A MANUAL MATERIALS HANDLING STUDY OF BAG LIFTING

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Chapter I

INTRODUCTION

Although automation is industry's objective today, manual materials handling (MMH) tasks are unavoidable in most work places. Millions of tons of goods are being handled manually every day.

Due to improper handling techniques or overloads, numerous back injuries and compensation costs have resulted from the manual handling of materials. The lifting of weights which are too heavy is thought to be the major contributor to over 400,000 back injuries suffered in the U.S. each year [9]. The National Safety Council reports that at least 25% of all injuries, accounting annually for 12 million lost workdays and over 1 billion dollars in compensation costs, are associated with the MMH of workers [50]. Recently, a great deal of research has been conducted which has contributed to the reduction of back injuries. In industries, however, the back injuries caused by MMH are still a serious problem.

Lifting is a common task of MMH in industry. Most of the past studies in this field have been concerned with the lifting of <u>boxes</u>. The present research investigated another kind of task which is often used in industry -- bag lifting .

1.1 General Ergonomics Approach

To fit the job to the man is the main role of the ergonomics approach. There are three ergonomics approaches that have been employed to investigate MMH tasks:

1. Physiological Approach: This approach is employed to examine the physical responses during MMH tasks. The physiological criteria often used in the literature are heart rate and oxygen consumption. This approach is usually applied in tasks in which large muscle masses are involved and the load is frequently lifted.
2. Psychophysical Approach: This approach studies the amount of weight people are willing to handle under different task conditions. In the psychophysical approach, subjects are instructed to adjust the amount of load to the maximum load that they can handle without strain or discomfort. The psychophysical approach takes the sensation as well as the physical stimuli into account during the test.
3. Biomechanical Approach: This approach considers the human body segments as the mechanism and employs the principles of Newtonian mechanics to analyze the system. The biomechanics approach is used in heavy slow lifting that is non-repetitive.

In the present research, the physiological approach and the psychophysical approach were used in the bag lifting tasks. The biomechanical approach was not used. However, the subjects' posture, stability and grip style during the bag lifting tasks were observed.

1.2 Bag Lifting Characteristics

A great deal of research regarding box lifting has been done [2, 4, 20, 22, 30, 31, 44]. According to these studies, box lifting characteristics can be classified into three categories -- human characteristics, task characteristics and environmental characteristics.

1. Human Characteristics: Included are sex, age, body weight, strength, physical work capacity (PWC), and anthropometric measurements.
2. Task Characteristics: Included are weight of the load, box size, frequency, height of the lift, starting and ending point of lift, couplings, posture and stability, angle of twist of the body, and location of the box.
3. Environmental Characteristics: Included are temperature, humidity, air velocity, and vibration.

The bag is also a kind of container which is commonly used in industry. Observations in the work places show that some of the task characteristics of bag lifting are different from the box lifting. The main differences between them are as follows:

1. A bag is a container which is soft and flexible. It can be pinched or gripped. The grip style of the bag is different from that of the box.
2. A bag can be considered to be an unstructured box with variable handles [34]. It can be lifted by any portion of the bag.
3. Different types of material are used for bags (e.g. paper, plastics, cloth, plastics coated, and burlap). The different surfaces of bag materials could have an effect on the handling technique.
4. Different packing techniques exist in industries. Some kinds of bags are packed fully (e.g. salt, sugar and flour), while some others are packed quite loosely (e.g. dog food and seed). The packing technique would affect the size of the bag and the stability of the operator.

Some of the above characteristics were selected as the investigated variables in this research.

Chapter II

SCOPE AND OBJECTIVES

2.1 Scope

In order to compare the results to other research in the field of MMH, physiological and psychophysical approaches were used to examine the characteristics of bag lifting tasks. Nine male subjects representative of the U.S. adult population were selected. Simulated tasks were selected so that they could represent the typical MMH tasks. Statistical analysis was employed to analyze the results.

2.2 Objectives

The primary objective of the present study was to investigate the effects of two factors on the bag lifting capacity of workers. These two factors were fullness of the bag, and the use of handles on the bag. Two levels of fullness (70% and 95%) and two conditions for handles (with/without handles) were selected. The physiological approach was employed to determine the effects of these two factors on the physiological responses (oxygen consumption and heart rate). And the psychophysical approach was employed to determine how these two variables (fullness and handles) affected the maximum acceptable weight, oxygen consumption and heart rate. This was the first study to consider fullness and handles as independent variables and to use both the physiological and psycophysical approaches simultaneously in a bag lifting task.

The secondary objective was to compare the generated results for bag lifting with box lifting, attempting to find the differences between these two tasks. Both the physiological and psychophysical approaches were employed in the box lifting experiment with the same experimental conditions as the bag lifting experiment (e.g. lifting height, frequency of lift, and weight lifted). Comparisons were made of the differences in physiological responses (oxygen consumption and heart rate) and psychophysical response (maximum acceptable weight lifted). Experimental observations of the differences between bag/box lifting were also made (e.g. gripping characteristics and lifting posture).

Chapter III

LITERATURE REVIEW

3.1 General

A review of the research conducted in MMH reveals that most of the efforts have focused on "box" lifting/lowering tasks and not on "bag" lifting/lowering tasks. This review of the literature will expound on two studies in the area of bag lifting because of their relevance to the present study. Furthermore, this review will describe the general approaches used for investigating those variables involved in lifting/lowering activities. These variables would pertain to both "box" and "bag" lifting/lowering.

3.2 MMH Study of Bag Lifting

Osgood [23] investigated bag lifting tasks by utilizing the psychophysical approach. The dimensions of the bag and box were 26" (frontal) x 19" (sagittal) x 6" (vertical) and 24" x 19" x 6", respectively. Investigations were made in three diferent ranges (floor to knuckle, floor to shoulder, and knuckle to shoulder), three different heights within each range (10, 20, and 30 inches), and four different frequencies of lift (5, 9, 14 and 60 seconds between lift). Results showed that the average weight lifted in the bag is significantly less than that on the box at an alpha level of 0.05. However, since there were only slight differences between them (1.35 pounds), he suggested that the data presented by Snook [44] for lifting tasks can be applied to bags with several limitations. Unfortunately, the lifting method in Osgood's research was restricted to the vertical plane of flat lying bags. The fullness and handles were not considered as independent variables which would have affected the nature of load and the grip style during lifting.

Garg and Saxena [25] adopted the psychophysical methodology to study the effect of handles and container type on maximum acceptable weight of lift. They studied the effect of three different size mailbags on the lifting tasks. The dimensions (length x diameter) of the three mailbags were 46 x 51; 89 x 56; and 91 x 71 cm. A maximum acceptable weight of box lifting was determined by ten subjects. According to their research, maximum acceptable weight of box lifting was significantly lower when lifting a box without handles, as compared to lifting a box with handles. The average decrement in lifting capacity was 7.2% due to lack of handles. The results also showed that the mean weight lifted in the mailbags (27.5 kg) was found to be significantly different ($p < 0.01$) from the mean weights for the boxes (28.2 kg) and the boxes without handles (26.2 kg). They suggested that the recommendations for maximum acceptable weight based on boxes with handles needed to be adjusted when applied to boxes without handles or to some other type of container. For the effect of three different size mailbags on the lifting task, they reported that there were significant differences ($p < 0.01$) among the three mailbags. However, since there was only a slight difference of value between them, they stated that bag size was not a limiting factor in determining the maximum acceptable weight.

Garg and Saxena [25] filled the bags with used mail and lead shot in their research centering on mailbag lifting task. Osgood [34] inserted wood chips into the bags until they were completely filled. The bags were firmly packed in both of the two studies mentioned above,so that there were no loose ends for gripping the bags.

3.3 Physiological Approach

A number of physiological reponses in the body vary with the level of physical demand. Some of these are oxygen consumption, heart rate, pulmonary ventilation volume, respiration rate, percent of PWC, lactic acid concentration, and body temperature. From the standpoint of practical instrumentation and reliability as indicators, heart rate and oxygen consumption are most useful [1]. In MMH tasks, measurements of energy expenditure are applicable to the study of repetitive work where large muscle masses are involved. The ability to maintain general circulatory homeostasis is indicated by the maximum oxygen uptake [38]. Oxygen consumption is easy to convert to an estimate of metabolic rate and expressed as kilogram calories (kcal) of energy expenditure per unit of time.

Rodgers [37] stated several reasons to measure oxygen consumption in MMH tasks. First, oxygen utilization is the most direct measure of the job's physical demands. Second, measurement of the oxygen demands of the task can be related to an individual's aerobic capacity in order to determine what percent of capacity it requires. Third, the metabolic demands of MMH tasks affect respiration levels and, thus, influence the acceptable exposure limits to physical and chemical agents in the environment.

Heart rate is an indicator of the circulatory capacity. It shows large differences among individuals. Many factors can affect the heart rate, such as environmental conditions, age and emotions. As described by Aquilano [1], it is also important to observe heart rate to assure that individual differences or varying environmental conditions do not impose excessive cardiac stress.

Physical Work Capacity (PWC) refers to a person's maximum aerobic capacity. Percent of PWC is thus a direct index of physical strain for a certain task.

Kamon and Ayoub [27] classified the U.S. male population into five levels according to the age and the adjusted PWC. These values are given in Table 1.

TABLE 1

THE RANGE OF EXPECTED MAXIMAL ADJUSTED PWC (MALE)

Age (yrs)	Max. Adjusted PWC (ml/kg min.)				
	Low	Fair	Average	Good	High
20-29	< 25	25-33	34-42	43-52	> 53
30-39	< 23	23-30	31-38	39-49	> 50
40-49	< 20	20-26	27-35	36-44	> 45
50-59	< 18	18-24	25-33	34-42	> 43
60-69	< 16	16-22	23-30	31-40	> 41

Percent of PWC has been used in literature to recommend working duration. As mentioned by Shephard [38], Bonjer stated the relationship between working time and PWC. He recommended setting the limit at 63% of PWC for one hour, 53% for two hours, 47% for four hours, and 33% for eight hours. The percentage of the recommended PWC intermediate times can be calculated from this formula:

Allowable load (Percent of PWC) = 32.3(log 5700 - logt)

where t is the duration of the activity in minutes.

