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Consumer Product Portability as Related to Warranty Rulemaking

Joel J. Kramer
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Final Report

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U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*

Edward O. Vetter, *Under Secretary*

Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

ABSTRACT

The Federal Trade Commission (FTC) has the responsibility for determining what may be reasonably expected of consumers in their fulfillment of the terms of a consumer product warranty. Such determination necessitates, in part, providing an empirical basis for defining and quantifying various factors influencing product portability. This report discusses the problem of defining consumer product portability within the context of a consumer product return activity, offers a working definition of product portability within this context, summarizes and discusses the results and utility of previous portability related studies, and describes the results of a controlled experiment which more directly relates to the task of establishing maximum reasonable product weight for a consumer product return activity. Statistically significant differences in maximum reasonable product weight were found for the variables of method of product carry and sex of customer. No statistically significant differences were found for the variables of consumer age and product size (at least for the sizes chosen for study). Distributions of maximum reasonable weight for product return are presented and recommendations for warranty rulemaking are given.

Key words: Anthropometry; biomechanics; carrying; consumer product portability; ergonomics; human factors; lifting; manual materials handling; physiology; psychophysics; safety; warranty

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1. Introduction

The Magnuson-Moss Warranty-Federal Trade Commission Improvement Act of 1975 is aimed at improving the adequacy of consumer product warranty information, preventing deception in the sale of products, and improving competition in the market place. To this end, the Federal Trade Commission (FTC) is required to promulgate rules for the warranting of consumer products based upon substantive evidence. Included as a rule-making item is a statement of what consumers must do and expenses they must bear relative to full and limited product warranties in the event of a product defect or malfunction. Related to the requirements to be imposed upon consumers is the determination of what may be reasonably expected of consumers in their fulfillment of the terms of a warranty. Determining what a consumer may reasonably be expected to do necessitates, in part, considering and defining the portability of consumer products, since a product return requirement presumes that the product is, in fact, portable.

The objective of the National Bureau of Standards' (NBS) support to FTC was to contribute to the empirical basis for defining and quantifying the various factors influencing product portability. This objective was implemented in two phases. Phase I consisted of a review of the portability-related literature, and the preparation of a study design suitable for FTC's developing quantitative portability guidelines to be used in consumer product warranty rule-making. Phase II consisted of operational testing, data analysis, and formulating portability recommendations for FTC based upon testing results.

The first three sections of this report summarize the activities undertaken during Phase I and, as such, are essentially identical to the corresponding sections of an earlier report (Center for Consumer Product Technology Memorandum Report, April, 1976). Sections 4, 5 and 6 of this report detail the methodology, results, conclusions and recommendations of Phase II experimentation. These sections thus represent the principal difference between the earlier Phase I report and the present final report.

2. Problem Analysis

FTC's goal in the development of reasonable consumer product portability requirements, as related to product warranty provisions, is to ensure a reasonable degree of ease and safety for consumers in the manual handling of consumer products. A major problem in achieving this goal is the development of a meaningful definition and quantification of product portability.

Numerous variables are known to influence the ease and safety with which products can be manually handled. These variables may be classified into four major types: (1) human characteristics, e.g. motivation and strength; (2) task characteristics, e.g. method and duration of manual handling; (3) product characteristics, e.g. size, shape and weight; and (4) environmental characteristics, e.g. temperature and humidity. Furthermore, many of these variables are known to interact in complex ways, making generalizations concerning product portability a difficult undertaking requiring extensive multi-variate experimentation and analysis. Table 1 provides a listing of the variables most frequently cited in the portability literature and gives illustrative references.

Table 2 lists the variables chosen for study during Phase II experimentation. Comparing Tables 1 and 2, it is evident that many potentially significant variables were excluded from formal consideration in the present investigation. These exclusions were dictated for the following reasons: (1) project schedule and funding limitations did not permit systematic investigaton of all variables, (2) some variables appeared to have little practical utility in terms of FTC's rule-making responsibilities, and (3) the results of the Phase I literature review (highlighted in Section 3) suggested that several variables were of only marginal significance in the determination of overall level of portability.

2.1 Human Variables

Of all the human characteristics of potential significance in the determination of product portability, those of age and sex were felt to be of most potential utility for FTC's rule-making objectives. Information concerning the lifting and carrying capabilities of males and females of various ages would provide FTC with greater flexibility in the development of rules for warrantors and manufacturers whose products are used by identifiable sub-populations of consumers. Information concerning the makeup of product user populations is frequently available to manufacturers through detailed marketing analyses.

The significance of age and sex as determinants of product portability has been supported by numerous earlier studies (see Section 3). For example, it is widely accepted that, on the average, the lifting strengths of women (and their perceived estimates of "maximum reasonable weight of lift") are approximately 60 to 70 percent of those of men. Whether this relationship holds true within the context of a consumer product return activity had not previously been investigated. Previous research dealing with the possible effects of age on product portability are equivocal. Thrussel (96) has shown that a general decrease in overall work capacity occurs with increasing age, beginning at about age 28. However, Snook (85) found no significant differences between the maximum acceptable weights of lift and carry for young versus middle aged men. Snook suggests that older people may be able to lift and carry as much as younger people because they utilize more efficient manual handling techniques, e.g. by using slower rates of work, taking more frequent rests, etc. It should be noted that Snook's results were based upon a task in which subjects were allowed to

Table 1

Variables Known to Influence Portability

Variable Type	Common Variables	Reference
Human	Sex Age Body Measurements Strength Motivation Skill & Experience	(87) (85) (7) (83) (55) (15)
Task	<u>Lifting Action</u> Method Frequency Height: beginning & end <u>Carrying Action</u> Method Frequency/rate Distance/Duration	 (77) (52) (56) (28) (85) (18)
Product/Object	Size Weight Shape Weight distribution Location of handles	(104) (91) (57) (45) (50)
Environment	Temperature, humidity air movement Lighting, noise, chemical environment Discrete hazards (stairs, doorways, etc.)	(53) (45) (30)

Table 2
Variables Chosen for Consideration in Phase II

Variable Type	Variables Studied in Phase II
Human	Sex Age Body Measurements
Task	<u>LIFTING ACTION</u> Method <u>CARRYING ACTION</u> Method Distance
Product/Object	Size Weight
Environment	Discrete hazards

pace themselves, whereas Thrussell was concerned with tasks of a forced-pace nature. While it may be appropriate to assume that a consumer product return activity is essentially a self-paced activity, Snook's findings with respect to age needed further substantiation.

Many investigators have reported significant relationships between anthropometric characteristics (body dimensions) and the manual handling capacities of human subjects. Ayoub (7) has developed several psychophysical models capable of predicting with a fair degree of accuracy the lifting capacities of industrial workers based upon their anthropometric characteristics. While the merits of such predictive modeling techniques are many, they do not appear to be of any direct relevance to FTC's rulemaking responsibility, i.e. separate portability limitations for individual consumers based upon their anthropometric characteristics is certainly well beyond the scope of FTC's intentions.

For the purposes of Phase II experimentation, subjects were selected to be representative of the general consumer population in terms of height, weight, and various body dimensions. Thus, the results obtained should reflect the manual handling capacities of persons distributed over a wide range of human body types.

Related to the method of representative subject sampling, and the considerable amount of variability which is typically found among subjects in measurement of human characteristics and capacities, is the concept of population percentiles. Within the context of defining reasonable warranty portability requirements, the question becomes: what percentage of the consumer population should be accommodated by product warranty size and weight limitations? The answer to this question involves a trade-off between the desire to accommodate as large a percentage of the consumer population as possible and the necessity to maintain reasonable standards for engineering quality, while avoiding severe economic impacts. For example, setting warranty limitations on the sizes and weights of products based upon the judgments of the "average consumer" (50th percentile) could result in unreasonable requirements being imposed on the remaining 50% of the consumer population, while limitations based upon the "95th percentile consumer" could result in undesirable engineering and economic impacts. While military systems and equipment are generally designed to be acceptable to at least 90% of the military population (46, 70), it is difficult to ascertain whether this value would provide a satisfactory trade-off for the definition of product-warranty portability requirements. Hence, for the purposes of this report, 95th, 90th, 75th, and 50th percentile values have been provided wherever possible to ensure adequate information for anticipated trade-off evaluations.

Consumer strength, motivation, skill and experience were not proposed for study in Phase II. As was the case for consumer anthropometric characteristics, the physical strength characteristics of individual consumers did not seem germane to FTC's informational needs. Furthermore, physical strength is more related to the determination of maximum <u>capability</u>

than to judgments of maximum reasonable. Clearly, consumers capable of lifting a product weighing 45.4 kg (100 lbs) with a maximum peak physical exertion would probably not judge the requirement for returning such a product to a retailer as being reasonable. The return activity involves components including both strength and endurance, two aspects which tend to be mutually exclusive in a given individual.

Description and evaluation of consumer motivational factors were felt to be beyond the scope of the present investigation, requiring extensive consumer surveys and extended operational testing. Furthermore, it would not have been possible to study all of the potentially significant motivational factors (and combinations of factors) related to the willingness of consumers to return products. For example, given the option of paying a service call charge for product pickup and delivery, what would consumers decide to do? How might this cost alter consumers' judgments of portability? To what lengths would consumers go to avoid the payment of service charges? Certainly many consumers would prefer to seek the assistance of friends or relatives or employ readily available external aids in the return of unusually heavy or bulky products. Obviously, such economic and motivational factors contribute to the difficulty involved in defining and quantifying consumer product portability.

Skill and experience in manual handling were judged to be of only minor significance in the determination of warranty portability requirements, since consumers generally receive little or no specific instruction in the use of proper lifting and carrying techniques.

2.2 Task Variables

Numerous manual handling task characteristics are known to influence product/object portability. Perhaps the most important of these characteristics are: (1) the frequency with which the task is performed, (2) the rate at which the task is performed, (3) the method of lift and carry used in completing the task, (4) the height of lift involved, and (5) the distance of carry involved.

Since the product return activity is presumably a relatively infrequent event in the life of a consumer and the rate at which the activity is accomplished is entirely at the discretion of the consumer, these variables were felt to be irrelevant to the determination of warranty portability requirements. The method of lift and carry used in the handling of a product, however, was felt to be of possible significance, as certain product design configurations may influence the method by which a product is handled. For example, products having a top-mounted, single handle or recessed hand hold may be lifted and carried more easily by means of a "one-handed" method, while products lacking a top-mounted handle and/or of moderately bulky dimensions may be lifted and carried more easily by means of a "two-handed" method. For this reason, one-handed vs. two-handed methods of lift and carry were included in Phase II experimentation. While the use of other manual handling techniques, e.g. use of shoulders, backs, external aids, etc. are undoubtedly employed by consumers in the movement of bulky products, these methods were judged to occur far less frequently in actual product return activities.

The distances of carry and heights of lift associated with product return activities probably vary considerably from one situation to another. Since data concerning the influence of these variables on product portability was felt to be of little practical value for FTC purposes, these variables were not selected for detailed investigation. It was necessary, however, to select specific values for these variables to be used during Phase II experimentation. The distance of carry selected was 122m (400 ft), while the height of lift at the beginning of the experimental task was 43.2 cm (17 in). The simulated product had to be lowered to floor level at the end of the experimental task. The rationale behind the selection of these values is found in Section 4.5.

2.3 Product Variables

Consumer products may be characterized by a wide variety of physical attributes relevant to the determination of ease of manual handling. These attributes include weight, shape, size, distribution of internal weight load and number and type of built-in handling aids (e.g. wheels, handles, straps, etc.). As a result of time and funding constraints, detailed analyses of each of these attributes could not be undertaken in the present investigation. More specifically, this study was aimed primarily at consumer products of a relatively compact size and shape, such as television sets, air conditioners, sewing machines, vacuum cleaners, and the like.

Since weight and size are the attributes most frequently cited in the literature as being of prime importance in the determination of ease of manual handling, these attributes were selected for more detailed investigation during Phase II experimentation. Product weight, or more properly "perceived maximum reasonable weight" was actually the dependent variable of Phase II, while product size was an independent variable. The rationale behind the selection of weight as the dependent variable and the selection of two specific sizes are found in Section 4.3.

2.4 Environmental Variables

Under the assumption that most consumers return products under relatively favorable environmental conditions, it was felt that environmental variables (stressors) play comparatively minor roles in the determination of ease of manual handling. Hence, all Phase II experimentation was conducted under relatively ideal environmental conditions: level, non-slippery walking surfaces; cool, still, dry air; adequate illumination levels, etc. In an attempt to maintain realism with respect to common discrete hazards associated with manual handling activities, however, impediments were incorporated into the Phase II experimental task. These included a flight of stairs (with landing) and a doorway (with unopened door).

2.5 Definition of Consumer Product Portability

In view of the number and complexity of variables known to influence product portability, it was extremely difficult to arrive at a completely satisfactory quantitative definition of consumer product portability. However, based upon the problem analysis presented in the preceding sections and a review of the pertinent literature (Section 3.0), the following non-quantitative definition was derived for the purposes of the present report:

> "A consumer product is portable within the context of a typical warranty product return activity if it can be lifted and carried by most consumers a distance of at least one city block without excessive strain or exhaustion and without the use of external aids."

The selection of a specific percentage value associated with most consumers involves a trade-off between consumer interests and manufacturer interests. That is, a value judgment is required concerning the percentage of consumers which should be accommodated by warranty portability legislation, the percentage of manufacturers which should be accommodated by warranty portability legislation, and the percentage of manufacturers which should be required to alter their existing warranty policies. Nevertheless, the most commonly accepted values found today in the literature of the human engineering profession are in the range of 90 to 100 percent.

Variables which may significantly alter product warranty weight and size limitations in accordance with the above definition of consumer product portability are (1) the sex of the consumer, (2) the age of the consumer, (3) the method by which the product is handled (which in turn is influenced by the location of product handles), and (4) the size of the product. These variables were studied in Phase II of the present investigation.

