

ADD637764

01

AMRL-TR-66-17

A STUDY OF ONE-HANDED LIFTING

JOHN T. McCONVILLE
ANTIOCH COLLEGE

H. T. E. HERTZBERG
AEROSPACE MEDICAL RESEARCH LABORATORIES

MAY 1966

Distribution of this document
is unlimited



AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

2004 0205140

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Requests for copies of this report should be directed to either of the addresses listed below, as applicable:

Federal Government agencies and their contractors registered with Defense Documentation Center (DDC):

DDC
Cameron Station
Alexandria, Virginia 22314

Non-DDC users (stock quantities are available for sale from):

Chief, Input Section
Clearinghouse for Federal Scientific & Technical Information (CFSTI)
Sills Building
5285 Port Royal Road
Springfield, Virginia 22151

Organizations and individuals receiving reports via the Aerospace Medical Research Laboratories' automatic mailing lists should submit the addressograph plate stamp on the report envelope or refer to the code number when corresponding about change of address or cancellation.

Do not return this copy. Retain or destroy.

A STUDY OF ONE-HANDED LIFTING

JOHN T. McCONVILLE

H. T. E. HERTZBERG

**Distribution of this document
is unlimited**

FOREWORD

The work described herein was conducted under Contract AF 33(616)-6792, funded under Project 7184, "Human Performance in Advanced Systems," Task 718408, "Anthropology for Design," as a joint effort of the Anthropology Branch, Aerospace Medical Research Laboratories, and Antioch College, Yellow Springs, Ohio. Mr. C. E. Clauser and Mr. Milton Alexander of the Anthropology Branch served as contract monitors during the period of this work.

This report is a consequence of the second and senior author's sustained interest in human muscle-strength capabilities. The research itself and the data analyses were executed by the first author. Both authors share responsibility for the manuscript, the first author primarily for the description of the experiment and its results, and the second for the introduction and the implications of the research. The authors wish to express their thanks to the contract monitors for their assistance, and to Mr. Ken Kennedy, also of the Anthropology Branch, who aided in the design and fabrication of the test equipment; to Mr. Edmund Churchill of Antioch College for his continued guidance, statistical and otherwise; and especially to Dr. M. J. Warrick, Human Engineering Division, who critically reviewed the manuscript and greatly improved it by his many helpful suggestions.

This technical report has been reviewed and is approved.

WALTER F. GREYER, PhD
Technical Director
Behavioral Sciences Laboratory
Aerospace Medical Research Laboratories

ABSTRACT

This research is intended to assist in establishing realistic criteria for the size and weight of industrial packages. The problem of such criteria is discussed, numerous important objective and subjective factors that potentially affect human weight-lifting ability are mentioned, the proper approach to the design of industrial loads is pointed out, and additional programs of investigation that would clarify other aspects of the problem are outlined. This study examined the interaction of two variables: (a) the weight, and (b) the width—of one-handled, symmetrical boxes which a sample of 30 adult males were able to lift from the floor to a table 30 inches high. No carrying was involved in this study. The subject sample was chosen to be a reasonable representation by height and weight of the U. S. Air Force population. All lifts were made with the preferred hand under "ideal" laboratory conditions. The experimental variable, box width, was varied from 6 to 32 inches. The maximum weight of box that subjects were able to lift varied linearly, but inversely, with the width of the box. From this sample, the maximum weight that 95% of the population would be able to lift—but not necessarily carry—can be expressed by a linear equation: $Y = 60 - X$, where Y is the weight (in pounds) of the package to be lifted and X is the width (in inches). The numerical values of this formula provide a recommended upper limit on the design of industrial or military equipment which must be lifted under ideal conditions. If the expected conditions of use are less than ideal, or if carrying for appreciable distances is likely to be necessary, reasonable reductions in weight, or size, or both should be made by the manufacturer.

TABLE OF CONTENTS

SECTION	PAGE
I INTRODUCTION	1
II OBJECTIVES AND DESIGN OF THE STUDY	4
III TEST RESULTS	9
APPENDIXES	
I DESCRIPTION OF ANTHROPOMETRIC MEASUREMENTS	15
II TEST PROCEDURE	17
REFERENCES	19

LIST OF ILLUSTRATIONS

FIGURE	PAGE
1. Container and Insert Used in Study	7
2. Details of Handle Construction	7
3. Technique of Weight-Lifting Used in This Study	8
4. Container Weight As A Function of Container Width	11

SECTION I

INTRODUCTION

In the past few decades we have witnessed an unprecedented flood of products which are packaged and moved by men. To assist men in handling these loads all manner of trucks, cranes, dollies, chutes and other transport devices have come into common use. But even in this mechanized age, lifting and muscular exertion remain very much a part of industrial activity - and so too are bodily injuries, strains, sprains, and back dislocations.

How heavy is too heavy? It would be of great scientific, economic, medical and actuarial value to have comprehensive weight-lifting-ability data upon which to base a rational work code. Weight-lifting data are, of course, preserved as records of athletic competitions and record books show that certain individuals have made lifts - i.e., exerted forces - nearly four times their own weight. But such feats are extraordinary, performed by men whose physiques and motivations place them at the extreme end of the muscle-strength spectrum of the population. For most people weight-lifting is work, not sport, and competitive weight-lifting records are obviously unsuitable as criteria for sizing industrial packages. Only the champions - a vanishingly small percentage of the population - could lift such packages.

