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FORCES, TORQUES AND ACCELERATIONS
INVOLVED IN SELECTED LIFTING AND LOWERING TECHNIQUES

by

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B.E. (Mech.), University of Burdwan, India, 1970

A MASTER'S REPORT

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requirements for the degree

MASTER OF SCIENCE

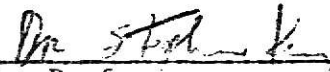
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INTRODUCTION

Man is limited in manual material handling by both his skeleto-muscular system and his cardiorespiratory system. The skelto-muscular system limits the amount of weight that he can handle at infrequent intervals. The cardio-respiratory system, on the other hand, limits the amount of weight if the task is frequent. An important aspect of all weight lifting operations is the risk of structural injuries -- in particular to the skeleto-muscular structure of the back. Much attention has been given to the problem of back-injuries and there are numerous publications available on the subject. However, most of them deal with repetitive lifting. In the United States, the problem today is injuries due to occasional peak loads. The percentage of industrial injuries due to lifting has remained constant for the last two or three decades. In order to analyze the effects of forces and torques on the spine when a lift is made and thereby to establish safety standards for different percentiles of the population, it is essential to know how different variables in lifting are related to the various forces, torques and accelerations involved.

LITERATURE REVIEW

Industrial Accidents

According to a study made by Brown (1958), approximately 25 percent of handling accidents are due to lifting. Peres (1964) stated "in most countries, about one third of all compensible industrial injuries arise from incorrect handling of materials". Troup (1965) stated "manual handling accounts for 25 percent of all reported industrial accidents in the United Kingdom and 34 percent in France". Bond (1970) commented that every year about 2 percent of all employees will have a compensible injury. Snook, Irvine and Bass (1970) reported that 24 percent of all "high cost workman's compensation accidents" compiled by Liberty Mutual Insurance Company were associated with manual material handling. Brown (1971) reported, from the records of Workmen's Compensation Board, Ontario, that back injuries were 24.8% of all reportable injuries for the period 1964-1968.

Back Injuries

Wayne (1954) and Ruseck (1955) made statistical inquiries and established that there was a high number of back injuries in tasks involving weight lifting. According to Morris, Lucas and Breasler (1961), Nachemon (1962) and Armstrong (1965), injuries to the spine in lifting seem to be concentrated on the vertebral bodies, intervertebral discs and soft tissues (muscles and ligaments). Similarly, Thieme (1950), Perey (1957) and Sonoda (1962) investigated the effect of injuries on the general anatomy of the body. Fine (1966), Chaffin (1967), and

Chaffin and Baker (1970) developed mathematical models to study the different parts of the spine affected by different forces involved in lifting.

Varying Recommendations

The laws and recommendations for weight lifting vary in different countries and states both for adult males and females. The International Labour Office (Muchinger, 1962) gave the maximum permissible weight for "occasional lifting with straight back" as a surprising "880 lbs for 0 degrees of trunk inclination and 110 lbs for 90 degrees of trunk inclination" for males and "528 lbs for 0 degrees of trunk inclination and 66 lbs for 90 degrees of trunk inclination" for females. Peres (1964) recommended maximum load for male adults in the U.K. as 130 pounds.

Bending Vs Squatting

Two types of lifting are generally used -- a "bend" and a "squat". "Bend" is defined as bending over from the waist, with the legs kept straight at all times, lifting the weight, and placing it on a shelf. "Squat" is defined as lifting by bending the knees and keeping the back relatively straight (See Fig. 1).

A "squat" is the lifting method recommended by most authors and researchers. Anderson (1951) has suggested "when the trunk is erect and straight, the spinal joints are stabilized and the resistance or weight to be lifted by the spinal lever is more directly over the fulcrum. The spine should be straight when it takes the load to avoid back strain". Munchinger (1960) stated that to prevent back injuries, loads should be

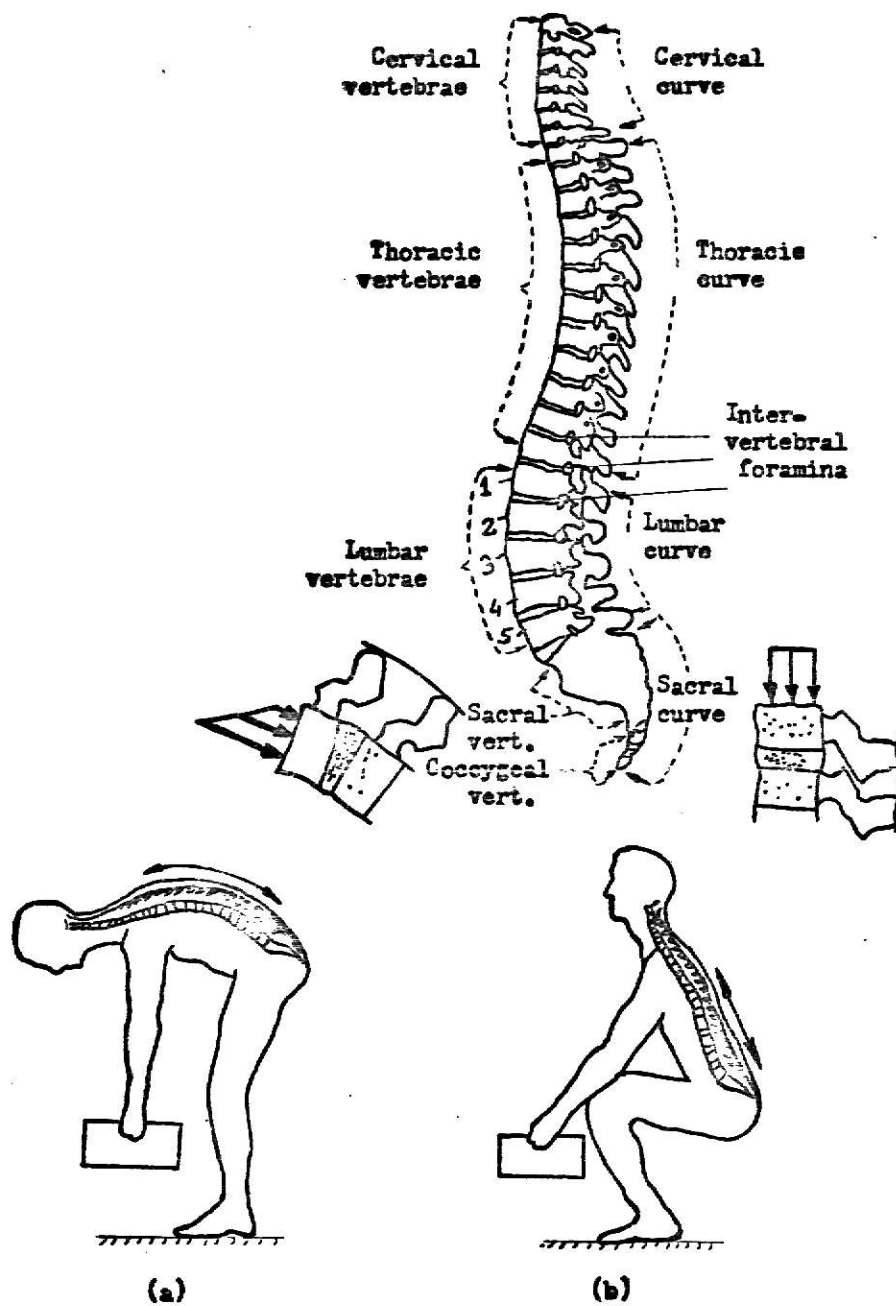


Fig. 1. Effect on the lumbar intervertebral discs when lifting in (a) 'bending' position and (b) 'squatting' position.

raised smoothly from a squatting position with the upper part of the body erect and the back flat. He found that in bending a pressure of 300 kg on the 5th lumbar intervertebral disc is induced by an average upper body weight of 45 kg. and lever arm of the bent trunk amounting to about 35 cm. Thus, high pressure develops on the periphery of the disc and increases the risk of rupture (see Fig 1a). When the same operator lifts a load of 50 kg, the disc pressure reaches 700 kg. On the other-hand, in squatting the pressure is equally distributed and the danger of accident is reduced (see Fig 1b). Similarly, McFarland (1969) has concluded "Leg lift, with back vertical and knees bent, affords a stronger vertical pull than back lift, and entails much less risk of injury".

Stueve (1968) studied the physiological cost of lifting and lowering a 25 pound tote-box. Three orthogonal forces were measured by a force platform for bending versus squatting. For the lifting procedures studied, Stueve found that the physiological cost is less for a bending manner than a squatting manner. He also concluded that the physiological cost for lowering an object was greater than for lifting it. While most researchers advocate the squatting manner for lifting, a few doubt its supremacy over the bending manner. According to Brown (1972), "workers prefer to use some method which is more suitable to their own physical strength and physical anthropology. ... for small weights up to 20-30 pounds the manner of lifting would not appear to be dictated by the weight lifted". Jones (1971) also questions the sole use of the straight back lifting method for it causes unnecessary fatigue. "However", Brown

concludes, "for objects weighing more than 50 pounds, it would appear that the only way possible from a physical mechanical point of view, is with bent legs and a straight back, for this task only but not necessarily for a static lift from the ground".

Repetitive vs Occasional Lifting

Most of the work done in the field of lifting concerns repetitive lifting. However the problem today in the U.S.A. is not injuries due to repetitive loads but occasional peak loads.

Whitney (1958) conducted a study on the maximum isometric lifting force by varying the distance between feet and frontal plane through the grasp axis. He concluded that maximum lifting force decreased with the increase of this distance. Switzer (1962) studied the capabilities of human males for lifting weights to three different heights using three different positions. The weight limit decreased significantly with increased height but no significant lifting differences were found for the three lifting positions. Snook and Irvine (1965) investigated maximum weight and workloads for performing different tasks such as lifting, lowering, pulling and pushing without strain or discomfort. Damon, Stoudt and McFarland (1966) concluded that less powerfully built persons can be more efficient in performing repetitive lifting tasks. Kamon and Belding (1971) reported 33 lbs to be about the limit for repetitive handling of bulky loads. Snook, Irvine and Bass (1970) used heart rate and subject determined loads as criteria for lifting.

Larau (1957) studied lifting in France with a three axis force platform. Peak force was 45 kg for a 5 kg load, 70 kg for a 15 kg load and 85 kg for a 25 kg load. Morris, Lucas and Bresler (1961) showed the importance of

the intra-abdominal and intra-thoracic pressures -- especially for dynamic loading of the spine such as occurs at the beginning of the lift when acceleration takes place. Zajaczkowska (1962) used photography to study velocity and acceleration as a function of skill. He concluded, "skill in lifting consists of a progressive shift in the direction from constant accelerations to constant velocities. ... In terms of force, the contention that skill in lifting consists of reducing acceleration to zero can be restated in the proposition that the skill consists of in using force equal to the force represented by the lifted weight for sometime during movement". Nachemson (1965) reported that the load on the lumbar discs, when the effect of increased intra-abdominal pressure is taken into consideration, is considerably less than was thought. Konz and Day (1966) proved that the force for a task had two components: (i) force due to the task and (ii) force due to the body position. Groh, Thos and Baumann (1967) studied the effect of various angles of lifting on load of the fifth lumbar disc. Chaffin (1969) reported on a biomechanical model of lifting in the sagittal body plane. Chaffin and Baker (1970) developed a computerized model of lifting with eight solid links representing the major body segments. Poulsen (1970) gave a formula to predict lifting ability; she stated the correlation between maximum load and body weight was low (r less than 0.2) but r was 0.7 for load versus back muscle strength; she also noted that the regression lines for men and women were different with men being able to lift heavier loads than women for the same measured muscle strength. Poulsen and Jorgensen (1971) gave two formulas: for men, maximum load to be lifted is equal to 1.10 (isometric back muscle strength); for women maximum load to be lifted should equal to 0.95 (isometric back strength)

minus 8 kg. Tichauer (1971) used a one-axis force platform in combination with electromyography and photography and concluded that weight/bulk of the object lifted is a major determinant of the severity of the lifting task. Martin and Chaffin (1972) evaluated lifts, pushes and pulls over a range of body positions with a nine link model.

As can be seen from the above, experiments have been done using two types of criteria. "Endurance oriented" criteria have been used mostly. The other type is "biomechanical". Maximum stress is more relevant for a safety oriented study than is the average stress. Average stress is more relevant for an endurance or energy oriented study. Thus, maximum or peak output was used as the criterion in our experiment of lifting and lowering.

PROBLEM

In order to find the limiting conditions of stress on the spine for safety in any lifting and lowering task, the major lifting variables must be explored. A mathematical model employing a set of equations may be developed to predict stress on any part of the body (say lumbar discs) for a particular task, after all the major lifting variables have been thoroughly investigated. Lifting variables can be placed into three major categories — task, individual and technique. Task variables include object weight, original location of the object to be lifted, load size, load rigidity and density, handles and symmetry of the lift. Individual variables include body weight, height, sex, age and physical fitness. Technique variables include back position, hand position, foot position, acceleration of body (slow, medium and jerky), distance of the body centerline from the load and subject training.

Konz, Dey and Bennett (1971) investigated the effect of the task variable (by changing the weight of load, distance of load from heel and angle of turn) on lifting. They found that the average peak vertical force did not triple when the object weight was tripled; the vertical force was 47 lbs. with a load of 11 lbs and 54 lbs; with a load of 33 lbs. It was concluded that the weight of the body must be considered in addition to the weight of the object. The results also emphasized the importance of acceleration. Perkins and Konz (1973) investigated the individual variable (by using 10 subjects, each representing one decile of the distribution of heights of male U.S. adults for the same task) and concluded that weight squared was the best single predictor of peak lifting force ($r=.61$ for

vertical, .36 for frontal and .70 for lateral).

Whitney (1958) emphasized "that foot placement is the most important variable affecting the magnitude of the maximum lifting force".

Tichauer (1971) showed that torque was the true index of task severity. Brown (1972) commented that "a back injury may result equally well from lifting a pencil or a hundred pounds, and in this connection it should be stressed that it is not the weight which is important but the manner in which this weight is lifted". From above, the importance of technique is pointed up.

To supplement the work done by Konz, Dey and Bennett, this study dealt with the investigation of effect of two different foot positions — feet parallel and left foot leading (see Fig. 2 and Fig. 3 respectively). The effect was investigated both when lifting (or lowering) involved a '45 degree turn of body' and a '0 degree turn of body' (see Fig. 4 and Fig. 5 respectively). As acceleration had been established to be of great importance, its effect on vertical forces was analyzed. Finally, another purpose of the study was to find the moment when the force (or torque) was a high peak and hence to locate the "critical" elements of lifting in the force-time history or torque-time history.

The 'distance' between the center of the load and the center of gravity of the body was kept constant. The center of gravity of the body while standing erect was assumed to lie in the vertical plane passing through the center of the two ears of the body (Asmussen, 1960).

The 'weight' of the load lifted by the subject was also kept constant.

The individual variable of 'body weight' was kept constant as far as possible by choosing subjects whose weight fell between the 40th and 60th

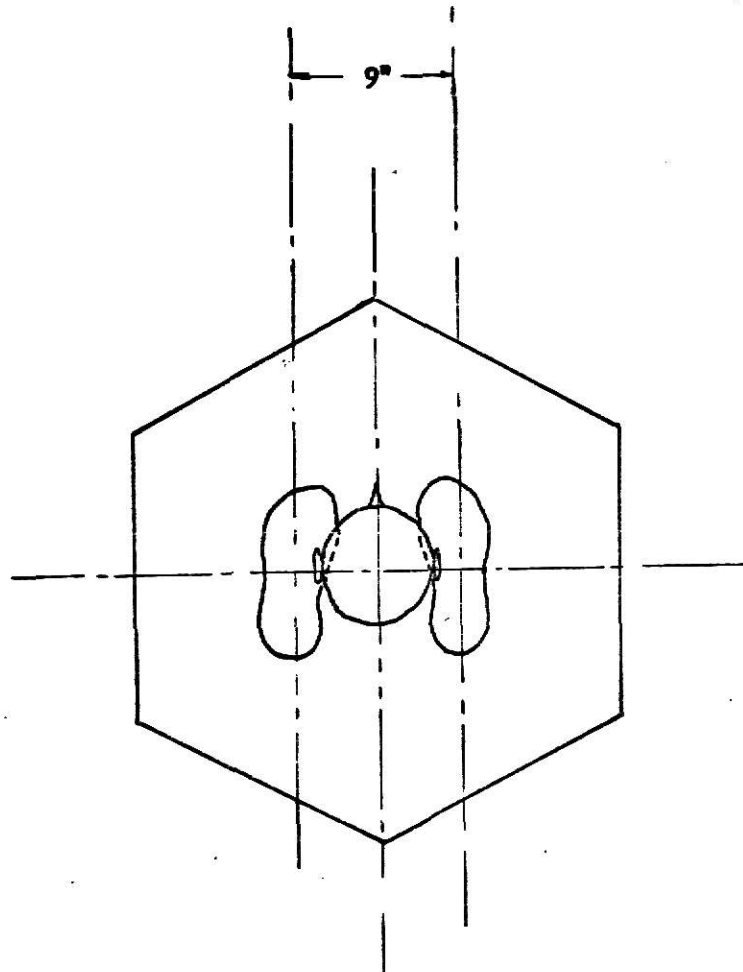


Fig. 2. Parallel feet (top view).

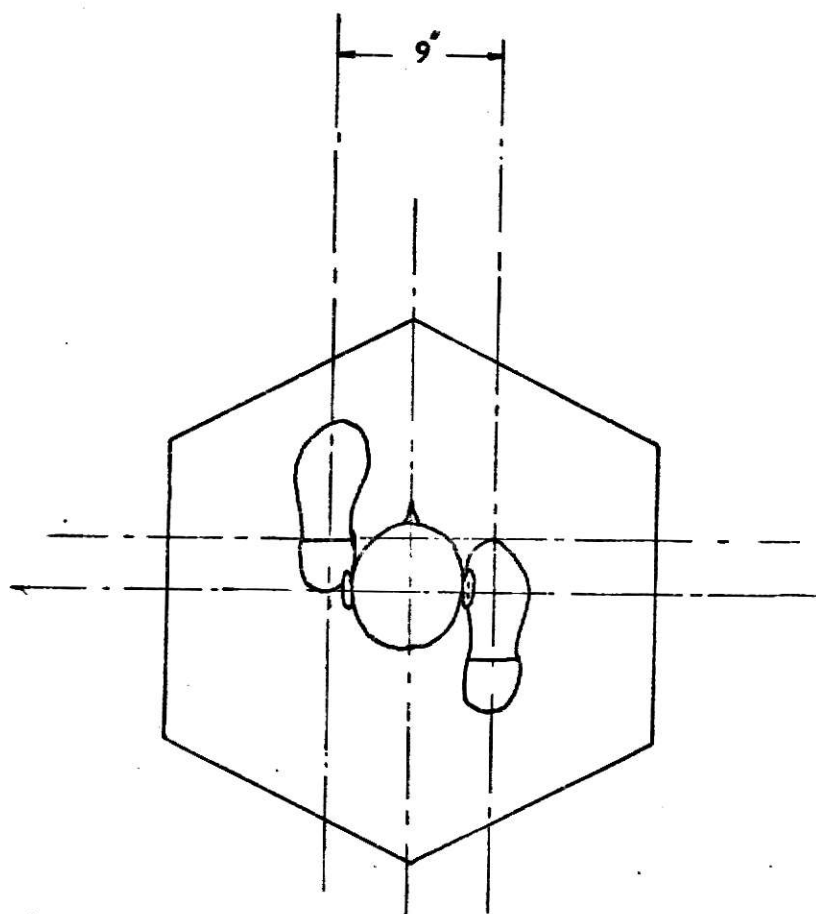


Fig. 3. Left foot leading (top view).

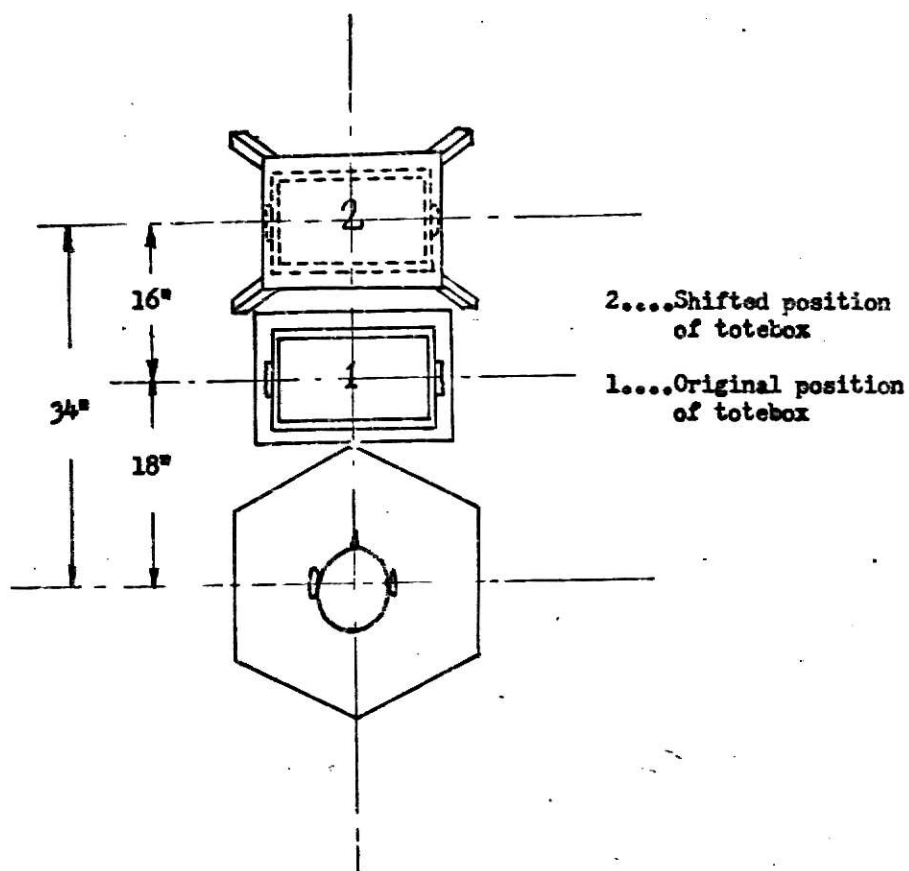


Fig. 4. Lifting with "0 degree angle of turn" (top view).

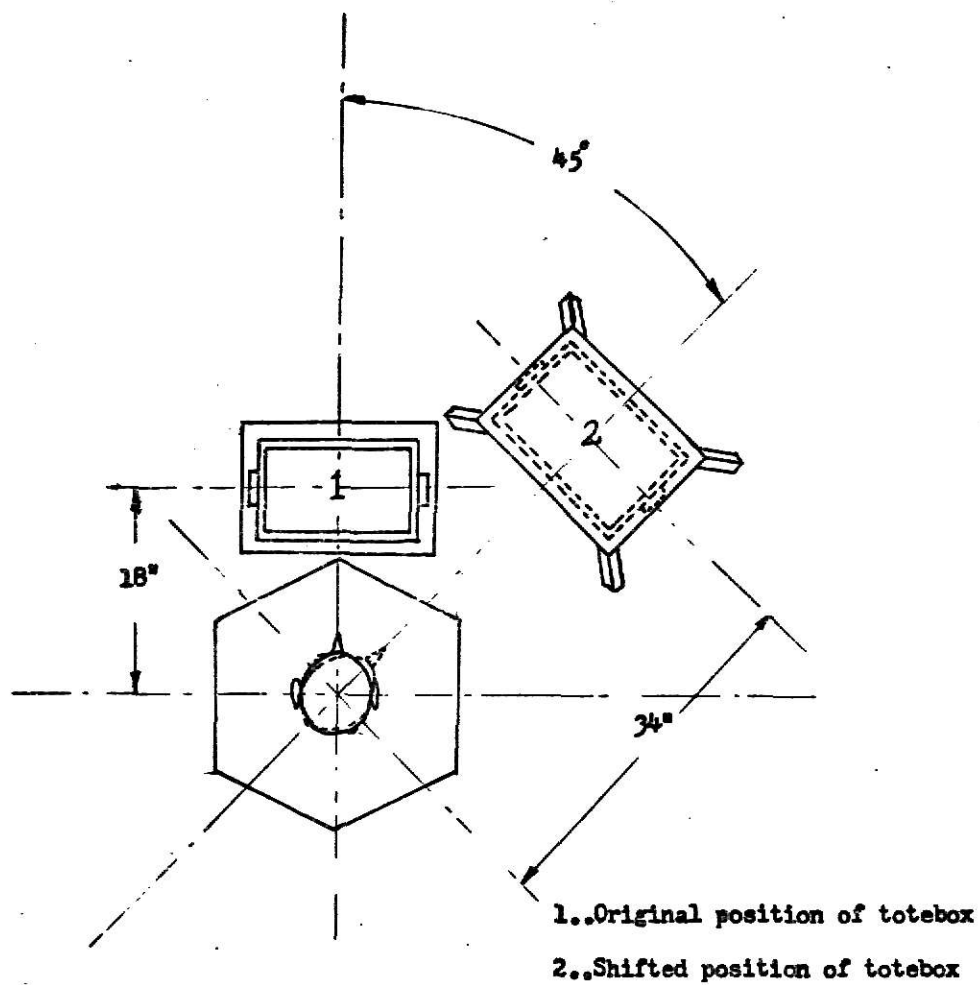


Fig. 5. Lifting with "45 degrees angle of turn to the right" (top view).

percentiles of the weight of the U.S. adult male population.

The 'angle' of rotation (amount of turn the spine rotates through during the task) was 0 degree and 45 degrees to the right.

The forces which were measured were vertical, lateral and frontal. The torques were twist, somersault and cartwheel. The forces and torques along and about the three orthogonal axes are shown in Fig. 6.

The vertical force acts along the vertical (Z) axis which is perpendicular to the plane containing the feet. The vertical force in the upward direction is considered as positive.

The lateral force acts along the lateral (X) axis which lies in the plane passing through the shoulders. The lateral force in the direction of the left side of the subject is considered as positive.

The frontal force acts along the frontal (Y) axis which is perpendicular to the plane passing through the shoulders. The frontal force in the front direction of the subject is considered as positive.

The twist torque is the torque acting about the vertical (Z) axis. It is considered as positive when it acts clockwise about that axis.

The somersault torque is the torque acting about the lateral (X) axis. A clockwise somersault torque about its axis is considered as positive.

The cartwheel torque is the torque acting about the frontal (Y) axis. A clockwise cartwheel torque about its axis is considered as positive.

The vertical acceleration acts along the vertical (Z) axis. A vertical acceleration in the upward direction is considered as positive.

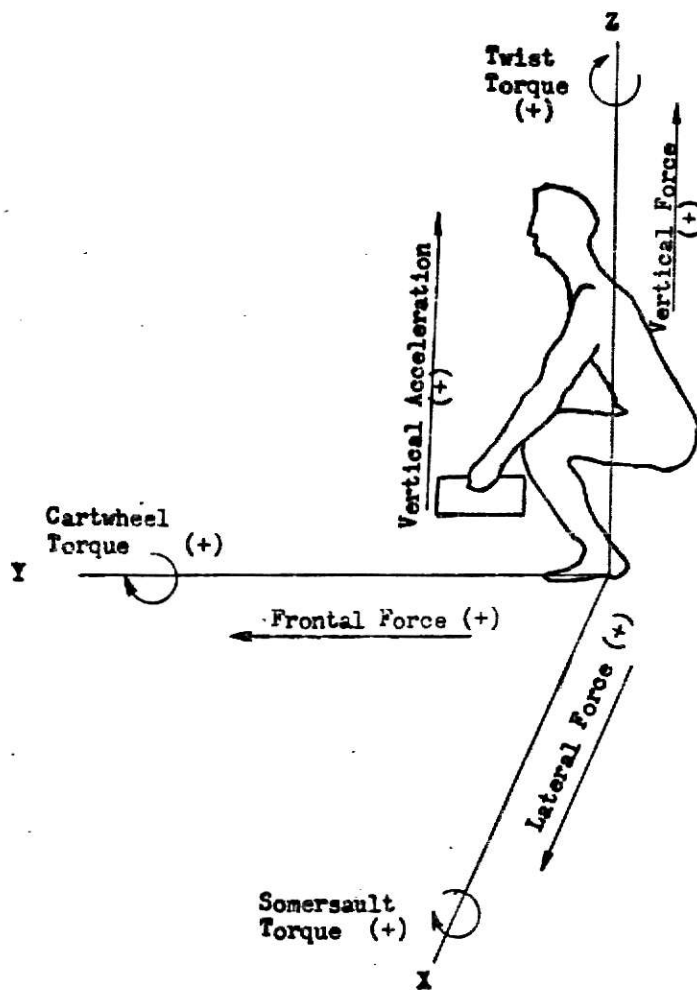


Fig. 6. Nomenclature of forces, torques, and accelerations involved in the body while lifting (or lowering).

This assumption is made because an acceleration in the upward direction adds to the gravitational pull and hence tends to increase the total force on the body. A corollary to this assumption is that deceleration in the upward direction is negative and likewise deceleration in the downward direction is positive.

All the forces and torques and in particular the accelerations were investigated in an attempt to define and establish their nature and their behaviour for a typical lifting and lowering task.

METHOD

Experimental Arrangement and Task

The apparatus for the experiment consisted of the following:

- A. A force platform.
- B. A linear accelerometer.
- C. Three two-channel oscillograph recorders.
- D. A one-channel dynograph recorder.
- E. A platform for the load at the start of lifting.
- F. A shelf for the load at the end of the lift.
- G. Standard weights in pounds.
- H. A tote-box.
- I. A stop watch.
- J. A chair.
- K. A video-tape recording set and monitor.

The force platform used was a six axis force platform (Hearn and Konz, 1968). The platform was calibrated at the beginning of the experiment.

A general purpose linear accelerometer (Entran Devices) was used to measure the acceleration of the tote box in the vertical direction. The range of the accelerometer was $\pm 10g$. Fig. 7a shows an output for acceleration while lifting a tote box with "feet parallel and 45° turn of body".

The three two-channel recorders were used to record forces on the three orthogonal axes and their associated torques. The force (or torque) trace originates from an established "zero" or "datum" line and deviates up or down. The distance deviated is directly proportional to the force or

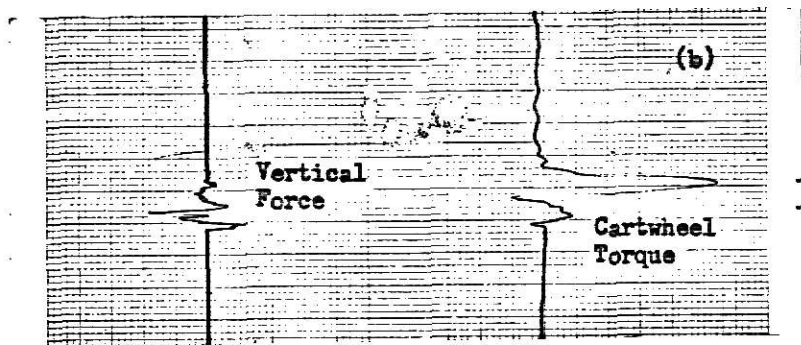
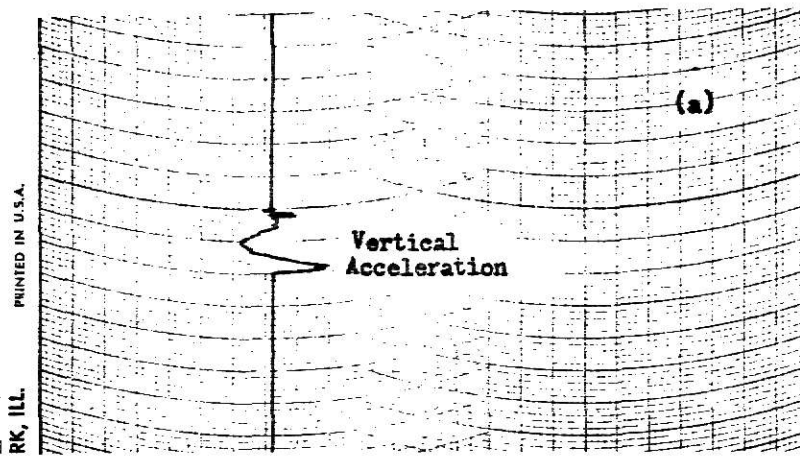


Fig. 7. Outputs from recorders for (a) vertical acceleration and (b) vertical force and cartwheel torque.

torque exerted in the specific plane. It, when multiplied by the proper calibration factor, gives the actual force or torque. Fig. 7 shows a sample output for vertical force and cartwheel torque while lifting with "feet parallel and 45° turn of body".

A one-channel recorder with a strain-gauge coupler was used to record the acceleration.

Fig. 8 shows the dimensions of the experimental situations. To avoid shocks to the accelerometer (a very sensitive and fragile instrument), padding was provided on the top of both the load platform and the upper load shelf.

Standard weights from 1 to 20 lbs were added on the platform in case the subject weighed less than the maximum weight of 170 lbs for which the platform was calibrated.

A tote box with dimensions 16.5" x 13" x 6" was used in the experiment. It was filled with sand to 11 lbs. The stop watch was used to measure the rest interval between conditions of lift and lowering.

A chair was used for the subject to rest on after he had finished lifting for one condition.

A video tape recording set consisting of a camera, a videocorder and a monitor was used for recording the task and showing it to the subjects before the start of the experiment.

The task was to lift and lower the tote box through a vertical height of 30" using a squat lift while standing on the force platform. The subject

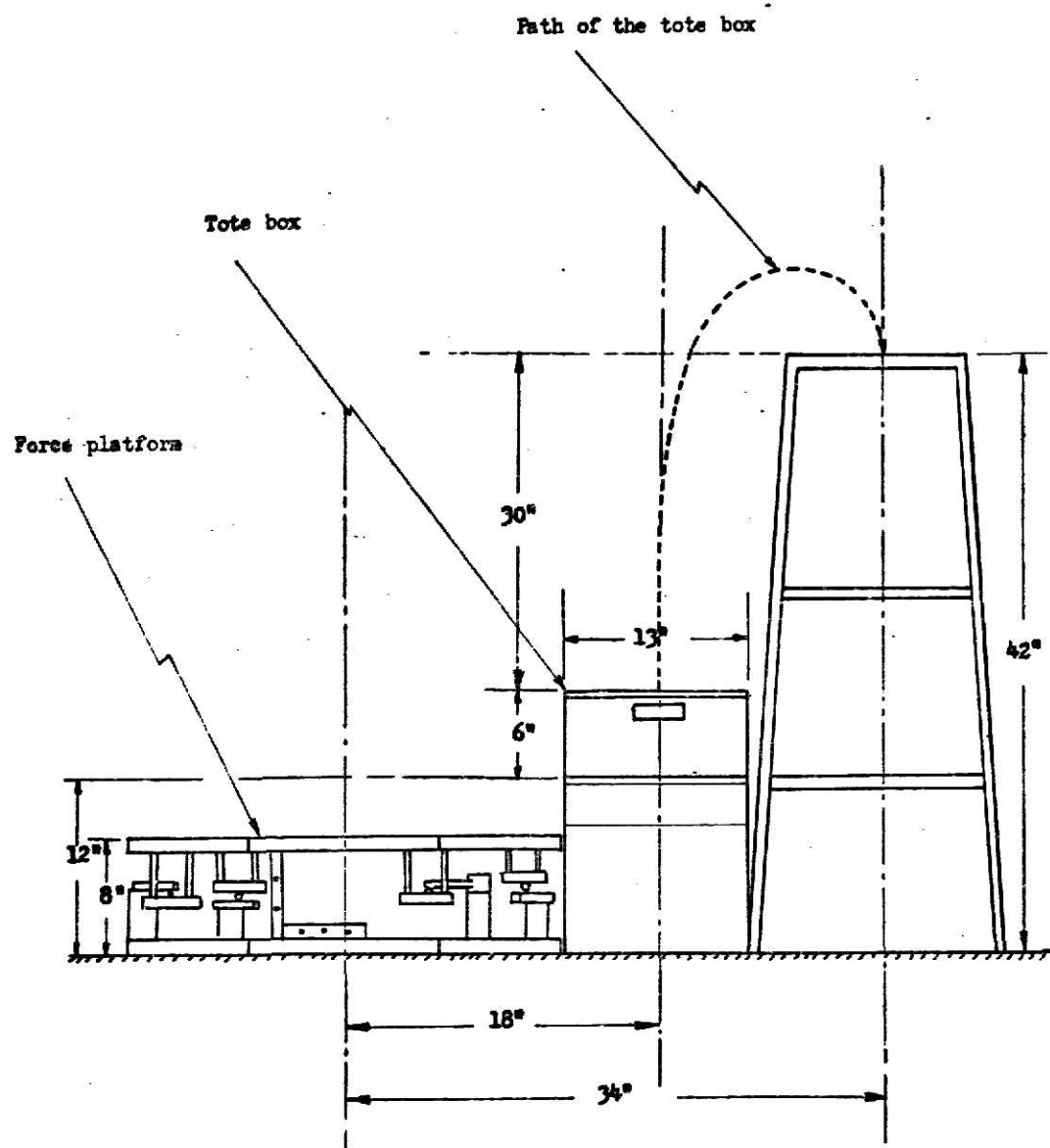


Fig. 8. Schematic of arrangement for the experiment.

assumed two different foot positions in lifting and lowering:

- 1) "parallel feet" while keeping the feet 9" apart (See Fig. 3)
and
- 2) "left foot leading" such that the toe of the right foot was aligned with the front of the heel of the left foot (see Fig 4).

