WORKSHOP PROCEEDINGS

CRITERIA FOR RESEARCH ON THE HAZARDS OF MANUAL MATERIALS HANDLING

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PREFACE

by Forrest E. Rieke, M. D.

For many decades it has been assumed that a large number of personal work injuries arise from mishandling of materials. These injuries are attributed to strain in lifting, to slipping and falling, or to dropping of the load. Critical review of the literature on injuries and on material handling reveals a sharp focus on protection of the load, very little on protection of the worker. Also evident are many untested assumptions about causality and too little validated knowledge about measurement of human ability to lift or move loads safely. If workers are to be successfully selected, instructed and protected from damage, more facts and better methods are required.

This study is concerned with research requirements regarding the hazards of manual material handling. It includes a search of the literature, identification of gaps in knowledge, and development of a matrix for systematic closure of those gaps. Such tasks are complicated by large variations in humans, in loads, and in the work environment. The goal of the study is clear - safety for both the worker and the load or package. Routes to the goal are obscure in light of present knowledge.

The study is limited to the unaided human act of lifting, carrying and releasing an object having definable mass and form. As an approach to their relationships, a literature taxonomy has been defined which includes several system components: worker, material/container; task requirements; and work practices actually used. It is recognized that personal damage from the hazards of material handling will vary widely, depending on disparities in host, agent, and the environment. Human responses to the stresses of the physical act of handling loads needs to be studied to enable a comprehensive definition of "hazards" of such activities. As a start, responses have been categorized into "hazard indices" including injury indices, physiologic indices, and behavioral indices.

There are variations and transpositions of agent, host and environment which complicate this study. The agent ... package or load ... is assumed to have a wide spectrum of size, shape and consistency; it may range from a bale of cotton, to a case of canned food, a television set, a barrel of oil or a patient in a nursing home. The host, a male or female worker, comes in all sizes, ages, degrees of strength and of intelligence, with a multiplicity of health conditions. Generalizations cannot vitiate individual differences and limitations caused by diseases which reduce the worker's sensory or motor competence. Not infrequently the worker may be both host and agent; an aging or ailing worker with incipient joint disease may precipitate disabling pain by starting to twist or bend to move a load of minuscule proportions. The environment may be dry, warm, well-lighted and properly engineered; on the other hand it is often slippery, frigid, crowded, unapproachable or otherwise hostile.

Load, worker and environment may be amenable to improvement; admittedly it is not possible to accommodate all packages or loads to all workers. Loads can be systematized and better identified, the environment can be better engineered, workers can be selected and trained to cope with stressful conditions. Any or all of these improvements depend upon research and studies yet to be done.

SECTION I
INTRODUCTION

Hazard is a term used in the accident and safety literature to identify the causes of injuries due to over stressing of individuals and groups of workers. It is an amorphous term possessing rather hazy boundaries and must be viewed as a non-discriminating category. In dealing with the first causes of worker injuries, it is particularly difficult to identify clearly what is and what is not a result of hazardous conditions. The problems associated with providing definitions which facilitate discrete gradations of these classes of phenomena become very great indeed. Overexertion, for example, is one form of hazard which is an after-the-fact phenomenon. Its potential for occurrence remains hidden in the environment and only emerges after the damage has been done. In a sense it is a hidden hazard, unlike those associated with more readily identifiable components of the external environment such as noxious chemicals or slippery floors.

In another sense, however, the effects of overexertion are more insidious. For example, in the region of the lower back the effects often do not show themselves immediately, but only long after a causal agent can be identified. Both of these difficulties, amorphous conceptualization and the delayed emergence of effects, have long plagued accident investigator and researcher alike.

The reader may ask, given the importance of and need for knowledge in this area, why has it been so long in coming? A number of reasons stand out. The major obstacle has been the complexity inherent in the problems at hand. Attempts at solving these issues through unidimensional approaches ignores the multidimensional nature of the phenomena. The resultant return in knowledge has been fragmented. Little federal money has been made available to fund any generic type of planning or analysis. Secondly, until recently the focus of research has been on products, not the people who handle those products. The present charge or mandate deals directly with people, not products. The difficulty in reversing these priorities is understandable as one begins to appreciate the complexity of the task ... to lay out a comprehensive workable way of guiding future research to protect the health and well-being of the worker. A somewhat smaller obstacle has been that the study of the injuries, which generated concern in the first place, was after-the-fact and very limited in focus. Piecing together something out of the past magnifies initial errors of perception in the witness and victim. Knowing this made many competent investigators wary of the field of worker safety and hazard analysis. And, finally, pockets of research talent and sometimes important findings tend to remain within private organizations who naturally focus on their own safety problems.

I.1 Purpose

Recently in a NIOSH sponsored report, A. D. Little, Inc. (1972) identified and ranked in order of importance a collection of subcategories of hazards which require attention in research programs supporting accident reduction. The act of manually handling materials was singled out as highly hazardous. In order to initiate the recommendations of A. D. Little, it was determined by NIOSH that a more specific study of the hazards of manual materials handling was required. Although an impressive proportion of the technical literature provides valuable findings, there has been no generic thrust. The potential for concerted and coherent future research incursions in this problem area remains stunted unless an effort is made to draw together what has been done and found up until now, and after digesting this thoroughly, to make recommendations for the direction which research should travel in the future and what avenues are apt to prove dead ends. This is the mandate the National Institute of Occupational Safety and Health (NIOSH) laid before the research community.

The dimensions of the problem and the issues surrounding the channeling of research in the complex field of manual materials handling are considerable. The final goal of research is to increase the safety of the worker. The role of NIOSH is to fund research whose results can be readily applied in the setting of standards designed to protect the worker. Theoretically, the worker is always at risk while on the job. The level of risk, however, varies from moment to moment and is dependent on an, as yet, incompletely defined galaxy of circumstances and variables. In attempting to examine the variables which are already apparent, one is stymied by the realization that many of these factors are operating on the worker at once.

The major components of the worker, the load, and surrounding environment are considered herein in relation to the physiological and behavioral reactions to inherent hazards. Only the unaided process of lifting, carrying, or releasing an object having definable mass and form is considered. A taxonomy developed from the literature for its subsequent classification is used (see Section II) to categorize the findings and knowledge directly related to the hazards of manual materials handling. Each taxonomic category contains the results of a highly specific literature summary, an identification of the gaps in the knowledge, and finally recommendations in the form of criteria or resolutions to fill those gaps.

I.2 Objectives

The thrust of the present effort involves three major objectives to better understand the hazards in manual materials handling:

1. To provide a critique of the published literature regarding the hazards of manual materials handling to identify the state of knowledge in this area.
2. To define specific gaps in the present knowledge regarding the hazards of manual materials handling.

3. To develop criteria upon which future programs of research in this field can be based.

I.3 Procedure

In order to meet and secure these goals, a committee composed of informed researchers in the area of manual materials handling was formed early in the summer of 1974. These participants provided vital inputs, suggestions, and recommendations throughout the genesis of the study. The hub of the NIOSH-sponsored group was located at the University of Michigan.

Initially a taxonomy of the problems of lifting and handling was prepared which broke down the bulk of the research in an acceptable and heuristic way. A thorough description of the taxonomy is treated separately in Section II. It should be noted that an iterative method was used in its development, involving continual modifications and updating of the taxonomy serving the areas and functions under investigation. Along with the initial taxonomy, a selected list of published articles was prepared. Because of the serious self-imposed time constraints only those articles which were immediately available and identified to be of particular relevance were included. Both the publications list and the initial taxonomy were sent to the group members prior to the first of two scheduled workshops for their study and changes. Commentary on the definitiveness of the taxonomy was requested along with additions for the list of relevant works in an attempt to broaden the coverage.

The first two-day workshop was held on July 18-19, 1974 in Rockville, Md., under the sponsorship of NIOSH. Prior to the workshop, a number of tentatively worded recommendations for future research within certain of the taxonomic categories were prepared. During the two days each of these statements was prefaced with a verbal review of literature thus far abstracted. Additions, corrections, and clarifications were made on the spot. Additional reference lists as well as article abstracts were submitted by each of the conferees. This list was continually updated.

When issue was taken with the structure of the taxonomy reformulation often resulted. The major product of this meeting consisted of approximately 100 recommendations - regarding research necessary for understanding and ultimately reducing the hazards found in manual materials handling.

Before the convening of a second workshop less than a month later, the recommendations were redrafted to reflect changes agreed to at the first meeting along with expansion of many of the literature summaries. These were sent to the participants for review and comment in preparation for the second workshop.

On August 15 and 16 in Rockville, the second workshop focused on the research criteria or recommendations. Closure or consensus was sought via the adversary process and only resolutions which were not met by disapproval by more than two members were adopted. Additional resolutions were developed as a result of new input from the group. Both the taxonomic categories and the cast of resolutions were re-examined for their conceptual validity. Then each resolution was scaled along three separate dimensions each of which lead to judgements of the probability of additional knowledge or benefit from future research devoted to that recommendation.

I.4 Scaling of Resolutions

As will be seen in sections III and IV, each resolution (which incidently is made to stand out through a different typescript) has some combination of three numbers - either zero or one - attached to it.

The first scaling index represents an evaluation of the need for such work. Only secondarily may it be viewed as any indication of the priority of such work. If the need for the research is substantiated in the technical literature or by the consensus of the participants, it was scaled 1. If the need was considered speculative or was not unanimously agreed upon by the participants it was awarded a zero scaling. One must keep in mind, however, that a zero here does not indicate that the resolution is irrelevant, just that it is not as substantial as others. All resolutions should be considered as having significant research need.

The second scaling index represents the judged state of knowledge. If, based on the literature reviewed and experiences of the participants, the recommended research criteria were based on adequate substantive knowledge and accepted, well-developed methods, the recommendation was scaled as one. If further methodological developments or basic research techniques will be required before the work can be profitably initiated, the identified work is scaled with a zero in this second category.

The third scaling index reflects the availability of research resources in terms of personnel, equipment, and/or facilities. A one in the third entry reflects that resources are clearly visible and easily identified in today's research community.

Thus a research recommendation which has substantiated need but requires additional methodological development by qualified and identifiable researchers before benefits will be realized is scored: *1 0 1.* No attempt was made to rank or order the recommendations in terms of importance across the entire list. Nor was there any attempt to equally dichotomize each of the three categories; i. e. half the recommendations having ones, the other half zeroes. In terms of the certainty of return or payoff from the research, however, those recommendations having three ones are obviously preferred to those scaled with three zeroes.

After the second and final meeting of the workshop, a draft of the proceedings was prepared and sent to the workshop participants for final commentary and changes requisite to this report. No pretense is made about the comprehensiveness of the final literature pool. Although 594 articles were cited by the participants as pertinent to the issues at hand only 208 articles, on the basis of previously mentioned criteria, were ultimately summarized for inclusion in this document.

Overall response to the goals and needs of the Workshop was excellent. A more or less continuous dialogue was set up between the workshop participants and the co-chairmen as the latter prepared the final document in iterative fashion. An almost continuous stream of information, abstracts of relevant publications, and suggestions flowed between the participants.

Because of the huge amount of material needing consideration and assimilation, the initial process was data gathering. Only later did integration, recasting, and refinement of sections of the document occur. The mechanics of the process described in this section may warrant consideration as a template with which to develop similar exercises in the future.

SECTION II

MANUAL MATERIALS HANDLING PROBLEM TAXONOMY

The state of knowledge of the hazards associated with manual materials handling is not easily characterized. In order to provide a workable critique of the published literature and to identify those factors which characterize this problem area, a taxonomy was developed by the workshop participants. This section presents a description of a taxonomy of the various factors involved in manual materials handling. The taxonomy is used to organize both the summaries of the literature and the recommended research criteria presented in later sections.

II.1 Definitions

The hazard to a person involved in a physical task can result in many individual responses which are generally accepted as not conducive to the person's health and general well-being. The large number of different human responses to the stresses of the physical act of handling loads may be divided in three general categories:

1. Injury and Illness
2. Physiological
3. Behavioral

Injuries and illnesses are most often characterized by the statistics on the frequency (rate of occurrence) and severity of specific damages. The physiological measures which reflect hazard are either circulatory/pulmonary, metabolic, biomechanical, or neuromuscular/neurological in nature. The most difficult to quantify are the behavioral measures which include psychological, psychophysical, and sociological measures. Recommended research criteria for these nine hazard measures are presented in Section III.

The phrase manual material handling must also be carefully delineated before the characteristics of the system can be examined. For the purposes here, manual material handling refers to the unaided human act of lifting, carrying, pushing, pulling, and releasing of an object having definable form and mass. Electromechanical lifting and moving aids (i.e., cranes, hooks, block and tackles, slings, dollys, fork-lift trucks, etc.) are excluded from consideration in this report. Since these devices are detachable from an object being handled, they present a separate set of potential hazards depending on the application and use. Handles or grasping devices, however, which are part of an object being handled are considered as part of the manual materials handling system and are included in this report. In this regard, the following system characteristics of the act of manual materials handling are seen as independent, discriminatory categories:

1. Worker Characteristics
2. Material/Container Characteristics
3. Task Characteristics
4. Work Practices Characteristics

The worker characteristics which may make a person more susceptible to hazard include his physical characteristics, sensory capabilities, motor capabilities, and psychomotor skills; his personality, training/experience, general health status, and leisure time activities. The material/container characteristics which may contribute to hazard potential include the load, dimensions of object, distribution of the load, couplings, and stability of the load. Characteristics of the task which may modify the hazard include the workplace geometry, the frequency/duration/pace of the handling activity, the complexity of the movement, and the environmental conditions within the workplace. Finally, work practices which may modify the hazards of manual materials handling are subcategorized as individual practices, organizational practices, and administrative practices. Specific research criteria for these system characteristics are presented in Section IV.

Definitions for each of the subcategories for both the hazard measures and system characteristics are presented in

Exhibit 1. This problem taxonomy is used in the remainder of this report as a format for both the critique of relevant technical literature and the recommended research criteria.