3. Literature Review

3.1 Approach

Some 600 to 700 references of possible relevance were identified during the Phase I literature search. These references were obtained through a variety of sources, including (1) computerized searches of American Psychological Association abstracts, National Technical Information Service abstracts, Defense Documentation Center abstracts, and Consumer Product Safety Commission abstracts; (2) manual searches of Ergonomic Abstracts and many other technical journals; and (3) personal communications with several of the leading authorities in the field of portability including:

(1) Dr. M. M. Ayoub
Professor of Industrial Engineering and Biomechanical Engineering
Texas Technical University
Lubbock, Texas

(2) Dr. Donald B. Chaffin
Professor of Industrial and Operations Engineering
University of Michigan
Ann Arbor, Michigan

(3) Dr. Colin G. Drury
Assistant Professor of Industrial Engineering
State University of New York
Buffalo, New York

(4) Dr. Stover H. Snook
Director, Ergonomics Research
Liberty Mutual Research Center
Hopkinton, Massachusetts

As a result of project schedule and funding constraints it was not possible to review all of the reference articles identified. Therefore, priority was given to reviewing only those articles which were (1) written by recognized authorities in the field, (2) non-medical in nature, and (3) provided specific, quantitative data. In this manner, 104 articles were selected and reviewed. The complete references for these articles are listed alphabetically in the bibliography.

3.2 Findings

Of the 104 articles reviewed, none dealt specifically with the problem of consumer product portability as related to a product return activity. The great majority of the articles were oriented toward industrial manual materials handling. More specifically, these studies emphasized object portability requirements from the viewpoint of young, healthy, male, industrial workers who repeatedly handle heavy objects as part of their day-to-day job requirements. While the latter situation is considerably different than that of the typical consumer involved in the return of a defective product, the results of approximately 30 of the articles reviewed were thought to be of some general relevance to the determination of product portability guidelines. The results of these studies are highlighted briefly below, while specific details concerning the methodological approaches used in these studies are provided in Appendix A.

It was evident from the studies reviewed that a great number of empirical approaches have been utilized in the study of product/object portability. These approaches have generally been of three basic types: medical, physiological, and behavioral.

Medical studies tend to emphasize the type, severity and frequency of manual handling injuries, and as such are primarily safety oriented. The usefulness of such studies for defining warranty portability requirements is extremely limited, however, primarily as a result of the inadequate diagnostic and statistical techniques characteristic of these studies (45). While the size, shape, and weight of products/objects are identified in these studies as the the attributes of greatest significance in the determination of manual handling injuries, recommendations for reducing these injuries vary considerably and place a strong emphasis upon improved worker selection and training techniques. In view of their inconclusive results and poor statistical controls, medically oriented studies were excluded from further consideration in the present literature review.

Physiological studies tend to emphasize the physiologically optimum conditions for manual handling, and thus are primarily efficiency oriented. The results of these studies are generally stated in terms of amount of physiological stress (circulatory, metabolic, biomechanical, or neuromuscular) per unit of manual work accomplished. Studies of this type usually employ long duration, repetitive, manual handling tasks, which allow sufficient time for physiological indices to stabilize. Problems associated with this approach include: (1) the lack of agreement amoung authorities on what constitutes "Maximum acceptable physiological stress" and (2) the complexity of procedures and techniques employed in the measurement of physiological stress.

Behavioral (psychophysical) studies tend to emphasize the preferences and judgments of people regarding the reasonableness of manual handling tasks. Measurements are made of what people are willing and capable of doing in the movement of heavy objects. Advantages of this approach include simple procedural techniques and high reliability. The main disadvantage is that they are based upon highly subjective data and hence appear to have low face validity.

In reviewing the portability literature, emphasis was placed on those studies which provided specific, quantitive data of possible relevance to the development of product warranty portability requirements. To simplify inter-study comparisons, the results of these studies are presented in tabular form (Tables 3, 4 and 5*) and categorized in accordance with the portability variables identified in the preceding sections (see Table 2). In view of the diversity of experimental approaches used and the possibility that these approaches may lead to substantially different conclusions, study results were also categorized in terms of "study approach." The results of studies for which appropriate percentage values could not be determined have generally been assumed to be acceptable to 90 percent of the population studied, as this is a commonly accepted percentage value for product design for military and some industrial users (46, 70). In some cases the results have been assumed appropriate for 50 percent of the population, as the authors have made reference to the "average man" or some similar statement.

Table 3 summarizes the effects of sex and task characteristics (method and frequency) on maximum acceptable weights of lift and carry. The "Two-handed" method refers to objects grasped with both hands in front of the body, while the "One-handed" method refers to objects grasped using a handle centrally located on top of the object and held at the side of the body. "Repeated lifts" implies insufficient time between "single lifts" for fatigue effects to dissipate.

Based upon the data shown in Table 3, the following observations appear to be worth noting:

(1) Mean maximum acceptable weights of lift and carry for women tend to cluster around 50 to 70 percent of the weights for men. These values are in good agreement with the value of 60 percent which is generally recognized by authorities in the field of portability (45, 87).

*Further details concerning the studies referenced in Tables 3, 4, and 5 are presented in Appendix A. The order of presentation of the Appendix A studies is identical to that of the table references.

Table 3
Summary of Research Related to Maximum Acceptable Weight (kg) of Lift and Carry* for Males and Females

Task	Study Approach	Percentage of Population to Which Acceptable						Reference
		Male			Female			
		95%	90%	50%	95%	90%	50%	
Two-handed Single Lift	Behavioral	35	39	52	–	–	–	(37)
		10	13	23	4	5	13	(21)
	Physiological	–	–	[67]	–	–	[34]	(83)
	Unspecified	–	[30]	–	–	–	–	(70)
		–	[46-59]	–	–	–	–	(80)
Two-handed Repeated Lifts	Behavioral	–	–	[24]	–	–	[13]	(56)
		–	16	24	–	9	15	(7)
		16	18	25	–	–	–	(85)
		–	–	–	5	6	10	(87)
		22	24	30	–	–	–	(88)
		15	17	25	–	–	–	(91)
		–	33	42	–	–	–	(95)
	Physiological	–	[30]	–	–	[19]	–	(6)
		–	–	[48]	–	–	[23]	(83)
	Unspecified	–	12-19	–	–	8-11	–	(72)
		–	–	[34]	–	–	–	(104)
One-handed Single Lift	Behavioral	19	22	30	–	–	–	(67)
Two-handed Carry	Behavioral	18	20	27	–	–	–	(85)
		–	–	–	5	6	10	(87)
		17	19	27	–	–	–	(91)
	Physiological	–	[30]	–	–	[24]	–	(20)
		–	[15]	–	–	–	–	(53)
		–	[18]	–	–	–	–	(57)
		–	[15-28]	–	–	–	–	(74)
	Unspecified	–	–	–	21	22	23	(9)
		–	[16]	–	–	–	–	(22)
		–	[18]	–	–	[12]	–	(42)
		–	[40]	–	–	[15-20]	–	(51)
		–	[16]	–	–	–	–	(70)
One-handed Carry	Physiological	–	[14]	–	–	[12]	–	(20)
	Unspecified	–	[16]	–	–	–	–	(29)

*Maximum acceptable weights of lift and carry for compact objects. Lifting is from floor to table top height. Brackets indicate assumed percentile values.

(2) In 25 of 31 studies, maximum acceptable weights of lift and carry for 90 percent of the male (industrial worker) population were found to be between 13 and 30 kg (29 and 65 lbs). For women, 13 of 14 studies showed these weights to be between 6 and 24 kg (13 and 52 lbs).

(3) Maximum acceptable weights for single lift tend to be considerably greater than those for repeated lift.

(4) Maximum acceptable weights for two-handed repeated lift tend to be of similar magnitude to those for two-handed carry.

(5) Maximum acceptable weights for two-handed lift tend to be slightly higher than those for one-handed lift and carry.

Table 4 summarizes the effects of age on maximum acceptable weights of lift and carry for males and females. These data suggest that, with the possible exception of persons under 20 or over 50 years, age generally is not an important variable in the determination of object portability. However, it should be noted that in most of these studies subjects were required to maintain a constant rate of lift or carry, a situation probably not found in most consumer product return activities. Snook (85) found the age of male industrial workers to be unrelated to maximum acceptable weight of lift in an unpaced task situation.

Table 5 summarizes the effects of object size (widths) on maximum acceptable weights of lift and carry for 50 percent of the male (industrial worker) population. Two study types are represented: (1) those which suggest or imply a maximum acceptable size for lift or carry (70, 22 and 47), and (2) those which suggest a compensatory reduction in weight for increases in object size (66, 5, 67 and 98). The former suggest maximum acceptable objects sizes of 38, 51, 63.5 cm (15, 20 and 25 in), respectively, while the latter suggest weight reductions of .45 - .91 kg (1 - 2 lbs) for each additional 2.54 cm (1 in) of object size. No studies were found which provided useful information on acceptable object shapes.

3.3 Summary and Conclusions

In reviewing the literature no references aimed directly at the quantification of consumer product portability requirements were found. Most of the studies reviewed were concerned with portability requirements for healthy, male, industrial workers in the context of performing their jobs.

Because of the complexity of the variables involved, the variety of experimental approaches used, and the unrepresentativeness of the subject samples studied, no definitive recommendations concerning absolute product weight and size limitations for consumer product return activities can be made based upon the Phase I literature review. While maximum acceptable weights of lift and carry for 90% of the industrial worker population (13-30 kg for males; 6-24 kg for females) may be considered suggestive of

Table 4
Summary of Research Related to Maximum Acceptable Weights (kg) of Lift and Carry for 50% of Male and Female Population by Age Group*

Task	Study Approach	Male				Female				Reference
		16-20	21-35	36-50	51-65	16-20	21-35	36-50	51-65	
Two-handed Single Lift	Physiological	54	66	69	65	31	35	33	27	(83)
Two-handed Repeated Lifts	Behavioral	-	23	26	26	-	-	-	-	(85)
	Physiological	29	31-32	32	30	19	(19-20)	(19-20)	16	(6)
		39	47	49	47	21	24	23	20	(83)
	Unspecified	15-17	19	16	12	9-11	11	10	8	(72)
Two-handed Carry	Behavioral	-	26	28	28	-	-	-	-	(85)
	Unspecified	11-16	18	18	18	7-11	12	12	12	(42)
		16-20	40	40	40	12-15	12-15	15-20	15-20	(51)

*Lifting is from floor to table top height for compact objects. Parentheses indicate uncertainty as to percentage of population and are probably the 90% male and female values.

Table 5
Summary of Research Concerning the Effects of Size Upon Maximum Acceptable Weight (kg) of Lift and Carry*

Method of Lift/Carry	Study Approach	Width of Product/Object				Reference
		25 cm	38 cm	51 cm	64 cm	
Two-handed single lifts	Behavioral	Approximately 2.3 kg for each additional 13 cm of width - base value not cited				(66)
	Unspecified	30	30	-	-	(70)
Two-handed repeated lifts	Behavioral	32	30	27	25	(5)
One-handed single lift	Behavioral	31	29	27	25	(67)
	Unspecified	-	-	16	16	(22)
		-	-	-	9	(47)
Two-handed Carry	Behavioral/ Biomechanical	2.3 - 4.6 kg for each additional 13 cm of width - base value not cited				(98)

*Table entries represent maximum acceptable weights for 50% of the male populations studied. Lifting is from floor to table top height. Carrying involves holding the object with two hands in front of the body.

appropriate product weight limitations, these values can not be assumed adequate for warranty rule-making purposes. The development of such rules requires controlled experimentation with subjects more representative of the consumer population, performing tasks more closely related to those actually involved in consumer product return activities. Such study was undertaken during Phase II of the present investigation.

Some general observations concerning relative limits for maximum acceptable weights of lift and carry did emerge from the literature review. Specifically, maximum acceptable weights of lift and carry are (1) less for women (60%) than for men, (2) less for persons under 20 or over 55 years of age, (3) less for objects designed to be carried with one hand than with two, and (4) likely to be reduced by 2-5 kg (4.4-11.0 lbs) for each additional 13 cm (5 in) of product/object width within the range of 25 to 65 cm. The utility of these observations is largely dependent on the specific nature of the portability rule contemplated by FTC. Should a multi-variate approach to the ruling be undertaken (e.g. by setting different weight and size limitations for products returned by predominantly men or women), these observations may be helpful. If no such multivariate approach is attempted, they may serve little directly useful purpose.

4. Experimental Approach

Numerous approaches were available to NBS researchers during Phase II experimentation. These approaches included: (1) the analysis of manual materials handling injury data, (2) the measurement of physiological stress and strain, (3) the measurement of human energy expenditure, and (4) the measurement of subjectively perceived stress and strain utilizing psychophysical/behavioral techniques.

An analysis of manual materials handling injury data was not undertaken because Herrin, Chaffin, et al. (45) have indicated that the diagnostic categories associated with these data are often so non-specific that the resulting injury and illness statistics are totally inadequate. Furthermore, data from statistical "control groups" are unavailable. Measurements of physiological stress and strain and human energy expenditure were also not undertaken as the same authors have noted a lack of agreement between authorities with respect to the criteria to be used in the evaluation of these physiological and energy expenditure measures. These same problems were noted in the Phase I literature review.

Numerous studies have demonstrated that subjectively perceived stress and strain is positively correlated with physiological stress and strain (11, 12, 14 and 35). This correlation is in the range of .70 to .85, and these studies have typically been aimed at demonstrating that the perception of muscular effort and force obeys the psychophysical power law (i.e., the perceived amount of muscular effort or force is directly related to the amount of weight lifted by means of a mathematical power function). Several of these authorities have noted that with adequate repetition and experimental control, psychophysical techniques may be just as reliable as their corresponding physiological techniques (35, 62 and 85). Numerous authorities have utilized psychophysical techniques for the specific purpose of establishing weight and size limitations for safe manual handling (7, 20, 32, 33, 85, 86, 88, 89, 90, 91). The methodological and procedural simplicity of the psychophysical/behavioral approach coupled with the merits of previous research utilizing this approach, provided the rationale for selecting this approach for Phase II experimentation.

4.1 Method

The approach used was a variation of the psychophysical method of "magnitude production." In magnitude production, the experimenter states or indicates a series of sensory magnitudes, and the subject attempts to adjust a stimulus to produce them. This experiment did not deal with a series of weight magnitudes, but rather with only one -- the maximum reasonable weight of lift and carry. More specifically, subjects were required to adjust the weight of simulated products to final values which they believed to be the maximum reasonable weight that they would be willing to handle in a real-life, product-return activity. Reasonable was defined as meaning without excessive strain or exhaustion. The adjustment was accomplished by adding and/or removing lead shot to/from the simulated products.