The second variable was the angle of turn of the body. Keeping the feet stationary, the subject lifted and lowered with

- (1) "0 degrees turn of body" ie. straight ahead (see Fig 5) and
- (2) "45 degrees turn of body to the right" (see Fig 6).

In each case the subject stood such that the feet were 9" apart, center to center and also that the center of gravity of his body passed through the center of the force platform. The center of gravity of the body while standing erect was assumed to lie in the vertical plane passing through the center of the two ears of the body. Forces and torques were measured along and about the three orthogonal axis respectively and acceleration for the tote box was measured in the vertical direction.

Subjects

Eight male students between the 40th and 60th percentile of weight (152 lbs - 168 lbs) of the U.S. adult male population performed the task. An effort was made to insure that the subjects were between the 40th to 60th percentile of height (68" - 69.5") of the U.S. adult male population. However, they varied between 69" and 70.5". The subjects were of fairly medium build. The subjects were paid \$5 for the experiment. The anthropometric data of the subjects is given in Table 1.

Table 1. Anthropometric Data of the Subjects

<u>Sub. No.</u>	<u>Age (years)</u>	<u>Weight (lbs.)</u>	<u>Height (inches)</u>
1.	18	157	69
2.	21	167	70
3.	21	162	70.25
4.	19	152	70
5.	23	153	69
6.	20	160	70.5
7.	23	155	69.75
8.	26	164	70

Experimental Design

The two variables investigated were angle of turn of body and foot position. There are four combinations of these two parameters for lifting and same four for lowering (see Table 2). Each combination was called a condition. The sequence of the four conditions was randomized differently with each subject, with the constraint that each of the four conditions appears twice in each position (see Table 2). This was achieved by using two latin squares.

Each subject lifted and lowered four times at each condition in the first set of trials; the sequence was mirrored for the replicate set of trials (see Table 2). Thus there were eight observations per subject for each condition for lifting and eight observations for lowering. Different peaks were calculated for each lift (or lowering). The mean of the corresponding eight peaks was the criterion in each condition (for each force, torque or acceleration).

Experimental Procedure

The experiment was performed in the Human Engineering Laboratory at Kansas State University.

A weight of 170 pounds (weight of the heaviest subject expected) was placed on the force platform and the calibration of the force platform was then done for the one hundred and seventy pounds weight. Each subject was weighed and his height and age was noted. Before he performed the experiment, additional weights were placed on the platform to bring the total weight on the platform to 170 pounds. This eliminated the requirement

Table 2. Sequence of Conditions*

Subject no	First set of trials				Replicate set of trials			
1.	2	4	1	3	3	1	4	2
2.	3	2	4	1	1	4	2	3
3.	1	3	2	4	4	2	3	1
4.	4	1	3	2	2	3	1	4
5.	2	1	3	4	4	3	1	2
6.	1	2	4	3	3	4	2	1
7.	3	4	1	2	2	1	4	3
8.	4	3	2	1	1	2	3	4

* 1 = Feet parallel; 0 degrees turn

2 = Feet parallel; 45 degrees turn

3 = Left foot leading; 0 degrees turn

4 = Left foot leading; 45 degrees turn

of adjusting the transformers for each individual subject's weight. By calibration with known weights, the scale factors, which give the amount of force in pounds/millimeter of deflection on the output paper for the force axes and the torque in inch-pounds/millimeter of deflection on the output paper for the torques axes, were determined for each axis.

The dynograph recorder was calibrated for the acceleration given by the accelerometer. The control panel knob was put in the 'OPERATE' position and the accelerometer was rotated through an angle of 180° about its lateral axis. This gave a deflection in millimeters which represented 2 g (ie. 64.4 ft/sec^2) of vertical acceleration. The calibration was then done accordingly.

The task was explained to the subject on the television screen with the help of a pre-recorded video-tape. He was then orally instructed about the task and any questions were answered. For all conditions the subject had to squat; that is, he started with a particular foot position, bent his knees while keeping the back as straight as possible, grasped the box with both hands, straightened up while he kept his back straight as he lifted and placed the box on the upper load shelf. An event marker was used on the oscillograph recorders to mark the occurrence of two events: A) When the subject just grasps the tote box and picks it up (see Fig. 9 for condition 2) and B) when the subject just releases the tote box (see Fig. 10 for condition 4). This was done both in lifting and lowering in all trials and in all conditions. The subject was told to lift and lower in rhythm and to avoid jerks. Two or three practice lifts and lowerings were allowed before the data was collected for the experiment.



Fig. 9. Subject about to pick the tote box up with "feet parallel and 45 degrees turn of body".



Fig. 10. Subject about to release the tote box with "left foot leading and 0 degrees turn of body".

The subject rested standing for 15 seconds between each of the four lifts or lowerings at each condition and for 180 seconds sitting between conditions. The replicate set of trials was performed 180 seconds after the first set of trials was over. The rest conditions were the same as in the first set of trials. The experiments on eight subjects were run over a period of 7 days.

RESULTS

One of the major purposes of the experiment was to develop the graphical patterns of the forces, torques and accelerations involved in the body both for lifting and lowering. Curves were developed for vertical acceleration, vertical, lateral and frontal forces and cart-wheel and somersault torque for each of the four conditions. Values were averaged over the eight trials of a representative subject (subject 7). Due to a malfunction in one recorder, twist torque was not recorded and hence no curves were developed for it.

The curves for acceleration are shown in Fig 11 and Fig 12. The maximum upward acceleration while lifting occurred at peak "l" (86% of the trials in condition 1, 69% of the trials in condition 2, 86% of the trials in condition 3, and 84% of the trials in condition 4; see tables 3 through 10). The maximum downward acceleration while lowering occurs 41% of the trials at "f" and 31% of the trials at "e" in condition 1, 48% of the trials at "f" and 37% of the trials at "e" in condition 2, 44% of the trials at "f" and 37% of the trials at "e" in condition 3 and 39% of the trials at "f" and 30% of the trials at "e" in condition 4. For the remainder of the trials peaks "e" and "f" made one common peak. For lifting, peak "l" occurred about 1.5 seconds after the start. For lowering, peak 'a' occurred about 0.9 seconds and 'f' about 1.7 seconds after the start. All values of acceleration for the representative subject are given in Table A1 through A4 in the appendix.

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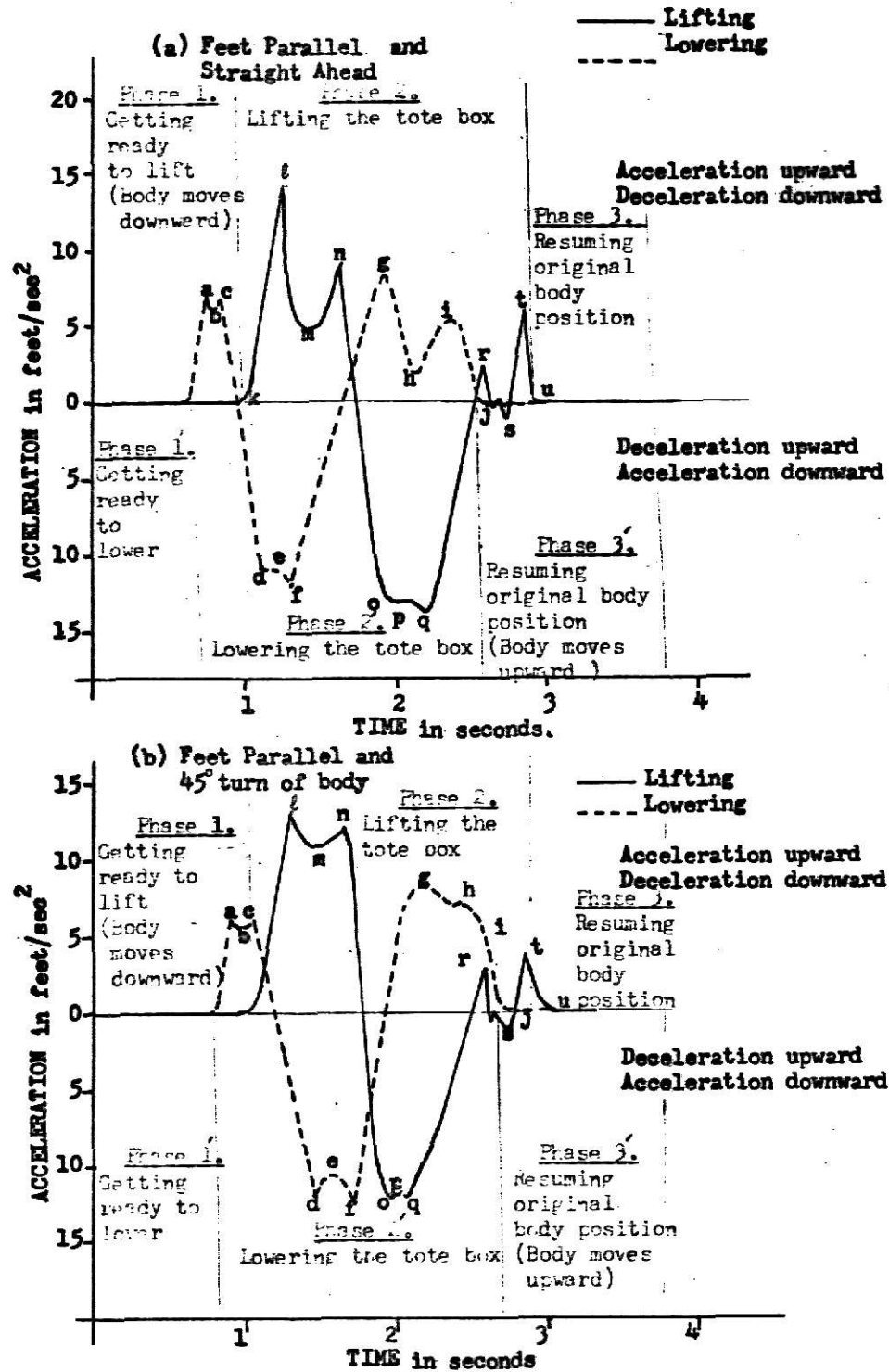


Fig. 11. Vertical accelerations of the box in lifting and lowering for (a) "feet parallel and straight ahead" and (b) "feet parallel and 45° turn of body".

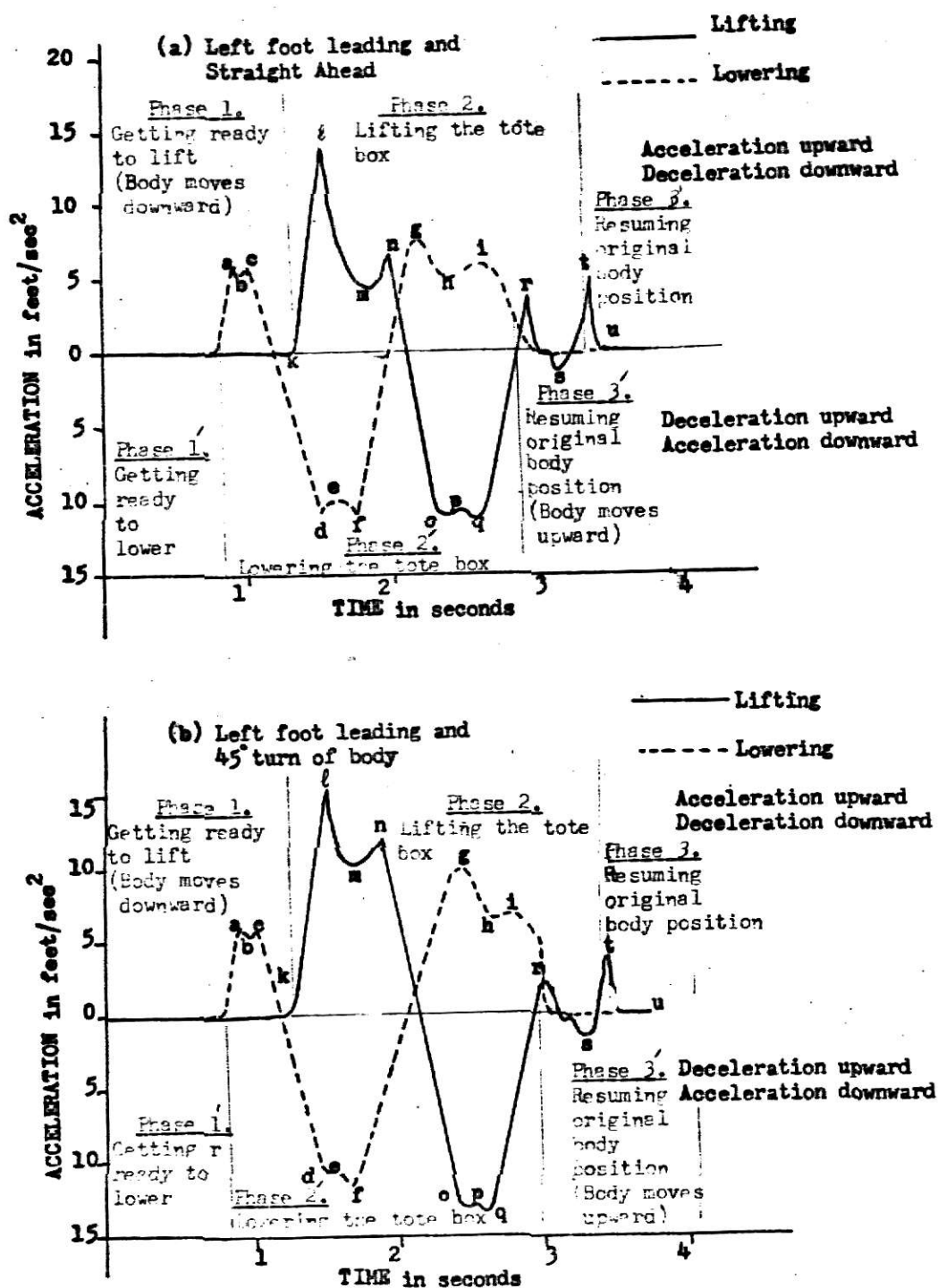


Fig. 12. Vertical accelerations of the box in lifting and lowering for (a) "left foot leading and straight ahead" and (b) "left foot leading and 45° turn of body".

TABLE 3

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LIFTING IN CONDITION 1

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greatest of 1, 2, 3, 4, 5, 6, 7, 8	SUBJECT1	17.00	22.00	24.00	14.00	20.00	19.20	20.00	26.00	20.27	
	SUBJECT2	14.00	16.00	17.00	18.00	14.70	20.00	14.00	18.00	16.46	
	SUBJECT3	19.00	16.50	21.00	16.00	29.50	24.00	13.10	16.00	19.39	
	SUBJECT4	18.00	16.00	20.00	14.00	19.00	15.00	14.00	16.80	16.60	
	SUBJECT5	13.00	13.00	13.00	12.00	12.50	12.00	13.00	14.00	12.44	
	SUBJECT6	9.00	16.00	13.00	14.00	16.00	22.50	25.00	24.00	17.44	
	SUBJECT7	11.00	16.00	17.50	7.00	15.00	14.00	18.00	17.80	14.54	
	SUBJECT8	15.00	16.00	20.00	12.00	14.00	18.00	14.00	15.00	15.50	
	M E A N	14.50	16.44	17.31	13.38	17.59	18.09	16.39	18.45		16.58
Greatest of 9, 10, 11, 12, 13, 14, 15, 16	SUBJECT1	12.00	19.30	17.00	16.00	15.00	14.00	15.00	15.00	15.41	
	SUBJECT2	16.00	14.00	16.00	12.00	12.00	12.00	12.00	14.00	13.70	
	SUBJECT3	14.00	11.00	11.00	12.00	9.30	10.20	11.00	11.80	11.29	
	SUBJECT4	18.00	10.00	10.00	12.00	15.00	10.00	10.00	12.00	12.13	
	SUBJECT5	13.00	9.00	8.00	7.00	9.00	8.00	8.00	9.00	8.50	
	SUBJECT6	10.00	12.00	13.00	15.50	14.00	14.00	11.00	17.00	13.31	
	SUBJECT7	15.50	12.00	8.00	14.00	14.00	14.50	16.00	18.00	14.00	
	SUBJECT8	12.00	14.00	14.00	16.00	14.00	12.00	18.00	14.00	14.25	
	M E A N	13.44	12.66	12.13	13.16	12.89	11.84	12.63	13.85		12.92
1	SUBJECT1	6.00	4.00	6.00	8.00	6.00	5.80	4.00	5.20	5.62	
	SUBJECT2	3.80	6.00	8.00	6.50	4.20	5.80	3.80	4.20	5.29	
	SUBJECT3	6.00	4.00	4.20	3.80	4.00	6.00	3.40	3.80	4.40	
	SUBJECT4	10.00	3.00	4.00	4.00	3.80	5.80	3.00	4.00	4.70	
	SUBJECT5	2.00	3.00	3.50	3.00	2.80	4.00	3.00	5.00	3.29	
	SUBJECT6	5.00	5.40	4.00	2.00	2.80	6.00	6.50	2.80	4.44	
	SUBJECT7	9.00	6.00	8.00	4.00	6.00	4.00	8.00	3.00	6.00	
	SUBJECT8	2.00	4.00	9.00	6.00	5.60	3.00	2.00	2.00	4.20	
	M E A N	5.60	4.42	5.84	4.66	4.40	5.05	4.21	3.75		4.74

TABLE 4

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LOWERING IN CONDITION 1

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	M 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
Greatest of a, b, c	SUBJECT1	6.00	5.00	5.00	8.00	8.50	7.00	7.50	7.00	6.75			
	SUBJECT2	14.00	7.00	12.00	7.50	9.00	9.80	7.00	8.00	9.29			
	SUBJECT3	11.00	12.00	5.00	8.00	10.00	7.00	8.00	10.00	8.88			
	SUBJECT4	8.00	6.00	7.00	5.00	7.00	8.00	8.00	7.00	7.00			
	SUBJECT5	5.80	3.80	6.00	5.00	2.00	3.50	3.00	2.00	3.89			
	SUBJECT6	8.00	12.00	12.00	8.80	10.00	9.00	7.50	7.00	9.29			
	SUBJECT7	8.00	5.50	10.50	12.00	8.00	6.50	5.00	8.00	7.94			
	SUBJECT8	<u>4.00</u>	<u>6.00</u>	<u>3.00</u>	<u>4.50</u>	<u>4.50</u>	<u>3.00</u>	<u>4.00</u>	<u>5.00</u>	<u>4.25</u>			
	M E A N	8.10	7.16	7.56	7.35	7.38	6.72	6.25	6.75				7.15
Greatest of d, e, f	SUBJECT1	10.00	15.00	16.00	16.00	16.00	16.00	16.00	16.00	15.13			
	SUBJECT2	11.00	14.50	16.00	16.00	13.00	16.00	13.00	14.00	14.19			
	SUBJECT3	18.00	18.00	15.00	13.00	16.00	18.00	16.00	12.00	15.75			
	SUBJECT4	10.50	12.00	13.00	12.50	10.00	11.00	10.00	11.00	11.25			
	SUBJECT5	7.50	9.00	8.00	7.00	8.00	9.00	7.00	8.00	7.94			
	SUBJECT6	14.00	15.00	18.00	18.00	15.00	16.00	13.80	15.00	15.60			
	SUBJECT7	13.50	18.00	20.00	11.00	12.00	14.00	14.50	15.00	14.75			
	SUBJECT8	<u>14.00</u>	<u>14.00</u>	<u>14.00</u>	<u>12.00</u>	<u>12.00</u>	<u>10.00</u>	<u>10.00</u>	<u>11.00</u>	<u>12.13</u>			
	M E A N	12.31	14.44	15.00	13.19	12.75	13.75	12.54	12.75				13.34
Greatest of g, h, i	SUBJECT1	10.00	16.00	17.00	20.00	18.00	16.00	16.00	18.00	16.38			
	SUBJECT2	10.00	10.00	7.60	7.00	5.00	8.40	10.00	11.20	8.65			
	SUBJECT3	10.50	8.00	7.00	9.00	12.00	12.50	8.00	10.00	9.63			
	SUBJECT4	8.00	8.00	12.00	14.00	9.00	12.00	13.00	9.00	10.63			
	SUBJECT5	9.00	9.00	10.00	8.00	11.00	8.50	10.00	7.00	9.06			
	SUBJECT6	9.00	11.00	15.00	12.00	10.00	10.80	14.00	12.00	11.72			
	SUBJECT7	11.00	6.00	6.00	8.00	9.00	8.00	7.00	8.00	7.88			
	SUBJECT8	<u>4.00</u>	<u>10.00</u>	<u>8.00</u>	<u>10.00</u>	<u>6.00</u>	<u>9.00</u>	<u>8.00</u>	<u>9.00</u>	<u>8.00</u>			
	M E A N	9.94	9.75	10.32	11.03	10.00	10.65	10.75	10.52				10.24

TABLE 5

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LIFTING IN CONDITION 2

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greatest of 1, n, n	SUBJECT1	11.00	16.50	15.00	22.00	22.00	16.00	20.00	22.00	18.06	
	SUBJECT2	16.00	17.00	24.00	20.00	20.80	26.00	24.00	19.50	20.91	
	SUBJECT3	26.00	27.00	23.00	20.00	24.00	14.00	18.00	17.60	21.20	
	SUBJECT4	18.00	14.00	20.00	14.00	12.00	14.00	18.00	22.00	16.50	
	SUBJECT5	11.00	9.00	9.00	10.00	11.00	14.00	12.00	14.00	11.25	
	SUBJECT6	18.00	20.00	16.00	18.00	22.00	22.50	20.00	29.00	20.69	
	SUBJECT7	11.00	14.00	14.00	12.00	14.00	15.50	18.50	16.00	14.38	
	SUBJECT8	<u>15.20</u>	<u>17.00</u>	<u>24.00</u>	<u>16.00</u>	<u>12.00</u>	<u>16.00</u>	<u>18.00</u>	<u>13.00</u>	<u>16.40</u>	
	M E A N	15.77	16.81	18.13	16.50	17.22	17.25	18.56	19.14		17.42
Greatest of o, p, q	SUBJECT1	12.00	12.00	7.50	7.50	15.00	16.00	16.50	18.00	13.06	
	SUBJECT2	12.00	12.00	12.00	12.40	13.00	10.80	12.00	13.50	12.21	
	SUBJECT3	14.00	11.00	11.00	13.00	13.00	13.00	15.50	10.00	12.56	
	SUBJECT4	13.50	13.00	9.00	10.00	12.00	10.00	13.80	12.00	11.66	
	SUBJECT5	12.00	6.00	8.00	8.00	10.00	8.00	6.00	10.00	8.50	
	SUBJECT6	12.00	10.00	12.50	16.00	15.20	14.00	16.00	13.00	13.59	
	SUBJECT7	11.00	14.00	8.00	14.00	11.50	12.00	16.00	13.00	12.44	
	SUBJECT8	<u>13.00</u>	<u>19.00</u>	<u>16.00</u>	<u>12.00</u>	<u>16.00</u>	<u>11.00</u>	<u>10.00</u>	<u>12.00</u>	<u>13.63</u>	
	M E A N	12.44	12.13	10.50	11.61	13.21	11.85	13.22	12.69		12.21
t	SUBJECT1	6.00	6.00	5.00	5.30	4.00	3.00	4.00	6.00	4.91	
	SUBJECT2	6.00	2.80	3.00	2.00	3.00	5.00	6.80	4.80	4.17	
	SUBJECT3	6.20	6.00	2.00	5.00	3.20	2.20	2.20	2.00	3.60	
	SUBJECT4	6.00	4.50	4.00	6.00	5.50	3.50	4.80	12.00	5.79	
	SUBJECT5	2.80	2.20	3.80	3.00	3.00	2.00	2.80	4.00	2.95	
	SUBJECT6	6.00	5.00	6.00	4.00	5.00	3.00	6.00	5.00	5.00	
	SUBJECT7	3.90	3.00	4.00	4.00	5.50	4.00	5.00	4.00	4.17	
	SUBJECT8	<u>2.90</u>	<u>3.00</u>	<u>6.00</u>	<u>5.00</u>	<u>4.00</u>	<u>3.00</u>	<u>4.00</u>	<u>3.00</u>	<u>3.85</u>	
	M E A N	4.96	4.06	4.22	4.29	4.15	3.21	4.45	5.10		4.31

TABLE 6

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LOWERING IN CONDITION 2

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
Greatest of a, b, c	SUBJECT1	6.00	5.00	6.00	4.80	6.00	7.80	8.00	8.00	6.45			
	SUBJECT2	12.00	5.70	10.00	12.00	12.00	5.50	10.00	8.20	9.42			
	SUBJECT3	10.00	11.00	8.00	6.00	10.00	8.00	6.80	8.00	8.47			
	SUBJECT4	4.00	6.00	9.00	6.00	4.00	4.80	4.00	6.00	5.47			
	SUBJECT5	4.00	4.80	3.80	2.00	4.50	3.50	3.20	6.00	3.97			
	SUBJECT6	11.00	8.00	8.00	10.00	13.00	12.00	11.00	12.00	10.63			
	SUBJECT7	7.00	7.00	6.50	8.00	7.50	6.00	7.00	6.00	6.88			
	SUBJECT8	<u>5.60</u>	<u>6.80</u>	<u>3.50</u>	<u>2.00</u>	<u>2.50</u>	<u>4.00</u>	<u>9.00</u>	<u>2.00</u>	<u>4.42</u>			
	M E A N	7.45	6.79	6.85	6.35	7.44	6.45	7.37	7.02				6.97
Greatest of d, e, f	SUBJECT1	18.00	12.00	12.00	12.00	16.00	16.00	14.00	12.00	14.00			
	SUBJECT2	22.50	14.00	12.00	10.50	16.00	11.00	10.80	8.80	13.20			
	SUBJECT3	18.00	15.00	13.00	12.00	11.00	11.70	13.00	18.00	13.96			
	SUBJECT4	8.00	10.00	11.00	10.00	10.00	14.00	10.00	10.00	10.38			
	SUBJECT5	9.50	7.80	8.00	10.50	8.00	8.00	7.80	9.00	8.57			
	SUBJECT6	15.00	14.00	14.00	13.80	16.00	18.00	16.00	14.20	15.12			
	SUBJECT7	14.00	13.00	17.00	13.00	13.50	17.00	13.00	15.00	14.44			
	SUBJECT8	<u>10.50</u>	<u>12.00</u>	<u>13.00</u>	<u>15.00</u>	<u>10.00</u>	<u>12.00</u>	<u>8.00</u>	<u>10.00</u>	<u>11.31</u>			
	M E A N	14.44	12.22	12.50	12.10	12.56	13.46	11.57	12.12				12.62
Greatest of g, h, i	SUBJECT1	16.00	15.00	12.00	12.00	14.50	14.00	13.00	11.00	13.44			
	SUBJECT2	11.00	12.00	10.50	10.50	11.00	8.00	12.00	9.50	10.56			
	SUBJECT3	13.00	12.00	10.00	14.00	12.80	10.40	10.00	14.80	12.12			
	SUBJECT4	9.00	9.00	9.00	10.50	10.00	10.00	9.00	12.00	9.81			
	SUBJECT5	10.00	8.00	6.00	6.00	10.00	9.00	9.50	8.00	8.31			
	SUBJECT6	10.00	11.00	13.00	10.60	13.00	16.00	14.60	16.00	13.02			
	SUBJECT7	10.00	12.00	10.50	9.00	7.50	9.50	10.00	12.00	10.06			
	SUBJECT8	<u>9.00</u>	<u>13.00</u>	<u>14.00</u>	<u>12.00</u>	<u>10.00</u>	<u>8.00</u>	<u>10.50</u>	<u>9.00</u>	<u>10.69</u>			
	M E A N	11.00	11.50	10.63	10.57	11.10	10.61	11.07	11.54				11.00

TABLE 7

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LIFTING IN CONDITION 3

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greatest of 1, 2, 3	SUBJECT1	13.00	15.00	14.00	22.00	12.00	18.00	22.00	19.00	16.88	
	SUBJECT2	16.00	14.00	10.00	11.00	11.00	16.00	17.00	11.80	13.35	
	SUBJECT3	16.00	14.00	16.00	18.00	24.00	17.00	24.00	17.00	18.25	
	SUBJECT4	14.00	14.00	18.80	21.00	13.00	18.00	18.60	16.00	16.67	
	SUBJECT5	10.00	13.00	9.00	8.00	10.00	10.80	11.00	10.00	10.22	
	SUBJECT6	21.00	23.00	21.00	16.80	20.00	18.00	20.60	18.00	19.80	
	SUBJECT7	11.00	10.50	15.00	12.00	14.00	18.00	17.00	18.00	14.44	
	SUBJECT8	19.00	18.00	14.00	15.00	15.00	13.00	18.00	18.00	16.25	
	M E A N	15.00	15.19	14.73	15.48	14.88	16.10	18.52	15.97		15.73
Greatest of 4, 5, 6	SUBJECT1	14.00	15.00	16.20	18.00	12.80	15.00	14.00	14.00	14.87	
	SUBJECT2	14.00	17.60	14.50	16.00	12.00	12.00	12.00	12.00	13.76	
	SUBJECT3	10.00	16.50	13.00	14.00	16.00	10.00	10.00	13.00	12.81	
	SUBJECT4	11.00	9.00	11.00	10.00	14.50	10.00	11.00	12.00	11.06	
	SUBJECT5	8.20	5.80	6.30	6.00	8.00	7.00	7.00	9.00	7.13	
	SUBJECT6	14.00	14.00	14.60	11.50	14.00	12.00	16.00	14.00	13.76	
	SUBJECT7	14.50	16.00	15.00	11.50	13.00	8.60	10.00	14.00	12.82	
	SUBJECT8	16.00	10.50	12.00	13.00	13.00	13.50	13.00	11.00	12.75	
	M E A N	12.71	13.05	12.79	12.50	12.91	11.01	11.63	12.38		12.37
8	SUBJECT1	5.00	4.20	5.00	5.20	4.20	6.00	4.00	5.00	4.82	
	SUBJECT2	6.00	6.50	5.00	5.00	4.00	3.50	4.80	3.20	4.75	
	SUBJECT3	5.80	4.00	5.50	3.80	3.00	3.20	3.00	4.20	4.06	
	SUBJECT4	3.00	3.00	3.00	4.00	2.00	3.00	4.00	3.00	3.13	
	SUBJECT5	2.80	6.00	3.50	2.00	4.00	4.00	2.00	2.00	3.29	
	SUBJECT6	4.00	3.80	1.80	2.80	6.00	2.60	4.20	2.20	3.42	
	SUBJECT7	4.00	6.00	8.00	4.00	4.00	10.00	5.00	6.00	5.88	
	SUBJECT8	6.00	3.00	4.00	3.00	5.00	2.00	3.00	3.00	3.63	
	M E A N	4.57	4.56	4.47	3.72	4.02	4.29	3.75	3.57		4.12

TABLE 8

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LOWERING IN CONDITION 3

PEAKS	SUBJECTS	1	L FIRST 2	3 SET 3	W 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
Greatest of a, b, c	SUBJECT1	7.80	6.50	3.30	8.50	9.00	7.00	10.00	8.00	7.47			
	SUBJECT2	5.00	10.00	6.00	12.50	10.00	6.00	9.00	10.00	8.56			
	SUBJECT3	4.00	10.00	10.50	3.00	8.00	8.00	7.00	4.20	6.84			
	SUBJECT4	7.00	6.00	6.00	7.00	8.00	7.00	8.00	9.00	7.25			
	SUBJECT5	5.00	4.00	3.80	2.60	3.00	3.80	2.00	2.00	3.27			
	SUBJECT6	12.50	10.00	8.00	14.00	11.50	12.00	6.00	11.00	10.63			
	SUBJECT7	6.50	5.80	7.00	8.00	5.00	7.50	4.00	8.00	6.47			
	SUBJECT8	5.00	6.00	6.00	6.00	3.00	2.00	2.50	3.00	4.19			
	M E A N	6.60	7.29	6.29	7.70	7.19	6.66	6.06	6.90				6.84
Greatest of d, e, f	SUBJECT1	16.00	14.00	15.50	14.00	15.00	16.00	13.20	16.00	14.96			
	SUBJECT2	9.50	15.00	10.80	17.00	11.00	11.20	14.00	10.00	12.31			
	SUBJECT3	13.00	20.00	18.00	15.50	10.00	10.00	11.00	10.00	13.44			
	SUBJECT4	11.00	10.00	11.50	7.00	11.00	11.00	10.00	10.00	10.19			
	SUBJECT5	9.00	10.00	9.60	10.00	8.00	6.50	8.00	7.20	8.41			
	SUBJECT6	14.00	13.00	11.00	14.00	10.00	12.00	13.00	13.00	12.50			
	SUBJECT7	13.00	15.00	13.30	12.00	10.00	14.00	12.00	9.00	12.25			
	SUBJECT8	12.00	14.00	11.00	15.00	6.00	12.00	13.50	11.00	11.81			
	M E A N	12.19	13.88	12.42	13.06	10.13	11.59	11.84	10.77				11.98
Greatest of g, h, i	SUBJECT1	14.00	12.00	16.00	12.00	20.00	18.00	10.00	16.00	14.75			
	SUBJECT2	9.00	10.00	5.00	12.50	10.00	9.20	5.00	10.50	8.90			
	SUBJECT3	9.80	8.00	12.00	8.00	10.00	9.80	10.00	8.00	9.45			
	SUBJECT4	12.00	10.50	10.00	10.00	10.00	11.00	10.00	8.00	10.19			
	SUBJECT5	9.00	7.80	8.00	8.00	10.80	5.00	8.50	7.00	8.01			
	SUBJECT6	13.00	11.50	11.40	14.50	13.00	8.00	13.00	12.00	12.05			
	SUBJECT7	8.00	8.00	10.00	8.00	12.00	7.00	8.00	6.00	8.38			
	SUBJECT8	9.00	10.50	10.50	9.00	6.80	8.50	12.00	12.00	9.54			
	M E A N	10.35	9.79	10.36	10.13	11.57	9.56	9.56	9.94				10.16

