Fatigue Measurement by Lifting Index

Kim, Dae-Sik*
Kang, Kyong Sik**

ABSTRACT

The purpose of this study was to reduce the chronical low back pain for the manual material handlers. The objectives of this study was to: (1) examine lifting variables, (2) analyze collected data, and (3) suggest lifting redesign recommendations in workplace. The data were collected in A company, manufactures various paints in Si-Wha industrial complex, Kyunggi-Do. It was found that Sb(horizontal distance), Sc(vertical distance), Sd(travelling distance) and Sf(frequency) were significant at the 0.01 level and Sa(weight) was significant at the 0.05 level.

1. INTRODUCTION

In most manual material handling(MMH) tasks, the worker must assume an awkward posture to perform the task and/or his entire muscular system must brought into action.

The total injuries due to overexertion in MMH task took account for 477,785(27.6%) out of the total amount of injuries (1,730,534). (U. S. Department of Labor, 1998, "BLS Case and Demographic Characteristics for Workplace Injury and Illness Involving Days away from Work. Injuries due to lifting took account for 58.76%(280,725) out of the total overexertion in MMH(477,785).

The purpose of this paper was to reduce the chronical low back pain for the manual material handlers. The objectives of this study was to: (1) examine lifting variables, (2) analyze collected data, and (3) suggest lifting redesign recommendations in workplace.

* Dept. of Industrial & Management Engineering, Ansan College of Technology
** Dept. of Industrial Engineering, Myong Ji University

2. LIFTING VARIABLES

2.1 Weight of lift

Lewis (1982) studied effects of fatigue on kinematics of sagittal lifting. There were four levels of weight - 12.75, 12.88, 18.96 and 23.77 kg. Khalil et al. (1985) studied physiological limits in lifting. There were six levels of weight - 6.82, 13.64, 20.45, 27.27, 34.09 and 40.91 kg. Asfour et al. (1986) conducted an experiment for a data base of physiological responses to manual lifting. There were three levels of weight of lift - 6.8, 13.6, and 20.4 kg. Gargon and Smyth (1992) studied biomechanical exploration on dynamic modes of lifting. There were two levels of loads - 6.4 and 11.6 kg. Potvin et al. (1992) studied regression models for the prediction of dynamic L4/L5 compression forces during lifting. There were five levels of weight - 5.8, 13.6, 21.5, 29.2 and 32.4 kg.

2.2 Vertical height of lift

Lewis (1982) studied effects of fatigue on kinematics of sagittal lifting. There were four height levels - 171.00, 175.70, 175.90, and 183.45 cm. Mital (1984) investigated maximum weights of lift acceptable to male and female individual workers for extended work shifts. There were three height levels - floor to knuckle, knuckle to shoulder, and shoulder to reach. Khalil et al. (1985) studied physiological limits in lifting. There were three height levels - floor level to 76.2 cm above the floor (floor to knuckle height), 76.2 cm above the floor to 127 cm above the floor (knuckle to shoulder height), and floor level to 127 cm above the floor (floor to shoulder height). Asfour et al. (1986) conducted an experiment for a data base of physiological responses to manual lifting. There were three levels of height of lift - floor to 76 cm, 76 cm to 127 cm, and floor to 127 cm. Intaranont et al. (1986) studied physical lifting capacity : the anaerobic threshold approach. The range of lift were from floor to knuckle height and from knuckle height to shoulder height. Mital and Ayoub(1986) conducted an experiment for prediction lifting capabilities. There were six levels of lifting height - floor to knuckle (0 to 80 cm), floor to shoulder (0 to 127 cm), floor to reach (0 to 165 cm), knuckle to shoulder (80 to 127 cm), knuckle to reach (80 to 165 cm), and shoulder to reach (127 to 165 cm). Waikar et al.(1991) investigated evaluating lifting tasks using subjective and biomechanical estimates of stress at the lower back. Lifting tasks with five different heights of lifts - floor to knuckle, knuckle to elbow, elbow to shoulder, shoulder to reach, and reach to overreach lifting. Gargon and Smyth (1992) studied biomechanical exploration on dynamic modes of lifting. The lifts were executed from height of 15 cm to a height of 185 cm above the head.

2.3 Angle of twist

Asfour et al. (1986) conducted an experiment for a data base of physiological

responses to manual lifting. There were two levels of angle of twist - 0 and 90 degrees.