4.2 Subjects

A total of 96 subjects participated in the Phase II experimentation as follows:

		Number of Subjects		
	Age	16 - 29	30 - 44	45 - 60+
Sex	Male	16	16	16
	Female	16	16	16

Subjects were NBS employees who volunteered to participate and were selected to be representative of the U.S. population in terms of age, sex, height and weight based on 1970 Bureau of Census and 1960-62 HEW National Health Survey data (94). Each subject was required to attend two, 30-minute experimental sessions, each session occurring on a different day.

4.3 Apparatus

Two simulated consumer products were used, one being a 38.1 cm (15 in) cubical wooden box, the other a 30.5 cm (12 in) cubical wooden box. These box sizes were chosen to reflect acceptable and unacceptable sizes for one-handed and two-handed lifting and carrying activities based upon related anthropometric data for the general population (25). The sizes were also chosen to be representative of many of the compact consumer products found in the Sears and J. C. Penney 1975 spring and summer catalogs, i.e., portable television sets, sewing machines and microwave ovens. Available catalog models of these products were found to range in volume from .016 - .18 m^3 (.56 - 6.3 ft^3). The volumes of the simulated consumer products chosen for experimentation were within this range, and at least one model of each product had dimensions approximately equivalent (within $\pm$ 5 cm) to one of the chosen sizes. Project schedule and funding constraints did not permit more systematic and extensive investigation of the size variable or, for that matter, product load characteristics (e.g., top-heavy and bottom-heavy products). However, the larger simulated product was nearly twice the volume of the smaller simulated product and reflected a size which was judged by most participants as being awkward.

Smaller wooden inner boxes were located at the physical centers of the two simulated products to enable the addition and/or removal of lead shot to/from the products, yet maintaining the center of gravity at or near the physical centers of each box. False bottoms below the inner boxes were present to enable setting the initial weight of the products in a manner such that subjects could not use visual clues to bias their judgments. A hinged top with a central handle (for one-handed lifting and carrying task) was located on each box. The simulated products are shown in Figure 1.

4.4 Experimental Design

A 3x2x2x2 repeated measures, mixed-model design was employed. The major independent variables were: (1) Age of Consumers (3 levels: 16-29, 30-44, 45-60+, (2) Sex of Consumers (2 levels: male, female), (3) Method of Carry (2 levels: one-handed, with handle; two-handed, without handle) and (4) Size of Product (2 levels; 38.1 cm cube; 30.5 cm cube). The between-subjects variables were Age and Sex, while the within-subjects variables were Method and Size. The dependent variable was the subject's judgment of maximum reasonable weight. The design did not include a check on repeatability because pilot study results showed a within-subject, by condition standard deviation of only $\pm$ 2.3 kg (5 lbs). For the purposes of this study, this level of variability was thought to be acceptable, and resulted in not having to take repeated measurements within subjects for each condition.

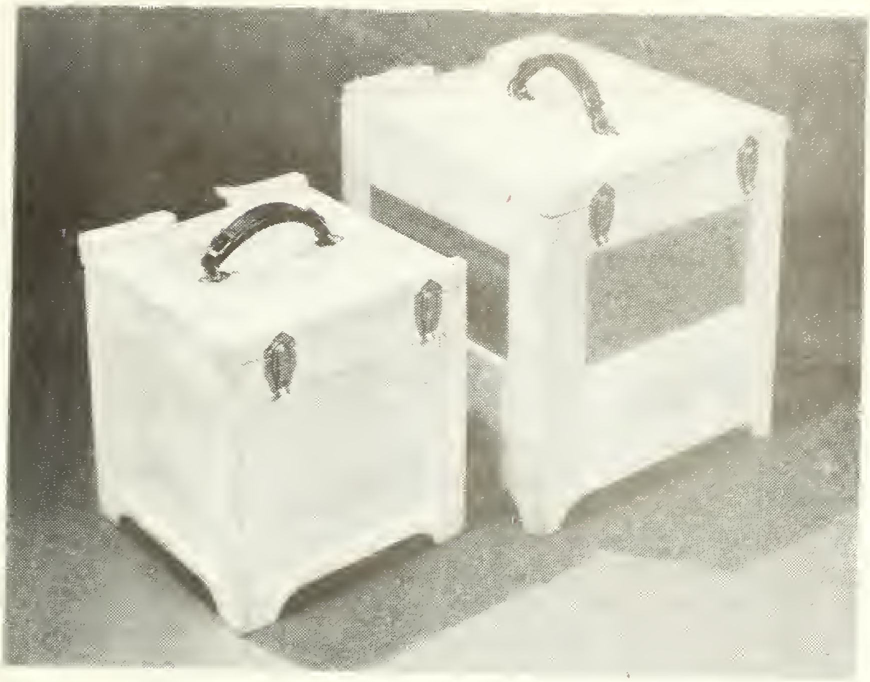

Figure 1: Simulated Products

4.5 Procedures

Each subject was required to adjust the weight of each of the two simulated consumer products under both one and two-handed handling conditions to a value which he or she believed to be the maximum reasonable weight which he or she would be willing to carry in a real-life product return situation. "Reasonable" was defined for subjects as meaning without excessive strain or exhaustion. This weight adjustment was accomplished through the addition and/or removal of lead shot from the simulated products. The initial (pre-adjustment) weights of the simulated products were different for each of the four within-subjects treatment conditions, and for each of two same-day trials. These weights were either 10% or 40% of the subject's ideal body weight (based on height and body frame) and were selected in an effort to force subjects to arrive at their judgments of maximum reasonable weight by both adding (10% initial weight) and subtracting (40% initial weight) to/from the simulated products. The results of a pilot study indicated that the 10% value was generally perceived as being "too light", while the 40% value was generally perceived as being "too heavy."

The order of presentation of the various within-subjects treatment conditions was counterbalanced across subjects with the following restrictions: (a) subjects experienced only one level of size on any given day, (b) subjects never experienced two successive trials using the same carrying method, and (c) subjects never experienced two successive trials using the same initial simulated product weight. Table 6 depicts the counterbalanced condition orders and the number of subjects assigned to each of these conditions.

Upon completion of each of the four weight adjustment tasks, each subject was required to lift and carry the simulated product through a simulated product return activity to verify his/her judgment of maximum reasonable weight. This activity included carrying the simulated product a distance approximating one city block (122 m (400 ft)), through a closed door, and up a flight of stairs. This distance was selected to represent a worst-case condition distance-wise. Due to project schedule and funding constraints it was not possible to formally survey the actual distances consumers carry products in return activities. Furthermore, considering the many consumers who return products to facilities located in shopping centers, the distance selected was thought to be representative of the carrying distances commonly encountered when close-in parking is not available.

Subjects were permitted to stop and rest as often as desired during the carrying activity and were allowed a single opportunity at about the half-way point for one final weight adjustment to the simulated product. Subjects were allowed to walk at their own preferred pace. Subjects were given instructions concerning the experiment via a standard portable tape-recorder. The instructions given are presented in Appendix B.

Table 6. Counterbalancing of Treatment Conditions

	Trial #	Condition Order #1 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size	Trial #	Condition Order #2 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size	Trial #	Condition Order #3 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size	Trial #	Condition Order #4 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size
Day 1	1	1	10%	30.5cm	1	1	40%	30.5cm	1	2	10%	30.5cm	1	2	40%	30.5cm
	2	2	40%	30.5cm	2	2	10%	30.5cm	2	1	40%	30.5cm	2	1	10%	30.5cm
Day 2	3	1	10%	38.1cm	3	1	40%	38.1cm	3	2	10%	38.1cm	3	2	40%	38.1cm
	4	2	40%	38.1cm	4	2	10%	38.1cm	4	1	40%	38.1cm	4	1	10%	38.1cm

	Trial #	Condition Order #5 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size	Trial #	Condition Order #6 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size	Trial #	Condition order #7 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size	Trial #	Condition Order #8 12 total subjects; 2 subjects from each age/sex treatment # Hands	Init. Wt.	Size
Day 1	1	1	10%	38.1cm	1	1	40%	38.1cm	1	2	10%	38.1cm	1	2	40%	38.1cm
	2	2	40%	38.1cm	2	2	10%	38.1cm	2	1	40%	38.1cm	2	1	10%	38.1cm
Day 2	3	1	10%	30.5cm	3	1	40%	30.5cm	3	2	10%	30.5cm	3	2	40%	30.5cm
	4	2	40%	30.5cm	4	2	10%	30.5cm	4	1	40%	30.5cm	4	1	10%	30.5cm

Upon completion of each of the four carrying activities, subjects were asked to fill out a five-point semantic differential questionnaire to further verify the maximum reasonable weight selected. If, at this time, a subject indicated that the weight carried was unreasonably too heavy or too light, the subject was asked to return at a later date to repeat the experimental task. A copy of the semantic differential questionnaire used is presented in Appendix D.

4.6 Safety and Ethical Considerations

The Phase II experimentation plans discussed in the preceding sections were submitted to the NBS Human Research Ethics Committee for review. The Director of NBS approved conducting the experiment on December 9, 1975. The major safety concerns raised during the approval process were (1) the maximum weight a subject would be allowed to experience in the study, and (2) determining the medical history of subject volunteers.

Based upon the opinion of the NBS Medical Officer, to ensure safety of subjects and experimenters, the maximum weight a subject was allowed to experience during the course of Phase II experimentation was 50% of his ideal body weight (based upon height and body frame) or 34 kg (75 lbs), whichever was less. If any subject reached this limit during the course of the weight adjustment process, he or she was to be terminated before beginning the verification carrying activity. The impact of this safety limitation on the experimental procedures employed was negligible, however, as no subjects attempted to make a weight adjustment at or in excess of the safety limits set. It should be noted that subjects had no knowledge of these restrictions at any time during their participation.

NBS experimenters were required to ascertain the medical history of each volunteer subject. Volunteers indicating any of the following ailments were not permitted to participate in the Phase II experimentation: (1) dizziness, fainting spells or loss of balance, (2) hernias, (3) heart trouble, (4) back trouble, (5) recent operations or (6) "any other medical problems which the volunteer felt might disqualify him or her from participating in the study." The experimenters were also required to obtain approval from the NBS Medical Officer in the event of the slightest doubt concerning the physical soundness of a subject. Thus, all generalizations based upon the results of the present investigation must be limited to essentially healthy persons.

5. Results

As described in Section 2, two fundamentally different product characteristics are of prime importance in the determination of product portability for consumer product return activities, product weight and product size. As these characteristics are qualitatively dissimilar, the results concerning each are discussed separately below.

5.1 Product Weight

The dependent variable of the experiment was maximum reasonable weight of lift and carry, where subjects were free to adjust the weight of the simulated products to their subjective limit of reasonableness. Upon completion of each experimental task, subjects were given a final opportunity to indicate their satisfaction with the weight they had handled. Their opinion was obtained through the use of a forced-choice semantic differential-type questionnaire (See Appendix D). On this questionnaire "slightly" less or more than the maximum reasonable weight was defined for the subjects as being within 2.3 kg (5 lbs) of what they thought might be their actual maximum reasonable weight. While on most (60%) of the 384 total experimental trials the subjects indicated that the weight they had carried was maximum reasonable, some trials did in fact result in opinions of "slightly less than maximum reasonable" (21%) or "slightly more than maximum reasonable" (19%). Only 4 trials resulted in opinions of either "unreasonable-too light" or "unreasonable-too heavy," and the subjects offering these opinions were asked to return at a later date to repeat the trials. After repeating these trials, each subject changed his/her opinion to "maximum reasonable weight" with a corresponding change in the weight actually selected.

In an effort to improve the validity of subjects' selected weight values, all weights identified as being "slightly less than maximum reasonable" were increased in magnitude by 10% for the purpose of statistical analysis, while all weights identified as "slightly more than maximum reasonable" were decreased by 10%. This 10% correction factor was selected based upon the results of an earlier pilot study, and typically resulted in weight adjustments of between .9 and 2.3 kg (2 and 5 lbs) for 9 and 23 kg (20 and 50 lb) original product weights, respectively. Product weights identified as being "the maximum reasonable weight" were left unaltered. It should be noted that the net effect of applying this correction factor to mean maximum reasonable weight values is minor, as an approximately equal number of subjects rated their weights as either "slightly less than maximum reasonable" or "slightly more than maximum reasonable."

Before conducting statistical analyses of a more sophisticated nature, elementary descriptive statistics were compiled to characterize the frequency distribution of "maximum reasonable weight" for each treatment condition. These statistics included the arithmetic mean ($\bar{X}$), the standard deviation (s), the moment coefficient of kurtosis (m_k)

and the moment coefficient of skewness (m_s). These statistics are presented in Table 7 along with some descriptive characteristics concerning the 96 subjects who participated in the study. Appendix E reviews the interpretation of these basic descriptive statistics.

A cursory examination of Table 7 reveals considerable information relevant to maximum reasonable product weight for product return. Thus, a comparison of the 24 treatment means suggests that the sex of the consumer and the method of product carry play far more important roles in the determination of maximum reasonable product weights than do the age of the consumer and the size - within the range of (30.5-38.1 cm^3) ((12-15 $in)^3$). These cursory observations are made even more apparent when the means of the appropriate treatment cells are "pooled" together, as in Table 8.

Of more theoretical than practical significance are the intercell differences between s, m_s, m_k statistics. These values provide some insight into to the <u>shapes</u> of the various treatment frequency distributions of product weight. Briefly, these values indicate that there is less variability among females (mean s = 3.6 kg) than among males (mean s = 5.1 kg) in judgments of maximum reasonable weight, probably as a result of the more marked positive skewness in the female distributions (mean m_s = 0.5) than in the male distributions (mean m_s = 0.1). Both female and male distributions are characterized by roughly equivalent amounts of kurtosis (mean m_k = 2.7), both distributions being slightly platykurtic. In other words, the male frequency distributions may be considered more nearly normal in nature than the female distributions, primarily with respect to the amount of skewness present. This conclusion was further substantiated by the results of a series of (χ^2) "goodness-of-fit" tests, which revealed the male distributions to be statistically normal, while the female distributions differed significantly from normal.