TABLE 9

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LIFTING IN CONDITION 4

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8.	MEAN	GRAND MEAN
Greatest of 1, 2, 3	SUBJECT1	16.00	16.00	20.00	16.00	16.00	18.00	16.00	18.00	17.00	
	SUBJECT2	17.00	12.00	17.00	16.00	22.00	19.00	19.50	18.00	17.56	
	SUBJECT3	19.00	21.50	22.00	16.00	20.50	19.00	18.50	22.00	19.81	
	SUBJECT4	10.00	16.00	19.00	18.00	16.00	14.50	15.00	12.00	15.06	
	SUBJECT5	12.00	13.00	15.00	15.00	15.00	15.00	11.00	13.00	13.63	
	SUBJECT6	21.00	20.00	22.00	19.50	20.00	30.00	21.50	26.00	22.50	
	SUBJECT7	16.00	13.00	14.00	18.00	15.00	14.00	18.00	18.50	15.81	
	<u>SUBJECT8</u>	<u>16.00</u>	<u>17.00</u>	<u>19.50</u>	<u>20.00</u>	<u>11.00</u>	<u>17.00</u>	<u>15.00</u>	<u>16.50</u>	<u>16.50</u>	
	MEAN	15.83	16.06	18.56	17.31	16.94	18.31	16.81	18.00		17.23
Greatest of 4, 5, 6	SUBJECT1	12.00	10.00	12.00	14.00	16.00	16.00	16.00	14.00	13.75	
	SUBJECT2	9.00	14.00	18.00	13.00	12.00	11.00	14.00	12.00	12.88	
	SUBJECT3	13.00	13.00	16.50	10.00	13.00	14.00	14.20	15.00	13.59	
	SUBJECT4	8.00	12.00	11.00	10.00	10.00	13.50	11.80	10.00	10.79	
	SUBJECT5	8.00	12.00	11.50	9.00	10.00	9.00	9.00	7.00	9.44	
	SUBJECT6	16.00	18.00	16.00	15.00	16.00	14.00	14.00	17.00	15.75	
	SUBJECT7	14.00	13.50	14.00	16.40	10.20	13.00	14.50	13.00	13.57	
	<u>SUBJECT8</u>	<u>14.00</u>	<u>13.00</u>	<u>12.00</u>	<u>12.00</u>	<u>14.00</u>	<u>13.00</u>	<u>13.00</u>	<u>14.00</u>	<u>13.13</u>	
	MEAN	11.75	13.19	13.88	12.42	12.65	12.94	13.31	12.75		12.86
t	SUBJECT1	6.00	5.00	4.00	6.00	4.00	4.00	5.50	3.00	4.69	
	SUBJECT2	3.00	4.00	6.00	3.00	3.40	6.00	4.00	4.40	4.22	
	SUBJECT3	2.00	3.60	2.40	8.00	5.80	4.40	4.50	3.80	4.31	
	SUBJECT4	4.00	4.00	6.00	3.00	4.00	3.20	4.00	4.00	4.02	
	SUBJECT5	3.80	3.20	4.00	1.00	4.00	3.00	2.00	2.00	2.88	
	SUBJECT6	6.00	5.00	6.50	2.00	4.00	3.00	2.80	3.20	4.06	
	SUBJECT7	4.00	11.00	5.00	3.00	3.00	3.50	3.50	4.00	4.63	
	<u>SUBJECT8</u>	<u>4.80</u>	<u>2.50</u>	<u>5.50</u>	<u>4.00</u>	<u>2.00</u>	<u>4.00</u>	<u>4.00</u>	<u>4.00</u>	<u>3.85</u>	
	MEAN	4.20	4.79	4.92	3.75	3.77	3.89	3.79	3.55		4.08

TABLE 10

PEAK VALUES OF ACCELERATION IN FEET / SEC. SQUARE
DURING LOWERING IN CONDITION 4

PEAKS	SUBJECTS	1	L FIRST 2	N SET 3	M 4	F 5	R 6	I 7	N REPLICATE 8	G 9	S SFT 10	R 11	MEAN	GRAND MEAN
Greatest of a,b,c	SUBJECT1	2.00	6.50	6.00	4.50	4.00	8.00	5.00	4.00	5.00				
	SUBJECT2	9.00	10.00	9.50	9.00	9.00	9.50	8.00	8.00	9.00				
	SUBJECT3	9.00	9.00	4.20	8.00	9.50	7.50	8.20	7.00	7.80				
	SUBJECT4	7.00	10.00	10.00	6.00	4.00	7.00	4.00	6.00	6.75				
	SUBJECT5	4.00	4.20	6.00	4.00	4.50	4.00	5.40	5.00	4.64				
	SUBJECT6	11.00	11.00	13.80	13.50	11.50	11.00	14.00	11.00	12.10				
	SUBJECT7	4.50	9.00	5.60	9.00	6.00	6.50	6.00	7.00	6.70				
	SUBJECT8	6.00	7.00	6.00	6.00	5.00	3.00	2.00	2.00	4.63				
	M E A N	6.56	8.34	7.64	7.50	6.59	7.06	6.57	6.25					7.08
Greatest of d,e,f	SUBJECT1	16.00	12.00	18.00	12.00	12.50	15.00	15.00	14.00	14.31				
	SUBJECT2	12.70	12.50	15.40	15.00	14.00	14.00	12.00	12.00	13.45				
	SUBJECT3	18.00	16.00	14.00	16.00	14.00	11.00	12.00	11.00	14.00				
	SUBJECT4	10.00	11.00	10.00	12.00	12.00	12.00	12.00	12.00	11.38				
	SUBJECT5	7.00	10.00	8.00	7.00	7.80	8.00	6.00	6.00	7.47				
	SUBJECT6	15.00	12.00	16.00	16.60	14.00	12.00	13.00	15.00	14.20				
	SUBJECT7	19.00	11.00	14.00	12.50	12.00	12.00	16.00	16.00	13.94				
	SUBJECT8	9.00	9.50	5.80	12.20	9.00	12.00	14.00	12.00	10.81				
	M E A N	13.21	11.75	13.15	12.91	11.79	12.00	12.50	12.25					12.45
Greatest of g,h,i	SUBJECT1	12.00	13.50	14.00	10.00	12.00	13.00	12.20	12.00	12.34				
	SUBJECT2	10.00	9.50	8.00	15.00	9.00	8.00	9.00	9.00	9.69				
	SUBJECT3	12.70	12.00	10.50	11.00	11.00	7.00	13.00	11.50	11.09				
	SUBJECT4	8.50	9.00	11.50	10.50	12.00	8.00	15.00	10.00	10.56				
	SUBJECT5	8.00	8.00	7.60	7.00	8.00	8.00	8.00	8.00	7.82				
	SUBJECT6	12.00	11.00	16.00	12.00	14.00	16.50	14.00	18.00	14.19				
	SUBJECT7	13.00	14.00	11.00	10.50	10.00	10.00	14.00	9.00	11.44				
	SUBJECT8	9.00	10.00	9.00	9.00	10.00	10.00	10.00	12.00	9.75				
	M E A N	10.52	10.88	10.95	10.63	10.75	10.36	11.90	11.19					10.86

The curves for vertical force are shown in Fig 13 and Fig 14. The maximum vertical force occurred at peak 'f' while lifting and peak 'u' while lowering. Peak 'f' was the maximum for 81% of the trials in condition 1, 70% of the trials in condition 2, 48% of the trials in condition 3, and 65% of the trials in condition 4 (see Tables 11 through 18). Peak 'd' was the maximum for 5%, 14%, 25% and 14% of the trials in condition 1, 2, 3 and 4 respectively. Peaks 'd' and 'f' coincided the remaining times. Peak 'f' occurred between 1.2 and 1.5 seconds after the start. Peak 'u' was the highest for 80% of the trials in condition 1, 71% of the trials in condition 2, 89% of the trials in condition 3 and 89% of the trials in condition 4. Peak 's' was maximum for 20% of the trials in condition 1, 20% of the trials in condition 2, 9% of the trials in condition 3 and 9% of the trials in condition 4. Peaks 's' and 'u' coincided for the remainder of the trials. Peak 'u' occurred between 2.7 to 3.1 seconds after the start. Peak 'e' during lifting and peak 't' during lowering assumed values both above and below the neutral axis between e_1 and e_2 , and t_1 and t_2 respectively. All values of the vertical forces for the representative subject are given in Tables A5 through A9 in the appendix.

Curves for frontal force, lateral force, cartwheel torque and somersault torque are shown in Figs. 15, 16, 17 and 18 respectively. The values for different peaks on these curves for the representative subject (subject 7) are given in Tables A10 through A20. Selected peak values for all subjects are given in Tables 19 through 50.

To examine the acceleration effect, the acceleration curves were plotted over the curves for the vertical forces for lifting and lowering (see

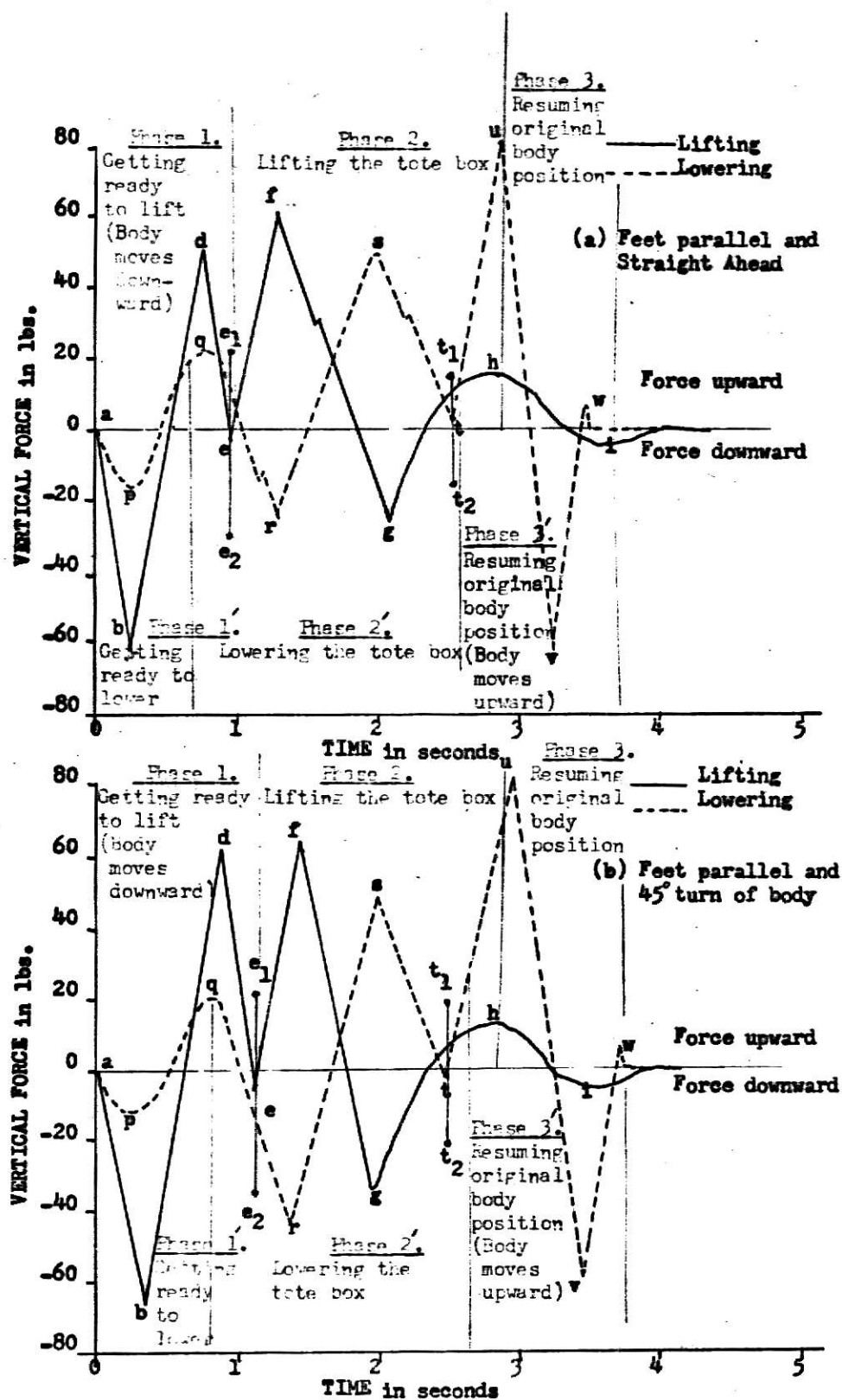


Fig. 13. Vertical forces in lifting and lowering of the representative subject for (a) "feet parallel and straight ahead" and (b) "feet parallel and 45° turn of body".

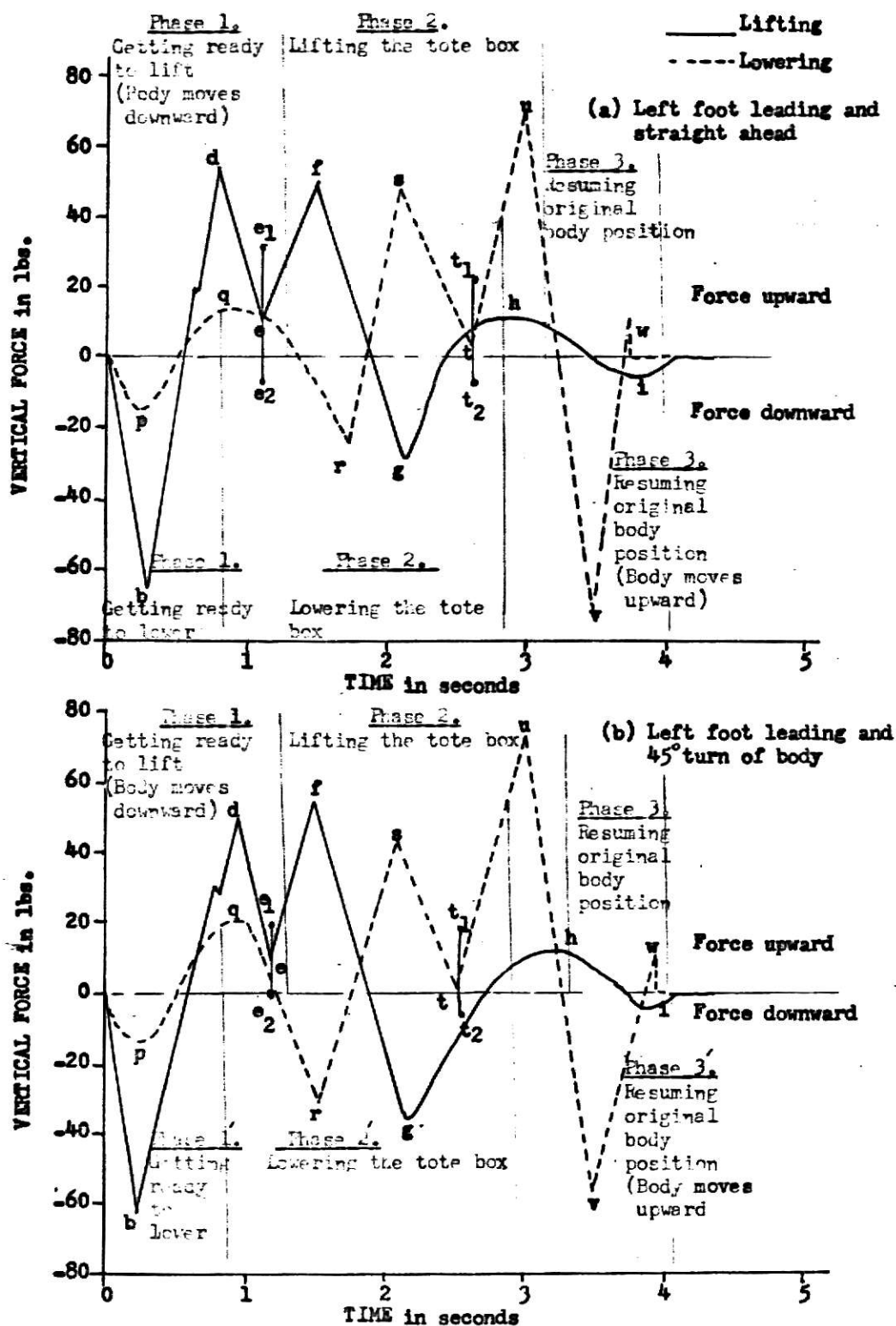


Fig 14. Vertical forces in lifting and lowering of the representative subject for (a) "left foot leading and straight ahead" and (b) "left foot leading and 45° turn of body".

TABLE 11

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 1

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L	I	F	T	S	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	51.75	54.25	69.75	58.50	67.50	60.00	63.00	67.50	62.16				
	SUBJECT2	30.75	45.00	41.25	60.00	30.75	40.50	34.50	38.25	40.12				
	SUBJECT3	39.75	54.75	60.75	60.00	33.00	63.75	69.75	56.25	54.75				
	SUBJECT4	42.75	40.50	42.00	45.00	46.75	43.50	45.00	47.25	44.34				
	SUBJECT5	33.75	45.00	37.50	45.00	44.25	45.00	42.00	37.50	41.25				
	SUBJECT6	32.75	37.50	54.00	45.00	52.50	60.00	60.00	61.50	50.16				
	SUBJECT7	56.25	60.00	60.00	58.50	63.75	62.25	75.00	63.75	62.44				
	SUBJECT8	41.25	49.50	45.00	34.50	40.50	41.25	40.50	38.25	41.34				
	M E A N	42.67	48.94	51.28	50.81	47.62	52.03	53.72	51.28					49.57
Greater of d,f	SUBJECT1	39.75	69.75	73.50	61.50	39.75	81.00	81.75	87.00	66.75				
	SUBJECT2	61.50	69.75	60.75	75.75	51.75	73.50	78.75	67.50	67.41				
	SUBJECT3	42.00	42.75	41.25	54.75	51.75	57.00	44.25	56.25	48.75				
	SUBJECT4	48.75	49.50	33.75	36.75	49.50	47.25	46.50	48.75	45.09				
	SUBJECT5	54.00	60.00	57.00	60.75	55.50	60.75	74.25	71.25	61.69				
	SUBJECT6	42.00	57.75	52.50	53.25	64.50	65.25	67.50	65.25	58.50				
	SUBJECT7	63.75	61.50	75.00	45.00	52.50	67.50	63.75	60.00	61.12				
	SUBJECT8	75.00	78.75	67.50	69.75	39.00	67.50	52.50	60.00	63.75				
	M E A N	53.34	61.22	57.66	57.19	50.53	64.97	63.66	64.50					58.13
e	SUBJECT1	17.25	30.00	28.50	22.50	36.75	27.00	23.25	30.00	26.91				
	SUBJECT2	37.50	32.75	30.00	23.25	23.25	22.50	17.25	22.50	26.25				
	SUBJECT3	25.50	24.75	31.50	24.00	18.00	27.75	23.25	36.75	25.14				
	SUBJECT4	15.00	18.75	20.25	30.00	24.00	21.75	22.50	22.50	21.94				
	SUBJECT5	30.00	18.00	22.50	27.00	28.50	37.50	28.50	36.75	28.59				
	SUBJECT6	27.00	35.25	45.00	45.75	20.25	42.75	48.75	33.00	37.22				
	SUBJECT7	21.75	27.00	25.50	17.25	26.25	30.00	30.75	19.50	24.75				
	SUBJECT8	30.75	37.50	33.75	33.75	30.00	43.50	17.25	36.75	32.91				
	M E A N	25.59	28.12	29.62	27.94	25.97	31.59	26.44	29.72					28.11
h	SUBJECT1	16.50	28.50	17.25	15.75	15.00	15.00	15.00	15.00	17.25				
	SUBJECT2	19.50	23.25	26.25	22.50	27.75	22.50	22.50	22.50	23.34				
	SUBJECT3	5.25	3.00	7.50	9.75	12.75	15.00	11.25	10.50	9.37				
	SUBJECT4	15.00	18.00	14.25	15.75	18.75	16.50	15.75	15.75	16.22				
	SUBJECT5	14.25	15.00	15.00	17.25	14.25	15.00	15.00	15.00	15.09				
	SUBJECT6	15.75	18.75	15.00	15.75	14.25	15.00	15.00	16.50	15.75				
	SUBJECT7	15.00	15.00	19.50	15.00	17.25	17.25	22.50	21.00	17.81				
	SUBJECT8	14.25	15.75	15.00	18.75	13.50	15.00	14.25	15.00	15.10				
	M E A N	14.44	17.16	16.22	16.31	16.19	16.41	16.41	16.41					16.25

TABLE 12

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 1

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	M 4	E 5	R 6	I 7	N 8	G 9	S 10	MEAN	GRAND MEAN
Q	SUBJECT1	20.25	16.50	23.25	17.25	22.50	21.00	21.75	19.50	20.25			
	SUBJECT2	36.00	24.00	30.00	27.75	22.50	26.25	26.25	25.50	27.28			
	SUBJECT3	10.50	10.50	11.25	8.25	13.50	12.75	42.00	18.75	15.94			
	SUBJECT4	15.00	15.00	16.50	15.00	17.25	21.00	15.75	19.75	16.78			
	SUBJECT5	18.75	15.75	17.25	21.00	21.00	21.00	15.75	15.00	18.19			
	SUBJECT6	18.75	19.50	20.25	16.50	21.00	22.50	18.75	21.75	19.87			
	SUBJECT7	23.25	17.25	18.75	22.50	21.00	21.00	21.00	20.25	20.62			
	SUBJECT8	16.50	21.00	21.00	22.50	21.00	15.00	21.00	17.25	19.41			
	M E A N	19.87	17.44	19.78	19.84	19.97	20.06	22.78	19.59				19.79
R	SUBJECT1	22.50	33.75	41.25	44.25	37.50	24.75	32.25	38.25	34.31			
	SUBJECT2	15.75	21.75	30.00	26.25	15.00	15.00	22.50	23.25	21.19			
	SUBJECT3	21.00	24.00	30.00	7.50	54.75	22.50	33.75	15.75	26.16			
	SUBJECT4	21.00	7.50	15.00	34.50	15.75	29.25	30.00	21.00	21.75			
	SUBJECT5	18.75	17.25	24.00	23.25	26.25	26.25	22.50	24.00	22.78			
	SUBJECT6	15.00	28.50	30.00	33.75	30.75	42.00	43.50	34.50	32.25			
	SUBJECT7	36.75	22.50	22.50	24.00	21.75	23.25	24.75	15.75	23.91			
	SUBJECT8	20.25	30.00	33.75	29.25	24.75	39.25	30.75	31.50	29.81			
	M E A N	21.37	23.16	28.31	27.84	28.31	27.66	30.00	25.50				26.52
Greater of a, u	SUBJECT1	47.25	62.25	71.25	60.00	60.00	36.00	55.50	60.00	56.53			
	SUBJECT2	53.25	64.50	60.00	73.50	67.50	71.25	82.50	97.50	71.25			
	SUBJECT3	45.00	48.75	52.50	57.75	47.25	53.25	63.75	81.00	56.16			
	SUBJECT4	40.50	37.50	42.75	37.50	39.00	44.25	34.50	39.00	39.37			
	SUBJECT5	45.75	46.50	60.00	52.50	75.75	67.50	46.50	53.25	55.97			
	SUBJECT6	45.75	51.75	38.25	37.50	56.25	57.00	56.25	67.50	51.28			
	SUBJECT7	55.50	90.00	105.00	89.25	74.25	92.50	62.25	90.00	81.09			
	SUBJECT8	67.50	69.75	73.50	59.25	60.75	59.25	72.00	63.00	65.62			
	M E A N	50.06	58.87	62.91	58.41	60.09	58.87	59.16	68.91				59.66
v	SUBJECT1	52.50	75.00	64.50	48.75	53.25	37.50	52.50	61.50	55.69			
	SUBJECT2	41.25	52.50	51.00	48.00	52.50	58.50	59.25	52.50	51.94			
	SUBJECT3	37.50	30.00	37.50	39.00	36.75	42.00	45.00	48.75	39.56			
	SUBJECT4	37.50	30.75	36.75	33.00	34.50	30.00	23.25	35.25	32.62			
	SUBJECT5	33.00	30.00	31.50	30.00	41.25	37.50	37.50	35.25	34.50			
	SUBJECT6	60.00	45.00	52.50	45.75	54.75	60.00	60.75	59.25	54.75			
	SUBJECT7	42.00	78.75	75.00	51.00	54.00	60.75	45.75	63.75	60.00			
	SUBJECT8	58.25	67.50	60.00	54.75	61.50	52.50	67.50	69.00	61.50			
	M E A N	45.37	51.12	51.09	43.78	48.56	48.47	49.94	53.16				48.82

TABLE 13

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 2

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE -6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	39.75	58.50	52.50	70.50	56.25	71.25	52.50	67.50	58.59	
	SUBJECT2	39.00	42.00	45.00	43.50	38.25	50.25	45.00	53.25	44.53	
	SUBJECT3	48.00	66.00	60.00	53.25	45.00	52.50	52.50	52.50	53.72	
	SUBJECT4	40.50	45.00	45.00	45.00	48.00	45.75	45.75	45.00	45.00	
	SUBJECT5	57.00	44.25	36.75	42.75	39.00	36.00	42.00	45.75	42.94	
	SUBJECT6	45.00	52.50	52.50	60.00	60.00	60.00	60.00	60.75	56.34	
	SUBJECT7	55.50	60.00	66.00	75.00	52.50	78.75	69.00	75.00	66.47	
	SUBJECT8	42.00	42.75	40.50	46.50	38.25	42.00	45.75	42.75	42.56	
	M E A N	45.84	51.37	49.78	54.56	47.16	54.56	51.56	55.31		51.27
Greater of d, f	SUBJECT1	43.50	44.25	45.00	67.50	67.50	81.00	87.75	84.00	65.06	
	SUBJECT2	59.25	52.50	45.00	53.25	105.00	90.00	73.50	66.75	68.16	
	SUBJECT3	45.75	52.50	90.00	78.75	49.50	37.50	45.00	60.75	57.47	
	SUBJECT4	54.00	45.00	56.25	45.00	46.50	38.25	53.25	60.75	49.87	
	SUBJECT5	60.75	51.75	47.25	57.75	52.50	63.75	66.75	93.00	61.69	
	SUBJECT6	49.50	66.00	64.50	60.00	75.00	61.50	60.75	72.75	63.75	
	SUBJECT7	57.75	73.50	67.50	58.50	58.50	67.50	71.25	69.00	65.44	
	SUBJECT8	54.00	67.50	63.75	64.50	63.75	60.75	67.50	60.75	62.81	
	M E A N	53.06	56.62	59.91	60.66	64.78	62.53	65.72	70.97		61.78
g	SUBJECT1	30.75	33.75	34.50	30.75	32.25	28.50	36.75	36.75	33.00	
	SUBJECT2	30.00	32.25	30.00	33.75	30.00	24.00	26.25	26.25	29.06	
	SUBJECT3	30.75	30.00	30.00	34.50	27.75	26.25	35.25	33.75	31.03	
	SUBJECT4	18.75	30.00	30.00	28.50	22.50	24.00	30.75	31.50	27.00	
	SUBJECT5	24.75	30.00	29.25	30.00	27.00	37.50	19.50	37.50	29.44	
	SUBJECT6	35.25	51.00	51.00	37.50	40.50	34.50	39.75	37.50	40.87	
	SUBJECT7	18.75	37.50	37.50	42.75	33.00	30.00	29.25	41.25	33.75	
	SUBJECT8	23.25	34.50	34.50	46.50	22.50	22.50	23.25	22.50	28.69	
	M E A N	26.53	34.88	34.59	35.53	29.44	28.41	30.09	33.37		31.61
h	SUBJECT1	12.00	15.00	16.50	14.25	10.50	15.00	15.00	15.75	14.25	
	SUBJECT2	15.75	15.00	15.00	15.75	19.50	21.00	16.50	20.25	17.34	
	SUBJECT3	3.75	6.00	7.50	9.75	11.25	7.50	2.25	7.50	6.94	
	SUBJECT4	21.00	16.50	15.00	15.75	18.00	15.00	15.00	15.00	16.41	
	SUBJECT5	15.00	15.00	13.50	15.00	18.75	15.00	15.00	15.00	15.28	
	SUBJECT6	13.50	12.75	7.50	9.00	15.00	14.25	15.00	15.00	12.75	
	SUBJECT7	15.00	15.00	16.50	18.00	19.50	15.00	18.00	21.00	17.25	
	SUBJECT8	13.50	13.50	15.00	15.00	15.00	14.25	15.00	17.25	14.81	
	M E A N	13.69	13.59	13.31	14.06	15.94	14.62	13.97	15.84		14.38

TABLE 14

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 2

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W	E	R	I	N	G	S	SET 7	8	MEAN	GRAND MEAN
Q	SUBJECT1	13.50	13.50	14.25	15.00	12.75	14.25	18.00	14.25	14.44					
	SUBJECT2	18.75	19.50	15.75	22.50	21.75	21.75	21.75	22.50	20.53					
	SUBJECT3	11.25	15.00	15.75	13.50	3.75	12.75	12.00	9.75	11.72					
	SUBJECT4	18.75	13.50	16.50	15.00	12.75	15.00	15.00	15.00	15.19					
	SUBJECT5	15.00	18.75	15.00	15.75	15.00	15.00	15.75	15.00	15.66					
	SUBJECT6	15.75	21.00	15.75	16.50	18.00	17.25	15.00	21.75	17.62					
	SUBJECT7	17.25	28.50	16.50	15.75	21.75	21.00	20.25	22.50	20.44					
	SUBJECT8	12.00	12.75	14.25	12.75	12.00	14.25	15.75	15.00	13.59					
	M E A N	15.28	17.81	15.47	15.84	14.72	16.41	16.69	16.97						16.15
R	SUBJECT1	45.00	35.25	43.50	32.25	44.25	41.25	37.50	33.75	39.09					
	SUBJECT2	24.00	33.00	38.25	27.00	28.50	36.75	33.75	25.50	30.84					
	SUBJECT3	34.50	38.25	21.75	45.00	34.50	29.25	23.25	18.75	30.66					
	SUBJECT4	15.00	26.25	26.25	30.00	28.50	30.00	22.50	19.50	24.75					
	SUBJECT5	37.50	27.00	27.00	33.75	26.25	30.00	29.25	26.25	29.62					
	SUBJECT6	44.25	45.00	39.00	38.25	33.75	39.75	45.00	43.50	41.06					
	SUBJECT7	30.00	43.50	51.00	38.25	41.25	42.75	42.00	44.25	41.62					
	SUBJECT8	28.50	37.50	37.50	27.00	27.00	30.00	27.00	36.75	31.41					
	M E A N	32.34	35.72	35.53	33.94	33.00	34.97	32.53	31.03						33.63
Greater of u, v	SUBJECT1	44.25	48.75	52.50	59.25	52.50	46.50	45.00	56.25	50.52					
	SUBJECT2	45.75	51.00	45.75	48.75	91.50	90.00	82.50	86.25	67.69					
	SUBJECT3	46.50	66.00	69.00	51.00	60.00	72.00	57.00	66.00	60.94					
	SUBJECT4	41.25	42.00	45.00	45.00	36.75	43.50	41.25	36.75	41.44					
	SUBJECT5	45.75	48.75	40.50	56.25	73.50	62.25	60.75	63.75	56.44					
	SUBJECT6	51.75	37.50	51.75	45.00	69.75	60.00	59.25	51.75	53.34					
	SUBJECT7	75.75	72.00	72.75	89.25	61.50	96.75	105.00	67.50	60.06					
	SUBJECT8	74.25	66.75	67.50	74.25	66.75	60.75	60.75	53.25	65.55					
	M E A N	53.16	54.09	55.59	58.59	64.03	66.47	63.94	60.19						59.51
V	SUBJECT1	60.00	42.00	47.25	60.00	67.50	60.00	75.00	60.00	56.97					
	SUBJECT2	48.75	47.25	57.75	48.75	52.50	46.50	49.50	53.25	50.53					
	SUBJECT3	45.00	45.00	42.00	42.75	45.00	48.75	57.75	56.25	47.81					
	SUBJECT4	27.75	45.00	31.50	37.50	30.75	37.50	33.75	37.50	35.16					
	SUBJECT5	30.00	24.00	30.75	39.75	37.50	54.75	30.75	30.50	33.56					
	SUBJECT6	44.25	46.50	58.50	49.50	52.50	52.50	56.25	55.50	51.94					
	SUBJECT7	43.50	67.50	60.00	66.75	36.00	67.50	82.50	53.50	59.53					
	SUBJECT8	58.50	63.75	71.25	67.50	67.50	71.25	59.50	52.50	63.84					
	M E A N	44.72	47.62	49.87	50.44	48.66	54.84	55.50	49.60						50.17

TABLE 15

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 3

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L 4	T 5	F 6	T 7	S 8	MEAN	GRAND MEAN
b	SUBJECT1	48.75	60.00	66.00	66.75	66.00	67.50	61.50	60.00	62.06	
	SUBJECT2	48.00	45.75	37.50	57.00	41.25	48.75	45.00	52.50	46.97	
	SUBJECT3	45.00	43.50	57.00	60.75	51.75	60.00	57.75	67.50	55.41	
	SUBJECT4	36.75	40.50	40.50	32.25	37.50	40.50	35.25	36.75	37.50	
	SUBJECT5	45.00	44.25	45.00	45.00	38.25	45.00	46.50	43.50	44.06	
	SUBJECT6	37.50	52.50	63.75	62.25	54.00	55.50	61.50	63.75	56.34	
	SUBJECT7	61.50	72.00	70.50	60.00	58.50	71.25	58.50	67.50	64.97	
	SUBJECT8	44.25	52.50	52.50	45.00	41.25	45.75	45.00	45.00	46.41	
	M E A N	45.84	51.37	54.39	53.62	48.56	54.28	51.37	54.56		51.71
Greater of d, 2	SUBJECT1	46.50	27.75	71.25	69.00	34.50	45.00	66.00	51.00	51.37	
	SUBJECT2	70.50	75.00	59.25	67.50	63.75	108.00	63.75	86.25	74.25	
	SUBJECT3	45.00	50.25	56.25	52.50	57.00	75.00	55.50	67.50	57.37	
	SUBJECT4	52.50	45.00	59.25	45.00	52.50	51.00	52.50	48.75	50.81	
	SUBJECT5	44.25	53.25	46.50	38.25	51.00	57.75	60.00	52.50	50.44	
	SUBJECT6	75.00	60.00	73.50	62.25	60.00	52.50	60.00	56.25	62.44	
	SUBJECT7	60.00	56.25	75.00	52.50	39.75	67.50	37.50	45.00	54.19	
	SUBJECT8	63.00	60.00	75.00	60.75	56.25	59.25	53.25	56.25	60.47	
	M E A N	57.09	53.44	64.50	55.97	51.84	64.50	56.06	57.94		57.67
g	SUBJECT1	30.00	16.50	27.00	24.00	22.50	31.50	19.50	20.25	23.91	
	SUBJECT2	33.75	38.25	33.75	30.00	22.50	22.50	26.25	26.25	29.16	
	SUBJECT3	12.75	21.75	15.00	12.75	30.00	20.25	36.00	37.50	23.25	
	SUBJECT4	31.50	22.50	29.50	30.75	26.25	28.50	30.00	27.00	28.12	
	SUBJECT5	26.25	22.50	27.00	22.50	30.75	30.00	27.00	24.00	26.25	
	SUBJECT6	46.50	48.00	34.50	45.00	37.50	43.50	48.75	37.50	42.66	
	SUBJECT7	16.50	31.50	24.00	32.25	28.50	32.25	27.75	34.50	28.41	
	SUBJECT8	34.50	37.50	42.00	46.50	24.00	36.75	31.50	38.25	36.37	
	M E A N	28.97	29.81	28.97	30.47	27.75	30.66	30.84	30.66		29.77
h	SUBJECT1	12.75	12.75	15.00	13.50	14.25	14.25	11.25	13.50	13.41	
	SUBJECT2	18.00	15.75	15.00	15.75	13.50	15.00	16.50	15.75	15.66	
	SUBJECT3	7.50	7.50	3.00	6.75	6.00	9.75	11.25	11.25	7.87	
	SUBJECT4	14.25	12.00	12.00	14.25	13.50	12.00	12.75	12.00	12.84	
	SUBJECT5	7.50	8.25	13.50	12.75	15.75	21.00	20.25	15.00	14.25	
	SUBJECT6	12.00	12.75	12.00	15.00	11.25	7.50	10.50	11.25	11.53	
	SUBJECT7	8.25	12.75	15.00	12.00	15.00	13.50	15.00	13.50	13.13	
	SUBJECT8	13.50	11.25	13.50	9.75	11.25	12.00	13.50	7.50	11.53	
	M E A N	11.72	11.62	12.37	12.47	12.56	13.12	13.47	12.47		12.53

