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Review paper on Optimal position of handle of a container in manual material handling

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***Abstract*—To find the optimal position of the handle on a container, which is being used in industries for manual material handling purpose, a review of research papers on manual material handling using containers is conducted to find some design consideration of containers for safer manual material handling.**

***Keywords* - optimal handle position, manual material handling.**

1) INTRODUCTION

Manual handling relates to the moving of items either by lifting, lowering, carrying, pushing or pulling. But it's not just a case of 'pulling something' due to the weight of the item, although this can be a cause of injury. Injuries can be caused because of the amount of times you have to pick up or carry an item, the distance you are carrying it, the height you are picking it up from or putting it down at (picking it up from the floor, putting it on a shelf above shoulder level) and any twisting, bending stretching or other awkward posture you may get in whilst doing a task. Manual handling is one of the most common causes of injury at work and causes over a third of all workplace injuries which include work related Musculoskeletal Disorders (MSDs) such as upper and lower limb pain/disorders, joint and repetitive strain injuries of various.

Manual handling injuries can occur almost anywhere in the workplace and heavy manual labour, awkward postures and previous or existing injury can increase the risk. Work related manual handling injuries can have serious implications for both the employer and the person who has been injured. Employers may have to bear substantial costs, through lost production, sickness absence costs of retraining, wages/overtime to cover for the absent person and potentially compensation payments. The injured person may find that their ability to do their job is affected and there may be an impact on their lifestyle, leisure activities, ability to sleep and future job prospects. It is essential therefore that employer manage the risks to their employees. If possible you should not carry out any manual handling tasks. Where these are necessary mitigate the risk by using some equipment - trollies, fork lift truck etc. Where tasks are essential and cannot be done using lifting equipment, conveyors or wheeled trollies/cages, a suitable and sufficient risk assessment should be conducted. But still MMH activities cause many Musculoskeletal disorders (MSDs) to the workers doing MMH.

1.1. What are musculoskeletal disorders?

A musculoskeletal disorder is a condition where a part of musculoskeletal system is injured over time. This disorder occurs when the body part is called on to work harder, stretch farther, impact more directly or otherwise functions at a greater level then it is prepared for. The immediate impact may be the term musculoskeletal disorder identifies a large group of conditions that result from traumatizing the body in either a minute or major way over a period of time. It is the build-up of trauma that causes the disorder. These conditions are often focused on a joint and affect the muscle and bone. However other areas can be strained and their response to that trauma can be an injury. Some common examples of musculoskeletal disorders are:

- Vibration White Finger
- Shin Splints
- Scoliosis

The full list of what can be classified as a musculoskeletal disorder is quite extensive. Other terms used interchangeably with Musculoskeletal Disorder are:

- Repetitive stress injury (RSI)
- Repetitive stress disorder (RSD)
- Repetitive strain injury (RSI)
- Repetitive strain disorder (RSD)
- Repetitive motion injury (RMI)
- Repetitive motion disorder (RMD)
- Repetitive Injury
- Overuse Syndrome
- Cumulative Trauma Disorder (CTD)

A Repetitive Stress Injury or RSI, is simply an injury caused by physically stressing a body part repetitively. The stress can be major or minor, but it is the continuous stressing that eventually causes the injury. Repetitive stress injury is the term this site will use to refer to any and all of these conditions

A Repetitive Stress Disorder or RSD, is the same as a repetitive stress injury except for a word change. Some people feel more comfortable classifying these conditions as disorders. In this way an injury is something that is broken, whereas a disorder is something worse than normal. It is really six of one, half a dozen of another.

A repetitive Strain Injury or RSI (again), is simply an injury caused by physically straining a body part repetitively. See the similarity? Again some people simply feel more comfortable classifying this type of action as a strain. Stress would be the mental fatigue we all know as stress and strain would be physically overexerting a body part.

A Repetitive Strain Disorder or RSD, follows the pattern above.

A Repetitive Motion Injury or RMI, is an injury caused by performing the same motion over and over again. This term becomes a little more descriptive. It also has a narrower focus. Not all repetitive stress injuries are caused solely by repetitive motion.

A Repetitive Motion Disorder or RMD, is another injury versus disorder alternative.

A Repetitive Injury is an injury caused by repetition. It does not matter if it is stress, strain or motion. It only matters if it is repetitive.

Overuse Syndrome is a condition where you have overused something to the point of injury. This is a little broader than your typical definition for repetitive stress injury. Although repetition usually plays a key role in developing it, overuse does not have to occur through a repetitive action.

A Cumulative Trauma Disorder or CTD, is a disorder (injury) that occurs through the build-up of trauma over time. The trauma can be acute (happening in an isolated event) or repetitive. It is the weakening or the body part through repeat trauma that finally causes it to break down. This is probably the best term to use, but it is quite a mouthful so it does not get as much air play as the others. When it occurs repeatedly the constant trauma cause damage. So to avoid or minimize these MSDs, RSIs and CTDs a new field of science is used which is called ergonomics.