2.4 Frequency of lift

Mital (1984) investigated maximum weights of lift acceptable to male and female individual workers for extended work shifts. There were four lifting frequency - 1, 4, 8, and 12 lifts/min. Khalil et al. (1985) studied physiological limits in lifting. There were six levels of frequency - 1, 3, 5, 7, 9 and 11 lifts/min. Asfour et al. (1986) conducted an experiment for a data base of physiological responses to manual lifting. There were three levels of frequency of lift - 3, 6, and 9 times/minute. Intaranont et al. (1986) studied physical lifting capacity : the anaerobic threshold approach. There were three levels of frequency of lift - 6, 7.5 and 9 lifts/min. Mital and Ayoub(1986) conducted an experiment for prediction lifting capabilities. There were four levels of lifting frequency - 2, 4, 6 and 8 lifts per minutes. Welbergen et al.(1991) studied efficiency and effectiveness of stoop and squat lifting at different frequencies. Gargon and Smyth (1992) studied biomechanical exploration on dynamic modes of lifting. There were two levels of lifting frequency - slow continuous lift and accelerated continuous lift. Mital et al. (1994) studied physical fatigue in high and very high frequency manual materials handling: perceived exertion and physiological indicators. The frequency of lifting was independent variable with five levels : 14, 16, 18, 20 and 22 times per minutes.

2.5 Posture of lift

Waiker et al.(1986) conducted strength test for low back injuries with squat and stoop positions. The positions were variations of the leg lifting (squat) and torso lifting (stoop) positions. Welbergen et al.(1991) studied efficiency and effectiveness of stoop and squat lifting at different frequencies. Giat and Pike (1992) investigated mechanical and electromyographic comparison between the stoop and the squat lifting models. Potvin et al. (1992) studied regression models for the prediction of dynamic L4/L5 compression forces during lifting. The squat and stoop lifts were used. Mital (1995) studied the use of biomechanical measures in the investigation of changes in lifting strategies over extended periods.

3. MANOVA

The following data was collected in A company, manufactures various paints in Si-Wha industrial complex, Kyunggi-Do. The nine workers were used as subjects. The subjects lifted sack of law materials (61 × 41 × 10 cm), have three levels of weight - 20, 25 and 30 kg. The various lifting task variables (weight, lifting height, traveling distance, horizontal distance, angle of twist, frequency, etc.) were collected and Lifting Index(LI) were

calculated. [Table 3 - 1] The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. It was found that all of twenty LI were over 1.0. The subjects were working with fatigue.

The results of the LI was analyzed by MANOVA to find the relation with lifting task variables collected. From the [Table 3 - 2], it was found that Sb(horizontal distance), Sc(vertical distance), Sd(travelling distance) and Sf(frequency) were significant at the 0.01 level and Sa(weight) was significant at the 0.05 level.

4. REDESIGN

The followings are task redesign from MANOVA.

(1) Eliminate the need to bend by:
   1) Using lift tables, work dispensers and similar mechanical aids.
   2) Raising the work level to an appropriate height.
   3) Lowering the worker.
   4) Providing all material at work level.
   5) Keeping materials at work level (e.g., don't lower anything to the floor that must be lifted later).

(2) Eliminate the need to reach by:
   1) Providing tools and machine controls close to the worker, to eliminate horizontal reaches over 16 inches.
   2) Placing materials, workpieces, and other heavy objects as near the worker as possible.
   3) Reducing the size of the cartons or pallets being loaded, or allowing the worker to walk around them, or rotate them.
   4) Reducing the size of the object being handled.
   5) Allowing the object to be kept close to the body.