TABLE 16

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 3

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W	E	R	I	N	G REPLICATE 6	S SET 7	8	MEAN	GRAND MEAN
q	SUBJECT1	12.75	12.00	12.00	12.75	12.00	10.50	15.00	13.50	12.56				
	SUBJECT2	15.00	15.00	15.00	15.00	18.00	15.00	18.75	14.25	15.75				
	SUBJECT3	7.50	12.00	8.25	15.00	12.75	11.25	6.00	15.00	10.97				
	SUBJECT4	8.25	13.50	15.00	14.25	8.25	8.25	7.50	11.25	10.78				
	SUBJECT5	11.25	11.25	7.50	8.25	15.00	18.00	15.00	18.75	13.12				
	SUBJECT6	16.50	15.75	15.75	18.00	15.75	18.75	15.00	16.50	16.50				
	SUBJECT7	12.00	11.25	15.75	9.00	15.00	16.50	15.00	18.75	14.16				
	SUBJECT8	<u>11.25</u>	<u>9.75</u>	<u>11.25</u>	<u>13.50</u>	<u>15.75</u>	<u>9.00</u>	<u>12.00</u>	<u>15.00</u>	<u>12.19</u>				
	M E A N	11.81	12.56	12.56	13.22	14.06	13.41	13.03	15.37					13.25
r	SUBJECT1	30.00	34.50	28.50	27.75	30.00	24.75	27.75	30.00	29.16				
	SUBJECT2	7.50	27.75	7.50	22.50	20.25	22.50	12.75	18.75	17.44				
	SUBJECT3	22.50	15.00	30.00	30.00	24.00	33.75	31.50	17.25	25.50				
	SUBJECT4	22.50	17.25	15.00	15.00	21.75	18.75	21.00	21.00	19.03				
	SUBJECT5	33.75	27.00	26.25	27.00	26.25	15.75	18.75	26.25	25.13				
	SUBJECT6	36.00	35.25	37.50	30.00	29.25	33.75	36.75	36.75	34.41				
	SUBJECT7	15.00	22.50	30.75	26.25	23.25	28.50	33.00	15.00	24.28				
	SUBJECT8	<u>33.00</u>	<u>24.75</u>	<u>23.25</u>	<u>23.25</u>	<u>24.00</u>	<u>22.50</u>	<u>20.25</u>	<u>27.75</u>	<u>24.84</u>				
	M E A N	25.03	25.50	24.94	25.22	24.84	25.03	25.22	24.69					24.97
Greater of s, u	SUBJECT1	30.00	45.00	57.75	33.75	45.75	67.50	37.50	47.25	45.56				
	SUBJECT2	45.00	54.00	52.50	54.75	69.00	78.75	86.25	68.25	63.56				
	SUBJECT3	55.50	64.50	61.50	54.00	63.75	67.50	54.00	66.00	60.84				
	SUBJECT4	45.00	38.25	33.75	39.75	33.75	38.25	32.25	41.25	37.78				
	SUBJECT5	50.25	45.00	51.75	37.50	52.50	56.25	63.75	45.00	50.25				
	SUBJECT6	54.75	52.50	60.00	63.75	52.50	51.75	52.50	46.50	54.28				
	SUBJECT7	75.00	75.00	71.25	78.75	75.00	81.75	90.00	82.50	78.66				
	SUBJECT8	<u>67.50</u>	<u>61.50</u>	<u>56.25</u>	<u>75.00</u>	<u>41.25</u>	<u>52.50</u>	<u>60.00</u>	<u>58.50</u>	<u>59.06</u>				
	M E A N	52.87	54.47	55.59	54.66	54.19	61.78	59.53	56.91					56.25
v	SUBJECT1	53.25	58.50	56.25	38.25	68.25	54.00	38.25	42.75	51.19				
	SUBJECT2	34.50	45.75	38.25	36.75	60.00	45.00	48.75	69.75	47.34				
	SUBJECT3	26.25	39.00	37.50	34.50	48.00	39.75	46.50	38.25	38.72				
	SUBJECT4	37.50	26.25	19.50	28.50	25.50	27.75	30.75	34.50	28.78				
	SUBJECT5	36.75	30.75	29.25	30.75	38.25	33.75	32.25	39.00	33.84				
	SUBJECT6	51.75	51.75	60.00	59.25	52.50	51.75	52.50	56.25	54.47				
	SUBJECT7	52.50	75.00	65.25	60.00	67.50	67.50	65.25	84.00	67.12				
	SUBJECT8	<u>60.00</u>	<u>64.50</u>	<u>60.00</u>	<u>60.00</u>	<u>46.50</u>	<u>62.25</u>	<u>69.00</u>	<u>58.50</u>	<u>60.09</u>				
	M E A N	44.06	48.94	45.75	43.50	50.81	47.72	47.91	52.87					47.70

TABLE 17

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 4

PEAKS	SUBJECTS	L I F T S								MEAN	GRAND MEAN
		1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8		
b	SUBJECT1	53.25	51.75	54.00	56.25	67.50	70.50	47.25	58.50	57.37	
	SUBJECT2	41.25	41.25	33.75	41.25	26.25	41.25	42.75	37.50	38.16	
	SUBJECT3	54.00	60.00	59.25	59.25	45.00	52.50	63.75	52.50	55.78	
	SUBJECT4	48.00	41.25	38.25	36.75	34.50	42.00	36.00	39.00	39.47	
	SUBJECT5	45.00	36.75	39.00	45.00	38.25	46.50	52.50	39.00	42.75	
	SUBJECT6	49.50	57.00	52.50	59.25	47.25	52.50	56.25	60.00	54.28	
	SUBJECT7	71.25	60.00	61.50	69.75	48.75	56.25	67.50	60.00	61.87	
	SUBJECT8	45.00	41.25	38.25	54.75	33.00	44.25	60.00	48.00	45.56	
	M E A N	50.91	48.66	47.36	52.78	42.56	50.72	53.25	49.31		49.41
Greater of d, f	SUBJECT1	26.25	43.50	26.25	41.25	57.00	73.50	74.25	66.00	51.00	
	SUBJECT2	63.75	63.75	75.00	75.00	101.25	97.50	81.75	108.00	83.25	
	SUBJECT3	66.75	61.50	67.50	66.00	60.00	57.00	60.00	67.50	63.28	
	SUBJECT4	47.25	51.00	58.50	48.75	45.00	37.50	45.00	39.00	46.50	
	SUBJECT5	52.50	52.50	60.00	49.50	60.75	46.50	45.00	61.50	53.53	
	SUBJECT6	72.00	60.00	63.75	61.50	61.50	60.00	60.00	67.50	63.28	
	SUBJECT7	51.75	63.75	67.50	61.50	45.00	61.50	75.00	54.75	60.09	
	SUBJECT8	60.00	60.75	70.50	64.50	57.75	62.25	60.75	64.50	62.62	
	M E A N	55.03	57.09	61.12	58.50	61.03	61.97	62.72	66.09		60.45
g	SUBJECT1	29.25	30.00	26.25	22.50	17.25	37.50	30.00	22.50	26.91	
	SUBJECT2	18.75	30.00	46.50	30.00	30.00	24.00	37.50	22.50	29.91	
	SUBJECT3	30.00	29.25	21.75	30.75	27.00	39.75	34.50	34.50	30.94	
	SUBJECT4	15.75	18.00	22.50	22.50	15.75	26.25	18.75	20.25	19.97	
	SUBJECT5	22.50	37.50	37.50	22.50	26.25	24.00	36.00	22.50	28.59	
	SUBJECT6	43.50	37.50	36.75	48.75	33.00	38.25	45.75	45.75	41.16	
	SUBJECT7	37.50	26.25	30.00	31.50	29.25	45.75	45.00	37.50	35.34	
	SUBJECT8	30.00	24.75	37.50	25.50	15.00	24.75	29.25	30.00	27.09	
	M E A N	28.41	29.16	32.34	29.25	24.19	32.53	34.59	29.44		29.99
h	SUBJECT1	14.25	15.00	18.00	12.00	15.00	13.50	16.50	15.00	14.91	
	SUBJECT2	15.00	15.75	19.50	15.00	16.50	18.75	15.75	22.50	17.34	
	SUBJECT3	9.25	13.50	15.00	12.00	12.75	9.75	11.25	13.50	12.00	
	SUBJECT4	16.50	15.00	18.75	20.25	15.00	19.50	18.75	19.50	17.91	
	SUBJECT5	15.00	15.00	15.75	15.00	15.75	18.00	18.75	18.75	16.50	
	SUBJECT6	15.75	16.50	20.25	18.00	15.75	15.75	15.00	17.25	16.78	
	SUBJECT7	15.00	16.50	19.50	17.25	18.75	17.25	18.75	15.00	17.25	
	SUBJECT8	15.00	14.25	15.00	14.25	19.50	12.75	15.00	15.75	15.19	
	M E A N	14.34	15.19	17.72	15.47	16.12	15.66	16.22	17.16		15.98

TABLE 1A

PEAK VALUES OF VERTICAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 4

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	M 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
4	SUBJECT1	7.90	15.00	15.75	18.75	15.00	22.50	12.75	18.75		15.75		
	SUBJECT2	27.50	26.25	23.25	26.25	21.75	22.50	22.50	22.50		23.44		
	SUBJECT3	18.75	20.25	16.50	22.50	16.50	15.75	22.50	30.00		20.34		
	SUBJECT4	22.50	21.00	22.50	16.50	21.00	15.00	12.75	13.50		18.09		
	SUBJECT5	15.00	21.00	21.00	21.75	18.75	20.25	22.50	19.50		19.97		
	SUBJECT6	30.00	25.50	30.00	26.25	25.50	29.25	30.00	30.00		28.31		
	SUBJECT7	19.50	22.50	19.75	21.75	18.75	16.50	22.50	21.75		20.25		
	SUBJECT8	14.25	15.75	15.00	20.25	15.00	13.75	13.50	13.50		15.75		
	M E A N	18.75	20.91	20.34	21.75	19.03	20.06	19.27	21.19				20.24
7	SUBJECT1	39.00	33.75	41.25	35.25	32.25	45.00	37.50	38.25		37.78		
	SUBJECT2	27.00	26.25	21.00	25.50	23.25	29.25	33.75	39.00		28.12		
	SUBJECT3	22.50	29.25	22.50	24.00	23.25	41.25	24.75	15.75		25.41		
	SUBJECT4	18.75	15.75	15.00	21.75	27.00	24.75	25.50	26.25		21.84		
	SUBJECT5	18.75	27.75	23.25	24.00	24.00	30.00	22.50	24.75		24.37		
	SUBJECT6	33.75	37.50	38.25	39.00	42.00	34.50	37.50	45.00		38.44		
	SUBJECT7	39.75	31.50	39.00	23.25	23.25	37.50	27.00	22.50		30.47		
	SUBJECT8	36.75	27.75	24.75	34.50	29.25	37.50	24.00	33.75		31.03		
	M E A N	29.53	28.69	28.12	28.41	28.03	34.57	29.06	30.66				29.68
Greater of 8, 10	SUBJECT1	38.25	45.00	24.75	43.50	59.25	45.75	37.50	41.25		41.91		
	SUBJECT2	75.00	60.00	69.00	56.25	61.50	66.75	68.25	75.75		66.56		
	SUBJECT3	46.50	52.50	70.50	75.00	57.75	78.75	53.25	56.25		61.31		
	SUBJECT4	52.50	45.00	48.75	53.25	45.75	33.75	45.75	36.00		45.09		
	SUBJECT5	41.25	42.00	51.00	45.00	67.50	63.00	60.00	60.00		53.72		
	SUBJECT6	63.75	57.75	71.25	61.50	45.00	48.75	46.50	56.25		56.34		
	SUBJECT7	82.50	75.00	90.00	76.50	63.75	68.25	60.00	73.50		73.69		
	SUBJECT8	66.75	58.50	67.50	63.75	60.00	52.50	54.00	47.25		58.78		
	M E A N	58.31	54.47	61.59	59.34	57.56	57.19	53.16	55.78				57.18
7	SUBJECT1	60.00	72.00	43.50	87.75	62.25	45.00	48.75	36.75		57.00		
	SUBJECT2	37.50	39.00	56.25	43.50	46.50	52.50	51.75	46.50		46.69		
	SUBJECT3	40.50	48.75	45.00	47.25	45.00	45.75	46.50	31.50		43.78		
	SUBJECT4	39.00	24.75	34.50	48.75	26.25	34.50	34.50	39.75		35.25		
	SUBJECT5	36.00	37.50	30.75	41.25	42.00	39.00	41.25	45.00		39.09		
	SUBJECT6	42.75	51.75	48.00	51.75	46.50	52.50	62.25	61.50		52.12		
	SUBJECT7	57.00	44.25	63.75	51.00	59.25	50.00	67.50	50.25		56.62		
	SUBJECT8	45.75	63.75	71.25	71.25	63.75	46.75	61.50	45.75		61.22		
	M E A N	44.81	47.77	49.12	55.31	48.74	49.50	51.75	44.67				48.97

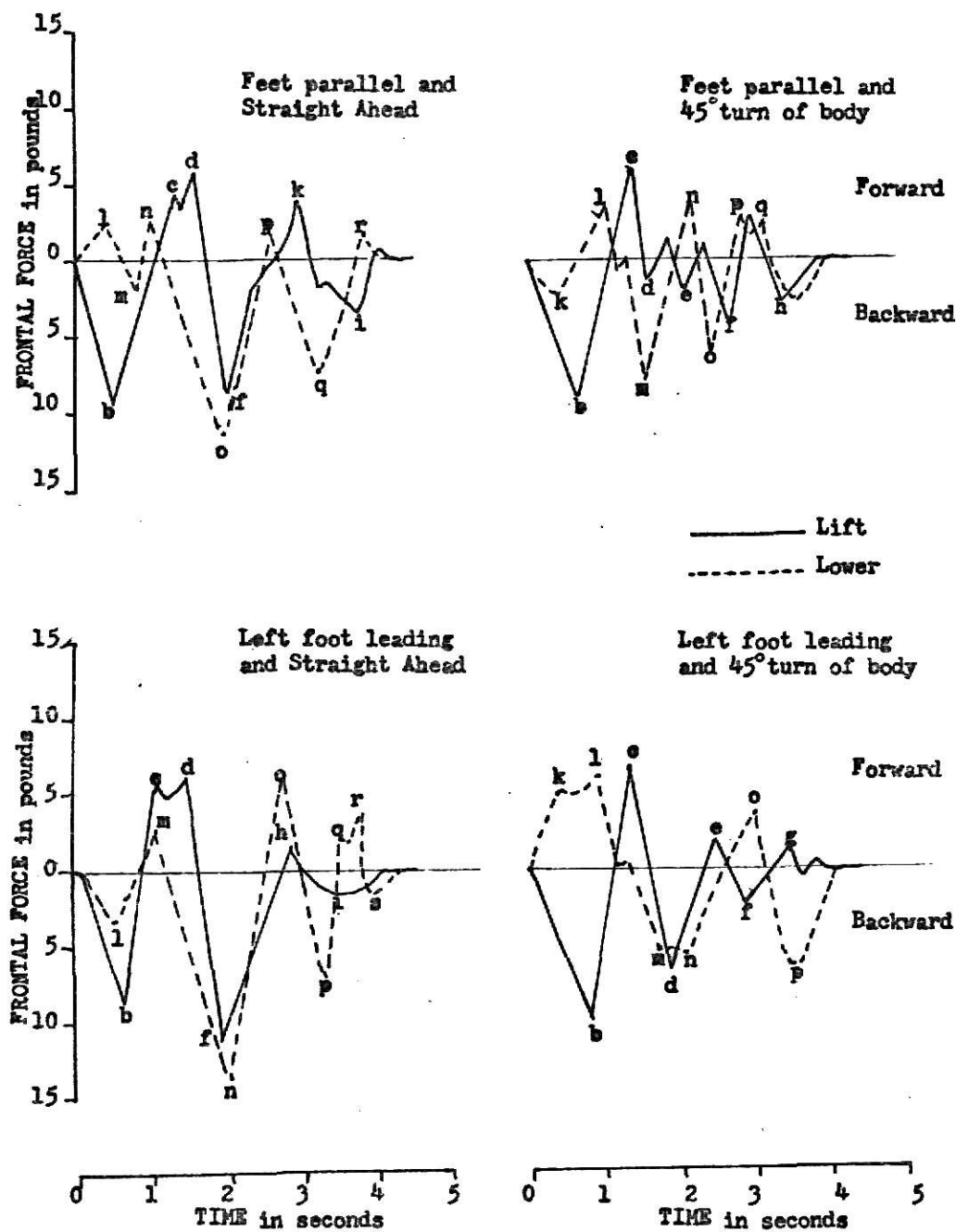


Fig. 15. Time history of frontal force for lifting and lowering in the four conditions.

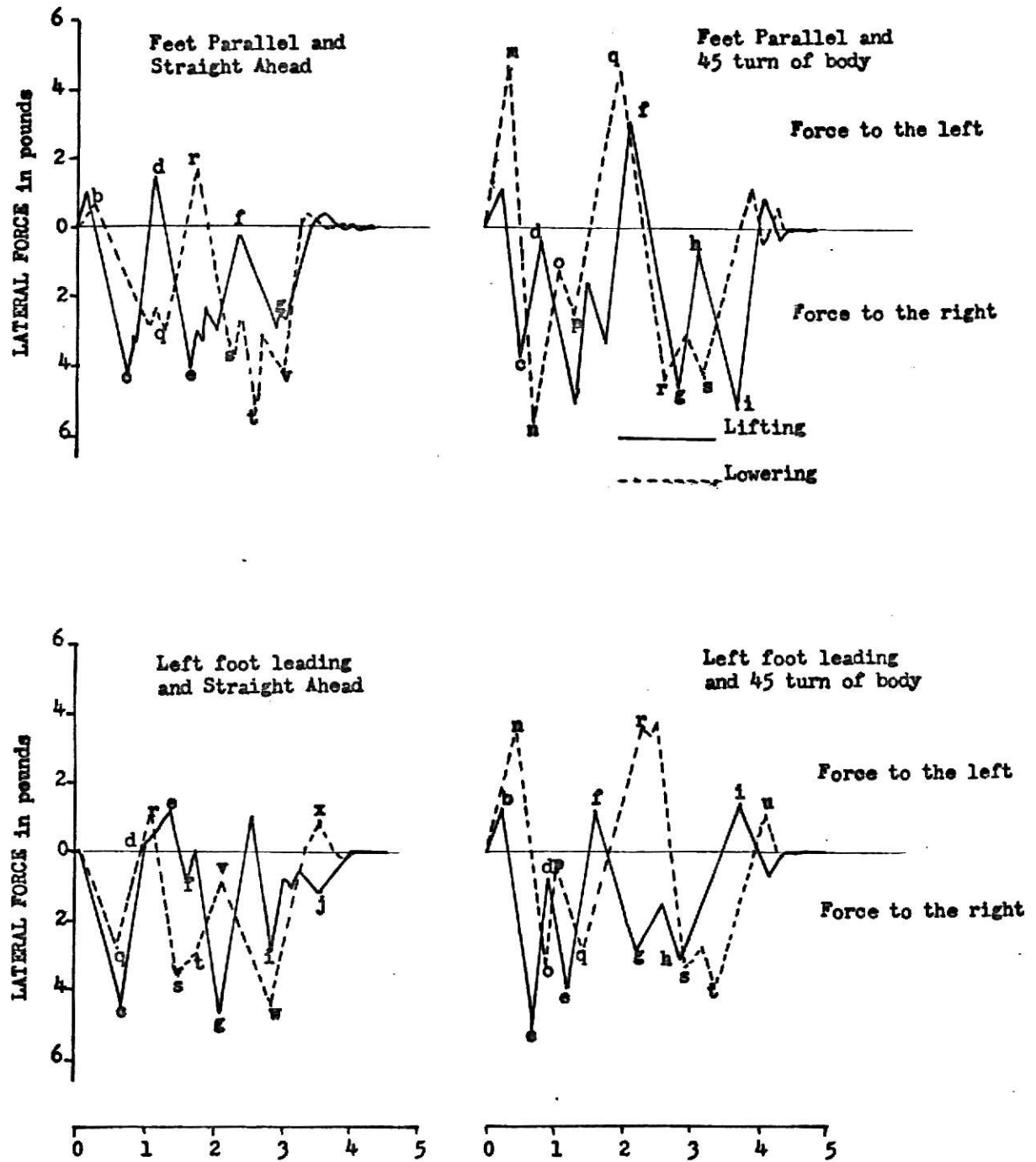


Fig. 16. Time history of lateral torque for lifting and lowering in the four conditions.

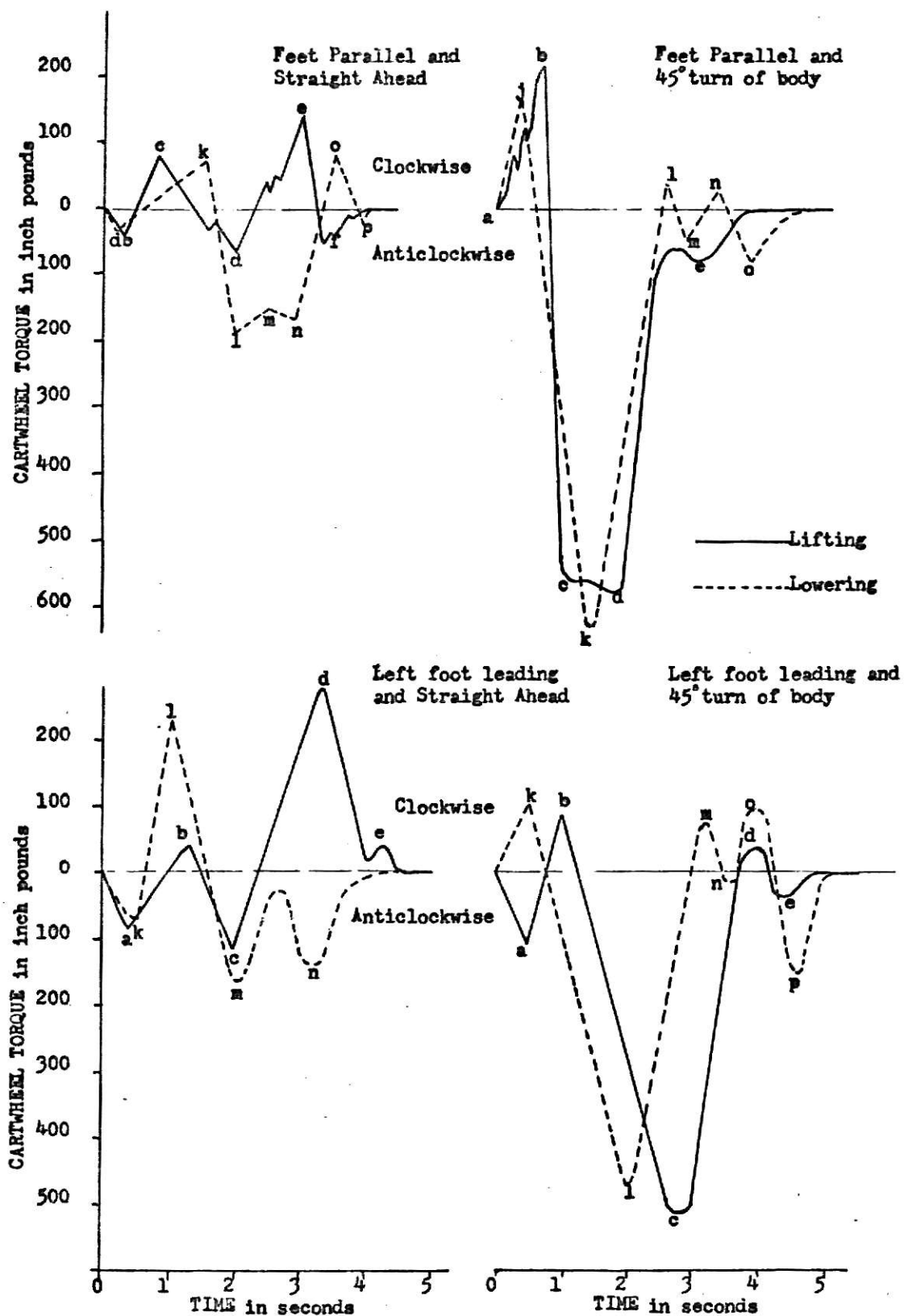


Fig. 17: Time history of cartwheel torque for lifting and lowering in the four conditions.

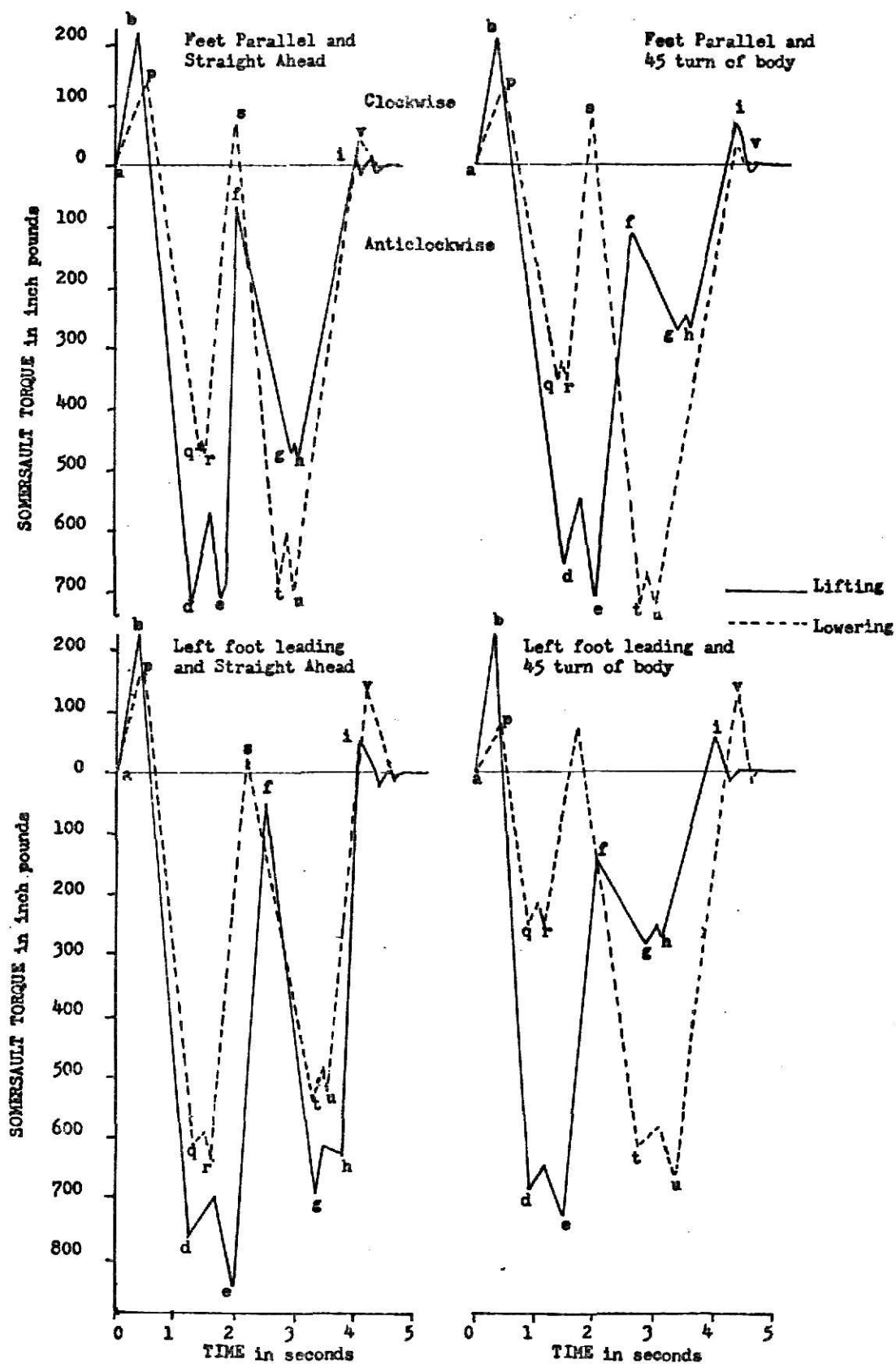


Fig. 18. Time history of somersault torque for lifting and lowering in the four conditions.

TABLE 19

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 1

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L 4	I 5	F 6	T 7	S 8	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	10.50	10.25	10.75	9.75	10.00	8.75	8.75	10.50	9.91				
	SUBJECT2	5.00	6.25	5.00	8.00	6.25	7.00	5.00	5.50	6.00				
	SUBJECT3	8.50	10.50	10.00	7.50	7.50	5.50	7.50	5.50	7.81				
	SUBJECT4	5.50	5.00	4.50	5.00	8.75	4.75	7.50	5.50	5.81				
	SUBJECT5	4.50	3.00	2.00	3.75	3.25	3.00	3.75	3.00	3.28				
	SUBJECT6	7.50	3.50	5.50	5.00	7.25	6.75	7.50	8.75	6.47				
	SUBJECT7	8.00	8.75	10.25	6.50	10.00	8.75	10.50	8.75	8.94				
	SUBJECT8	<u>5.50</u>	<u>7.00</u>	<u>5.50</u>	<u>9.50</u>	<u>5.50</u>	<u>7.50</u>	<u>5.25</u>	<u>7.00</u>	<u>6.59</u>				
	M E A N	6.87	6.73	6.69	6.87	7.31	6.50	6.97	6.81					6.85
d	SUBJECT1	10.25	12.50	15.25	8.75	7.50	12.50	13.75	15.50	12.00				
	SUBJECT2	10.00	8.75	6.25	9.50	7.00	12.00	8.00	7.50	8.62				
	SUBJECT3	12.50	5.50	11.25	13.00	10.00	12.00	7.50	7.00	9.64				
	SUBJECT4	10.00	11.25	9.00	8.75	6.50	7.50	5.00	7.50	8.19				
	SUBJECT5	5.00	3.25	6.75	6.25	3.75	7.00	5.00	6.75	5.47				
	SUBJECT6	6.50	5.75	7.50	11.50	10.00	12.50	10.00	12.00	9.47				
	SUBJECT7	4.50	3.75	6.25	4.25	6.25	4.50	7.00	5.00	5.19				
	SUBJECT8	<u>5.25</u>	<u>6.00</u>	<u>5.25</u>	<u>5.25</u>	<u>7.00</u>	<u>3.25</u>	<u>4.25</u>	<u>5.75</u>	<u>5.25</u>				
	M E A N	8.00	7.09	8.44	8.41	7.25	8.91	7.56	8.37					8.00
f	SUBJECT1	5.50	8.75	9.50	10.25	10.00	10.50	12.50	12.50	9.94				
	SUBJECT2	6.25	10.00	8.50	10.00	12.50	10.00	8.75	10.00	9.50				
	SUBJECT3	11.25	12.50	15.50	11.00	17.00	12.50	11.25	13.75	12.59				
	SUBJECT4	7.50	6.75	8.75	6.75	6.00	4.50	6.25	7.50	6.75				
	SUBJECT5	5.75	6.50	4.50	6.25	4.25	4.25	4.00	5.00	5.06				
	SUBJECT6	6.00	5.50	5.00	8.25	10.25	11.50	8.75	8.25	7.94				
	SUBJECT7	5.00	2.50	4.50	5.00	10.50	7.75	10.50	12.50	7.28				
	SUBJECT8	<u>7.50</u>	<u>7.50</u>	<u>5.25</u>	<u>6.25</u>	<u>7.50</u>	<u>7.00</u>	<u>5.00</u>	<u>5.25</u>	<u>6.41</u>				
	M E A N	6.84	7.50	7.59	7.97	9.25	8.50	8.37	9.34					8.18

TABLE 20

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 1

PEAKS	SUBJECTS	1	L FIRST 2	3 SET	W 4	E 5	R 6	I 7	N REPLICATE	G 8	S SET	9	MEAN	GRAND MEAN
	SUBJECT1	8.25	11.00	9.25	7.50	13.75	14.25	15.00	16.00	11.87				
	SUBJECT2	10.50	9.50	16.00	12.50	12.50	14.25	10.25	12.00	12.19				
	SUBJECT3	10.50	15.00	10.00	12.50	15.00	20.00	20.00	13.75	14.59				
0	SUBJECT4	7.00	8.00	6.25	7.50	5.50	6.25	13.00	5.50	7.00				
	SUBJECT5	7.00	7.00	5.75	6.75	5.75	3.75	5.75	5.00	5.84				
	SUBJECT6	7.00	10.00	7.00	9.50	16.25	13.50	10.00	7.00	10.03				
	SUBJECT7	7.50	16.25	9.75	10.00	12.00	15.00	10.00	8.50	11.12				
	SUBJECT8	7.50	5.50	7.75	7.50	11.25	5.50	5.50	5.00	6.94				
	M E A N	8.16	10.28	8.97	9.22	11.50	11.56	10.81	9.09	9.95				

TABLE 21

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 2

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	6.25	8.00	8.75	9.00	7.50	8.75	7.00	6.25	7.69	
	SUBJECT2	5.50	5.75	5.00	7.50	8.00	5.00	7.00	7.50	6.41	
	SUBJECT3	10.00	5.50	5.75	7.50	5.50	5.50	6.50	7.50	6.72	
	SUBJECT4	3.00	3.75	4.00	5.00	6.50	6.00	5.50	7.00	5.09	
	SUBJECT5	3.00	5.00	5.00	3.00	2.50	2.50	3.25	2.25	3.31	
	SUBJECT6	7.50	6.25	7.00	6.25	7.50	9.00	6.75	6.50	7.09	
	SUBJECT7	9.50	10.50	8.75	7.25	9.50	10.50	9.50	7.50	9.12	
	<u>SUBJECT8</u>	<u>6.25</u>	<u>12.75</u>	<u>5.00</u>	<u>5.50</u>	<u>5.25</u>	<u>6.25</u>	<u>7.25</u>	<u>7.00</u>	<u>7.03</u>	
	M E A N	6.37	7.19	6.28	6.37	6.53	6.69	6.59	6.44		6.56
c	SUBJECT1	5.00	8.00	7.50	12.50	12.00	12.00	12.25	14.75	10.50	
	SUBJECT2	8.75	7.50	7.50	5.00	18.75	13.75	11.25	10.00	10.31	
	SUBJECT3	12.50	9.50	17.50	12.00	8.50	13.50	8.75	6.25	11.06	
	SUBJECT4	10.00	5.00	5.50	3.75	5.50	6.75	4.50	6.75	5.97	
	SUBJECT5	7.00	5.25	5.50	4.50	3.75	5.00	4.50	6.50	5.25	
	SUBJECT6	12.00	10.00	11.25	12.50	8.75	10.50	9.25	15.00	11.16	
	SUBJECT7	4.25	3.50	9.00	6.25	7.50	5.50	7.50	7.00	6.31	
	<u>SUBJECT8</u>	<u>5.25</u>	<u>3.00</u>	<u>10.00</u>	<u>4.50</u>	<u>5.00</u>	<u>5.00</u>	<u>5.00</u>	<u>9.00</u>	<u>5.72</u>	
	M E A N	8.09	6.47	9.22	7.63	8.72	9.00	7.87	9.28		8.29
f	SUBJECT1	3.75	5.50	8.75	7.00	7.00	8.25	7.75	8.75	7.09	
	SUBJECT2	5.00	5.50	6.25	6.25	6.25	7.00	9.50	7.00	6.59	
	SUBJECT3	6.25	12.00	15.00	9.50	8.00	9.50	11.25	8.75	10.03	
	SUBJECT4	3.75	3.75	5.00	6.75	6.25	8.00	5.50	5.75	5.59	
	SUBJECT5	5.50	5.25	7.50	7.50	5.25	5.50	5.50	5.00	5.87	
	SUBJECT6	10.00	7.50	9.00	8.75	5.25	7.25	6.75	10.50	8.00	
	SUBJECT7	2.50	5.50	6.00	7.00	5.50	5.00	7.50	5.50	5.56	
	<u>SUBJECT8</u>	<u>5.50</u>	<u>4.50</u>	<u>9.50</u>	<u>6.25</u>	<u>3.75</u>	<u>5.00</u>	<u>5.00</u>	<u>5.00</u>	<u>5.56</u>	
	M E A N	5.28	6.19	8.25	7.37	5.91	6.94	7.34	7.03		6.79

TABLE 22

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 2

PEAKS	SUBJECTS	1	L FIRST 2	S SET 3	W 4	E 5	R 6	I 7	N 8	G REPLICATE 6	S SET 7	8	MEAN	GRAND MEAN
	SUBJECT1	6.25	5.00	6.50	5.00	6.00	7.00	9.50	7.50	6.59				
	SUBJECT2	10.00	11.25	7.50	8.00	10.50	7.50	12.00	7.75	9.31				
	SUBJECT3	18.00	17.00	13.75	11.50	17.00	17.50	13.75	15.00	15.44				
	SUBJECT4	4.50	5.00	8.25	8.75	8.00	6.75	6.50	10.00	7.22				
	SUBJECT5	5.00	7.25	6.50	5.50	4.50	4.00	4.50	4.00	5.16				
	SUBJECT6	9.50	7.75	8.75	7.50	7.50	6.25	7.25	7.50	7.75				
	SUBJECT7	7.50	8.50	5.50	11.25	8.00	5.50	4.50	8.00	7.34				
	SUBJECT8	7.50	5.00	4.25	7.50	6.25	6.25	5.00	5.75	5.94				
	M E A N	8.53	8.34	7.62	8.12	8.47	7.59	7.87	8.19					8.09