1.2. Ergonomics

The word "Ergonomics" comes from two Greek words "ergon," meaning work, and "norms" meaning "laws." Today, however, the word is used to describe the science of "designing the job to fit the worker, not forcing the worker to fit the job." Ergonomics covers all aspects of a job, from the physical stresses it places on joints, muscles, nerves, tendons, bones and the like, to environmental factors which can effect hearing, vision, and general comfort and health. Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system. Practitioners of ergonomics, ergonomists, contribute to the planning, design and evaluation of tasks, jobs, products, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people. In this substantial effort has been directed at determining 'safe' lifting capacities for individuals and groups of individuals. The assumption used for these studies was that there is a relationship between an individual's capacity and his or her injury potential. In other words, a person with a small capacity with respect to a given task demand is more likely to be injured than another person with larger capacities. For the measurement of a safe and permissible lifting capacity three approaches are commonly used.

- The first approach is the biomechanical approach,
- The second approach is the physiological approach,
- And the third is the psychophysical approach.

1.2.1. Biomechanical approach

The biomechanical approach, researchers attempt to model directly the mechanical stresses placed upon the internal structures of the body during lifting. The goal of this approach is to accurately estimate how work activities stress the bones, muscles and connective tissues of the body and to predict when these stresses will lead to damage of these structures. This approach is very popular in ergonomics because it closely corresponds with most expert views of the aetiology of injury during manual materials handling (NIOSH, 1981). Biomechanical models typically model the human body as a series of mechanical link sand joints corresponding to the human skeleton. Both external forces, needed to perform the work activity, and internal forces, as a result of muscle contraction, are modelled to estimate the mechanical stresses. Most models focus on estimating only a few mechanical stress parameters related to the injury of interest in the analysis. For manual materials handling the parameter most often selected is the compressive force on the low back, usually the L5/S1 spine segment.

1.2.2. Psychophysical approach

Psychophysics deals with the relationship between human sensations and their physical stimuli. Snook (1978) Psychophysics has been applied to practical problems in many areas, such as the scales of effective temperature, loudness and lightness, and ratings of perceived exertion (RPE). To apply the principle of psychophysics to men at work is to utilize the human capability to judge the subjectively perceived strain at work in order to determine voluntarily accepted work stresses. In terms of MMH activities, it can be used to determine what the subject can handle (capacity) without strain or discomfort. As stated by Legg & Myles (1981), With good subject cooperation and firm experimental control, the psychophysical method can identify loads that subjects can lift repetitively for an eight-hour workday without metabolic, cardiovascular or subjective evidence of fatigue. The measure of capacity used in this approach is 'maximum acceptable weight of lift.' Maximum acceptable weight of lift is generally defined as the maximum weight, determined experimentally that a given person could lift repeatedly for long periods of time without undue stress or fatigue. From Mital et al.., (1997). Frequency, Task duration, Object size, Object shape (various), Couplings (good) Load stability/distribution, Vertical lift height, Height of force Application/starting point, Distance travelled, Speed/grade, Asymmetrical handling.

1.2.3. Physiological approach

The physiological approach is applicable to repetitive lifting where the load is within the physical strength of the worker. During repetitive handling tasks, a person's endurance is primarily limited by the capacity of the oxygen transport system. As muscles contract and relax, their increased metabolic energy demand requires an increase in the delivery of oxygen and nutrients to the tissues. If this demand for increased oxygen and nutrients cannot be met, the activity cannot be sustained for long. When a person is engaged in physical work, such as MMH activities, several physiological responses are affected. These include metabolic energy cost, heart rate, blood pressure, blood lactate, and ventilation volume. Of all these responses, metabolic energy expenditure has been the widely accepted physiological response to repetitive handling as it is directly proportional to the workload at steady-state conditions. So one of this approach was used to reduce the workload and MSDs. Manual lifting is major cause of MSDs. Manual lifting is affected by the factor like Frequency of handling, Task duration, Object size, Object shape, Object weight, Vertical height and methods of lifting the object. Some other factors that cause physical stress are as: position of the load's centre of gravity with respect to the worker. Repetition in handling task, consistency in the location of the load's centre of gravity when handling bulky or liquid materials, handles size and handles location, handle shape, Distance of movement, direction, obstacles, postural constraints and environmental factors such as temperature, humidity, illumination, noise, vibration and the frictional stability of the foot. So an approach was made to find the accurate weight under different conditions to reduce the MSDs caused by manual lifting.

2) REVIEW OF LITERATURE

Ayoub (1977).