For example, for 30 minutes' work, percent of PWC = 32.3 (log 5700 -log 30) = 73.6%.

Other authors have proposed 35 to 50 percent of PWC as an acceptable ceiling for a normal eight hour working day. However, Garg and Ayoub [24] mentioned that it is generally accepted in industry that an eight-hour average metabolic rate should not exceed approximately 5 kcal/min or 33% of individual PWC. Further, it is generally accepted that mean heart rate should not exceed 110 to 115 beats/min. Table 2 summarizes the recommendations in the literature as to the relationship of physiological strain and work duration.

Troup [49] stated that measurements of energy expenditure were made originally to determine the industrial work load for women, and then several researchers utilized the physiological approach to distinguish between lifting methods and to determine reasonable rates of work. In recent years, numerous researchers have studied the effect

TABLE 2

PHYSIOLOGICAL STRAIN AND WORK DURATION +

	Moderate	Heavy	Very Heavy	Extremely Heavy
Oxygen Consumption (L/min.)	0.5-1.0	1.0-1.5	1.5-2.0	> 2.0
Heart Rate (beats/min.)	90-110	110-130	130-150	> 150
Percent of PWC	< 33%	33-50%	50-75%	> 75%
Work Duration	8 hrs	1-8 hrs	20 min-1hr	< 20 min

+ Adapted from Astrand, et al. [3], DHHS (NIOSH) [50].

of different variables on the MMH tasks by using the physiological approach. [1, 2, 23, 26].

Few prediction models for energy expenditure have been developed. Asfour [2] recognized that knowledge of the energy cost of a task can help in determining whether the task is within the physical capabilities of the individuals, the frequency and duration of rest periods, and aid in the pre-employment screening of applicants.

Garg, et al.[23] developed regression equations to estimate metabolic energy expenditure rate for MMH operations. The basic assumption in this model is that the net total metabolic cost of activities can be estimated by summing their net state individual metabolic costs as obtained from their separate performance. Asfour [2] proved the invalidity of this assumption in his research.

Asfour [2] developed a model of lifting/lowering tasks based on the following variables: weight of load, frequency of lift/lower, box length, box width , height range of lift, and angle of twist of the body. These models were developed by ten male students after they were given a six weeks' training period.

The containers used in the previous studies are mostly boxes or cartons. No finding in the literature used bags as containers in MMH task by physiological approach.

3.4 Psychophysical Approach

Psychophysics is a very old branch of Psychology that is concerned with the relationship between sensations and their physical stimuli; very rarely is this a one-to-one relationship [44]. As reported by Stevens [46], psychophysics may be said to have been born when scientists began to think seriously about the possibility that they might measure sensation. Snook [44] stated that psychophysics has been applied to practical problems in many areas, such as the scales of effective temperature, loudness and brightness, and ratings of perceived exertion (RPE).

To apply the principle of psychophysics to men at work is to utilize the human capability to judge the subjectively perceived strain at work in order to determine voluntarily accepted work stresses. In terms of MMH tasks, the subject can adjust one task variable, usually the weight of load or frequency, to the maximum load so that he/she can handle without strain or discomfort.

A few researchers have studied the maximum acceptable weight for male and female industrial workers [4, 7, 9, 10, 43]. The psychophysical models attempt to establish correlations between physical characteristics and lifting capacity of industrial workers [8].

Psychophysical capacity models have been developed by several investigators [7, 16, 28, 30]. Ayoub, et al. [11] compared these models and pointed out the limitations of each model. They found that most of these models were applicable to only one or two height levels for lifting, and that all of these models applied to lifting in the sagittal plane.

Considerable disagreement or high discrepancy of the psychophysical data was pointed out by several researchers [25, 2]. Asfour [2] was the first one who utilized physiological and psychophysical approaches simultaneously to develop the energy cost prediction models. To compare these two approaches, he pointed out that at the low frequency of lift/lower, the lifting/lowering capacity data obtained by the psychophysical approach are much lower than those obtained by the physiological approach. At high frequencies of lift/lower, however, the two approaches appeared to be in agreement. He also suggested utilizing biomechanical, physiological, and psychophysical approaches simultaneously to determine the handling capacities of individuals.

Table 3 summerized the work capacity recommended by the previous researchers which is related to the present study.

3.5 Biomechanical Approach

The basis of biomechanics is the application of engineering principles to biological and physiological systems.

For the infrequent MMH tasks, the primary concern is local muscle fatigue and the loading of certain musculoskeletal joints. As presented by Ayoub [8], the spinal column of the human body has been shown to have a

TABLE 3

MAXIMUM ACCEPTABLE WEIGHT LIFTED FROM FLOOR TO SHOULDER HEIGHT IN THE SAGITTAL PLANE +

Researcher	Weight (lbs)	Frequency (lifts/min)	Comment
McDaniel (1972)	63.00	1	S.D.=18.0 Adjusted for frequency
Snook and Ciriello (1974)	53.74	1	S.D.=12.88
Ayoub (1978)	51.21	1	S.D.=12.11
Ayoub (1978)	47.00	6	S.D.=11.76
Snook (1978)	63.81	1	S.D.=17.12
Ayoub (1980)	48.84	6	45.72 cm height lifted in sagittal plane

+ Adapted from Ayoub [7,10,11]

poor mechanical efficiency from the mechanics' point of view. Interveterbral discs may be destroyed by spinal forces as low as 1568N (160 kg).

Both static and dynamic biomechanical models have been developed that evaluate the effect of a given load and predict the working capacity to perform a given task.

Examples of static biomechanical models are given by Chaffin [12], Chaffin and Baker [13], Martin and Chaffin [29], Garg and Chaffin [21], and Fish [18]. Ayoub [8] recognized that most of these models assume that the body performs a lifting task very slowly, and therefore, they negelect the effects of acceleration.

Examples of dynamic models are given by Fisher [19], El-Bassoussi [17], Tichauer [48], Muth, et al. [33], and Smith [39]. These models can cover a large range of lifting postures and can provide stress data at several points of the musculoskeletal system [10].

Several researchers have employed the biomechanical approach to determine the work capacity. Garg and Ayoub [24] have stated that the acceptable weight limit based on muscle strength and biomechanical modeling is generally higher than the value based on the psychophysical methodology.

3.6 Variables Related to MMH tasks

For investigating the operator's capability in a certain MMH task, the variables involved in the task should first be defined. Traditionally, these factors can be grouped into three categories: operator variables, task variables, and environmental variables.

Ayoub, et al. [6] listed a comprehensive summary of variables affecting MMH capacity which is shown as Table 4.

3.7 Container Characteristics

According to Ayoub [5], containers can be characterized in terms of the following:

1. Weight of the container and its contents;
2. Distribution of the weight inside the container;
3. Geometry (shape and bulk) of the container;
4. Stiffness of the load/or of the container itself;
5. Possible modes of interface between the container and the man performing the task.

Weight of the load and container size have been studied more than any other container characteristics. Findings in the literature have shown that an increase in the load to be lifted leads to an increase in the metabolic energy rate [1, 2, 20, 22, 26, 31].

From the biomechanics' point of view, increasing the container size in the sagittal plane results in an increase of the moment arm which increases the force exerted by the back muscle. Tichauer [47] utilized a biomechanical

TABLE 4

VARIABLES AFFECTING MANUAL MATERIALS HANDLING CAPACITY

Individual Variables
Physical: Age, sex, anthropometry, strength, mobility, motor, and psychomotor function.
Physiological: Physical work capacity, aerobic capacity, anaerobic capacity, metabolic capacity, and circadian tolerance.
Psychological: Motivation, emotional status, job satisfaction, attitudes towards work.
Task Variables
Load handled: Weight, size, shape, distribution of the load, ease or difficulty of coupling, the degree of shift of the load in the container.
Workplace layout: Degree of movement required, obstacles, postures dictated, distances moved and direction of movement.
Level of demand: Both static and dynamic-frequency of lift, duration of lift, acceleration and velocities of lift, shift duration, degree of precision, degree of body members involvement.
Environmental Variables
Environmental conditions include heat and cold stress, noise and vibration factors, lighting, toxic agents, traction, stability of the work platform.
+ Adapted from Ayoub [6]

approach to study the effect of the box size in the sagittal plane on lifting capacity. He introduced the concept of the biomechanical lifting equivalent which was caculated as follows:

$$M = (8 + L/2)(W)$$

where M = the biomechanical lifting equivalent, in lb-in.

8 = approximate distance in inches from the joint of lumbar spine to front of abdomen

L = length in inches of the side of the object lying in the sagittal plane

W = the weight of the load in pounds

Ayoub, et al. [7] adopted a psychophysical approach to study the effect of box size in the sagittal plane on lifting capacity of workers. They reported that the amount of weight lifted was inversely proportional to the box size in the sagittal plane and the relationship between them being linear.

Mital and Ayoub [32] employed the physiological approach to study the effect of the box size in three dimensions on lifting/lowering tasks. The results showed that the box size in both sagittal and frontal planes significantly affected the heart rate and oxygen consumption for lifting activities.

3.8 Handles

Handles are considered simple devices used to aid in grasping and manipulating the work load. Rigby [36] showed that containers fitted with handles are less likely to be dropped. Ayoub [5] pointed out that the position of handles on a load or container can have a large effect biomechanically on the forces the operator must exert.

Drury [15] studied the effect of handle diameter on holding time, comfort rating, and reduction in grip strength using different handle diameters. He made the following recommendations on handle design:

1. Use handles on all containers.
2. Allow the load to be carried with both hands rather than one hand.
3. Make handles or hand hold cutouts 115 mm long, with a 25-38 mm diameter bearing surface and a hand clearance of 30-50 mm.
4. Design handles to distribute the load over the largest possible surface area of the hand and fingers.

Research on the effects of handles on the energy expenditure during the MMH tasks is rare.

Drury [15] mentioned that Nielson (1978) showed that handholds can reduce oxygen consumption in a lifting task by 11% and can increase the exertable forces by up to 20% over no handholds or handles.

According to Mital and Ayoub [32], lifting boxes without handles resulted in an extra 0.17 kcal/min. energy expenditure. However, the difference was not significant from a practical standpoint.