TABLE 23

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 3

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	7.00	9.50	8.00	9.50	7.50	7.00	7.00	10.50	8.25	
	SUBJECT2	3.75	5.00	3.00	5.00	5.00	5.50	6.25	7.00	5.06	
	SUBJECT3	6.25	10.00	5.00	5.00	5.00	6.25	5.00	7.50	6.25	
	SUBJECT4	5.00	4.00	5.00	4.00	7.50	7.50	5.50	5.25	5.47	
	SUBJECT5	2.50	5.00	3.25	4.00	2.50	3.00	2.00	2.50	3.09	
	SUBJECT6	7.50	8.75	8.00	7.75	7.50	8.00	9.00	9.50	8.25	
	SUBJECT7	10.50	12.50	10.00	3.75	8.75	10.00	7.50	7.50	8.81	
	SUBJECT8	<u>4.00</u>	<u>5.25</u>	<u>5.25</u>	<u>6.25</u>	<u>4.00</u>	<u>5.50</u>	<u>7.00</u>	<u>5.50</u>	<u>5.34</u>	
	M E A N	5.81	7.50	5.94	5.66	5.97	6.59	6.16	6.91		6.32
d	SUBJECT1	5.25	8.75	12.50	11.00	7.50	10.25	10.50	10.50	9.53	
	SUBJECT2	6.25	11.25	7.50	8.75	7.50	13.75	13.75	12.50	10.16	
	SUBJECT3	5.00	10.00	10.00	12.00	7.00	12.00	12.50	12.00	10.06	
	SUBJECT4	6.25	10.75	6.50	7.50	5.00	8.75	11.00	9.50	8.16	
	SUBJECT5	5.00	5.00	3.75	6.25	2.50	5.00	5.50	2.50	4.44	
	SUBJECT6	6.25	12.50	8.00	12.00	10.00	10.50	13.25	18.00	11.31	
	SUBJECT7	8.00	7.50	12.00	2.50	5.00	7.00	6.25	4.50	6.59	
	SUBJECT8	<u>10.50</u>	<u>7.00</u>	<u>5.50</u>	<u>6.25</u>	<u>4.50</u>	<u>9.50</u>	<u>7.50</u>	<u>6.00</u>	<u>7.09</u>	
	M E A N	6.56	9.09	8.22	8.28	6.13	9.59	10.03	9.44		8.42
f	SUBJECT1	9.50	6.50	12.00	13.00	8.00	7.50	14.50	10.25	10.16	
	SUBJECT2	6.25	7.50	6.50	7.75	7.50	8.75	10.50	12.00	8.34	
	SUBJECT3	7.00	13.00	11.25	11.25	10.00	9.50	13.75	10.50	10.78	
	SUBJECT4	9.00	7.00	7.00	7.25	7.75	7.50	5.50	10.50	7.69	
	SUBJECT5	5.50	7.00	5.00	3.50	6.75	5.00	4.00	5.00	5.22	
	SUBJECT6	10.00	10.50	11.25	10.25	10.50	10.50	13.00	10.75	10.84	
	SUBJECT7	12.50	11.25	13.50	13.75	10.00	10.00	13.00	8.00	11.50	
	SUBJECT8	<u>9.25</u>	<u>5.00</u>	<u>6.00</u>	<u>9.50</u>	<u>7.50</u>	<u>10.25</u>	<u>7.50</u>	<u>5.00</u>	<u>7.50</u>	
	M E A N	8.62	8.47	9.06	9.53	8.50	8.62	10.22	9.00		9.00

TABLE 24

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 3

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
	SUBJECT1	12.00	13.00	11.50	14.50	14.50	14.50	14.00	13.00			13.37	
	SUBJECT2	7.50	10.00	7.50	11.00	10.75	11.50	12.00	14.75			10.62	
	SUBJECT3	15.00	17.50	21.25	18.75	17.50	13.75	27.50	22.50			19.22	
	SUBJECT4	6.25	6.75	7.25	7.75	8.75	10.75	10.00	11.00			8.56	
	SUBJECT5	8.75	7.50	5.25	6.25	5.00	5.00	5.00	5.00			5.97	
	SUBJECT6	7.50	10.00	10.75	14.50	15.50	12.75	10.25	13.00			11.78	
	SUBJECT7	17.00	12.75	15.50	8.00	5.00	9.00	5.00	5.50			9.72	
	SUBJECT8	10.00	10.50	8.75	15.00	5.00	9.00	5.00	5.50			8.59	
	M E A N	10.50	11.00	10.97	11.97	10.25	10.78	11.09	11.28				10.98

TABLE 25

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 4

PEAKS	SUBJECTS	L I F T S								MEAN	GRAND MEAN
		1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8		
b	SUBJECT1	6.50	8.50	8.50	9.50	6.50	7.50	8.00	7.00	7.75	
	SUBJECT2	3.75	3.75	3.75	3.75	4.00	5.50	5.50	6.50	4.56	
	SUBJECT3	5.00	7.50	7.50	7.50	5.00	5.50	7.50	7.50	6.62	
	SUBJECT4	5.00	5.00	4.75	8.00	8.50	7.00	7.00	8.75	6.75	
	SUBJECT5	4.50	4.50	2.50	3.25	4.50	4.00	2.50	2.50	3.53	
	SUBJECT6	6.25	7.75	7.50	7.75	8.00	8.75	8.00	9.50	7.94	
	SUBJECT7	10.00	10.00	9.75	11.25	8.50	7.50	7.25	7.75	9.00	
	SUBJECT8	5.00	7.50	3.25	5.00	5.00	5.00	5.00	5.25	5.13	
	M E A N	5.75	6.81	5.94	7.00	6.25	6.34	6.34	6.84		6.41
c	SUBJECT1	8.25	8.00	7.50	8.75	12.50	12.00	13.75	13.50	10.53	
	SUBJECT2	6.25	3.75	4.00	7.50	10.50	12.75	12.50	12.75	8.75	
	SUBJECT3	8.50	14.50	6.25	10.00	12.50	12.50	12.50	13.00	11.22	
	SUBJECT4	5.00	8.75	9.50	7.25	5.50	8.00	7.25	9.50	7.59	
	SUBJECT5	4.75	6.00	5.50	5.00	5.50	5.00	3.75	3.00	4.81	
	SUBJECT6	6.25	10.00	12.50	8.75	9.50	15.00	10.00	10.00	10.25	
	SUBJECT7	6.25	7.75	9.00	8.00	6.25	5.50	5.50	6.00	6.78	
	SUBJECT8	3.75	7.75	9.00	7.50	5.00	5.00	7.50	5.50	6.37	
	M E A N	6.12	8.31	7.91	7.84	8.41	9.47	9.09	9.16		8.29
d	SUBJECT1	5.00	6.25	5.50	7.00	6.25	6.00	7.50	7.25	6.34	
	SUBJECT2	7.50	6.25	6.25	6.25	7.00	8.75	4.50	5.50	6.50	
	SUBJECT3	7.50	9.50	7.50	7.50	8.75	6.25	10.00	12.50	8.69	
	SUBJECT4	5.00	4.50	5.00	7.25	5.75	4.50	5.25	5.75	5.37	
	SUBJECT5	5.00	4.50	5.25	5.75	5.50	5.00	5.00	3.00	4.87	
	SUBJECT6	5.00	6.75	5.50	7.00	5.00	6.50	5.50	6.25	5.94	
	SUBJECT7	7.75	5.25	6.25	7.50	4.50	7.50	8.00	7.00	6.72	
	SUBJECT8	4.00	5.00	4.00	5.75	3.00	2.50	5.00	5.50	4.34	
	M E A N	5.84	6.00	5.66	6.75	5.72	5.87	6.34	6.59		6.10

TABLE 26

PEAK VALUES OF FRONTAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 4

PEAKS	SUBJECTS	1	L FIRST 2	D SET 3	M	E	R	I	N	G REPLICATE 6	S SET 7	8	MEAN	GRAND MEAN
	SUBJECT1	7.00	7.50	4.75	6.50	6.00	5.00	4.50	4.75	5.75				
	SUBJECT2	6.25	6.25	7.00	9.00	10.00	7.50	8.50	10.50	8.12				
	SUBJECT3	13.00	13.50	16.25	13.00	15.50	13.75	7.50	14.50	13.37				
	SUBJECT4	5.00	6.25	7.00	8.00	5.50	6.00	5.50	9.00	6.53				
	SUBJECT5	5.00	5.00	5.00	5.00	3.50	5.00	2.50	2.50	4.19				
	SUBJECT6	6.25	9.00	10.00	5.00	12.00	5.50	7.50	7.00	7.78				
	SUBJECT7	7.25	5.25	5.50	5.25	5.50	7.00	7.50	5.75	6.12				
	SUBJECT8	7.50	5.25	5.25	5.75	5.75	5.50	4.50	6.00	5.69				
	M E A N	7.16	7.25	7.59	7.19	7.97	6.91	6.00	7.50					7.20

TABLE 27

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 1

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
a	SUBJECT1	3.33	5.83	5.00	4.17	5.83	4.17	3.33	3.33	4.37	
	SUBJECT2	3.33	2.92	5.00	1.67	5.00	5.00	5.83	3.33	4.01	
	SUBJECT3	5.17	6.67	7.92	5.00	6.67	5.25	9.00	6.50	6.52	
	SUBJECT4	4.58	4.00	6.00	4.17	7.50	3.83	4.83	6.67	5.20	
	SUBJECT5	3.33	1.67	2.08	3.17	2.33	2.92	2.33	3.00	2.60	
	SUBJECT6	6.67	7.92	6.75	7.50	5.83	6.67	6.50	5.67	6.69	
	SUBJECT7	5.67	5.83	2.92	5.00	4.17	3.33	4.17	3.33	4.30	
	<u>SUBJECT8</u>	<u>5.00</u>	<u>4.00</u>	<u>4.58</u>	<u>4.17</u>	<u>3.75</u>	<u>5.00</u>	<u>3.75</u>	<u>5.00</u>	<u>4.41</u>	
	M E A N	4.64	4.85	5.03	4.35	5.14	4.52	4.97	4.60		4.75
b	SUBJECT1	3.75	4.17	4.17	3.33	2.50	4.17	2.50	3.33	3.49	
	SUBJECT2	5.42	2.50	4.17	5.00	2.50	5.00	4.17	4.17	4.11	
	SUBJECT3	4.17	3.33	3.33	3.33	5.42	5.00	4.83	3.33	4.09	
	SUBJECT4	3.33	2.50	2.50	2.92	4.00	2.50	4.00	2.92	3.08	
	SUBJECT5	2.92	3.33	2.92	2.58	2.92	2.67	2.00	2.50	2.73	
	SUBJECT6	2.50	3.75	4.17	2.92	4.17	3.50	2.92	3.50	3.43	
	SUBJECT7	1.67	3.33	5.00	2.50	1.67	3.33	3.33	4.17	3.12	
	<u>SUBJECT8</u>	<u>2.17</u>	<u>4.33</u>	<u>2.50</u>	<u>2.50</u>	<u>2.08</u>	<u>3.17</u>	<u>3.33</u>	<u>2.08</u>	<u>2.77</u>	
	M E A N	3.24	3.41	3.59	3.14	3.16	3.67	3.39	3.25		3.35

TABLE 28

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 1

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	M	E	R	I	N G S REPLICATE 6	7	8	MEAN	GRAND MEAN
	SUBJECT1	4.58	5.83	4.17	5.00	3.33	5.42	2.50	3.33	4.27			
	SUBJECT2	5.83	4.58	5.00	2.50	7.50	3.33	3.33	5.83	4.74			
	SUBJECT3	2.50	3.75	3.17	2.50	3.75	5.17	4.58	5.00	3.80			
	SUBJECT4	2.67	4.17	4.25	2.50	2.50	2.67	2.33	3.17	3.03			
	SUBJECT5	2.92	4.17	3.83	3.00	3.50	3.50	4.00	3.00	3.49			
	SUBJECT6	3.33	3.33	4.17	2.92	4.58	4.17	5.00	3.42	3.86			
	SUBJECT7	2.92	3.33	2.50	1.67	2.50	2.50	2.50	3.17	2.64			
	SUBJECT8	2.50	3.33	2.50	2.92	3.33	2.83	1.33	5.50	3.03			
	M E A N	3.41	4.06	3.70	2.87	3.87	3.70	3.20	4.05				3.61
	SUBJECT1	4.50	3.33	5.83	5.00	3.33	5.00	3.33	3.33	4.21			
	SUBJECT2	6.67	3.75	4.17	5.00	5.83	5.00	5.83	5.00	5.16			
	SUBJECT3	2.92	3.33	2.08	3.17	3.17	4.83	5.33	4.83	3.71			
	SUBJECT4	4.25	3.50	3.42	5.67	3.50	4.83	3.33	2.33	3.85			
	SUBJECT5	2.17	4.17	3.17	2.67	1.83	3.83	1.83	1.67	2.67			
	SUBJECT6	5.42	7.08	5.42	6.25	6.50	5.67	4.83	5.42	5.82			
	SUBJECT7	4.83	4.58	5.83	7.08	6.25	5.83	5.42	4.58	5.55			
	SUBJECT8	3.33	5.00	4.58	2.92	4.17	3.33	3.75	2.75	3.73			
	M E A N	4.26	4.34	4.31	4.72	4.32	4.79	4.21	3.74				4.34

TABLE 29

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 2

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
a,e	SUBJECT1	6.67	4.17	5.00	4.17	5.83	5.83	5.83	3.33	5.10	
	SUBJECT2	5.00	5.00	6.67	4.17	7.50	5.00	5.83	5.00	5.52	
	SUBJECT3	7.50	8.17	6.92	5.42	6.67	6.17	6.67	4.83	6.54	
	SUBJECT4	4.83	4.17	6.25	5.00	7.17	4.83	4.17	4.83	5.16	
	SUBJECT5	4.17	3.17	5.00	2.50	7.92	2.33	2.58	2.67	3.79	
	SUBJECT6	9.17	6.67	7.50	7.08	5.00	7.08	5.83	7.08	6.93	
	SUBJECT7	4.17	4.17	4.58	4.58	4.00	4.17	2.50	3.75	3.99	
	SUBJECT8	<u>3.33</u>	<u>4.00</u>	<u>5.67</u>	<u>5.67</u>	<u>3.33</u>	<u>4.58</u>	<u>5.42</u>	<u>3.33</u>	<u>4.42</u>	
	M E A N	5.60	4.94	5.95	4.82	5.93	5.00	4.85	4.35		5.18
f	SUBJECT1	1.67	3.33	3.33	5.00	1.67	2.50	2.50	1.67	2.71	
	SUBJECT2	1.67	3.33	5.00	0.83	4.17	5.00	2.50	3.33	3.23	
	SUBJECT3	3.75	3.75	5.00	1.67	2.50	4.58	4.83	5.33	3.93	
	SUBJECT4	1.67	1.67	2.50	1.83	2.50	5.00	3.33	2.67	2.65	
	SUBJECT5	1.67	4.58	3.00	4.58	1.25	1.67	2.92	2.67	2.79	
	SUBJECT6	3.33	3.75	5.42	3.33	1.67	5.00	4.83	3.75	3.89	
	SUBJECT7	4.17	2.92	5.42	3.33	4.17	9.17	4.33	2.92	4.55	
	SUBJECT8	<u>0.42</u>	<u>2.08</u>	<u>4.00</u>	<u>6.00</u>	<u>3.75</u>	<u>2.08</u>	<u>4.58</u>	<u>2.92</u>	<u>3.23</u>	
	M E A N	2.29	3.18	4.21	3.32	2.71	4.37	3.73	3.16		3.37
h,i	SUBJECT1	5.00	5.83	5.00	5.83	3.33	4.17	4.17	3.33	4.58	
	SUBJECT2	5.83	4.17	5.83	5.00	4.17	5.00	5.00	5.00	5.00	
	SUBJECT3	9.17	7.50	8.33	5.83	9.17	9.17	7.92	8.33	8.18	
	SUBJECT4	5.00	4.17	4.58	4.50	5.17	6.25	4.58	5.00	4.91	
	SUBJECT5	4.58	4.00	4.42	5.67	5.83	4.58	4.58	5.00	4.83	
	SUBJECT6	7.08	7.08	7.92	7.08	6.67	7.08	5.00	7.50	6.93	
	SUBJECT7	5.42	5.00	4.17	4.17	4.33	4.17	7.00	4.58	4.85	
	SUBJECT8	<u>5.00</u>	<u>4.83</u>	<u>3.33</u>	<u>4.17</u>	<u>5.00</u>	<u>3.50</u>	<u>3.75</u>	<u>4.58</u>	<u>4.27</u>	
	M E A N	5.89	5.32	5.45	5.28	5.46	5.49	5.25	5.42		5.44

TABLE 30

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 2

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
	SUBJECT1	3.33	6.67	6.67	5.00	2.50	3.33	1.67	2.50	3.96			
	SUBJECT2	2.50	4.17	3.33	2.50	6.67	4.17	5.00	4.58	4.11			
	SUBJECT3	4.17	3.33	3.75	3.33	4.00	4.17	5.00	4.17	3.99			
	SUBJECT4	7.92	5.00	7.08	4.83	8.33	1.50	1.50	5.00	5.15			
	SUBJECT5	4.17	4.17	4.58	4.17	4.17	3.33	3.33	2.50	3.80			
	SUBJECT6	5.83	6.67	6.00	6.67	7.92	7.08	7.08	7.92	6.90			
	SUBJECT7	3.50	4.17	4.17	3.75	5.83	5.00	5.00	5.00	4.55			
	SUBJECT8	3.75	3.33	4.00	4.17	4.83	5.00	2.92	3.17	3.90			
	M E A N	4.40	4.69	4.95	4.30	5.53	4.20	3.94	4.35				4.54
	SUBJECT1	7.08	5.83	5.00	5.00	5.83	3.33	6.25	6.67	5.62			
	SUBJECT2	7.50	4.17	6.67	4.17	6.67	5.83	5.83	5.42	5.78			
	SUBJECT3	9.17	7.67	5.83	10.83	9.17	8.33	7.92	9.58	8.56			
	SUBJECT4	5.83	5.42	5.83	6.50	7.08	6.67	6.50	6.67	6.31			
	SUBJECT5	5.00	4.17	5.00	3.75	5.83	5.83	5.83	5.83	5.16			
	SUBJECT6	7.50	7.33	7.50	6.67	8.33	6.67	7.50	8.33	7.48			
	SUBJECT7	3.33	5.83	4.17	5.83	5.83	5.00	7.92	5.83	5.47			
	SUBJECT8	4.50	5.67	5.00	5.83	5.83	4.17	5.00	5.83	5.23			
	M E A N	6.24	5.76	5.62	6.07	6.82	5.73	6.59	6.77				6.20
	SUBJECT1	4.17	4.17	5.00	6.00	6.00	6.25	4.58	3.33	4.94			
	SUBJECT2	6.67	5.00	6.25	5.00	7.50	5.00	5.42	5.00	5.73			
	SUBJECT3	4.33	5.17	5.42	5.42	9.17	7.50	6.67	7.50	6.40			
	SUBJECT4	5.00	4.58	2.08	4.17	2.50	4.17	4.58	6.83	4.24			
	SUBJECT5	4.33	0.67	3.33	2.33	4.17	2.92	3.33	2.50	2.95			
	SUBJECT6	7.50	5.83	5.83	7.08	5.83	5.83	3.33	8.33	6.20			
	SUBJECT7	4.17	5.83	4.17	4.17	4.17	4.00	5.00	4.58	4.51			
	SUBJECT8	2.50	3.17	3.33	4.17	3.33	5.00	3.33	2.52	3.47			
	M E A N	4.83	4.30	4.43	4.79	5.33	5.08	4.53	5.12				4.80

TABLE 31

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 3

PEAKS	SUBJECTS	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
c	SUBJECT1	4.83	6.67	5.00	3.33	7.50	3.75	5.00	5.00	5.14	
	SUBJECT2	5.83	8.33	4.17	3.33	3.33	6.67	5.83	5.00	5.31	
	SUBJECT3	2.50	5.83	3.33	4.83	4.83	6.67	6.17	5.83	5.00	
	SUBJECT4	4.17	3.50	3.67	5.00	2.92	3.00	4.00	4.17	3.80	
	SUBJECT5	4.00	1.67	2.33	4.00	2.92	1.67	2.50	1.67	2.59	
	SUBJECT6	7.50	5.17	4.58	5.42	4.17	7.08	3.33	5.00	5.28	
	SUBJECT7	3.75	5.42	4.58	2.50	5.25	5.83	3.33	3.67	4.29	
	SUBJECT8	2.50	3.33	3.50	7.50	2.92	4.33	5.17	5.17	4.30	
	M E A N	4.39	4.99	3.90	4.49	4.23	4.67	4.42	4.44		4.46
E	SUBJECT1	4.83	4.17	5.00	4.17	7.50	5.00	5.83	5.83	5.29	
	SUBJECT2	4.17	4.17	3.33	3.75	5.00	5.83	6.67	5.00	4.74	
	SUBJECT3	4.17	5.42	4.17	5.75	5.00	6.67	5.00	2.92	4.89	
	SUBJECT4	6.25	4.17	4.67	4.58	4.25	4.33	4.58	5.67	4.81	
	SUBJECT5	1.67	2.08	3.33	1.67	3.75	2.33	2.17	1.83	2.35	
	SUBJECT6	6.67	3.50	5.00	4.58	6.25	3.67	4.17	4.17	4.75	
	SUBJECT7	3.33	4.58	5.83	3.33	4.42	4.17	6.67	3.83	4.52	
	SUBJECT8	6.67	5.83	3.33	5.00	4.58	5.00	5.00	2.50	4.74	
	M E A N	4.72	4.24	4.33	4.10	5.09	4.62	5.01	3.97		4.51

TABLE 32

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 3

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
F	SUBJECT1	1.67	2.50	1.67	0.83	2.08	3.33	2.50	2.50	2.50	2.14		
	SUBJECT2	1.67	1.67	1.67	0.83	2.92	1.67	2.50	1.67	1.67	1.82		
	SUBJECT3	2.50	5.00	4.17	4.17	5.00	4.50	6.50	4.58	4.58	4.55		
	SUBJECT4	1.67	1.00	2.92	1.50	1.67	2.08	3.17	5.00	2.37	2.37		
	SUBJECT5	1.67	1.25	1.67	1.00	4.00	2.50	2.50	2.58	2.15	2.15		
	SUBJECT6	5.67	2.92	5.00	3.33	3.75	4.17	3.75	3.33	3.99	3.99		
	SUBJECT7	1.67	1.25	1.25	2.08	1.67	0.83	0.83	1.25	1.35	1.35		
	SUBJECT8	<u>2.50</u>	<u>2.08</u>	<u>1.67</u>	<u>3.33</u>	<u>1.67</u>	<u>1.67</u>	<u>1.67</u>	<u>3.75</u>	<u>2.29</u>	2.29		
	M E A N	2.37	2.21	2.50	2.14	2.84	2.59	2.93	3.08				2.58
F, W	SUBJECT1	5.00	4.17	5.00	5.00	5.83	6.25	5.00	6.67	5.36	5.36		
	SUBJECT2	5.00	5.00	8.33	4.17	7.50	5.00	5.83	6.67	5.94	5.94		
	SUBJECT3	3.75	3.75	6.00	7.50	5.67	4.58	7.92	4.17	5.42	5.42		
	SUBJECT4	5.83	3.33	5.00	5.42	6.25	6.67	6.50	5.42	5.55	5.55		
	SUBJECT5	2.50	2.08	3.33	2.67	2.08	1.67	1.67	2.17	2.27	2.27		
	SUBJECT6	6.25	6.00	7.08	6.67	7.50	5.00	5.83	5.83	6.27	6.27		
	SUBJECT7	4.17	6.67	6.25	3.33	2.50	2.50	5.00	4.17	4.32	4.32		
	SUBJECT8	<u>3.33</u>	<u>3.17</u>	<u>4.17</u>	<u>7.50</u>	<u>3.75</u>	<u>4.17</u>	<u>5.00</u>	<u>6.00</u>	<u>4.64</u>	4.64		
	M E A N	4.48	4.27	5.65	5.28	5.14	4.48	5.34	5.14				4.97

TABLE 33

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LIFTING IN CONDITION 4

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
g	SUBJECT1	3.33	7.50	6.25	5.42	4.17	5.42	5.83	4.17	5.89	
	SUBJECT2	3.33	3.33	3.17	4.58	2.50	3.75	4.17	5.00	3.73	
	SUBJECT3	5.17	4.17	3.50	4.17	6.50	7.50	7.08	7.50	5.70	
	SUBJECT4	5.67	3.75	5.00	4.67	4.17	4.33	5.17	5.83	4.82	
	SUBJECT5	2.50	2.50	3.33	3.33	3.75	4.00	3.33	2.92	3.21	
	SUBJECT6	5.83	4.17	4.58	3.33	8.33	6.67	7.92	6.25	5.89	
	SUBJECT7	4.17	6.67	5.83	5.00	5.83	3.75	5.00	3.33	4.95	
	SUBJECT8	5.42	5.67	6.25	3.33	4.17	5.00	4.17	3.33	4.67	
	M E A N	5.05	4.72	4.74	4.23	4.93	5.05	5.33	4.79		4.86
f	SUBJECT1	2.92	2.50	2.50	2.50	4.17	3.33	1.67	5.00	3.07	
	SUBJECT2	1.67	2.08	0.00	1.67	1.67	3.33	1.67	5.00	2.14	
	SUBJECT3	1.25	2.92	2.92	2.50	1.83	4.58	4.17	3.33	2.94	
	SUBJECT4	4.17	2.92	3.17	2.67	2.50	2.33	3.17	2.00	2.86	
	SUBJECT5	1.67	2.33	2.50	0.83	1.25	1.67	1.67	1.67	1.70	
	SUBJECT6	1.83	5.00	5.42	2.08	2.50	3.33	1.67	2.50	3.04	
	SUBJECT7	1.67	1.67	1.67	0.00	1.67	0.00	1.67	4.17	1.56	
	SUBJECT8	3.67	3.75	4.17	5.00	3.33	2.50	4.17	2.50	3.64	
	M E A N	2.35	2.90	2.79	2.16	2.36	2.64	2.48	3.27		2.62
g	SUBJECT1	4.58	4.17	4.17	3.33	4.58	3.33	4.17	5.00	4.17	
	SUBJECT2	4.17	3.75	3.33	5.00	3.33	3.33	5.00	5.00	4.11	
	SUBJECT3	3.17	5.33	4.00	5.83	4.00	7.00	7.08	5.42	5.23	
	SUBJECT4	4.00	2.92	4.33	3.17	3.17	2.00	4.17	4.17	3.49	
	SUBJECT5	3.33	2.08	2.08	2.50	1.25	1.50	1.67	2.50	2.11	
	SUBJECT6	4.00	2.50	3.33	4.00	3.75	3.33	2.08	3.75	3.34	
	SUBJECT7	2.92	5.00	2.50	2.92	3.33	3.33	2.50	2.50	3.12	
	SUBJECT8	1.67	2.92	3.75	2.08	2.33	2.50	3.33	2.92	2.69	
	M E A N	3.48	3.58	3.44	3.60	3.22	3.29	3.75	3.91		3.53

TABLE 34

PEAK VALUES OF LATERAL FORCE IN POUNDS
DURING LOWERING IN CONDITION 4

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	M	E	R	I	N	G REPLICATE 6	S SET 7	8	MEAN	GRAND MEAN
M	SUBJECT1	2.50	2.50	3.33	3.33	5.00	3.33	5.00	2.50	3.44				
	SUBJECT2	2.50	1.67	1.67	1.67	3.33	4.17	3.33	3.33	2.71				
	SUBJECT3	5.00	5.33	2.08	5.83	3.33	3.75	3.33	2.50	3.90				
	SUBJECT4	1.67	1.67	5.00	2.67	4.58	2.67	2.50	3.42	3.02				
	SUBJECT5	1.67	3.33	1.67	2.92	1.67	1.67	2.50	1.67	2.14				
	SUBJECT6	5.00	5.00	1.67	4.17	4.58	4.58	4.33	3.33	4.08				
	SUBJECT7	2.08	2.08	3.33	2.50	2.50	5.00	3.75	5.00	3.28				
	<u>SUBJECT8</u>	<u>2.50</u>	<u>2.92</u>	<u>2.50</u>	<u>2.08</u>	<u>1.67</u>	<u>2.92</u>	<u>2.92</u>	<u>2.92</u>	<u>2.55</u>				
	M E A N	2.86	3.06	2.66	3.15	3.33	3.51	3.46	3.08					3.14
Q	SUBJECT1	4.58	4.58	5.83	5.00	5.42	5.83	4.17	2.50	4.74				
	SUBJECT2	1.67	3.33	4.17	5.00	4.17	4.17	2.92	3.75	3.65				
	SUBJECT3	4.17	7.08	5.00	5.00	4.58	6.67	5.00	5.83	5.42				
	SUBJECT4	6.50	5.00	3.33	4.17	5.83	4.00	3.33	4.17	4.54				
	SUBJECT5	4.17	5.00	5.00	5.33	5.00	4.17	4.17	3.33	4.52				
	SUBJECT6	5.33	4.58	4.50	6.67	4.17	6.25	6.00	5.83	5.42				
	SUBJECT7	3.33	2.50	2.50	3.33	3.75	3.75	2.50	4.17	3.23				
	<u>SUBJECT8</u>	<u>4.58</u>	<u>4.00</u>	<u>3.17</u>	<u>3.33</u>	<u>3.33</u>	<u>3.33</u>	<u>4.17</u>	<u>2.92</u>	<u>3.60</u>				
	M E A N	4.29	4.51	4.19	4.73	4.53	4.77	4.03	4.06					4.39
S	SUBJECT1	4.17	5.83	5.00	5.00	4.00	4.58	4.17	5.83	4.82				
	SUBJECT2	4.17	5.83	5.00	5.00	5.00	4.17	4.17	7.50	5.10				
	SUBJECT3	4.33	3.58	6.17	3.33	4.00	3.33	7.50	3.33	4.45				
	SUBJECT4	3.33	4.83	4.83	4.58	2.50	6.33	5.00	5.00	4.55				
	SUBJECT5	3.33	3.33	4.17	2.50	3.33	2.92	4.17	3.17	3.36				
	SUBJECT6	5.50	7.92	5.00	5.83	5.83	5.83	3.75	4.58	5.53				
	SUBJECT7	5.42	5.00	4.17	3.33	3.75	2.50	2.92	3.33	3.80				
	<u>SUBJECT8</u>	<u>4.58</u>	<u>4.33</u>	<u>3.17</u>	<u>3.33</u>	<u>5.00</u>	<u>3.17</u>	<u>2.92</u>	<u>0.00</u>	<u>3.31</u>				
	M E A N	4.35	5.28	4.69	4.11	4.18	4.10	4.32	4.09					4.37

TABLE 35

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 1

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
	SUBJECT1	154.29	51.43	12.86	51.43	51.43	102.86	128.57	25.71	72.32	
	SUBJECT2	25.71	25.71	0.00	51.43	0.00	102.86	154.29	0.00	45.00	
	SUBJECT3	0.00	102.86	51.43	25.71	25.71	77.14	77.14	180.00	67.50	
	SUBJECT4	51.43	25.71	51.43	51.43	77.14	128.57	51.43	77.14	64.29	
	SUBJECT5	102.86	102.86	0.00	12.86	51.43	77.14	0.00	51.43	49.82	
	SUBJECT6	128.57	128.57	77.14	77.14	0.00	128.57	154.29	12.86	88.39	
	SUBJECT7	102.86	180.00	51.43	102.86	25.71	51.43	77.14	61.71	81.64	
	SUBJECT8	128.57	154.29	128.57	180.00	128.57	0.00	25.71	128.57	109.29	
	M E A N	86.79	96.43	46.61	69.11	45.00	83.57	83.57	67.18		72.28
	SUBJECT1	51.43	77.14	12.86	64.29	0.00	154.29	51.43	25.71	54.64	
	SUBJECT2	102.86	180.00	102.86	205.71	205.71	51.43	231.43	180.00	157.50	
	SUBJECT3	205.71	0.00	180.00	205.71	180.00	128.57	51.43	77.14	128.57	
	SUBJECT4	102.86	128.57	51.43	102.86	128.57	0.00	0.00	51.43	70.71	
	SUBJECT5	102.86	77.14	102.86	38.57	51.43	25.71	0.00	102.86	62.68	
	SUBJECT6	102.86	77.14	77.14	25.71	12.86	128.57	102.86	51.43	72.32	
	SUBJECT7	180.00	154.29	128.57	180.00	154.29	0.00	154.29	154.29	138.21	
	SUBJECT8	25.71	0.00	25.71	180.00	25.71	25.71	25.71	51.43	45.00	
	M E A N	109.29	96.79	85.18	125.36	94.82	64.29	77.14	86.79		91.21

TABLE 36

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 1

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W	E	R	I	N	G REPLICATE 6	S SET 7	8	MEAN	GRAND MEAN
K	SUBJECT1	154.29	64.29	77.14	51.43	51.43	0.00	77.14	77.14	69.11				
	SUBJECT2	180.00	154.29	77.14	102.86	205.71	180.00	25.71	128.57	131.79				
	SUBJECT3	51.43	257.14	51.43	25.71	25.71	25.71	25.71	25.71	61.07				
	SUBJECT4	51.43	154.29	154.29	102.86	51.43	77.14	64.29	51.43	88.39				
	SUBJECT5	51.43	51.43	128.57	0.00	25.71	25.71	0.00	25.71	38.57				
	SUBJECT6	25.71	25.71	25.71	154.29	25.71	128.57	154.29	128.57	83.57				
	SUBJECT7	51.43	51.43	46.29	51.43	64.29	90.00	159.43	25.71	67.50				
	SUBJECT8	51.43	154.29	154.29	154.29	128.57	25.71	102.86	102.86	109.29				
	M E A N	77.14	114.11	89.36	80.36	72.32	69.11	76.18	70.71					81.16
M	SUBJECT1	0.00	0.00	51.43	51.43	51.43	128.57	51.43	51.43	48.21				
	SUBJECT2	25.71	77.14	102.86	51.43	77.14	51.43	154.29	51.43	73.93				
	SUBJECT3	77.14	154.29	128.57	257.14	395.71	77.14	0.00	102.86	147.86				
	SUBJECT4	128.57	51.43	51.43	154.29	77.14	102.86	25.71	0.00	73.93				
	SUBJECT5	51.43	0.00	0.00	25.71	77.14	102.86	25.71	77.14	45.00				
	SUBJECT6	25.71	25.71	77.14	154.29	25.71	51.43	154.29	180.00	86.79				
	SUBJECT7	252.00	102.86	128.57	252.00	128.57	180.00	231.43	154.29	178.71				
	SUBJECT8	102.86	77.14	180.00	25.71	128.57	154.29	51.43	51.43	96.43				
	M E A N	82.93	61.07	90.00	121.50	118.93	106.07	86.79	83.57					93.86

TABLE 37

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 2

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	167.14	102.86	154.29	154.29	77.14	51.43	38.57	115.71	107.68	
	SUBJECT2	257.14	180.00	205.71	154.29	0.00	51.43	205.71	437.14	186.43	
	SUBJECT3	128.57	115.71	205.71	205.71	154.29	205.71	154.29	77.14	155.89	
	SUBJECT4	51.43	51.43	77.14	154.29	180.00	77.14	51.43	77.14	90.00	
	SUBJECT5	77.14	77.14	25.71	102.86	77.14	77.14	25.71	77.14	67.50	
	SUBJECT6	257.14	154.29	205.71	25.71	51.43	180.00	77.14	77.14	128.57	
	SUBJECT7	308.57	128.57	308.57	102.86	180.00	205.71	360.00	205.71	225.00	
	SUBJECT8	<u>12.86</u>	<u>128.57</u>	<u>72.00</u>	<u>51.43</u>	<u>25.71</u>	<u>128.57</u>	<u>102.86</u>	<u>102.86</u>	<u>78.11</u>	
	M E A N	157.50	117.32	156.86	118.93	93.21	122.14	126.96	146.25		129.90
Greater of c, d	SUBJECT1	514.29	488.57	540.00	488.57	617.14	668.57	655.71	617.14	573.75	
	SUBJECT2	565.71	694.29	617.14	617.14	797.14	565.71	720.00	668.57	655.71	
	SUBJECT3	514.29	501.43	488.57	360.00	527.14	586.29	540.00	565.71	510.43	
	SUBJECT4	694.29	694.29	668.57	617.14	720.00	694.29	732.86	727.71	693.64	
	SUBJECT5	591.43	642.86	542.86	538.57	604.29	617.14	637.71	642.86	630.96	
	SUBJECT6	694.29	848.57	771.43	797.14	694.29	874.29	694.29	720.00	761.78	
	SUBJECT7	617.14	591.43	540.00	501.43	617.14	578.57	617.14	514.29	572.14	
	SUBJECT8	<u>411.43</u>	<u>617.14</u>	<u>591.43</u>	<u>745.71</u>	<u>694.29</u>	<u>642.86</u>	<u>694.29</u>	<u>668.57</u>	<u>633.21</u>	
	M E A N	575.36	634.82	607.50	599.46	658.93	653.46	661.50	640.61		628.95