The container in manual material handling represents the point of interface between the worker and his task as well as with the surrounding environment. It is at this point that many of the well-known handling hazards occur which manifest themselves in stresses and strains that are transmitted to the body via the musculoskeletal system. If a substantial number of handling hazards is to be controlled or eliminated at the source, containers designed in accordance with principles of biomechanics and related recommendations provide a logical starting point. The container characteristics to be considered in the design process are weight (and its distribution), shape, stiffness, and availability of coupling devices. This paper presents several examples which outline and detail a number of problems associated with the design of containers involved in manual tasks. Application of basic mechanics, coupled with the use of optimization techniques, is presented as the approach for dealing with the hazards and problems of containers.

Drury (1980)

The humble handle is one device available to designers of products and packages to improve the coupling between a human operator and the load he/she has to lift, hold or carry. Studies of handle design show that handles can help and that some are better than others but agreement on how handles should be studied, parametric values of 'optimum' handles, and even criteria for handle choice is low. Design parameters are reviewed, two new experiments on handle diameter are presented and a guide for handle designers is provided.

Garg &sexsena (1980)

A laboratory study was conducted to evaluate the effects of handles, shape of the container, and dimensions of the container on maximum acceptable weight of lift using a psychophysical methodology. Ten male college students were required to lift six different boxes with handles, six without handles, and three different mailbags from the floor to a bench height (76 cm), using a free-style lifting technique. The six boxes varied in length and width, and the three mailbags varied in diameter and length. Statistical analysis showed that the maximum acceptable weights for mailbags and boxes without handles were lower than those for boxes with handles. The maximum acceptable weight significantly increased with an increase in dimensions of the mailbag. Among all the container characteristics studied, handles were found to have the most profound effect on maximum acceptable weight. It is concluded that the recommendations for maximum acceptable weight of the load based on boxes with handles need to be adjusted when applied to boxes without handles or to some other types of containers.

Ayoub, M.A. (1982)

Job content and workplace components can be altered to assure that lifting stresses remain within the acceptable limits defined for the industrial population-at-large. The plan for redesign advocates (1) maintaining the weight handled within the recommended limits; (2) modifying the workplace to enhance postural stability and to avoid handling weights and excessive physical loading; and (3) increasing available job time by reducing frequency of lifts and/or introducing appropriate rest periods. Limits recommended by the National Institute for Occupational Safety and Health on acceptable loads are reviewed.

AndrisFreivalds et al. (1984)

A biomechanical evaluation of the job-related stresses imposed upon a worker is a potential means of reducing the high incidence rates of manual material handling injuries in industry. A biomechanical model consisting of seven rigid links joined at six articulations has been developed for this purpose. Using data from cinematographic analysis of lifting motions the model calculates: (1) body position from articulation angles, (2) angular velocities and acceleration, (3) inertial moments and forces, and (4) reactive moments and forces at each articulation, including the joint. Results indicated effects of the common task variables. Larger load and box sizes increased the rise times and peak values of both vertical ground reaction forces and predicted compressive forces. However, boxes with handles resulted in higher compressive forces than for boxes without handles. Also, in lifting the larger boxes the subjects did not sufficiently compensate with reduced box weights in order to maintain uniform compressive forces. Smoothed and rectified EMG of erector spine muscles correlated significantly with compressive forces, while predicted and measured vertical ground reaction forces also correlated significantly, indicating the validity of the model as a tool for predicting job physical stresses.

J.M. Deeb et al. (1985)

Six handle positions in a two-handed container holding task were tested with the container at floor, waist and shoulder heights. Fifteen male and fifteen female manual materials handlers participated. Handle-position effects on forces exerted, heart rate and psychophysical indices were large compared with the effect produced by a 25% change in container weight. As in a previous study (at waist height only) and an industrial survey, handle positions providing both horizontal and vertical stability were better than symmetrical positions. Optimal angles of handle to container changed greatly with task height, giving almost horizontal angles at floor level and almost vertical angles at waist and shoulder level. Implications for the design of handle cut outs on containers are discussed

Colin G. Drury & J.M. Deeb (1986)

This first part of a two-part paper describes the biomechanical (body and box angle) measurements taken during a study of manual lifting and lowering of cubic boxes. Fifteen male and fifteen female manual materials-handling workers lifted and lowered boxes with all combinations of two handle angles to the horizontal (35° and 70°) and four handle positions (three asymmetric and one symmetric) through three lifting (lowering) distances (floor-waist, waist-shoulder, floor-shoulder; reversed for lowering). Angles were measured at each of five stages of lift or lower between floor and shoulder heights. The main accommodation of the subject to the changing demands of the task was to let the handle ‘slip’ with respect to the hand so that the handle was mainly gripped with either the first or fourth digits. This ‘slippage angle’ could be minimized with a 70° angle between handle and box horizontal and by choosing an asymmetric handle position with one hand in the centre of the lower edge and the other in the centre of the front edge of the box. A box design incorporating hand-hold cut-outs with these features is proposed.

C.G. Drury & J.M. Deeb (1986)

This paper continues the results of the experiment on handle positions and angles in lifting described in Part 1. Heart rate rated perceived exertion, and body part discomfort were measured on 30 subjects lifting boxes from floor to waist, waist to shoulder and floor to shoulder. Movement distance had a large effect on all measures. A handle angle of 70° between box and horizontal was found better than an angle of 35°. Handle position differences were minimal. The design for cut-out handles on a box, presented in Part 1, was confirmed by these results.

C.K. Anderson & D.B. Chaffin (1986)

Five lifting methods which cover the range of techniques recommended by various back schools have been biomechanically analysed with a static sagittal-plane computer model. The analysis was performed with two load-types (compact and bulky) and three weights in the hands (44 N, 222 N and 400 N). The methods were compared in terms of predicted L5/S1 disc compression, low-back ligament strain and strength requirements at the shoulders, L5/S1, hip and knee joints. In general, the method entailing a squat posture, straddle foot stance and flat back (oriented as when standing erect) yielded lower compressions, ligament strains and overall strength requirements than the other methods.

Colin G. Drury & J.M. Deeb (1986)

Thirty industrial subjects took part in a manual lifting task, using different handle positions on a container and different angles between handle and container. Lifts were from floor to waist, waist to shoulder and floor to shoulder. Upper extremity body angles were measured, with heart rate and rated perceived exertion. As in previous static holding experiments, it was found that handle positions with both horizontal and vertical stability gave good results. As a result of this work, handle positions are recommended in the middle of the front edge of a box (at 60°) and in the middle of the lower edge (at 50°). Such an arrangement will minimize wrist deviation and slippage angle between handle and hand.

Manfred S. Green et al. (1986)

The influence of several factors on the heart-rate (HR) response to tasks performed during regular work has been evaluated in a study population of 1654 male factory employees in Israel. Each worker was monitored for approximately one hour with an ambulatory electrocardiogram. The percentage change from resting HR decreased with increasing age and, as expected, was lower in sedentary workers than in manual workers. A highly significant negative correlation between the HR response and both systolic and diastolic blood pressure was found in the manual workers only. In further multiple regression analysis, after controlling for age, relative weight, smoking status, resting HR and the presence of abnormalities on the resting ECG, the association persisted for systolic BP only. Among young workers, both smoking and relative body weight were significantly associated with a higher HR response to work. Those with ECG abnormalities had lower HR response than those with normal ECGs, but not significantly so. These findings indicate that for roughly equivalent tasks and levels of resting HR, the HR response to regular work is influenced by several constitutional and behavioural factors. It may therefore be important to consider these factors when assigning workers to tasks involving strenuous effort.

Chi C.F. & Drury C.G. (1988)

The psychophysical method of constants was applied to two-handed lifting. A sequence effect was found, with subject's response biased toward which stimulus was presented most recently. This sequence effect drastically reduced the sensitivity of the method for two-handed lifting, so that a further study of comparing sequential and simultaneous lifting was conducted. The results indicated that simultaneous lifting was significantly more sensitive to changes in handle design.

C.G. Drury et al. (1989)

To study the physiological and psychophysical costs of symmetric and asymmetric manual materials handling, two tasks were performed by 30 industrial subjects. In both tasks, box weight and handle position were varied. The symmetric task, lifting and lowering between floor and conveyor, showed handles to be beneficial. The asymmetric task was palletizing and de-palletizing 36 boxes between a pallet and a conveyor. Both palletizing and de-palletizing proved strenuous for females with heart rates exceeding 140b/min. All handle positions were better than No Handles, but the best handle position changed from asymmetric for 9 kg boxes to symmetric for 13 kg boxes. The effect of handles was equivalent to a weight change of 1-2 kg for Heart Rate and Rated Perceived Exertion, but much higher (2-14 kg) for Body Part Discomfort measures.

H.R. Stalhammar (1989)

Rating of acceptable load (RAL) was used to determine the load-handling capacity of women (n = 54) and men (n = 49) and the effects of handles on the acceptable weight. The RAL test was administered using 30×30×30 cm boxes, one without handles and the other with handles 20 cm above the base. Subjects were asked to fill a box with the weight that they considered would be acceptable for lowering from table (72 cm) to floor and again lifting back to the table at 5-min intervals over an 8-hour working day. The tests were done in their actual place of work. Subjects selected heavier acceptable loads for the box with handles. The overall means for women and men for the box with handles were 8.8 kg for women and 19.1 kg for men and for the box without handles 7.5 kg and 14.9 kg, respectively. The greater difference of the selected weight of two the boxes for men than for women suggests that the heavier the box more important it is to have it equipped with handles.

K.P. Kothiyal et al. (1991)

A mathematically simple but revealing biomechanical model was employed to investigate and clarify the role of various biomechanical factors such as magnitude of load, individual anthropometric characteristics, shape, size and location of loads etc. involved in the load lifting process. From the model, the concept of determining optimal lifting postures based on minimizing the reaction force at the L4/L5 joint subject to all other muscle/joint complexes not being overstressed is developed. Various moment-load relationships for the various joints are computed along with moment-moment relationships between various joints which were shown to well match experimental results. The model was able to propose many interesting and practical suggestions in the area of manual material handling tasks, especially the lifting aspect.

Ram R. Bishu& Wang Wei (1992)

Handle locations and geometry play an important role in container design. The objective of this study was threefold: (a) to determine the effectiveness of the handles in a lifting and carrying task, (b) to determine if force endurance relationship curves could be used as criterion for comparing the handle positions, and (c) to compare the handle positions through biomechanical modelling. The first two objectives were evaluated through a pair of laboratory experiments, while the University of Michigan 'Two-dimensional static biomechanical model' was modified for the third objective. The results indicate that symmetric handle positions are the best. The results are discussed in light of recommendations to the designer of container.

Maxwell Fogleman& James L. Smith (1994)

The experiment presented here was conducted for the purpose of investigating changes in lifting patterns that occur due to the effects of learning and due to the effects of lifting over extended periods. It also illustrated the use of biomechanical measures in tracking these changes. Biomechanical measures usually have not been used to make inferences about changes in lifting patterns due to such effects as practice, the number of lifts performed in a session, the frequency of lifting, etc. Six inexperienced subjects were asked to lift for an initial 4-hour session, six half-hour practice sessions, and a final 4-hour lifting session. All lifts were conducted at the rate of one lift per minute, from floor to shoulder height, with a weight chosen by the subject. Results indicated that there is a change from a leg lift to a more biomechanically stressful back lift (as inferred from greater joint centre moments) due to the effects of training, but once these effects are observed they were maintained through the second 4-hour session. Furthermore, reduction in time per lift over the course of the experiment was accompanied by increases in moments at all of the joint centres, but this was more pronounced in the hip and knee joints for half of the subjects. Conclusions to be drawn from these results are that biomechanical modelling can be used under such circumstances with meaningful results and that there is a natural tendency to lift more quickly and to shift moments to the stronger muscles in the process of learning lifting patterns.

Yuh-Chuan Shih & Mao-Jiun J. Wang (1996)

The objectives of this study were, firstly, to apply an efficient approach to assess both optimal handle diameter and angle by subjective perception of heaviness, and secondly, to evaluate one-hand power grip on alternative container handles, using weight discrimination as a criterion. Twelve student subjects six males and six females participated in the four experiments designed in this study. Six handle diameters (25.4 mm (1”), 31.8 mm (1.25”), 38.1 mm (1.5”), 44.5 mm (1.75”), 50.8 mm (2”). and 57.2 mm (2.25”) were evaluated. The results indicated that the containers were perceived less heavy when handle diameter was about 51 mm (2”). and handle angle was about neutral position. Further, insignificant influences of handle diameter and handle angle on human’s ability to discriminate weight difference were found when the standard weight was 8.2 kg.

PernilleKofoed Nielsen et al. (1997)

The aim of the study was to investigate the muscular load on the lower back and shoulders and the circulatory load on employees at a post centre during repetitive lifting of mail transport boxes. A mock-up was designed in the laboratory, a total of nine combinations of lifting height and frequency were studied. Surface EMG was recorded bisymmetrically from m. erector spine (L3-level) and m. trapezius. The circulatory load was evaluated by measuring the heart rate. The results show a trade of between the low back and shoulders. The maximum load on the low back occurred at the low lifting height (36.3 and 54.4 cm) whereas the maximum load on the shoulders occurred at the high lifting height (144.9 and 163.0 cm).

T.M Bernard et al. (1997)

The kinetics and kinematics produced by a computerized dynamic biomechanical simulation model were examined and compared to those produced by actual human lifters. The purpose of the comparison was to demonstrate the accuracy of the simulation in predicting stresses imposed on the human body during the performance of a lifting task. The simulation model was shown to predict quite well under different task conditions (range of lift, weight of load, size of box, and gender of lifter.) Use of the simulation model is advocated for evaluations of lifting performed under a variety of conditions. Although highly correlated, the simulation tended to overestimate the kinetics and kinematics. The results provided in this study demonstrate that the simulation model can be an effective alternative for lifting task analyses. Through use of the simulation model, the tedious, time-consuming and costly data collection step required for lifting analyses can be eliminated so time and effort can be spent more productively on evaluation and design.