At this point some will hastily conclude that a package should be sized to weigh what the "average man" can lift. Though this would provide a better criterion than weight-lifting records, it still would not be the best because, by definition, the weight the "average man" can lift is the mid-point of a range of force outputs. The weaker half of the population would still be unable to lift such a weight. Thus even the use of the "average" eliminates too large a percentage of the working population.

The best approach to choosing the best size-weight combination is to ascertain the full range of lifting ability of the working population, from its strongest to its weakest member, and then adopt the weight and size which 90 percent, or 95 percent, or even 98 percent of the population are able to lift under the expected conditions. This last phrase is important; lifting, like all human performance, involves both individual and environmental factors.

There are many properties of a package that affect a person's ability to lift it. Its weight, its size, the location of its center of gravity with respect to its periphery are all of immediate importance. Other factors are the sharpness of the edges, the number of handles, their shape and diameter, and their locations with respect to the center of gravity. The lifter's footing - the slipperiness of the standing surface, its roughness or solidity, and similar external factors - may affect the situation because of the

balance required when exerting force. Besides these, of course, there are the several factors unique to each individual that affect his lifting ability: age, health, basic amount of muscle mass, physical condition, fatigue and motivation.

In addition to the package itself and the lifter's bodily condition, certain anatomical limitations and interactions are part of the situation. Man's body is a complex and varied structure whose center of gravity must remain within a given relationship to its base (the feet) to maintain balance while lifting. Therefore, the relationships between the lifter's structure, center of gravity and mass, and the package's structure, center of gravity and mass, all constitute an important complex of factors in the design of a piece of equipment.

Structurally, the hand is a hook at the end of a cantilever beam hinged in the middle, and the movement of any of the members alters the center of gravity of the arm and of the body. Because of this structure, it is axiomatic that, for one-handed lifting, (1) the size of a package from its periphery to its handle must be limited by the arm's length (except for very light packages that can be swung up and managed overhead); (2) the larger a package, the less must be its weight relative to its volume; and (3) conversely, so as not to overload the shoulder muscles, the heavier a package, the more nearly its center of gravity must approach the vertical center-line through the point of support, the shoulder. In other words, the greater the weight, the less able the shoulder muscles are to elevate the cantilever. This much is evident from every man's experience.

The primary objective of the present investigation is to determine by test the best combination of container size and width that the Air Force population can conveniently lift with one hand. Unfortunately, the detailed and time-consuming tests necessary to establish sound criteria usually trail far behind a recognition of the need for such data. The present tests are a case in point. Some years ago, while HIAGSED (ref 5) was in the planning stage, its editors desired load lift-and-carry information which simply was not available then and could not be determined in time for publication. Realizing that reasonable estimates are better than no data at all, the second author simply drew on his experience and recommended upper limits of weight and size which were incorporated into the Handbook (see HIAGSED, Vol 1, Part B.3-2.3, figure B.3-1). These limits have remained in force ever since as the best available. They were, however, only occasional beacons in a general gloom - useful, but incomplete. The present series is intended to illuminate the scene by providing a spectrum of solidly-based data for each important variable so as eventually to replace the previous estimates. Although a number of variables affect the amount of weight that can be lifted, in this study only the variables of

container weight and width were investigated.

The major result of this study is a formula by which the recommended upper limit of either package weight or package width may be designed. (It may be noted that the HIAGSED-recommended upper weight limit of 45 pounds coincides with the weight determined in this study for a 15-inch-wide box, showing that the original estimates were not wide of the mark.) In using the formula, manufacturers of industrial or military packages should remember that the tests were conducted under ideal conditions, involving no carrying, while the HIAGSED recommendations assumed both carrying and less than optimal conditions. In the place of the old data, designers should of course use new data as they appear; but the new data must be relevant, and the designer cannot avoid the responsibility to exercise sound judgment in reducing the load size or weight, or both, when the expected conditions of use indicate the need for it.

Future tests should be planned to establish approximate guidelines for the limits of size and weight for two-handed lifts of loads with the center of gravity under the handle; for one- and two-handed lifts whose cg is not under the handles; for one-man and two-man loads hand-carried over specified distances; and for other similar conditions, which may affect man's ability to work efficiently.

SECTION II

OBJECTIVES AND DESIGN OF THE STUDY

The subject sample consisted of thirty healthy male volunteers ranging in age from 18 to 39 years. The sample included military and civilian employees of Wright-Patterson Air Force Base and students from Antioch College and the University of Dayton. The sample was random in that all who volunteered as subjects were accepted with the exception of three individuals, each of whom had a previous history of body injuries that might be aggravated by heavy lifting. The subject sample was arbitrarily divided into two groups of 15 men each (hereafter referred to as Groups I and II).