3.9 Fullness

No findings in the literature mentioned the fullness of the container as an investigated variable of MMH tasks. The container used in the past studies was usually the box. Due to the stiffness of the box surface, the fullness of it was not an important factor.

Drury [14] reported a 40% decrease in lifting capacity for non-compact objects (20 x 20 x 20 inches) as compared to the lifting capacity for compact objects (8.5 x 19 x 19 inches). The container used by Drury was still a box and the torque of the task was the main factor considered in that study.

Chapter IV

METHODS AND PROCEDURES

4.1 Subjects

Nine male subjects were selected from the student population at Texas Tech University. The subjects' ages varied between 18 and 33, with the average age being 24.9. Selected on the basis of their body weight and stature, they constituted a representative sample of the U.S. male population [45]. The subjects body weight and stature are specified in Table 5.

4.2 Apparatus

The lifting appratus used by Asfour [2] was also used in this study. The shelf was fixed at the height of 50 inches from the floor. A Beckman Metabolic Measurement Cart and four channel Narco Bio-systems Physiograph were used to measure the oxygen consumption and heart rate, respectively. Figure 1 shows the layout of this experiment and the sequence of lifting a bag from floor to 50" height.

The following pieces of equipment were also used in this experiment:

TABLE 5

SUBJECTS' HEIGHT AND WEIGHT WITH THEIR CLASSIFICATION

	Stature		Weight	
Subject	Cm	Percentile of U.S. male population +	Kg	Percentile of U.S. male population +
S1	176.3	67.1%	76.08	53.7%
S2	172.7	46.5%	69.61	33.7%
S3	173.6	52.1%	70.18	35.6%
S4	184.8	95.3%	89.57	87.7%
S5	186.8	97.7%	83.90	76.1%
S6	165.6	13.4%	82.54	72.8%
S7	178.1	76.0%	74.83	49.8%
S8	174.9	59.5%	78.57	61.4%
S9	174.2	55.5%	66.44	25.1%
Mean	176.3		76.86	
S.D.	6.39		7.56	

\+ According to the public health survey, 1962 -- U.S. male [45].
Height: Mean = 173.24 cms S.D. = 6.89
Weight: Mean = 74.89 kgs S.D. = 12.62

(a)

(b)

(c)

(d)

Figure 1: THE SEQUENCE OF LIFTING A BAG FROM FLOOR TO 50" HEIGHT

1. Bicycle ergometer: This was used to measure Physical Work Capacity (PWC).
2. Strength test equipment used by Asfour [2] was used to determine strength measurements.
3. Anthropometric measurement equipment.
4. Face mask with harness.
5. Plexiglass two-way breathing valve.
6. A buzzer with electronic timing circuit was used to pace the subjects' lift.

4.3 Experimental Design

Due to the characteristics of the bag lifting tasks, fullness and handles were selected as independent variables in this experiment. A randomized complete block design with factorial treatment combinations was utilized. Each subject was considered as a block.

4.3.1 Experiment (A) -- Physiological Approach in Bag Lifting

Physiological responses (heart rate and oxygen consumption) were measured during this experiment.

a) Independent Variables

(1) Fullness: Fullness is defined as follows:

Fullness = (Volume of the objects within the bag)

/(Volume of the bag)

In industries, some kinds of bags are packed fully (e.g. sugar, salt and flour), while some others are packed quite loosely(e.g. dog food and seed). This experiment was designed to determine if the packing technique was a significant factor in bag lifting. Two levels of fullness -- 70% and 95% -- were selected.

(2) Handles: Handles were devised so that the operator could lift the container easily. Ayoub [7] suggested in his "Guidlines for Job Design" that properly designed handles should be provided. However, most bags currently used in industry have no handles. The present study considered the handles as an independent variable in bag lifting tasks; the presence and absence of handles on bags were examined.

(3) Replication: To increase the power of the significant test and to test the interaction of the variables, two repetitions were conducted.

b) Dependent Variables

Oxygen consumption, heart rate and percent of PWC were used as the dependent variables. They are the basic physiological responses used for determining the energy expended and cardiovascular strain on the subject during a physical activity.

c) Controlled Variables

(1) Weight of the load -- 45 pounds

(2) Frequency -- 6 lifts/min.

(3) Height to be lifted -- floor to 50"

(4) Size of the bag --

26" (frontal) x 18" (sagittal) x 5" (vertical)

(5) Location of the bag -- the sagittal plane in front of the subject

(6) Handling technique -- free style

Summary of the variables used in this experiment is shown in Table 6.

4.3.2 Experiment (B) -- Psychophysical Approach in Bag Lifting

The main difference between Experiment (A) and Experiment (B) was that the subjects were allowed to adjust the weight of the load to the maximum amount that they could lift without strain or discomfort. Each subject was given 10 minutes to decide the maximum weight he was willing to lift, and then lift that weight for 6-10 minutes, while heart rate and oxygen consumption were recorded. The weight of the load, heart rate,

TABLE 6

SUMMARY OF EXPERIMENTAL DESIGN OF EXPERIMENT (A) -- PHYSIOLOGICAL APPROACH IN BAG LIFTING

Independent Variables	Levels
Fullness	70% and 95%
Handles	with handles and without handles
Subjects	nine males
Replication	two
Dependent Variables	
Heart rate	
Oxygen consumption	
Percent of PWC	
Controlled Variables	**Explanation**
Bag material	cloth
Weight of the load	45 pounds
Height of lift	floor to 50"
Frequency	6 lifts/min.
Size of the bag	26" x 18" x 5"
Location of the bag	sagittal plane
Handling technique	free style

oxygen consumption and percent of PWC were treated as dependent variables. The summary of variables is shown in Table 7.

The bag characteristics during a particular experiment were controlled as follows:

a) The size of the bag was fixed.

b) A certain weight and fullness were specified before the test.

c) Lead shot, sand, and seed were used as the weight for the bag. They mixed up in the bag so that the distribution of the weight was even.

d) A velcro strap both opened and closed the top of the bag so that the subjects could easily adjust the weight of the bag. The weight of the bag could be adjusted by changing the ratio of the lead shot, sand and seed. The fullness of the bag was kept the same.

f) The construction of the bag is shown in Figure 2.

4.3.3 Box Lifting Task

The secondary objective of this study was to compare the results of bag lifting tasks with box lifting tasks. Six subjects performed both the bag lifting and box lifting tasks in this study.

The size of the box was selected so that the dimensions in the sagittal and frontal planes were almost the same as

TABLE 7

SUMMARY OF EXPERIMENTAL DESIGN OF EXPERIMENT (B) -- PSYCHOPHYSICAL APPROACH IN BAG LIFTING

Independent Variables	Levels
Fullness	70% and 95%
Handles	with handles and without handles
Subjects	nine males
Replication	two
Dependent Variable	
Weight of the load	
Oxygen consumption	
Heart Rate	
Percent of PWC	
Controlled Variables	**Explanation**
Bag material	cloth
Frequency	6 lifts/min.
Size of the bag	26" x 18" x 5"
Location of the bag	sagittal plane
Height of lift	floor to 50"
Handling technique	free style

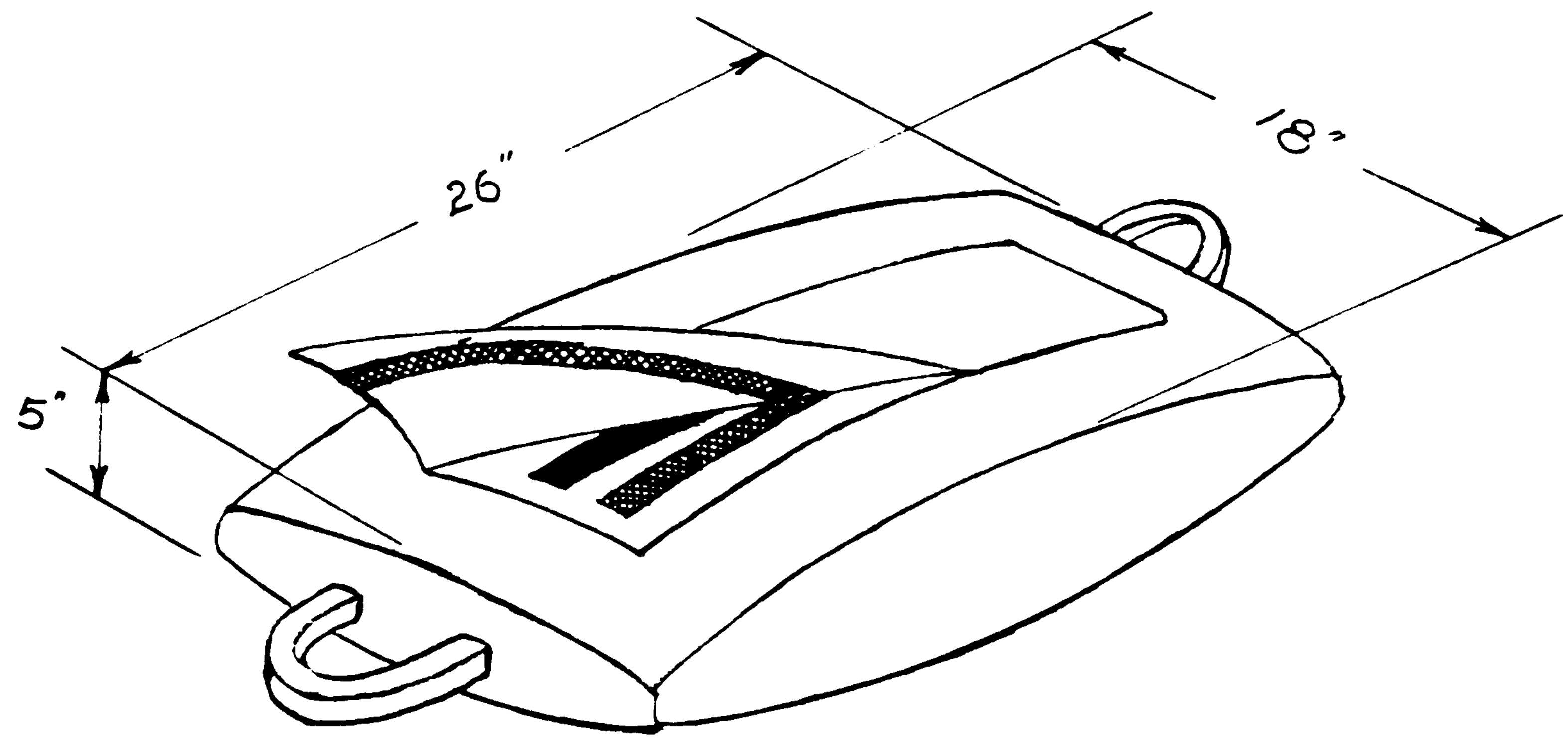

Figure 2: CONSTRUCTION OF THE BAG

the bags used in Experiment (A) and (B). Box dimensions vs. bag dimensions were 26" (frontal) x 15" (sagittal) x 10" (vertical) and 26" x 18" x 5", respectively. For both tasks, the weight (45 pounds), height of the lift (floor to 50") and frequency (6 lifts/min) were kept constant.