TABLE 38

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 2

PEAKS	SUBJECTS	L O W E R I N G S								MEAN	GRAND MEAN
		1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8		
	SUBJECT1	540.00	591.43	488.57	617.14	668.57	668.57	668.57	668.57	613.93	
	SUBJECT2	642.86	642.86	540.00	694.29	694.29	720.00	668.57	745.71	668.57	
	SUBJECT3	617.14	630.00	694.29	540.00	663.43	591.43	591.43	565.71	611.68	
1	SUBJECT4	771.43	642.86	617.14	668.57	720.00	720.00	732.86	668.57	692.68	
	SUBJECT5	642.86	642.86	591.43	668.57	617.14	604.29	565.71	604.29	617.14	
	SUBJECT6	771.43	848.57	797.14	745.71	771.43	848.57	874.29	797.14	806.78	
	SUBJECT7	514.29	565.71	617.14	668.57	694.29	720.00	694.29	565.71	630.00	
	SUBJECT8	720.00	771.43	720.00	694.29	771.43	771.43	591.43	745.71	723.21	
	M E A N	652.50	666.96	633.21	662.14	700.07	705.53	673.39	670.18		670.50
	SUBJECT1	205.71	154.29	102.86	77.14	154.29	51.43	0.00	0.00	93.21	
	SUBJECT2	128.57	0.00	77.14	77.14	180.00	128.57	77.14	0.00	83.57	
	SUBJECT3	308.57	102.86	102.86	180.00	205.71	51.43	0.00	25.71	122.14	
1	SUBJECT4	77.14	154.29	205.71	102.86	0.00	51.43	51.43	51.43	86.79	
	SUBJECT5	0.00	51.43	77.14	77.14	0.00	51.43	25.71	51.43	41.79	
	SUBJECT6	102.86	77.14	77.14	51.43	0.00	77.14	51.43	0.00	54.64	
	SUBJECT7	25.71	102.86	25.71	77.14	51.43	25.71	77.14	25.71	51.43	
	SUBJECT8	25.71	25.71	51.43	102.86	25.71	25.71	154.29	51.43	57.86	
	M E A N	109.29	83.57	90.00	93.21	77.14	57.86	54.64	25.71		73.93

TABLE 39

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 3

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
b	SUBJECT1	102.86	128.57	205.71	128.57	77.14	25.71	77.14	154.29	112.50	
	SUBJECT2	25.71	77.14	128.57	154.29	128.57	102.86	77.14	102.86	99.64	
	SUBJECT3	154.29	51.43	51.43	102.86	77.14	25.71	51.43	51.43	70.71	
	SUBJECT4	128.57	257.14	180.00	308.57	257.14	180.00	205.71	257.14	221.79	
	SUBJECT5	12.86	77.14	0.00	25.71	77.14	77.14	51.43	25.71	43.39	
	SUBJECT6	257.14	205.71	128.57	90.00	205.71	205.71	77.14	154.29	165.54	
	SUBJECT7	25.71	51.43	149.14	0.00	128.57	0.00	30.86	25.71	51.43	
	SUBJECT8	<u>385.71</u>	<u>334.29</u>	<u>51.43</u>	<u>205.71</u>	<u>102.86</u>	<u>102.86</u>	<u>128.57</u>	<u>25.71</u>	<u>167.14</u>	
	M E A N	136.61	147.86	111.86	126.96	131.79	90.00	87.43	99.64		116.52
d	SUBJECT1	257.14	437.14	360.00	385.71	411.43	321.43	231.43	282.86	335.89	
	SUBJECT2	282.86	360.00	411.43	462.86	411.43	514.29	411.43	334.29	398.57	
	SUBJECT3	591.43	360.00	334.29	231.43	385.71	437.14	360.00	437.14	392.14	
	SUBJECT4	565.71	514.29	462.86	540.00	540.00	462.86	565.71	514.29	520.71	
	SUBJECT5	360.00	437.14	360.00	385.71	77.14	51.43	51.43	180.00	237.86	
	SUBJECT6	488.57	334.29	385.71	372.86	360.00	257.14	360.00	385.71	368.04	
	SUBJECT7	360.00	334.29	231.43	231.43	231.43	257.14	257.14	205.71	263.57	
	SUBJECT8	<u>565.71</u>	<u>437.14</u>	<u>257.14</u>	<u>360.00</u>	<u>282.86</u>	<u>347.14</u>	<u>385.71</u>	<u>308.57</u>	<u>368.04</u>	
	M E A N	433.93	401.79	350.36	371.25	337.50	331.07	327.86	331.07		360.60

TABLE 40

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 3

PEAKS	SUBJECTS	1	L FIRST 2	N SET 3	M	E	R	I	N REPLICATE 6	G SET 7	S 8	MEAN	GRAND MEAN
1	SUBJECT1	231.43	102.86	257.14	180.00	282.86	334.29	154.29	308.57	231.43			
	SUBJECT2	540.00	488.57	617.14	437.14	437.14	617.14	565.71	411.43	514.29			
	SUBJECT3	257.14	257.14	334.29	282.86	385.71	334.29	360.00	411.43	327.86			
	SUBJECT4	514.29	437.14	514.29	462.86	527.14	514.29	565.71	540.00	509.46			
	SUBJECT5	489.57	411.43	360.00	411.43	205.71	102.86	154.29	25.71	270.00			
	SUBJECT6	565.71	385.71	462.86	462.86	450.00	514.29	372.86	411.43	453.21			
	SUBJECT7	257.14	262.29	231.43	154.29	257.14	231.43	244.29	180.00	227.25			
	SUBJECT8	411.43	540.00	334.29	514.29	360.00	360.00	321.43	360.00	400.18			
	M E A N	408.21	360.64	388.93	363.21	363.21	376.07	342.32	331.07				366.71
Greater of m, n	SUBJECT1	0.00	51.43	77.14	25.71	51.43	51.43	51.43	102.86	51.43			
	SUBJECT2	360.00	102.86	77.14	180.00	205.71	308.57	257.14	51.43	192.86			
	SUBJECT3	180.00	0.00	77.14	51.43	0.00	154.29	0.00	25.71	61.07			
	SUBJECT4	0.00	51.43	231.43	102.86	128.57	25.71	154.29	0.00	86.79			
	SUBJECT5	128.57	128.57	205.71	128.57	51.43	102.86	25.71	154.29	115.71			
	SUBJECT6	180.00	25.71	77.14	154.29	0.00	77.14	51.43	154.29	90.00			
	SUBJECT7	100.29	115.71	257.14	205.71	154.29	77.14	192.86	154.29	157.18			
	SUBJECT8	180.00	205.71	128.57	154.29	102.86	0.00	115.71	25.71	114.11			
	M E A N	141.11	85.18	141.43	125.36	86.79	99.64	106.07	83.57				108.64

TABLE 41

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 4

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
	SUBJECT1	115.71	123.43	102.86	231.43	77.14	51.43	51.43	226.29	122.46	
	SUBJECT2	162.00	77.14	154.29	102.86	77.14	257.14	334.29	154.29	164.89	
	SUBJECT3	102.86	180.00	154.29	128.57	205.71	102.86	226.29	154.29	156.86	
b	SUBJECT4	385.71	360.00	334.29	228.86	205.71	154.29	180.00	205.71	256.82	
	SUBJECT5	0.00	51.43	0.00	25.71	154.29	128.57	51.43	205.71	77.14	
	SUBJECT6	51.43	231.43	257.14	180.00	180.00	154.29	12.86	154.29	152.68	
	SUBJECT7	64.29	64.29	133.71	102.86	154.29	90.00	0.00	115.71	90.64	
	SUBJECT8	231.43	51.43	282.86	292.86	51.43	252.00	205.71	25.71	172.93	
	M E A N	139.18	152.39	177.43	160.39	138.21	148.82	132.75	155.25		149.30
	SUBJECT1	385.71	637.71	462.86	360.00	591.43	565.71	565.71	617.14	523.29	
	SUBJECT2	308.57	385.71	154.29	154.29	257.14	205.71	257.14	360.00	260.36	
	SUBJECT3	128.57	180.00	282.86	360.00	360.00	411.43	483.43	334.29	317.57	
o	SUBJECT4	385.71	411.43	360.00	257.14	488.57	488.57	488.57	437.14	414.64	
	SUBJECT5	694.29	565.71	565.71	617.14	668.57	514.29	488.57	565.71	585.00	
	SUBJECT6	540.00	617.14	540.00	637.71	591.43	617.14	642.86	617.14	600.43	
	SUBJECT7	372.86	462.86	437.14	514.29	475.71	511.71	720.00	630.00	515.57	
	SUBJECT8	411.43	411.43	360.00	385.71	488.57	432.00	565.71	488.57	442.93	
	M E A N	403.39	459.00	395.36	410.79	490.18	468.32	526.50	506.25		457.47

TABLE 42

PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 4

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	W	E	R	I	N	G	S REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
1	SUBJECT1	380.57	411.43	308.57	372.86	694.29	694.29	732.86	565.71	520.07					
	SUBJECT2	334.29	385.71	252.00	437.14	514.29	488.57	540.00	514.29	433.29					
	SUBJECT3	334.29	205.71	360.00	380.57	565.71	308.57	411.43	385.71	369.00					
	SUBJECT4	411.43	334.29	308.57	437.14	540.00	591.43	514.29	488.57	453.21					
	SUBJECT5	617.14	591.43	591.43	591.43	514.29	565.71	514.29	642.86	578.57					
	SUBJECT6	488.57	642.86	591.43	591.43	668.57	617.14	642.86	552.86	599.46					
	SUBJECT7	334.29	385.71	437.14	501.43	493.71	668.57	475.71	516.86	476.68					
	SUBJECT8	475.71	501.43	372.86	334.29	437.14	411.43	514.29	540.00	448.39					
	M E A N	422.04	432.32	402.75	455.79	553.50	543.21	543.21	525.86						484.83
2	SUBJECT1	64.29	154.29	154.29	77.14	77.14	25.71	0.00	51.43	75.54					
	SUBJECT2	0.00	154.29	102.86	51.43	102.86	77.14	77.14	0.00	70.71					
	SUBJECT3	128.57	77.14	0.00	205.71	231.43	25.71	51.43	51.43	96.43					
	SUBJECT4	257.14	154.29	51.43	51.43	102.86	180.00	128.57	128.57	131.79					
	SUBJECT5	180.00	180.00	0.00	25.71	51.43	51.43	0.00	0.00	61.07					
	SUBJECT6	128.57	77.14	128.57	205.71	77.14	51.43	180.00	180.00	128.57					
	SUBJECT7	133.71	205.71	154.29	102.86	0.00	77.14	64.29	180.00	114.75					
	SUBJECT8	102.86	102.86	102.86	0.00	25.71	180.00	25.71	25.71	70.71					
	M E A N	124.39	138.21	86.79	90.00	83.57	83.57	65.89	77.14						93.70

TABLE 43

PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 1

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greater of d, e	SUBJECT1	796.99	910.84	959.64	796.99	666.87	813.25	764.46	715.66	803.09	
	SUBJECT2	862.05	878.31	910.84	894.58	910.84	943.37	910.84	910.84	902.71	
	SUBJECT3	715.66	715.66	715.66	731.93	813.25	879.31	845.78	878.31	786.62	
	SUBJECT4	650.60	618.07	513.98	471.69	634.34	585.54	585.54	536.75	574.56	
	SUBJECT5	520.48	357.83	325.30	390.36	455.42	325.30	341.57	357.83	384.26	
	SUBJECT6	683.13	683.13	748.19	748.19	764.46	813.25	748.19	945.78	754.29	
	SUBJECT7	650.60	796.99	748.19	618.07	796.99	673.37	796.99	813.25	736.81	
	SUBJECT8	<u>715.66</u>	<u>764.46</u>	<u>683.13</u>	<u>601.81</u>	<u>748.19</u>	<u>715.66</u>	<u>683.13</u>	<u>715.66</u>	<u>703.46</u>	
	M E A N	699.40	715.66	700.62	656.70	723.79	718.51	709.56	721.76		705.75
Greater of g, h	SUBJECT1	526.99	536.75	601.81	448.92	439.16	553.01	422.89	390.36	489.98	
	SUBJECT2	611.57	650.60	569.28	601.81	715.66	683.13	650.60	618.07	637.59	
	SUBJECT3	683.13	683.13	650.60	650.60	683.13	748.19	780.72	715.66	699.40	
	SUBJECT4	487.95	513.98	487.95	422.89	579.04	471.69	487.95	471.69	490.39	
	SUBJECT5	390.36	390.36	390.36	390.36	455.42	390.36	439.16	357.83	400.53	
	SUBJECT6	536.75	504.22	487.95	618.07	601.81	569.28	553.01	601.81	559.11	
	SUBJECT7	504.22	487.95	422.89	455.42	553.01	455.42	487.95	504.22	483.89	
	SUBJECT8	<u>439.16</u>	<u>585.54</u>	<u>416.39</u>	<u>357.83</u>	<u>553.01</u>	<u>455.42</u>	<u>487.95</u>	<u>455.42</u>	<u>468.84</u>	
	M E A N	522.51	544.07	503.40	493.24	572.53	540.81	538.78	514.38		528.72

TABLE 44

PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 1

PEAKS	SUBJECTS	1	L FIRST 2	O SET 3	M	E	R	I	N G S REPLICATE 6	7	8	MEAN	GRAND MEAN
Greater of t, u	SUBJECT1	520.48	439.16	448.92	481.45	357.83	487.95	357.83	260.24	419.23			
	SUBJECT2	650.60	715.66	748.19	813.25	683.13	699.40	715.66	683.13	713.63			
	SUBJECT3	520.48	618.07	634.34	585.54	715.66	683.13	748.19	748.19	656.70			
	SUBJECT4	471.69	455.42	487.95	471.69	487.95	471.69	455.42	487.95	473.72			
	SUBJECT5	487.95	455.42	487.95	455.42	455.42	455.42	439.16	422.89	457.45			
	SUBJECT6	650.60	504.22	553.01	487.95	569.28	513.98	520.48	569.28	546.10			
	SUBJECT7	504.22	422.89	455.42	351.32	536.75	520.48	520.48	585.54	487.14			
	SUBJECT8	<u>357.83</u>	<u>439.16</u>	<u>390.36</u>	<u>390.36</u>	<u>325.30</u>	<u>455.42</u>	<u>292.77</u>	<u>455.42</u>	<u>388.33</u>			
	M E A N	520.48	506.25	525.77	504.62	516.42	535.93	506.25	526.58				517.79
Greater of t, u	SUBJECT1	852.29	862.05	878.31	894.58	520.48	715.66	650.60	487.95	732.74			
	SUBJECT2	813.25	845.78	839.28	904.34	845.78	943.37	910.84	910.84	876.69			
	SUBJECT3	455.42	390.36	357.83	227.71	553.01	878.31	878.31	813.25	569.28			
	SUBJECT4	536.75	910.84	504.22	553.01	487.95	585.54	569.28	520.48	583.51			
	SUBJECT5	390.36	390.36	390.36	390.36	292.77	227.71	292.77	227.71	325.30			
	SUBJECT6	526.99	520.48	585.54	683.13	699.40	666.87	715.66	715.66	639.22			
	SUBJECT7	618.07	764.46	748.19	715.66	683.13	813.25	780.72	796.99	740.06			
	SUBJECT8	<u>618.07</u>	<u>553.01</u>	<u>650.60</u>	<u>422.89</u>	<u>553.01</u>	<u>657.11</u>	<u>585.54</u>	<u>569.28</u>	<u>576.19</u>			
	M E A N	601.40	654.67	619.29	598.56	579.44	685.98	672.97	630.27				630.37

TABLE 45

PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 2

PEAKS	SUBJECTS	L I F T S								MEAN	GRAND MEAN
		1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8		
Greater of d, e	SUBJECT1	780.72	780.72	806.75	975.90	715.66	683.13	764.46	715.66	777.88	
	SUBJECT2	813.25	813.25	845.78	764.46	1073.49	975.90	975.90	975.90	904.74	
	SUBJECT3	748.19	780.72	845.78	871.81	618.07	683.13	699.40	715.66	745.35	
	SUBJECT4	618.07	650.60	585.54	618.07	650.60	585.54	634.34	618.07	620.10	
	SUBJECT5	504.22	439.16	569.28	520.48	520.48	422.89	455.42	585.54	502.18	
	SUBJECT6	845.78	780.72	780.72	813.25	683.13	813.25	813.25	813.25	752.92	
	SUBJECT7	683.13	796.99	683.13	585.54	731.93	813.25	699.40	748.19	717.69	
	SUBJECT8	748.19	553.01	618.07	618.07	683.13	618.07	683.13	650.60	646.54	
	M E A N	717.69	699.40	716.98	720.95	709.56	699.40	715.66	727.86		713.42
Greater of g, h	SUBJECT1	520.49	390.36	422.89	487.95	325.30	357.83	455.42	309.04	408.66	
	SUBJECT2	618.07	553.01	536.75	601.81	553.01	553.01	553.01	455.42	553.01	
	SUBJECT3	650.60	735.18	780.72	715.66	520.48	650.60	650.60	634.34	667.27	
	SUBJECT4	390.36	357.83	309.04	253.73	357.83	416.39	341.57	390.36	352.14	
	SUBJECT5	357.83	364.34	455.42	390.36	455.42	357.83	422.89	422.89	403.37	
	SUBJECT6	422.89	487.95	520.48	520.48	422.89	455.42	448.92	390.36	458.67	
	SUBJECT7	341.57	357.83	357.83	357.83	422.89	390.36	406.63	390.36	378.16	
	SUBJECT8	341.57	325.30	325.30	260.24	390.36	455.42	390.36	357.83	355.80	
	M E A N	455.42	446.48	463.55	448.51	431.02	454.61	458.67	418.82		447.14

TABLE 46

PEAK VALUES OF SEMIPLANT TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 2

PEAKS	SUBJECTS	1	L FIRST 2	R SET 3	W	E	R	I	N	G	S	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greater of a, r	SUBJECT1	292.77	227.71	390.36	292.77	292.77	325.30	292.77	296.02	301.31						
	SUBJECT2	520.48	422.89	487.95	455.42	455.42	504.22	553.01	390.36	473.72						
	SUBJECT3	585.54	618.07	585.54	618.07	611.57	553.01	504.22	601.81	584.73						
	SUBJECT4	406.63	390.36	351.32	364.34	390.36	309.04	374.10	364.34	368.81						
	SUBJECT5	357.83	439.16	422.89	455.42	455.42	390.36	439.16	455.42	426.96						
	SUBJECT6	455.42	422.89	390.36	422.89	439.16	357.83	455.42	422.89	420.86						
	SUBJECT7	276.51	341.57	341.57	374.10	331.81	357.83	406.63	374.10	350.51						
	SUBJECT8	390.36	393.86	260.24	325.30	374.10	325.30	292.77	390.36	342.79						
	M E A N	410.69	405.81	403.78	413.54	418.82	390.36	414.76	411.91	408.71						
Greater of b, u	SUBJECT1	748.19	813.25	878.31	731.93	650.60	780.72	715.66	699.40	752.26						
	SUBJECT2	813.25	894.58	878.31	748.19	975.90	943.37	975.90	1008.43	904.74						
	SUBJECT3	741.69	780.72	813.25	845.78	618.07	715.66	699.40	715.66	741.28						
	SUBJECT4	585.54	579.04	579.04	471.69	579.04	579.04	650.60	504.22	566.02						
	SUBJECT5	325.30	331.81	379.84	341.57	292.77	292.77	383.86	357.83	337.09						
	SUBJECT6	699.40	731.93	780.72	699.40	715.66	728.67	780.72	780.72	739.65						
	SUBJECT7	683.13	764.46	731.93	683.13	780.72	774.22	787.23	715.66	740.06						
	SUBJECT8	553.01	494.46	471.69	520.48	666.87	683.13	553.01	634.34	572.12						
	M E A N	643.69	673.78	688.01	630.27	659.95	687.20	693.30	677.03	669.15						

TABLE 47

PEAK VALUES OF SCHEERSAULT TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 3

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L I F T S 4	5	REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greater of d, e	SUBJECT1	748.19	683.13	650.60	683.13	683.13	650.60	650.60	650.60	675.00	
	SUBJECT2	731.93	487.95	618.07	650.60	780.72	764.46	774.22	878.31	710.78	
	SUBJECT3	325.30	618.07	650.60	650.60	676.63	780.72	813.25	650.60	645.72	
	SUBJECT4	585.54	618.07	553.01	601.81	569.28	683.13	585.54	683.13	609.94	
	SUBJECT5	471.69	455.42	422.89	455.42	504.22	211.45	341.57	325.30	398.49	
	SUBJECT6	813.25	862.05	813.25	780.72	780.72	845.78	845.78	813.25	819.35	
	SUBJECT7	904.34	975.90	878.31	676.63	715.66	699.40	741.69	764.46	794.55	
	SUBJECT8	845.78	520.48	634.34	748.19	650.60	780.72	780.72	585.54	693.30	
	M E A N	678.25	652.63	652.63	655.89	670.12	677.03	691.67	668.90		668.39
Greater of g, h	SUBJECT1	585.54	487.95	536.75	520.48	585.54	553.01	520.48	520.48	538.78	
	SUBJECT2	764.46	813.25	715.66	813.25	780.72	813.25	774.22	813.25	786.01	
	SUBJECT3	683.13	748.19	748.19	796.99	969.40	780.72	945.78	780.72	794.14	
	SUBJECT4	683.13	676.63	630.13	731.93	699.40	715.66	650.60	748.19	698.58	
	SUBJECT5	520.48	487.95	455.42	455.42	601.81	357.83	406.63	357.83	455.42	
	SUBJECT6	715.66	731.93	748.19	683.13	683.13	748.19	683.13	748.19	717.69	
	SUBJECT7	845.78	731.93	553.01	585.54	569.28	601.81	618.07	618.07	640.44	
	SUBJECT8	585.54	569.28	536.75	657.11	715.66	585.54	585.54	585.54	602.62	
	M E A N	672.97	655.99	622.14	655.48	700.62	644.50	635.56	646.54		654.21

TABLE 48

PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 3

PEAKS	SUBJECTS	1	L FIRST 2	R SET 3	W 4	E 5	R 6	I 7	N REPLICATE 8	G SET 9	S 10	MEAN	GRAND MEAN
Greater of q, r	SUBJECT1	487.95	471.69	455.42	520.48	553.01	536.75	455.42	601.81	510.32			
	SUBJECT2	715.66	796.99	845.78	813.25	715.66	748.19	715.66	878.31	778.69			
	SUBJECT3	715.66	650.60	683.13	683.13	683.13	878.31	715.66	618.07	703.46			
	SUBJECT4	764.46	780.72	780.72	796.99	780.72	845.78	748.19	796.99	786.82			
	SUBJECT5	520.48	487.95	520.48	536.75	439.16	422.89	471.69	422.89	477.79			
	SUBJECT6	764.46	748.19	666.87	699.40	715.66	699.40	650.60	715.66	707.53			
	SUBJECT7	748.19	731.93	601.81	634.34	487.95	618.07	585.54	634.34	630.27			
	SUBJECT8	650.60	585.54	536.75	455.42	748.19	585.54	520.48	487.95	571.31			
	M E A N	670.93	656.70	636.37	642.47	640.44	666.87	607.91	644.50				645.77
Greater of t, u	SUBJECT1	780.72	774.22	787.23	715.66	715.66	699.40	683.13	585.54	717.69			
	SUBJECT2	683.13	731.93	774.22	585.54	796.99	709.16	806.75	829.52	739.65			
	SUBJECT3	520.48	448.92	487.95	481.45	676.63	650.60	611.57	520.48	549.76			
	SUBJECT4	553.01	553.01	618.07	585.54	504.22	520.48	487.95	553.01	546.91			
	SUBJECT5	325.30	374.10	292.77	357.83	227.71	292.77	211.45	276.51	294.80			
	SUBJECT6	715.66	748.19	796.99	715.66	683.13	601.81	618.07	764.46	705.50			
	SUBJECT7	520.48	878.31	748.19	683.13	676.63	683.13	764.46	715.66	708.75			
	SUBJECT8	535.54	601.81	569.28	536.75	657.11	601.81	390.36	520.48	557.89			
	M E A N	585.54	638.81	634.34	582.70	617.26	594.89	571.72	595.71				602.62

TABLE 49

PEAK VALUES OF SOMERSAINT TORQUE IN INCH POUNDS
DURING LIFTING IN CONDITION 4

PEAKS	SUBJECTS	1	FIRST 2	SET 3	L 4	I 5	F 6	T 7	S 8	REPLICATE 9	SET 10	R 11	MEAN	GRAND MEAN
Greater of d, e	SUBJECT1	813.25	459.64	839.28	943.37	715.66	618.07	618.07	634.34	767.71				
	SUBJECT2	699.40	553.01	689.64	585.54	780.72	845.78	829.52	839.28	727.86				
	SUBJECT3	683.13	813.25	845.78	325.30	748.19	910.84	813.25	813.25	744.13				
	SUBJECT4	741.69	715.65	780.72	650.60	715.66	618.07	650.60	650.60	690.45				
	SUBJECT5	455.42	455.42	504.22	520.48	536.75	520.48	487.95	487.95	496.08				
	SUBJECT6	945.78	800.24	845.78	780.72	813.25	780.72	748.19	845.78	807.56				
	SUBJECT7	666.87	728.67	845.78	666.87	633.13	715.66	699.40	780.72	723.39				
	SUBJECT8	618.07	553.01	565.28	748.19	748.19	634.34	780.72	764.46	677.03				
	M E A N	690.45	697.36	750.36	652.63	717.69	705.50	703.46	727.05					704.28
Greater of E, h	SUBJECT1	201.69	260.24	211.45	390.36	292.77	162.65	276.51	243.98	254.95				
	SUBJECT2	487.95	455.42	455.42	585.54	553.01	422.89	455.42	487.95	487.95				
	SUBJECT3	553.01	634.34	715.66	331.81	585.54	813.25	618.07	553.01	600.59				
	SUBJECT4	357.83	325.30	455.42	504.22	292.77	227.71	325.30	309.04	349.70				
	SUBJECT5	292.77	162.65	211.45	357.83	227.71	260.24	221.20	520.48	281.79				
	SUBJECT6	325.30	253.73	325.30	325.30	292.77	325.30	357.83	325.30	316.35				
	SUBJECT7	276.51	227.71	243.98	146.39	260.24	292.77	162.65	260.24	233.81				
	SUBJECT8	227.71	178.92	195.18	260.24	260.24	292.77	276.51	195.18	235.84				
	M E A N	340.35	312.29	351.73	362.71	345.63	349.70	336.69	361.90					345.12

TABLE 50

PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
DURING LOWERING IN CONDITION 4

PEAKS	SUBJECTS	1	L FIRST 2	R SET 3	W	E	R	I	N	G	S REPLICATE 6	SET 7	8	MEAN	GRAND MEAN
Greater of t, u	SUBJECT1	221.20	276.51	292.77	302.53	162.65	97.59	113.86	195.18	207.79					
	SUBJECT2	374.10	481.45	487.95	520.48	422.89	390.36	390.36	455.42	440.38					
	SUBJECT3	504.22	585.54	683.13	520.48	422.89	536.75	455.42	601.81	538.78					
	SUBJECT4	487.95	390.36	439.16	374.10	221.20	162.65	292.77	309.04	334.65					
	SUBJECT5	227.71	211.45	211.45	211.45	260.24	195.18	276.51	195.18	223.64					
	SUBJECT6	325.30	325.30	390.36	422.89	325.30	325.30	292.77	309.04	339.53					
	SUBJECT7	234.22	234.22	266.75	227.71	260.24	195.18	292.77	227.71	242.35					
	SUBJECT8	<u>292.77</u>	<u>260.24</u>	<u>292.77</u>	<u>325.30</u>	<u>260.24</u>	<u>325.30</u>	<u>276.51</u>	<u>260.24</u>	<u>286.67</u>					
	M E A N	333.43	345.63	383.04	363.12	291.96	278.54	298.87	319.20						326.72
Greater of t, u	SUBJECT1	943.37	992.17	813.25	816.51	650.60	650.60	601.81	520.48	746.60					
	SUBJECT2	569.29	676.63	618.07	676.63	683.13	715.66	715.66	813.25	683.54					
	SUBJECT3	715.66	748.19	845.78	683.13	683.13	699.40	813.25	715.66	738.03					
	SUBJECT4	683.13	709.16	536.75	657.11	553.01	618.07	553.01	585.54	611.97					
	SUBJECT5	390.36	439.16	406.63	374.10	422.89	357.83	341.57	357.83	386.29					
	SUBJECT6	748.19	715.66	845.78	780.72	748.19	715.66	715.66	764.46	754.29					
	SUBJECT7	666.87	731.93	683.13	683.13	780.72	683.13	618.07	520.48	670.93					
	SUBJECT8	<u>618.07</u>	<u>585.54</u>	<u>585.54</u>	<u>666.87</u>	<u>650.60</u>	<u>553.01</u>	<u>569.28</u>	<u>650.60</u>	<u>609.94</u>					
	M E A N	666.87	699.80	666.87	667.27	646.54	624.17	615.04	616.04						650.45

Figs 19 and 20). The peak force for lifting occurred corresponding to peak 'l' for maximum acceleration. Peak 'l' occurs about 0.1 sec. after the box leaves the lower shelf.

The total force at all peaks is broken into 2 components: 1) Force due to the load and 2) Force due to body weight. Force due to the load is given by

$$F = L \left(\frac{g+a}{g} \right)$$

where F is the force, in lbs

L is the load, in lbs

g is the acceleration due to gravity = 32 ft/sec²

a is the vertical acceleration in the upward direction, feet/sec².

Acceleration "a" is positive when either the acceleration is in the upward direction or deceleration is in the downward direction; it is negative when either the acceleration is in the downward direction or the deceleration is in the upward direction.

The acceleration corresponding the peak 'f' was 14.54 ft/sec². For the load (11 lbs) lifted, the force will be

$$F = \frac{11 \times (32.2 + 14.54) \text{ lbs}}{32.2} = 15.95 \text{ lbs}$$

The difference between the total force (61.0 lbs) and the force due to load (16.0 lbs) gives the force due to body which is 45.0 lbs. Curve abdef'g'h'i' (Fig. 21) gives the force due to body alone. The acceleration effect in lifting for all conditions is given in Table 51.

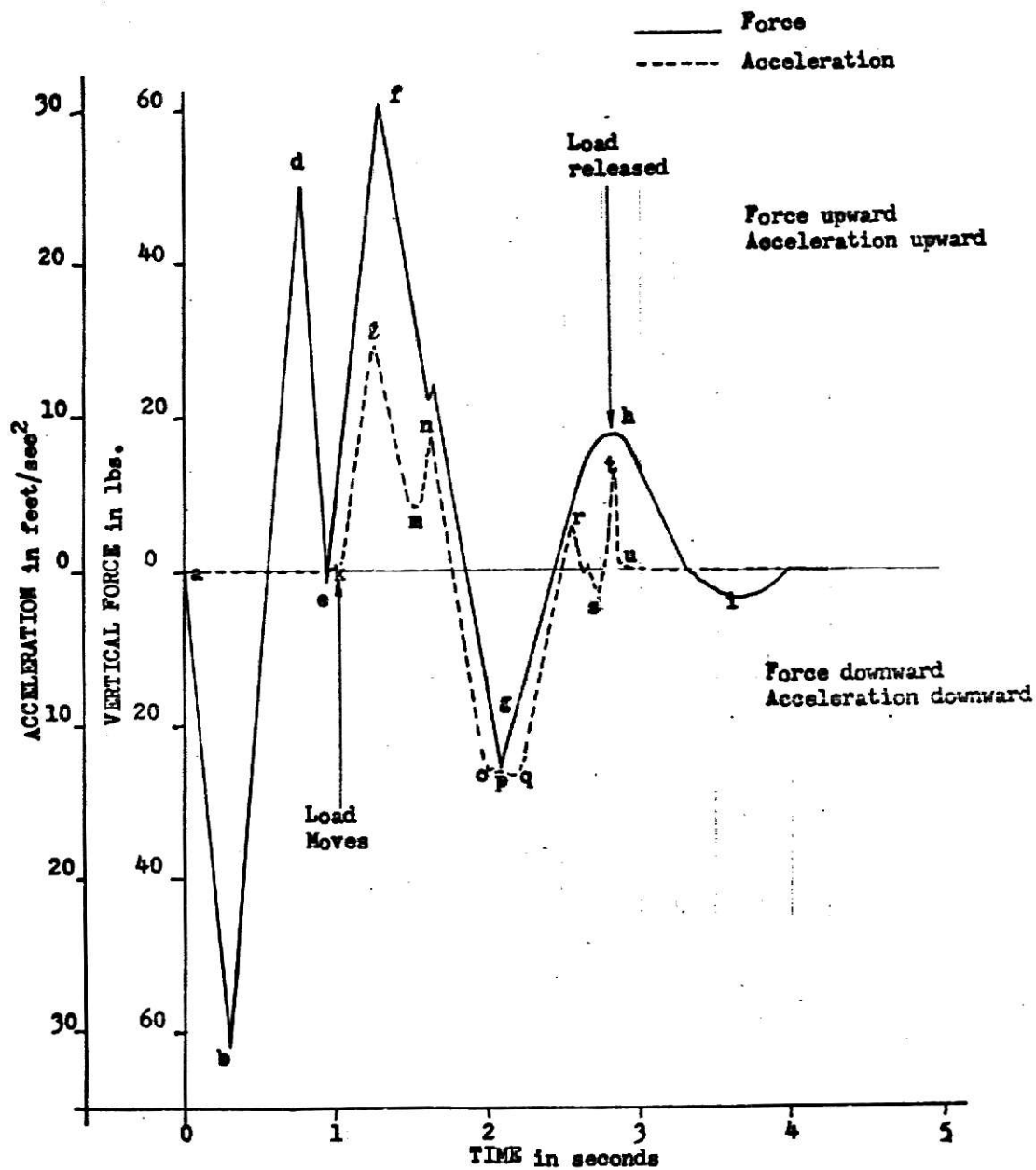


Fig. 19. Vertical force and vertical acceleration vs time relationship for lifting for "feet parallel and straight ahead".

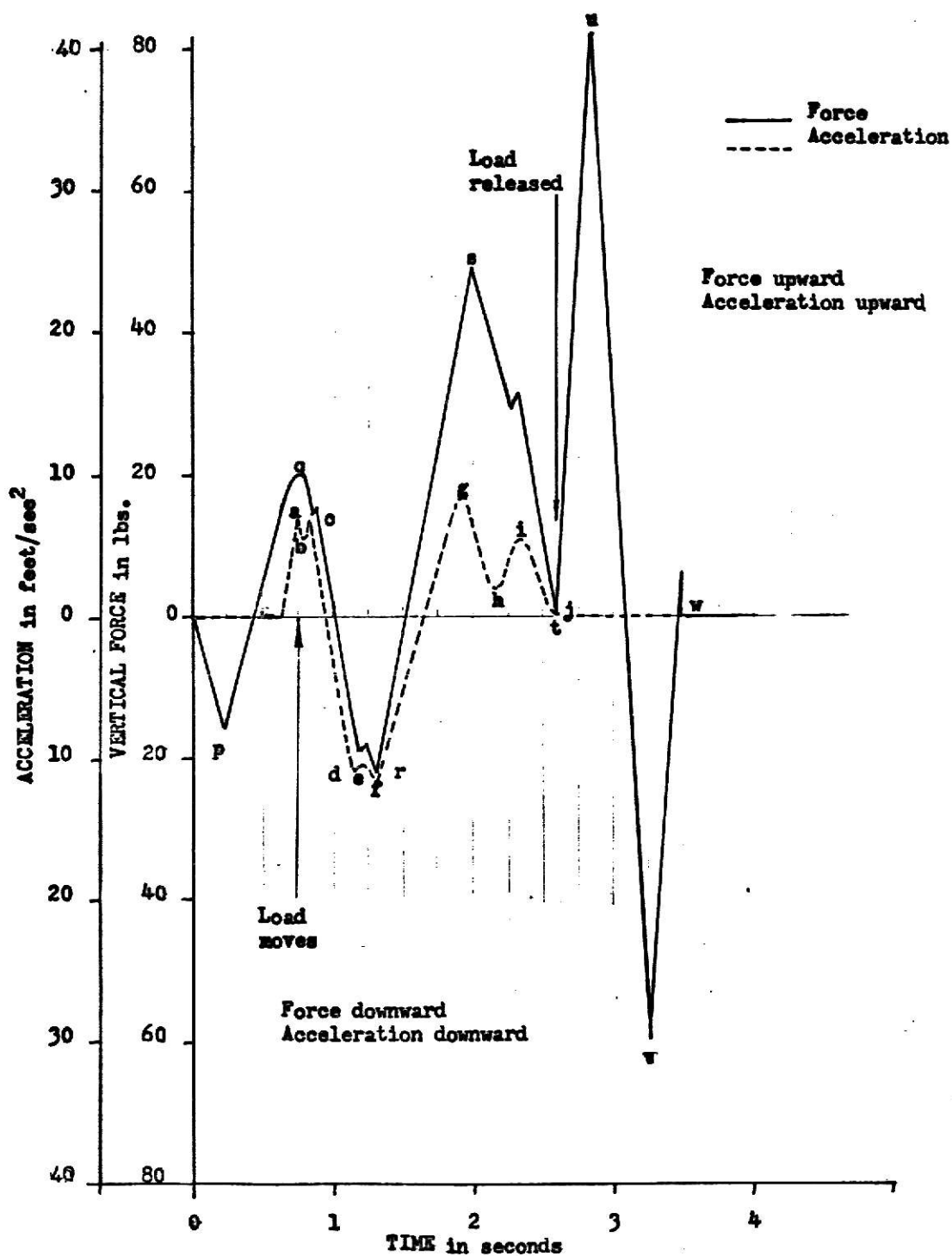


Fig. 20. Vertical force and vertical acceleration vs time relationship for lowering for "feet parallel and straight ahead".