All but two of the 30 subjects tested were in, or were in training for, professional or technical work. The two individuals not so classified were engaged in work of a light industrial nature. Twenty-two of the subjects were, or had previously been, in the military service. The average service career of this group was 2.3 years. The work history, physical training and athletic background of the group as a whole indicated very limited experience in heavy lifting activities. While a few subjects stated that they had practiced weight-lifting in a gymnasium, it was of a casual nature as opposed to the intensive training of weight-lifters.

Various investigators have found in past studies of human strength that a significant relationship exists between body size and strength test scores (refs 1, 3, 9). Since the results of this study are intended to be applicable to the Air Force population, it is desirable to know how well the body-size characteristics of the samples being tested compare with those of the Air Force population. If the body-size characteristics of the one are quite comparable to those of the other the results of the study can be generalized to an Air Force population with reasonable confidence. And since the USAF body-size characteristics are probably fairly similar to those of the healthy, adult work force, the results of the study may also apply reasonably well to civilian groups. A comparison of the body-size characteristics of the samples and an Air Force population is illustrated in Table 1. Unfortunately, no comparative anthropometric data on the general civilian work force are available.

The statistics indicate that there are but minor differences in body size between the two study groups and the USAF population. Those Group I and II body dimensions listed in Table 1, for which there are no comparable Air Force population dimensions, were obtained so that the relationship, if any, between lifting strength, muscle mass and lengths of limb segments could be examined.

TABLE 1

COMPARISON OF THE STUDY GROUPS AND AIR FORCE
POPULATION IN SELECTED ANTHROPOMETRIC DIMENSIONS

<u>Measurement</u> ⁽¹⁾	<u>Group I</u>		<u>Group II</u>		<u>AF Population</u> ⁽²⁾	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
1. Age	26.20	5.44	26.67	6.76	27.87	4.22
2. Weight	158.00	13.99	167.93	21.83	163.66	20.86
3. Stature	69.45	2.28	69.38	1.88	69.11	2.44
4. Acromial Height	56.95	1.98	57.08	1.72	56.50	2.28
5. Waist Height	42.84	1.46	42.04	1.30	42.02	1.81
6. Trochanteric Height	37.90	1.84	36.95	2.99		(3)
7. Biceps Circ., Min.	11.63	0.63	12.27	1.08		(3)
8. Biceps Circ., Max.	12.46	0.73	12.89	1.12	12.79	1.07
9. Forearm Circ., Min.	10.85	0.52	11.01	0.61		(3)
10. Forearm Circ., Max.	11.39	0.57	11.43	0.68	11.50	0.73
11. Chest Circumference	35.56	1.61	37.74	2.49		(3)
12. Waist Circumference	31.93	1.95	33.57	3.06	32.04	3.02
13. Shoulder-Elbow Length	14.11	0.52	13.75	0.56	14.32	0.69
14. Forearm-Grip Length	13.97	0.53	13.74	0.48		(3)
15. Grip Reach	25.19	1.13	24.92	1.02		(3)
16. Hand Length	7.48	0.25	7.25	0.21	7.49	0.34
17. Hand Breadth	3.38	0.14	3.35	0.13	3.48	0.16

(1) Age is in years, weight in pounds; all other values are in inches.

(2) Ref 7.

(3) No comparable USAF body dimension.

The test equipment used in the study consisted of five wooden boxes of the following dimensions:

Container	Height	Width	Length
1	10"	6"	8"
2	10"	10"	12"
3	10"	14"	16"
4	10"	20"	24"
5	10"	28"	32"

Each container had a D-shaped metal handle centered on its top (Figure 1). The handles were of 3/8-inch diameter, similar to those in use on many of the portable military equipments. They were attached to the containers by a metal plate which, when unlocked, permitted 90-degree rotation in the horizontal plane (Figure 2). This arrangement allowed the width of the container to be shifted from one axis to another, thus placing the container at different distances from the body without changing containers. Test container 3, for example, was 14 inches wide and 16 inches long; by rotating the handle 90 degrees the effective distance of the handle from the side of the body was increased one inch.

The weight of the container was increased by addition of either five-pound shot bags or ten-pound lead slabs, depending upon the particular phase of the test. A hinged door on the side of each container provided access to a compartmented insert into which the weights were placed. This compartmented insert facilitated positioning of the weights to maintain the center of gravity of the load directly under the handle and prevented the weights from shifting in the container during a lift.

In these tests, all subjects were bare-handed, since the wearing of heavy (2-layer) gloves is known to decrease the forces the fingers can exert in certain conditions (ref 6). Also, the tests were conducted under reasonably ideal conditions of footing, balance, health and physical condition.

Prior to the actual tests, each subject filled out a brief personal history form. (See Appendix II.) The subject was then given an empty container and instructed in the manner in which he was to lift. Each subject was told to lift using his right hand only, with his palm and fingers up. This grip, while not always preferred by subjects, tends to keep the stress distributed along the distal ends of the metacarpals, as opposed to the distal phalanges when an overhand grip is used. The subject was instructed to lift the container from the floor by straightening his leg, to pause in the lift briefly after coming upright, and then make a biceps-flexion lift to the table top. Swinging or jerking the container from the floor, or using the upper leg and hip to steady the load during the lift were not permitted.