Both physiological and psychophysical approaches were used in the box lifting tasks. The dependent variables and experimental procedures of the box lifting tasks were the same as Experiments (A) and (B) of the bag lifting tasks.

4.4 Experimental Procedures

All subjects were asked to fill out and sign a personal data and consent form (See Appendix B). A physical exam as well as a general medical history were requested.

The subjects had to be familiarized with the tasks and experimental procedures before data were recorded. A short training period was given so that the subjects could become familiar with the tasks and procedures of the experiment.

Anthropometric data were then collected for each subject. Anthropometric data for each subject are given in Appendix C.

The PWC was estimated on a bicycle ergometry device using submaximal techniques. Each subject was asked to work at three different submaximal loads, (e.g. 400, 600 and 900 kpm/min.), for 4 minutes at each load. Heart rate and oxygen consumption were recorded for the last minute of each load. The regression line for heart rate and oxygen consumption was then computed using the method of least-squares regression. Then the PWC was estimated via extrapolation by using the maximum heart rate which was calculated as: 220 - the age of the subject. The PWC values of all nine subjects and the classification used by Kamon and Ayoub [27] are given in Appendix D.

The protocal for the strength test was adopted from Ayoub, et al. [7]. The following strength measurements were made: static shoulder strength, static arm strength, static leg strength, static back strength and composite strength. The strength data for all nine subjects are given in Appendix E.

The nine subjects were divided into three groups. Each group consisted of three subjects, one was lifting, one was lowering, while the other was resting. Each subject followed the sequence of lifting, lowering, and then resting.

All subjects performed the eight treatment combinations in Experiment (A). The experimental design layout is shown in Table 8. Each treatment combination lasted from 6 to 10 minutes. For the first few minutes no recordings were made. After the subject had attained his steady state plateau, three minutes of physiological data was recorded. The average value over this three minute period was recorded as the value for heart rate and oxygen consumption. After performing each lifting task, the subjects were given a 20 minute rest.

TABLE 8

THE EXPERIMENTAL DESIGN LAYOUT

		Fullness		Handles	
		70%	95%	with	without
S1	Rep 1				
	Rep 2				
S2	Rep 1				
	Rep 2				
.					
.					
.					

The procedure of Experiment (B) was similar to that of Experiment (A). The difference was that each subject was given ten minutes to decide the maximum weight he was willing to lift. Then he was asked to lift that weight for

6 to 10 minutes. Three minutes of steady state data for oxygen consumption and heart rate were then recorded.

Each data collection session lasted for a maximum of four hours. The subjects were asked to adhere to a regiment of normal sleep and food intake during the 24 hours prior to the experiment. The physiological responses of all subjects were monitored constantly. The reason was that should a subject appear fatigued or become over-stressed the experiment would cease immediately.

Chapter V

RESULTS AND DISCUSSION

5.1 General

The main objective of this study was to determine the effects of the two characteristics: fullness and use or non-use of handles on a bag lifting task. The statistical analysis was conducted using statistical analysis systems package (SAS 79.4).

A total of 144 bag lifting combinations were performed by nine subjects. As mentioned in Chapter IV, oxygen consumption, heart rate, and percent of PWC were the response variables for Experiment (A), the physiological approach. The response variables in Experiment (B), the psychophysical approach, were weight of the load, oxygen consumption, heart rate, and percent of PWC. A comparison of bag lifting versus box lifting was also conducted.

5.2 Statistical Analysis of Experiment (A)

The physiological approach was used in Experiment (A). The independent variables considered were: fullness, handles, subjects, and replications. The response variables were: oxygen consumption, heart rate, and percent of PWC. The experimental data for each subject is given in Appendix F.

The analysis of variances of the data is given in Tables 9, 10 and 11. Since there were no significant interactions (at 10% level) between subjects and task variables shown in a preliminary analysis, the subjects * task interactions were pooled together with the error term. The replication is assumed to be a random variable having no interaction with the other independent variables. To determine if the results would apply to the general population, the data were analyzed with the subjects treated as a random variable. Handle usage had significant effect (at 10% level) on oxygen consumption and percent of PWC in this experiment. However, when examining the effect of handles on lifting tasks, there was no significant increase in heart rate. This finding could be attributed to the possibility that various extraneous factors (i.e. environmental, emotional, etc.) influenced the subjects' heart rate. Furthermore, the data revealed that the lifting task generated a PWC of less than 50% of the subject's maximum capacity. Research has shown that the relationship between oxygen consumption and heart rate loses some of its linearity when a subject's PWC is less than 50% [3].

TABLE 9

ANOVA FOR EXPERIMENT (A) WITH OXYGEN CONSUMPTION AS THE DEPENDENT VARIABLE

SOURCE	DF	SS	MS	F-VALUE
MODEL	12	0.6021	0.0502	5.03
ERROR	59	0.5881	0.0100	
TOTAL	71	1.1902		

SOURCE	DF	SS	F-VALUE	
SUBJECTS	8	0.53710	6.74	***
FULLNESS	1	0.00194	0.19	
HANDLES	1	0.03790	3.80	*
REPLICATION	1	0.02486	2.49	
FUL*HAN	1	0.00033	0.03	

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

TABLE 10

ANOVA FOR EXPERIMENT (A) WITH HEART RATE AS THE DEPENDENT VARIABLE

SORCE	DF	SS	MS	F-VALUE
MODEL	12	18377.084	1531.424	18.76
ERROR	59	4816.125	81.629	
TOTAL	71	23193.209		

SOURCE	DF	SS	F-VALUE	
SUBJECTS	8	18181.028	27.84	***
FULNESS	1	24.851	0.30	
HANDLES	1	28.753	0.35	
REPLICATION	1	140.281	1.72	
FUL*HAN	1	2.170	0.03	

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

TABLE 11

ANOVA FOR EXPERIMENT (A) WITH THE PERCENT OF PWC AS THE DEPENDENT VARIABLE

SOURCE	DF	SS	MS	F-VALUE
MODEL	12	4116.111	343.009	26.68
ERROR	59	758.519	12.856	
TOTAL	71	4874.631		

SOURCE	DF	SS	F-VALUE	
SUBJECTS	8	4038.607	39.27	***
FULNESS	1	2.657	0.21	
HANDLES	1	42.335	3.29	*
REPLICATION	1	32.093	2.50	
FUL*HAN	1	0.419	0.03	

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

The overall mean of oxygen consumption, heart rate, and percent of PWC with the different levels is summarized in Table 12. The Table shows that an extra 0.23 kcal/min (45.9 ml/min) is consumed when lifting a bag without handles. That is, the energy expenditure of a bag with handles and without handles was 6.665 kcal/min and 6.895 kcal/min, respectively. The difference is so small that there is no practical significance in the physiological responses. Similar results were found by Mital [31], in box lifting trials with and without handles. He reported an extra 0.17 kcal/min of energy is consumed by lifting boxes without handles. Figure 3 shows the physiological responses of bag lifting tasks.

5.3 Statistical Analysis of Experiment (B)

The psychophysical approach was used in Experiment (B). Fullness, use or non-use of handles, subjects, and replications were the independent variables. Weight of the load, heart rate, oxygen consumption, and percent of PWC were the response variables. The statistical analysis systems package (SAS 79.4) was used to perform all of the analysis.

TABLE 12

OVERALL RESPONSE MEANS FOR EXPERIMENT (A)

		FULLNESS		HANDLES	
		70%	95%	Handles	No-Handles
Heart Rate (beats/min)	Mean	129.2	128.0	127.9	129.2
	S.D.	17.80	18.59	18.82	17.54
Oxygen Consumption (L/min)	Mean	1.351	1.361	1.333	1.379
	S.D.	0.144	0.115	0.127	0.129
Percent of PWC	Mean	47.00	47.38	46.42	47.96
	S.D.	8.362	8.324	8.273	8.344