Exhibit 1

HAZARD MEASURES

INJURY AND ILLNESS EFFECTS

SEVERITY: measures of the severity of a specific type of injury or illness, such as: lost time; time on medical work restriction; compensation costs; medical treatment costs; lost employment.

FREQUENCY: measures of the rate of occurrence of a specific type of injury or illness, such as: injury incidents per million man hours; injury incidents per job classification.

PHYSIOLOGICAL EFFECTS

CIRCULATORY/PULMONARY: measures of the responses to manual materials handling, such as: heart rate; cardiac output; blood pressure; aberations in myocardial functions (EKG); alterations in respiration; peripheral blood flows.

MUSCLE METABOLISM: measure of the steady state and transient metabolic responses to manual materials handling, such as: oxygen uptake rates; caloric costs; body temperature changes; hormonal shifts; plasmic constituents; enzyme levels.

BIOMECHANICAL: measures of the biomechanical stresses and strains, such as: forces and/or pressures associated with tissues of the musculoskeletal system; rotational moments and/or torques at various articulations; EMG and kinesiological indications of muscle loads and fatigue states; altered radiographic findings in tissue following manual materials handling.

NEUROMUSCULAR AND NEUROLOGICAL: measures of the neurologic responses associated with manual materials handling, such as: slowed neural conduction velocities; altered motor unit behavior as indicated by EMG changes; altered reflexes; abnormal sensory functions.

BEHAVIORAL EFFECTS

PSYCHOLOGICAL: measures of the mental states of workers during and after manual materials handling activities, such as: MMPI profiles; clinical ratings of trauma induced neurosis; attitudinal indices; attribution scales.

PSYCHOPHYSICAL: measures of the psychological acceptability of manual materials handling activities, such as: tolerance of physical exertion; physical discomfort ratings; perception of unsafe physical acts or risk taking behaviors in such acts.

SOCIOLOGICAL: measures related to the social responses of people associated with manual materials handling, such as: turnover rates; absenteeism attributed to work environment; antisocial behavior patterns.

Exhibit 1 (cont.)

SYSTEM CHARACTERISTICS

WORKER CHARACTERISTICS

PHYSICAL: include general worker measures, such as: age; sex; anthropometry; postures.

SENSORY: measures of worker sensory processing capabilities, such as: visual; auditory; tactual; kinesthetic; vestibular; proprioceptive.

MOTOR: measures of worker motor capabilities, such as: strength; endurance; range-of-movement; kinematic characteristics; muscle training state.

PSYCHOMOTOR: measures of worker capabilities interfacing mental and motor processes, such as: information processing; reaction/ response time; coordination.

PERSONALITY: measures of worker values and job satisfaction by attitude profiles; attribution; risk acceptance; perceived economic need.

TRAINING/EXPERIENCE: measures of the worker education level in terms of formal training or instruction in manual material handling skills; informal training; work experience.

HEALTH STATUS: measures from worker general health appraisal, such as: previous medical complaints; diagnosed medical status; emotional status; regular drug usage; pregnancy; diurnal variations; deconditioning.

LEISURE TIME ACTIVITIES: measures of the persons choosing to be involved in physical activities during leisure hours, such as: holding a second job or regular participation in sports.

MATERIAL/CONTAINER CHARACTERISTICS

LOAD: measure of force; pushing/pulling force requirements, mass moment of inertia.

DIMENSIONS: measures of size of unit workload, such as: height; width; breadth when indicating the form as rectangular, cylindrical, spherical, etc.

DISTRIBUTION OF LOAD: measure of the location of the unit load CG with respect to the worker for one hand and two handed carrying.

COUPLINGS: measures of simple devices used to aid in grasping and manually manipulating the unit load, such as: texture; handle size, shape, and location.

STABILITY OF LOAD: measures of load CG location consistency, as a concern in handling liquids and bulk materials.

Exhibit 1 (cont.)

SYSTEM CHARACTERISTICS
(CONT.)

TASK CHARACTERISTICS

WORKPLACE GEOMETRY: measures of the spatial properties of the task, such as: movement distance; direction and extent of path; obstacles; nature of destination.

FREQUENCY/DURATION/PACE: measures of the time dimensions of the handling task including frequency, duration and required dynamics of activity over the short term and long term.

COMPLEXITY: measures of combined or compounding demands of the load, such as: manipulation requirements of movement; objective of activity; precision of tolerance; number of kinetic components.

ENVIRONMENT: measures of added deteriorative environmental factors, such as: temperature; humidity; lighting; noise; vibration; foot traction; seasonal toxic agents.

WORK PRACTICES CHARACTERISTICS

INDIVIDUAL: measures of operating practices under the control of the individual worker, such as: speed and accuracy in moving objects; postures (i.e., lifting techniques) used in moving objects.

ORGANIZATIONAL: measures of work organization, such as: physical plant size; staffing of medical/hygiene/engineering/and safety functions; and utilization of teamwork.

ADMINISTRATIVE: measures of administration of operating practices, such as: work and safety incentive system; compensation scheme; safety training and control; hygiene and safety surveys; and medical aid and rescue; long work shifts; rotation; personal protective devices.

II.2 Literature Summary

To identify the gaps in knowledge associated with the hazards of manual materials handling a preliminary literature search was performed. In total, 594 articles were cited by the workshop participants. Of these, 208 articles were summarized for special consideration by the group. Due to the time available for the workshop, the articles formally summarized had to be deemed particularly relevant and immediately available. The most significant findings and recommendations presented in the relevant papers are summarized later in this report.

Using the terminology of the previously outlined taxonomy, a tabulation was made of the major relationships between the system characteristics and the hazard measures examined in the literature. This tabulation is presented in Exhibit 2. Each number presented denotes the number of reviewed articles which consider a specified combination of hazards and system characteristics. A given article, of course, could be counted more than once in any given column or row.

A summary for each article formally reviewed by the participants is presented in Appendix A. The checked items denote that the author(s) examined a particular combination of hazard and system characteristic measures, not that any particular relationship was observed. Exhibit 2 and Appendix A highlight the fact that most studies have considered only a few system characteristics and associated hazard measures at a time, a fact that will be referred to several times in subsequent discussions of the literature.

			System Characteristics																				
			worker								material / container					task				work practices			
			Physical	Sensory	Motor	Psychomotor	Personality	Training	Health Status	Leisure Activity	Load	Dimensions	Distribution	Couplings	Stability	Workplace Geom.	Frequency/Pace	Complexity	Environment	Individual	Organizational	Administrative	TOTALS
Hazard Indices	injury	Severity	11	0	1	1	5	2	14	0	8	2	1	0	2	0	0	0	1	4	1	3	56
		Frequency	18	1	4	1	5	5	22	0	24	7	2	1	3	0	3	0	1	17	1	5	120
	physiological	Circulatory	4	1	0	0	0	1	2	0	12	2	4	2	0	0	4	0	3	3	0	1	39
		Metabolic	7	0	0	0	0	0	1	0	18	3	6	2	0	0	7	0	2	11	0	2	59
		Biomechanical	21	1	12	0	0	6	5	0	31	9	7	6	1	1	5	0	0	29	0	3	137
		Neuromuscular	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	behavioral	Psychological	1	0	0	0	1	0	1	0	2	1	1	0	1	0	0	0	0	2	0	1	11
		Psychophysical	14	0	6	0	0	1	3	0	19	2	8	0	1	0	1	0	1	6	0	0	62
		Sociological	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	4
		TOTALS	77	3	23	3	11	15	49	0	115	26	29	11	8	1	20	0	8	72	2	15	

SECTION III

RESEARCH NEEDS ON HAZARD INDICES

It is apparent from the literature that researchers have used many different indices (or measures) of the hazards to an individual involved in the act of manual material handling. Several issues raised by the workshop participants form the basis for subsequent discussion of the specific hazard indices.

Two recurring observations stood out. First, only a few researchers have considered more than one hazard measure at a time. While from a practical standpoint this is often necessary, it cannot be encouraged. Univariate experimentation does not depict the complexities characterizing human accommodation to everyday stresses. Hence, *research should strive to use multivariate evaluations to identify and define the hazards of manual materials handling.*

Second, methods for measuring the various responses to the stresses of manual materials handling often are neither well validated nor standardized. Generally, validation of a method requires the establishment of both conceptual and consensual validity. The method should be shown by both experimental results and logical deduction to provide a measure of a particular human attribute. Likewise, in many cases it is necessary to show that the measurements are in agreement with other investigators' methods, where such exist, and are widely accepted. Neither criterion is meant to retard the development of newer and possibly more sensitive and valid hazard measures. They are mentioned to remind researchers that *before embarking on the development of new hazard measures, existing measures should be carefully examined to determine those with confirmed validity. If methods for measurement are not suitable, then researchers should carefully develop and report the validity of new methods.*

With the preceding two observations as an introduction, the more apparent hazard indices emerging from the literature are discussed in the following subsections. Each measure is treated separately. First the pertinent literature on the measure is summarized, then criteria or guidelines are set down which focus on improving future research employing the measure. The hazard indices which follow are divided into three major groups:

III.1 Injury and Illness Indices
III.2 Physiological Indices
III.3 Behavioral Indices

III.1 Injury and Illness Hazard Indices

Both frequency and severity of various injuries and illnesses are often utilized to suggest that a particular system component of manual materials handling is hazardous. Though these statistics are helpful, it is the consensus of the workshop participants that the diagnostic categories and treatment modalities are often so non-specific that the resulting injury and illness statistics can only be used as gross indicators of potential cause, and then only when specific trauma is present. Unfortunately, the more serious disorders due to manual materials handling may be slow to develop, further complicating the assignment of cause.

It is the conclusion of the workshop participants that *the reported statistics on injuries and illness do not accurately reflect the magnitude of the medical problem,* since there exist direct economic incentives to the reporting organizations not to admit that a medical incident is job-related. The less specific the trauma involved, the greater the underestimation of job-related medical incidents. Because of this *it is important that national occupational health statistics be gathered by survey methods which will not be biased by monetary incentives.* It is only through such surveys that the genuine nature and extent of occupational medical disorders will be determined, so as to serve as an adequate basis for research and control development.

In this same regard, *the use of such techniques as the critical incident technique or biomechanical profiles of various job conditions (i.e., evaluation of the system characteristics* *which could most probably cause injury or illness to a worker) should be given more attention in order to build models predictive of injury.* The use of such techniques changes the emphasis from one of a "reactive mode," wherein research and control are instigated only after a set of conditions have resulted in significant medical findings, and hence personal suffering, to the situation wherein research and controls would be based on a combination of basic physiological and behavioral findings meant to predict the potential for injury and illness in a given job.

As should become apparent in the following sections, the basic knowledge necessary to predict in advance potential injury or illness in manual materials handling jobs is not well developed at present. It is, therefore, a fact that existing injury and illness incidents, as weak as they are, will need to be used to determine the gross hazard associated with various manual materials handling operations. The following two subsections discuss some of the uses of such statistics, as well as present recommendations as to how future statistics could be improved.

III.1a Frequency of Injuries and Illnessess. Various types of injuries and illnesses have been associated with manual materials handling activities. In a retrogressive, or "after-the-fact," study of dock workers, Jackson (1968) reported that the trunk, spine and hands were most often involved in injuries requiring three or more days off the job. In reviewing over 6000 industrial accident cases, Brown (1958) concluded that about 30% are due to manual load handling, of which about 25% are directly attributable to the lifting of loads while another 16% are related to the person becoming entrapped between the object being handled and the floor, wall, shelf, etc. Injuries thus incurred are to the back, hands and feet. Both because the act of lifting and the severity of injury is often great, most literature on injuries and illnesses associated with manual materials handling has utilized the incidents of low-back pain as the primary indicator of hazard. This is unfortunate in as much as this particular type of medical incident is most difficult to diagnose, and thus, lends confusion to the interpretation of such statistics. As discussed by Brackett (1924), spinal impairment is often slow to develop. The onset of acute symptoms tends to occur when the person attempts to lift an object. Naturally, the symptoms are attributed to the act of lifting, but the actual cause of the resulting disability may have stemmed from a prior condition with the lifting act simply aggrevating the previous problem. More recently Rowe (1969, 1971) has elaborated on this difficulty in interpretation by reviewing a large number of industrial back cases. In many cases, diagnosis was only evident after close medical surveillance had taken place for an average of five years on each patient. With such surveillance Rowe concluded that about 70% of the symptoms were related to spinal disc degeneration. It should be quickly mentioned, however, that many diagnosticians have not accepted this high percentage of discogenic back problems, and instead support the earlier thesis of Herndon (1927) and Osgood (1920) that the frequent episodes are simple muscle and ligament strains and sprains. The recent review by Brown (1973) discloses that about 82% of all low-back pain cases reported today are diagnosed as muscle or ligament strains or sprains, with few having prolonged complications.

Even though diagnostic criteria for low-back pain are not well developed, the incidence rates of low-back pain episodes per se have been useful in many studies to identify certain manual materials handling system characteristics as hazardous. For instance, studies by Becker (1953, 1955) disclosed that the incidents of low-back pain were drastically reduced by stringent pre-placement medical examination of persons slated for manual materials handling. Hult (1954) and Magora and Taustein (1969) disclosed that the initial episodes most often occur in young age groups (25-30 years), and are more frequent in people performing heavy labor. Chaffin and Park (1973) agreed with this latter result, disclosing that low-back incidence rates in jobs having significant manual handling of heavy materials were four times those in sedentary jobs. Magora (1970) found that women involved in manual materials handling had over twice the number of incidents of low-back pain as men performing similar jobs. And recently, Chaffin (1974) reported that the incidence rate of low-back pain was significantly higher in those people who could not isometrically demonstrate the lifting strengths required by the job.

In conclusion, data on the frequency of injuries and illnessess has been used to identify some very general system characteristics which are potentially hazardous. However, the lack of diagnostic power and statistical controls has limited the effectiveness of these studies. In specific, injury frequency data are necessarily gathered over time. If well defined experimental or after-the-fact statistical controls are not exercised to assure that the hazards and exposures of the individuals being sampled do not change, then the resulting frequency data may be subject to question. Furthermore, without good diagnostic criteria it is all the more important to utilize well defined injury and illness classification schemes.