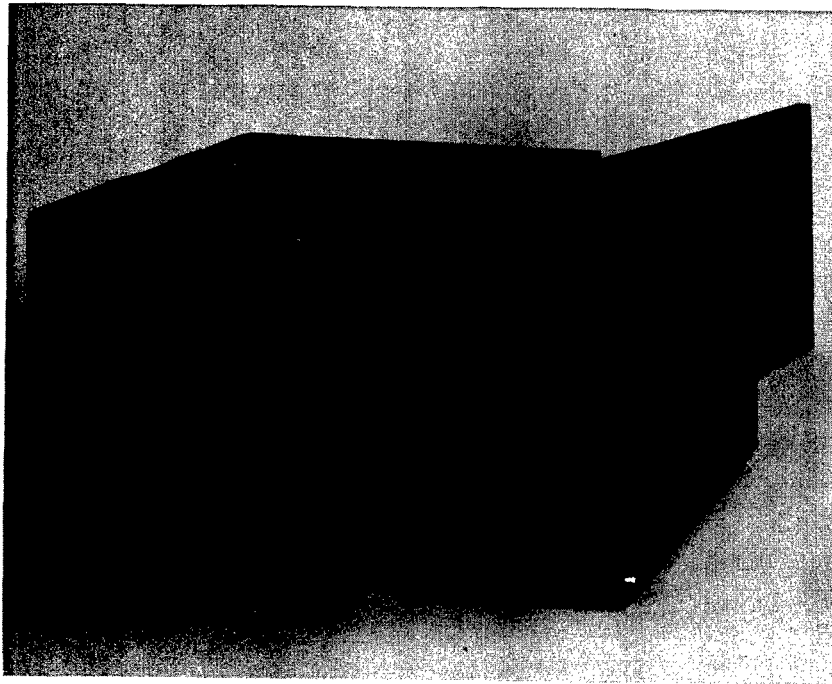


Figure 1. Container and Insert Used in Study

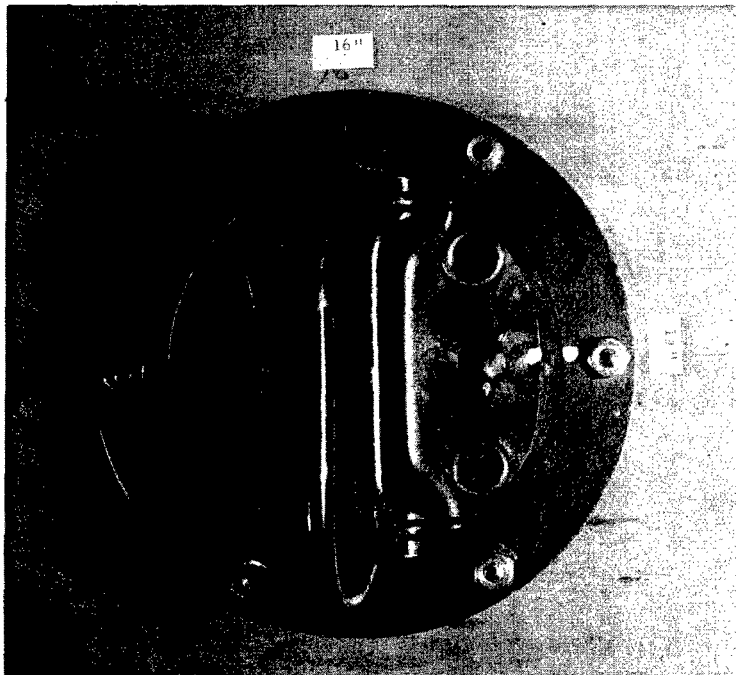


Figure 2. Details of Handle Construction
The central ring holding the handle can turn 90° , and is locked in either position by the wing-nut. Outer ring is $5\text{-}1/4$ inches in diameter; inside dimension of handle is $3\text{-}3/4$ inches. The diameter of the handle grip itself is $3/8$ -inch.

Following the instructions, weights were placed in the central compartment of the containers and the tests were begun. The initial starting weight (thirty pounds) was kept constant for all subjects. A trial was considered successful when the subject was able to lift the container with one hand from the floor to the table surface 30 inches above the floor. (See Figure 3.) After a successful trial, the observer replaced the container on the floor and added an increment of weight; either five or ten pounds, depending upon how easily the previous lift was carried out. The trials were continued until the subject had achieved his maximum possible one-handed lift. The score for any series of trials on a particular container was the maximum weight (weight of container and lead) successfully lifted. No attempt was made by the observer to influence the subject as to the amount of weight he should endeavor to lift. There was no definite rest period for the subject beyond the time needed for the observer to change the weights and reposition the container.

After the test using one size of container had been completed the subject was allowed a five-minute rest period. After the rest period the next series of trials using a different container was begun. The order of the container sizes was random for each subject so that the scores for any one container would not be biased by its order in the series. The same procedures were followed for Group II except that the handles on all containers were rotated 90 degrees to increase the container's effective width.