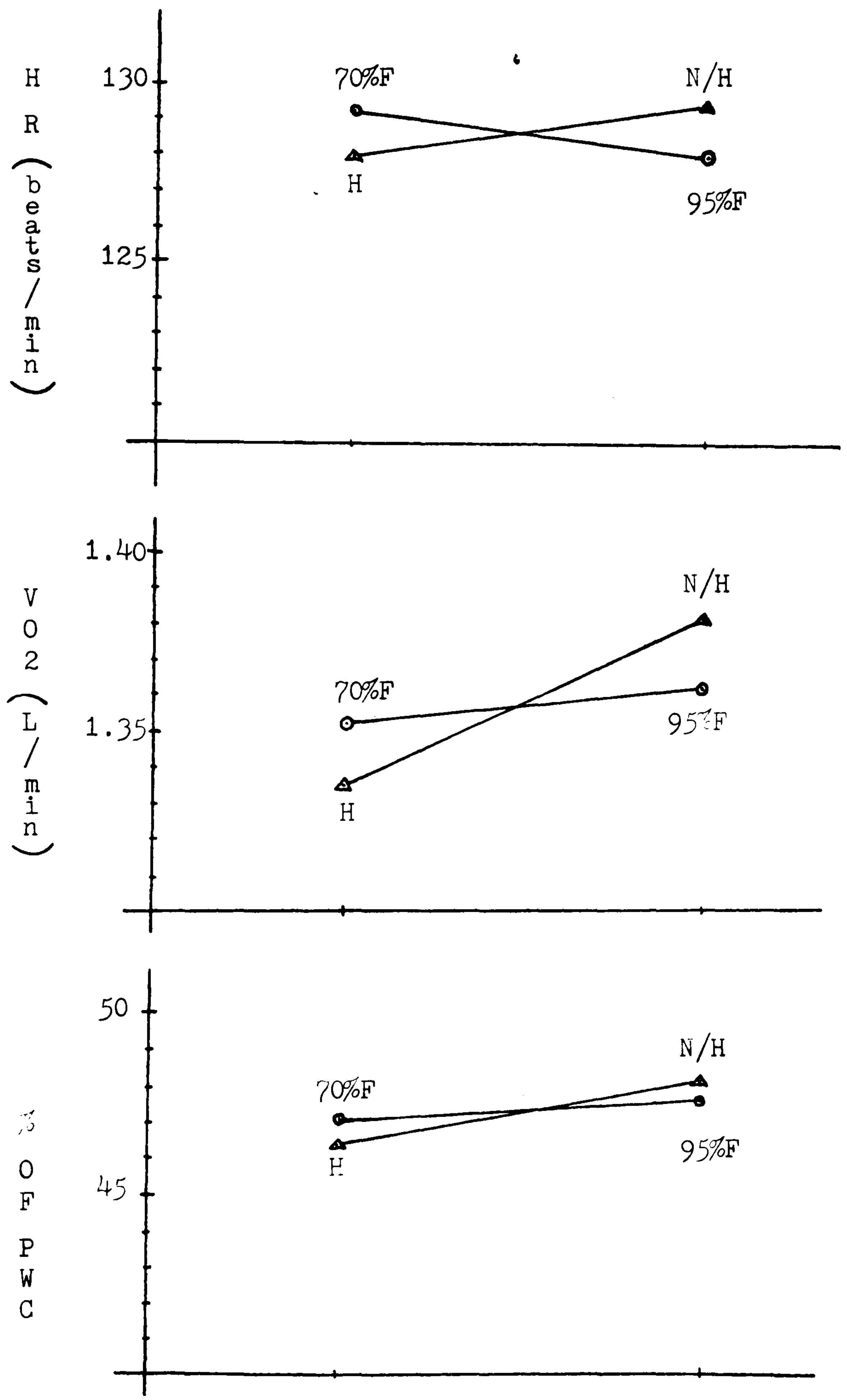

Figure 3: PHYSIOLOGICAL RESPONSES OF BAG LIFTING

There were no significant interactions (at 10% level) in the preliminary analysis between subjects and the task variables. Therefore, the subject * task variables interactions were pooled together with the error term. The replication was assumed to be a random variable having no interaction with the other independent variables. The analysis of variances is given in Tables 13, 14, 15 and 16. Shown are the significant differences in the maximum acceptable weight (at 1% level) between the two fullness levels and the with/without handles variable. No significant difference in the fullness and handles interaction was found. The variables heart rate, oxygen consumption, and percent of PWC showed no significant difference (at 10% level) in response to bag fullness. Significant differences (at 10% level) did appear in the percent of PWC and oxygen consumption when the handles variable was introduced. The fact that there were notable differences in the PWC percentage indicates that the with/without handles variable affected the subjects' ability to adjust the loads of weight in order to produce a uniform level of physical response.

TABLE 13

ANOVA FOR EXPERIMENT (B) WITH LOAD AS THE DEPENDENT VARIABLE

SOURCE	DF	SS	MS	F-VALUE
MODEL	12	2187.842	182.320	9.75
ERROR	59	1102.715	18.690	
TOTAL	71	3290.557		

SOURCE	DF	SS	F-VALUE	
SUBJECTS	8	987.640	6.61	***
FULLNESS	1	579.701	31.02	***
HANDLES	1	613.083	32.80	***
REPLICATION	1	0.133	0.01	
FUL*HAN	1	7.283	0.39	

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

TABLE 14

ANOVA FOR EXPERIMENT (B) WITH OXYGEN CONSUMPTION AS THE DEPENDENT VARIABLE

SOURCE	DF	SS	MS	F-VALUE
MODEL	12	2.49758	0.20813	6.28
ERROR	59	1.95502	0.03314	
TOTAL	71	4.45261		

SOURCE	DF	SS	F-VALUE	
SUBJECTS	8	2.20702	8.33	***
FULLNESS	1	0.03489	1.05	
HANDLES	1	0.17395	5.25	**
REPLICATION	1	0.03587	1.08	
FUL*HAN	1	0.04585	1.38	

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

TABLE 15

ANOVA FOR EXPERIMENT (B) WITH HEART RATE AS THE DEPENDENT VARIABLE

SOURCE	DF	SS	MS	F-VALUE
MODEL	12	34565.597	2880.466	30.47
ERROR	59	5576.632	94.519	
TOTAL	71	40142.229		

SOURCE	DF	SS	F-VALUE	
SUBJECTS	8	34389.918	45.48	***
FULLNESS	1	0.361	0.004	
HANDLES	1	174.533	1.85	
REPLICATION	1	0.333	0.004	
FUL*HAN	1	0.451	0.005	

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

TABLE 16

ANOVA FOR EXPERIMENT (B) WITH PERCENT OF PWC AS THE DEPENDENT VARIABLE

SOURCE	DF	SS	MS	F-VALUE
MODEL	12	11351.36	945.95	21.17
ERROR	59	2636.54	44.69	
TOTAL	71	13987.90		

SOURCE	DF	SS	F-VALUE
SUBJECTS	8	11033.05	30.86 ***
FULLNESS	1	40.83	0.91
HANDLES	1	156.94	3.51 *
REPLICATION	1	51.51	1.15
FUL*HAN	1	69.03	1.54

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

The overall mean values of response variables are given in Table 17. Figure 4 shows the psychophysical response (load) of bag lifting tasks. The average value of the PWC was 55.3% in Experiment (B). This agrees with industry recommendation that work duration limits be set between 20 minutes and 1 hour whenever PWC percentage of the work load reaches 50% [see Table 2].

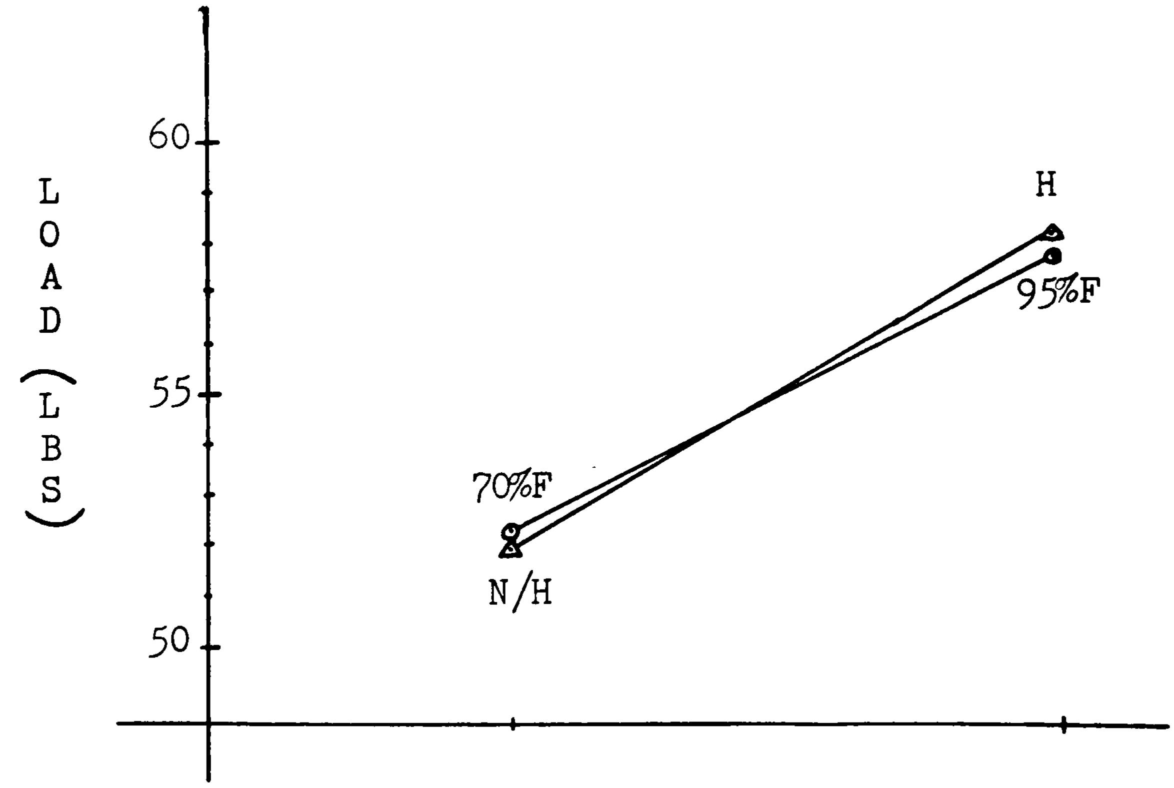

Figure 4: PSYCHOPHYSICAL RESPONSE (LOAD) OF BAG LIFTING

TABLE 17

OVERALL RESPONSE MEANS FOR EXPERIMENT (B)

		Fullness		Handles	
		70%	95%	Handles	No-Handles
Load (lbs)	Mean	52.03	57.71	57.79	51.95
	S.D.	6.46	5.98	6.01	6.31
Heart Rate (beats/min)	Mean	137.9	138.0	139.5	136.4
	S.D.	39.3	24.3	24.1	23.7
Oxygen Consumption (L/min)	Mean	1.556	1.600	1.628	1.529
	S.D.	0.265	0.237	0.243	0.251
Percent of PWC	Mean	54.55	56.06	56.78	53.83
	S.D.	14.63	13.58	13.25	14.82

Direct comparison of psychophysical responses from the past and present studies is difficult due to differences in experimental conditions. Variables such as container characteristics, load distribution, handling techniques, frequency, and the height lifted make comparisons speculative at best. A comparison of the data of the present study to several past studies is in Table 3 indicates that the present and past data are within the same range. The difference was due primarily to the differences in instructions given to the subjects. The author was concerned with a short work period (30 minutes) instead of an eight hour work day (see Appendix A).