Sample frequency distributions more accurately reflect their corresponding population distributions the greater the number of sample observations. One way of increasing the number of sample observations is to "pool" the observations of those treatment conditions which can be shown to be statistically nonsignificantly different from each other (i.e. the observations can be thought of as coming from identical frequency distributions). Clearly, in the present investigation two of the treatment conditions studied appear to meet this criterion: consumer <u>age</u> and product <u>size</u>. Before proceeding with the pooling of the age and size distributions, however, it is necessary to demonstrate statistically that these distributions, do not, in fact, differ from each other significantly. To do this, a statistical technique known as Analysis of Variance (ANOVA) was required (see Appendix F). One of the assumptions underlying ANOVA is that treatment standard deviations be homogenous. Since male and female standard deviations are not homogeneous, it is clear that separate ANOVA's are required for the male and female data. The results of these ANOVA's are presented in Tables 9 and 10.

Table 7. Descriptive Statistics for "Maximum Reasonable Weight" for each of 24 Experimental Treatments and Subject Characteristics.

Sex	Box Size:	30.5 cm (12 in) cubical box		38.1 cm (15 in) cubical box		SUBJECT CHARACTERISTICS			
	Carry Method:	One-Hand kg (lb)	Two-Hand kg (lb)	One-Hand kg (lb)	Two-Hand kg (lb)	Number	Age in Years	Weight in kgs (lbs)	Height in cms (in)
	Age Group:								
Male	16 - 29	$\bar{X}$ = 18.2 (40.2) s = 5.2 (11.4) m_k = 2.5 m_s = 0.2	$\bar{X}$ = 23.6 (52.1) s = 5.6 (12.4) m_k = 2.1 m_s = 0.0	$\bar{X}$ = 18.4 (40.5) s = 4.4 (9.7) m_k = 2.5 m_s = 0.4	$\bar{X}$ = 22.5 (49.7) s = 4.7 (10.3) m_k = 2.4 m_s = 0.0	n = 16	$\bar{X}$ = 25.7 s = 2.8	$\bar{X}$ = 73.6 (162.3) s = 13.3 (29.4)	$\bar{X}$ = 176.5 (69.5) s = 7.9 (3.1)
Male	30 - 44	$\bar{X}$ = 18.4 (40.5) s = 6.2 (13.7) m_k = 1.8 m_s = 0.4	$\bar{X}$ = 21.5 (47.5) s = 6.0 (13.3) m_k = 2.6 m_s = 0.4	$\bar{X}$ = 18.5 (40.7) s = 4.9 (10.8) m_k = 2.2 m_s = 0.5	$\bar{X}$ = 19.7 (43.4) s = 5.8 (12.8) m_k = 3.2 m_s = 0.6	n = 16	$\bar{X}$ = 37.1 s = 5.1	$\bar{X}$ = 75.0 (165.3) s = 10.0 (22.1)	$\bar{X}$ = 177.3 (69.8) s = 6.1 (2.4)
Male	45 - 60+	$\bar{X}$ = 19.7 (43.5) s = 5.1 (11.2) m_k = 1.9 m_s = 0.1	$\bar{X}$ = 22.7 (50.1) s = 4.9 (10.7) m_k = 2.8 m_s = 0.3	$\bar{X}$ = 19.3 (42.6) s = 3.8 (8.3) m_k = 3.4 m_s = -0.1	$\bar{X}$ = 21.9 (48.2) s = 4.0 (8.8) m_k = 4.4 m_s = -1.2	n = 16	$\bar{X}$ = 53.1 s = 6.1	$\bar{X}$ = 81.8 (180.4) s = 14.3 (31.6)	$\bar{X}$ = 177.8 (70.0) s = 5.1 (2.0)
Female	16 - 29	$\bar{X}$ = 13.2 (29.2) s = 2.9 (6.4) m_k = 2.8 m_s = -0.1	$\bar{X}$ = 16.1 (35.6) s = 3.9 (8.7) m_k = 2.0 m_s = 0.0	$\bar{X}$ = 13.0 (28.7) s = 3.1 (6.9) m_k = 3.3 m_s = 0.8	$\bar{X}$ = 15.5 (34.2) s = 3.6 (8.0) m_k = 2.3 m_s = 0.1	n = 16	$\bar{X}$ = 23.6 s = 3.5	$\bar{X}$ = 61.7 (136.1) s = 7.7 (16.9)	$\bar{X}$ = 160.3 (63.1) s = 7.9 (3.1)
Female	30 - 44	$\bar{X}$ = 13.5 (29.7) s = 5.3 (11.6) m_k = 2.7 m_s = 0.7	$\bar{X}$ = 16.0 (35.3) s = 3.9 (8.6) m_k = 1.6 m_s = 0.2	$\bar{X}$ = 14.3 (31.5) s = 4.1 (9.1) m_k = 2.7 m_s = 0.6	$\bar{X}$ = 15.8 (34.8) s = 3.6 (8.0) m_k = 2.1 m_s = 0.0	n = 16	$\bar{X}$ = 36.3 s = 4.9	$\bar{X}$ = 62.6 (138.1) s = 15.8 (34.8)	$\bar{X}$ = 160.8 (63.3) s = 5.6 (2.2)
Female	45 - 60+	$\bar{X}$ = 12.5 (27.6) s = 3.2 (7.1) m_k = 4.0 m_s = 1.2	$\bar{X}$ = 14.3 (31.5) s = 3.4 (7.4) m_k = 2.6 m_s = 0.5	$\bar{X}$ = 12.2 (26.9) s = 3.0 (6.7) m_k = 3.4 m_s = 0.9	$\bar{X}$ = 14.3 (31.6) s = 3.0 (6.7) m_k = 3.2 m_s = 0.7	n = 16	$\bar{X}$ = 52.4 s = 5.9	$\bar{X}$ = 64.3 (141.8) s = 10.5 (23.1)	$\bar{X}$ = 163.8 (64.5) s = 6.1 (2.4)

Table 8. Mean Maximum Reasonable Product Weight for the Four Main Treatment Effects.

Effect	Treatment Level	Mean Maximum Reasonable Product Weight in	
		kg	lbs
Sex of Consumer	Males	20.4	44.9
	Females	14.2	31.4
Age of Consumer	16 - 29	17.6	38.8
	30 - 44	17.2	37.9
	45 - 60+	17.1	37.7
Size of Product	$(30.5\ cm)^3$ $(12\ in)^3$	17.5	38.6
	$(31.8\ cm)^3$ $(15\ in)^3$	17.1	37.7
Method of Carry	One-Hand	15.9	35.1
	Two-Hand	18.7	41.2

Table 9. Analysis of Variance: Male Data

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	Statistical Significance at $p < .05$ level
Total	191	26,049.32			
Between Subjects (S)	47	17,377.61			
Age (A)	2	351.05	175.53	<1.00	No
S/A	45	17,026.56	378.37		
Within Subjects	144	8,671.71			
Method of Carry (B)	1	2,468.20	2,468.20	30.56	Yes
AB	2	283.02	141.51	1.75	No
SB/A	45	3,634.97	80.78		
Size of Product (C)	1	105.02	105.02	3.29	No
AC	2	5.33	2.66	<1.00	No
SC/A	45	1,436.08	31.91		
BC	1	85.87	85.87	6.11	Yes
ABC	2	20.56	10.28	<1.00	No
SBC/A	45	632.65	14.06		

Table 10. Analysis of Variance: Female Data

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	Statistical Significance at $p < .05$ level
Total	191	13,371.17			
Between Subjects (S)	47	9,369.46			
Age (A)	2	410.21	205.11	1.03	No
S/A	45	8,959.25	199.09		
Within Subjects	144	4,000.71			
Method of Carry (B)	1	1,154.44	1,154.44	27.86	Yes
AB	2	25.91	12.95	<1.00	No
SB/A	45	1,864.52	41.43		
Size of Product (C)	1	1.77	1.77	<1.00	No
AC	2	22.13	11.07	<1.00	No
SC/A	45	629.91	14.00		
BC	1	8.42	8.42	1.38	No
ABC	2	19.07	9.54	1.56	No
SBC/A	45	275.54	6.12		

For males, the ANOVA showed that two treatment effects were statistically significant at the .05 level of probability*: Method of Carry (B) and the interaction between Method of Carry and Size of Product (BC). All other effects were nonsignificant. The significant BC interaction for males may be interpreted to mean that maximum reasonable product weights were significantly greater for the 30.5 cm (12 in) cubical box than for the 38.1 cm (15 in) cubical box, but only in the two handed method of carry.

For females, the ANOVA showed that only one treatment effect was statistically significant at the .05 level of probability: Method of Carry (B). All other effects were again nonsignificant.

Finally, a series of separate "t-tests" revealed that male-female differences in the judgment of maximum reasonable product weight were also significant at the .05 probability level. This was true not only for the overall sex effect ($t = 7.7$), but also for the sex effect associated with the 30.5 cm (12 in) cubical box ($t = 7.8$), the 38.1 cm (15 in) cubical box ($t = 7.4$), the one-hand carry method ($t = 9.8$), and the two-hand carry method ($t = 6.6$).

In summary, only the main effects of Method of Carry and Sex of Consumer were found to be statistically significant at the .05 level (i.e. the frequency distributions associated with males and females, and one-handed and two-handed carries were significantly different), while the other effects were statistically nonsignificant. This does not imply that the Consumer Age and Product Size effects were trivial under all circumstances, but that these effects were trivial under the range of conditions studied in the present investigation. Hence for FTC's purposes, the various frequency distributions associated with Consumer Age and Product Size effects may be pooled together, resulting in larger overall distributions for the Consumer Sex and Method of Carry treatment conditions.

Table 11 presents the maximum reasonable product weights acceptable to various percentages of the consumer population. Separate distributions are presented for males and females, and for one-handed and two-handed methods of carry. In addition, an "overall" distribution is provided which represents pooling of data over all conditions. The latter distribution while being the most general, is also the least flexible in dealing with differential capabilities of men and women using different product carrying methods.

*Results which would be expected to occur by chance only 5% of the time.

Table 11. Maximum Reasonable Product Weights for a Consumer Product Return Activity for Various Percentages of the Consumer Population.

Percentage of Consumer Population to which Indicated Product Weights are "Maximum Reasonable"*	MALES				FEMALES				All Conditions	
	One-Hand Carry		Two-Hand Carry		One-Hand Carry		Two-Hand Carry			
	kg	(lbs)	kg	(lbs)	kg	(lbs)	kg	(lbs)	kg	(lbs)
95%	11.0	(24.3)	13.1	(28.9)	8.1	(17.8)	9.4	(20.8)	9.4	(20.8)
90%	12.1	(26.6)	15.6	(34.4)	9.0	(19.9)	10.8	(23.9)	10.7	(23.5)
75%	14.8	(32.6)	18.3	(40.4)	10.4	(22.9)	12.8	(28.3)	13.0	(28.7)
50%	18.4	(40.5)	22.0	(48.5)	12.7	(28.1)	14.7	(32.4)	16.6	(36.6)
25%	22.1	(48.8)	25.1	(55.3)	15.2	(33.5)	18.6	(40.9)	21.0	(46.4)
10%	26.1	(57.5)	28.4	(62.7)	17.9	(39.5)	20.6	(46.2	25.0	(55.1)
5%	28.0	(61.7)	32.0	(70.6)	21.2	(46.7)	21.4	(47.1)	27.0	(59.5)
Form of Distribution	Normal		Normal		Positively Skewed		Positively Skewed		Bimodal	

*Table weights are accurate to approximately $\pm$1 kg under the conditions of the experimental task reported in the present investigation.

5.2 Product Size

The data of the present investigation are equivocal with respect to the determination of maximum reasonable product size for a consumer product return activity. While no significant differences were found to exist between the maximum reasonable weight distributions for the 30.5 cm (12 in) and 38.1 cm (15 in) cubical boxes (except for males using the two-handed carrying method), the post experimental opinions of subjects expressed by means of the semantic differential scale (Appendix D) indicate that volume changes of this magnitude may contribute significantly to the difficulty involved in the manual handling of consumer products.

Table 12 shows the percentage of subjects who agreed with each of the five semantic differential scale values and indicates a strong difference in opinion concerning the reasonableness of the two simulated product sizes. Thus approximately 97% of the male subjects (averaged over method of carry) felt the smaller box ($(30.5\ cm)^3$ $(12\ in)^3$) was at or below their criterion for maximum reasonable size, while approximately 78% felt this to be true about the larger box ($(38.1\ cm)^3$ $(15\ in)^3$). For females, the corresponding percentages were approximately 97% and 54%.

It should be noted, however, that a more detailed review of the raw data summarized in Table 12 indicates that, of the total of 384 size opinions given by the subjects using the semantic differential scale, approximately 18% (70) of the responses reflected some degree of within subject inconsistency. For example, 75% of the male subjects (one-handed condition) found the larger box to be at or below their criterion for maximum reasonable size, while only 68.8% found the smaller box to be below their criterion for maximum reasonable size, thus resulting in an inconsistency of 6.3%. Examination of the raw data reveals that 94% of the 70 inconsistent opinions concerning maximum reasonable size were of the same type, i.e. the same subject using the same method of carry rated both the smaller and larger box as being "maximum reasonable." When the data are reanalyzed after elimination of all inconsistent opinions, the difference in opinion concerning the reasonableness of the two simulated product sizes becomes more pronounced; then, averaged over method of carry, 97% of the males found the smaller box to be at or below their criterion for maximum reasonable size, while only 73% found the larger box to be at or below this criterion. The corresponding values for females were 96% and 46%.

Subjects apparently were not compensating for their judgment of increased awkwardness of the larger box by reducing the weight selected (as reflected by ANOVA results). This suggests that there is little relationship between maximum reasonable product size and weight.

5.3 Product Handles

Although the present investigation was not intended to study the relationship between product handle placement and product portability, the data collected for the one and two-handed methods of carry indicate that subjects, for a given product size, consistently selected greater maximum reasonable product weights in the two-handed (no handle available) than in the one-handed (a single central handle on the top of the box available) carrying method. This would seem to imply that the availability of handles on the top of consumer products adds little to the amount of weight which the consumer can comfortably handle, but rather is more of a convenience in that it precludes the necessity of stooping to get the product into a comfortable, two-handed carrying position.