Chien-Chi Chang et al. (2000)

Previous optimization techniques for the prediction of lifting motion patterns often require a change in either the number of variables or the order of the mathematical functions used to express the angular displacement of selected joints in response to change in variant conditions. The resolution of predicted results can also be seriously constrained by the number of variables used. These restrictions may often limit the applicability of these methodologies. In this paper, we proposed a new methodology for generating the optimum motion patterns for para-sagittal lifting tasks. A detailed description of this methodology is introduced. An example of an analysis using this methodology is presented. The computer program generated lifting motion patterns with a reduction of the overall objective function values. The actual versus predicted lifting motion patterns are compared. Using this method, constraints can be added anywhere within the lifting cycle without the need of rewriting the whole program. These features provide for a more flexible and efficient prediction of the lifting motion.

Micheline Gagnon et al. (2001)

The purpose of the study was to evaluate, in 10 novice workers, the effect of the free practice of asymmetrical lifts with 3 different 15-kg containers. Practice effects were evaluated during one session (trials 1, 25 and 49), and also one month later (trial 50); containers effects were evaluated for homogeneity (2 boxes: homogeneous vs. heterogeneous) and for format (homogeneous box and cylinder). Each subject performed 150 lifts (50 practice trials and 3 containers per trial) but only 12 lifts were first analyzed. The data were obtained from 4 video cameras and a large force plate. A 3D dynamic rigid body model was used to evaluate low-back kinetics and kinematics. There were not any significant differences between the practice trials nor the boxes but there was high variability of performance within and between subjects. The main objective was then to evaluate the variability of these trials by contrasting the worst and best trials using three safety criteria: mechanical work, back efforts and asymmetry. The best strategies of reduced mechanical work (mean difference: 31%) was mainly associated with reduced knee flexion at take-off; strategies of reduced low-back moments at take-off (27%) were associated with smaller knee flexion and asymmetrical trunk efforts but larger feet spacing; finally, strategies of reduced back asymmetry at take-off (155%) were associated with reduced asymmetry of posture i.e. a better parallelism between shoulders/pelvis/handgrips and shoulders more parallel to the ground. Conclusions based on analyses of single trials or even means may be misleading.

Hwa S. Junga&Hyung-ShikJung (2002)

The idea for this study came from the research findings which show that the maximum acceptable weight of lift for boxes without handles was significantly lower than that for boxes with handles. A polypropylene (PP) laminated bag with carrying handles was developed to increase safety and decrease physical stress. Physiological and psychophysical approach as well as subjective ratings was applied to evaluate the effects of handles on the aforementioned PP laminated bag. A statistical analysis showed that the VO2, heart rate and Borg-rating of perceived exertion scores for a PP laminated bag with carrying handles were relatively lower than those for bags without handles. Moreover, the maximum acceptable lifting endurance time for bags with handles was relatively higher than that for bags without handles. It is thus recommended that various kinds of bags and boxes have handles to reduce musculoskeletal, physiological, psychophysical and subjective perceptional stresses.

Vincent M. Ciriello (2003)

In the development of our present manual materials handling (MMH), the assumption was made that the effects of frequency on maximum acceptable weights (MAWs) of lifting with a large box (hand distance, 38 cm from chest) were similar to frequency effects on MAWs of lifting with a small box (hand distance, 17 cm from chest). The first purpose of the present experiment was to investigate this assumption. The second purpose was to study the effects of extended horizontal reach lifting (hand distance, 48 cm from chest) on MAWs as a confirmation of the results of a previous study on this variable. Lastly we studied the effects of high frequency (20 lifts/min) on MAWs of lifting. Eight male industrial workers performed 15 variations of lifting using our psychophysical methodology. As expected the results revealed that MAWs of lifting with the large box was significantly affected by frequency. Frequency factors based on the 1 lift/min task illustrated less change to higher frequencies (>1 lift/min) and more change to slower frequencies (1 lift/min) as compared to lifting with the small box. It was concluded that our existing guidelines present a conservative estimate of lifting large boxes in the spectrum of frequencies studied. The results also verified the extreme effects of lifting with an extended horizontal reach and quantified the effects of the20 lifts/min lifting frequency.

Tzu-Hsien Lee (2004)

Twelve healthy right-handed male subjects were recruited to investigate their maximum static lifting strengths for right-handed, left-handed and two-handed exertions at five different exertion heights (10, 45, 75, 105, and 140 cm). The results showed that the highest lifting strength occurred in the interval of exertion height between 10 and 45 cm while the lowest lifting strength at the exertion height of 105 cm. The hand dexterity seemed to have little connection with lifting strengths especially for higher exertion heights. This study suggests that two-handed lifting should be encouraged since it resulted in both higher lifting strengths and less strains on load-bearing shoulder, elbow and wrist structures compared with one-handed lifting. Additionally, the sum of right-handed and left-handed lifting strengths was greater than the two-handed lifting strength for exertion height below 75 cm, while it was smaller than the two-handed lifting strength at 140 cm exertion height.