5.4 Bag Lifting Vs. Box Lifting

Six subjects (S4-S9) performed both the bag lifting and box lifting tasks in the present combined study. Box dimensions vs. bag dimensions were as follows: 26"(frontal) x 15"(sagittal) x 10"(vertical), and 26" x 18" x 5" respectively. For both tasks the weight (45 pounds), frequency (6 lifts/min), and height of the lift (floor to 50") were held constant. The mean value of oxygen consumption for the bag lifting (1.377 L/min) was less than the box lifting value (1.454 L/min). The mean value for weight lifted increased by using the bag (53.49 lbs) as opposed to the box (48.62 lbs). Student T-tests were conducted to compare these mean values. Table 18 shows the results of the bag lifting and box lifting T-test. Significant differences (at 5% level) in the mean weight lifted when comparing bags to boxes was found in the literature [25, 34].

Further comparisons were conducted by T-tests. These tests compared bag lifting tasks with different fullness levels and handle use with a box lifting task using the handles. It was discovered that significant differences were found between the box lifting task and the following tasks:

1. Lifting 70% fullness bag with handles (at 5% level)
2. Lifting 95% fullness bag with handles (at 1% level)
3. Lifting 95% fullness bag without handles (at 10% level)

The following were thought to be the main reasons for these results:

1. Container Characteristics: The rectangular bag's being soft and flexible was also a more pleasant texture to grip, even though it constantly changed shape, while the rectangular wooden box was rigid, and kept the same shape during the lift.

TABLE 18

COMPARISON WITH THE BAG LIFTING DATA AND BOX LIFTING DATA +

Approach	Variable	Container	Mean	S.D.	T-Value
PHYSIOLOGICAL	Oxygen Consumption	Bag ++	1.377	0.134	-1.146
		Box +++	1.454	0.222	
	Heart Rate	Bag	125.6	18.68	0.214
		Box	124.4	14.23	
	Percent of PWC	Bag	44.88	7.836	-0.833
		Box	46.97	7.346	
PSYCHOPHYSICAL	Load	Bag	53.49	5.80	2.597 **
		Box	48.62	5.87	
	Oxygen Consumption	Bag	1.497	0.213	0.661
		Box	1.450	0.240	
	Heart Rate	Bag	129.7	24.29	1.128
		Box	121.3	16.43	
	Percent of PWC	Bag	48.65	9.66	1.480
		Box	46.32	2.52	

\+ Comparison conducted by Student T-test
++ Bag data based on 48 observations
+++ Box data Based on 12 observations
** Significant at 5% level

2. Load Stability: Because it was soft and flexible, the bag's load distribution changed throughout the lift. Centralization of the load due to the repeated lifting resulted in less stress biomechanically. A more compact load due to bag flexibility allowed the bag to be lifted closer to the body and reduced the biomechanical stress of lifting.
3. Handling Techniques: Free style techniques were employed for lifting both bags and boxes. Several differences in handling techniques were observed during the experiment.

   The starting point: Because the bag flexed when lifted, the bag was still in partial contact with the floor as the lift started. This resulted in less initial force being required to perform the lift.

   The Method of Lifting: The box's being rigid kept the hands the same distance apart, which also meant the flat bottom had to be kept the same level when setting the box on the platform. However, the bag would flex and allow the hands to come together while moving the load closer into the body. Usually when lifting the bag without the use of handles, the subject would grasp the diagonal corners of the bag.

   The Ending Point: The lifting height was 50" from floor to platform. The box required a short push onto the platform after being carefully lifted to the proper height. Due to the bag's flexibility, it could be more easily thrown onto the platform. Furthermore, it was found that bag lifting allowed greater freedom in the lifting method used by the subjects, thus avoiding the awkward postures which a subject assumed when lifting a box onto a platform. For example, in box lifting a subject must bend slightly backward in order to place the box onto the platform. In bag lifting the subject could adjust his grip in such a way as to avoid bending backward.

5.5 Physiological Vs. Psychophysical Approaches

There are three approaches that have been adopted by different researchers to investigate MMH tasks: (1) physiological approach, (2) psychophysical approach, and (3) biomechanical approach. As mentioned in Chapter I, each approach has its advantages for certain characteristics. Most studies have been conducted using each method separately. Few studies have been conducted using two of the approaches simultaneously [2]. The present study employed both the physiological and the psychophysical approaches simultaneously on the same group of subjects. This allowed a direct comparison of the results that are generated by the two differing approaches.

Analysis of Experiment (A) showed only slight differences in oxygen consumption and heart rate between lifting bags with and without handles; this difference was of no practical significance. Similar findings were reported by Mital [31]. Analysis of Experiment (B) showed that a subject was willing to lift significantly more weight when handles were provided on the bag.

Arguments favoring the psychophysical methodology state that this method is simple to use and understand, and has the ability to integrate various sensory inputs into a meaningful response [26]. That is, the psychophysical approach integrates both physiological and biomechanical considerations into a singular meaningful sensory response. In the present research, due to such task variables as handles versus no handles and fullness of the bag, the subject must assume certain postures which could affect the biomechanics of lifting (e.g. gripping style, concentrated forces on the hand, subject's lifting posture). And, it is the change in these biomechanical factors which affects the subject's judgment on the maximum acceptable load and contributes to the differences found within the psychophysical approach.

5.6 Discussion

The physiological approach of this study has shown that fullness and handles have no practical effect on the oxygen consumption and heart rate. The average values for oxygen consumption and heart rate were 1.356 L/min and 128.6 beats/min, respectively. Based on the psychophysical approach, significant effects (at 1% level) of fullness and handles appeared when considering the maximum acceptable weight that a person could safely lift. The average increase in the weight lifted was 11.2% (5.84 lbs) due to providing handles on the bag, while a 10.9% (5.68 lbs) increase was due to an increasing of the bag's fullness from 70% to 95%. The average percent of PWC for the psychophysical approach was 55.3%. This percentage, according to recommendations from literature on industrial workers, is considered a 'very heavy' level [see Table 2]. The author was concerned with the subject's lifting capacity for a short work period (30 minutes) instead of an 8 hour work day. Due to the different work period used, a higher PWC percentage resulted during the experiment.

This would seem to suggest that providing handles and filling the bags to their uppermost capacity would increase productivity from the psychophysical standpoint. The fullness of the bag reduces the load shifting caused by handling. Handles make it easier to control the bag with the palms and to reduce the finger fatigue. Mital [31] also stated that handles should be provided on boxes from a safety viewpoint, although the differences in the physiological responses are small. The handles provide a firm, secure grip so as to insure safe handling [25, 31].

There were significant differences in the load lifted between bag and box lifting tasks. The average weight lifted in the bag was 53.49 lbs as opposed to 48.62 lbs for the box. This increase in the bag lifting average is 10.1% (4.87 lbs) more than the average box weight lifted. This indicates that the recommended maximum acceptable weight for box lifting tasks should not apply to bag lifting tasks. Therefore, when using a bag as a container, adjustments for the maximum acceptable weight should be considered. Similar findings were reported by Garg and Saxena [25].

Osgood [34] reported a slight decrease (1.35 lbs) in the maximum acceptable weight when he employed bags as opposed to boxes. His results showed a significant difference between the two containers. However, Osgood used plastic bags and required the subjects to lift them flatly. He did not consider variables such as fullness and use of handles in the study of the bag/box lifting tasks.

It is worthwhile to note that there are large individual differences that exist among the nine subjects. Apparently there are three PWC percentage levels reached using the psychophysical approach:

High Level (50-87%): S1, S3 and S6

Medium Level (40-75%): S2, S8 and S9

Low Level (35-51%): S4, S5 and S7

This was possibly attributed to the different motivations the subjects had during the experiment. Separate ANOVA analysis were conducted for each group. Both handles and the 95% fullness showed significant effects (at 5% level) on the maximum acceptable weight lifted. This agrees with the analyzed results taken from the nine subjects. Unfortunately, the small sample size selected for this study made it difficult to categorize the subjects into the different PWC percentage levels. However, it could prove interesting, thus meriting further study.

From a comparison of the physiological and psychophysical approaches, it is apparent the differing methodologies could result in different conclusions. Based on the present research, when taking the biomechanical factors into consideration the psychophysical approach shows better indices when compared to the physiological approach. Further study is needed, using physiological, psychophysical and biomechanical approaches simultaneously to determine the handling capacities of an individual.

Chapter VI

CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to determine the effects of fullness and handles on bag lifting tasks. The secondary objective was to compare bag/box lifting. The following conclusions were drawn based on the present study.

6.1 Conclusions Based Upon Bag Lifting Experiment

1. Physiological Approach: When examining the oxygen consumption values generated under the with/without handles condition, these values were statistically significant (at 10% level). However, from a practical viewpoint, these differences were small enough to be considered negligible in an industrial setting. That is, the use of handles or no handles would make little difference in the physiological cost inherent in a bag lifting task.
2. Psychophysical Approach:
   1) The maximum acceptable weight to be lifted by a person is significantly lower (at 1% level) when performing a bag lifting task without handles as compared to use of handles. In the present study,

the average decrease in maximum acceptable weight was 10.1% (5.84 lbs) due to the non-use of handles.

2) The maximum acceptable weight a person can lift was significantly higher (at 1% level) when lifting a bag at the 95% fullness, as compared to the 70% fullness. This study found the average increase in the maximuum acceptable weight was 11.0% (5.7 lbs).

3. When examining the results generated, under the physiological and psychophysical approaches, a consideration of the unique effects that certain task variables have within an approach is important. For example, the use of handles and the fullness of the bag had its significant effects on the amount of weight lifted under the psychophysical method, while the same task variables did not affect such physiological responses as heart rate and oxygen consumption. These differences are due to the biomechanical factors which could affect the subjective judgment of the maximum acceptable load within the psychophysical approach. A cautious selection of methods should be taken before conducting the experiments.