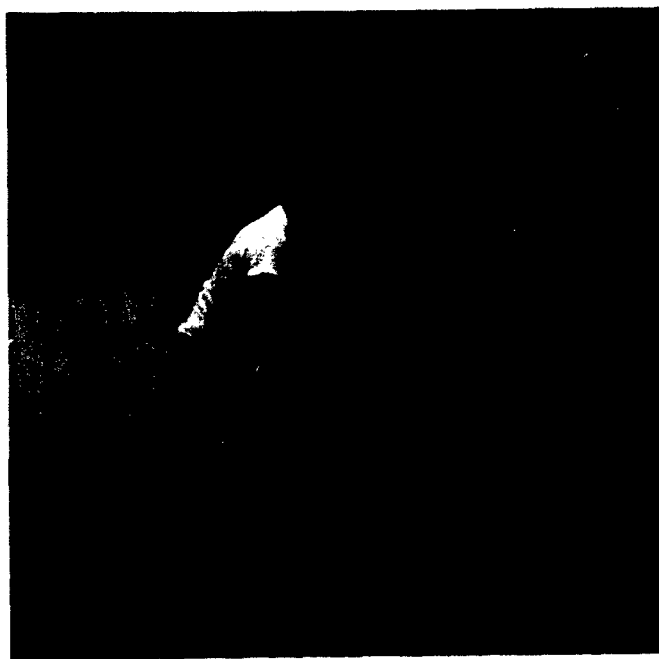


Figure 3. Technique of Weight-Lifting Used in This Study

SECTION III

TEST RESULTS

The test results reported in this section are based upon the weight-lifting scores achieved by two groups of fifteen subjects each. The two groups were tested under nearly identical conditions, only one variable being changed. The variable which was changed was container width. After the first group had been tested the handle on each of the five containers was rotated 90 degrees, which increased the width of each container 2 or 4 inches. The scores reported are the maximum weight in pounds a subject could lift to a table top, 30 inches above floor level, in a single trial. The horizontal distance the container was moved was kept to a minimum consistent with the size of the container being lifted.

Table 2 presents the statistics on the weight-lifting scores by group and container width. The means and standard deviations were computed using small-sample techniques. The percentile values were determined by plotting the cumulative frequencies on normal probability graph paper and approximating a line of best fit. Strength data are usually slightly skewed in distribution. This tendency, along with the small size of the sample, accounts for the differences between mean values and the 50th-percentile values. The coefficients of variation for these data are somewhat higher than is common for biological statistics, but are well within the range of values reported by others who have investigated muscle strength using weight-lifting tests (refs 4, 9).

The mean values from Table 2 are plotted in Figure 4 as a line graph. The over-all decrement in weight lifted, as container width was increased, is obvious. The line connecting the data points is fairly smooth except at the extreme left of the graph. The data points in this area appear somewhat erratic in comparison to the rest of the data. Two scores appear high, those for the containers 8 and 12 inches in width. As both of these scores are from the second sample tested, we might assume that it is the stronger group; however, the rest of the data points for other container sizes do not substantiate such an assumption.

The standard deviations of the lifting scores for Group II are in general greater than those for Group I. The single exception is for the 32-inch-wide container. This would indicate that Group II probably contained both "stronger" and "weaker" individuals than Group I. This was verified by plotting the scores on a scatter diagram.

A second explanation would be that weight-lifting scores are not significantly affected by container width of less than 12 inches and, therefore, such deviations from the otherwise linear response would not be unexpected. This interpretation, which cannot be fully verified, appears to offer the most logical explanation of

TABLE 2

AVERAGE WEIGHT-LIFTING SCORES*

GROUP I	N=15	Effective Container Width	Percentile								
			Mean	SD	CV	5th	25th	50th	75th	95th	
Container											
1		6"	70.33	8.55	12.16	56.2	62.5	70.3	77.2	85.2	
2		10"	66.20	9.73	14.70	48.0	59.0	67.8	73.9	80.6	
3		14"	65.00	9.64	14.83	51.0	57.8	64.6	71.7	86.8	
4		20"	60.33	7.04	11.67	42.0	54.6	58.8	63.6	74.0	
5		28"	50.13	11.07	22.08	31.8	44.0	51.1	56.3	68.1	

GROUP II	N=15	Effective Container Width	Percentile								
			Mean	SD	CV	5th	25th	50th	75th	95th	
Container											
1		8"	73.33	14.42	19.66	48.5	63.2	73.8	82.2	97.1	
2		12"	69.07	12.67	18.34	48.8	60.5	69.1	77.5	89.0	
3		16"	63.67	11.10	17.43	42.0	55.5	65.2	72.5	81.4	
4		24"	56.27	9.22	16.38	38.1	51.9	56.5	62.2	71.6	
5		32"	47.67	9.83	20.62	27.2	40.0	49.0	53.8	62.9	

*All statistical values are in pounds except CV which is given in percent.

