ERGONOMICS AND THE DISABLED/ REHABILITATED WORKER: USING ANALYTICAL TOOLS TO ASSESS RISK

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ABSTRACT

A poor fit between the worker and the work environment can cause unnecessary stress to the operator. In many cases the ergonomist, therapist, or other practitioner must optimize the fit between a specific worker and the workplace and make design recommendations to minimize job related stress. In addition, in many cases, the individual of interest is returning to the workforce after an injury or illness or has a reduced capability of some type. This paper presents proposed adaptations to some available analytical tools, dealing with manual material handling and metabolic analysis, to increase their applicability to the disabled/rehabilitated worker.

INTRODUCTION

The ergonomist deals with the relationship between the worker and the work environment to optimize the "fit" between the worker and the job. A poor fit can cause unnecessary stress to the operator and may adversely affect the worker through job related injuries or illnesses or may adversely affect the product through reduced quantity, quality, or efficiency of production. Ergonomists are generally trained to use analytical tools based on the assumption that the target population is "normal". In some cases, however, the individual of interest may be returning to the workforce after an injury or illness with a reduced capability of some type and the ergonomist, therapist, or other practitioner must optimize the fit between a specific worker and the workplace.

This paper will deal with the proposed adaptation of some available analytical tools, dealing with manual material handling and metabolic analysis, to the disabled/rehabilitated worker.

MUSCULOSKELETAL STRESS ANALYSIS TECHNIQUES

The NIOSH Work Practices Guide for Manual Lifting (NIOSH WPG)

The revised NIOSH WPG (NIOSH, 1993) recognizes the effect of metabolic energy expenditure, strength, and compressive forces on the low back and determines "acceptable' load weights. The NIOSH WPG notes that "The assumed workforce is physically fit and accustomed to physical labor".

The Recommended Weight Limit or lifting limit established in the 1991 NIOSH WPG equation can be calculated by 51 lbs x HM x VM x DM x FM x AM x CM

where the factors relate to physical parameters as follows: HM = horizontal distance that the load is held out from the body (ankles), VM = vertical distance of the load above the floor at the beginning of the lift, DM = vertical distance that the load moves during the lift/lower, FM = frequency and duration of the lift, AM = torso rotation at beginning and end of lift, and CM = type of grip between the hands and the load. In an optimum posture (load at waist level close to the front of the body) with good grip and low frequency and duration of lift, each of these factors has a value of 1.0 and the lifting limit is 51 lbs. As the lift/lower deviates from optimum these factors become less than 1.0 and the lifting limit decreases from the 51 lb value. The use of a 51 lb constant in the above NIOSH WPG equation is based on the assumption that the members of the workforce are "...physically fit and accustomed to physical labor" (NIOSH, 1993) and can lift 51 lbs in an optimum posture. It is proposed that the 51 lb load constant used in the NIOSH WPG be reduced to recognize the actual lifting capacity of the disabled or rehabilitated worker in the "optimum" posture. As the actual task posture varies from the optimum the factors will decrease from 1.0 and the lifting limit for the specific worker for specific tasks will also be reduced. This appears to be more appropriate than applying the 51 lb constant to the disabled/rehabilitated worker.

These factors also relate to different aspects of the hazard associated with the task and provide information relating to the redesign of the task for disabled/rehabilitated workers. The horizontal factor (HM) relates to the low-back hazard or musculoskeletal hazard associated with the shoulder and elbow. If this factor is low the task presents a higher risk for individuals with limitations or decrements in these areas. The frequency factor (FM) relates to the metabolic load associated with the task If this factor is low the task presents a higher risk for individuals with cardiovascular limitations.

These factors also provide information relating to task redesign which will facilitate worker accommodation. The horizontal factor (HM) and vertical factor (FM) relate to the low-back hazard or musculoskeletal hazard associated with the shoulder and elbow. When these factors are low, some sort of biomechanical analysis is indicated. The frequency factor (FM) relates to the metabolic load associated with the task When this factor is low, some sort of metabolic analysis is indicated.

Biomechanical Analysis

Biomechanical Analysis is possible with any of several different computer models such as that developed by the University of Michigan. One simple hand-calculation method to estimate low-back compressive forces which has gained some acceptance is shown on Figure 1. This estimate tends to be within 5-10% of the results of the University of Michigan model and may serve as an initial estimate when computer facilities are not available. This estimate also provides information about the components of the task which contribute most to the low back hazard.