[Table 3 - 1] Collected data in A company

Replication	W(kg)	H(cm)	V(cm)	D(cm)	A(°)	F(t/m)	C	LI
1	20	28	20	5	60	5	poor	1.2
2	20	28	20	5	75	9	poor	1.9
3	20	28	20	5	90	12	poor	2.9
4	20	46	50	35	60	5	poor	3.1
5	20	46	50	35	75	9	poor	5.1
6	20	46	50	35	90	12	poor	7.7
7	20	63	70	55	60	5	poor	4.2
8	20	63	70	55	75	9	poor	6.9
9	20	63	70	55	90	12	poor	10.5
10	25	28	50	55	60	9	poor	3.8
11	25	28	50	55	75	12	poor	5.8
12	25	28	50	55	90	5	poor	2.8
13	25	46	70	5	60	9	poor	3.1
14	25	46	70	5	75	12	poor	4.6
15	25	46	70	5	90	5	poor	2.3
16	25	63	20	35	60	9	poor	8.9
17	25	63	20	35	75	12	poor	13.2
18	25	63	20	35	90	5	poor	6.6
19	30	28	70	35	60	12	poor	5.8
20	30	28	70	35	75	5	poor	2.9
21	30	28	70	35	90	9	poor	4.7
22	30	46	20	55	60	12	poor	12.0
23	30	46	20	55	75	5	poor	5.9
24	30	46	20	55	90	9	poor	9.7
25	30	63	50	5	60	12	poor	7.5
26	30	63	50	5	75	5	poor	3.7
27	30	63	50	5	90	9	poor	6.1

[Table 3 - 2] MANOVA table

	S	D.F	V	F	f(0.05)	f(0.01)
Sa	12.1	2	6.05	5.882	3.74	6.51
Sb	72.2	2	36.1	35.1		
Sc	21.4	2	10.7	10.4		
Sd	52.7	2	26.35	25.62		
Se	0.9	2	0.45	0.437		
Sf	77.4	2	38.7	37.63		
Sg	14.4	14	1.029			
St	251.1	26				

(3) Reduce the weight of the object by:

1) Reducing the size of the object (specify size to suppliers).

2) Reducing the capacity of containers.

3) Reducing the weight of the container itself.

4) Reducing the load in the container (administrative controls).
5)Reducing the number of objects lifted or lowered at one time (administrative controls).

5. CONCLUSIONS AND FUTURE RESEARCH

The LBP is one of modern human being's most common and complex ailments. Everyone might have experienced more than one time LBP during one's whole life. The less than 25% of LBP suffers who do not improve spontaneously consume approximately 90% of the total health care resources and associated costs. Average cost per case was $40,000 in the United States. The total cost associated with back problems was $40 billion, and potentially reaching $90 billion annually.

The data was collected in A company, manufactures various paints in Si-Wha industrial complex, Kyunggi-Do. From the results of MANOVA, it was found that Sb(horizontal distance), Sc(vertical distance), Sd(travelling distance) and Sf(frequency) were significant at the 0.01 level and Sa(weight) was significant at the 0.05 level.

Without optimal lifting works, workers cannot work safely. Top and middle managers should concern working environment in order to reduce industrial injuries and protect employees from potential hazards. Offering safe working environment is to improve productivity.

REFERENCES

[1] Ayoub, M.M. and Mital, A., (1989) *Manual Material Handling*, Taylor and Francis, London.

[2] Chaffin, D.B. and Andersson, G.B.J., (1991) *Occupational Biomechanics*, John Wiley & Sons, New York.

[3] Ciriello, V.M. and Snook, S.H., (1983) "A Study of Size, Distance, Height, and Frequency Effects on Manual Handling Tasks", *Human Factors*, 25, pp. 473-483.

[4] Khalil, T.M., Abdel-Moty, E.M., Rosomoff, R.S. and Rosomoff, H.L., (1993) *Ergonomics in Back Pain: A Guide to Prevention and Rehabilitation*, Van Nostrand Reinhold, New York, NY.

[5] Mital, A. and Ayoub, M.M., (1981) "Effect of Task Variables and Their Interactions in Lifting and Lowering Loads", *American Industrial Hygiene*

Association Journal, 42(2), pp. 134-142.
[6] Mital, A., Nicholson, A.S., and Ayoub, M.M., (1993) *A Guide to Manual Materials Handling*, Taylor & Francis, London.
[7] National Institute for Occupational Safety and Health (NIOSH), (1981) *Work Practices Guide for Manual Lifting,* Edited by D.W. Badges, U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, Division of Biomedical and Behavioral Sciences, Cincinnati, National Institute of Occupational Safety and Health, DHH(NIOSH) Publication No. 81-122.
[8] National Safety Council, *Accident Facts,*
[9] U. S. Department of Labor, (1998), "BLS Case and Demographic Characteristics for Workplace Injury and Illness Involving Days away from Work.
[10] http://www.lni.wa.gov/wisha/ergo/lifting/lessons.htm
[11] http://www.lni.wa.gov/wisha/ergo/lifting/louie.htm