It is, therefore, recommended that future injury and illness frequency statistics intended to elucidate the hazards of manual materials handling reflect the following:

1 1 1 *Use of a standardized injury or illness classification scheme (e.g., Z16.1 or OSHA system) where applicable, or a clear definition of alternative injury and illness categories.*

1 0 1 *More comprehensive documentation of the system characteristics and exposures of individuals and groups involved in the studies.*

1 0 1 *A concern for all types of injuries and illnessess associated with manual materials handling, rather than just those associated with the low-back.*

1 0 1 *Longitudinal field experiments with control or measurement of as many system variables as possible are preferred over cross-sectional or retrogressive field studies. This is especially desirable as better methods of data taking and evaluation are developed.*

1 0 0 *A delineation of whether the medical incidents being counted are believed to be of occupational or non-occupational cause at the time of diagnosis.*

III.1b <u>Severity of Injuries and Illnesses</u>. As in the preceding discussion of the frequency of injuries and illnesses associated with manual materials handling, cases concerning low-back injuries predominate in the literature. Compensable low-back cases account for anywhere from 12% of all industrial injuries (Clark, 1958) to as high as 34% of all injuries in dockworkers (Blow, 1971). Besides the apparent lack of concern in the literature for disability related to other types of injuries, there is a general lack of specific information regarding the distribution of measures often used to indicate the severity of the low-back injury. Most papers report such indices in terms of mean lost time rates, i.e., 122 hours/1000 employees/year due to low-back pain (Becker, 1953), or 90% of low-back patients recover in one or two weeks (Bond, 1970 and Clark and Russek, 1958), or the mean compensation cost of each low-back case is between $1000.00 (Jones, 1974) and $2000.00 (Leavitt, et al., 1971).

The system characteristics that affect these severity statistics are of great importance. For instance, Clark and Russek (1958), White (1966), Magora and Taustein (1969) and Hirschfeld and Behan (1966) indicate that recovery from a physical disability is heavily dependent upon the desire of the patient to return to his former activities. Also, confounding the recovery process is the exact cause of the symptoms. Runge (1958) disclosed that low-back pain patients with spondylolisthesis required 50% more time to recover from an episode than a person with negative X-ray findings. Wilkins, et al. (1957) indicated that anomalies detected by X-ray prior to symptoms are related to longer disability and expense after a low-back strain. Furthermore, Gillespie (1941) indicated that symptoms originating from the sacroiliac region have significantly longer recovery times than those originating in the lumbar spine. Undoubtedly severity rates can be sensitive to still other factors.

Future studies to collect statistics on the severity of injury and illness in order to determine the extent of individual suffering due to manual materials handling should reflect the following:

1 0 1 *Development of better methods to determine the degree of disability due to other types of injuries and illnesses than just those associated with the low-back (e.g., tenosynovitis, carpal tunnel syndrome, contusions and lacerations of extremities, etc.).*

1 0 1 *A more detailed study of the distributions of severity indices associated with such disability, (e.g., medical, lost time, lost job opportunities, replacement and training, rehabilitation, etc.) under conditions which are well controlled and documented.*

1 0 0 *Concern for the interactive causal conditions which contribute to varied disabilities is needed.*

III.2 Physiological Hazard Indices

Four major physiologic system responses are commonly associated with the act of manual handling which may indicate potential hazard to a person. These are:

III.2a Circulatory/Pulmonary
III.2b Metabolic
III.2c Biomechanical
III.2d Neurologic

The available literature describing how these have been utilized to determine the adverse effects of manual materials handling will first be reviewed for each general system response. Following each set of effects are recommendations for describing how future research might better utilize these responses to more precisely determine the effects of potential hazards.

III.2a Circulatory/Pulmonary Indices. Manual materials handling combines both rhythmic and isometric exercise in highly variable proportions. The matter deserves consideration because the physiological responses to the two kinds of muscular activity are quite different. It is worth considering those differences briefly.

A good deal is known about the cardiopulmonary responses of men and women to rhythmic exercise such as walking or cycling and are extensively reviewed, for example, by Astrand and Rodahl (1970) and Rowell (1974). The dominant factor controlling those responses appears to be the level of metabolic activity which shows an almost linear relationship between O_2 uptake and the cardiac output, the heart rate and the minute ventilation; other factors such as arterial mean blood pressure and ventilatory equivalent change little, if at all. Steady state responses are elicited by continued exercise up to about 50% of the max $\dot{V}O_2$; at higher levels of rhythmic exercise, fatigue eventually occurs and heart rate, for example, continues to rise throughout the period of exercise. After rhythmic exercise, return of those measures of the cardiopulmonary activity to control levels is relatively slow and is more prolonged as the intensity of the exercise increases.

Isometric exercise produces quite different cardiopulmonary responses and they have been reviewed, for example, by Lind

(1970) and Simonson and Lind (1971). At all tensions above 15% of the maximum voluntary contraction (MVC), sustained isometric exercise results in rapid muscular fatigue and elicits a continuing and almost linear rise of both heart rate and blood pressure. The increase in heart rate is, however, modest, and appears to be directly related to the relative tension (%MCV) exerted. The increase in mean blood pressure is large and is, apparently, independent of the tension exerted. A marked hyperventilation commonly occurs, though it is not yet known if it is related to the tension. The cardiovascular responses are independent of the muscle mass involved and are, thereby, not related to the metabolism, as is the case for rhythmic exercise. Recovery to pre-exercise levels is rapid. When sustained static effort occurs during continued rhythmic exercise, the responses to the static effort are simply superimposed on those due to the rhythmic exercise. Little is known at present of the cardiopulmonary responses or of the development of muscular fatigue in intermittent isometric exercise. It is known, however, that light rhythmic exercise can alleviate some part of the fatigue induced by heavier exercise.

Much of the existing knowledge of cardiopulmonary responses to these two kinds of exercise comes from laboratory studies where the conditions are deliberately stylized and, in that sense, artificial. Few studies have been made on actual lifting and handling activities which obviously combine both kinds of exercise and in which the levels of both the rhythmic exercise and the static component can vary widely. Furthermore, control of the levels of either type of muscular activity in terms of max $\dot{V}O_2$ or MVC has not been established, and the physiological responses are usually presented as a mean value for periods of continued activity. But the nature of lifting/handling operations must lead us to expect rapid and transient cardiopulmonary responses, exacerbated during lifting activity by the influence of known rapid increases in the intra-abdominal and intra-thoracic pressures.

So far as measurements made during lifting and handling tasks are concerned, the preponderance of available data in the literature pertains to steady state heart rate responses. Mean heart rate has been stated to vary 1) proportionally with the sum of the body weight and load carried (Datta, et al., 1973), 2) with the location of the load on the body (Datta and Ramanathan, 1971), 3) as the pace of the lifting task (Hamilton and Chase, 1969), 4) between leg and arm lifting tasks (Snook and Irvine, 1969) and 5) with the sex of the worker (Snook and Ciriello, 1974). It may be concluded from these studies that mean heart rate is one possible indicator of the cardiovascular strain resulting from manual materials handling activities. However, the real problem lies in setting a criterion to determine hazardous or permissible mean heart rates. With the exception of psychophysical studies of Snook and Irvine (1969), little attention has been given to determining the tolerance of a person performing a manual material handling job based on mean heart rate. Thus far, in the main, heart rate has been used to compare the physiological demand of various work loads under different manual material-handling system components. The well known fact that heart rates vary greatly with individuals (see, for example, Davis, et al., 1969) must be recognized if it is to be used to establish work load tolerances.

Similarly, the time necessary for the heart rates to return to normal has been utilized, for example, by Gupta and Rohmert (1964) to indicate the level of severity of various types of materials handling tasks. Although many studies have recovery of heart rate to be an index of overall cardiovascular fitness (see Consolazio et al., 1963 for review), the problem again revolves around the establishment and validation of a criterion which has practical meaning.

A general conclusion which can be drawn from review of the information on the circulatory and pulmonary responses to manual materials handling activities is that both systems react in a complex fashion and that individual and temporal variations can be large. Future research into the circulatory and pulmonary responses to manual materials handling should reflect the following:

1 0 1 *Improved methods of measuring circulatory and pulmonary changes necessary to document the transient as well as the steady state responses of the systems to the physical impulse loading often associated with manual materials handling.*

1 0 1 *Methods of measuring physiologic subsystem responses (eg., thermographic, intra-tissue pressures, peripheral blood flows, etc.) as well as of typical more general physiologic responses should be improved.*

1 1 1 *The relationships of parameters which best reflect human and tissue tolerance to a physical stress (eg., pleural and cardiac tissue rupture levels, EKG, angina, arrythmias, elevated recovery pulse rates and blood pressures and hyperventilation, etc.) with physiological and mechanical fatigue should be further clarified.*

III.2b <u>Metabolic Indices</u>. From the literature examined, the primary metabolic index used to determine the potential hazard of various manual materials handling jobs has been oxygen uptake ($\dot{V}O_2$) under steady state conditions. Like heart rate, the primary concern has been to determine relative physiological work loads of various material handling activities. In this regard the estimated metabolic rates from $\dot{V}O_2$ measures have been shown to vary with 1) the length of rest periods between lifts (Aquilano, 1968), 2) the weight and posture used during lifting (Åberg, 1961; Kamon and Belding, 1971), 3) how the load is supported on the body (Cathcart, et al., 1928 and Datta and Ramanathan, 1971), 4) the load, grade, and terrain during carrying (Goldman and

Iampeitro, 1962; Haisman and Goldman, 1974), 5) the height of lifting loads (Hanson, 1969), 6) the weight/bulk ratio of the material lifted (Tichauer, 1965) and 7) how a cart is designed for pushing loads (Haisman, et al., 1972). Estimates of "safe" average metabolic rates range from 33% to 50% of the person's aerobic capacity (Chaffin, 1968 and Astrand, 1960) for an eight hour period. The bases for these estimates are not well validated at present.

More importantly, the metabolic demand during most manual materials handling jobs is variable over time, particularly during high peak loads. These peaks place special demands on the anaerobic pathways and thereby the recovery periods may be longer. Models and data to understand the relationships between transitional loadings and metabolic response are not evident, but are clearly needed.

Furthermore, heat stress imposed in addition to the metabolic stress appears to reduce a person's capacity to perform manual materials handling (Snook and Ciriello, 1974). Acclimatization to the heat, and development of skill in manual materials handling as discussed by Williams (1966), may play a significant but undefined role in how much material a person can handle during the work day.

Although gross metabolic measurements are well accepted as a relevant physiological response which often indicates hazard potential in manual materials handling, future research using this response variable could be further improved by reflecting the following:

1 1 1 Documentation of the appropriate aerobic capacities of workers involved in manual materials handling jobs so as to establish tolerance and fatigue states based on the metabolic rates and muscle functions required by these activities.

1 1 1 *Measurement of the concomitant body core and muscle temperatures often associated with manual materials handling activities.*

0 1 1 *Better measurement and documentation of the transient metabolic responses to the impulse loadings often associated with manual materials handling jobs, reflecting the limitation imposed by anaerobic pathways on the capacity to do work.*

0 1 1 *Evaluation and use of more sensitive measures of metabolic functions than simply* $\dot{V}_{O_2}$ *and/or its hematological correlate measures (e.g., plasma constituents), during both short term impulse loads and long term continuous manual materials handling.*

III.2c Biomechanical Indices. Various biomechanical factors have been studied in relationship to the hazards of manual materials handling. Some of the more relevant findings from such studies are briefly summarized in the following.

First, there are those who have constructed simple mechanical analogs of the human body (Tichauer, 1965 and Chaffin, 1969) for analysis of manual materials handling. These models have been used to grossly estimate mechanical stresses at various articulations or attitudes of the body during lifting, pushing and pulling in the sagittal plane. Also, such models as well as direct pressure measurements have indicated high intra-abdominal pressures, (Davis and Troup, 1964; Davis, 1969; Morris et al., 1961 and Bartelink, 1957), are created during lifting, and these could result in various abdominal herniations (Davis, 1959). Furthermore, Nachemson (1970) discloses that intradiscal pressure at the L_3 level can become quite high during lifting, and such pressures are subject to many postural and load lifting considerations. In particular, the initial acceleration phase of lifting creates high peak disc pressures.

Konz (1973) using a force platform, demonstrated a similar dynamic affect.

Electromyograms have disclosed that the coordination of the muscles involved in lifting loads is complex (Chapman and Troup, 1969; Tichauer, 1972 and Asmussen, 1960). Such complexity must be considered in refined estimates of specific forces operating within the body during load handling.

It was also noted in the literature that lumbo-sacral dimensions and configurations may have an important role in individual tolerance to mechanical stresses (Chaffin and Moulis, 1969; Kumar, 1974 and Tichauer, 1974), but that some current injury statistics do not now support these concerns as predictive of individual risk for employment purposes (LaRocca and MacNab, 1970).

It was concluded by the workshop participants that though many researchers have used biomechanical rationales as the basis for certain recommendations regarding hazardous manual materials handling conditions, often, known kinesiological and biomechanical factors are not well utilized in such rationales. In other cases, much more basic knowledge regarding the measurement, function, and tolerance of the musculoskeletal components is required to predict the hazard potential.

