Determination of Safe Asymmetric Lifting of Hand-Pump Body

Bansal R., Gupta A., Garg S., and Srivastava S.*
Industrial Kinesiology Lab, Faculty of Engineering, Dayalbagh Educational Institute (DEI), Agra-282005, India
ravibansal.dei@gmail.com, gupta11ay@gmail.com, sonikgarg@gmail.com, and ssrivastava@dei.ac.in*

Abstract: An analysis of asymmetric lifting of hand-pump body (HPB) manufactured in an industrial unit in Agra is presented in this paper. This task turns out to be highly unsafe as per the results of revised NIOSH lifting equation. Owing to high circumferential width of HPB, a low value of horizontal multiplier is obtained, which becomes the main cause of significant increase in lifting index. A physiological approach, involving measurement of heart rate in a simulated laboratory setup, is used to verify the results. Experiments are performed on 8 workers (male, age range 28-42 years, 5 years minimum work experience). