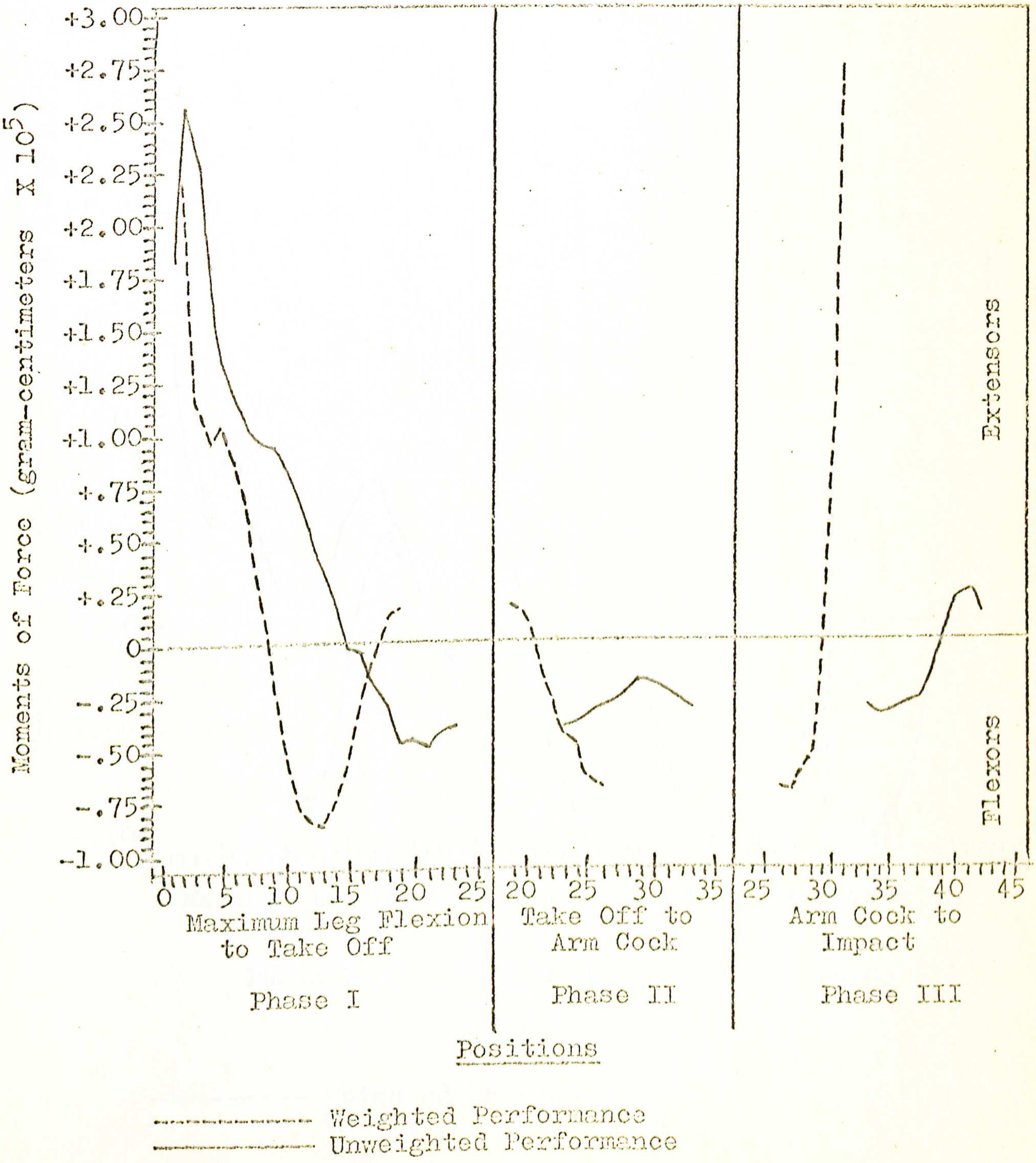
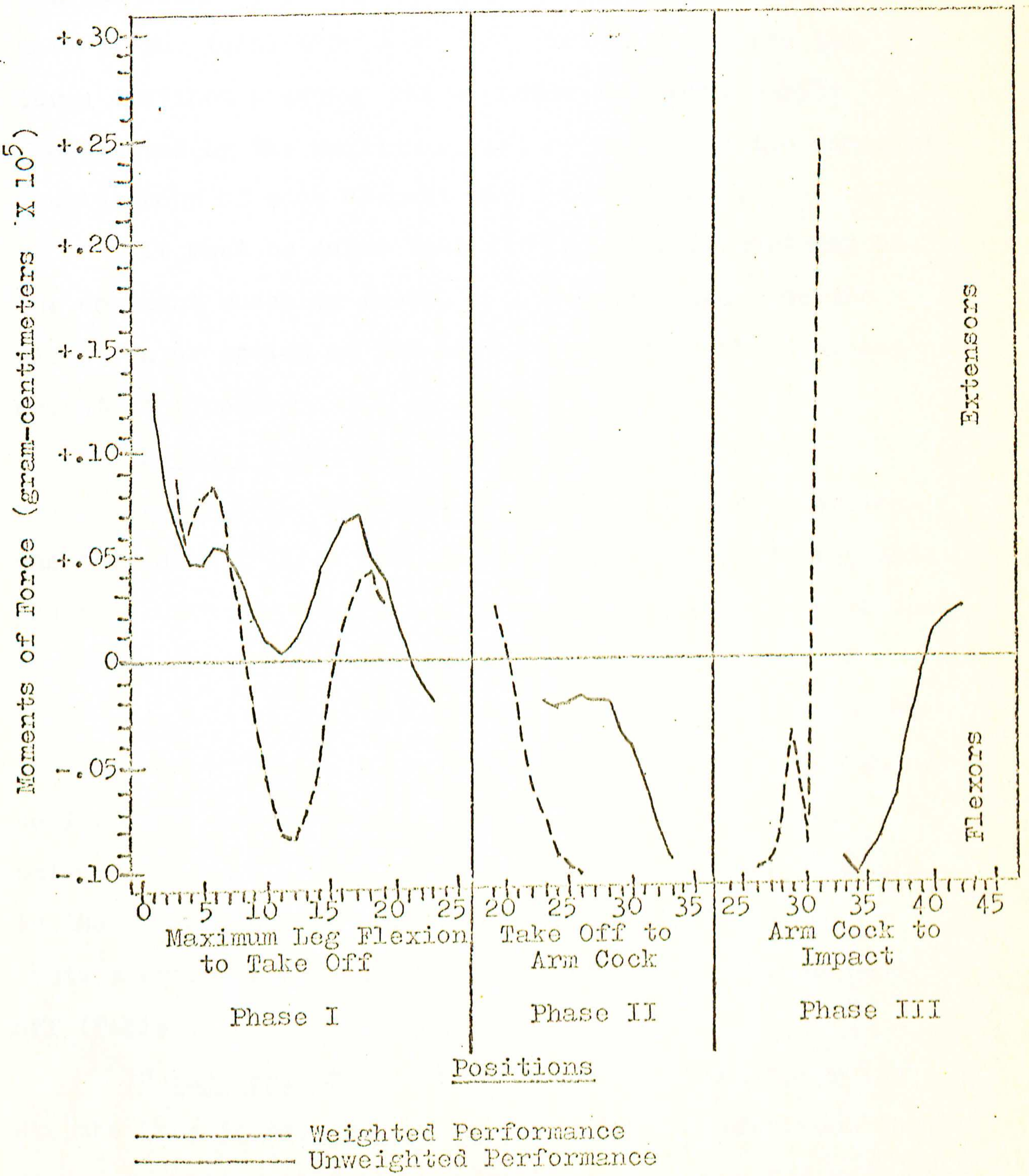


Fig. 12.--Moments of Force: Hand



To compare the moments of force of the unweighted and the weighted performance of the volleyball spike, the data of the total body motion was broken down into the three distinct phases. The segments were most easily represented by the maximum moment of force and the dominant muscle group of each segment during each phase.

It must be noted that although the flexors may be the dominant muscular force, this does not indicate the direction or action of the segment, but only the dominant moment of force.

Phase I - Maximum Leg Flexion to Take Off

Lower leg. The axis of rotation of the lower leg was the ankle joint. The dominant muscle group during this phase for the unweighted performance was the flexors of the lower leg in varying magnitude. The maximum moment of force was -192.44×10^5 gram-centimeters which occurred at the beginning of the phase (Table VI). During the weighted performance the dominant muscle group varied from the extensors with a maximum of $+174.76 \times 10^5$ gram-centimeters, to the flexors with a maximum of -147.26×10^5 gram-centimeters, and back to the extensors just prior to take off (Table VI).

Upper leg. The axis of rotation of the upper leg was the knee joint. During the unweighted performance the dominant muscle group throughout this phase was the extensors of the leg with a maximum of -84.75×10^5 gram-centimeters

(Table VII). This maximum was noted early in the phase with the moments decreasing just prior to take off. During the weighted performance the dominant muscle group varied from the flexors early in the phase with a maximum of +96.79 X 10^5 gram-centimeters to the extensors with a maximum of -94.91 X 10^5 gram-centimeters, and back to the flexors just prior to take off (Table VII).

TABLE VI

Maximum Moments of Force
of the Lower Leg

Phase	Unweighted Performance	Weighted Performance
PHASE I		
Flexors:	-192.44	-147.26
Extensors:	-	+174.96
PHASE II		
Flexors:	-2.90	-51.72
Extensors:	+48.05	+74.97
PHASE III		
Flexors:	-38.19	-45.81
Extensors:	+54.83	+316.30

Note: All values are X 10^5 gram-centimeters.

Trunk. The axis of rotation of the trunk was the hip joint. During the unweighted performance the motion was dominated muscularly by the flexors of the trunk with a maximum of -39.17×10^5 gram-centimeters which was noted early in the phase. The extensors dominated the phase briefly with a maximum of $+5.77 \times 10^5$ gram-centimeters just prior to the body extending in preparation for take off, but the flexors dominated as the body extended (Table VIII).

The dominant muscle group also varied during the weighted performance, but in exact reverse of the unweighted performance. The phase began with the extensors dominating with a maximum of $+31.59 \times 10^5$ gram-centimeters which was approximately 26 times the muscular force exerted by the extensors in the unweighted performance. The flexors dominated briefly with a maximum of -27.07×10^5 gram-centimeters just prior to the body extending in preparation for take off, but the extensors dominated as the body left the floor surface (Table VIII).

<u>Upper arm</u>. The axis of rotation of the upper arm was the shoulder joint. During the unweighted performance the dominant muscle group varied from the extensors with a maximum of $+10.92 \times 10^5$ gram-centimeters to the flexors with a maximum of -2.59×10^5 gram-centimeters as the body extended in preparation for take off. The moments of force during the weighted performance was similar to the unweighted performance. They indicated the same variation of dominant muscle groups from extensors with a maximum of $+3.13 \times 10^5$ gram-centimeters to the flexors with a maximum

of -3.56×10^5 gram-centimeters as the body extended in preparation for take off. At this point the weighted performance varied back to the extensors just as the body left the floor (Table IX).

TABLE VII

Maximum Moments of Force
of the Upper Leg

Phase	Unweighted Performance	Weighted Performance
PHASE I		
Flexors:	-	-94.91
Extensors:	-84.75	+96.79
PHASE II		
Flexors:	+24.43	+44.13
Extensors:	-2.40	-51.72
PHASE III		
Flexors:	+21.94	+199.61
Extensors:	-20.82	-29.47

Note: All values are $\times 10^5$ gram-centimeters.

Lower arm. The axis of rotation of the lower arm was the elbow joint. The moment of force pattern for the lower arm during this phase was very similar to the upper arm.

During the unweighted performance the dominant muscle group varied from the extensors with a maximum of

+1.79 X 10^5 gram-centimeters to the flexors with a maximum of -.445 X 10^5 gram-centimeters as the body extends in preparation for take off. The moments of force during the weighted performance were similar. They indicated the same variation of dominant muscle groups from the extensors with a maximum of +1.16 X 10^5 gram-centimeters to the flexors with a maximum of -.86 X 10^5 gram-centimeters as the body extended in preparation for the take off. At this point the weighted performance varied back to the extensors just as the body left the floor (Table X).

TABLE VIII

Maximum Moments of Force
of the Trunk

Phase	Unweighted Performance	Weighted Performance
PHASE I		
Flexors:	-39.17	-27.07
Extensors:	+5.77	+31.59
PHASE II		
Flexors:	-4.94	-14.31
Extensors:	+7.58	+11.39
PHASE III		
Flexors:	-9.28	-11.75
Extensors:	+8.20	+77.65

Note: All values are X 10^5 gram-centimeters.

TABLE IX

Maximum Moments of Force of the Upper Arm

Phase	Unweighted Performance	Weighted Performance
PHASE I		
Flexors:	-2.59	-3.56
Extensors:	+10.92	+3.13
PHASE II		
Flexors:	-1.56	-2.18
Extensors:	+.62	+1.02
PHASE III		
Flexors:	-.98	-1.87
Extensors:	+.84	+11.47

Note: All values are X 10^5 gram-centimeters.

Hand. The axis of rotation of the hand was the wrist joint. During the unweighted performance the dominant muscle group was the extensors with a maximum of +.068 X 10^5 gram-centimeters completely throughout the phase with a brief switch to the flexors with a maximum of -.021 X 10^5 gram-centimeters just as the body left the floor. The dominant muscle group greatly varied during the weighted performance from the extensors with a maximum of +.089 X 10^5 gram-centimeters to the flexors with a maximum of -.082 X 10^5 gram-centimeters, and back to the extensors as the body extended and left the floor surface (Table XI).

TABLE X

Maximum Moments of Force of the Lower Arm

Phase	Unweighted Performance	Weighted Performance
PHASE I		
Flexors:	-.445	-.86
Extensors:	+1.79	+1.16
PHASE II		
Flexors:	-.366	-.66
Extensors:	-	+.13
PHASE III		
Flexors:	-.315	-.60
Extensors:	+.201	+2.82

Note: All values are X 10^5 gram-centimeters.

Phase II - Take Off to Maximum Arm Cock

Lower leg. During the unweighted performance the dominant muscle group throughout this phase was the extensors with a maximum of +48.05 X 10^5 gram-centimeters. The moments increased in magnitude from take off to maximum arm cock. The extensors also dominated the weighted performance with a maximum of +74.97 X 10^5 gram-centimeters, but toward the end of the phase the flexors dominated with a maximum of -51.72 X 10^5 gram-centimeters (Table VI).

TABLE XI

Maximum Moments of Force of the Hand

Phase	Unweighted Performance	Weighted Performance
PHASE I		
Flexors:	-.021	-.082
Extensors:	+.068	+.089
PHASE II		
Flexors:	-.095	-.10
Extensors:	-	+.004
PHASE III		
Flexors:	-.104	-.097
Extensors:	+.023	+.248

Note: All values are X 10^5 gram-centimeters.

Upper leg. During the unweighted performance the extensors dominated briefly at the beginning with a maximum of -2.40 X 10^5 gram-centimeters, but the majority of the phase was dominated by the flexors with a maximum of +23.43 X 10^5 gram-centimeters. The weighted performance indicated the complete reversal of dominant muscle groups with the flexors dominating briefly at the beginning of the phase with a maximum of +44.13 X 10^5 gram-centimeters, and the extensors completing the phase with a maximum of -51.72 X 10^5 gram-centimeters (Table VII).

Trunk. As the body left the floor the dominant muscle group for the unweighted performance was the flexors with a maximum of -4.94 X 10^5 gram-centimeters, but this quickly changed to the extensors with a maximum of +7.58 X 10^5 gram-centimeters which increased in magnitude until the end of the phase. During the weighted performance the dominant muscle groups were reversed with the extensors dominating with a maximum of +11.39 X 10^5 gram-centimeters as the body left the floor, and the flexors dominating with a maximum of -14.31 X 10^5 gram-centimeters through the end of the phase (Table VIII).

Upper arm. During the unweighted performance the flexors dominated with a maximum of -1.56 X 10^5 gram-centimeters as the body left the floor, but the extensors dominated with a maximum of +.617 X 10^5 gram-centimeters as the arm extended back into arm cock position. This pattern was reversed during the weighted performance with the extensors dominating as the body left the floor with a maximum of +1.02 X 10^5 gram-centimeters, and the flexors dominating with a maximum of -2.18 X 10^5 gram-centimeters as the arm extended back into arm cock position (Table IX).

Lower arm. During the unweighted performance the flexors dominated with a maximum of $-.365 \times 10^5$ gram-centimeters throughout the phase. During the weighted performance the flexors also dominated completely throughout the phase with a maximum of $-.66 \times 10^5$ gram-centimeters (Table X).

Hand. During the unweighted performance the flexors dominated with a maximum of $-.095 \times 10^5$ gram-centimeters throughout the phase. During the weighted performance the flexors also dominated completely throughout the phase with a maximum of $-.10 \times 10^5$ gram-centimeters (Table XI).

Phase III - Maximum Arm Cock to Actual Impact

Lower leg. As the arm came forward for ball impact during the unweighted performance the dominant muscle group was the extensors with a maximum of $+54.83 \times 10^5$ gram-centimeters, but as the actual impact took place the flexors dominated with a maximum of -38.19×10^5 gram-centimeters. During the weighted performance the pattern was reversed with the flexors dominating with a maximum of -45.81×10^5 gram-centimeters as the arm came forward, and the extensors dominating with a maximum of $+316.30 \times 10^5$ gram-centimeters as impact took place (Table VI).

Upper leg. As the arm came forward for ball impact during the unweighted performance the dominant muscle group was the flexors with a maximum of $+21.94 \times 10^5$ gram-centimeters, but as the actual impact took place the extensors dominated with a maximum of -20.82×10^5 gram-centimeters. During the weighted performance the pattern was reversed with the extensors dominating with a maximum of -29.47×10^5 gram-centimeters as the arm came forward, and the flexors dominating with a maximum of $+199.61 \times 10^5$ gram-centimeters as impact took place (Table VII).

Trunk. As the arm came forward for ball impact during the unweighted performance the dominant muscle group was the extensors with a maximum of $+8.20 \times 10^5$ gram-centimeters, but as actual impact took place the flexors dominated with a maximum of -9.28×10^5 gram-centimeters. During the weighted performance the pattern was reversed with the flexors dominating with a maximum of -11.75×10^5 gram-centimeters as the arm came forward, and the extensors dominating with a maximum of $+77.65 \times 10^5$ gram-centimeters as impact took place (Table VIII).

Upper arm. During the unweighted performance as the arm came forward the dominant muscle group was the extensors with a maximum of $+.839 \times 10^5$ gram-centimeters, but the flexors dominated briefly with a maximum of $-.980 \times 10^5$ gram-centimeters as actual impact took place. During the weighted performance the pattern was reversed with the flexors dominating with a maximum of -1.87×10^5 gram-centimeters as the arm came forward, and the extensors dominating with a maximum of $+11.47 \times 10^5$ gram-centimeters as the ball impact took place (Table IX).

Lower arm. During the unweighted performance the flexors dominated with a maximum of $-.315 \times 10^5$ gram-centimeters as the arm came forward, but the extensors dominated with a maximum of $+.201 \times 10^5$ gram-centimeters as ball impact took place. During the weighted performance the pattern was similar with the flexors dominating with a maximum of $-.60 \times 10^5$ gram-centimeters as the arm came forward, and the extensors dominating with a maximum of $+2.82 \times 10^5$ gram-centimeters as impact took place (Table X).

Hand. During the unweighted performance the flexors dominated with a maximum of $-.104 \times 10^5$ gram-centimeters as the arm came forward, but the extensors dominated with a maximum of $+.023 \times 10^5$ gram-centimeters as ball impact took place. During the weighted performance the pattern was similar with the flexors dominating with a maximum of $-.097 \times 10^5$ gram-centimeters as the arm came forward, and the extensors dominating with a maximum of $+.248 \times 10^5$ gram-centimeters as impact took place (Table XI).

C H A P T E R V

SUMMARY, DISCUSSION, CONCLUSIONS IMPLICATIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to compare a volleyball spike pattern performed without ankle weights with one performed while wearing 2.5 pound ankle weights on each ankle.

From the literature reviewed it was evident that there was a dearth of actual research literature on the alteration of skill patterns through overweighting through the use of wearable weights and weighted implements. But it was evident that there exists general opinion or fear that overweighting a performance will alter the skill pattern, though no actual research was available to support this opinion. Research was needed to indicate exactly if and how ankle weights alter skill patterns.

The study included one right handed subject, a female graduate student at the University of Massachusetts. The method used in analysis was a kinetic method developed by Plagenhoef (17). The subject was filmed while she performed several volleyball spikes without ankle weights and several spikes while wearing 2.5 pound ankle weights on each ankle.

Two of the volleyball spike pattern sequences were chosen for analysis, one without ankle weights and one with ankle weights, and frame by frame tracings were made of both sequences. Utilizing the tracings of the two sequences, the angle of each segment at each joint was measured from the right horizontal counterclockwise to the segment for each instantaneous position desired. These angular measurements, the film time, and the number of positions were used to calculate the angular acceleration and velocity of each segment. Once this data was calculated, the angular velocity and acceleration, the segments' length, weight, center of gravity, and radius of gyration were utilized to calculate the moments of force of each segment for each instantaneous position.

The analysis included comparison of the mean time of flight for all unweighted and weighted performances, maximum angular velocity of the leg, maximum angular velocity of the arm, and the maximum moments of force and dominant muscle group of each segment.

Since the unweighted performance was .15 seconds longer in execution and included 10 more frame positions than the weighted performance, it was necessary to divide the analysis of the performance of the volleyball spike into three distinct phases (Figure 1). Phase I included the positions from the maximum leg flexion to the actual take off of the foot from the floor surface. Phase II included the positions from the take off to the maximum arm cock. Phase III included the positions from maximum arm cock to actual impact of the ball.

Discussion

The data collected in analysis promoted the following discussion about the alteration of a volleyball spike pattern through the application of ankle weights.

<u>Time of flight</u>. The time of flight of all the weighted performances was less in all cases ($\bar{X}$ = .411 seconds) than the unweighted performances ($\bar{X}$ = .491 seconds). The shorter time of flight of the weighted performances indicated less height of jump achieved during the weighted spike pattern.

<u>Angular velocity of the leg</u>. The maximum angular velocity of the leg for each phase was presented in Tables I and II, and the velocity curve for the total leg motion was depicted in Figures 2 and 3. The actual velocity for each instantaneous position is included in Appendix C. These values which were presented initiated the following discussion:

Lower leg. The maximum angular velocity of the lower leg occurred earlier in Phase I and reached a greater magnitude during the weighted performance than during the unweighted performance.

1. The study may be extended to include a larger number of male and female subjects.

2. The study may be extended to include subjects who have achieved various levels of skill.

3. The study may be extended to utilize various poundages of ankle weights.

4. Studies may be performed utilizing other skill patterns.

5. Studies may be performed on the application of weights to other segments of the body.

6. Studies may be performed on the alteration of skill patterns when utilizing weighted implements.

A P P E N D I X   A

TIME OF FLIGHT

Unweighted Performances:

1. .495 seconds
*2. .525 seconds
3. .480 seconds
4. .465 seconds

$\Sigma = 1.965$ $\bar{X} = .491$

Weighted Performances:

1. .435 seconds
2. .390 seconds
3. .405 seconds
4. .420 seconds
5. .405 seconds
6. .405 seconds
*7. .420 seconds

$\Sigma = 2.880$ $\bar{X} = .411$

*The performance chosen for analysis.

A P P E N D I X B

LENGTHS AND WEIGHTS OF BODY SEGMENTS

Body Segment	Length	Weight *
Lower Leg	36.50 cm.	3103.0 grams
Upper Leg	38.21 cm.	6497.0 grams
Trunk	49.51 cm.	15960.0 grams
Upper Arm	27.74 cm.	1468.0 grams
Lower Arm	25.29 cm.	728.0 grams
Hand	17.55 cm.	244.0 grams

*All weights are for one-half of the body.

A P P E N D I X C

DATA SHEETS

KEY

W = Weight (Grams) of the Body Segment (One-Half Body)

θ = Angle (Degrees)

L = Length (cm.) of Body Segment

R = Distance (cm.) of Center of Gravity from Either the Distal or Proximal Joint

K = Distance (cm.) of Radius of Gyration from Distal or Proximal Joint

ω = Angular Velocity (Radians per Second)

α = Angular Acceleration (Radians per Second per Second)

S = Segment Number

P = Position Number

DATA SHEET

UNWEIGHTED PERFORMANCE

SEGMENT 1 -- LOWER LEG

Θ	L	R	K	W	∝	S	P
26.847	34.0	13.4	19.5	808.9	-20409.3	1	1
36.908	34.0	13.4	19.5	546.7	-14739.0	1	2
43.632	34.5	13.6	19.7	361.4	-10131.9	1	3
48.059	35.0	13.8	20.0	238.0	-6469.6	1	4
51.015	35.0	13.8	20.0	163.2	-3639.6	1	5
53.138	36.4	14.3	19.8	125.2	-1535.6	1	6
54.904	36.4	14.3	19.8	114.0	-57.2	1	7
56.647	37.0	14.6	21.2	120.8	889.8	1	8
58.582	35.3	13.9	20.2	138.4	1393.5	1	9
60.823	35.3	13.9	20.2	160.8	1536.1	1	10
63.405	34.6	13.6	19.8	183.1	1393.8	1	11
66.297	34.2	13.5	19.0	201.6	1036.4	1	12
69.419	34.5	13.6	19.7	213.4	528.0	1	13
72.658	34.5	13.6	19.7	216.9	-73.5	1	14
75.879	35.0	13.8	20.0	211.0	-716.2	1	15
78.940	34.0	13.4	19.5	195.5	-1354.3	1	16
81.697	34.2	13.5	19.0	170.6	-1948.1	1	17
84.017	35.5	14.0	20.3	137.4	-2463.9	1	18
85.784	35.8	14.1	20.5	97.2	-2874.0	1	19
86.908	34.6	13.6	19.8	51.8	-3156.9	1	20
87.323	35.8	14.1	20.5	3.2	-3297.0	1	21
87.030	37.0	14.6	21.2	-46.3	-3284.8	1	22
85.941	38.1	14.9	21.8	-94.5	-3117.0	1	23
84.163	38.2	15.0	21.8	-139.1	-2796.1	1	24
81.798	38.2	15.0	21.8	-177.7	-2330.8	1	25
78.892	38.2	15.0	21.8	-208.3	-1735.9	1	26
75.597	34.7	13.7	19.8	-229.2	-1032.1	1	27
72.072	35.5	14.0	20.3	-238.9	-246.4	1	28
68.492	35.6	14.0	20.3	-236.4	588.4	1	29
65.044	34.5	13.6	19.7	-221.2	1433.3	1	30
61.918	34.5	13.6	19.7	-193.5	2243.4	1	31
59.296	34.7	13.7	19.8	-154.3	2967.4	1	32
57.339	34.2	13.5	19.0	-105.2	3548.4	1	33
56.176	37.0	14.6	21.2	-48.9	3923.1	1	34
55.850	37.0	14.6	21.2	11.1	4022.2	1	35
56.503	38.1	14.9	21.8	70.0	3770.6	1	36
57.957	37.0	14.6	21.2	122.0	3086.9	1	37
60.095	35.3	13.9	20.2	160.0	1883.6	1	38
62.645	35.3	13.9	20.2	175.5	67.3	1	39
65.197	34.6	13.6	19.7	158.5	-2461.5	1	40
67.180	34.2	13.5	19.0	97.6	-5808.3	1	41
67.839	35.3	13.9	20.2	-20.4	-10084.5	1	42
66.289	35.3	13.9	20.2	-210.2	-15408.7	1	43

DATA SHEET

UNWEIGHTED PERFORMANCE

SEGMENT 2 -- UPPER LEG

Θ	L	R	K	ω	α	S	P
105.815	37.9	21.5	24.8	467.9	4642.8	2	1
113.204	38.5	21.8	25.1	507.6	815.0	2	2
120.792	38.5	21.8	25.1	496.7	-2131.4	2	3
127.915	36.2	20.5	23.6	447.6	-4299.5	2	4
134.083	38.5	21.8	25.1	371.1	-5787.3	2	5
138.960	38.6	21.9	25.2	276.9	-6687.3	2	6
142.342	37.4	21.2	24.4	173.0	-7086.6	2	7
144.138	37.9	21.5	24.8	66.4	-7067.4	2	8
144.349	38.7	21.9	25.2	-37.3	-6706.1	2	9
143.057	36.3	20.6	23.7	-133.4	-6074.2	2	10
140.402	36.8	20.8	24.0	-218.5	-5237.6	2	11
136.571	36.8	20.8	24.0	-289.8	-4257.0	2	12
131.784	36.3	20.6	23.7	-345.8	-3187.8	2	13
126.281	36.3	20.6	23.7	-385.3	-2080.2	2	14
120.309	38.7	21.9	25.2	-408.2	-978.8	2	15
114.116	38.2	21.5	25.0	-414.9	76.6	2	16
107.939	36.8	20.8	24.0	-406.3	1052.6	2	17
101.997	36.4	20.5	23.8	-383.8	1919.6	2	18
96.484	36.3	20.5	23.7	-349.4	2654.3	2	19
91.566	36.4	20.6	23.8	-305.0	3258.6	2	20
87.373	36.4	20.6	23.8	-253.0	3659.4	2	21
84.000	36.4	20.6	23.8	-196.0	3909.2	2	22
81.504	38.6	21.8	25.2	-136.6	3985.6	2	23
79.901	37.9	21.5	24.8	-77.3	3891.8	2	24
79.171	38.5	21.8	25.1	-20.7	3636.0	2	25
79.256	38.5	21.8	25.1	31.0	3231.8	2	26
80.066	36.2	20.5	23.6	75.6	2698.2	2	27
81.451	38.5	21.8	25.1	111.4	2059.4	2	28
83.357	38.6	21.9	25.2	137.0	1345.1	2	29
85.536	37.4	21.2	24.4	151.6	590.0	2	30
87.848	37.9	21.5	24.8	154.7	-165.7	2	31
90.123	38.7	21.9	25.2	146.8	-876.5	2	32
92.232	36.3	20.6	23.7	128.9	-1491.5	2	33
93.949	36.3	20.8	24.0	102.8	-1954.7	2	34
95.260	36.8	20.8	24.0	71.3	-2204.6	2	35
96.081	36.3	20.6	23.7	38.1	-2174.6	2	36
96.418	36.3	20.6	23.7	7.9	-1792.6	2	37
96.361	36.7	21.9	25.2	-13.5	-981.2	2	38
96.092	38.2	21.6	25.0	-19.0	342.2	2	39
95.911	36.8	20.5	24.0	-0.3	2265.5	2	40
96.253	36.4	20.6	23.8	52.4	4882.1	2	41
97.709	36.3	20.5	23.7	150.2	8290.5	2	42
101.046	36.4	20.6	23.8	305.6	12594.6	2	43

DATA SHEET

UNWEIGHTED PERFORMANCE

SEGMENT 3 -- TRUNK

Θ	L	R	K	ω	α	S	P
71.604	47.0	18.6	23.4	195.0	-6720.9	3	1
73.857	48.2	19.0	24.0	110.6	-4607.2	3	2
75.065	48.2	19.0	24.0	54.8	-2894.0	3	3
75.616	48.7	19.3	24.2	22.0	-1537.3	3	4
75.815	48.7	19.3	24.2	7.1	-495.4	3	5
75.898	48.7	19.3	24.2	5.8	271.0	3	6
76.037	48.7	19.3	24.2	14.1	789.3	3	7
76.352	49.3	19.5	24.4	28.7	1124.6	3	8
76.917	48.2	19.0	24.0	47.0	1279.7	3	9
77.767	48.2	19.0	24.0	66.4	1295.3	3	10
78.907	50.4	20.2	25.0	85.3	1199.9	3	11
80.315	51.0	20.6	25.3	102.0	1019.7	3	12
81.951	50.4	20.2	25.0	115.6	778.9	3	13
83.762	49.3	19.5	24.4	125.2	499.2	3	14
85.684	49.3	19.5	24.4	130.4	200.5	3	15
87.652	48.2	19.0	24.0	131.2	-99.9	3	16
89.598	48.2	19.0	24.0	127.5	-386.7	3	17
91.457	50.3	20.2	25.0	119.7	-646.7	3	18
93.171	52.6	21.4	26.2	108.3	-869.0	3	19
94.691	51.5	20.8	25.6	93.9	-1045.1	3	20
95.976	50.4	20.2	25.0	77.2	-1168.3	3	21
97.000	51.5	20.8	25.6	59.1	-1234.5	3	22
97.747	51.0	20.6	25.3	40.5	-1241.5	3	23
98.216	50.4	20.2	25.0	22.2	-1189.4	3	24
98.418	50.4	20.2	25.0	5.1	-1080.5	3	25
98.378	52.6	21.4	26.2	-10.0	-919.4	3	26
98.132	53.2	21.8	26.4	-22.3	-712.6	3	27
97.727	52.6	21.4	26.2	-31.2	-469.3	3	28
97.216	50.4	20.2	25.0	-36.2	-200.3	3	29
96.661	51.5	20.8	25.6	-37.1	80.8	3	30
96.124	51.5	20.8	25.6	-33.8	358.8	3	31
95.667	52.6	21.4	26.2	-26.5	615.8	3	32
95.347	54.4	22.4	27.9	-15.5	832.0	3	33
95.214	54.4	22.4	27.9	-1.8	985.3	3	34
95.301	54.4	22.4	27.9	13.6	1051.4	3	35
95.623	54.9	22.7	27.2	29.2	1003.7	3	36
96.167	56.0	23.3	27.8	43.0	813.7	3	37
96.891	56.0	23.3	27.8	52.7	450.4	3	38
97.713	54.9	22.7	27.2	55.5	-119.3	3	39
98.594	54.4	22.4	27.9	47.9	-930.6	3	40
99.080	56.0	23.3	27.8	26.1	-2021.1	3	41
99.195	56.0	23.3	27.8	-14.3	-3430.4	3	42
98.531	54.9	22.7	27.2	-78.6	-5200.4	3	43

DATA SHEET

UNWEIGHTED PERFORMANCE

SEGMENT 4 -- UPPER ARM

θ	L	R	K	ω	α	S	P
272.896	26.9	11.7	14.6	-328.7	8249.5	4	1
268.844	27.5	12.4	15.4	-197.2	9190.9	4	2
266.941	27.5	12.4	15.4	-55.5	9626.5	4	3
267.196	27.5	12.4	15.4	89.5	9629.7	4	4
269.611	26.9	11.7	14.6	231.6	9269.7	4	5
274.196	26.3	11.5	14.2	366.1	8611.3	4	6
280.534	25.2	11.0	13.6	488.8	7715.5	4	7
288.695	22.9	10.0	12.4	596.6	6638.8	4	8
298.347	21.8	9.5	11.8	687.3	5433.8	4	9
309.220	21.8	9.5	11.8	759.2	4148.7	4	10
321.026	21.8	9.5	11.8	811.6	2827.6	4	11
333.468	21.8	9.5	11.8	844.1	1510.6	4	12
346.251	21.8	9.5	11.8	857.1	233.4	4	13
359.057	22.4	9.8	12.1	851.4	-972.4	4	14
371.707	22.4	9.8	12.1	828.4	-2079.4	4	15
383.861	24.1	10.5	13.0	789.7	-3064.3	4	16
395.328	27.5	12.4	15.4	737.2	-3907.9	4	17
405.919	25.2	11.0	13.6	673.2	-4595.5	4	18
415.480	25.8	11.3	14.0	600.2	-5116.1	4	19
423.892	26.3	11.9	14.3	520.6	-5463.3	4	20
431.078	27.5	12.5	15.4	437.1	-5634.5	4	21
437.000	26.3	11.9	14.3	352.4	-5631.8	4	22
441.658	28.0	12.2	15.2	269.0	-5460.2	4	23
445.090	26.9	11.7	14.6	189.4	-5131.7	4	24
447.370	27.5	12.4	15.4	115.8	-4658.9	4	25
448.604	28.0	12.2	15.2	50.3	-4060.7	4	26
448.927	28.6	12.5	15.5	-5.5	-3359.8	4	27
448.495	28.6	12.5	15.5	-50.2	-2583.0	4	28
447.483	28.0	12.2	15.2	-82.8	-1761.3	4	29
446.074	27.5	12.4	15.4	-102.9	-929.7	4	30
444.456	27.5	12.4	15.4	-110.8	-127.6	4	31
442.808	26.9	11.7	14.6	-107.1	601.4	4	32
441.293	26.9	11.7	14.6	-93.4	1209.5	4	33
440.046	27.5	12.4	15.4	-71.7	1645.9	4	34
439.165	27.5	12.4	15.4	-45.1	1853.5	4	35
438.698	28.0	12.2	15.2	-17.5	1772.4	4	36
438.622	28.0	12.2	15.2	6.3	1338.4	4	37
438.838	28.0	12.2	15.2	20.5	452.9	4	38
439.155	27.5	12.4	15.4	18.3	-866.8	4	39
439.265	27.5	12.4	15.4	-8.3	-2787.4	4	40
438.737	27.5	12.4	15.4	-68.6	-5360.1	4	41
436.988	27.5	12.4	15.4	-172.8	-8670.1	4	42
433.273	27.5	12.4	15.4	-332.8	-12806.7	4	43

DATA SHEET

UNWEIGHTED PERFORMANCE

SEGMENT 5 -- LOWER ARM

Θ	L	R	K	ω	α	S	P
310.288	24.6	10.6	12.9	-548.3	40454.4	5	1
306.183	25.2	10.8	13.2	-26.6	29446.2	5	2
308.739	24.6	10.6	12.9	344.6	20349.3	5	3
315.906	24.6	10.6	12.9	592.4	12960.8	5	4
326.017	24.1	10.0	12.7	741.0	7088.3	5	5
337.748	24.6	10.6	12.9	811.8	2549.1	5	6
350.074	24.1	10.0	12.7	823.3	-829.1	5	7
362.233	22.4	9.6	11.8	791.9	-3208.6	5	8
373.685	22.4	9.6	11.8	731.3	-4741.7	5	9
384.084	22.4	9.6	11.8	653.1	-5570.2	5	10
393.240	21.8	9.4	11.5	567.0	-5826.3	5	11
401.094	21.8	9.4	11.5	480.6	-5631.8	5	12
407.687	21.8	9.4	11.5	399.8	-5098.3	5	13
413.137	21.3	9.2	11.2	328.8	-4327.5	5	14
417.616	21.3	9.2	11.2	270.7	-3410.9	5	15
421.329	21.8	9.4	11.5	226.8	-2429.9	5	16
424.495	21.8	9.4	11.5	197.7	-1455.7	5	17
427.333	22.9	9.8	12.0	182.8	-549.6	5	18
430.044	26.9	11.5	14.2	180.7	237.5	5	19
432.806	26.9	11.5	14.2	189.1	864.5	5	20
435.759	26.3	11.3	13.8	205.6	1300.7	5	21
439.0[illegible]	26.9	11.5	14.2	227.1	1525.4	5	22
442.580	25.2	10.8	13.3	250.3	1527.9	5	23
446.531	24.6	10.6	12.9	271.8	1307.7	5	24
450.711	25.2	10.8	13.2	288.5	874.5	5	25
455.114	24.6	10.6	12.9	297.1	248.1	5	26
459.570	24.6	10.6	12.9	295.1	-541.9	5	27
463.902	24.1	10.0	12.7	280.2	-1455.3	5	28
467.905	24.6	10.6	12.9	251.1	-2442.1	5	29
471.359	24.1	10.0	12.7	206.9	-3442.1	5	30
474.039	22.4	9.6	11.8	148.1	-4385.1	5	31
475.735	22.4	9.6	11.8	76.0	-5190.6	5	32
476.267	22.4	9.6	11.8	-6.5	-5768.1	5	33
475.508	21.8	9.4	11.5	-95.4	-6017.0	5	34
473.403	21.8	9.4	11.5	-184.8	-5826.5	5	35
469.997	22.9	9.8	12.0	-267.4	-5075.7	5	36
465.463	26.9	11.5	14.2	-333.6	-3633.7	5	37
460.126	26.9	11.5	14.2	-372.2	-1359.5	5	38
454.502	26.3	11.3	13.8	-369.5	1898.3	5	39
449.327	26.9	11.5	14.2	-309.5	6300.8	5	40
445.594	25.2	10.8	13.3	-173.9	12019.6	5	41
444.593	25.2	10.8	13.3	58.5	19236.1	5	42
447.952	25.2	10.8	13.3	411.6	28142.0	5	43

DATA SHEET

UNWEIGHTED PERFORMANCE

SEGMENT 6 -- HAND

Θ	L	R	K	ω	α	S	P
351.927	15.7	7.9	9.2	-251.4	45095.8	6	1
352.676	15.7	7.9	9.2	316.2	31054.0	6	2
360.461	16.8	8.5	9.9	693.2	19619.4	6	3
372.705	17.4	8.8	10.2	916.4	10506.7	6	4
387.350	17.4	8.8	10.2	1018.7	3445.1	6	5
402.805	17.9	9.1	10.5	1028.8	-1822.2	6	6
417.878	16.8	8.5	9.9	971.8	-5537.3	6	7
431.731	16.8	8.5	9.9	869.3	-7928.2	6	8
443.820	16.2	8.2	9.5	739.5	-9208.8	6	9
453.854	16.2	8.2	9.5	597.5	-9578.2	6	10
461.747	16.2	8.2	9.5	455.8	-9221.6	6	11
467.576	15.7	7.9	9.2	323.7	-8309.8	6	12
471.542	15.7	7.9	9.2	208.4	-6999.1	6	13
473.939	15.7	7.9	9.2	115.0	-5431.8	6	14
475.115	15.1	7.7	8.9	46.1	-3735.7	6	15
475.451	15.7	7.9	9.2	3.0	-2024.3	6	16
475.330	15.7	7.9	9.2	-15.0	-396.8	6	17
475.117	16.2	8.2	9.5	-9.8	1061.8	6	18
475.138	16.8	8.5	9.9	15.6	2281.0	6	19
475.667	16.8	8.5	9.9	57.2	3204.4	6	20
476.911	16.8	8.5	9.9	110.1	3790.1	6	21
479.000	16.8	8.5	9.9	169.1	4010.3	6	22
481.985	17.4	8.8	10.2	228.5	3851.7	6	23
485.829	16.8	8.5	9.9	282.7	3315.3	6	24
490.412	16.8	8.5	9.9	326.1	2416.2	6	25
495.533	16.8	8.5	9.9	353.5	1183.9	6	26
500.914	17.4	8.8	10.2	360.2	-537.6	6	27
506.215	17.4	8.8	10.2	342.2	-2090.1	6	28
511.043	17.4	8.8	10.2	296.7	-4001.4	6	29
514.970	16.8	8.5	9.9	221.8	-5984.4	6	30
517.550	16.8	8.5	9.9	117.3	-7938.3	6	31
518.347	16.8	8.5	9.9	-15.6	-9747.6	6	32
516.956	16.2	8.2	9.5	-173.7	-11282.5	6	33
513.034	16.2	8.2	9.5	-352.0	-12399.2	6	34
506.333	15.7	7.9	9.2	-542.8	-12939.2	6	35
496.735	15.7	7.9	9.2	-736.4	-12730.0	6	36
484.290	15.7	7.9	9.2	-920.1	-11584.7	6	37
469.260	14.6	7.4	8.6	-1078.3	-9302.0	6	38
452.162	14.6	7.4	8.6	-1192.4	-5666.4	6	39
433.819	14.6	7.4	8.6	-1240.3	-448.0	6	40
415.410	14.6	7.4	8.6	-1196.7	6597.3	6	41
398.523	14.6	7.4	8.6	-1032.0	15728.0	6	42
385.220	14.6	7.4	8.6	-713.0	27216.8	6	43

DATA SHEET

WEIGHTED PERFORMANCE

SEGMENT 1 -- LOWER LEG

θ	L	R	K	ω	α	S	P
30.152	37.0	10.8	21.2	-270.2	27910.3	1	1
28.860	35.8	10.4	20.5	74.1	18366.1	1	2
31.739	35.3	10.5	20.2	291.2	10901.4	1	3
37.105	35.3	10.5	20.2	410.1	5234.9	1	4
43.677	35.8	10.4	20.5	455.9	1103.5	1	5
50.522	36.4	10.6	20.8	449.7	-1737.6	1	6
56.996	35.3	10.5	20.2	409.1	-3514.7	1	7
62.696	37.0	10.8	21.2	348.5	-4436.0	1	8
67.409	37.0	10.8	21.2	279.3	-4691.0	1	9
71.076	36.4	10.6	20.8	210.2	-4451.3	1	10
73.749	36.4	10.6	20.8	147.5	-3869.9	1	11
75.554	36.4	10.6	20.8	95.2	-3081.5	1	12
76.667	35.8	10.4	20.5	55.5	-2202.6	1	13
77.285	35.8	10.4	20.5	29.1	-1331.2	1	14
77.602	35.8	10.4	20.5	15.1	-547.0	1	15
77.793	36.4	10.6	20.8	11.9	88.5	1	16
78.000	36.4	10.6	20.8	16.8	532.3	1	17
78.323	36.4	10.6	20.8	26.8	759.6	1	18
78.812	36.4	10.6	20.8	38.5	764.0	1	19
79.470	37.0	10.8	21.2	48.7	557.5	1	20
80.249	37.0	10.8	21.2	54.3	170.3	1	21
81.065	36.4	10.6	20.8	53.1	-349.0	1	22
81.800	36.4	10.6	20.8	43.5	-933.5	1	23
82.326	35.8	10.4	20.5	25.2	-1497.9	1	24
82.517	36.4	10.6	20.8	-0.8	-1938.7	1	25
82.277	36.4	10.6	20.8	-31.7	-2133.9	1	26
81.563	36.4	10.6	20.8	-62.9	-1943.3	1	27
80.423	37.0	10.9	21.5	-87.3	-1208.2	1	28
79.024	37.6	10.9	21.5	-95.5	248.1	1	29
77.698	37.0	10.8	21.2	-75.3	2621.1	1	30
76.983	37.0	10.8	21.2	-11.3	6124.2	1	31
77.672	36.4	10.6	20.8	115.2	10939.4	1	32
80.863	36.4	10.6	20.8	326.5	17466.9	1	33

DATA SHEET

WEIGHTED PERFORMANCE

SEGMENT 2 -- UPPER LEG

θ	L	R	K	ω	α	S	P
109.613	37.9	21.5	24.8	-148.9	28257.9	2	1
110.094	38.5	21.8	25.1	183.9	16601.2	2	2
114.361	38.5	21.8	25.1	362.6	7635.3	2	3
120.389	36.2	20.5	23.6	424.6	996.9	2	4
126.678	38.5	21.8	25.1	402.4	-3654.6	2	5
132.177	38.6	21.9	25.2	323.3	-6636.4	2	6
136.208	38.6	21.9	25.2	210.2	-8242.6	2	7
138.405	38.6	21.9	25.2	81.5	-8744.5	2	8
138.651	37.4	21.2	24.4	-47.9	-8389.9	2	9
137.021	37.9	21.5	24.8	-167.0	-7404.0	2	10
133.733	38.7	21.9	25.2	-267.9	-5988.5	2	11
129.102	36.3	20.6	23.7	-345.4	-4322.3	2	12
123.500	36.8	20.8	24.0	-397.1	-2561.0	2	13
117.322	38.7	21.9	25.2	-422.4	-837.2	2	14
110.952	38.2	21.6	25.0	-422.9	739.5	2	15
104.745	36.8	20.8	24.0	-401.4	2082.5	2	16
99.000	36.4	20.6	23.8	-361.9	3129.2	2	17
93.953	36.3	20.5	23.7	-309.2	3838.4	2	18
89.753	36.4	20.6	23.8	-248.5	4193.4	2	19
86.510	37.9	21.5	24.8	-185.2	4200.0	2	20
84.196	38.5	21.8	25.1	-124.1	3887.1	2	21
82.752	38.5	21.8	25.1	-69.9	3307.0	2	22
82.048	36.2	20.5	23.6	-25.9	2534.6	2	23
81.913	38.5	21.5	25.1	5.7	1668.3	2	24
82.153	38.6	21.9	25.2	24.3	829.4	2	25
82.583	37.4	21.2	24.4	31.4	152.3	2	26
83.056	38.7	21.9	25.2	30.8	-165.5	2	27
83.502	36.3	20.6	23.7	29.1	36.6	2	28
83.979	36.8	20.8	24.0	35.7	982.2	2	29
84.677	36.8	20.8	24.0	63.5	2908.2	2	30
86.062	36.3	20.6	23.7	129.1	6074.2	2	31
88.842	36.3	20.6	23.7	253.3	10763.4	2	32
94.079	38.7	21.9	25.2	461.1	17281.6	2	33

DATA SHEET

WEIGHTED PERFORMANCE

SEGMENT 3 -- TRUNK

Θ	L	R	K	ω	α	S	P
71.975	48.2	19.0	23.9	144.9	-2548.8	3	1
73.884	48.2	19.0	23.9	111.1	-1963.2	3	2
75.350	48.7	19.3	24.2	85.8	-1409.5	3	3
76.498	48.7	19.3	24.2	68.6	-900.6	3	4
77.443	48.2	19.0	23.9	58.5	-447.1	3	5
78.286	48.7	19.3	24.2	54.8	-57.6	3	6
79.114	48.7	19.3	24.2	56.4	261.2	3	7
80.000	49.3	19.5	24.4	62.3	504.8	3	8
80.998	49.3	19.5	24.4	71.2	670.7	3	9
82.145	48.7	19.3	24.2	82.0	758.5	3	10
83.462	49.3	19.5	24.4	93.6	769.7	3	11
84.951	49.3	19.5	24.4	104.7	708.0	3	12
86.597	52.0	21.1	25.8	114.5	579.1	3	13
88.373	52.6	21.4	26.2	121.8	390.8	3	14
90.235	52.6	21.4	26.2	125.9	152.8	3	15
92.132	49.3	19.5	24.4	126.2	-123.0	3	16
94.000	52.6	21.4	26.2	122.1	-422.8	3	17
95.773	53.7	22.1	26.7	113.5	-730.6	3	18
97.382	54.9	22.7	27.2	100.3	-1028.4	3	19
98.760	50.4	20.2	25.0	82.8	-1296.2	3	20
99.847	52.6	21.4	26.2	61.6	-1512.0	3	21
100.595	53.2	21.8	26.4	37.8	-1651.6	3	22
100.974	52.6	21.4	26.2	12.6	-1688.8	3	23
100.975	50.4	20.2	25.0	-12.2	-1595.4	3	24
100.621	51.5	20.8	25.6	-34.5	-1341.2	3	25
99.968	54.4	22.4	27.9	-51.5	-893.8	3	26
99.118	54.4	22.4	27.9	-60.1	-219.0	3	27
98.224	54.9	22.7	27.2	-56.7	719.8	3	28
97.498	54.9	22.7	27.2	-37.0	1961.0	3	29
97.219	56.0	23.3	27.8	3.8	3545.1	3	30
97.745	54.9	22.7	27.2	71.3	5514.5	3	31
99.520	56.0	23.3	27.8	171.4	7914.1	3	32
103.085	54.9	22.7	27.2	311.1	10790.3	3	33

DATA SHEET

WEIGHTED PERFORMANCE

SEGMENT 4 -- UPPER ARM

Θ	L	R	K	ω	α	S	P
306.027	22.9	10.0	12.4	-1159.9	66582.5	4	1
295.377	21.8	9.5	11.8	-307.1	47750.9	4	2
295.537	21.8	9.5	11.8	290.2	32432.2	4	3
303.052	21.8	9.5	11.8	681.3	20210.5	4	4
315.166	22.9	10.0	12.4	910.0	10694.2	4	5
329.729	22.9	10.0	12.4	1013.9	3515.9	4	6
345.121	21.8	9.5	11.8	1025.4	-1667.8	4	7
360.169	21.8	9.5	11.8	972.2	-5175.9	4	8
374.078	21.8	9.5	11.8	877.1	-7303.4	4	9
386.365	22.4	9.8	12.1	758.6	-8321.1	4	10
396.796	22.4	9.8	12.1	631.7	-8475.6	4	11
405.331	22.4	9.8	12.1	507.6	-7989.3	4	12
412.078	24.1	10.5	13.0	394.3	-7060.5	4	13
417.240	27.5	12.4	15.4	297.1	-5863.3	4	14
421.086	25.2	11.0	13.6	219.0	-4547.5	4	15
423.908	25.8	11.3	14.0	160.6	-3239.0	4	16
426.000	26.3	11.9	14.3	121.2	-2039.4	4	17
427.629	27.5	12.4	15.4	98.5	-1026.0	4	18
429.023	26.3	11.9	14.3	89.3	-252.0	4	19
430.355	26.9	11.7	14.6	89.6	253.4	4	20
431.739	27.5	12.4	15.4	95.5	485.3	4	21
433.227	28.0	12.2	15.2	102.9	463.1	4	22
434.816	28.6	12.5	15.5	108.3	230.2	4	23
436.453	28.6	12.5	15.5	109.1	-145.8	4	24
438.057	28.0	12.2	15.2	103.7	-573.1	4	25
439.533	27.5	12.4	15.4	92.2	-935.8	4	26
440.802	27.5	12.4	15.4	76.6	-1093.7	4	27
441.832	26.9	11.7	14.6	61.2	-882.5	4	28
442.674	26.9	11.7	14.6	52.9	-113.8	4	29
443.505	28.0	12.2	15.2	61.7	1425.2	4	30
444.675	28.0	12.2	15.2	100.7	3971.1	4	31
446.763	28.0	12.2	15.2	187.1	7785.1	4	32
450.631	28.0	12.2	15.2	342.0	13152.2	4	33

DATA SHEET

WEIGHTED PERFORMANCE

SEGMENT 5 -- LOWER ARM

Θ	L	R	K	ω	α	S	P
334.849	24.6	10.6	12.9	728.8	-13212.8	5	1
344.456	25.2	10.8	13.2	562.5	-9107.0	5	2
351.999	24.6	10.6	12.9	451.5	-5826.2	5	3
358.218	24.1	10.0	12.7	384.0	-3276.3	5	4
363.687	24.6	10.6	12.9	350.0	-1368.0	5	5
368.838	22.4	9.6	11.8	340.2	-16.8	5	6
373.976	22.4	9.6	11.8	347.1	857.3	5	7
379.300	22.9	9.8	12.0	363.9	1329.4	5	8
384.916	22.4	9.6	11.8	385.3	1470.1	5	9
390.859	21.8	9.4	11.5	406.7	1344.9	5	10
397.100	21.8	9.4	11.5	424.6	1015.1	5	11
403.567	21.8	9.4	11.5	436.4	536.8	5	12
410.152	21.3	9.2	11.2	440.2	-38.3	5	13
416.728	21.3	9.2	11.2	435.0	-663.4	5	14
423.155	21.8	9.4	11.5	420.3	-1296.2	5	15
429.291	22.9	9.8	12.0	396.3	-1899.4	5	16
435.000	26.9	11.5	14.2	363.6	-2440.1	5	17
440.162	26.3	11.3	13.8	323.5	-2890.3	5	18
444.676	26.9	11.5	14.2	277.5	-3226.8	5	19
448.466	24.6	10.6	12.9	227.4	-3431.0	5	20
451.488	25.2	10.8	13.2	175.3	-3488.9	5	21
453.727	24.6	10.6	12.9	123.5	-3391.4	5	22
455.206	24.1	10.0	12.7	74.4	-3134.0	5	23
455.982	24.1	10.0	12.7	30.3	-2717.0	5	24
456.151	22.4	9.6	11.8	-6.4	-2145.5	5	25
455.839	22.4	9.6	11.8	-33.4	-1429.0	5	26
455.209	22.9	9.8	12.0	-48.6	-582.0	5	27
454.449	26.9	11.5	14.2	-50.3	376.4	5	28
453.776	26.3	11.3	13.8	-36.9	1422.4	5	29
453.424	26.9	11.5	14.2	-7.3	2527.4	5	30
453.641	25.2	10.8	13.3	39.1	3658.1	5	31
454.681	25.2	10.8	13.3	102.4	4776.6	5	32
456.795	25.2	10.8	13.3	182.1	5840.1	5	33

DATA SHEET

WEIGHTED PERFORMANCE

SEGMENT 6 -- HAND

Θ	L	R	K	ω	α	S	P
28.853	17.9	9.1	10.5	172.8	19066.4	6	1
33.250	16.8	8.5	9.9	392.3	10609.7	6	2
40.076	16.8	8.5	9.9	502.3	4389.2	6	3
47.925	16.2	8.2	9.5	533.5	65.0	6	4
55.818	16.2	8.2	9.5	512.1	-2680.2	6	5
63.132	16.2	8.2	9.5	459.5	-4140.7	6	6
69.534	15.7	8.0	9.2	392.9	-4588.0	6	7
74.918	15.7	8.0	9.2	325.7	-4270.9	6	8
79.350	15.7	8.0	9.2	267.5	-3415.4	6	9
83.021	15.1	7.7	8.9	224.9	-2224.7	6	10
86.194	15.7	8.0	9.2	201.5	-879.1	6	11
89.169	15.7	8.0	9.2	198.5	463.7	6	12
92.246	16.2	8.2	9.5	214.7	1668.9	6	13
95.693	16.8	8.5	9.9	247.3	2624.5	6	14
99.725	16.8	8.5	9.9	291.8	3241.3	6	15
104.478	16.8	8.5	9.9	342.5	3452.7	6	16
110.000	16.8	8.5	9.9	393.1	3215.3	6	17
116.236	17.4	8.8	10.2	436.6	2508.1	6	18
123.028	16.8	8.5	9.9	466.0	1333.1	6	19
130.112	16.8	8.5	9.9	474.4	-255.0	6	20
137.124	16.8	8.5	9.9	455.5	-2298.7	6	21
143.612	17.4	8.8	10.2	403.8	-4637.7	6	22
149.053	17.4	8.8	10.2	315.2	-7208.8	6	23
152.870	16.8	8.5	9.9	187.0	-9896.2	6	24
154.460	16.2	8.2	9.5	18.4	-12561.1	6	25
153.228	16.2	8.2	9.5	-182.0	-15042.2	6	26
148.618	15.7	8.0	9.2	-431.0	-17155.0	6	27
140.159	15.7	8.0	9.2	-700.7	-18692.5	6	28
127.509	15.7	8.0	9.2	-987.8	-19425.1	6	29
110.508	15.7	8.0	9.2	-1278.2	-19029.9	6	30
89.234	14.6	7.4	8.6	-1554.1	-17441.5	6	31
64.067	14.6	7.4	8.6	-1793.3	-14151.6	6	32
35.753	14.6	7.4	8.6	-1968.9	-8909.3	6	33

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