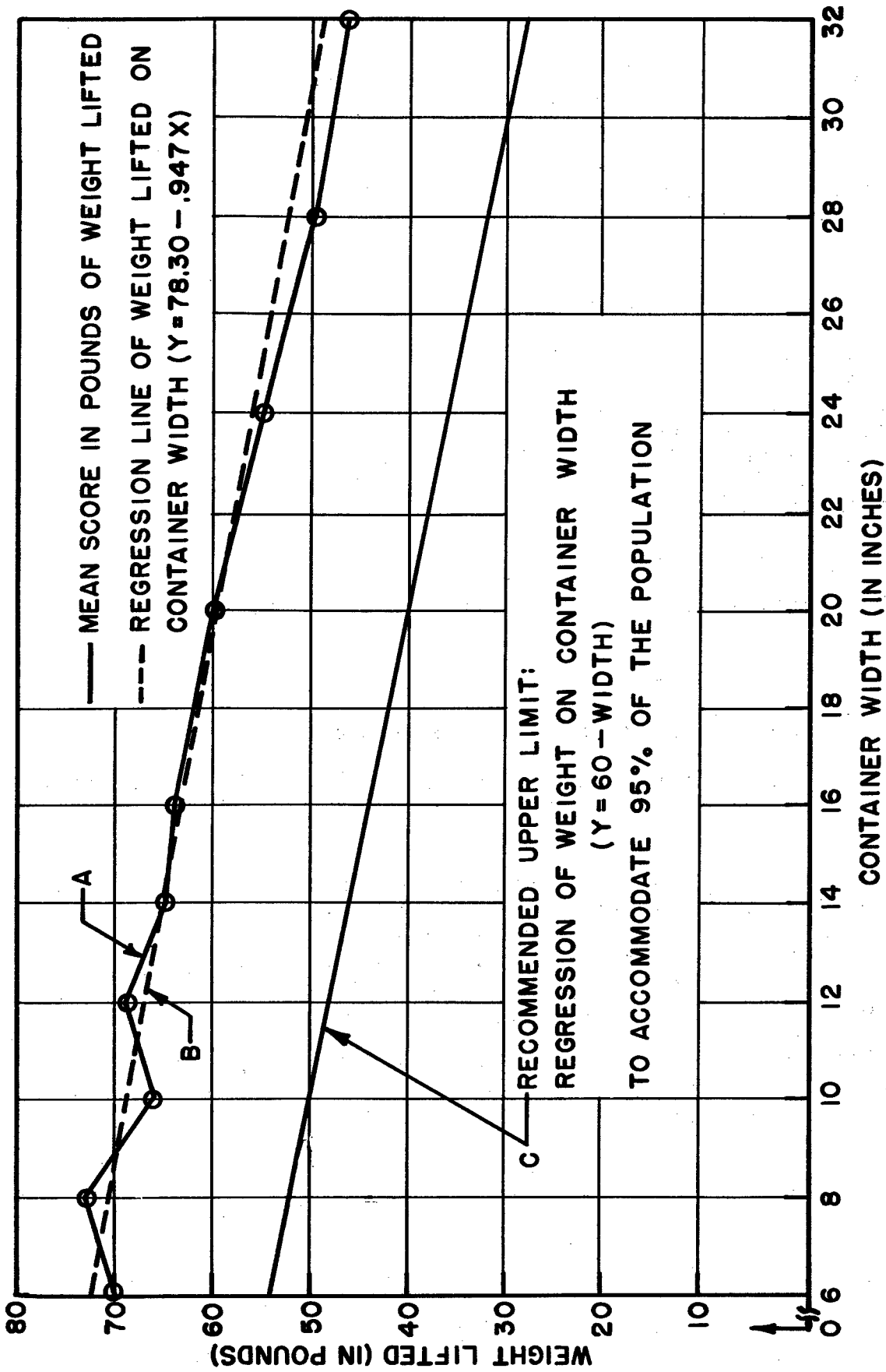


Figure 4. Container Weight As A Function of Container Width.

- A. Mean Score in Pounds of Weight Lifted in Tests
- B. Regression Line of Weight Lifted on Container Width ($Y = 78.30 - .947X$)
- C. Recommended Upper Limits of Weight for Container Design ($Y = 60 - \text{width}$)

these data.

A regression computed from the data is plotted as the dashed line on Figure 4. The formula for this regression line is:

$$Y = 78.30 - .947 X \quad (1)$$

where Y = pounds of weight lifted and
X = container width in inches
 $SE_{est} = 10.37$

As this computation is based upon average scores, it is of limited use in most design problems. The proper procedure is to design equipment to the capabilities of as large a per cent of the population as is possible. In this instance, if it were necessary to accommodate all but the weakest 5 per cent of the population (with regard to one-handed weight-lifting), the point of origin of the regression line would be shifted downward by 1.65 times the value of the standard deviation of the regression. This shift results in the equation:

$$Y = 61.22 - .947 X \quad (2)$$

With little error, this equation can be replaced by the somewhat simpler one:

$$Y = 60 - X \quad (3)$$

It is recommended that formula (3) be used for most design purposes.

From the plot of equation (3) in Figure 4, one variable may be selected as a design criterion based upon the value of the other variable.