It is therefore the consensus of the workshop participants that though biomechanical indices have provided the basis for hazard assessment in a large number of studies, the complexity and direct relevance of these indices warrant future research and development. This research should reflect the following considerations:

1 1 1 *More comprehensive biomechanical models should be constructed and used to predict the complex mechanical stresses imparted to the various body tissues during manual materials handling. Such models should also be used to interpret experimental findings, (e.g., EMG levels, tissue force and pressure measurements, radiographic alterations, etc.), as well as to be validated by such parameters.*

1 1 1 *Better techniques should be developed for evaluating the kinesiological and postural changes associated with manual materials handling.*

1 1 1 *The methods for collecting and using cadaver data to determine their mechanical properties must be adapted to the occupational trauma situation.*

1 0 1 *Additional methodological/measurement development is necessary to determine the mechanical tolerances and fatigue of the various live tissues non-destructively stressed during manual materials handling. New techniques such as thermography may offer potential here.*

1 0 0 *Better techniques for measuring tissue forces and pressures non-destructively should be developed and used to determine the stress patterns induced during manual materials handling.*

III.2d **Neuromuscular and Neurological Indices**. Though literature relating neuromuscular and neurological changes to manual materials handling per se could not be found, several papers by Lance and Chaffin (1971), Chaffin (1974), and Tichauer (1974) clearly indicate that sustained muscle exertions can alter coordination of specific muscle groups. Such alterations are typically described in terms of a reduction in the precision of the movement, increased tremor amplitudes, and a reduction in the sensitivity to application of force. They are often used to indicate fatigue. These types of responses to exertion could not only be used to indicate the vulnerable physiological status of a person involved in manual materials handling, but may indicate an increased risk of injury while handling heavy loads. Furthermore, mechanical stresses imparted to the tissues might directly involve the neural tissue itself. Perhaps the best example of this is the neurologic signs that are often associated with spinal disc herniation and resulting compression of the nerve root. Therefore,

1 0 1 *it is proposed that future research on the adverse effects of manual materials handling include consideration of potential neurologic and neuromuscular responses. With developmental work some responses may provide a valuable basis for determining the hazard potential of specific types of manual materials handling, as well as assisting in the development of the diagnostic techniques for assessing pathomechanical injuries and illnesses.*

III.3 Behavioral Hazard Indices

Maintaining the health and well-being of the individual must extend beyond concern for his physical status. His behavior and the motivations and emotions which help to shape it figure as important indices both in the perception of potential hazard as well as in response to hazard and its occasional accompaniment, injury. Viewed as a human feedback mechanism, the worker's subjective perception of what physical forces he can successfully overcome has captured a substantial segment of interest in the behavioral literature focused on manual materials handling. And finally, man as a social animal and how institutions and others around him influence his behavior and emotions stands worthy of serious attention. In this regard the responses discussed under the heading of behavioral indices group into three categories: psychological indices, psychophysical indices and psychosocial indices. Each category is discussed in turn along with recommendations for the direction and focus of future research efforts.

III.3a Psychological Indices. As might be expected, few research efforts have been directed at the psychological status of the worker engaged in manual materials handling or his attitudes toward its potential hazards whether in cases where injury remains a possibility or has become a reality. This may be so for any number of reasons chief among which are that many psychological measures retain their reputation for instability or unreliability. Subjective states under the conscious control of the individual can be hidden or changed momentarily. Serious emotional injury can often be successfully camouflaged just as inconsequential hurts can be blown out of proportion. Transient levels of awareness can influence perception. In short, serious productive inquiry into the complexities making up psychological well-being in the generic sense has only just begun.

Clark and Russek (1958) state that the "desire" of the individual to return to his former job following a low-back episode is a major factor in the ultimate success or failure of the treatment. They speculated that if the worker believed his job was responsible for his injury, he may dislike the job - a factor that may present a special problem in rehabilitation. In estimating that approximately 10% of low-back cases eventually become chronic, these authors agree with Hirschfeld and Behan (1963) that unnamed psychological factors operating in the work setting may play a large part.

In a now dated survey, Herndon (1927) found about one percent of low-back cases to be psychosomatic in origin. Concurring with this, Paul (1950) suggested that many low-back pains are due to something he identified as musculoskeletal neurosis which is simply postural reactions to psychological stresses. Current observations single out the low-back syndrome as the bane of modern man and attribute closer to half its causes to psychosomatic origin particularly the psychological stresses encountered in high pressured life styles. The vast clinical literature on body posture and mental illness (see Mach, 1972, for review) emerges with a central theme that muscular tonus or tension (and potentiated spasm) reflects the internal psychological stresses. These events may operate as components in a servo-mechanism or as part of a feedback loop in that as either worsens, so does the other. The modern day epidemic concern with the lack of intrinsic meaning in many industrial production jobs may exacerbate the problem and elevate those psychosomatic illnesses which manifest this dissatisfaction.

In a review paper, Walters (1966) discusses many potential psychosomatic causes of low-back pain but maintains that no one method will be wholly effective in preventing prolonged or recurring episodes in individuals. However, both Clark (1958) and White (1966) agree that preventing malingering requires early psychological support in the treatment of the low-back patient.

Certain individuals are more susceptible to psychological trauma resulting from manual material handling injuries. This is clear. What remains unclear is whether these stresses are due to any of the components of a manual materials handling system. And, if so, how predictable are they?

Although the literature is admittedly marginal on this specific problem, a vast number of articles concerned with psychological response to various real life stress situations are available (Appley and Trumbull, 1967). From this extant literature, both conceptual approaches and methodological applications can be extrapolated to the issues under scrutiny. In any case, substantial support must be accorded to the notion that the degree of disability and suffering resulting from manual materials handling injuries is a function of the psychological reaction of the person to his own impairment, the impairment of others or the fear of injury. Similarly, the studies of risk taking and the notion of injury-proneness as a psychological trait although presently in an equivocal state, bear watching for future developments focused on the high risk-taker or the injury-prone personality.

In this regard the following recommendations warrant considerations:

1 0 1 *Specific attitudes and attribution of the injured worker may play an important part in the severity of an illness or injury particularly in the time taken to recover. Various available psychological techniques coupled with epidemiological analysis may establish the characteristics of this relationship.*

1 0 1 *Similarly the worker's perception of and attitudes towards his hazardous job may predispose him both to injury and poor performance. Research examining the relationships between actual performance and attitudes toward especially hazardous manual materials handling is warranted.*

III.3b Psychophysical Indices. The literature surveyed in this regard can be catalogued into two subgroups, those concerned with muscular strength and those concerned with endurance. Both rely on the concept that a person can sense his comfortable physical capability as well as his absolute performance limit in a given task.

Many researchers have used maximum, short term strength (voluntary exertion) to predict the potential hazard for many of the manual materials handling system components. As an example, maximum voluntary strengths appear to be a function of many factors including 1) width of an object lifted (McConville and Hertzberg, 1968), 2) height of the lift (Emanuel, et al., 1956; Switzer, 1964), 3) foot position (Grieve and Arnott, 1970; and Whitney, 1957), 4) whether seated or standing (Troup and Chapman, 1969), 5) sex (Chaffin, 1974; and Snook and Ciriello, 1974), 6) age (Asmussen and Heebold-Nielson, 1961), 7) whether pushing or pulling (Kroemer, 1974) and 8) stature (Strindberg and Peterssons, 1972). From such relationships, simulation models have been developed for more general task strength measurements (Chaffin and Martin, 1972; and Drury and Pfeil, 1973).

The ability of a person to subjectively endure frequent submaximal exertions has been studied by Caldwell (1964) who noted that when pulling loads muscle endurance varied greatly with body postures. He found a good correlation between the postures involved in static strength and those involved in static endurance. However, Smith and Edwards (1968) point out that static strength may not predict the dynamic endurance required in many common tasks. On the basis of hundreds of subjective self reports, Snook and Irvine (1968) and Snook, et al., (1970), developed estimates of the load magnitudes a person would tolerate for varying rates of exertion (frequency of lifts) and for three different lifting heights. Also Snook (1971) and Snook and Ciriello (1974) have shown that both age and heat affect the physical endurance capacity of people allowed to choose their own work loads.

While it is the consensus of the workshop participants that psychophysical indices have been widely and effectively used to determine the subjective acceptability of manual materials handling acts, several basic inquiries are still warranted.

1 1 1 *It is necessary to determine how well a person can perceive his or her own maximum capacity to sustain a physical effort.*

In other words, how accurately can a person estimate the physiological and injury based hazard potential in a manual materials handling activity?

1 1 1 *Since psychophysically based human performance limitations can and are providing useful guidelines for the specification of manual materials handling tasks of many kinds, research should be instigated to define the testing conditions which could significantly affect the results.*

Factors, such as the instructions used, time of day, previous activities and training, and incentives may each influence the results.

1 1 1 *Larger and more heterogeneous working populations should be studied under a variety of conditions to determine their psychophysical tolerance to manual materials handling.*

III.3c Psychosocial Indices. Early versions of this subsection had entitled it sociological effects. However, the entire document focuses on the worker within a certain context or impinged upon by specified events or things. This focus on the individual worker is retained by substituting psycho-social for sociological effects. In effect one attempts to investigate the question of what effects does one's social milieu, specifically the people composing it, have on the individual worker.

The modern day worker, whether in a plant or office, hardly operates in a social vacuum. He is in the company of others - other workers and supervisory personnel alike - who can and do influence his behavior and his attitudes. He may belong to a myriad of small groups most of which lack any formal structure. In short he is a social animal while residing within a community, discharging his responsibilities as a citizen, and participating in various functions, both in and outside of the work situation.

What factors may influence the attitudes and behaviors of the hypothetical worker? Perhaps of particular importance are the experiences the worker has lived vicariously through the experiences of others. Accidents, injuries, or the tales of extreme hazards passed along to the worker stand to affect his overall perceptions of the job. The opinions, expectations, and attitudes of others may do the same. This may become a particularly powerful factor if these are shared by the entire group of which our worker is a member. Such social pressure whether overt or implied is often manifested as a pressure to conform or align oneself with the group. Clearly this kind of pressure may often come from a union and may be particularly potent when hazardous circumstances constitute part of the worker's job. Often hazards of the job can be magnified out of proportion particularly where realistic information about inherent hazard is subverted or where rumor becomes a substitute for fact. Rumor transmission usually results in an over-magnified, selectively sharpened image of the event.

The results of negative perceptions of the hazards experienced by the worker may result in "anti-social" or anti-management acts including high turnovers, absenteeism, job disruptions and stoppages, and in some cases strikes. Finally, the impact on the worker of others' perceptions or images of him following a partially disabling or disfiguring injury is food for consideration.

Although the committee has been unable to find articles focusing on the psychosocial effects of manual material handling it is believed that social forces have an effect on morale, large scale social movements, and subsequently worker performance. Social factors may also play an important role in the workplace in terms of the perception of and response to hazard whether or not it eventually results in accident or injury. In this regard, the following general recommendations are made:

1 0 1 *The most potent social factors operating in the workplace should be identified and their relation to the hazards of manual materials handling examined.*

0 0 1 *An inventory of techniques amenable to studying these factors should be compiled.*

0 0 1 *Past sociological analysis in the workplace should be reviewed for viable and heuristic conceptual and technical approaches.*

1 0 1 *Multivariate examination in the field of the outstanding social factors should be considered.*

SECTION IV

RESEARCH NEEDS ON SYSTEM CHARACTERISTICS

The preceding section has attempted to define the research needed to better establish the degree and type of hazard associated with manual materials handling. This section defines the research needed to establish valid controls of individuals and groups and the tasks and materials involved in manual materials handling slated to reduce recognized hazard levels. To do this the four major manual materials handling system components identified earlier in this report are each discussed both in terms of the literature that indicates the various hazard levels, and in terms of the research needed to develop controls of such hazards.

The order of reporting and subsection numbers are:

IV.1 Worker Characteristics
IV.2 Material/Container Characteristics
IV.3 Task Characteristics
IV.4 Work Practice Characteristics

IV.1 Worker Characteristics

One of the major components of the manual materials handling system is the worker himself. As will be shown in this subsection, the capacity to perform the physical acts embedded in the manual handling of materials varies considerably not only from individual to individual but within any given individual over time. Furthermore, the limitations of this capacity are complex and interrelated. Each is dependent upon many personal characteristics. Understanding the relationship of these characteristics to the resulting risk of injury or illness to the worker would allow development of schemes which would place people in jobs which do not compromise their health and safety. Clearly the worker's characteristics limiting his ability to handle materials safely must be carefully researched before thorough protective placement schemes can be developed. The worker related characteristics regarded as being of most relevance to the topic of worker risk are grouped below and will be discussed in subsections under the following headings:

IV.1a Anthropologic
IV.1b Sensory
IV.1c Motor
IV.1d Psychomotor
IV.1e Personality
IV.1f Training and
IV.1g Health Status
IV.1h Leisure Time Activity

Recommendations regarding future research needs are presented at the end of the subsections discussing each of these characteristics.

IV.1a Anthropologic Characteristics. The sex, age and various anthropometric descriptors of an individual's size and form collectively comprise this system characteristic. The literature suggests the potential effect of these attributes on risk of injury during manual handling of materials should be of major concern.

The literature reveals that the sex of the worker may be related to the risk of a materials handling injury or illness. It must be noted that both the ILO (1966) and more recently the U.S. Department of Labor (1970) recommended that women not be permitted to lift as much as men. It appears to be accepted that on the average a woman's lifting strengths (primarily arms and torso strengths) are about 60% of a man's according to Asmussen and Heeboll-Neilson (1961), Chaffin (1974), Snook and Ciriello (1974) and Petrofsky and Lind (1974). Furthermore, the biomechanical linkage mechanism when lifting differs between males and females with respect to the lever systems employed as reported by Tichauer (1973). Hence if asked to handle a given load, a woman is more highly stressed than a man relative to their individual strengths. However, it must be noted that the range in the strength of males and the strength of females are very large. Gender thus becomes secondary to the strength factor per se. Strength as a risk factor will be discussed within the subsection entitled motor characteristics.

It has also been reported that women have higher heart rates for given lifting tasks (Snook and Ciriello, 1974) and similarly the metabolic rates were higher for certain above shoulder lifts (Tichauer, 1965). It is, therefore, possible that women are at higher risk of injury or illness during given highly repetitive and continuous materials handling tasks since they must work closer to their maximum aerobic capacities than men, particularly as a woman nears her own individual maximums.

In regard to low-back injuries, Brown (1974) in a survey of industrial workers reports that women appear to have larger relative numbers of complaints than men when required to perform heavy, physical jobs. Magora (1970) reports a similar result. In a test of this Chaffin and Park (1973) studied both men and women performing equally demanding, light-to-moderate load handling jobs, and reported equal incidence of low-back pain cases. However, the women in this latter study performing moderate materials handling jobs were stronger than the average women in the study (i.e., an unknown selection process was operating). This last study demonstrates the complexity of the issue. Sex is confounded with many other worker and job characteristics, and hence only carefully designed multifactor studies must be considered as valid approaches to understanding the hazard related to sex.