Table 12. Results of Semantic Differential Evaluation of Simulated Product Size

Sex	Method of Carry	Product Size	After Participating in Experimental Task the Following Percentages of Subjects Indicated that the Simulated Product Size Carried was:				
			Unreasonable Too Small	Slightly Less than Maximum Reasonable	Maximum Reasonable	Slightly More than Maximum Reasonable	Unreasonable Too Big
Male (n=48)	One-hand	$(30.5cm)^3$ $(12\ in)^3$	2.1%	66.7%	25.0%	6.2%	0%
		$(38.1cm)^3$ $(15\ in)^3$	0%	8.3%	66.7%	25.0%	0%
	Two-hand	$(30.5cm)^3$ $(12\ in)^3$	4.2%	62.5%	33.3%	0%	0%
		$(38.1cm)^3$ $(15\ in)^3$	0%	14.6%	66.7%	18.7%	0%
Female (n=48)	One-hand	$(30.5cm)^3$ $(12\ in)^3$	2.1%	41.7%	52.1%	4.2%	0%
		$(38.1cm)^3$ $(15\ in)^3$	0%	8.3%	45.9%	37.5%	8.3%
	Two-hand	$(30.5cm)^3$ $(12\ in)^3$	2.1%	54.2%	41.7%	2.1%	0%
		$(38.1cm)^3$ $(15\ in)^3$	0%	4.2%	50.0%	35.4%	10.4%

6. Conclusions and Recommendations

The results of the present investigation are in agreement with the findings of the Phase I literature review. The variables of greatest significance to the determination of product portability for a product return activity appear to be (1) the sex of the consumer, (2) the method of carry used in handling the product, and to a lesser extent (3) the size of the consumer product, at least over the range of sizes studied here. The age of the consumer appears to have little effect in the determination of what weight he/she judges to be maximum reasonable. The latter conclusion is, of course, limited to persons of 16 to 60 years of age who are in good health. The lack of a significant age effect is presumably the result of the willingness of older persons to walk more slowly and take more rests than younger persons in carrying objects of roughly similar weight.*

The selection of the most appropriate population percentage value to be used in the promulgation of consumer product portability rules is a complex problem. While a value of at least 90% is most frequently encountered in the human engineering literature dealing with military equipment and systems design, many other factors should be considered by FTC before reaching a final decision. Thus, the <u>behavioral</u> data of this study would be viewed as providing just one of the many pieces of information on which to base a ruling. Other factors which should be considered are the influence of the ruling on (1) product cost, (2) competition among manufacturers, (3) the cost and duration of product repairs, and (4) the willingness of consumers to use other inconvenient, but safe, means of returning consumer products (e.g. the use of external aids or rental vehicles, the assistance of friends and neighbors, etc.). Furthermore, it should be stressed that the generalization of results obtained from this investigation is limited to situations where the tasks and product characteristics are similar to those employed in this study. The results are based on laboratory conditions and may be of limited applicability to conditions substantially different from those represented herein. Hence, products with unstable loads, handles placed at locations other than over the center of gravity, having slippery surfaces, etc. may be expected to have smaller values of maximum reasonable weight and size. Inclement weather conditions, unusually long carrying distances, lifting activities associated with trunk, roof, back and front seats of cars, numerous flights of stairs, and the like may have similar effects.

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*In the present study differences were found between the three age groups studied in terms of both the mean duration and the total number of rests taken. The mean durations of carry for the 16-29, 30-44, 45-60+ age groups were 137, 139, and 155 seconds respectively. The total number of rests taken by these same groups were 67, 81 and 119.

Nevertheless, with the above limitations in mind, the present investigation fully supports all of the previous observations concerning <u>relative</u> limits for maximum acceptable weights of lift and carry (pages 12-13), and, in addition, suggests that for behavioral purposes <u>absolute</u> limits for product weight should be on the order of 9.0 kg (19.9 lbs) to 15.6 kg (34.4 lbs) (depending upon the specific sub-population under consideration) to satisfy 90% of the consumer population. The limit for maximum acceptable size of lift and carry should be within the range of $(30.5\ cm)^3$ ($(12\ in)^3$) to $(38.1\ cm)^3$ ($(15\ in)^3$) for compact products of roughly cubical dimensions, again to satisfy approximately 90% of the consumer population. While the presence of handles on products may contribute to handling convenience (e.g. provide a choice of one-handed versus two-handed method of carry), they should not influence the maximum acceptable weight of lift and carry associated with product-warranty rulemaking.

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APPENDIX A - Details of Studies Referenced in Tables 3, 4 and 5

The details concerning each of the 35 references cited in the Section 3.0 literature review (Tables 3, 4 and 5) are presented here. Each study is detailed on a separate page using a standardized summarization format. The studies are grouped according to type and frequency of task, and methodological technique employed. The results shown in many cases had to be derived from data provided in the actual studies through such techniques as interpolation and extrapolation and inferences concerning the standard normal distribution. Thus, in many cases the specific values presented in the "results summary" should be considered only approximate. The conditions selected as being most relevant to the typical consumer product handling task generally include: (1) lifts to "table top height" (3 to 4 ft; or approximately 1 m) and (2) carrying distance of as long a value as possible.

Reference (37)   Task: Two-Handed, Single Lift   Study Approach: Behavioral

Emmanuel, I., Chaffee, J. W., and Wing, J. A Study of Human Weight Lifting Capabilities for Loading Ammunition into the F-86H Aircraft.

Subject Summary

Number: 19
Sex: Male
Age: 17 to 28
Occupation: Soldiers and college students
Physical Condition: "Good"
Task Training: None

Task Summary

Method: Two-handed, straight back lift, but backs not necessarily vertical
Frequency: Not stated
*Distance/Height/Duration: 5 heights studied
Criterion: Psychophysical adjustment procedure to avoid feeling of possible injury

Product/Object Summary

Type: Box
Size: 27.3 cm x 64.8 cm x 17.1 cm (10 3/4" x 25 1/2" x 6 3/4")
Load Distribution: Not stated; however 4.5 kg (10 lb) bags of shot used to adjust weight
Presence of Handles & Location: Not stated

Results Summary

Maximum Acceptable Weights of Lift (in kg) for Five Heights of Lift and for Various Population Percentiles

Height of Lift	Percent of Population to Which Acceptable				
	95%	75%	50%	25%	5%
0 to 1 foot (0-30.5 cm)	65	91	105	121	137
0 to 2 feet (0-61.0 cm)	63	75	86	97	118
0 to 3 feet (0-91.4 cm)**	35	44	52	62	78
0 to 4 feet (0-121.9 cm)	25	31	37	44	51
0 to 5 feet (0-152.4 cm)	17	21	26	32	38

*Independent variable
**Condition selected as being most relevant to a consumer product lifting task

Reference (21) Task: Two Handed, Single Lift Study Approach: Behavioral

Chaffin, D. B. Human Strength Capability and Low Back Pain.

Subject Summary

Number: Approximately 400
*Sex: Approximately 250 male; 150 female
Age: "Wide range"
Occupation: Industrial workers
Physical Condition: "Good"
Task Training: Not stated

Task Summary

Method: Two-handed lift, object 51 cm (20") off floor and 51 cm (20") in front of subject
Frequency: Once
Distance/Height/Duration: 4 second duration
Criterion: Maximum capable lift that could be sustained for 4 seconds

Product/Object Summary

Type: Platform attached to "lifting force meter"
Size: 46 cm (18") across
Load Distribution: Not applicable
Presence of Handles & Location: 2 handles, one on each side of platform

Results Summary

Maximum Capable Lifting Weight (in kg) for Various Percentages of the Male and Female Populations					
SEX	% of Population Which is Capable				
	90%	75%	50%	25%	10%
Male	13	17	23	31	41
Female	6	9	13	18	24

Note: Chaffin's data show that lifting strength is positively skewed.

*Independent variable

Reference (83) Task: Two Handed, Single Lift Study Approach: Physiological

Poulsen, E. and Jorgenson, K. Back Muscle Strength, Lifting, and Stooped Working Positions.

Subject Summary

Number: 50
*Sex: Male and Female
*Age: 4 age groups investigated
Occupation: "Various"
Physical Condition: Not stated
Task Training: Not stated

Task Summary

Method: Two-handed lift
*Frequency: Single and repeated lifts
Distance/Height/Duration: Table height
Criterion: Maximum capable for single lift only

Product/Object Summary

Type: Not stated
Size: Not stated
Load Distribution: Not stated
Presence of Handles and Location: Not stated

Results Summary

Maximum Capable and Permissible Weights for Single and Repeated Lifts for Males and Females by Age (in kg)

LIFTING CONDITIONS	Sex:	Average Male				Average Female			
	Age:	15	25	45	55	15	25	45	55
Maximum Capable for Single Lift		77	95	98	93	43	49	47	39
Maximum ** Permissible for Single Lift***		54	66	69	65	31	35	33	27
Maximum ** Permissible for Repeated Lifts		39	47	49	47	21	24	23	20

* Independent variables
** Table values not based on data, but represent these authors' judgment. This rationale for maximum permissible, single lift being 70% of maximum capable, single lift and maximum permissible, repeated lifts being 50% of maximum capable, single lift is not specified in reference.
***Condition selected as being most relevant to a consumer product lifting task

Reference (70) Task: Two Handed, Single Lift Study Approach: Unspecified

MIL-STD-1472A: Human Engineering Design Criteria for Military Systems, Equipment and Facilities (pg. 141).

For objects "of convenient configuration (not more than 15" long, or 12" high)".

Height of Lift	Maximum Acceptable Weight of Lift (in kg)
1 ft. (30.5 cm.)	39
2 ft. (61.0 cm)	36
3 ft. (91.4 cm)*	29
4 ft. (121.9 cm)	23
5 ft. (152.4 cm)	16

*Condition selected as being most relevant to a consumer product lifting task.

Reference (80) Task: Two Handed, Single Lift Study Approach: Unspecified

Peres, N. Human Factors in Industrial Strain (textbook not retrieved)

> ".... recommended maximum load for male adults in the United Kingdom as 130 lbs., but then recommended 100 lbs. for Australian males" (Quote is from reference no. 61, pg. 237)

Reference (56) Task: Two Handed, Repeated Lift Study Approach: Behavioral

Kassab, S. J. and Drury, C. G. The Effects of Working Height on a Manual Task. Personal Communication.

Subject Summary

Number: 11
*Sex: 5 male, 6 female
Age: 19-24
Occupation: Industrial workers, professionals, and students
Physical condition: "Good"
Task Training: None, but industrial workers had experience in lifting as part of job.

Task Summary

Method: Two-handed, improper lifting techniques used as a result of large container size.
Frequency: "Frequent lifting"
*Distance/Height/Duration: 6 heights studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Cubic box
Size: 50.8 cm (20") per side
Load Distribution: Not stated
Presence of Handles and Location: Not stated

Results Summary

Mean Acceptable Weights (in kg) of Repeated Lift for Six Heights of Lift for Males and Females.

HEIGHT OF LIFT From	HEIGHT OF LIFT To	Males	Females
0"	23.4"(59.4 cm)	27	16
0"	47.2"(119.9cm)**	24	13
0"	70.9"(180.1 cm)	18	9
23.4"(59.4cm)	47.2"(119.9 cm)	29	15
23.4"(59.4cm)	70.9"(180.1 cm)	19	13
47.2"(119.9cm)	70.9"(180.1 cm)	20	10

Note: Acceptable weights for females range from 50% to 59% of acceptable weights for males.

*Independent variables
**Condition selected as most relevant to a consumer product lifting task.

Reference (7) Task: Two Handed, Repeated Lift Study Approach: Behavioral

Ayoub, M. M., Dryden, R. D., McDaniel, J. W., and Knipfer, R. E. Psychophysical Based Models for the Prediction of Lifting Capability of Industrial Workers.

Subject Summary

Number: 135
*Sex: 68 males; 67 females
Age: 25-50
Occupation: Industrial workers and students
Physical Condition: "Good"
Task Training: Brief instruction on proper lifting method

Task Summary

Method: Two handed, using proper lifting technique
Frequency: Frequent lifting as part of job
*Distance/Height/Duration: 3 heights studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Industrial tote box
Size: 34.3 cm x48.3 cm x14.0 cm (13 1/2"x19"x5 1/2")
Load Distribution: Not stated
Presence of Handles and Location: Two handles, one on each side of box

Results Summary

Maximum Acceptable Weights of Repeated Lift (in kg) for Three Heights of Lift and for Various Population Percentiles

		Percent of Population to Which Acceptable				
HEIGHT OF LIFT	Sex	90%	75%	50%	25%	10%
Floor to Knuckle Height**	M	16	19	24	30	35
	F	9	10	15	18	21
Knuckle Height to Shoulder Height	M	18	21	25	28	31
	F	10	11	12	13	14
Shoulder Height to Extended Arm Reach	M	16	19	22	26	29
	F	8	10	12	14	16

*Independent variables
**Condition selected as being most relevant to a consumer product lifting task.

Reference (85) Task: Two Handed, Repeated Lift Study Approach: Behavioral

Snook, S. H. The Effects of Age and Physique on Continuous-Work Capacity.

Subject Summary

Number: 28
Sex Male
*Age: 14 subjects 25-35,
14 subjects 45-65
Occupation: Industrial workers
Physical Condition: "Good"
Task Training: Brief instructions on proper lifting method, also exercized for one week prior to experiment

Task Summary

Method: Two handed using proper lifting technique
*Frequency: frequent lifting as part of job; slow and fast lifting rates studied.
*Distance/Height/Duration: 3 heights studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot
Presence of Handles and Location: Two handles, one on each end of box

Results Summary

Mean Maximum Acceptable Weights of Repeated Lift (in kg) for Three Heights of Lift at Slow and Fast Lifting Rates

HEIGHT OF LIFT	Frequency, once every	25-35 yr. males	45-60 yr. males	Mean
Floor to Knuckle Height**	60 sec.**	23	26	24.5***
	14 sec.	19	22	20.5
Knuckle Height to Shoulder Height	60 sec.	23	25	24
	11 sec.	20	21	20.5
Shoulder Height to Extended Arm Reach	60 sec.	23	21	22
	10 sec.	17	17	17

*Independent variables
**Condition selected as being most relevant to a consumer product lifting task
***Percentile values in Table 3 are based upon a standard deviation of 5.7 kg (12.50 lbs).