Biomechanical calculations are frequently used to determine the back compressive forces resulting from a material handling task so that these forces can be compared to the NIOSH limits of 770 lbs which can be tolerated by most young, healthy workers, and 1430 lbs which is stressful for nearly all workers. This limit of 770, while tolerable for most healthy workers, would be excessive for a worker returning to work after a back surgery. The job should be redesigned to reduce the compressive forces in accordance with the relative task hazards indicated by the magnitudes of terms A (back muscle

Table 1. Physical Work Capacity (kcal/min) for Males as a Function of Age and Work Duration.

AGE	PFI	120 min.	240 min.	480 min.	510 min.
20	1.16	9.68	7.82	5.95	5.79
30	1.09	9.09	7.34	5.59	5.44
40	0.95	7.93	6.40	4.88	4.74
50	0.91	7.59	6.13	4.67	4.54
60	0.83	6.92	5.59	4.26	4.14

force reacting to upper body weight)and B (back muscle force reacting to load moment.).

The worksheet can also give an indication of the shoulder stresses. If term A is low and term B is high then the shoulder stresses are likely to be high. If the worker is returning to work after a shoulder surgery, and does not have a history of back problems, then a minimization of the shoulder stress is most important. The job should be redesigned to reduce term B even if it means that term A might have to increase slightly.

50	0.91x.7	5.31	4.29	3.27	3.18

METABOLIC STRESS ANALYSIS TECHNIQUES

The fatigue resulting from a situation where the metabolic demands of the job exceed the worker's capacity may result in a direct cardiovascular threat or a change in work methods which could increase the biomechanical risks discussed earlier. In order to minimize this risk it is important to estimate the energy requirements of the job and the work capacity of the worker.

One relatively simple method of estimating job energy requirements developed by Thomas Bernard under contract with the American Automobile Manufacturers Association (Bernard, 1991) uses measures of arm use, walk distance, lift frequency and weigh, and push/pull weight force and distance. This metabolic analysis method not only allows the determination of the overall metabolic rate associated with a job but identifies the most stressful job components.

The workers capacity is dependent on his/her physical condition, sometimes called the physical fitness index) and on the work duration (Bink, 1962; Bonjer, 1962; Chaffin, 1966) This capacity to do work is called the physical work capacity or PWC and is summarized in Table 1 for male workers.

If the energy expenditure requirement of a job exceeds the physical work capacity of the worker, rest breaks need to be incorporated to avoid whole-body fatigue. In the case of a disabled/rehabilitated worker the values in Table 1 will have to be reduced by (at least) a factor representing the worker's metabolic capability compared to a "normal" worker of the same age. For example if a 50 year old male worker were determined to have 70% of the metabolic capability of an average 50 year old person then the values in the table above would be multiplied by .7 and reduced from the table values to:

SUMMARY

In this paper an attempt has been made to propose adaptations of several ergonomic analytical tools so that they are more appropriate for the analysis and redesign of tasks which are to be performed by the disabled/rehabilitated worker. The authors are confident that these modifications make the noted analytical tools better suited for these workers. The reader is, however, cautioned and encouraged to review the NIOSH Work Practices Guide, biomechanical analysis techniques, and metabolic analysis techniques prior to using these recommendations.

REFERENCES

Barnard,T.E., Metabolic Heat Assessment, 1991, MVMA Agreement USF 9008-C0173, University of South Florida, Tampa, FL.

Bink,B. 1962, The physical work capacity in relation to working time and age 1962, Ergonomics 5(1):25-28.

Bonjer,F. 1962, Actual energy expenditure in relation to the physical work capacity, Ergonomics 5(1):29-31.

Chaffin,D.B., 1966, The prediction of physical fatigue during manual labor, Journal of Methods-Time Measurement 11(5):25-31.

NIOSH 1993, Applications Manual for the Revised NIOSH Lifting Equation, NIOSH .

BW	= BODY WEIGHT	=	________
L	= LOAD IN HANDS	=	________
HB	= HORIZ DISTANCE FROM HANDS TO LOW BACK	=	________
COS (α)	=COS OF TORSO ANGLE WITH HORIZ	=	________

Fc = A + B + C

Where:	**A** = 3(BW)cos(a)	= 3(____)*(_____)	=	________
	B = .46(L * HB)	=.5(____)*(_____)	=	________
	C = .8[(BW)/2 + L] [1-cos(a)]	=.8[(____)/2 + ____]	=	________

TOTAL COMPRESSIVE FORCE ESTIMATE (LBS) ________

Remember that:

1.A = 3(BW)cos(a) =Back muscle force reacting to upper body weight. To lower this one must change the upper body angle with the horizontal.
2.B = .5(L * HB) = Back muscle force reacting to load moment. To lower this one must change the magnitude of the load or the distance that the load is held out from the body.
3.C = .8[(BW)/2 + L] = Direct compressive component of upper body weight and load. To lower this one must change the magnitude of the load.

Figure 1. Estimation of back compressive force.

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