Age, like sex, has often been considered before placing people on jobs requiring the manual handling of materials. In practice, advanced age is often used in restricting a person from load handling jobs. In fact, this is mainly based on speculation, namely that older workers have diminished capacity to withstand physical stresses (Åberg, 1961). Yet the literature indicates the greatest incidence of low-back pain (LBP) occurs in the 30 to 50 year old group (Herndon, 1927; Hult, 1954;

Kosiek et al., 1968; Magora and Taustine, 1969; Rowe, 1969 and Brown, 1973). Whether this is because older workers are not as likely to be exposed to the injury producing stresses of manual materials handling, or whether only those older workers who have survived a rigorous history of earlier stresses remain in the work force is not clear. It appears, however, that heavy physical work, even when performed in the twenties, can cause accelerated rates of injury (Blow and Jackson, 1971). Clearly age and aging have a complex effect on many attributes necessary for workers to safely handle heavy loads. It seems likely that the younger person may not have developed the requisite abilities to recognize and control the hazards of manual materials handling as has the older worker. He may be overly stressing his body; yet may have the strength to withstand the rigor of the job. On the other hand, the older individual, while having perfected his skills in handling heavy or cumbersome loads, is likely to have some diminished physical capabilities. Age must therefore be viewed as a potential risk factor. Nonetheless it is secondary to many other anthropometric attributes discussed in the following subsection.

Body weight has a potentially complex affect on an individual's risk of injury during manual materials handling. First, it is generally accepted that body weight has a direct affect on the metabolic rate of a person while lifting and carrying loads (Kamon and Belding, 1971). Thus a heavier person would have a greater metabolic rate and concomitant circulatory load, which could lead to earlier fatigue or cardiovascular problems if the person were so predisposed. On the other hand, a heavier person is usually stronger than his lighter counterpart, and usually has the mass necessary to counter-balance the handling of large objects (Snook and Irvine, 1967; Troup and Chapman, 1969 and Konz et al., 1973), though isometric muscular fatigue has been shown to develop more readily in overweight people (Petrofsky and Lind, 1974).

Besides body weight there are several other anthropometric variables which appear to have a potential influence on individual risk. Tauber (1970), for instance, indicates taller people have larger numbers of low-back incidents than shorter people. Tichauer, et al., (1973) report that changes in the lordotic curvature while holding a load in front of the body may be predictive of increased risk of future injuries to the back which may well relate to somatotype. Yet Troup and Chapman (1969) found that trunk/hip mobility did not correlate with the lifting strength of the trunk in flexion or extension.

The above is just a sample of the literature related to anthropologic factors. It is the opinion of the workshop participants that these worker characteristics must be comprehensively studied.

As presented in the literature summary, the past studies regarding personal risk associated with anthropologic variables divide into several topics. Hence, the research recommendations will be presented with regard to these same divisions.

Sex differences are evident in the literature, but are highly confounded with other anthropologic variables (e.g., strength, body mass, postures, anthropometry, etc.), which may be the more valid indicators of individual risk in a manual materials handling job.

1 1 1 *Hence, research is strongly recommended which will study the hazard potential of these more fundamental physical characteristics, both within and between sexes.*

Age and aging as a risk factor is unclear. For example, the incidents of low-back pain indicate that age may be correlated with reduced incidents in older individuals. Those older workers in heavy jobs may be survivors, however. It is clear that many other worker characteristics change with age. Experience usually leads to more skill, but diminished sensory and motor capacities with age may eliminate such advantages.

1 1 1 *Therefore, controlled laboratory and field studies are highly recommended, wherein the job stresses and specific worker characteristics are studied for different age groups in a multivariate fashion.*

Body weight and other related anthropometry are also factors which are highly confounded with other worker characteristics in the studies reviewed.

1 1 1 *It appears that these are not simple risk factors and therefore they need to be studied in conjunction with other anthropologic and motor characteristics (eg., stature, strength, mobility, reach, lean muscle mass, ponderal index, etc.).*

1 1 1 *Body postures and somatotypes in the unloaded state are not reported in the literature to indicate specific risk of later injury or illness, but work postures (under load) may be of predictive value, and should be researched further.*

IV.1b Sensory Characteristics. None of the literature reviewed described the role of the worker's sensory capabilities and sensory limitations in manual materials handling. Workers with certain diminished sensory capabilities may be more susceptible to the hazards of manual materials handling. The sensory processes expected to be most influential in assigning relative hazard include: visual, auditory, tactile, kinesthetic, vestibular and proprioceptive.

The need for research in this area of worker characteristics was first recognized in the recommendations of Badger, et al., (1972) and was reinforced in the current workshop deliberations.

1 1 1 *In particular, research is needed to understand better the role of the depth perception of a worker interfacing*

with material as well as the role of visual adaptation in hazards associated with poorly illuminated work areas. Since angular acuity is often corrected, in gross material handling, it would probably not be a factor in assigning risk. The use of multifocal corrective glasses, however, may be a factor and further research is needed. Contrast and dynamic visual acuity are also important sensory capabilities which are expected to affect handling performance and warrant additional study in this context.

0 1 1 *Sometimes heavy manual materials handling jobs are performed in adversely noisy environments. Recommended research is needed to understand the importance of auditory cues and the masking of these cues in manual materials handling environments. Shifts in audibility thresholds of susceptible workers may impinge on safe handling abilities and should also be considered in studies of sensory capabilities.*

1 1 1 *The tactile (cutaneous) senses may be important to the worker handling slippery, hot, or cold objects. The proprioceptive senses may be important to the material handler of unstable loads which require an awkward body posture. Further, kinesthetic abilities (awareness of position and movement of body parts) may affect material handling capabilities as may the vestibular orientation mechanisms related to body balance. Each of these sensory process capabilities may play important roles in materials handling illnesses and injuries and thus warrant careful delineation and study in the context of the hazards of manual materials handling.*

IV.1c Motor Characteristics. As with the sensory capabilities of workers, little is known of the relationship between motor capabilities (strength, endurance, range of movement, speed of movement and hypermobility) and the hazards of manual materials handling. Here to, Badger et al., (1972) recommended research to develop better body mobility tests and better strength testing techniques to supposedly reduce incidences of low-back pain injuries.

A number of studies by Chaffin (1970, 1972, 1974) have begun to examine the correlation of strength testing results with incidents of low-back pain. For example, it was observed that the incidence (rate) of low-back pain was three times greater for people lacking adequate lifting strengths to perform all job elements than for stronger workers. A biomechanical model was developed to predict lifting strength based on anthropometry, sex, coupling point dimension, and body position. At present, a rigorous validation of the model has not been attempted.

Keaney (1954) studied championship weight lifters, representing the upper limit of strength capability of the population, and concluded that contestants in lighter weight classes are stronger in proportion to body size than heavier weight classes. This change in strength/weight ratio with increased body weight may be a factor in the greater agility and endurance found in smaller men. Likewise these latter two factors may partially counterbalance the brute strength of heavier men.

Other references related to worker motor capabilities include Kraus (1967) who asserts that tests for strength and flexibility of key postural muscles are essential for good pre-employment back examinations. Kroemer (1970) points out the difficulties and pitfalls in current strength testing methods and emphasizes the need for standardization of strength testing techniques. Davis (1959), Bartelink (1957), and Alston (1966) discuss the role of abdominal and back musculature in controlling the manual lifting process and associated stresses.

All of the reviewed research on worker motor capabilities has been limited primarily to assessments of muscle strengths measured for exertions in the sagittal plane.

1 1 1 It is recommended that research strive to provide a more comprehensive characterization of the role of the motor capabilities of the working population to include:

1. *strength in postures other than the sagittal plane,*
2. *endurance capabilities, including localized, whole body, and sporadic endurance,*
3. *range of movement capabilities,*
4. *kinematic capabilities, and*
5. *muscle training state.*

1 1 1 As data is made available from the research of the above recommendation, the focus of study should turn to the development of methods for using motor capabilities (in particular, strength data) more effectively in task design.

1 1 1 It is also recommended that study of how worker motor capabilities relate to hazard indices other than biomechanical and psychophysical (e.g., metabolic, circulatory/pulmonary, and psychological) be made.

IV.1d <u>Psychomotor Characteristics</u>. No reported research was found to relate the psychomotor capabilities and limitations of manual materials handlers to the hazard indices. The information processing capabilities, reaction/response times, and coordination abilities of workers may all contribute to the occupational hazards associated with handling materials.

1 0 1 *Research is required to define the risk associated with the coordinative aptitudes and skills of the worker engaged in manual materials handling. It is believed that these capabilities may have only marginal effects in routine situations but are expected to be associated with greater risk under highly stressful tasks and/or working conditions.*

IV.1e Personality Characteristics. The characteristics of the worker's personality which may increase susceptibility to the hazards of manual materials handling are not easily measured or interpreted. The difficulties of translating measures of worker values and job satisfaction such as attitude profiles into useful criteria are evidenced in the research reviewed by the workshop participants.

The most recent study by Blow and Jackson (1971) attributes the observation of more injuries in young workers under the age of 25 years to inadequate training or experience and an immature attitude among youthful workers. Magora (1970) in Israel observed that formal education and religious training may increase low-back pain severity. He earlier (1969) reported that psychosocial background and attitude toward life were observed to affect duration of sick leave from work. Shano and Edwards (1956) observed that the number of accidents was equal for permanent and temporary workers over 45 years of age. White (1966) speculates that people receiving low-back pain compensation may become insincere after exaggerating claims of disability, that people try to avoid work whenever possible, and that the psychosomatic aspects of low-back pain compensation cases should be studied.

As with many of the other worker variables, the study of personality characteristics is most often confounded with other demographic or anthropometric variables such as age, training, or experience. Clear evidence as to how the role of worker values and job satisfaction contribute to risk does not exist.

0 0 1 *The measurement and prediction of worker attitudes with respect to manual materials handling warrants research attention. What are the attitudes of workers toward the hazards of manual material handling? What are their attitudes toward training? Is their attitude toward training a predictor of hazard susceptibility? How is attitude measured? Does poor attitude lend itself to aggressive/destructive behavior?*

0 0 0 *Virtually nothing is known about how workers perceive risks and how their attitudes and behaviors are influenced by their perceptions of risk. Thus, it is recommended that research address the concept of risk acceptance to define what levels of risk are tolerable to the working population.*

0 0 0 *It is expected that risk acceptance of the manual materials handling hazards is influenced by perceived economic need. Attention to the strength of this relationship is needed to better characterize the susceptibility of the workforce to hazards.*

IV.1f Training/Experience Characteristics. The importance of training and work experience in reducing hazard is generally accepted in the technical literature. The lacking ingredient is largely a definition of what the training should be and how this early experience can be given to the naive worker without harm.

Davis and Troup (1964) and Brown (1958) discuss the need for training, particularly on self-pacing, to reduce worker fatigue, especially with heavy loads. Glover and Davies (1961) present a training course scheme which involved a physiotherapist giving instruction in manual materials handling and lifting methods to workers. Afterward they observed a reduction in manual materials handling accidents. Himbury (1967) discussed a similar training course for manual workers with supervisors emphasizing the kinematic method for lifting using the strong leg muscles and body weight momentum. Smith and Edwards (1968) report increases in isotonic strengths, geometric strengths, and endurance after training.

According to some researchers, laymen appear to imitate the mechanical body positions shown in instructional pamphlets. This shortcoming of many training schemes was the subject of a critique by Anderson (1970). Burch (1965) suggests that disc degeneration in adult males is largely due to the "soft way of life" and points out the need for physical conditioning in addition to safety instruction.

The sole study reviewed which explicitly considered the experience of workers was by Magora (1970). He found a discrepancy between the subjective assessments of work performed between a group of workers with low-back pain histories and a control group of workers. This discrepancy was also apparently related to the time spent in the same occupation.

It is interesting to note that in all of the literature reported there were no thoroughly controlled experiments. Those experiments with training were of a "before" versus "after" training type with no comparison group of workers which had undergone no training during the duration of the study. Studies of experience characteristics invariably confound experience with age. There were no workers of any age who were neither trained nor experienced.

1 0 1 *It is concluded that little is known of the training/experience phenomenon in the context of manual materials handling. Study is needed to evaluate the effectiveness of diverse training schemes. A few alternatives for future comparative study include*

1. *conditioning training: the physical conditioning of the body to the specific demands of the job,*
2. *experiential training: learning by experiencing controlled hazard at the workplace,*

3. *vestibule training: training of "correct" methods for handling prior to job placement,*
4. *on-the-job training: training of "correct" methods for handling for a particular job after placement,*
5. *general job orientation: similar to experiential training with the exception that some general information in the form of do's and don't's are passed from one worker or foreman to the new worker.*

With respect to worker experience, it is not uncommon for older workers to enter the more demanding jobs later in their careers. It is also possible for some young workers to have considerable experience.

1 0 1 Research is certainly warranted to discern between the importance of age versus experience as contributory factors to the hazards of manual materials handling.

IV.1g <u>Health Status Characteristics</u>. At the time of an employment examination a variety of medical tests have been used to forecast individual risk of later injury or illness. The literature summarized below examines some of the complexities of this characteristic of the worker.

There are strong opinions, as summarized by such experienced physicians as Clark and Russek (1958), Hanman (1958), and Peres (1960) that good physical examinations are effective in reducing the number of workers who will later experience low-back pain. Studies by Magnuson and Coulter (1921), Becker (1955), Moreton et al., (1958), McGill (1968), Kosiek et al., (1968) and Rowe (1969) appear to justify this approach. More skeptical opinions are expressed by White (1966) and, earlier, by Osgood (1919). Rowe (1969) states about 10% of later low-back pain sufferers could be detected by a complete physical examination, including a lumbo-sacral radiographic evaluation upon employment.