Reference (87) Task: Two Handed, Repeated Lift Study Approach: Behavioral

Snook, S. H. Circello, M. Maximum Weights and Work Loads Acceptable to Female Workers.

Subject Summary

Number: 31
Sex: Female
Age: Mean age industrial workers = 38.5
Mean age housewives = 35.6
*Occupation: 15 industrial workers
16 housewives
Physical Condition: "Good Health"
Task Training: Brief instructions on proper lifting method, also exercised for one week prior to experiment

Task Summary

Method: Two handed using proper lifting technique
Frequency: Frequent lifting as part of job
*Distance/Height/Duration: 3 heights studied
Criterion: Psychophysical adjustment procedure to avoid execessive strain

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot.
Presence of Handles and Location: Two handles, one on each end of box

Results Summary

Maximum Aceptable Weights of Lift (in kg) for Three Heights of Lift, Two Occupations, and Various Population Percentiles

		Percent of Population to Which Acceptable				
HEIGHT OF LIFT	Occupation	90%	75%	50%	25%	10%
Floor to Knuckle Height**	Ind. women	13	15	17	19	21
	Housewives**	6	8	10	11	12
Knuckle Height to Shoulder Height	Ind. women	11	13	15	17	19
	Housewives	7	8	10	11	12
Shoulder Height to Extended Arm Reach	Ind. women	11	12	13	15	16
	Housewives	6	7	8	10	11

*Independent variables
**Conditions selected as being most relevant to a consumer product lifting task

Reference (88) Task: Two Handed, Repeated Lift Study Approach: Behavioral

Snook, S. H. and Irvine, C. M. Maximum Acceptable Weight of Lift.

Subject Summary

Number: 9
Sex: Male
Age: 25 - 37, mean = 30.1
Occupation: Industrial workers
Physical Condition: "Good health"
Task Training: Brief instruction on proper lifting method, also exercized for one week prior to experiment.

Task Summary

Method: Two handed using proper lifing technique
Frequency: Frequent lifting as part of job
*Distance/Height/Duration: 3 heights studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14cm. (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot
Presence of Handles and Location: Two handles, one at each end of box

Results Summary

Maximum Acceptable Weights of Repeated Lifts (in kg) for Three Heights of Lift and for Various Population Percentiles

	Percent of Population to Which Acceptable				
HEIGHT OF LIFT	90%	75%	50%	25%	10%
Floor to Knuckle Height**	24	27	30	33	36
Knuckle Height to Shoulder Height	23	26	28	31	33
Shoulder Height to Extended Arm Reach	22	24	27	31	33

Note: Snook recommends 23 kg (50 lbs) as the maximum acceptable weight of lift for unselected male industrial workers.

*Independent variable
**Condition selected as being most relevant to a consumer product lifting task

Reference (91) Task: Two-Handed, Repeated Lift Study Approach: Behavioral

Snook, S. H., Irvine, C. M. and Bass, S. F. Maximum Weights and Work Loads Acceptable to Male Industrial Workers.

Subject Summary

Number: 28
Sex: Male
Age: Mean age = 39.9
Occupation: Industrial workers
Physical Condition: "Good"
Task Training: Brief instructions on proper lifting methods, also exercised for one week prior to experiment

Task Summary

Method: Two-handed, using proper lifting technique
Frequency: Frequent lifting as part of job
*Distance/Height/Duration: 3 heights studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot
Presence of Handles and Location: Two handles, one at each end of box

Results Summary

Maximum Acceptable Weights of Repeated Lifts (in kg) for Three Heights of Lift and for Various Population Percentiles

HEIGHT of LIFT	Percent of Population to Which Acceptable				
	90%	75%	50%	25%	10%
Floor to Knuckle Height**	17	21	25	29	32
Knuckle Height to Shoulder Height	16	20	24	28	32
Shoulder Height to Extended Arm Reach	13	18	22	27	31

*Independent variable
**Condition selected as being most relevant to a consumer product lifting task

Reference (95) Task: Two-Handed, Repeated Lift Study Approach: Behavioral

Switzer, S. A. Weight Lifting Capabilities of a Selected Sample of Human Males.

Subject Summary

Number: 75
Sex: Males; three stature groups*
Age: Mean age = 19.5
Occupation: College students
Physical condition: "Good"
Task Training: Brief instruction on proper lifting methods

Task Summary

Method: Two-handed, "proper lift methods"
Frequency: "Work to be carried out for some time"
*Distance/Height/Duration: 3 heights studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Sheet metal box
Size: 15.2cm x30.5cm x30.5cm (6"x12"x12")
Load Distribution: not stated, but bags of lead shot added to box
Presence of Handles and Location: Two, 11.4 cm. (4-1/2") handles; one on each side of box

Results Summary

Mean Maximum Acceptable Weights of Repeated Lifts (in kg) for Three Male Stature Groups

HEIGHT of LIFT	Short Male Subjects (1-15%)	Medium Male Subjects (45-60%)	Tall Male Subjects (85-99%)
0 to 18 inches (0 to 45.7 cm)	56	63	66
0 to 42 inches (0 to 106.7cm)**	33	42	44
0 to 62.5 inches (0 to 158.8cm)	24	30	31

*Independent variables
**Condition selected as being most relevant to a consumer product lifting task

Reference (6) Task: Two-Handed, Repeated Lift Study Approach: Physiological

Asmussen, E., Poulsen, E., and Rasmussen, B. Quantitative Evaluation of the Activity of the Back Muscles in Lifting.

Subject Summary

Number: 610
*Sex: 360 males, 25 females (10th percentile body heights)
*Age: 8 age groups studied
Occupation: Not stated, but "residents of urban area"
Physical Condition: Not stated
Task Training: Brief training on proper lifting methods

Task Summary

Method: Two-handed, "straight back inclined 45°"
Frequency: Repeated lifting required; "few rest intervals"
Distance/Height/Duration: Table height
Criterion: Physiological measures (electromyograms). Recommended weights based on 40-55% of maximum capable isometric back strength.

Product/Object Summary

Type: Box
Size: "15.7 inches across" (39.9 cm)
Load Distribution: Not stated
Presence of Handles and Location: Two handles, one on each end of box

Results Summary

Maximum Acceptable Weights of Repeated Lift for Males and Females of Various Ages (in kg)

SEX	AGE	15	20	25	35	45	50	55	65	Mean**
Male		25	29	31	32	32	-	30	27	30
Female		18	19	19	20	19	18	16	-	19

*Independent variables
**Data selected as being most relevant to a consumer product lifting task.

Reference (83) Task: Two-Handed, Repeated Lift Study Approach: Physiological

Poulsen, E. and Jorgenson, K. Back Muscle Strength, Lifting, and Stooped Working Positions.

Subject Summary

Number: 50
*Sex: Male and Female
*Age: 4 age groups investigated
Occupation: "Various"
Physical Condition: Not stated
Task Training: Not stated

Task Summary

Method: Two-handed lift
*Frequency: Single and repeated lifts
Distance/Height/Duration: Table height
Criterion: Maximum capable for single lift only

Product/Container Variables

Type: Not stated
Size: Not stated
Load Distribution: Not stated
Presence of Handles and Location: Not stated

Results Summary

Maximum Capable and Permissible Weights for Single and Repeated Lifts for Males and Females by Age (in kg)

LIFTING CONDITIONS	Sex:	Average Male				Average Female			
	Age:	15	25	45	55	15	25	45	55
Maximum Capable for Single Lift		77	95	98	93	43	49	47	39
Maximum Permissable** for Single Lift		54	66	69	65	31	35	33	27
Maximum Permissible** for Repeated Lifts***		39	47	49	47	21	24	23	20

*Independent variables
**Table values not based on data, but represent these authors' judgment. Their rationale for maximum permissible, single lift being 70% of maximum capable, single lift and maximum permissible, repeated lifts being 50% of maximum capable, single lift is not specified in reference.
***Condition selected as being most relevant to a consumer product lifting task

Reference (72) Task: Two-Handed, Repeated Lift Study Approach: Unspecified

Munchunger, R. Manual Lifting and Carrying

Recommendations for Maximum Weight for Repeated Two-handed Lifts (in kg) of Compact Objects (International Occupational Safety and Health Information Center)							
SEX	AGE	14-16	16-18	18-20	20-35	35-50	Over 50
Male		11	15	17	19	16	12
Female		8	9	11	11	10	8

Reference (104) Task: Two-Handed, Repeated Lift Study Approach: Unspecified

Woodson, W. E. and Conover, D. W. Human Engineering Guide for Equipment Design (2nd Edition)

Recommendations for Maximum Weight* of Repeated, Two-Handed Lift (in kg) for Three Box Sizes and Three Heights of Lift			
	Size of Object in Inches		
HEIGHT of LIFT	30.5cm x30.5cm x30.5cm (12"x12"x12")	30.5cmx30.5cmx45.7cm (12"x12"x18")	15.2cmx20.3cmx91.4cm (6"x8"x36")
0 to 3 feet (0 to 91.4cm)**	34	43	50
0 to 4 feet (0 to 121.9cm)	25	34	43
0 to 6 feet (0 to 182.9cm)	18	23	23

*50th percentile - male
**Condition selected as being most relevant to a consumer product lifint task.

Reference (67) Task: One-Handed, Single Lift Study Approach: Behavioral

McConville, J. T., and Hertzberg, H.T.E. A Study of One-Handed Lifting.

Subject Summary

Number: 30
Sex: Male
Age: 18-39; mean = 26.4
Occupation: military & civilian employees college students
Physical Condition: "Average"
Task Training: Subjects told to use proper lifting method

Task Summary

Method: One-handed lift
Frequency: Not stated
Distance/Height/Duration: Table top height
Criterion: Psychophysical adjustment procedure to avoid excessive exhaustion.

Product/Object Summary

Type: Boxes
*Size: Various widths
Load Distribution: Evenly distributed; lead shot used
Presence of Handles and location: One handle at top of box

Results Summary

Maximum Acceptable Weight of Repeated One-Handed Lift (in kg) for Seven Box Sizes and for Various Population Percentiles

Width of Box	Percentage of Population to which Acceptable				
	95%	75%	50%	25%	5%
8 in (20.3cm)	22	29	34	37	44
12in (30.5cm)	22	28	31	35	40
16in (40.6cm)**	19	26	30	33	37
20in (50.8cm)	19	25	27	29	34
24in (60.9cm)	17	24	26	28	33
28in (71.1cm)	15	20	23	26	31
32in (81.3cm)	12	18	22	25	29

Note: According to these authors, the best equation for predicting maximum acceptable weight of one-hand lift is: Weight = (60-width)

*Independent variable

**Condition selected as being most relevant to a consumer product lifting task

Reference (85) Task: Two-Handed Carry Study Approach: Behavioral

Snook, S. H. The Effects of Age and Physique on Continuous-Work Capacity

Subject Summary

Number: 28
Sex: Male
*Age: 14 subjects 25-35,
14 subjects 45-65
Occupation: Industrial workers
Physical Condition: "Good"
Task Training: Brief instructions given on proper lifting method, also exercized for one week prior to experiment

Task Summary

*Method: Two-handed, "straight-arm" and "bent arm" carrying methods studied
*Frequency: 3 rates of carry studied
*Distance/Height/Duration: 3 distances studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot
Presence of Handles and Location: Two handles, one on each end of box

Results Summary

Maximum Acceptable Weights of Carry (in kg) for Two Distances, Three Rates, and Two Age Groups.

METHOD of CARRY	Distance Carried	Rate, Once Every	Age, 25-35	Age, 40-60	Mean
Knuckle Height** (Straight Arm)	2.13m (7ft)	60 seconds	30	35	32
	2.13m (7ft)	12 seconds	24	29	26
	8.5m (28ft)**	60 seconds**	26	28	27***
	8.5m (28ft)	18 seconds	20	20	20
Elbow Height (Bent Arm)	2.13m (7ft)	60 seconds	24	28	26
	2.13m (7ft)	12 seconds	21	22	21
	8.5m (28ft)	60 seconds	19	22	21
	8.5m (28ft)	18 seconds	15	15	15

*Independent variables
**Condition selected as being most relevant to a consumer product carrying task
***Percentile values presented in Table 3 are based upon a standard deviation of 5.7kg (12.50 lbs).

Reference (87) Task: Two-Handed Carry Study Approach: Behavioral

Snook, S.H., and Ciriello, M.S. Maximum Weights and Work Loads Acceptable to Female Workers

Subject Summary

Number: 31
Sex: Female
Age: Mean age: industrial workers = 38.5; housewives = 35.6
*Occupation: 15 industrial workders
16 housewives
Physical Condition: "Good health"
Task Training: Brief instructions given on proper lifting methods, also exercized for one week prior to experiment.

Task Summary

Method: Two-handed, "straight-arm" carry
Frequency: "As part of job"
*Distance/Height/Duration: 3 distances studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain.

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot
Presence of Handles and Location: Two handles, one on each end of box

Results Summary

Maximum Acceptable Weights of Carry (in kg) for Three Distances, Two Occupations, and Various Population Percentiles

		Percent of Population to Which Acceptable				
Distance Carried	Occupation	90%	75%	50%	25%	10%
2.13 m (7 ft)	Industrial Women	13	15	17	20	21
	Housewives	8	10	11	13	15
4.3 m (14 ft)	Industrial Women	13	15	17	19	21
	Housewives	7	9	10	12	14
8.5 m. (28 ft)**	Industrial Women	11	13	15	18	20
	Housewives**	6	8	10	11	12

*Independent variables
**Conditions selected as being most relevant to a consumer product carrying task.

Reference (91) Task: Two-Handed Carry Study Approach: Behavioral

Snook, S.H., Irvine, C.H., and Bass, S.F. Maximum Weights and Work Loads Acceptable to Male Industrial Workers.

Subject Summary

Number: 28
Sex: Male
Age: Mean age = 39.9
Occupation: Industrial workers
Physical Condition: "Good"
Task Training: Brief instructions given on proper lifting methods, also exercised for one week prior to experiment.