4. A short work period (30 minutes) was the time focus in this study. In this time frame, the percentage of PWC a person can safely work within was 55.3% for the nine

subjects tested. Individual variability was large for this study. Noted in the data were three percentage levels of the PWC. This study showed that the subjects in the highest level worked at least 50% of their PWC during the short period mentioned, while subjects in the lowest level did not attain a level over 50% for their PWC.

5. Due to differing individual, task and environmental conditions, it is difficult to compare this present study to past research. However, the results of the present study are in accordance with the recommendations found in the literature for industrial workers.

6.2 Conclusions Based Upon The Differences In The Physical Characteristics Between a Bag And a Box

Because of the differences in the physical characteristics between a bag and a box (e.g. size, material, rigidity, and contents), the following were observed:

1. The maximum acceptable weight was significantly affected by the container type (at 5% level). An average increase of 10% (4.87 lbs) in weight was noted when using a bag type container instead of box container.

2. The lifting technique for bags was shown to differ from the box lifting techniques. Bag lifting techniques proved more advantageous than box lifting in this study.

6.3 Recommendations For Future Study

This has been the first study done considering fullness and handles as independent variables on bag lifting tasks. This research indicates that further studies are needed for such considerations as load distributions and task characteristics of MMH tasks such as: bag materials, bag size, weight of the load, frequency and height of the lifts.

More research on short work periods also needs to be done. A large sample size should be selected to determine the percent of PWC a person could be expected to maintain during a lifting task.

More comparisons on bag/box lifting should be conducted so that the recommendations based on box lifting can be adjusted for bag handling.

It is also felt that further investigation of MMH tasks should include non-sagittal plane lifting, variable lifting heights, and the use of physiological, psychophysical and biomechanical approaches simultaneously.

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Appendix A

INSTRUCTION OF PSYCHOPHYSICAL APPROACH FOR SUBJECTS

The objective of this study is to determine the weight lifting ability of individuals in a representative work situation. It is an experiment to find reasonable quantities that normal healthy persons can lift from floor to 50" high at the rate of 6 lifts/min.

THIS IS NOT A TEST TO DETERMINE YOUR MAXIMUM WEIGHT LIFTING CAPACITY. I repeat, THIS IS <u>NOT</u> A TEST TO DETERMINE YOUR MAXIMUM WEIGHT LIFTING CAPACITY. Rather, it is a study to find <u>reasonable</u> <u>quantities</u> -- I repeat, <u>reasonable quantities</u> that individuals can lift repetitively under the specified conditions.

We want you to imagine that you are loading a truck during a normal working day, getting paid for the amount of work that you do. In other words, the more weight you lift the more money you make. You are expeced to work continuously at least 30 minutes, as hard as you can, without straining yourself or without becoming unusually tired, weakened, overheated, or out of breath.

ONLY YOU WILL ADJUST THE WORKLOAD. If you feel that you can work harder without getting overloaded, add more weight to the bag. If you feel you are working too hard and could not keep up the rate for a long period, you should remove some weight from the bag. Remember, only you will adjust this workload.

DO NOT BE AFRAID TO MAKE ADJUSTMENTS. 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.

REMEMBER .... THIS IS NOT A CONTEST.

EVERYONE IS NOT EXPECTED TO DO THE SAME AMOUNT OF WORK.

WE WANT YOUR JUDGMENT ON HOW HARD YOU CAN WORK WITHOUT BECOMING UNUSUALLY TIRED.

TAKE IT EASY.

Remember to adjust the weight, when necessary, so that the bag represents the maximum weight that you would be willing to lift at this pace and height.

Appendix B

PERSONAL DATA AND CONSENT FORM

A MANUAL MATERIALS HANDLING STUDY OF BAG LIFTING

NAME: ------------------------------- Date: ------------

Name and phone number of individual to be contacted in case of emergency:

Name and phone number of physician and physican's hospital:

CHECK IF SUSCEPTIBLE TO:

Shortness of Breath: Dizzyness: Headaches:

Fatigue: Pain in arm, shoulder, or chest:

IF SO, EXPLAIN: --

Are you currently taking any type of medicine? If so, explain:

Have you had or do you now have any problem with your blood pressure?

If so, explain: --

In the last six months, have you had any type of surgery or serious illness? If so, explain:

In the last six months, have you had any back pain, particularly in the lower back? If so, explain:

Have you had or do you now have a hernia? Corrective date:

Have you had your normal amount of sleep within the past 24 hours?

Have you had your normal amount of food within the past 24 hours?

PLEASE READ CAREFULLY

I have truthfully answered the questions to the best of my knowledge, pertaining to my personal data. I hereby give my consent for my participation in the project entitled: A Manual Materials Handling Study of Bag Lifting. I understand that the person responsible for this project is Dr. J. L. Smith (806) 742-3410. He or his authorized representative (806) 742-3543 has explained that these studies are part of a project that has the objective of assessing the physiological response to lifting bagged materials and compare those responses to previous work involving tote box lifting.

Dr. J. L. Smith or his representative has agreed to answer any inquiries I may have concerning the procedures and has informed me that I may contact the Texas Tech University Institutional Review Board for the Protection of Human Subjects by writing them in care of the Office of Research Services, Texas Tech University, Lubbock, Texas 79409, or by calling (806) 742-3884.

He or his authorized representative has (1) explained the procedure to be followed and indentified those which are experimental and (2) described the attendant discomforts and risks: (1) Briefly these procedures are: to lift a 45 pound bag of material from the floor to a height of 50 inches at a rate of 6 lifts per minute and also to add weight to the bag until I reach but do not exceed my maximum physical ability to do the task under the specified conditions. Strength tests and a submaximal test for physical work capacity will also be conducted.

If this research project causes any physical injury to you, treatment is not necessarily available at Texas Tech University or at the Student Health Center, or any program of insurance applicable to the institution and its personel.

Financial compensation must be provided through your own insurance program. Further information about these matters may be obtained from Dr. J. Knox Jones, Jr., Vice President for Research and Graduate Studies, (806)742-2152, Room 118 Administration Building, Texas Tech University, Lubbock, Texas 79409.

I understand that I will not derive any therapeutic treatment from participation in this study. I understand that I may discontinue my participation in the study at any time I choose without prejudice.

I understand that all data will be kept confidential and that my name will not be used in any reports, written or unwritten.

SIGNATURE OF SUBJECT: DATE:

Signature of Project Director
or his authorized representative:

Signature of Witness to Oral Presentation:

Appendix C

ANTHROPOMETRIC DATA OF SUBJECTS

Anthropometric Measure	S1	S2	S3	S4	S5
Weight (lbs)	167.8	153.5	154.8	197.5	185.0
Stature (cms)	176.3	172.7	173.6	184.8	186.8
Acromial Height (cms)	141.7	134.2	141.6	152.7	153.9
Trochanteric Ht. (cms)	90.6	85.0	89.3	95.7	97.7
Tibiale Ht. (cms)	49.9	44.7	50.3	51.5	53.6
Ankle Ht. (cms)	7.2	5.4	7.5	7.7	7.0
Elbow Ht. (cms)	110.0	104.4	111.7	117.4	120.4
Wrist Ht. (cms)	82.5	78.5	84.0	88.8	92.4
Shoulder-Elbow Ln. (cms)	37.4	35.0	34.4	38.5	37.9
Forearm-Hand Ln. (cms)	47.6	46.6	47.5	51.9	49.6
Biacromial Breadth (cms)	43.8	41.4	40.2	42.5	40.0
Bideltoid Breadth (cms)	47.4	46.1	44.4	49.3	45.6
Hand Length (cms)	19.1	18.3	18.6	20.1	19.3
Foot Length (cms)	25.5	26.1	26.2	27.3	28.0
Neck Circ. (cms)	41.9	39.0	36.8	40.8	38.0
Shoulder Circ. (cms)	118.0	113.5	111.7	121.7	115.9
Chest Circ. (cms)	96.0	92.0	92.9	103.2	95.4
Waist Circ. (cms)	84.3	82.1	82.2	92.1	88.0
Buttock Circ. (cms)	94.5	93.2	93.9	100.9	95.7
Thigh Circ. (cms)	58.1	55.9	56.8	60.3	56.1
Calf Circ. (cms)	34.7	35.8	37.7	38.7	41.0
Biceps (Flexed) (cms)	31.3	29.9	29.6	35.2	32.2
Forearm (Flexed) (cms)	29.6	28.4	27.4	32.2	28.7
Wrist (cms)	16.9	16.4	15.5	17.7	16.1

Appendix C

ANTHROPOMETRIC DATA OF SUBJECTS (Cont'd)

Anthropometric Measure	S6	S7	S8	S9
Weight (lbs)	182.0	165.0	173.3	146.5
Stature (cms)	165.6	178.1	174.9	174.2
Acromial Height (cms)	133.7	145.3	145.5	142.1
Trochanteric Ht. (cms)	80.0	91.1	93.8	92.4
Tibiale Ht. (cms)	45.3	47.4	49.8	54.6
Ankle Ht. (cms)	6.9	6.4	6.8	8.9
Elbow Ht. (cms)	103.5	112.2	110.4	108.9
Wrist Ht. (cms)	79.4	87.9	88.2	84.0
Shoulder-Elbow Ln. (cms)	32.5	36.0	34.6	35.2
Forearm-Hand Ln. (cms)	45.1	46.7	47.5	47.0
Biacromial Breadth (cms)	40.8	42.7	40.3	40.8
Bideltoid Breadth (cms)	52.8	47.1	46.2	46.4
Hand Length (cms)	17.6	18.7	18.9	18.6
Foot Length (cms)	23.9	26.7	26.6	26.0
Neck Circ. (cms)	42.2	40.2	37.0	36.1
Shoulder Circ. (cms)	128.3	114.7	115.3	110.4
Chest Circ. (cms)	102.3	97.0	103.3	92.0
Waist Circ. (cms)	100.4	79.6	87.9	81.2
Buttock Circ. (cms)	101.3	97.5	98.9	92.9
Thigh Circ. (cms)	63.8	55.7	57.9	51.7
Calf Circ. (cms)	36.6	37.6	38.9	35.7
Biceps (Flexed) (cms)	35.2	32.4	30.9	29.8
Forearm (Flexed) (cms)	29.7	29.5	30.6	28.2
Wrist (cms)	17.1	17.3	16.5	16.8