The use of radiographic findings for assessing the risk of later LBP has been thoroughly debated. Though papers by Stewart (1947), Becker (1955) Kosiek et al., (1968) and McGill (1968) strongly advocate the use of X-rays for pre-placement of people, more recent papers by LaRocca and MacNab (1970) and Redfield (1971) seriously question the predictive validity of such X-rays. It now appears that only the grossest of skeletal anomalies would be allowed to exclude a person from a materials handling job (Leggo and Mathiasen, 1973). Along these lines Runge (1958) had earlier suggested spondylolisthesis and obvious disc degeneration be considered as grounds for rejecting a person's placement on heavy manual materials handling jobs. Stewart (1947) and Kosiek, et al., (1968) indicated disc degeneration should also be considered as a basis for rejection of a person on jobs requiring heavy labor.

Because of a growing concern over radiation of people due to X-ray examinations, there has been a growing need for other more objective tests of a person's health status. The development and evaluation of such tests were highly recommended recently by a group of experts concerned with occupational low-back problems (Badger et al., 1973).

The literature also indicates that medical and occupational histories are important in determining an individual's risk (Rowe, 1969). Magora and Taustein (1969), Meyers (1967) and Hirschfield (1963) all strongly urge consideration of various psychosocial factors when determining the capability of a person to perform manual materials handling.

The available literature indicates that for a large number of operating conditions pre-placement medical examinations for manual materials handling jobs have been effective in protecting the workers. What is in question, however, is the validity of medical criteria and safety of methods used to select people for the jobs. Static visual measurements may be insufficient to judge safety motions. Spinal X-ray findings must be blended with a judicious medical history and physical examination in setting load limitations. When evaluating the status of the lower back in males and females: Concern for radiation injury has encouraged search for functional tests of equal or greater usefulness.

1 1 1 *It is therefore recommended that functional tests be more quickly developed and evaluated in well-controlled laboratory and field studies.*

The literature indicates that medical and occupational histories are important factors in assigning risk of future injury. This includes the habitual taking of drugs. Tichauer and Wolkenburg (1972) and Gold et al., (1973) have reported that changes in lifting posture are still observable for many hours after blood alcohol, following an episode of social drinking, has returned to zero.

1 0 1 *Unfortunately, the specific criteria for assigning risk based on such histories have not been evaluated, and thus research is recommended. In this regard the physical, psychosocial and occupational histories appear to be important, and should thus be included in such studies.*

1 0 1 *It is also recommended that studies be undertaken to better determine the individual risk to a person working in manual materials handling jobs when 1) using drugs of various kinds, 2) pregnant, 3) at various points in the diurnal cycle, and 4) deconditioned due to aging, sickness, injury or prolonged absence from physical activity.*

IV.1h Leisure Time Activity. This category of worker characteristics which must be better defined in relation to the hazards of manual materials handling was considered only by one researcher (Minard, 1971) in the literature reviewed. Discriminating between on-the-job or job related injuries and off-the-job injuries is often difficult, if not impossible. For instance, back injuries sustained off-the-job may not show up until the next day when special physical exertion is required at the work place.

1 0 1 *To better understand the role of extracurricular activities such as holding a second job or regular participation in sports, studies are needed to examine the relationship of these activities to the hazards of manual materials handling.*

Here, too, there are confounded variables. Second jobs affect diurnal rhythmns (see Health Status) and regular participation in sports or athletic activities promotes physical conditioning (see Training/Experience) so the potential hazards associated with leisure time activities will not be easily distinguishable from a number of other possible factors.

IV.2 Material/Container Characteristics

The second major component of the manual materials handling system is the material and/or container. The characteristics of the material which affect the worker/material interface are of primary importance here, since it is this interface, particularly that related to the material side, which is subject to the establishment of industry standards. These characteristics have been grouped into five categories as follows:

IV.2a Load
IV.2b Dimensions
IV.2c Distribution of Load
IV.2d Couplings
IV.2e Stability of Load

Recommendations regarding future research needs are presented at the end of the subsections discussing each of these characteristics.

IV.2a Load Characteristics. The findings reported in the literature are confusing and do little to provide a recognizable direction to be followed in future research. Consider first the reported incidence of low-back pain in industry. Hult (1954), Kosiek, (1968), Magora (1968) and Rowe (1970, 1971) are a few of the authors who contend that the frequency of low-back injuries is undoubtedly (though only moderately) greater in "heavy" than in "light" industries. Newcomers to this scene of research are invariably surprised at the frequency of this kind of injury in light indistry. Surprising, too, are reports that many of these injuries occur when individuals lift objects which are familar in size, shape and weight (Herndon, 1927; Brown, 1955). Another point of view is reported by Chaffin (1973) who found that the weight lifted, when considered as the sole criterion of the job, was not correlated with low-back pain when the weight was less than 35 pounds. Furthermore there is good reason to believe that the expenditure of a good deal of time and effort in the training and education of industrial workers in the "back-straight, lift-with-the-legs" method of lifting has been to little or no avail since the subsequent frequency of industrial injuries has not abated (Brown, 1972).

Second, many workers have used a variety of approaches to rationalize the definition of maximal permissible loads for workers. Gupta (1964) defined the maximal permissible load as that weight which could be carried for 30 minutes at a speed of 4.5 Km/hr without a continuing rise of heart rate, and with rapid recovery of the heart rate afterwards. Hamilton (1969) found a linear relationship between the weight of the load and $\dot{V}_{O_2}$ and heart rate when the weight was between 10 and 25 pounds; for a fixed work output he found it preferable to move heavier loads at a lower rate than lighter loads at a fast pace. But

Kamon (1971) advocated, on the basis of metabolic and cardiovascular responses, that 33 pound packages were preferable to 22 pound or 44 pound packages when large amounts of material were moved by hand. Åberg (1961) considered that when only one act of lifting was to be undertaken, the limiting load depended on the worker's body weight. Ronholm (1962) found that when lifting of a weight of 11 pounds is repeated, the optimal rate, in terms of $\dot{V}_{O_2}$ was 30 lifts/minute. Goldman (1962), however, considered that the energy cost, per unit weight, of reasonably fit men was constant, regardless of the distribution of weight between the body and the load, for weights up to 66 pounds. Datta (1973) described linear empirical relationships between the weight of the load, the $\dot{V}_{O_2}$ and peak heart rate. Chapman and Troup (1969) found a linear relationship between the integrated EMG output and the load pulled, but that training reduced the EMG output. Lind and McNicol (1968) showed that when two men carry a stretcher by hand with a total weight of 176 pounds (or 44 pounds per carrying hand), local isometric fatigue occurred rapidly, whereas if the same load was carried by a yoke, thereby distributing the load to much stronger muscles, the stretcher could be carried without fatigue. Jorgenson (1974) concluded that in repetitive, submaximal lifting, the capacity of both the oxygen-transport system and the muscle strength were limiting factors and advocated that loads should not exceed 50% of the maximum strength. Thomas (1959) found that carrying a load on the back produces increased spinal flexion as the weight increased from 26 pounds to 53 pounds. But Datta and Ramanathan (1971) found this mode of carrying to be much less demanding in terms of oxygen consumption than, for example, carrying the same weight by hand. Snook and Irvine (1967), who investigated the weight of loads to be lifted, in terms of voluntary acceptance, to be between 40 and 60 pounds depending on the height of the lift. Later, (1968) they described the acceptable weights to be lifted at specified rates, in terms of percentiles (from 10 to 90) of the subjects they examined. Snook (1970) found the maximum (voluntarily) acceptable weight to be moved by 90% of his subjects to be between 28 and 37 pounds and later (1974) described comparable values for female industrial workers. Tichauer (1970, 1971) advocated the weight/bulk ratio of the wieght to be lifted as a major determinant of the severity of the task, and proposed that weight limits set without regard to the bulk of the object would fail to take account of many accidents which occur with objects weighing less than 10 pounds. Tichauer (1973) also reported that there was no direct relation between spinal response and the weight, alone, of objects lifted. McConville and Hertzberg (1968) showed that the maximal weight that subjects could lift with one hand varied linearly with the width of the object lifted. Chaffin (1969) investigated the forces operating on the L_5/S_1 disc for various postures and loads; he found that individuals limited the L_5/S_1 forces to approximately those levels that lead to fracture in cadavers.

In summary, the statistical description of industrial injuries and accidents due to lifting and handling provides little clarification of the role of the weight lifted. Those statistics fail to consider the confounding features of rate of lifting, size and shape of the load, environmental factors, body size and any of the many other features which can be expected to influence the frequency of injuries and accidents, and the importance of which are repeatedly emphasized in this report. In terms of the studies reported, weight is an uncontrolled variable, and thus may be masking or amplifying the true cause of injuries.

The weights handled and forces required to move objects have been recognized as an important variable in most reported studies. Unfortunately, there is little agreement in research findings of the true role of the load as a contributor to the hazards of manual handling.

In laboratory studies, the study of weight is more easily controlled and in a number of studies this has been done. The indices of hazard also change to behavioral and physiological factors. Thus the experimental setting and the hazard-response variables are confounded. Unless a relationship between physiological and behavioral indices and injuries can be drawn either in the field or in the laboratory, the results of laboratory studies may lack validation and practical application. Strong relationships between weight and the behavioral and physiological indices have been drawn. However, they are always qualified by some other system characteristic. This interaction of system characteristics must be continually recognized.

1 1 1 *Weight is neither an additive variable nor is it a simple linear component. Care must be exercised in future research to assure that this non-additivity and non-linearity is taken into consideration.*

The extrapolation of the observed interactions in the laboratory to the working population in the field must also be carefully examined. Validation of interactions with uncontrolled "independent" variables is alway expensive in terms of research effort.

1 1 1 *The concept of the "load moment" as an indicator of stress has not been used enough in previous investigations and thus it is recommended that the use of this measure be emphasized in future research.*

1 1 1 *The majority of studies in the past have recorded only "lifting" of objects in the sagittal plane. If the true characteristics of load are to be understood more extensive study of "twisting" and "turning," "pushing" and "pulling" activities are needed.*

1 1 1 *Also, the moments of other body member may be used to characterize risk in terms of the kinetic chain of moments and certainly warrant future study.*

1 1 1 *Further, it is expected that some loads are hazardous due to inadequate labeling. The ability of the materials-handler to perceive load characteristics of weight and force is no doubt minimal for the non-repetitive handler. Hence, guidelines need to be developed regarding the labeling of objects for hazard due to weight and other container characteristics.*

IV.2b Dimensions. Unlike the load characteristics, the dimensions of objects has received relatively little attention in the research literature. Badger, et al., (1972) recommended that more careful research be performed including this task characteristic. The Ergonomic Guide to Manual Lifting (1970) without substantiation considers size of objects as a significant hazard factor to consider in lifting. The awkwardness effects presented by Drury and Pfeil (1973) reflect the possible load dimension effects, but only indirectly. McConville (1968) found that the maximum weight subjects would lift varied linearly with the width of boxes in a study of the interaction of weight and density of one-handed symmetrical boxes.

Tichauer (1970) presents the weight/bulk ratio as a major factor in determining severity of lifting tasks. He recommends the establishment of quantitative relationships between this ratio and physiological work stress. Later (1971) he shows that load moments about the L_5/S_1 disc and hips can be estimated for upright carrying by using the weight/bulk ratio of the load.

In general, it is observed that field studies which attempt to relate material dimensions and shape to the hazards of material handling are not abundant in the literature. Those reported laboratory studies of material handling do often quantify the material dimensions but seldom include height and width in the frontal plane as opposed to the sagittal plane. Further, how different load shapes may influence biomechanical adaptations or awkward positions has not been well studied.

1 1 1 *Research is needed to better characterize those shape parameters which may be standardized in measurement for use in hazard evaluation. Specifically, research is needed on the effects of frontal plane width and object height as they relate to risk.*

1 0 1 *The study of objects which change shape during handling would be worthwhile since many materials do not remain of the same shape/dimensions and require special considerations in handling.*

IV.2c <u>Distribution</u> <u>of</u> <u>Load</u>. A great many materials handling tasks are not the two-handed symmetrical lifting tasks emphasized in previous research. Some minimal attention has been paid to other load distributions and may be summarized as follows.

According to Anderson (1951) the proper method for lifting must be based on the load distribution. For example, lifting bags requires special foot, chin and grip positions. Brown (1973) hypothesizes that movement with a load in a plane which is not parallel to the plane of the center of gravity may result in injury. Cathcart (1928) showed that the cheapest (physiologically) method of carrying was by yoke. Carrying with hands at sides was also physiologically economical but with heavy loads tends to cause severe elbow and arm strains.

Chaffin's (1970, 1972, 1973) biomechanical models include the location of the load with respect to the worker as an important variable in load lift capability prediction. Datta (1971) evaluated seven load distribution schemes. Drury and Pfeil (1973) recognized the effect of load distribution to some extent in their study of object awkwardness.

Virtually all of this reported literature relates load distribution to the hazards of manual materials handling in a laboratory setting. No reference was found which examined asymmetric loads in symmetric containers and thus load distribution and load shape were treated synonymously. In practice, this is not a good strategy, since as has been pointed out above, distribution and shape are not always synonymous. That is, asymmetrical shapes, if carried correctly, may be reasonably well distributed while symmetrical shapes may be unbalanced.

1 1 1 *Future studies are needed to characterize the general problem of one-handed material handling. This coupled with a better characterization of the postures encouraged and stresses induced by asymmetric load distributions would fill a gap in knowledge which has been long overlooked.*

1 0 1 *Special functions such as drum chiming and barrel rolling also need to be considered in future studies as exceptions to the more general modeling approaches of the past.*

IV.2d <u>Couplings</u>. The design of handles and gripping surfaces as coupling devices to aid the manual materials handler has received little attention in the literature. Himbury (1967) and Koskela (1968) point out the need for full grasp handles to avoid injuries occasioned by dropping the load. The International Labor Office (1958, 1966) recommend large hand grips as necessary for couplings in dock work. Inspection of grips is also a recommended good practice. Powell (1971) recommends improved packaging of goods with plastic rather than metal bandings to reduce hand injuries. Better box construction is also recognized as important.