Task Summary

*Method: Two-handed, "straight-arm" and "bent-arm" carrying methods studied
Frequency: "As part of job"
*Distance/Height/Duration: 3 distances studied
Criterion: Psychophysical adjustment procedure to avoid excessive strain.

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Evenly distributed with lead shot
Presence of Handles and Location: Two handles, one on each end of box

Maximum Acceptable Weights of Carry (in kg) for Two Methods, Three Distances and Various Population Percentiles

METHOD of CARRY	Distance Carried	Percent of Population to Which Acceptable				
		90%	75%	50%	25%	10%
Knuckle Height Carry** (Straight-Arm Carry)	2.13 m (7 ft)	22	27	32	38	43
	4.3 m (14 ft)	20	24	29	33	37
	8.5 m (28 ft)**	19	23	27	31	35
Elbow Height Carry (Bent-Arm Carry)	2.13 m (7 ft)	18	22	26	30	34
	4.3 m (14 ft)	16	20	23	27	30
	8.5 m (28 ft)	15	17	20	24	26

*Independent variables
**Conditions selected as being most relevant to a consumer product carrying task.

Reference (20) Task: Two-Handed Carry Study Approach: Physiological

Chaffin, D. B. Some Effects of Physical Exertion

Subject Summary

Number: Not stated
*Sex: Male and female
Age: Not stated
Occupation: Not stated
Physical Condition: "Good"
Training: Not stated

Task Summary

*Method: Two carrying methods studied (see Table below)
Frequency: Walking rate of 4.8 kph (3 mph)
Distance/Height/Duration: 4 minutes
Criterion: Physiological, based upon maximum acceptable average metabolic rates (Kcal/min)

Product/Object Summary

Type: Industrial tote box
Size: 34.3cm x48.3cm x14.0cm (13-1/2"x19"x5-1/2")
Load Distribution: Balanced
Presence of Handles and Location: Two handles, one on each end

Results Summary

METHOD of CARRY	Maximum Acceptable Weight of Carry (in kg)	
	Males	Females
Two-handed, load held waist high	24	19
Two-handed, load held at arms length (against thigh)**	30	24

*Independent variables
**Condition selected as being most relevant to a consumer product carrying task

Reference (53) Task: Two Handed Carry Study Approach: Physiological

Kamon, E. and Belding, H. The Physiological Cost of Carrying Loads in Temperate and Hot Environments.

Subject Summary

Number: 3
Sex: Male (assumed)
Age: 20, 21, 24
Occupation: Not stated
Physical Condition: Not stated
Task Training: "Some"

Task Summary

Method: Two-handed carry
Frequency: Continuous carrying, without rest
Distance/Height/Duration: 5 minute carry at normal walking speed
Criterion: Physiological (heart rate), with emphasis on "efficiency of carry."

Product/Object Summary

Type: Corrigated fiberboard
Size: 40.6cm x30.5cm x30.5cm (16"x12"x12")
Load Distribution: Not stated
Presence of Handles and Location: None

Results Summary

"In terms of cardiac cost, approximately 15 kg (33 lbs) is the upper limit for repetitive handling of bulky loads in front of the body."

Reference (57) Task: Two-Handed Carry Study Approach: Physiological

Kellerman, F. T. and Van Wely, P. A. The Optimum Size and Shape of Container for Use of the Flower Bulb Industry

Subject Summary

Number: 18
Sex: Male
Age: Mean = 41.5
Occupation: Various (pro- professionals, students and clerks)
Physical Condition: "Good health"
Task Training: None

Task Summary

Method: Two-handed carry
Frequency: 3 frequencies** (6, 12, & 24 carries)
Distance/Height/Duration: 12.19m (40 ft)
Criterion: Physiological with emphasis on "efficiency of carry" in terms of "minimum use of energy per meter-kilogram (foot-pound) of work"

Product/Container Variables

Type: Flower bulb carrying boxes (wood)
*Size: 3 sizes studied***
*Load Distribution: Three weights 9,18,&35kg (19,39 & 77 lbs) each evenly distributed, with little load shifting
Presence of Handles and Location: Not stated

Results Summary

"18 kg (39 lbs)is carried slightly more efficiently than 35 kg (77 lbs)and both are carried more efficiently than 9 kg (19 lbs)"

*Independent variables
**35 kg box carried 6 times; 18 kg box carried 12 times; 9 kg box carried 24 times
***50.8cmx35.6cm x25.4cm; 99.1cm x30.5cmx20.3cm; 66.0cmx45.7cm x20.3cm recommendation for optimum size not based on physiological data, but rather on what could best fit on a pallet.

Reference (74) Task: Two-Handed Carry Study Approach: Physiological

Muller, E. A., Vetter, K., and Blumel, E. Transport of Muscle Power Over Short Distances

Subject Summary

Number:
Sex:
Occupation:
Physical Condition:
Task Training:
} Unknown

Task Summary

Method: Two-handed carry
Frequency: Continuous without rest
Distance/Height/Duration: Unknown
Criterion: Physiological with emphasis on "efficiency of carrying"

Product/Object Summary

Type:
Size:
Load Distribution:
Presence of Handles and Location:
} Unknown

Results Summary

"It was much more efficient to transport the same total load in units of 15 to 28 kg (33 to 62 lbs) instead of in units of 4.1 kg (9 lbs)" (Actual reference not yet retrieved; quote and Task Summary information obtained from Ergonomics Abstracts)

Reference (9) Task: Two-Handed Carry Study Approach: Unspecified

Bedale, E. M. Comparison of the Energy Expenditure of a Woman Carrying Loads in Eight Different Postions

> "A weight is heavy when it reaches 35% of body weight." While this recommendation translates to 21 kg , 22 kg , and 23 kg , for the 95th, 90th, and 50th percentile woman respectively, the recommendation is based on only one female subject.

Reference (22) Task: Two-Handed Carry Study Approach: Unspecified

Chaffin, D. B. and Ayoub, M. M. The Problem of Manual Material Handling

> "Hence, [for male industrial workers] objects of greater that 50.8 cm (20") breadth and/or which require the hands to be more than 40.6 cm (16") in front of the hips when in a carrying position should be handled by two persons when the load exceeds 16 kg (35 lbs)"

Reference (42) Task: Two-Handed Carry Study Approach: Unspecified

Grandjean, E. Fitting the Task to the Man: An Ergonomic Approach

Maximum Weights (in kg) "to avoid accidents"				
CONDITIONS	Adults		Youths	
	Male	Female	Male	Female
Occasional Lifts	50	20	20	15
Continuous work (carry)	18	12	11-16	7-11

Reference (51) Task: Two-Handed Carry Study Approach: Unspecified

International Laborer Office. Maximum Permissible Weight to be Carried by One Worker

Maximum Permissible Weight (in kg) to be Carried by One Worker		
AGE	Male	Female
Adult	40	15-20
16-18 yrs.	16-20	12-15

Reference (70) Task: Two-Handed Carry Study Approach: Unspecified

MIL-STD-1472A: Human Engineering Design Criteria for Military System, Equipment and Facilities (pg. 151)

> "Individual portions of equipment may weigh up to 16kg (35 lbs) if the load is balanced and is distributed over many muscle groups, and it is not necessary for the system to maintain the pace of an infantry movement."

Reference (20) Task: One-Handed Carry Study Approach: Physiological

Chaffin, D. B. Some Effects of Physical Exertion

Subject Summary

Number: Not stated
*Sex: Male and female
Age: Not stated
Occupation: Not stated
Physical Condition: "Good"
Task Training: Not stated

Task Summary

*Method: Two carrying methods studied (see table below)
Frequency: Walking rate of 4.8kph (3mph)
Distance/Height/Duration: 4 minutes
Criterion: Physiological, based upon maximum acceptable average metabolic rates (cal/min).

Product/Object Summary

Type: Not stated
Size: Not stated
Weight Distribution: Not stated
Presence of Handles and Location: Not stated, but "good grip available"

Results Summary

METHOD OF CARRY	Maximum Acceptable Weight of Carry (in kg)	
	Males	Females
One-handed, load held waist high	12	10
One-handed, load held at arm length*** (against thigh)	14	12

*Independent variables
**Condition selected as being most relevant to a consumer product carrying task

Reference (29) Task: One-Handed Carry Study Approach: Unspecified

Daman, A. The Human Body in Equipment Design

"For men the maximum load carried in one hand should be 27 kg (60 lbs) for short distances and 16 kg (35 lbs) for longer distances."

Reference (66) Task: Two-handed, Single Lift Study Approach: Behavioral

Martin, J. B. and Chaffin, D. B. Biomechanical Computerized Simulation of Human Strength in Sagittal-Plane Activities.

Subject Summary

Number: 89
*Sex: 41 Male and 48 Female
Age: (18-52) mean males = 31
mean females = 29
Occupation: "production workers"
Physical Condition: Not stated
Task Training: Not stated

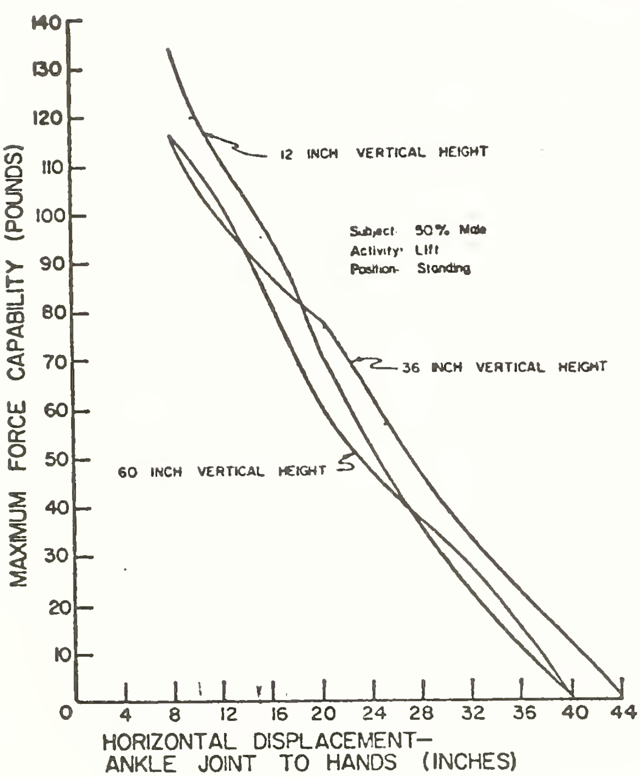
Task Summary

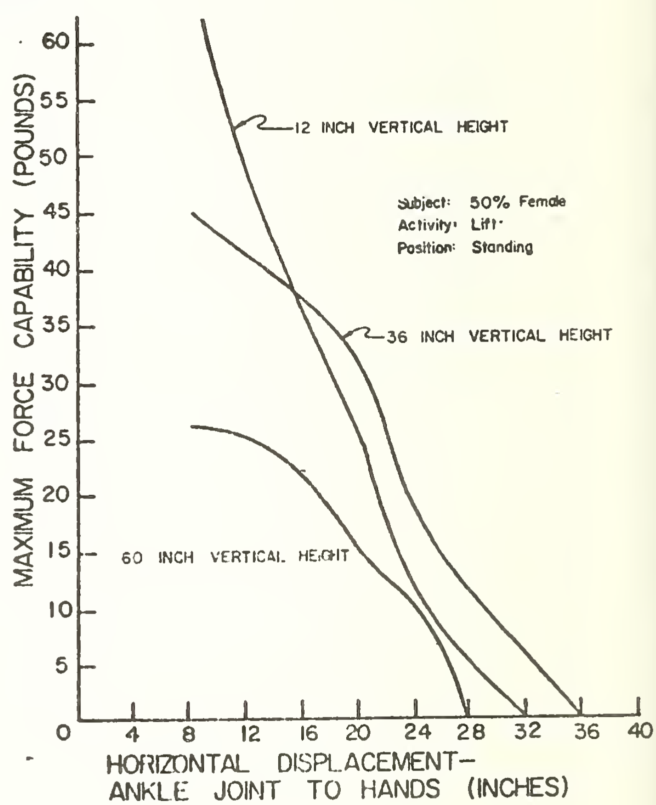
Method: Two-handed Lift
Frequency: Single Lift capability
Distance/Duration/Height: Lifting force from 30.5, 91.4, & 152.4 cm (12, 36 & 60 in) vertical heights
Criterion: Maximum Capable Single Lift

Product/Object Summary

Type: Platform attached to "lifting force meter"
*Size: 45.7 cm (18 inches) across, hand holds at different horizontal displacements from body.
Load Distribution: Not applicable
Presence of Handles and Location: 2 handles, one on each side of platform

Results Summary





Reference (5) Task: Two-Handed, Single Lift Study Approach: Behavioral

American Industrial Hygiene Association: Ergonomic Guide to Manual Lifting.*

The maximum number of pounds that 50 percent of the healthy, male industrial worker population can be expected to lift, is:

HEIGHT of LIFT	Object Width (inches away from the body)				
	10	15	20	25	30
Floor Level to Knuckle Height**	32	30	27	25	23
Knuckle Height to Shoulder Height	30	27	25	23	21
Shoulder Height to Extended Arm Reach	30	27	25	23	21

* Recommendations of AIHA are based upon the results of studies (88), (72), and (67).
**Condition selected as being most relevant to a consumer product lifting task.

Reference (47) Task: Two-Handed Carry Study Approach: Unspecified

Hertzberg, H.T.E. Handbook of Instructions for Aircraft Ground Support Equipment Design (2nd Edition).

The weight of bulky articles, around 76.2 cm. (30 inches) to a side should not exceed 9 kg (20 lbs).

APPENDIX B

Instructions for Subjects

We want you to assume that you are returning a product in need of service from your home to a service facility. More specifically, assume that you must (1) lift and carry the product, by yourself, and without the use of any external aids (carts, wheels, etc.), from your home to your car, (2) drive your car to the repair facility, and (3) lift and carry the product from your car to the repair facility, (assume the latter distance to be approximately one city block). At some point during these return activities, assume that you must carry the product either up or down a single flight of stairs.

With the above assumptions in mind, your job will be to adjust the weight of a simulated product to a level which you believe to be the maximum reasonable weight which you would be willing to handle in a real-life situation. By reasonable, we mean without excessive strain or exhaustion.