Appendix D

PWC OF THE SUBJECTS AND THEIR CLASSFICATION

Subject	Age	PWC (L/min)	Adjusted PWC + (ml/kg min.)	Classification ++
S1	26	2.275	29.90	Fair
S2	19	2.816	40.29	Average
S3	26	2.596	36.99	Average
S4	30	3.026	33.78	Average
S5	33	3.862	46.03	Good
S6	21	2.735	33.14	Fair
S7	23	4.131	55.21	High
S8	22	2.514	32.00	Fair
S9	25	2.700	40.64	Average
Mean	25	2.962	38.66	
S.D.	4.416	0.625	8.01	

+ Adjusted PWC calcuated as PWC/body weight

++ Based on Kamon and Ayoub [27]

Appendix E

STRENGTH TEST DATA FOR THE SUBJECTS (LBS)

Subject	Shoulder	Arm	Leg	Back	Composite
S1	129.7	86.7	325.3	197.3	348.3
S2	122.7	101.7	322.7	183.7	326.3
S3	146.3	105.0	327.3	173.0	327.3
S4	233.3	130.0	598.0	244.7	511.3
S5	104.7	69.7	267.7	176.3	254.3
S6	148.7	110.0	419.3	210.0	297.3
S7	164.3	115.7	340.0	180.7	309.3
S8	169.7	92.3	384.7	180.7	372.3
S9	117.7	89.3	316.0	131.3	274.3
Mean	148.6	100.0	366.8	186.4	335.6
S.D.	38.37	17.83	96.75	30.55	75.05

Appendix F

EXPERIMENTAL RAW DATA

KEY

SUBJ = Subject

CONT = Container
1. Bag
2. Box

FUL = Fullness
1. 70%
2. 95%

HAN = Handles
1. With Handles
2. Without Handles

REP = Replication

Physiological Data:

VO2 = Oxygen Consumption (L/min)

HR = Heart Rate (beats/min)

PMAX = Percent of PWC (%)

Psychophysical Data:

LOAD = Weight of Load (lbs)

AVO2 = Oxygen Consumption (L/min)

AHR = Heart Rate (beats/min)

APMAX = Percent of PWC (%)

SUBJ	CONT	FUL	HR	REP	VO2	HR	PMAX	LOAD	AVO2	AHR	APMAX
1	1	1	1	1	1.224	159.0	53.80	61.0	1.963	162.3	86.29
1	1	1	1	2	1.272	157.7	55.91	50.6	1.535	149.3	67.47
1	1	1	2	1	1.463	147.2	64.31	48.0	1.600	158.0	70.33
1	1	1	2	2	1.405	142.3	61.76	56.2	1.953	164.3	85.85
1	1	2	1	1	1.452	163.3	63.82	68.4	1.620	173.0	71.21
1	1	2	1	2	1.395	148.0	61.32	60.0	1.572	161.7	69.10
1	1	2	2	1	1.275	140.0	56.04	66.2	1.737	160.3	76.35
1	1	2	2	2	1.387	158.7	60.97	63.0	1.845	160.0	81.10
2	1	1	1	1	1.316	128.0	46.73	50.5	1.530	134.3	54.33
2	1	1	1	2	1.157	129.7	41.09	58.6	1.755	161.7	62.32
2	1	1	2	1	1.285	127.0	45.63	42.0	1.403	136.0	49.82
2	1	1	2	2	1.140	124.5	40.48	42.4	1.395	137.7	49.54
2	1	2	1	1	1.173	129.0	41.65	62.4	1.714	149.0	60.87
2	1	2	1	2	1.234	138.0	43.82	56.9	1.590	147.3	56.46
2	1	2	2	1	1.566	139.7	55.69	53.8	1.385	155.7	49.18
2	1	2	2	2	1.373	140.3	48.76	63.5	2.015	163.3	71.56
3	1	1	1	1	1.453	117.0	55.97	59.8	1.917	156.0	73.84
3	1	1	1	2	1.265	116.7	48.73	68.2	2.253	166.3	86.79
3	1	1	2	1	1.200	117.7	46.22	58.5	1.965	153.0	75.69
3	1	1	2	2	1.378	134.3	53.08	46.4	1.537	139.3	59.21
3	1	2	1	1	1.381	111.0	53.20	64.2	1.877	144.0	72.30
3	1	2	1	2	1.260	116.3	48.54	70.0	2.033	163.0	78.31
3	1	2	2	1	1.190	115.3	45.84	58.8	2.077	165.0	80.01
3	1	2	2	2	1.295	127.3	49.88	53.7	1.530	145.0	58.94
4	1	1	1	1	1.335	107.7	44.12	55.8	1.443	110.3	47.69
4	1	1	1	2	1.550	117.0	51.22	46.9	1.240	102.3	40.98
4	1	1	2	1	1.266	113.3	41.84	39.3	1.083	94.7	35.79
4	1	1	2	2	1.353	103.7	44.71	44.5	1.197	128.3	39.56
4	1	2	1	1	1.303	113.3	43.06	54.8	1.233	95.3	40.75
4	1	2	1	2	1.373	112.7	45.37	53.0	1.343	110.3	44.38
4	1	2	2	1	1.369	110.3	45.24	46.8	1.107	90.7	36.58
4	1	2	2	2	1.217	106.3	40.22	50.0	1.563	100.7	51.65
5	1	1	1	1	1.625	123.3	42.47	51.5	1.730	110.7	44.80
5	1	1	1	2	1.500	114.7	39.21	48.5	1.743	114.0	45.13
5	1	1	2	1	1.600	102.3	41.43	44.0	1.467	106.3	37.99
5	1	1	2	2	1.673	119.0	43.98	48.8	1.630	108.0	42.85
5	1	2	1	1	1.428	99.7	37.53	54.0	1.680	103.7	43.50
5	1	2	1	2	1.560	115.0	40.39	53.7	1.813	111.7	47.41
5	1	2	2	1	1.498	102.7	38.79	54.0	1.680	109.7	43.50
5	1	2	2	2	1.613	111.7	41.77	46.0	1.207	101.0	31.25
6	1	1	1	1	1.257	141.7	45.96	60.0	1.503	161.7	54.95
6	1	1	1	2	1.298	150.0	47.46	57.1	1.713	154.3	62.63
6	1	1	2	1	1.527	156.3	55.83	56.7	1.800	171.0	65.81
6	1	1	2	2	1.460	139.0	53.38	48.5	1.377	156.3	50.35
6	1	2	1	1	1.438	141.7	52.58	61.0	1.720	166.3	62.89

SUBJ	CONT	FUL	HR	REP	VO2	HR	PMAX	LOAD	AVO2	AHR	APMAX
6	1	2	1	2	1.280	154.7	46.80	62.3	1.877	148.0	68.63
6	1	2	2	1	1.411	151.0	51.59	53.4	1.593	163.0	58.24
6	1	2	2	2	1.376	141.7	50.31	52.0	1.463	140.0	53.49
7	1	1	1	1	1.323	113.7	32.02	62.3	1.753	114.7	42.44
7	1	1	1	2	1.133	110.0	27.43	56.2	1.660	114.7	40.18
7	1	1	2	1	1.440	127.3	34.86	54.5	1.460	106.7	35.34
7	1	1	2	2	1.344	116.7	32.53	50.5	1.503	109.0	36.39
7	1	2	1	1	1.410	116.0	34.13	64.8	1.770	118.7	42.84
7	1	2	1	2	1.386	111.3	33.55	67.0	1.720	124.3	41.63
7	1	2	2	1	1.448	112.7	35.05	52.5	1.513	122.7	36.63
7	1	2	2	2	1.328	113.3	32.14	59.8	1.605	114.7	38.85
8	1	1	1	1	1.547	162.7	61.54	51.4	1.543	175.3	61.39
8	1	1	1	2	1.247	115.3	49.59	56.3	1.500	170.0	59.67
8	1	1	2	1	1.423	163.3	56.62	44.5	1.010	155.7	40.18
8	1	1	2	2	1.217	153.0	48.40	50.0	1.440	152.0	57.28
8	1	2	1	1	1.363	160.7	54.22	58.0	1.160	171.3	46.15
8	1	2	1	2	1.333	142.3	53.04	63.2	1.573	147.3	62.59
8	1	2	2	1	1.577	151.3	62.72	52.3	1.567	162.7	62.32
8	1	2	2	2	1.385	143.0	55.10	57.1	1.530	141.5	60.86
9	1	1	1	1	1.183	133.0	43.82	52.3	1.260	121.0	46.67
9	1	1	1	2	1.180	113.0	43.71	47.8	1.313	132.0	48.61
9	1	1	2	1	1.257	138.0	46.56	49.5	1.303	129.7	48.27
9	1	1	2	2	1.337	114.3	49.51	54.0	1.553	146.0	57.53
9	1	2	1	1	1.160	111.3	42.97	53.3	1.290	127.7	47.78
9	1	2	1	2	1.200	111.0	44.45	58.5	1.653	148.0	61.24
9	1	2	2	1	1.323	131.0	49.01	56.5	1.563	131.7	57.90
9	1	2	2	2	1.247	115.5	46.18	52.5	1.397	129.7	51.73
4	2			1	1.360	113.3	44.94	54.3	1.367	102.3	45.17
4	2			2	1.307	101.3	43.18	55.0	1.400	99.0	46.27
5	2			1	1.878	121.3	49.36	44.5	1.813	118.3	47.67
5	2			2	1.817	116.7	47.76	42.0	1.725	109.0	45.35
6	2			1	1.187	143.7	43.39	49.2	1.360	150.7	49.73
6	2			2	1.247	140.7	45.58	47.0	1.237	143.0	45.22
7	2			1	1.543	116.7	37.36	57.0	1.750	113.3	42.36
7	2			2	1.517	107.0	36.71	57.7	1.773	113.3	42.92
8	2			1	1.473	137.3	58.61	42.5	1.247	133.7	49.59
8	2			2	1.537	142.3	61.13	45.1	1.253	138.3	49.86
9	2			1	1.207	128.0	44.70	46.3	1.267	120.3	46.92
9	2			2	1.373	124.0	50.87	42.8	1.210	114.7	44.82