Maury A. Nussbaum & Andrew Lang (2005)

Several guidelines for manual material handling have been derived using psychophysical methods. Despite ease of use and interpretation, such guidelines have received limited verification and can be criticized for their dependence on subjective measures. In this study, 10 participants reported both maximum acceptable loads and subjective ratings. This was done statically, and in postures that isolated the elbow, shoulder, or lower torso joint demands. Two major conclusions were reached from examination of the relationships among maximum acceptable loads, ratings of perceived exertion, and relative joint demands (external/strength moment). First, relative joint demands appeared to be used in determining acceptable limits, but this use differed both within and between individuals. Second, linear relationships were found between relative joint demands and perceived exertion, though again inconsistencies were found among individuals.

Rina Maiti&Tapan P. Bagchi (2006)

The National Institute for Occupational Safety and Health (NIOSH) developed a lifting equation in 1981 to indicate ‘‘safe’’ occupational lifting limits. This equation was revised in 1991. The equation uses a series of lifting multipliers (parameters)to calculate corresponding recommended task weight limits. Due to the nature of risk factor interactions, the limits obtained from the NIOSH equation may not be appropriate for all lifting tasks. This laboratory experiment examined the effect of lifting parameters and their interactions as follows: lifting frequency, vertical lifting distance, and load weight. In this simulation study, 10 female building construction workers lifted weights in 48 different combinations of lifting parameters, in which four different lifting frequencies (1, 4, 7, and 14 lifts min/1), three different load weights (5, 10, and 15 kg) and four different vertical lifting heights (knee, waist, shoulder, and maximum reach) were considered. The subjects did symmetric lifting for 10 min period in sagittal plane adopting free-style lifting technique. The recorded working heart rates were normalized based on the maximum heart rate obtained during maximum aerobic power measurement. ANOVA result showed that the main effects were significantly (po0.0001) related with normalized working heart rate and the interaction effects of different lifting parameters contributed 10.01% of total variance of normalized working heart rate. Factorial design was applied to verify the interaction effects. Then stepwise linear regression analysis was performed to identify the best predictive model using important parameters. It was observed that the contribution of interaction factors was not in similar pattern in case of different frequency responses. Finally, it is concluded that the interaction effects between different lifting parameters must be considered in addition to the effects of individual lifting parameters for further research as it implicates potential modifications to the currently recommended weight load estimation procedure.

Vincent M. Ciriello (2006)

In the development of our present manual materials handling (MMH) guidelines Snook, S.H. &Ciriello, V.M., (1991). The design of manual tasks: revised tables of maximum acceptable weights and forces. The assumption was made that the effects of frequency on maximum acceptable weights (MAWs) of lifting with a large box (hand distance, 38 cm from chest) were similar to that of lifting with a small box (hand distance, 17 cm from chest). The first purpose of the present experiment was to investigate this assumption with female industrial workers. The second purpose was to study the effects of extended horizontal reach lifting (hand distance, 44.6 cm from chest) on MAWs as a confirmation of the results of a previous study on this variable with males Ciriello, V.M., Snook, S.H., Hughes, G.J., (1993). Further studies of psychophysically determined maximum acceptable weights and forces. Ciriello, V.M., 2003. The effects of box size, frequency, and extended horizontal reach on maximum acceptable weights of lifting. Lastly, we studied the effects of high frequency (20 lifts/min) on MAWs of lifting. Ten female industrial workers performed 15 variations of lifting using our psychophysical methodology whereby the subjects were asked to select a workload they could sustain for 8 h without ‘‘straining themselves or without becoming unusually tired weakened, overheated or out of breath’’. The results confirmed that MAWs of lifting with the large box was significantly affected by frequency. The frequency factor pattern in this study was similar to the frequency pattern from a previous study using the small box Ciriello, V.M., & Snook, S.H., (1983). A study of size distance height and frequency effects on manual handling tasks. For all fast frequencies down to one lift every 2 min with deviations of 7%, 15%, and 13% for the one lift every 5 and 30 min tasks and the one lift in8 h task, respectively. The effects of lifting with an extended horizontal reach decreased MAW 22% and 18% for the mid and centre lift and the effects of the 20 lifts/min frequency resulted in a MAW that was 47% of a 1 lift/min MAW. Incorporating these results in future guidelines should improve the design of MMH tasks for female workers.