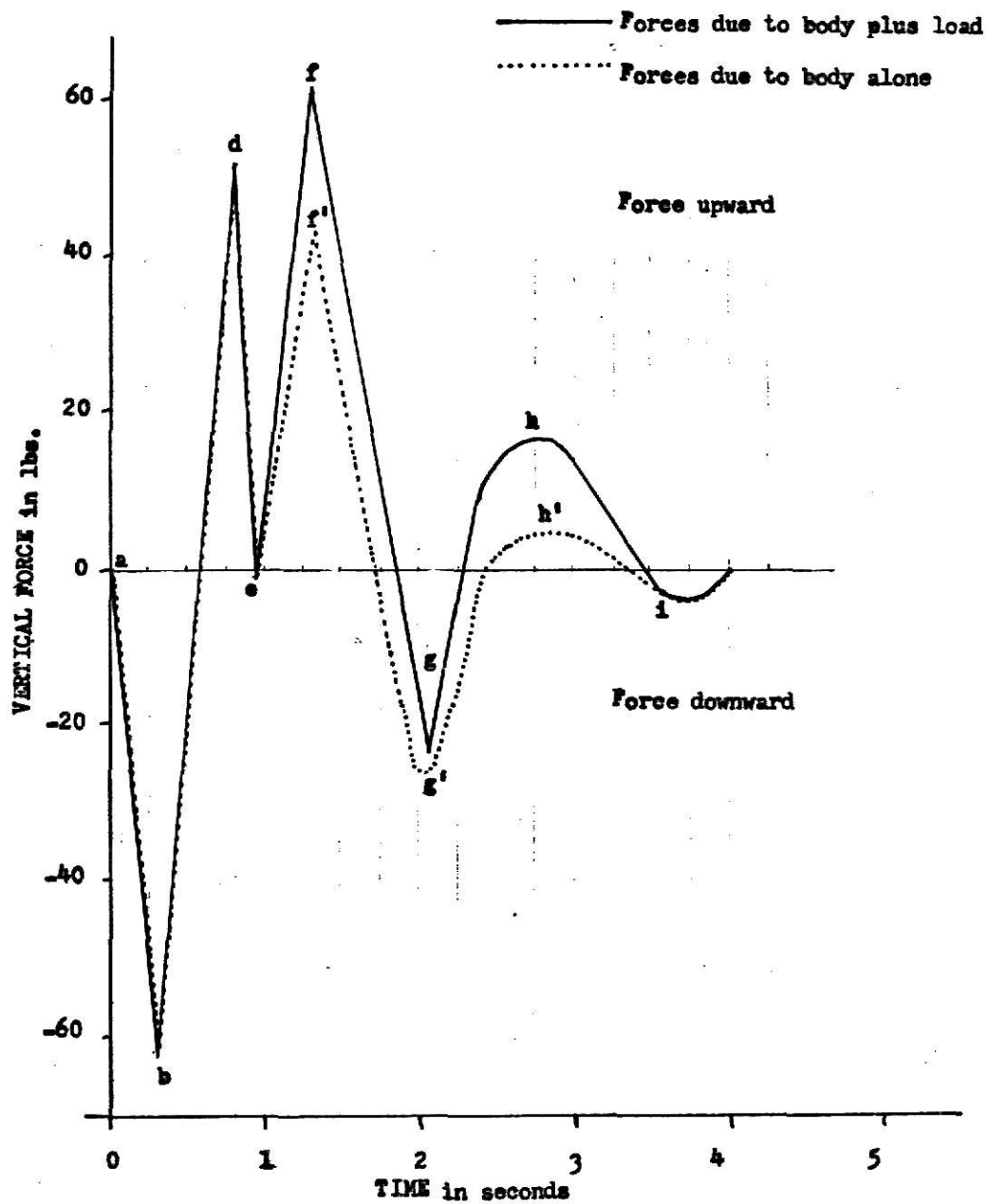


Fig. 21. Vertical forces due to the body weight plus load, and body weight without load for the representative subject during lifting with "parallel feet and straight ahead".

Table 51 Acceleration Effect in Lifting

Peak (of force)	Condition	Mean acceleration of tote box (ft/sec ²)	Effective vertical force due to tote box (pounds)	Mean total vertical force (pounds)	Effective vertical force due to body weight (pounds)
b	parallel feet; 0 degrees turn	0.0	0.0	49.6	49.6
	parallel feet; 45 degrees turn	0.0	0.0	51.3	51.3
	left foot leading; 0 degrees turn	0.0	0.0	51.7	51.7
	left foot leading; 45 degrees turn	0.0	0.0	49.4	49.4
f	parallel feet 0 degrees turn	+16.6	16.7	59.1	42.4
	parallel feet; 45 degrees turn	+17.4	16.9	61.8	44.9
	left foot leading; 0 degrees turn	+15.7	16.4	57.7	41.3
	left foot leading; 45 degrees turn	+17.2	16.8	60.5	43.7

Different peak values for the three forces and two torques are given in Tables 11 through 50. It is readily observed that vertical forces are the critical ones. A comparison of the means for lifting and lowering is given in Tables 52 and 53 respectively. To determine the effect of foot position, it is found that, for lifting, there is a penalty of 1.5 lbs for the critical peak 'f' (see Figs. 13 and 14) if the left foot is not put forward while lifting straight ahead and a penalty of 1.3 lbs if the left foot is not put forward while lifting with a 45 degrees turn in body. In lowering, the penalty when the left foot is not leading is 3.4 lbs for the critical peak 'u' (see Figs. 13 and 14) while lowering with 0 degrees turn and 2.3 lbs for lowering with 45 degrees turn to the right.

Means of cartwheel torques for the four conditions are shown in Table 54. Both in lifting and lowering with parallel feet and 45 degrees turn, the torques are very high (629.0 and 670.5 inch lbs respectively). But they reduce to 457.5 and 484.8 inch-lbs respectively if the left foot is leading. Thus, there is a penalty of 170 inch-lbs in lifting and 186 inch-lbs in lowering if the left foot is not used as leading. For somersault torque there is a penalty of 37 inch-lbs in lifting and 28 inch-lbs in lowering if the left foot is not used as leading for the '0 degree turn' situation (see Table 54). If the body involves a 45 degree turn to the right, the penalties for not using the left foot as leading are 9 inch-lbs and 19 inch-lbs for lifting and lowering respectively.

Table 52 Means for peaks of vertical force (lbs) during lifting

Condition	Peaks			
	b	greater of d,f	g	h
feet parallel; 0 degrees turn	49.6	59.1	28.1	16.3
feet parallel; 45 degrees turn	51.3	61.8	31.6	14.4
left foot leading; 0 degrees turn	51.7	57.6	29.7	12.5
left foot leading; 45 degrees turn	49.4	60.5	30.0	16.0

Table 53 Means for peaks of vertical force (lbs) during lowering

Condition	Peaks			
	<u>r</u>	<u>s</u>	<u>u</u>	<u>v</u>
feet parallel; 0 degrees turn	19.8	26.5	59.7	48.9
feet parallel; 45 degrees turn	16.2	33.6	59.5	50.2
left foot leading; 0 degrees turn	13.3	25.0	56.3	47.7
left foot leading; 45 degrees turn	20.2	29.7	57.2	49.0

Table 54 Summary of means of the maximum forces and torques

Task	Condition	Vertical (pounds)	Frontal (pounds)	Lateral (pounds)	Cartwheel (inch pounds)	Somersault (inch pounds)
L I F T	feet parallel; st. ahead	59.1	8.2	4.8	91	705
	feet parallel; 45 degrees turn	61.8	8.3	5.4	628	713
	left foot leading; st. ahead	57.6	9.0	4.5	360	668
	left foot leading; 45 degrees turn	60.5	8.3	4.9	457	704
L O W E R	feet parallel; st. ahead	59.7	10.0	4.3	81	630
	feet parallel; 45 degrees turn	59.5	8.1	6.2	670	669
	left foot leading; st. ahead	56.3	11.0	5.0	366	602
	left foot leading; 45 degrees turn	57.2	7.2	4.4	484	650

On conducting paired two-tailed t-tests on the means of the eight lifts (and lowerings), it is found that the vertical forces are less (the computed t-value being 1.79) at $p < 0.20$ for lowering with "left foot leading and 0 degrees turn of body" than with "feet parallel and 0 degrees turn of body"; they are not significantly different for lifting under similar condition (the computed t-value being 0.49) at $p < 0.20$. Again the vertical forces are less (the computed t-value being 1.43) at $p < 0.20$ for lowering with "left foot leading and 45 degrees turn of body" than for lowering with "feet parallel and 45 degrees turn of body"; they are not significantly different for lifting under similar conditions (the computed t-value being 0.43) at $p < 0.20$.

The cartwheel torques are significantly less both for lifting and lowering when the left foot is used as leading while a 45° body turn (to the right) is involved (the computed t-values being 4.44 and 6.34 respectively) at $p < 0.05$; they are significantly more for lifting and lowering when the left foot is used as leading while a 0° body turn is involved (the computed t-values being 8.03 and 8.29) at $p < 0.05$. The somersault torques are not significantly different for lifting and lowering both when a 0° turn of body or a 45° turn of body is involved (the computed t-values being 1.06, 0.29, 0.35, 0.69 respectively) at $p < 0.05$.

Least square lines for the learning effect in the four conditions are shown in Fig. 22 through Fig. 25. The forces shown are average values of vertical forces (in Tables 11 through 18) averaged over all (eight) subjects at the peaks for each lift (or lowering). 'POLRG' subroutine

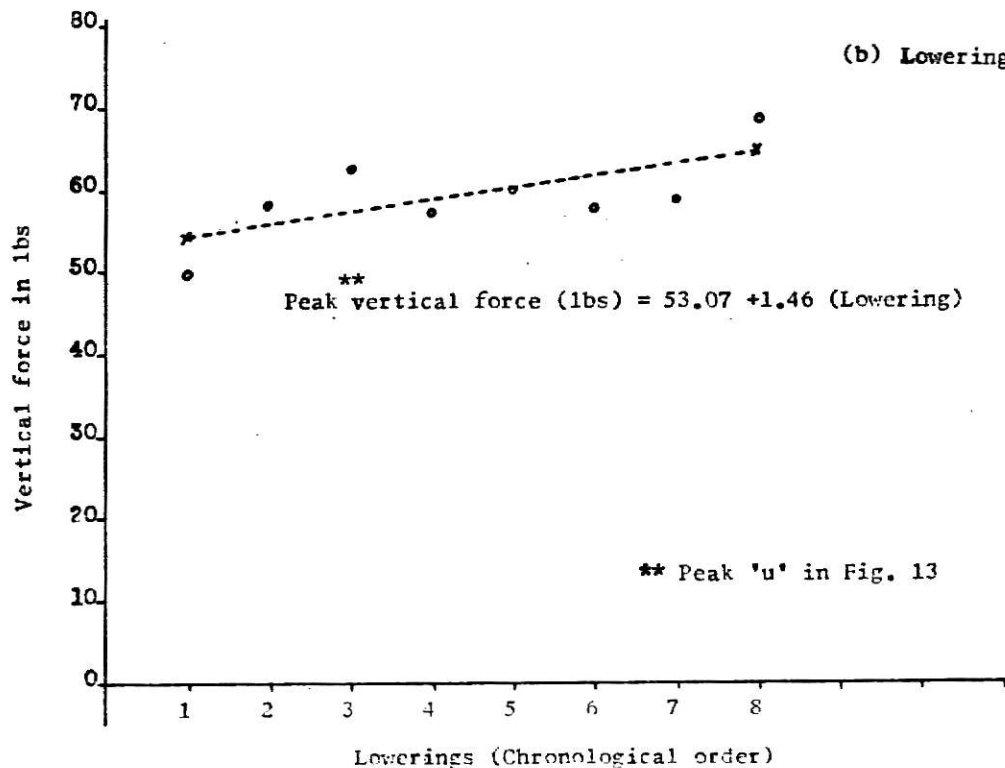
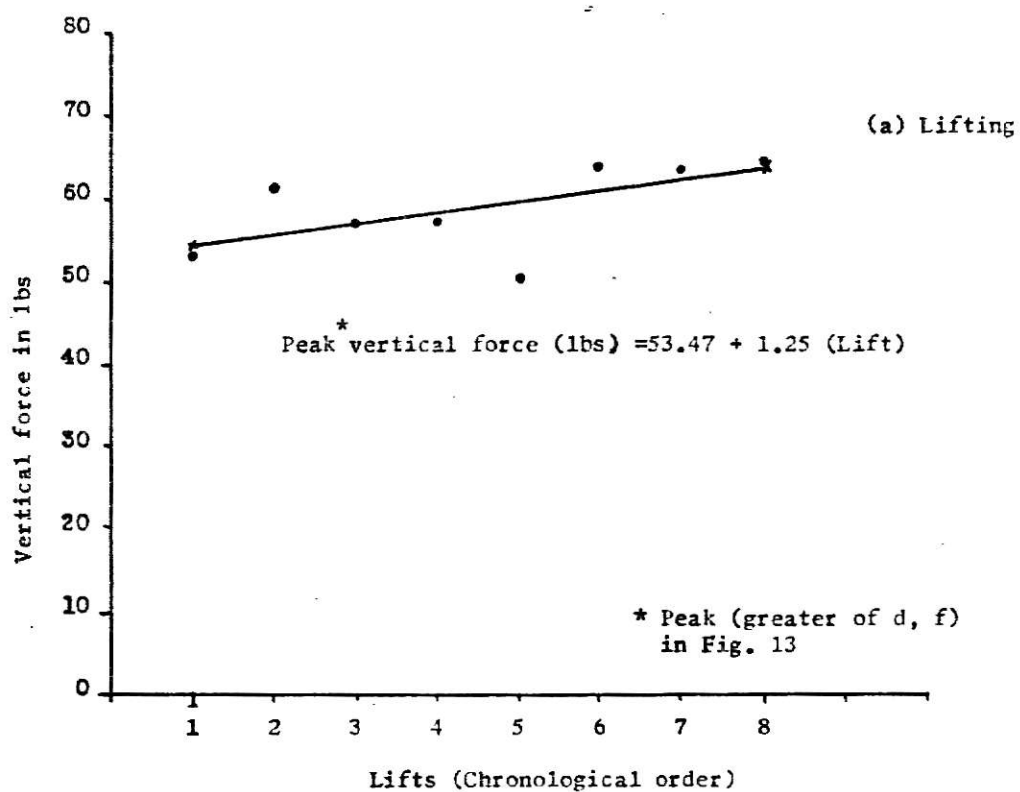


Fig. 22. Learning effect on vertical forces with "feet parallel and 0 degrees turn" for (a) lifting and (b) lowering.

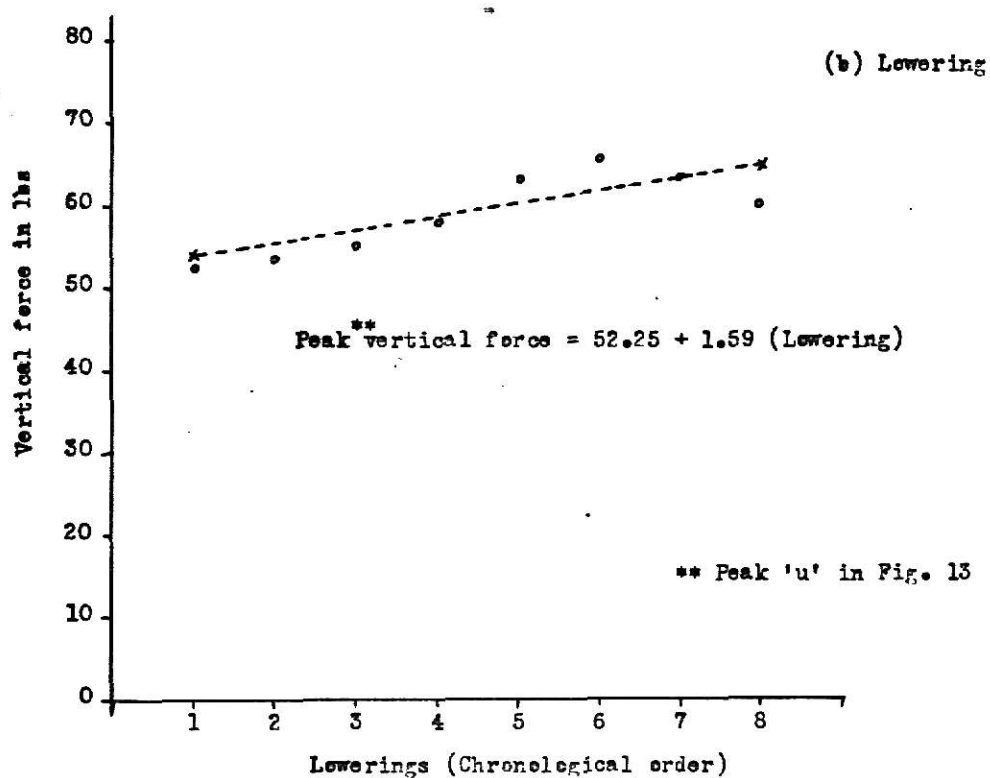
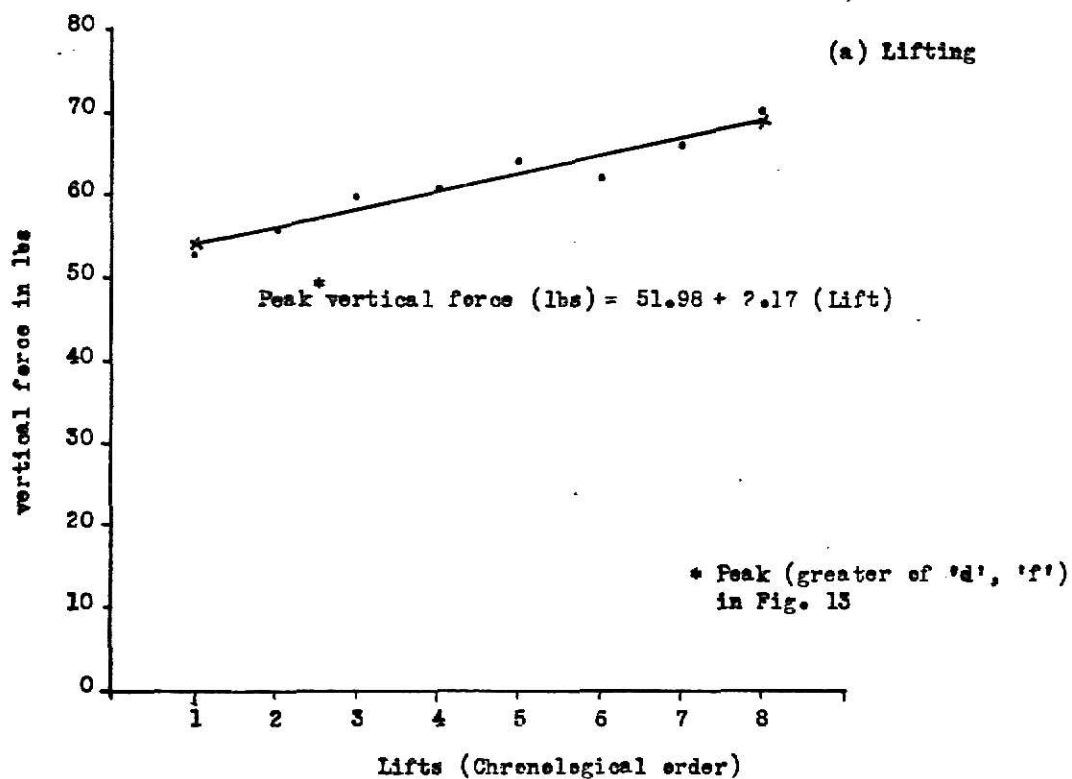


Fig. 23. Learning effect on vertical forces with "feet parallel and 45 degrees turn" for (a) lifting and (b) lowering.

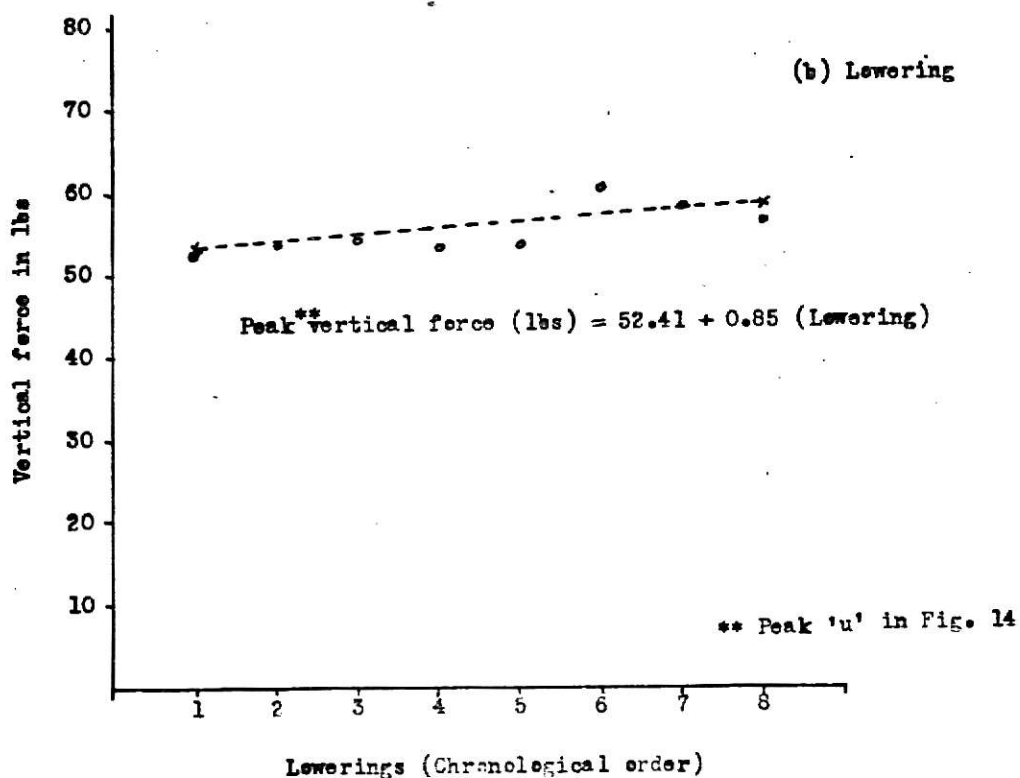
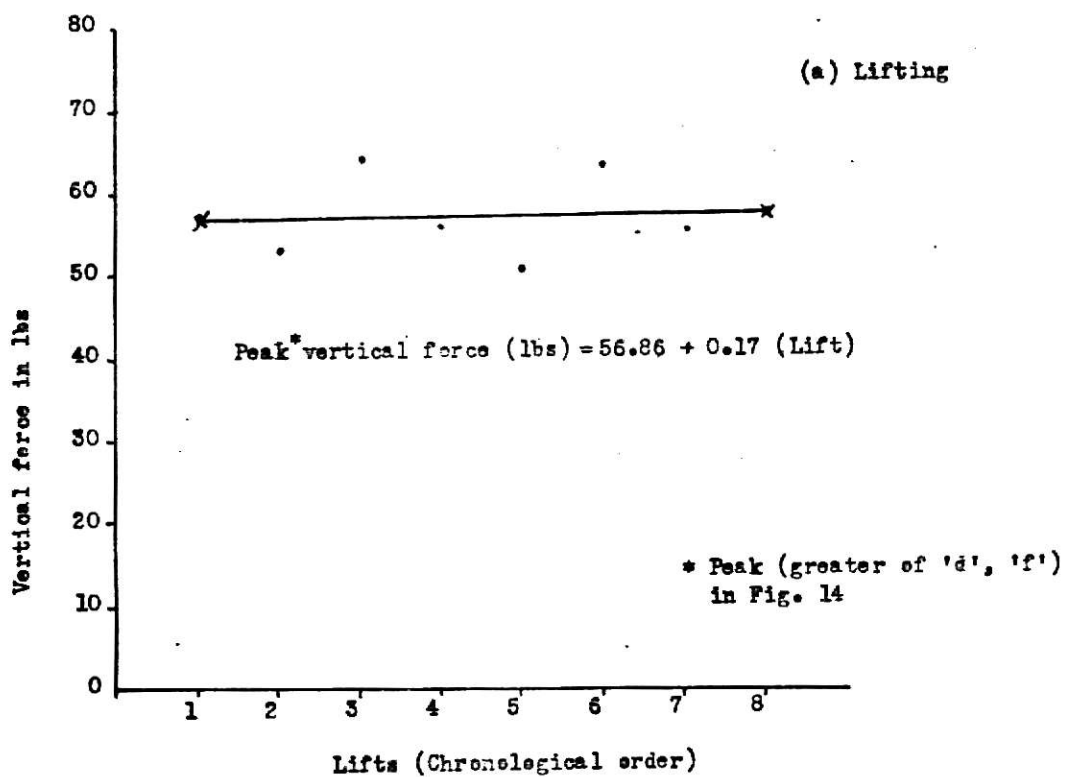


Fig. 24. Learning effect on vertical forces with "left foot leading and 0 degrees turn of body" for (a) lifting and (b) lowering.

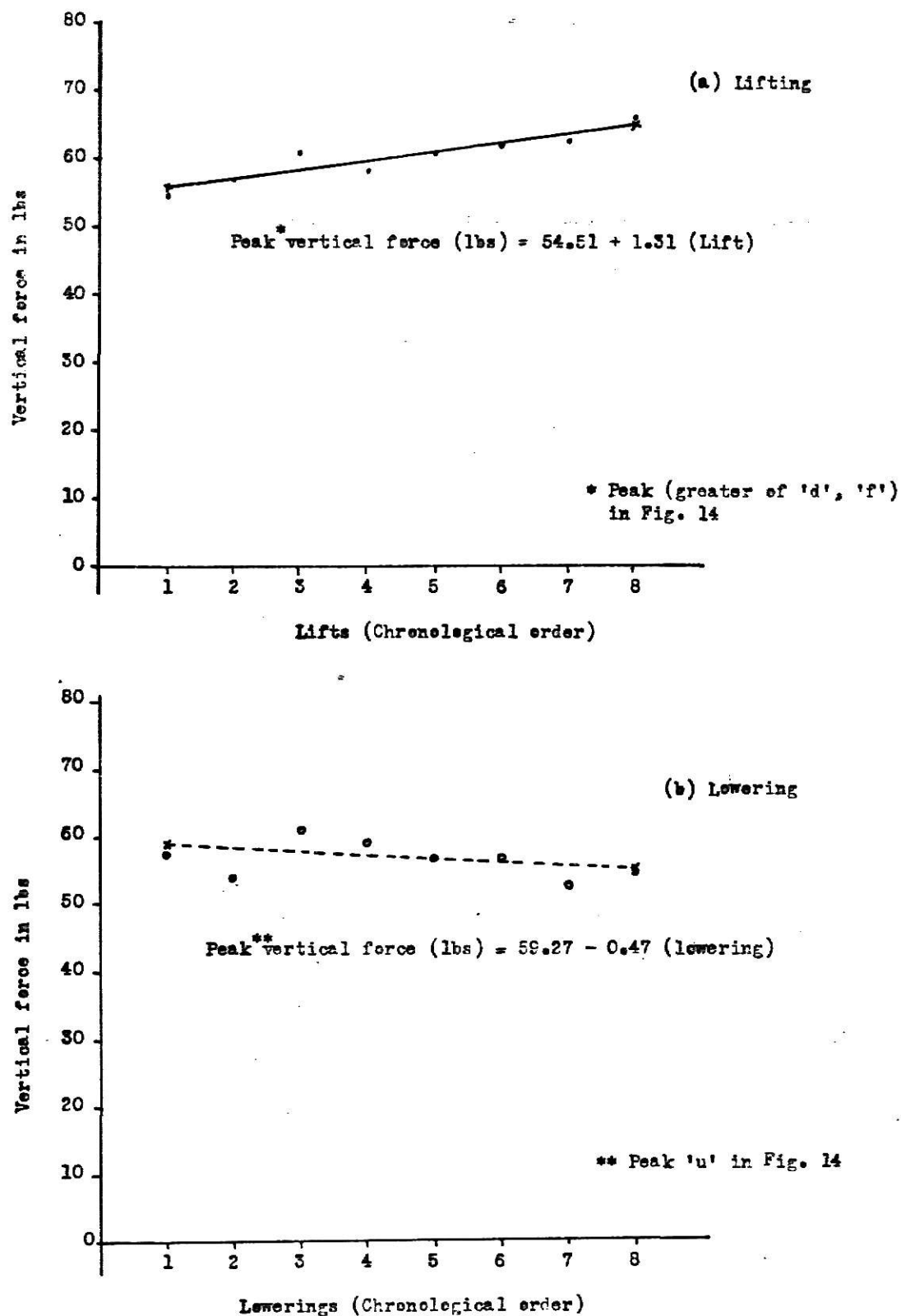


Fig. 25. Learning effect on vertical forces with "left foot leading and 45 degrees turn of body" for (a) lifting and (b) lowering.

was used for polynomial regression. Since the number of trials was fairly small (only 8), a first degree polynomial was used.

On conducting the analysis of variance for 1 degree polynomial, it is found that there is no significant learning effect (the computed F-value being 2.95) for $\alpha = 0.10$ on vertical forces in case of lifting in Condition 1 (see Fig. 22a). There is significant learning effect on vertical forces for lowering in Condition 1 (see Fig. 22b), lifting in Condition 2 (see Fig. 23a) and lowering in Condition 2 (see Fig. 23b) (the computed F-values being 5.31, 66.54, and 10.11 respectively) at $\alpha = 0.10$. Again there is a significant learning effect on vertical forces for lowering in Condition 3 (see Fig. 24b) and lifting in Condition 4 (see Fig. 25a) (the computed F-values being 5.56 and 37.53 respectively) at $\alpha = 0.10$. There is no significant learning effect on vertical forces for lifting in Condition 3 (see Fig. 24a) and lowering in Condition 4 (see Fig 25b) (the computed F-values being 0.05 and 1.31 respectively) at $\alpha = 0.10$.

DISCUSSION

From the summary of forces and torques given in Table 54 it was observed that the vertical forces are much greater than either the lateral force or frontal force. This result was expected inasmuch as the vertical component of the body weight and object weight and vertical accelerations and decelerations are dominant in lifting and lowering. Further, the critical values (the danger spots) of the vertical forces occur during lifting just after the load is picked up (peak f) and during lowering just after releasing the load (peak u).

Forces due to lowering are observed to be a mirror effect of forces due to lifting. However, the highest peaks (f and u, see Figs. 13 and 14) are not mirrored. This is explainable since the subjects in the case of lowering moved upwards faster and with more acceleration after releasing the load than they did downward with the load before releasing it. Although the mass effect is greater in moving downward than moving upward, the acceleration effect is greater in the later case leading to a higher peak force.

The accelerations and vertical forces when plotted on the same time scale showed that forces increased with increase of acceleration and vice versa. Further, it was seen that most of the force was due to the body weight.

An important fact is brought up that injury may occur because of excessive force without actually lifting or lowering any load. Thus it is the technique (acceleration) which is the critical factor and not the

load. This calls for proper training for all people involved in lifting and lowering. Training is important as it could lead to reduced back injuries and increased efficiency.

To find the exact position of the load when the peak vertical force occurs, the relationship between acceleration, velocity and displacement was employed. Acceleration is the time rate of change of velocity and velocity is the time rate of change of position. Acceleration when integrated over a time interval gives the velocity at the end of the time interval and by a similar process the integration over velocity gives the displacement. The integration process was performed graphically, merely by counting the squares enclosed by the curve and the times axis (see Fig. 26).

It was found that corresponding to the peak of the acceleration curve, the displacement was given by point "x" on the displacement curve, it measured about $\frac{1}{2}$ inch. Thus the maximum vertical force occurs after the load was moved by about $\frac{1}{2}$ inch.

Foot position affects the vertical forces in the body as can be seen from the results. Penalties of 1.3 lbs of vertical force and 170 inch-lbs of cartwheel torque in case of lifting with parallel feet while employing a turn of 45 degrees to the right suggest that the left foot should be leading. Again, penalties of 2.5 lbs of vertical force and 186 inch-lbs of cartwheel torque in case of lowering under similar conditions suggest the use of the left foot as leading. For lifting and lowering straight ahead with parallel feet, the penalties are 1.5 lbs and 3.4 lbs respectively. However, there were penalties of 269

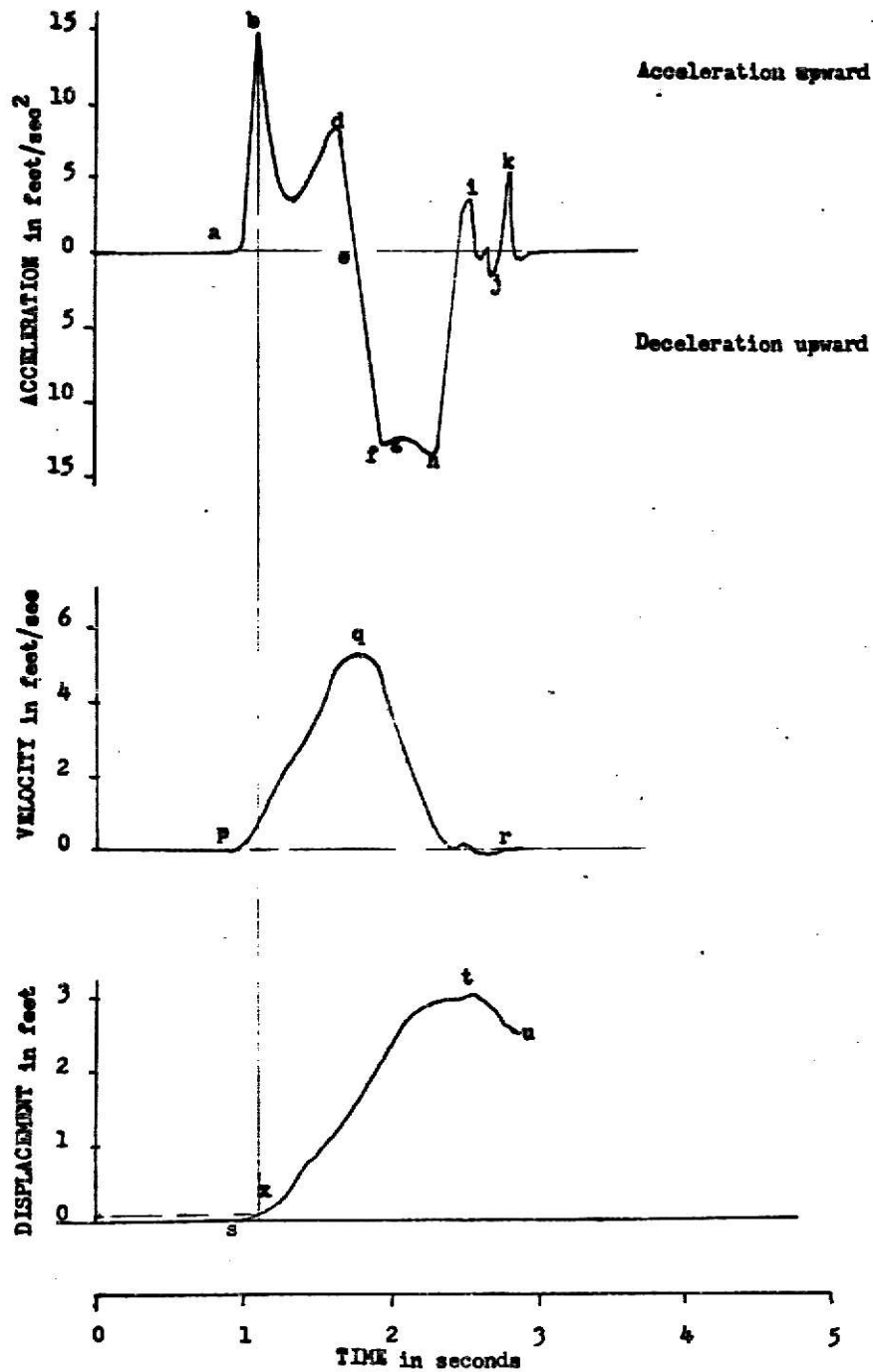


Fig. 26. Relationship between acceleration, velocity and displacement for lifting in 'condition 1'.

and 285 inch-lbs of cartwheel torque for using the left foot leading and straight ahead. This shows that the subjects tended to rest more weight on the right foot than on the left thus creating the torque. From the above, the left foot leading situation does not seem to be desirable in case of lifting or lowering straight ahead. Proper training for the people involved in lifting and lowering is stressed again.