Cathcart and Bedale (1928), Gupta and Rohmert (1964) and Datta (1971) point out the advantages of yokes (a special type of coupling) in carrying loads for long distances. Anderson (1951) recognizes that all objects cannot have handles, such as bags of material, and thus recommends adjustment of moving methods such as special footing and gripping techniques to facilitate handling.

1 1 1 As can be seen, virtually no relevant quantitative research was found on the proper design and placement of coupling devices. The criteria for including handles, the difference in capacity to carry loads, and the user acceptance of alternative coupling devices requires research attention.

1 1 1 Further, research is needed to determine the characteristics of good coupling devices, including for example,

1. surface texture
2. placement
3. orientation
4. dimension (including bearing surface).

Also, handles may affect postures and thus induce additional materials handling hazards so there is a need to discriminate between lifting, carrying, pushing and pulling-type coupling devices.

1 1 1 Adequate literature relating grip strength and basic hand dimensions to the hazards of manual materials handling (both gloved and ungloved) is lacking. Before viable safety criteria for coupling devices can be established, these data must be obtained.

1 0 1 It is important that more attention by given to the functional characteristics of the hand other than grip strength. At present these are neither well understood nor are they related to hazard potential and thus research is warranted.

1 0 1 Further, the interaction of the task variables and gripping surface needs to be studied, especially as it relates to hand function.

IV.2e Stability of Load. No literature was found which directly related load stability (i.e., consistency in location of the center of gravity) to any of the hazards associated with manual materials handling. As mentioned in conjunction with load distribution, it is not uncommon for a symmetrical container to contain asymmetrical materials whose weight is not evenly distributed across its mass or is somewhat smaller than the box. In the case of the latter event loads may shift in movement and it is not enough to consider just the shape and dimensions of a container.

1 0 1 *It is recommended that research attempt to define the compounding of hazards evidenced by special materials such as handling of liquids and bulk materials.*

IV.3 Task Characteristics

The third major category of system characteristic variables which is of concern in determining the potential hazards of manual materials handling are the characteristics of the task. Emphasis here is placed on those characteristics of the task which make up the worker/material interface. They are expected not only to modify the associated hazards but to uncover identifiable measures upon which standards may be based.

The task characteristics of concern in the following subsections include:

IV.3a Workplace Geometry
IV.3b Frequency/Duration/Pace
IV.3c Complexity
IV.3d Environment

Recommendations regarding future research needs are presented at the end of the discussion of literature related to each task characteristic.

IV.3a Workplace Geometry. The characteristics of workplace geometry which are expected to contribute to the hazards of manual material handling include the nature of the origin and destination points of movements, objects in the pathway, and confined spaces which may restrict the movement. Two references were found in the literature which specifically relate to workplace geometry, Peres (1960) and Powell (1971). While both of these articles point out the need for more research in this area they do not offer recommendations for workplace design.

Since workplace geometry is a major component of the manual materials handling system it requires research attention. Studies are necessary to understand:

1 1 1 *the sequencing of lifting patterns encouraged by workplace layout and the role of confined spaces on the hazards of manual materials handling;*

1 1 1 *the role of imperfect surfaces (e.g., stairs and grades and slippery surfaces) on hazards, including the worker's perceptions of imperfect surfaces;*

1 1 1 *the characteristics of good coupling and uncoupling points. Included here is a need for studies of the effects of movement distance, direction and extent of path, obstacles, and nature of the material destination.*

1 0 1 *the possible postural reflex hazard associated with certain workplace geometries;*

1 1 1 *the hazards associated with manual materials handling while in a seated position. Here, too, research is needed to determine criteria for seated workplace design to include the effectiveness of footrests and general chair configuration.*

1 0 1 *the hazards associated with manual materials handling while in other than seated or standing positions (e.g., kneeling, crouching, prone);*

1 0 1 *the interaction of workplace geometry with the material/ container variables.*

IV.3b Frequency/Duration/Pace. The relation of frequency, duration and pace of manual materials handling to the hazards of handling has been studied in a number of contexts. However, the results and inferences are far from clear, conclusive or exhaustive. For example, Åberg (1961) set out to determine how frequently lifting can be performed, and reached no generalizable conclusion. Bartina (1961) points out the need for a standard related to maximum lift frequency but offers no guidance to accomplish this effort.

Research which supports the need for better understanding of frequency was performed by Chaffin and Park (1973) who found occasional and high frequency load lifting to be related to increased incidence rates of low-back pain. Chapman and Troup (1969) examined pulling durations and found mean EMG levels to be related to the time of sustained exertion. During contraction at 30% of maximum for four minutes, they observed that EMG activity was reduced to 70%.

Goldman and Iampeitro (1962) present graphs of relationships between pace, grade of walking surface, and load to enery costs. Hamilton and Chase (1969) showed that pace and weight significantly affect energy expenditure and heart rate in a linear fashion. Ronholm (1962) shows the greatest physiological efficiencies occur for frequencies between 20 and 30 lifts per minute with 5 kilogram loads. Williams (1968) shows variation in mechanical efficiency with body weight and intensity of work, the latter of which is related to frequency, duration and pace.

Snook and Irvine (1968) provide profiles of different population percentiles for maximum lift frequencies based on psychophysical measurement techniques. Jorgensen and Poulsen (1974) conclude that maximum lift frequencies for females is approximately 70% of that for males at the same relative burden.

To clarify the role of frequency, duration and pace, a number of research efforts are required.

1 1 1 *A careful delineation of the role of periodicity of efforts is needed. For example, often a load may be lifted 20 times per day with an average lift duration of two seconds per lift for two weeks every other month with no lifting at other times. The quantification of the influence of frequency and duration on hazard potential is not easily delineated.*

1 1 1 *Frequency, duration and pace have historically been viewed only with mean (average) values; however, attention to the variability of these measures by spectral analysis would be desirable.*

1 1 1 *The possible interaction of these variables with the material/container characteristics, namely load, also merits attention.*

0 1 1 *The "warm-up" phenomenon for physical activity is not clearly understood. Does this warm-up reduce risk? This, too, is a topic for necessary research.*

1 1 1 *The effects of overtime (increased task duration) on the hazards to the individual involved in manual materials handling requires additional study.*

1 1 1 *The significance of self-paced versus machine-paced operations in terms of hazard potential warrants research attention.*

IV.3c Complexity. The concept of task complexity as addressed in the technical literature has not been in the context of the hazards associated with a manual materials handling task. Rather the concept was derived in relation to performance times and productivity standards associated with classical work measurement methodologies. Times required to perform various intricate movements of the hands and arms as a function of distance, load, and tolerance have been derived.

In terms of the hazard potential in gross manual handling, there is a scarcity of literature. Research is needed to:

1 0 0 *Examine the combined or compounding demands of the load due to manipulation requirements of the activity, precision tolerance of the movement activity, and the number of kinetic components.*

0 0 1 *Understand the degrees of freedom and kinetic components required in handling as indices of task cpmplexity and resulting hazards.*

0 0 1 *Determine the hazards associated with interactions of load dynamics and task complexities. For example, accelerations and decelerations required to position a load quickly and accurately may exaggerate the material handling hazards.*

IV.3d Environment. The environment in which the worker handles material to accomplish a task is known to affect performance. Little is known, however, of the hazards associated with adverse environments in terms of added deteriorative effects. Further, the interaction of these environmental factors with other system characteristics and with other environmental variables themselves has received little attention in previous research. This is at leastly partly due to the fact that researchers do not document the operating environments in which studies are undertaken unless the environment if of specific relevance to the study topic. Care should be exercised in future studies to report typical environmental conditions for reader perspective.

The four articles reviewed by the workshop participants in this context may be summarized as follows. Kamon (1971) showed that heart rate increases approximately 7 to 10 beats per minute for each 10 degree centigrade rise in temperature. Magora (1970) did not observe any effects of climate on the incidence rate of low-back pain in his study. Shano and Edwards (1956) found seasonal peaks (winter and summer) in accident rates but could not suggest that the effects were necessarily environmental. Tauber (1970) noted that more backaches appear to occur in warm months than during cold months, but again not necessarily temperature related.

> *Research is needed to identify the effects of those physical environmental variables which represent compounded stress and hazard to the worker including*

1 1 1 a) temperature

1 1 1 b) altitude

1 0 1 c) illumination

1 0 1 d) toxic substances

0 1 1 e) noise

0 1 1 f) vibration

Each of these variables is expected to affect other dimensions of the system characteristics. Temperature, for example, could affect worker coordination (see psychomotor capabilities) as well as sensory and motor capabilities. The effectiveness of gloves, clothing, and personal protective devices (see administrative work practice characteristics) may be modified by environmental conditions.

Altitude studies have been performed in the past and hypoxic effects are well documented. Unfortunately, most of the studies were performed in mines, submarines, or spacecraft. Little is known of the hazardous effects of moderate amounts of reduced oxygen when performing manual materials handling jobs. Fatigue due to climatic conditions such as temperature may also compound the hazards of manual materials handling. Here too, identifying the worker population is important for within limits native residents adapt to certain temperature and altitude environments.

0 0 0 *The long term adaptation phenomenon to altitude and temperature effects on the hazards of manual materials handling merits research attention.*

Finally, care must be exercised to assure that apparent environmental influences are not actually surrogates of other causative factors. Seasonal effects must be critically analyzed (eg., farm workers may not report or complain of injury until after harvest) to assure that real causes are not masked.

IV.4 <u>Work Practice Characteristics</u>

The following discussion of the potential hazards regarding various work practices of both the organization and the individual are grouped into the following three divisions:

IV.4a Individual Practices (including lifting techniques)
IV.4b Organizational Practices
IV.4c Administrative Practices

Recommendations regarding future research needs are presented at the end of the discussion of literature related to each type of work practice.

IV.4a <u>Individual Practices</u>. The major literature pertaining to this system characteristic is in regards to the "correct" posture during load lifting. Proponents of the universal, erect back, squat leg posture predicate their views basically on a simplistic biomechanics logic; namely that this posture allows the load to be held close to the torso and, therefore, the spinal bending moment and compression forces will be small. In addition, the stresses on the vertebrae will be better distributed with an erect back lifting posture, e.g., Floyd (1958), Davis (1959), Munchinger (1962), Himbury (1967), Andersen (1970) and Nachemson (1971). In such analyses, little concern is shown for the actual dynamic loadings on both the back and the knees during the actual lifting sequence, not withstanding the practical fact that many heavy objects are too large to be lifted between the knees, as is required by the squat lift method. Furthermore, papers by Clark and Russek (1958), Brown (1973) and Jorgensen and Poulsen (1974) disclose that leg lifting from a squat position is metabolically more demanding, thus possibly leading to more fatigue related injuries (e.g., slips and falls, or dropping of object). Chaffin (1969) found that the location of the load relative to the back is more important than the lifting posture in generating high compressive forces in the spine.

Confounding the issue of which posture is the safest for lifting is the realization that many low-back pains occur due to sudden slips and the resulting postural corrections necessary to regain balance (Hult, 1954; Brown, 1958). Therefore, to protect the back as well as other body segments one must maintain a posture which assures a maximum stability over the period of the activity. Grieve and Arnott (1970) indicate, for instance, that torso strength is directly affected by the relative foot positions, with a "wide stance" being recommended. Further complicating the dynamics effects is the fact that handling lighter loads often involves high initial accelerations which can overstress the back (Troup, 1965; Tichauer, 1970).

Brown (1973) also raises the question regarding the extra stresses imparted to the spine when having to laterally bend or torsionally rotate the torso. It was agreed by the Workshop participants that this is an important factor, but the degree of hazard has not been established.

Finally, the pace of lifting loads has been studied in mostly laboratory settings. The literature examined clearly indicates that the metabolic rate is increased in proportion to the frequency of lifts (Hamilton and Chase, 1969). Also, using self-paced lifting rather than machine-paced is more efficient (Karvonen and Ronholm, 1963), and free-paced lifting in brief bouts with specific rest periods minimizes the metabolic rates as opposed to paced lifting with distinct rests between each lift (Ronholm, 1962). Further, the maximum efficiency (metabolic expenditure/work done) is often accomplished with lighter loads and higher frequencies.

Biomechanical evaluations of the injury potential of various lifting postures appear to form the basis for most of the recommendations followed by many people today.

1 0 1 *Unfortunately, the rules used to recommend specific lifting postures have been overly simplistic, and conflicts exist which can only be resolved by further research leading to the development of more representative biomechanical models of the body and the critical validation of these models as they are developed.*

This latter need is particularly evident in as much as controlled field studies of lifting postures used in industry and the associated injuries were not obvious in the literature. It was reported by Tichauer (1973) that ten different elements of a lifting task have to be considered simultaneously if a statement about its stressfulness is to be made.

1 1 1 *Thus, field evaluations of common lifting postures in industry should be an initial investigation.*

1 0 1 *Industrial field studies are also needed to determine the extent to which meterials handling related injuries are due to the individual's work methods as opposed to other system characteristics (e.g., poor working conditions, task specification, or container design).*

The need for this type of inquiry appears to be supported by reports which relate many incidents of low-back pain to slips and falls as opposed to overexertions.

The literature appears to support the view that sudden movements which create high accelerations of both the body and load masses, and/or movements which twist and laterally bend the torso are potentially hazardous.

1 1 1 *Unfortunately, the degree or nature of the hazard due to these dynamics is not well described, and hence both laboratory and field studies are warranted.*

In essence, this latter recommendation simply requests that future studies attempt to broaden the scope of inquiry to include consideration of more realistic lifting, carrying, and pushing/pulling activities than have been studied in the past.

IV.4b <u>Organizational Practices</u>. Studies by Kosiak, et al., (1966) and Becker (1955), report that the incidence of low-back pain was significantly reduced when both organizational and administrative changes were introduced. The organizational changes were to instigate comprehensive medical, safety and hygiene programs. Though details of how these programs operated were not available, their experience would substantiate what is often reported informally by many occupational health and safety managers. Unfortunately, studies do not appear evident which could identify the specific organizational practices which might be generalizable to many different types and sizes of organizations.