Hwa s jung et al. (2009)

Handles on objects are very important for enhancing the safety and efficiency of manual handling for people who use them. In this study, four different prototype boxes with auxiliary handles were designed to determine the optimal handle position of a box based on the evaluated user preferences and body part discomfort (BPD). Twenty male students participated in the experiment. Likert-5 point summated rating was applied to evaluate user preferences for the provided boxes with handles in upper, middle, and lower positions, in four different sizes and manual handling positions. Ten additional subjects were asked to indicate their BPD on a body chart after performing a similar experiment. The results show that the subjects preferred the upper part of the handle on a small box regardless of handling position; while the mid to upper parts of the handle on a big box were preferred for handling above the waist height. BPD also indicated that an upper handle was less stressful for a relatively smaller box than a big one; and mid to upper handles were less comfortable for a big box. The optimal handle positions depending on box size and handling position were suggested based on the results of the evaluation. It is thus recommended that a box provides a handle according to its relevant position, depending on size and manual handling condition, to reduce the musculoskeletal stress and in turn to increase user satisfaction.

Swei-Pi Wu & Shu-Yu Chang (2009)

This study used a psychophysical approach to examine the effects of carrying methods and the presence or absence of box handles on the maximum acceptable weight carried and resulting responses (heart rate and rating of perceived exertion) in a two-person carrying task. After training, 16 female subjects performed a two-person carrying task at knuckle height for an 8-h work period. Each subject performed 4different carrying combinations two times. The independent variables were carrying methods (parallel and tandem walking) and box handles (with and without handles). For comparison with two-person carrying, the subjects also performed one-person carrying. The results showed that the maximum acceptable weight carried (MAWC), heart rate (HR), and rating of perceived exertion (RPE) were significantly affected by the presence of box handles. However, the subjects MAWC, HR, and RPE values were not significantly influenced by the carrying methods. The test–retest reliability of the psychophysical approach was 0.945. The carrying efficiency of two-person carrying was 96.2% of the one person carrying method. In general, the use of box with handles allows the subjects to carry a higher MAWC (with lower HR and RPE) compared to carrying boxes without handles.

W.P. Neumann & L. Medbo (2010)

This paper presents a design stage comparison of an existing ‘big box’ material supply strategy common in Swedish manufacturing to a proposed ‘narrow bin’ approach common in Japanese production systems. Performance times, walking distances, layout space requirements were evaluated for 6 workstations using ‘big boxes’ of parts along the line. Biomechanical loading on spine and shoulder was estimated for one of the workstations. Comparisons were made to simulated layouts with the ‘narrow bin’ approach. The use of narrow bin supply yielded significant reductions in rack lengths (-81%), Material Areas (-61%), Walking Distances (-61%), Indirect Work (-24%), and Cycle times (-8%). Peak and cumulative spinal load estimates showed reductions from 29% to 65% with similar load reductions in shoulders and hands. The ‘narrow bin’ strategy also has implications for the material re-supply system, enables the use of flexible racking and can reduce lift-truck use. Work intensification may increase risks if time-gains are used only to increase direct assembly work repetitions. It is concluded that the narrow bin supply strategy has potential to both improve productivity and reduce risk characteristics of the system. Further field testing is required. Relevance to industry: Supplying materials in smaller narrower bins poses a potential ‘win-win’ design tactic with decreased operator risks and improved performance in final assembly when compared to ‘big box’ supply strategies. The final choice of strategy requires a context-specific assessment.

Steven L. Fischer et al. (2011)

This research investigated if proportional relationships between psychophysically acceptable and maximum voluntary hand forces are dependent on the underlying biomechanical factor (i.e. whole body balance or joint strength) that limited the maximum voluntary hand force. Eighteen healthy males completed two unilateral maximal exertions followed by a 30 min psychophysical load-adjust protocol in each of nine pre-defined standing scenarios. Centre of pressure (whole body balance) and joint moments (joint strength) were calculated to evaluate whether balance or joint strength was most likely limiting maximum voluntary hand force. The ratio of the psychophysically acceptable force to the maximal force was significantly different depending on the underlying biomechanical factor. Psychophysically acceptable hand forces were selected at 86.3 ± 19.7% of the maximum voluntary hand force when limited by balance (pulling exertions), 67.5 ± 15.2% when limited by joint strength (downward pressing) and 78 ± 23% when the limitation was undefined in medial exertions.

3) CONCLUSION

As Yi-Lang Chen (2009) told in their study that the postures adopted by workers during vertical upward lifting (VUL) were also highly differentiated from novices while performing near-floor and This study demonstrated that the static-lifting strength of novices were significantly lower than those of experienced workers while upward lifting near the participant’s elbow height. It was concluded that workers tend to adopt a safer (i.e., more flexed knees) and more skilfultechnique than novices to generate forces, resulting in lower spinal loads during both methods of lifting. Because the experience workers adopt more safe and effective method to lift the object than novice so the data for student could not be directly used for design consideration. So by keeping all these parameters in mind there is a need to conduct a study on industrial workers with a precise data.

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