Wherever the effect of learning is significant, it causes the vertical forces to increase rather than decrease (see Figs. 22 through 25). This indicates that the subjects were relatively cautious for the initial lifts and as they became more confident, they tended to lift (or lower) with greater accelerations (with each lift or lowering). With proper training, workers can get skilled in lifting (or lowering) so that there is a progressive shift in the direction from constant accelerations to constant velocities (Zajackowska, 1972). The result will be lesser forces when their learning stabilizes (on the learning curve).

CONCLUSIONS

The study provides information about different forces, torques and accelerations involved in lifting and lowering. Curves have been drawn to depict the nature of actual forces on the body while lifting or lowering in the four conditions.

The 'critical' peaks of vertical force occurred just after the load is picked up while lifting and slightly after the load is released while lowering.

Most of the force is contributed by the body weight.

Acceleration of the body is a critical factor; injury may occur even in lifting a pencil from the ground since the major force was due to body weight rather than the object weight.

Left foot leading is better both for lifting and lowering when the body involves a turn of 45 degrees to the right. It can be generalized also that as one is lifting or lowering and turning to one side, the foot on the side to which one is turning should be back and the other foot should be forward. When no turn of body is involved, 'feet parallel' is better for lifting and lowering.

The implications of the results of the present study are several. They should be useful in further detailed exploration of the 'technique' variable. Future findings could then be applied in 'fitting the job to the man' in industry. In other words, tasks could be redesigned and techniques can be improved so that each individual can perform his task with less risk of injury.

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APPENDIX

All peak values of forces, torques and accelerations for a representative subject (subject 7).

TABLE A1

ALL PEAK VALUES OF ACCELERATION IN FEET/ SEC. SQUARE
FOR A REPRESENTATIVE SUBJECT IN CONDITION 1

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	l	11.00	16.00	17.50	7.00	15.00	14.00	18.00	17.80	14.54
	m	3.00	6.00	2.00	4.00	2.00	5.00	2.50	1.00	3.19
I	n	7.00	9.50	8.00	7.00	9.00	7.00	13.50	8.00	8.63
	o	15.50	8.00	5.00	14.00	12.50	14.50	16.00	18.00	12.94
F	p	15.50	6.00	6.00	14.00	12.00	14.50	16.00	18.00	12.75
	q	15.50	12.00	8.00	14.00	14.00	14.50	12.50	18.00	13.56
T	r	4.50	4.00	3.00	3.50	1.50	2.80	5.50	1.00	3.22
	s	4.00	1.00	4.00	0.00	2.50	0.00	0.00	0.00	1.44
	t	9.00	6.00	8.00	4.00	6.00	4.00	8.00	3.00	6.00
L	a	8.00	5.00	5.00	8.00	7.00	5.50	10.50	7.00	7.00
	b	8.00	3.80	5.00	7.00	2.00	4.80	4.00	6.00	5.07
O	c	8.00	6.50	5.00	7.00	8.00	4.80	6.00	12.00	7.16
	d	12.00	14.00	8.50	9.00	13.50	10.00	18.00	3.50	11.06
W	e	5.00	7.00	6.00	7.00	11.00	9.00	17.00	3.00	8.13
	f	11.00	8.00	14.50	15.00	15.00	18.00	20.00	11.00	14.06
E	g	7.00	8.00	6.00	8.00	11.00	6.00	6.00	8.00	7.50
	h	0.00	0.00	2.00	6.00	2.80	0.00	4.50	4.00	2.41
R	i	9.00	6.00	7.00	8.00	7.00	4.00	6.00	4.00	6.38

TABLE A2

ALL PEAK VALUES OF ACCELERATION IN FEET/ SEC. SQUARE
FOR A REPRESENTATIVE SUBJECT IN CONDITION 2

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I P T	l	9.00	10.00	14.00	8.00	14.00	15.50	18.50	16.00	13.13
	m	7.00	14.00	8.00	3.50	8.00	12.00	18.50	12.00	10.38
	n	11.00	10.00	9.50	12.00	12.00	14.00	18.50	12.00	12.38
	o	9.00	14.00	8.00	14.00	11.50	12.00	16.00	13.00	12.19
	p	11.00	14.00	8.00	14.00	11.50	10.00	16.00	11.00	11.94
	q	9.50	14.00	8.00	14.00	11.50	10.00	16.00	12.00	11.88
	r	4.00	1.00	5.00	3.00	3.00	2.00	2.00	4.00	3.00
	s	0.00	0.50	1.00	1.50	1.00	0.50	0.50	1.00	0.75
	t	3.90	3.00	4.00	4.00	5.50	4.00	0.50	4.00	3.61
L O W E R	a	7.00	5.00	5.00	5.00	7.50	5.00	7.00	5.50	5.88
	b	7.00	5.00	4.00	3.50	3.00	5.00	7.00	5.00	4.94
	c	7.00	7.00	6.50	8.00	6.00	6.00	7.00	6.00	6.69
	d	10.00	13.00	16.00	13.00	10.00	14.00	11.00	12.00	12.38
	e	10.00	7.00	14.50	9.00	8.50	14.00	10.00	11.50	10.56
	f	14.00	11.00	17.00	10.00	13.50	17.00	13.00	15.00	13.81
	g	8.00	4.00	8.00	9.00	6.00	12.00	10.00	12.00	8.63
	h	10.00	12.00	10.50	7.00	6.00	9.50	5.00	2.00	7.75
	i	10.00	8.00	6.00	8.00	7.50	5.00	8.50	4.00	7.13

TABLE A3

ALL PEAK VALUES OF ACCELERATION IN FEET/ SEC. SQUARE
FOR A REPRESENTATIVE SUBJECT IN CONDITION 3

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	l	11.00	10.50	15.00	12.00	14.00	18.00	17.00	18.00	14.44
	m	1.00	8.00	0.00	3.00	5.00	8.00	3.80	4.00	4.10
	n	4.00	9.00	4.50	11.50	6.00	6.00	6.00	5.00	6.50
	o	11.00	13.00	15.00	11.50	10.00	8.50	12.00	10.00	11.38
	p	14.50	16.00	13.50	8.00	13.00	3.80	8.00	9.00	10.72
	q	11.00	13.00	14.00	10.00	12.00	8.60	10.00	14.00	11.57
	r	3.50	6.80	4.00	5.00	2.00	5.00	2.00	1.50	3.72
	s	1.20	1.00	2.30	2.00	1.50	0.00	2.00	2.00	1.50
	t	4.00	6.00	8.00	4.00	4.00	10.00	5.00	6.00	5.88
L O W E R	a	4.00	4.00	7.00	8.00	5.00	7.50	4.00	8.00	5.94
	b	3.00	3.00	5.50	8.00	3.00	6.00	2.00	6.00	4.56
	c	8.50	5.80	5.50	8.00	4.00	6.00	4.00	6.00	5.97
	d	13.00	14.00	12.00	12.00	10.00	10.00	12.00	7.00	11.25
	e	13.00	12.00	10.00	7.00	8.00	8.50	12.00	7.50	9.75
	f	13.00	15.00	13.00	11.00	8.50	14.00	12.00	9.00	11.94
	g	8.00	8.00	8.00	8.00	12.00	5.00	8.00	6.00	7.88
	h	0.00	6.00	10.00	3.00	9.00	1.00	4.00	1.00	4.25
	i	7.50	6.00	7.00	6.00	4.00	7.00	8.00	6.00	6.44

TABLE A4

ALL PEAK VALUES OF ACCELERATION IN FEET/ SEC. SQUARE
FOR A REPRESENTATIVE SUBJECT IN CONDITION 4

TASK	PEAK	1	FIRST SET 2	3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	l	16.00	13.00	12.50	18.00	15.00	14.00	18.00	18.50	15.63
	m	10.00	4.00	7.00	8.20	8.80	10.00	18.00	18.00	10.50
	n	9.00	4.00	14.00	14.30	12.00	13.50	18.00	18.00	12.85
	o	14.00	13.50	14.00	16.40	10.20	13.00	13.00	13.00	13.39
	p	14.00	11.50	14.00	16.40	10.20	13.00	12.80	13.00	13.11
	q	14.00	11.30	14.00	16.00	10.20	13.00	14.50	13.00	13.25
	r	4.80	4.30	4.00	4.80	2.50	6.00	1.80	2.00	3.77
	s	2.00	4.00	2.00	2.50	1.80	1.00	1.00	2.00	2.04
L O W E R	t	4.00	11.00	5.00	3.00	3.00	3.50	3.00	4.00	4.56
	a	4.00	7.00	5.00	9.00	4.80	6.50	6.00	7.00	6.16
	b	2.50	9.00	5.00	9.00	2.50	5.00	6.00	7.00	5.75
	c	4.50	6.50	5.00	9.00	6.00	5.00	6.00	7.00	6.13
	d	15.00	6.00	14.00	0.00	12.00	12.00	12.00	13.00	10.50
	e	18.00	4.50	14.00	10.20	5.50	10.00	11.00	12.00	10.65
	f	15.00	11.00	14.00	12.50	6.50	12.00	16.00	16.00	12.88
	g	9.50	14.00	9.50	10.00	10.00	10.00	14.00	9.00	10.75
	h	3.00	5.00	11.00	8.00	7.50	2.00	7.50	7.00	6.38
	i	13.00	5.00	5.00	10.50	8.00	4.00	5.50	7.80	7.35

TABLE A5

ALL PEAK VALUES OF VERTICAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 1

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	56.25	60.00	60.00	58.50	63.75	62.25	75.00	63.75	62.44
	d	58.50	48.75	71.25	41.25	37.50	45.00	63.75	37.50	50.44
	e	-12.00	-15.00	-30.75	+6.00	-18.75	-22.50	-3.75	-3.75	-1.31
	f	63.75	61.50	75.00	45.00	52.50	67.50	63.00	60.00	61.03
	g	21.75	27.00	25.50	17.25	26.25	30.00	30.75	27.00	25.69
	h	15.00	15.00	19.50	15.00	17.25	17.25	22.50	21.00	17.81
	i	6.00	2.25	2.25	1.50	3.00	2.25	7.50	3.75	3.56
L O N E R	p	15.00	16.50	17.25	16.50	17.25	15.00	15.75	15.00	16.03
	q	23.25	17.25	18.75	22.50	21.00	21.00	21.00	20.25	20.62
	r	36.75	22.50	22.50	24.00	21.75	23.25	24.75	15.75	23.91
	s	30.00	60.00	52.50	45.00	52.50	44.25	52.50	59.25	49.50
	t	-0.75	15.00	11.25	6.75	-15.00	0.00	-15.00	7.50	1.22
	u	55.50	90.00	105.00	89.25	74.25	82.50	62.25	90.00	81.09
	v	42.00	78.75	75.00	51.00	54.00	69.75	45.75	63.75	60.00

TABLE A6

ALL PEAK VALUES OF VERTICAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 2

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	55.50	60.00	66.00	75.00	52.50	78.75	69.00	75.00	66.47
	d	45.00	73.50	67.50	43.50	56.25	67.50	67.50	69.00	61.22
	e	-16.50	-7.50	-7.50	+13.50	+22.50	-6.00	-36.00	-3.75	-5.16
	f	57.75	60.00	52.50	58.50	58.50	67.50	71.25	69.00	61.87
	g	18.75	37.50	37.50	42.75	33.00	30.00	29.25	41.25	33.75
	h	15.00	15.00	16.50	18.00	19.50	15.00	18.00	21.00	17.25
	i	4.50	6.75	6.00	6.75	4.50	1.50	11.25	2.25	5.44
L O W E R	p	11.25	9.75	9.00	18.00	12.75	15.00	11.25	9.75	12.09
	q	17.25	28.50	16.50	15.75	21.75	21.00	20.25	22.50	20.44
	r	30.00	43.50	51.00	38.25	41.25	42.75	42.00	44.25	41.62
	s	36.75	44.25	37.50	48.00	41.25	61.50	63.75	54.00	48.37
	t	15.00	+12.75	-7.50	-7.50	+9.75	-1.50	-22.50	+18.00	-1.69
	u	75.75	72.00	72.75	89.25	61.50	96.75	105.00	67.50	80.06
	v	43.50	67.50	60.00	66.75	36.00	67.50	82.50	52.50	59.53

TABLE A7

ALL PEAK VALUES OF VERTICAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 3

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	61.50	72.00	70.50	60.00	58.50	71.25	58.50	67.50	64.97
	d	60.00	56.25	75.00	52.50	39.75	67.50	37.50	45.00	54.19
	e	+11.25	+1.50	+7.50	+11.25	0.00	+9.00	+18.75	+15.00	+9.28
	f	20.25	45.00	31.50	48.75	70.50	56.25	48.75	67.50	48.56
	g	16.50	31.50	24.00	32.25	28.50	32.25	27.75	34.50	28.41
	h	8.25	12.75	15.00	12.00	15.00	13.50	15.00	13.50	13.13
	i	7.50	8.25	6.00	7.50	7.50	3.00	9.00	6.00	6.84
L O N E R	p	13.50	14.25	15.75	19.50	14.25	11.25	14.25	16.50	14.91
	q	12.00	11.25	15.75	9.00	15.00	16.50	15.00	18.75	14.16
	r	15.00	22.50	30.75	26.25	23.25	28.50	33.00	15.00	24.28
	s	36.75	75.00	71.25	42.75	47.25	41.25	41.25	43.50	49.87
	t	+7.50	0.00	+18.75	-6.00	-6.00	+16.50	0.00	+1.50	+4.03
	u	75.00	37.50	38.25	78.75	75.00	81.75	90.00	82.50	69.84
	v	52.50	75.00	65.25	60.00	67.50	67.50	65.25	84.00	67.12

TABLE A8

ALL PEAK VALUES OF VERTICAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 4

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	71.25	60.00	61.50	69.75	48.75	56.25	67.50	60.00	61.67
	d	51.75	63.75	67.50	61.50	33.75	37.50	33.75	37.50	48.37
	e	+31.50	+3.75	+18.75	+12.75	0.00	-7.50	+4.50	+22.50	+10.78
	f	43.50	43.50	54.00	58.50	45.00	61.50	75.00	54.75	54.47
	g	37.50	26.25	30.00	31.50	29.25	45.75	45.00	37.50	35.34
	h	15.00	16.50	19.50	17.25	18.75	17.25	18.75	15.00	17.25
	i	3.00	3.75	3.00	3.00	6.00	7.50	6.75	2.25	4.41
L O W E R	p	13.50	15.75	16.50	21.75	14.25	9.75	15.00	15.00	15.19
	q	19.50	22.50	18.75	21.75	18.75	16.50	22.50	21.75	20.25
	r	39.75	31.50	39.00	23.25	23.25	37.50	27.00	22.50	30.47
	s	43.50	34.50	52.50	44.25	42.00	45.00	45.00	45.00	43.97
	t	-1.50	+2.25	-7.50	+7.50	0.00	0.00	+22.50	0.00	+2.91
	u	82.50	75.00	90.00	76.50	63.75	68.25	60.00	73.50	73.69
	v	57.00	44.25	63.75	51.00	59.25	60.00	67.50	50.25	56.62

TABLE A9

ALL PEAK VALUES OF FRONTAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 1

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	8.00	8.75	10.25	6.50	10.00	8.75	10.50	8.75	8.94
	c	3.75	3.75	6.25	3.75	5.50	4.50	5.50	2.50	4.44
	d	4.50	3.75	6.25	4.25	6.25	4.50	7.00	5.00	5.19
	f	5.00	2.50	4.50	6.50	10.50	7.75	10.50	12.50	7.47
	h	3.75	4.50	10.00	2.00	2.00	0.50	0.50	1.00	3.03
L O W E R	i	6.25	7.00	5.00	3.00	2.00	2.00	3.00	2.00	3.78
	m	3.75	2.00	2.50	3.75	3.25	2.50	3.75	4.50	3.25
	o	7.50	16.25	9.75	10.00	12.00	15.00	10.00	8.50	11.12
	p	2.00	9.00	5.00	5.00	5.00	70.00	25.00	45.00	20.75
	q	3.25	10.00	11.00	10.50	6.25	8.75	5.00	8.00	7.84

TABLE A10

ALL PEAK VALUES OF FRONTAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 2

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	9.50	10.50	8.75	7.25	9.50	10.50	9.50	7.50	9.12
	c	4.25	3.50	9.00	6.25	7.50	5.50	7.50	7.00	6.31
	f	2.50	5.50	6.00	7.00	5.50	5.00	7.50	5.50	5.56
	g	6.00	6.75	2.00	1.00	1.00	2.00	0.50	3.50	2.84
	h	2.50	4.50	3.50	3.75	5.50	3.00	3.25	3.75	3.72
L O N E R	l	4.00	4.25	3.50	3.00	3.75	3.25	2.75	4.00	3.56
	m	7.50	8.50	5.50	11.25	8.00	5.50	4.50	8.00	7.34
	n	2.00	2.50	0.00	6.00	2.00	2.00	8.00	2.50	3.12
	o	4.50	8.00	5.00	8.50	5.00	10.00	5.50	3.00	6.19
	p	4.00	3.50	2.00	3.00	2.00	6.00	2.00	3.00	3.19
	q	3.50	7.50	0.50	3.50	4.50	3.00	2.50	3.00	3.50

TABLE A11

ALL PEAK VALUES OF FRONTAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 3

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	10.50	12.50	10.00	3.75	8.75	10.00	7.50	7.50	8.81
	c	8.00	9.00	12.00	2.50	4.50	5.00	2.50	6.75	6.28
I	d	8.00	7.50	12.00	2.50	5.00	7.00	6.25	4.00	6.53
	f	12.50	11.25	13.50	13.75	10.00	10.00	13.00	8.00	11.50
T	h	3.75	0.75	2.00	3.00	2.50	2.50	2.50	3.75	2.59
	i	2.50	3.75	1.00	3.75	2.00	1.00	2.00	2.50	2.31
L	l	4.00	8.00	2.00	4.50	1.25	2.50	3.75	5.00	3.88
D	m	5.00	5.00	4.25	2.50	3.75	2.50	5.50	3.50	4.00
W	n	17.00	12.75	15.50	8.00	12.50	14.50	10.00	12.50	12.84
E	o	3.00	10.50	10.50	7.50	8.00	4.50	7.50	5.00	7.06
R	p	4.50	10.50	8.00	5.00	9.50	3.00	10.00	11.25	7.72
	q	3.75	3.75	4.50	2.50	4.50	2.00	5.00	2.00	3.50
	r	6.00	5.25	4.50	3.50	5.00	3.25	5.00	3.00	4.44
	s	8.75	7.50	5.00	2.00	4.50	3.00	5.50	5.50	5.22

TABLE A13

ALL PEAK VALUES OF LATERAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 1

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	c	5.67	5.83	2.92	5.00	4.17	3.33	4.17	3.33	4.30
I	d	1.25	0.00	0.17	0.33	0.00	1.50	-1.25	10.00	1.50
F	e	3.33	3.33	4.17	4.17	4.17	4.00	4.00	5.00	4.02
T	f	+0.17	+1.00	0.00	+0.67	+0.08	-0.67	-1.50	-1.67	-0.24
	g	1.67	3.33	5.00	2.50	1.67	3.33	3.33	4.17	3.12
L	q	2.92	3.33	2.50	1.67	2.50	2.50	2.50	3.17	2.64
O	r	1.67	0.83	0.67	2.17	3.33	1.83	3.17	0.00	1.71
W	s	3.75	3.75	4.17	4.83	2.50	4.17	2.50	4.58	3.78
E	t	4.83	4.58	5.83	7.08	6.25	5.83	5.42	4.58	5.55
R	v	2.92	3.33	4.17	4.17	2.50	4.17	4.17	5.00	3.80

TABLE A14

ALL PEAK VALUES OF LATERAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 2

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	c	4.17	4.17	4.58	4.58	4.00	4.17	2.50	3.75	3.99
	d	2.08	1.00	0.83	0.00	0.17	1.67	0.83	0.42	0.87
	e	4.33	6.67	4.00	4.50	5.00	4.83	4.58	2.92	4.60
	f	4.17	2.92	5.42	3.33	4.17	0.83	4.33	2.92	3.51
	g	4.33	4.17	4.58	3.75	3.33	4.58	4.00	3.75	4.06
	h	-1.67	0.42	1.67	1.00	1.67	0.83	0.83	0.42	0.65
	i	5.42	5.00	4.17	4.17	4.33	4.17	7.00	4.58	4.85
L	m	3.50	4.17	4.17	3.75	5.83	5.00	5.00	5.00	4.55
O	n	3.33	5.83	4.17	5.83	5.83	5.00	7.92	5.83	5.47
W	o	2.50	0.00	0.17	4.17	0.67	1.67	0.67	1.67	1.44
E	p	3.50	1.67	2.92	4.17	2.92	3.33	1.50	2.08	2.76
R	q	3.67	3.33	2.08	3.33	2.92	2.08	2.50	1.50	2.68
	r	3.50	4.17	5.83	4.17	4.17	3.75	5.00	4.58	4.40
	s	4.17	4.17	4.17	4.17	4.17	4.00	3.33	3.33	3.94

TABLE A15

ALL PEAK VALUES OF LATERAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 3

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	c	3.75	5.33	4.58	2.50	5.25	5.83	3.33	3.67	4.28
	d	-1.25	1.50	0.00	2.08	0.42	0.00	-1.25	0.00	0.19
I	e	4.58	3.50	0.00	0.83	0.00	0.00	-1.25	0.00	0.96
F	f	-1.67	-0.83	0.00	0.00	0.42	0.00	-1.25	0.00	-0.42
	g	3.33	4.58	5.83	3.33	4.42	4.17	6.67	3.83	4.52
T	h	0.00	0.42	1.67	1.67	0.83	0.83	0.83	0.83	0.89
	i	3.33	2.67	2.92	3.75	2.50	3.33	2.50	3.33	3.04
	j	0.83	1.67	0.42	0.83	1.67	1.25	1.25	1.67	1.20
L	q	2.50	3.33	2.08	2.50	3.33	3.17	2.92	3.33	2.90
O	r	1.67	1.25	1.25	2.08	1.67	0.83	0.83	1.25	1.35
W	s	3.33	2.92	2.50	3.75	3.33	5.83	4.17	2.50	3.54
E	t	3.75	3.33	3.33	3.33	2.50	2.50	3.33	3.33	3.18
R	v	0.83	1.67	0.83	1.67	0.83	0.83	2.92	0.83	1.30
	w	4.17	6.67	6.25	3.33	1.67	1.67	5.00	4.17	4.11
	x	1.67	1.67	0.83	0.00	0.83	0.83	0.83	0.42	0.89

TABLE A16

ALL PEAK VALUES OF LATERAL FORCE IN POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 4

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	1.25	0.83	0.83	1.67	0.83	0.83	2.50	0.83	1.20
I	c	4.17	6.67	5.83	5.00	5.83	3.75	5.00	4.17	5.05
F	d	1.67	3.33	1.67	0.83	0.83	0.83	1.67	0.83	1.46
T	e	3.75	3.33	2.50	2.50	5.42	3.33	4.58	5.00	3.80
	f	1.67	1.67	1.67	0.00	1.67	0.00	1.67	4.17	1.56
	g	2.92	5.00	2.50	2.92	3.33	3.33	2.50	2.50	3.12
	h	3.33	3.75	3.33	2.50	4.17	3.75	2.50	3.75	3.39
	i	1.67	1.67	1.25	0.83	1.67	1.67	2.50	1.25	1.56
L O W E R	n	2.08	2.08	3.33	2.50	2.50	5.00	3.75	5.00	3.28
	o	2.92	3.33	3.33	2.50	4.17	4.17	5.00	3.75	3.65
	p	0.00	0.83	1.67	0.00	1.67	0.83	1.25	-2.50	0.47
	q	3.33	2.50	2.50	3.33	3.75	3.75	2.50	4.17	3.23
	r	4.58	1.67	3.75	1.67	1.67	4.83	4.58	5.00	3.47
	s	5.42	3.33	3.33	1.67	2.50	2.50	4.58	4.58	3.49
	t	5.42	5.00	4.17	3.33	3.75	2.50	2.92	3.33	3.80
	u	0.00	0.83	1.25	0.83	0.83	0.83	2.50	0.42	0.94

TABLE A17

ALL PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 1

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	102.86	72.00	41.14	51.43	25.71	12.86	0.00	5.14	38.89
I	c	102.86	180.00	51.43	102.86	25.71	51.43	77.14	61.71	81.64
F	d	-72.00	+51.43	-128.57	0.00	-128.57	-236.57	+38.57	-38.57	-64.29
T	e	180.00	154.29	128.57	200.57	154.29	0.00	154.29	154.29	140.79
	f	102.86	51.43	25.71	61.71	77.14	51.43	12.86	25.71	51.11
L	j	43.71	77.14	51.43	46.29	38.57	5.14	0.00	5.14	33.43
O	k	51.43	51.43	46.29	51.43	64.29	90.00	159.43	25.71	67.50
W	l	252.00	128.57	205.71	252.00	128.57	180.00	231.43	154.29	191.57
E	m	252.00	102.86	128.57	231.43	128.57	180.00	102.86	154.29	160.07
R	n	252.00	115.71	180.00	231.43	128.57	180.00	115.71	154.29	169.71
	o	128.57	51.43	0.00	115.71	133.71	218.57	102.86	25.71	97.07
	p	38.57	25.71	7.71	0.00	0.00	2.57	25.71	25.71	15.75

TABLE A18

ALL PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 2

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	308.57	128.57	308.57	102.86	180.00	205.71	360.00	205.71	225.00
I	c	617.14	591.43	540.00	514.29	617.14	514.29	591.43	514.29	562.50
F	d	617.14	591.43	540.00	501.43	617.14	578.57	617.14	514.29	572.14
T	e	-128.57	128.57	-77.14	-205.71	+25.71	-102.86	+51.43	-128.57	-86.79
L	j	154.29	167.14	141.43	180.00	192.86	177.43	180.00	180.00	171.64
O	k	514.29	565.71	617.14	668.57	694.29	720.00	694.29	565.71	630.00
W	l	+25.71	+102.86	-25.71	+77.14	+51.43	-25.71	+77.14	+25.71	+38.57
E	m	25.71	128.57	25.71	25.71	25.71	25.71	-51.43	126.00	41.46
R	n	+51.43	-102.86	+25.71	-77.14	+51.43	-25.71	+77.14	-30.86	+34.71
	o	+25.71	-102.86	-205.71	-25.71	-51.43	-128.57	+77.14	-180.00	-73.93

TABLE A19

ALL PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 3

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	a	51.43	128.57	102.86	154.29	72.00	38.57	38.57	64.29	81.32
I	b	-25.71	51.43	149.14	0.00	128.57	0.00	30.86	-25.71	38.57
F	c	205.71	244.29	51.43	141.43	-51.43	100.29	64.29	180.00	117.00
T	d	360.00	334.29	231.43	231.43	231.43	257.14	257.14	205.71	263.57
	e	51.43	46.29	25.71	51.43	59.14	77.14	12.86	51.43	46.93
L	k	77.14	56.57	51.43	102.86	77.14	51.43	51.43	102.86	71.36
O	l	257.14	262.29	231.43	154.29	257.14	231.43	244.29	180.00	227.25
W	m	174.86	159.43	102.86	231.43	180.00	231.43	128.57	205.71	176.79
E R	n	100.29	115.71	257.14	205.71	154.29	77.14	192.86	154.29	157.18

TABLE A20

ALL PEAK VALUES OF CARTWHEEL TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 4

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	a	77.14	128.57	128.57	131.14	51.43	90.00	154.29	108.00	108.64
I	b	64.29	64.29	133.71	102.86	154.29	92.57	0.00	115.71	90.96
F	c	372.86	462.86	437.14	514.29	475.71	511.71	720.00	630.00	515.57
T	d	77.14	12.86	38.57	12.86	128.57	77.14	0.00	0.00	43.39
	e	51.43	25.71	38.57	12.86	128.57	77.14	0.00	0.00	41.79
L	k	108.00	102.86	180.00	128.57	141.43	141.43	154.29	205.71	145.29
O	l	334.29	385.71	437.14	501.43	493.71	668.57	475.71	516.86	476.68
W	m	133.71	205.71	154.29	102.86	0.00	-77.14	64.29	180.00	95.46
E	n	0.00	+25.71	+25.71	+51.43	0.00	-180.00	-154.29	0.00	-28.93
R	o	+180.00	+205.71	+128.57	+82.29	+128.57	+51.43	+25.71	+102.86	+100.29
	p	102.86	25.71	231.43	180.00	192.86	257.14	128.57	38.57	144.64

TABLE A21

ALL PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 1

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	243.98	211.45	227.71	260.24	146.39	266.75	227.71	195.18	222.42
I	d	650.60	764.46	748.19	618.07	666.87	673.37	796.99	813.25	716.47
P	e	644.10	796.99	683.13	618.07	796.99	608.31	774.22	813.25	716.88
T	f	65.06	16.27	97.59	91.08	81.33	71.57	48.80	58.55	66.28
	g,h	504.22	487.95	422.89	455.42	553.01	455.42	487.95	504.22	483.89
	i	65.06	0.00	32.53	0.00	32.53	32.53	97.59	0.00	32.53
L	p	162.65	130.12	130.12	97.59	123.61	156.14	195.18	130.12	140.69
O	q,r	504.22	422.89	455.42	351.32	536.75	520.48	520.48	585.54	487.14
W	s	-146.39	+65.06	+113.86	+65.06	+188.67	+97.59	+81.33	+97.59	+70.35
E	t	618.07	764.46	683.13	618.07	683.13	813.25	715.66	764.46	707.53
R	u	471.69	699.40	748.19	715.66	585.54	813.25	780.72	796.99	701.43
	v	130.12	65.06	0.00	162.65	6.51	6.51	32.53	81.33	60.59

TABLE A22

ALL PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 2

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L I F T	b	211.45	204.94	227.71	162.65	195.18	195.18	260.24	260.24	214.70
	d	683.13	715.66	683.13	585.54	731.93	715.66	601.81	520.48	654.67
	e	666.87	796.99	683.13	585.54	731.93	813.25	699.40	748.19	715.66
	f	65.06	156.14	276.51	71.57	58.55	195.18	48.80	71.57	117.92
	g,h	341.57	357.83	357.83	357.83	422.89	390.36	406.63	390.36	378.16
	i	162.65	0.00	162.65	0.00	97.59	0.00	162.65	0.00	73.19
L O W E R	p	97.59	113.86	97.59	97.59	113.86	65.06	146.39	162.65	111.82
	q,r	276.51	341.57	341.57	374.10	331.81	357.83	406.63	374.10	350.51
	s	+97.59	+48.80	+65.06	+65.06	+58.55	+65.06	+48.80	+32.53	+60.18
	t	618.07	764.46	715.66	683.13	780.72	699.40	787.23	715.66	720.54
	u	683.13	731.93	731.93	683.13	780.72	774.22	748.19	618.07	718.91
	v	65.06	6.51	81.33	16.27	91.08	6.51	0.00	0.00	33.34

TABLE A23

ALL PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 3

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	227.71	243.98	227.71	221.20	188.67	276.51	227.71	211.45	228.12
I	d	904.34	878.31	878.31	676.63	618.07	699.40	731.93	764.46	768.93
F	e	904.34	975.90	845.78	650.60	715.66	699.40	741.69	764.46	787.23
T	f	-97.59	+48.80	-32.53	-325.30	+162.65	-48.80	-65.06	-97.59	-56.93
	g,h	845.78	731.93	553.01	585.54	569.28	601.81	618.07	618.07	640.44
	i	97.59	48.80	6.51	32.53	48.80	32.53	6.51	32.53	38.22
L	p	227.71	243.98	195.18	178.92	130.12	169.16	182.17	178.92	188.27
O	q,r	748.19	731.93	601.81	618.07	487.95	618.07	585.54	634.34	628.24
W	s	+260.24	-65.06	+97.59	+65.06	0.00	-65.06	+16.27	-113.86	+24.40
E	t	520.48	878.31	748.19	585.54	676.63	683.13	715.66	715.66	690.45
R	u	520.48	878.31	748.19	585.54	676.63	683.13	715.66	715.66	690.45
	v	520.48	455.42	634.34	683.13	634.34	650.60	764.46	715.66	632.30

TABLE A24

ALL PEAK VALUES OF SOMERSAULT TORQUE IN INCH POUNDS
FOR A REPRESENTATIVE SUBJECT IN CONDITION 4

TASK	PEAK	1	FIRST 2	SET 3	4	5	REPLICATE 6	SET 7	8	MEAN
L	b	260.24	195.18	97.59	130.12	84.58	162.65	65.06	65.06	132.56
I	d	195.18	234.22	195.18	292.77	195.18	195.18	227.71	260.24	224.46
F	e	666.87	715.66	845.78	666.87	618.07	683.13	601.81	780.72	697.36
T	f	666.87	728.67	845.78	666.87	683.13	715.66	699.40	780.72	723.39
	g,h	195.18	195.18	65.06	113.86	195.18	113.86	130.12	32.53	130.12
	i	276.51	227.71	243.98	146.39	260.24	292.77	162.65	260.24	233.81
L	p	65.06	97.59	6.51	65.06	81.33	32.53	65.06	65.06	59.77
O	q,r	65.06	91.08	97.59	58.55	81.33	71.57	65.06	58.55	73.60
W	s	234.22	234.22	266.75	227.71	260.24	195.18	292.77	227.71	242.35
E	t	-91.08	-16.27	0.00	-32.53	-97.59	-162.65	-65.06	-58.55	-65.47
R	u	634.34	634.34	650.60	579.04	683.13	553.01	579.04	683.13	624.58
	v	666.87	731.93	683.13	683.13	780.72	683.13	618.07	520.48	670.93

FORCES, TORQUES AND ACCELERATIONS
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by

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B.E. (Mech.), University of Burdwan, India, 1970

AN ABSTRACT OF A MASTER'S REPORT

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ABSTRACT

A six axis force platform was used to study the effect of foot position (feet parallel and left foot leading) on lifting and lowering when the body involved an angle of turn (45 degrees and 0 degrees). Eight subjects representing the 40th to 60th percentile of the distribution of weights of male U.S. adults, lifted and lowered an 11 lb weight through a vertical height of 30", eight times in each condition. Mean of the eight peaks was the criterion in each condition.

The mean peak vertical forces were 59.1, 61.8, 57.6, and 60.5 lbs in case of lifting and 59.7, 59.5, 56.3, and 57.2 lbs for lowering for: feet parallel and straight ahead, feet parallel and 45 degrees turn of body, left foot leading and straight ahead, and left foot leading and 45 degrees turn of body respectively. 'Critical' peaks of vertical forces occurred just after the load is picked up while lifting and slightly after the load is released while lowering. Vertical acceleration was found to be a critical factor. 'Left foot leading' was found to be better both for lifting and lowering when the body involved a turn of 45 degrees to the right; otherwise penalties of 1.3 lbs of vertical force and 170 inch-lbs of cartwheel torque, and 2.5 lbs of vertical force and 186 inch-lbs of cartwheel torque were involved in case of lifting and lowering respectively. When no turn of body is involved, 'left foot leading' was found to be neither better for lifting nor for lowering.