0 0 1 *It is recommended that field studies be initiated to determine if organizational factors play an important role in determining the hazards of manual materials handling.*

Typical questions which need to be researched are: What is the adequate number of medical, safety, hygiene and engineering professionals for a given group of productive employees engaged in manual materials handling? What type of consultative health and safety services are necessary and most effective when people are engaged in manual materials handling? How does plant size affect the level of hazard in various types of manual materials handling operations? If it does have an effect, why does it? What affect does the existence of "materials handlers" as a job classification have instead of allowing any worker to perform this activity in a plant?

IV.4c Administrative Practices. Several different administrative practices are discussed in the literature as they relate to the potential hazards of manual materials handling. For instance, Burch (1965) indicates many injuries are due to "soft" life styles, which can only be overcome by specific physical training for manual materials handling jobs. Wilkins, et al., (1957), Munchinger (1962) and Troup (1965) also support such a concept.

Aquilano (1968) evaluated several of the more classical schemes for establishing rest allowances, and concluded that these were not adequate to meet the metabolic demands of most people engaged in manual materials handling activities. Davis, et al., (1969) demonstrated that improved work methods and rest allowance specification could be developed by evaluating the metabolic and heart rate responses of people involved in manual materials handling jobs. Powell (1971) performed an ergonomic evaluation of many materials handling jobs and concluded that most were deficient in 1) good methods and workplace layout principals, 2) good package design, 3) training programs, 4) identifying safety responsibilities and 5) use of personal protective devices.

In regards to personal protective devices, it is generally accepted that many different types of manual materials handling jobs require the worker to wear personal protective devices (gloves, safety shoes, leg guards, etc.) as illustrated by the ILO (1958). Unfortunately, neither the effectiveness nor the design of such devices have been well evaluated (Fourt and Hollies, 1969).

The need for selecting and training people to perform manual materials handling jobs is agreed upon in principle by many authorities. Unfortunately, the research to substantiate the obvious social and economic costs of specific administrative policies and procedures in this regard is still needed.

1 0 1 *Such research should be conducted as field studies which could demonstrate the effectiveness of different, well defined selection and placement policies.*

It appears that existing criteria for determining rest allowance schemes may not be adequate in manual materials handling operations.

1 0 1 *There is a need to develop and evaluate criteria for predicting the rest requirements in manual materials handling jobs based on several of the hazard indices identified earlier in this report.*

1 0 1 *In this same regard, research is needed to determine if productivity incentive systems modify hazard potential in manual materials handling jobs.*

The general use of personal protective devices, though acknowledged as necessary in manual materials handling jobs, is not well substantiated by injury statistics.

1 0 1 *Because such devices can impede normal movements and sensations their design needs to be carefully researched, and their effectiveness proven in controlled field studies prior to general distribution and propagation.*

Too often this has not been done in the past.

Finally, periodic safety and health surveys and "safety incentive" programs are often reported to be of assistance in controlling the hazards of manual materials handling. Unfortunately, specificity of these practices is lacking, and little or no critical evaluations are evident to support their general propagation.

1 0 1 *Hence, field studies are recommended wherein well defined safety and health programs would be instigated and evaluated in plants having manual material handling under controlled operating conditions.*

SECTION V
CONCLUSION

The research criteria presented in the previous sections represent a broad spectrum of research disciplines and approaches for attacking the hazards of manual materials handling. In general, they specify the unidimensional probes which are necessary to fill the large gaps in knowledge of this complex problem. If these hazards are to be effectively reduced in the future, there is a need for studies which examine not only the effects of single factors of the problem but also the influence of multiple factors.

In many operating environments, hazards cannot be assumed to result from poorly engineered tasks alone, nor are they due singly to the nature of the material or container handled.

1 1 1 *Research of the interaction of the various system characteristics (the worker, the material/container, the task, and the work practices) as they collectively influence the hazards of handling is needed.*

1 1 1 *Studies must also reflect the multiplicity of hazards associated with manual materials handling, including not only injuries and illnesses, but the physiological and behavioral indices as well. To this end, multivariate statistical analysis techniques must be more conscientiously and consistently applied.*

1 1 1 *More careful elaboration and application of sound statistical measures and techniques are required to characterize hazard and to provide measures which are reliable and reproducible. Further, the use of critical incidence techniques and nonparametric statistical methods have not received enough attention in previous studies; their use in the future should be better documented.*

1 1 1 *To address the multiple dimensions of the hazards of manual materials handling it is recommended that deliberate programs be developed which bring to bear more subspecialties of expertise. For example, medical professionals should be encouraged to work together with engineers and research scientists to develop programs which incorporate each specialty in the design and implementation of safe/healthy systems.*

1 1 1 *Finally, there is a recognized lack of standardization of methods and measurements. To some degree this must be accepted. The important point is that these measurements and methods must be better documented in reports so that others may benefit from developments in the area and so that adequate verification and validation are possible.*

The recommendations of the Workshop participants will not be relisted here, nor will they be summarized in over generalizations and over simplifications. Rather, it must be emphasized that the recommendations of the preceding sections represent a subset of possible recommendations which could be made. Those which are reported should be viewed individually and collectively as worthy of consideration in the planning of any future research program to control the hazards of manual materials handling.

APPENDIX

LITERATURE REVIEW

Author: Ref. No.	Hazard Indices									System Characteristics																			
	injury		physiological				behavioral			worker								material / container					task				work practices		
	Severity	Frequency	Circulatory	Metabolic	Biomechanical	Neuromuscular	Psychological	Psychophysical	Sociological	Physical	Sensory	Motor	Psychomotor	Personality	Training	Health Status	Leisure Activity	Load	Dimensions	Distribution	Couplings	Stability	Workplace Geom.	Frequency/Pace	Complexity	Environment	Individual	Organizational	Administrative
Aberg (1)			●	●	●					●								●						●					
Aghazadeh (2)								●		●		●																	
Alston (6)		●										●																	
Anderson (13)					●															●	●						●		
Anderson (15)					●										●												●		
Aquilano (18)				●														●											
Asmussen (26)					●					●																	●		
Asmussen (31)										●		●																	
Ayoub (35)					●																						●		
Ayoub (36)					●							●									●								
Ayoub (39)					●					●		●						●											
Badger (40)		●			●					●	●	●						●	●			●					●		
Bartelink (43)					●							●																	
Bartina (45)		●	●															●	●					●					
Barton (47)					●											●													
Becker (51)	●	●														●													
Becker (52)		●			●											●													
Becker (53)	●	●			●											●													
Blow (63)	●									●				●	●														
Bobbert (64)												●									●								
Bond (67)	●	●																											
Brackett (70)		●														●													
Brown (76)		●													●			●									●		
Brown (77)																		●		●			●		●				
Brown (80)		●		●						●						●		●									●		
Brown (81)	●	●								●										●							●		

Brown (83)	●	●								●																			
Burch (88)		●			●										●	●													●
Caldwell (96)												●						●											
Cathcart (101)				●	●													●		●	●						●		
Chaffin (104)				●				●										●									●		
Chaffin (106)					●			●		●		●						●		●									
Chaffin (107)					●			●		●		●						●		●									
Chaffin (112)		●								●		●																	
Chaffin (114)					●					●																			
Chaffin (115)		●																●		●				●					
Chapman (118)					●													●						●					
Clark (123)	●	●					●									●											●		●
Conn (132)	●	●																											
Currier (140)					●																								
Datta (143)			●	●																●	●								
Datta (144)			●	●														●											
Davis (149)			●	●																							●		●
Davis (150					●													●									●		
Davis (151)					●							●															●		
Davis (152)					●							●															●		
Davis (153)					●													●									●		
Davis (154)					●					●								●											
Davis (158)					●													●											
Davis (160)					●																								
Dickson (164)		●																											
Diveley (167)					●											●													
Drury (172)								●										●	●	●		●							
Dryden (173)								●		●		●																	
El-Bassoussi (177)					●					●		●																	
Emanuel (178)								●										●											
"Ergo. Guide" (180		●						●		●								●	●								●		
Flatt (190)					●					●											●								
Fletcher (191)					●																								
Floyd (192)					●													●									●		
Freeman (203)		●																											
Fourt (192)												●																	●
Gillespie (209)	●																												
Glover (212)		●													●														
Goldman (215)				●						●								●						●					
Grieve (228)					●			●																			●		
Griffin (229)	●	●								●						●													

	Hazard Indices									System Characteristics																		
	injury		physiological				behavioral			worker								material / container					task				work practices		
	Severity	Frequency	Circulatory	Metabolic	Biomechanical	Neuromuscular	Psychological	Psychophysical	Sociological	Physical	Sensory	Motor	Psychomotor	Personality	Training	Health Status	Leisure Activity	Load	Dimensions	Distribution	Couplings	Stability	Workplace Geom.	Frequency/Pace	Complexity	Environment	Individual	Organizational	Administrative
Gupta (230)			●															●		●	●								
Haisman (232)				●														●		●									
Haisman (233)				●														●		●									
Hall (235)					●			●																			●		
Hamilton (236)			●	●														●						●			●		
Hanman (238)																●													
Hanson (239)				●																●							●		
Hart (244)		●																									●		
Herndon (250)	●	●					●			●								●	●			●							
Himbury (253)					●										●												●		
Himbury (254)					●										●						●						●		
Horner (258)																					●								
Hult (262)		●								●								●									●		
"Human Kinetics" (263)																											●		
ILO (269)																		●	●		●						●		●
ILO (270)										●								●											
ILO (271)										●						●		●	●	●	●								
Jackson (275)		●			●																								
Jones (281)					●																						●		
Jones (280)	●																												
Jorgensen (284)				●	●													●						●			●		
Kamon (290)			●	●				●		●								●								●			
Karvonen (292)				●	●																						●		
Keeney (294)					●					●		●																	
"Kinetic Hand," (297)																			●			●					●		
Klausen (300)					●													●		●									

Kloetzel (301)			●									●														●			
Knipfer (302)								●		●		●																	
Konz (304)					●					●								●		●									
Kosiak (307)	●	●														●												●	●
Kosiak (308)	●	●								●						●		●											
Koskela (309)		●																●			●								
Kottke (310)					●																								
Kraus (313)		●										●				●													
Kroemer (314)												●																	
Kroemer (315)										●		●						●											
Kroemer (317)					●			●																					
Kroemer (318)												●											●						
Kumar (319)					●					●																			
LaRocca (324)		●			●											●													
Leavitt (326)	●	●																									●		
Leggo (328)		●														●													
"Lifting-Carry." (332)																											●		
"Lifting-Carry." (333)															●														●
"Lifting-Ind." (335)																		●		●		●					●		●
Lind (337)			●					●										●									●		
Long (343)					●					●											●								
Magnuson (358)	●	●			●											●													
Magora (360)	●	●								●				●		●		●											
Magora (361)	●	●								●				●		●		●								●			
Magora (362)		●													●			●											
Magora (363)	●	●							●	●			●			●		●											
"Manual Handl." (366)		●																									●		
"Manual Lift." (369)					●					●		●			●												●		●
"Manual Lift." (370)		●			●																						●		
Marble (371)	●	●																●											
Maxwell (375)					●																						●		
McConville (348)								●										●	●	●									
McDaniel (350)								●		●		●																	
McGill (354)		●														●													
Meyers (376)																●													
Minard (381)			●	●												●										●			
Moreton (386)	●	●														●													
Moreton (387)		●														●													
Munchunger (395)										●						●		●									●		●
Nachemson (397)					●					●								●									●		
Nachemson (401)					●																						●		

Snook (497)	Snook (496)	Snook (495)	Snook (493)	Snook (492)	Snook(491)	Smith(488)	Shaw(477)	Runge(468)	Rowe(464)	Rowe(462)	Ronnholm(457)	Ronnholm(456)	Redfield(449)	Ramsey(448)	Powell(443)	Poole(436)	Pitto(433)	Pfitzer(430)	Peres(426)	Peres(425)	Paul(424)	Osgood(418)	Noro(413)	Napier(406)	Nachemson(402)			
				●			●	●		●																Severity	injury	Hazard Indices
				●			●	●	●	●			●				●		●	●	●	●	●			Frequency		
●			●		●	●								●									●			Circulatory	physiological	
											●	●		●												Metabolic		
									●					●							●		●		●	Biomechanical		
																										Neuromuscular		
																					●					Psychological	behavioral	
	●	●	●		●	●																				Psychophysical		
																										Sociological		
	●	●			●				●	●									●					●		Physical	worker	System Characteristics
																										Sensory		
																		●								Motor		
																										Psychomotor		
							●													●						Personality		
				●		●																				Training		
			●					●		●			●						●			●				Health Status		
																										Leisure Activity		
●	●	●			●			●	●		●	●		●					●				●		●	Load	material / container	
				●										●	●					●						Dimensions		
●		●													●					●						Distribution		
															●									●		Couplings		
							●																			Stability		
																										Workplace Geom.	task	
	●										●	●											●			Frequency/Pace		
																										Complexity		
							●																			Environment		
								●			●	●			●		●		●						●	Individual	work practices	
																										Organizational		
															●											Administrative		

Snook (499)								●										●		●									
Snook (500)			●					●		●								●		●									
Solheim (501)																													
Soule (502)				●														●		●									
Stewart (507)	●															●													
Strindberg (508)								●								●		●											
Switzer (516)								●		●								●		●									
Tauber (519)		●								●																●			
"Tech. Stud." (521)				●	●													●											
Teigh (522)																			●			●					●		
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Research requirements regarding the hazards of manual material handling are examined. Pertinent literature on the subject is summarized, and informational gaps identified. A system of hazard indices which characterize human responses to the stresses of the physical act of handling loads in terms of injury, physiologic, and behavioral indices, is presented. Criteria upon which future research in this field can be based are outlined. The authors conclude that hazards cannot always be assumed to result from poorly engineered tasks alone or the nature of the material handled. They recommend further research which examines not only the effects of single factors of the problem but also the influence of multiple factors.

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