Your weight adjustment of the simulated product will be accomplished through the addition and/or removal of lead shot. You have to make enough adjustments so that you get a good feeling for what is too heavy and what is too light. You can never make too many adjustments - but you can make too few. You will be required to perform this adjustment procedure twice today and twice at a later date. After each adjustment procedure you will be asked to actually lift and carry the simulated product the entire length of a hallway and up a single flight of stairs. You will be allowed to rest as frequently as you like during this task, but you should not plan on resting more often than you would normally in a real-life situation.

Remember:

This is not a contest!

We want your judgment of how much weight you feel is reasonable for you to lift and carry when returning a product for repair. Keep in mind that this is a task which would ordinarily be required of you only once or twice a year.

APPENDIX C - RESEARCH PARTICIPANT AGREEMENT

Informed Consent Form

1. Principal Investigator	2. Division/Section	4. Location
Joel J. Kramer	441.04	XX Gaithersburg ☐ Other (specify)

5. Experiment Name Code

Portability Guidelines for Federal Trade Commission

6. Description of Experiment

This experiment is designed to obtain data (information) related to the maximum reasonable size and weight limits for products that are to be returned by consumers for servicing, repair, etc. The participant will be required to adjust the weight of two simulated consumer products (by the addition and/or removal of lead shot) to a level which is believed to be the maximum reasonable weight which he/she would be willing to handle in a real-life situation. The participant will then be required to actually lift the product and carry it a distance of approximately 400 ft. and up a single flight of stairs.

7. Risks to Participant

Potential risks to the participant include all forms of accidental injury normally associated with the lifting and carrying of heavy objects (slips and falls, dropping objects on feet, muscle strain, over-exertion, etc.). The likelihood of such injuries occuring is extremely small, if the participant follows all of the instructions given.

8. Responsibilities of Participant

The participant will:
(1) Attend two, 30-minute experimental sessions, each session taking place on a different day.
(2) Wear flat-bottomed shoes and suitable clothing.
(3) Follow instructions of experimenter(s).
(4) Permit photographs to be taken.
(5) Permit measurements of (a) height, (b) weight, (c) arm reach, (d) shoulder-elbow length, (f) elbow breadth, (g) maximum body breadth, (h) distance from floor to knuckles (i) distance from body vertical center-line to product center-line for one-handed activity, and (j) distance from buttocks to fingers for two-handed activity

9. Responsibilities of Investigator(s).

The investigator(s) will:
(1) Ensure the safety of participants at all times.
(2) Schedule the experimental sessions at times convenient for the participants.
(3) Provide participants with knowledge of results upon completion of the experiment.
(4) Ensure that no data reported for the participants will be identifiable in any publication and that participant data will not be disclosed for any other purpose except as required by law.

10. IT IS UNDERSTOOD THAT EITHER THE PRINCIPAL INVESTIGATOR, THE PARTICIPANT, OR THE PARTICIPANT'S PARENT OR GUARDIAN MAY TERMINATE THE PARTICIPANT'S INVOLVEMENT IN THE RESEARCH AT ANY TIME WITHOUT INCURRING LEGAL LIABILITY FOR SUCH TERMINATION.

11. I hereby certify that my participation is voluntary and that I have read and accept the terms of this agreement.

Participant, or Parent or Guardian (Signature)	Date
12. Principal Investigator (Signature)	Date
13. Early Termination by (Signature)	Date

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APPENDIX D - Semantic Differential Scale used to Evaluate Subjects Opinions Concerning the Weights and Sizes of the Simulated Products Carried.

Instructions: Complete each of the following two statements so that they most accurately express your opinion concerning the (A) weight and (B) size of the simulated product which you have just handled. In completing these statements, keep in mind the specific task requirements which were imposed upon you by the experimenters (e.g. the 400 ft. distance of carry, the stairs, the method of carry used, etc.).

A. The weight of the simulated product was:

1. unreasonable - too light
2. slightly less than the maximum reasonable weight
3. maximum reasonable weight
4. slightly more than the maximum reasonable weight
5. unreasonable - too heavy

B. The size of the simulated product was:

1. unreasonable - too small
2. slightly less than the maximum reasonable size
3. maximum reasonable size.
4. slightly more than the maximum reasonable size
5. unreasonable - too big

APPENDIX E - Basic Descriptive Statistics

In an attempt to maintain both simplicity and technical accuracy, the following discussion is presented in terms of "population statistics" rather than "sample statistics," thus resulting in a discrepancy between the symbols used in the text of this report and those of this Appendix. Sample statistics are often used as estimates of population statistics, and the general concepts are the same for both types. The sample statistic symbols used in the text are $\overline{X}$, sample mean; s, sample standard deviation; n, number of observations in sample; m_s, sample skewness; and m_k, sample kurtosis.

The frequency of occurrence of many human traits (both physical and psychological) within the human population may often be characterized by the so-called "normal distribution," the shape of which is completely determined by its mean, μ, and standard deviation σ. The mean, μ, is a measure of central tendency and in the normal distribution represents (1) the most frequently occurring observation, (2) the midpoint of the range of observations, and (3) that value in the distribution around which all deviations sum to zero. The standard deviation, σ, is a measure of dispersion around the mean and for a finite population of N observations is estimated by the formula

$$\sigma = \sqrt{\sum_{i=1}^{N} \frac{(x_i - \mu)^2}{N}}$$

, where $\sum_{i=1}^{N}$ indicates summation over the entire range of observations (1 through N) and x_i indicates the value of each of the specific observations. In a normal distribution, the percentage of observations falling within plus or minus one, two or three standard deviations of the mean is a constant, these percentages being 68.3%, 95.5% and 99.7%, respectively (see Figure E-1). The percentage of observations occurring between the mean and any given X_i may be found through the use of the formula $Z = (X_i - \mu)/\sigma$, where Z represents a "standard normal score" which can be used with any standard "Z table" to obtain the corresponding percentage of observations.

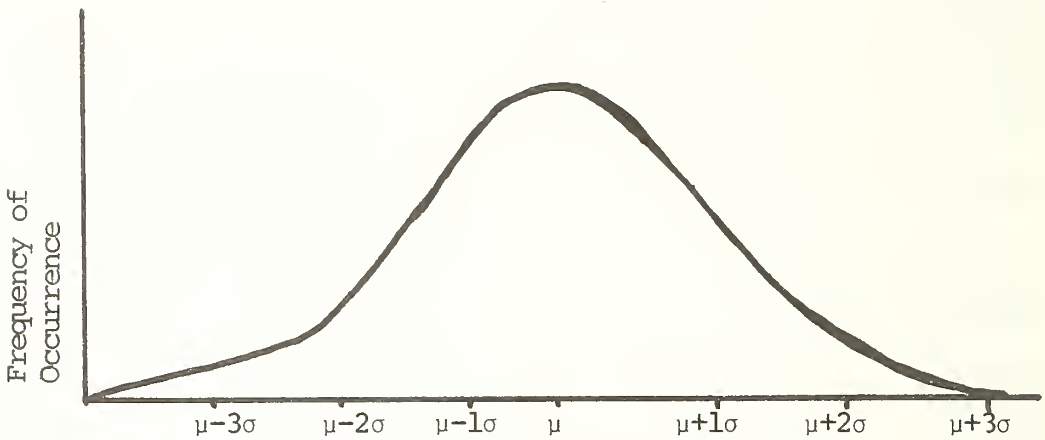

Figure E-1. The Normal Distribution

Some human traits are better characterized by skewed or flattened variations of the normal distribution. In such cases the amount of skewness, m_s, present in the distribution can be estimated by the formula $m_s = \sum_{i=1}^{N} (x_i - \mu)^3/N)/\sigma^3$, while the amount of flatness (kurtosis), m_k, present can be estimated by the formula $m_k = \sum_{i=1}^{N} (x_i - \mu)^4/N)/\sigma^4$. The expected value of m_s is zero in the normal distribution, while positive and negative values of m_s indicate distributions which are positively and negatively skewed, respectively (See Figures E-2 and E-3).

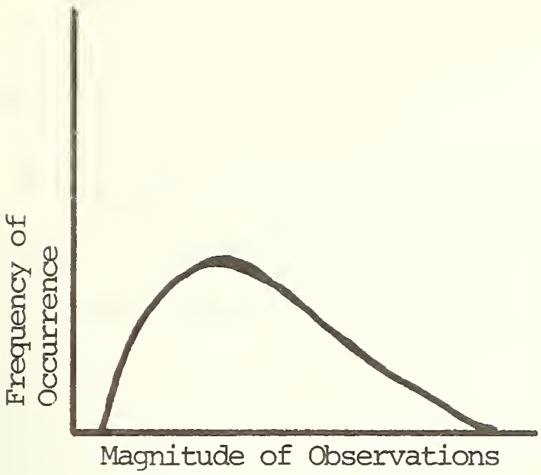

Figure E-2. Positively Skewed Distribution

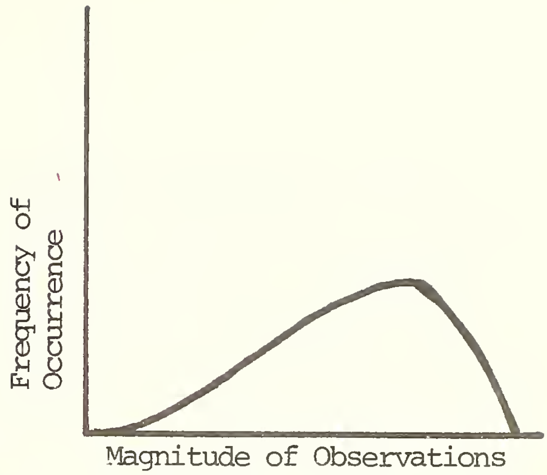

Figure E-3. Negatively Skewed Distribution

The expected value of m_k is three (3) in the normal distribution. Larger values indicate distributions which are peaked or "leptokurtic" in nature (See Figure E-4), while smaller values represent distributions which are flattened or "platykurtic" in nature (See Figure E-5).

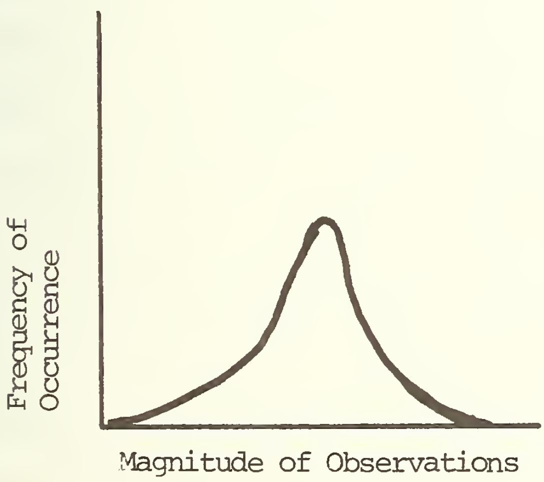

Figure E-4. Leptokurtic Distribution

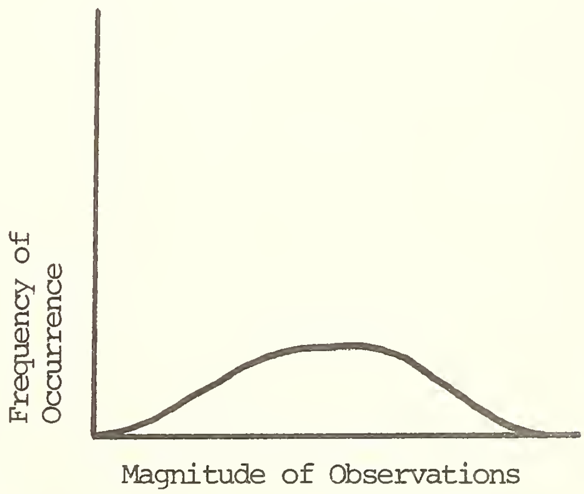

Figure E-5. Platykurtic Distribution

When distributions differ significantly from "normal," population percentiles can no longer be directly derived through the use of the standard Z tables, thus necessitating other statistical techniques to obtain the desired percentile values.

APPENDIX F - Statistical Hypothesis Testing (ANOVA)

Hypotheses concerning the differences between sets of scores collected under various experimental conditions are frequently tested through the use of statistical techniques involving a comparative analysis of between set score variances versus within set score variances. To the extent that these sets of scores are identical (i.e., when the experimental conditions have no significant effects), the ratio (F) of variance between set scores divided by variance within set scores should approximate a value of 1. The larger the difference between sets (i.e. the greater the effects of the experimental conditions), the greater should be the value of F. The level of statistical significance associated with F depends upon both the number of sets of scores, and the number of scores within each set (these numbers are roughly equivalent to the number of "degrees of freedom"). If more than two sets of scores are involved in the analysis of variance, the determination of statistical significance is called an "F-test," or Analysis of Variance (ANOVA), if only two sets of scores are involved, it is called a "t-test." A detailed discussion of the assumptions and computational procedures underlying these tests may be found in any standard statistical textbook. Of importance to the analysis conducted in the present investigation, however, is the requirement that all treatment variances involved in an ANOVA be roughly equivalent (homogeneous). Since the variances associated with male and female data were quite different, it necessitated the computation of separate ANOVA'a for the male and female data sets.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Federal Trade Commission (FTC) has the responsibility for determining what may be reasonably expected of consumers in their fulfillment of the terms of a consumer product warranty. Such determination necessitates, in part, providing an empirical basis for defining and quantifying various factors influencing product portability. This report discusses the problem of defining consumer product portability within the context of a consumer product return activity, offers a working definition of product portability within this context, summarizes and discusses the results and utility of previous portability related studies, and describes the results of a controlled experiment which more directly relates to the task of establishing maximum reasonable product weight for a consumer product return activity. Statistically significant differences in maximum reasonable product weight were found for the variables of method of product carry and sex of customer. No statistically significant differences were found for the variables of consumer age and product size (at least for the sizes chosen for study). Distributions of maximum reasonable weight for product return are presented and recommendations for warranty rulemaking are given.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Anthropometry; biomechanics; carrying; consumer product portability; ergonomics; human factors; lifting; manual materials handling; physiology; psychophysics; safety; warranty

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