The personal-history data taken on each subject (Appendix II) were also used in the analysis of the weight-lifting scores. The total sample was separated into sub-samples by age, occupation and physical activity with regard to sports. No statistically significant differences in weight-lifting scores were found to exist among the different sub-samples.

Correlation coefficients between weight-lifting scores and the anthropometric variables were computed but were found to be not statistically significant for the small samples used in this study.

* Converted into the metric system, formula (3) becomes:

$$Y = \frac{140 - X}{5},$$

where Y = kilograms of weight to be lifted
X = container width in centimeters.

This formula has been selected from several conversions for its simplicity and ease of remembrance. It closely approximates formula (3) for widths from 10 to 25 inches.

The partial correlation coefficient of body weight and lifting score, with the effects of age removed, was 0.608. This appears to indicate that body weight could be used with an appreciable degree of success in evaluating or predicting weight-lifting ability.

To evaluate the reliability of the techniques and procedures used in this study, four subjects of the original sample were re-tested. The re-test was performed under conditions as nearly identical as possible to those of the initial test. It was found that 20 percent of the test--re-test differences were zero, 30 percent were five pounds, 30 percent were ten pounds and the remaining 20 percent, fifteen pounds. In eleven of the twenty lifts made during the re-test, the individual being re-tested increased his previous score for a particular container; in the remaining cases, the re-test score was equal to or less than his previous test scores. Using an analysis of variance, the test--re-test differences were found to be not statistically significant. The techniques and procedures are, therefore, assumed to be adequate for the purposes of the study.

APPENDIX I

DESCRIPTION OF ANTHROPOMETRIC MEASUREMENTS

1. Weight. Determined on medical scales to the nearest quarter-pound.
2. * Stature. Subject stands erect looking directly forward. The vertical distance from the floor to the top of the head is measured.
3. * Acromial Height. Subject stands erect. The vertical distance from the floor to the acromion is measured.
4. * Waist Height. Subject stands erect. The vertical distance from the floor to the constriction of the waist is measured.
5. Trochanteric Height. Subject stands erect. The vertical distance from the floor to the superior lateral aspect of the greater trochanter is measured.
6. Biceps Circumference (Min. and Max.). Subject stands erect with his arms at his side. The measurement is made at the level of the maximum circumference of the biceps muscle (min.). Subject then flexes his forearm 90 degrees and makes a fist. The circumference is again measured at the same level (max.).
7. Forearm Circumference (Min. and Max.). Subject stands erect with his arms at his side. The measurement is made at the level of the maximum circumference of the brachio-radialis (min.). Subject then flexes his forearm 90 degrees and makes a fist. The circumference is again measured at the same level (max.).
8. Chest Circumference. Subject stands erect. The circumference of the chest is measured at the level of the nipples during normal breathing. As the circumference varies slightly during breathing, the maximum value is recorded.
9. * Waist Circumference. Subject stands erect with abdomen relaxed. The circumference of the waist is measured at the constriction of the waist.
10. * Shoulder-Elbow Length. Subject stands erect, with his upper arm at his side and his forearm flexed at 90 degrees. The vertical distance between acromion and the distal tip of the elbow is measured.

* Taken according to the descriptions reported in WADC TR 52-321.

11. Forearm-Grip Length. Subject stands erect with his upper arm at his side and his forearm flexed at 90 degrees. The distance from the dorsal tip of the right elbow to the center of the clenched hand is measured.
12. Grip-Reach. Subject stands erect with arm extended laterally from the body at an angle of 45 degrees. The distance from the superior aspect of the bicipital groove to the center of the clenched hand is measured. (The bicipital groove, also known as the intertubercular groove, can be palpated on the lateral surface of the humeral head just below acromion. The use of this dimension is an attempt to test the body link lengths as determined by Dr. Wilfrid T. Dempster in ref 2.)
13. * Hand Length. The subject's hand is extended with the palm up (supination). The distance from the proximal edge of the navicular bone to the distal tip of the third phalanx is measured.
14. * Hand Breadth. The subject's hand is extended, with the palm up (supination). The distance across the maximum breadth of the distal end of the metacarpals is measured.

* Taken according to the technique reported in WADC TR 52-321.

APPENDIX II

TEST PROCEDURE

Subject Information Sheet

The purpose of this study is to determine the amount of weight which can be lifted in containers of varied physical size. The data are to be obtained on a sample approximating the Air Force population, and are to be utilized in the design of optimally-sized "black boxes" for use in Air Force operations.

The first phase of this study is designed to determine the optimal weight and configuration of electronic packages that require lifting with one hand. Complete instructions as to test procedure will be given by the observer in charge of the test.

Great stress is placed upon impressing on the subject that he is not to strain or otherwise dangerously over-exert himself. The test does not constitute a contest and results will not be made known as individual scores. The problem here is to ascertain optimal rather than maximal capabilities under normal conditions of lifting heavy weight. The subject must not under any circumstances attempt to lift more weight than he feels may be handled without discomfort or pain.

Any subject who has functional limitations such as hernia, hemorrhoids, current and previous back injuries or related disorders, is requested to make this known to the observer.

In addition to the test, subjects will be requested to fill out a brief personal history form and be measured anthropometrically.

Weight-Lifting Study---Test Form

Name _____ Date _____
 Date of Birth _____ Age _____ Race _____ Marital Status _____
 Birthplace _____ Longest Residency _____
 Length of time in service _____
 Principal duties _____
 Previous Occupation _____
 Current physical training, sports or exercise _____

 Previous physical training, sports or exercise _____

Body Measurements

Weight	_____	Chest Circ.	_____
Stature	_____	Waist Circ.	_____
Acromion Height	_____	Shoulder-Elbow Length	_____
Waist Height	_____	Forearm-Hand Length	_____
Trochanteric Height	_____	Grip Reach	_____
Biceps Circ.	_____	Hand Length	_____
(Min. and Max.)	_____	Hand Breadth at	_____
Forearm Circ.	_____	Metacarpale	_____
(Min. and Max.)	_____	Grip Preference	_____

Weight-Lifting Study---Test Form

Subject _____
 Test 1 Date _____ Time _____ to _____

Configuration	Remarks	Max. Lifted Weight
1		
2		
3		
4		
5		

Retest 1

Configuration	Remarks	Max. Lifted Weight
1		
2		
3		
4		
5		

REFERENCES

1. Clarke, H. Harrison, "Relationship of Strength and Anthropometric Measures to Various Arm Strength Criteria," Research Quarterly, Vol 25:132-145, 1954.
2. Dempster, Wilfred T., Space Requirements of the Seated Operator, WADC TR 55-159 (AD 87892), Wright-Patterson Air Force Base, Ohio, July 1955.
3. Elbel, E. R., "Relationship Between Leg Strength, Leg Endurance, and Other Body Measurements," Journal of Applied Physiology, Vol 2:197-207, October 1949.
4. Emanuel, Irving, J. W. Chaffee, and John Wing, A Study of Human Weight-Lifting Capabilities for Loading Ammunition into the F-86H Aircraft, WADC TR 56-367 (AD 97206), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, August 1956.
5. Handbook of Instructions for Aircraft Ground Support Equipment Designers. AFSCM 80-6, Headquarters, Air Force Systems Command, Andrews Air Force Base, Washington, D.C.
6. Hertzberg, H. T. E., "Some Contributions of Applied Physical Anthropology to Human Engineering," Annals of the New York Academy of Sciences, Vol 63, No 4, 1955.
7. Hertzberg, H. T. E., G. S. Daniels, and Edmund Churchill, Anthropometry of Flying Personnel - 1950, WADC TR 52-321 (AD 47953), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, September 1954.
8. Hunsicker, Paul A., Arm Strength at Selected Degrees of Elbow Flexion, WADC TR 54-548 (AD 81792), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, August 1955.
9. Switzer, S. A., Weight-Lifting Capability of a Selected Sample of Human Males, MRL-TR 62-57 (AD 284054), Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, June 1962.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Antioch College, Yellow Springs, Ohio and Aerospace Medical Research Laboratories*, Wright- Patterson Air Force Base, Ohio		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP N/A	
3. REPORT TITLE A STUDY OF ONE-HANDED LIFTING			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final report			
5. AUTHOR(S) (Last name, first name, initial) McConville, John T. *Hertzberg, H. T. E.			
6. REPORT DATE May 1966		7a. TOTAL NO. OF PAGES 24	7b. NO. OF REFS 9
8a. CONTRACT OR GRANT NO. Prepared in part under AF 33(616)-6792		9a. ORIGINATOR'S REPORT NUMBER(S) AMRL-TR-66-17	
b. PROJECT NO. 7184		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c. Task No. 718408			
d.			
10. AVAILABILITY/LIMITATION NOTICES Distribution of this document is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Aerospace Medical Research Laboratories, Aerospace Medical Div., Air Force Systems Command, Wright-Patterson AFB, Ohio	
13. ABSTRACT This research study is intended to aid in establishing realistic criteria for size and weight of industrial packages. Size and weight, objective and subjective factors that potentially affect human weight-lifting, and proper approach to the design of industrial loads are discussed. Additional programs of investigation that would clarify other aspects of the problem are outlined. This study examined the interaction of two variables—weight and width—of one-handed, symmetrical boxes that a sample of 30 adult males were able to lift from the floor to a table 30 inches high. No carrying was involved. The subject sample was chosen to be a reasonable representation by height and weight of the U.S. Air Force population. All lifts were made with the preferred hand under "ideal" laboratory conditions. Box width was varied from 6 to 32 inches. The maximum weight of box that subjects were able to lift varied linearly, but inversely, with the width of the box. From this sample, the maximum weight that 95% of the population would be able to lift—but not necessarily carry—can be expressed by a linear equation: $Y = 60 - X$, where Y is the weight (in pounds) of the package to be lifted and X is the width (in inches). The numerical values of this formula provide a recommended upper limit on the design of industrial or military equipment which must be lifted under ideal conditions. If the expected conditions of use are less than ideal, or if carrying for appreciable distances is likely to be necessary, reasonable reductions in weight, or size, or both should be made by the manufacturer.			

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Weight-lifting Human muscle-strength capabilities Containers, size and weight Anthropometry						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.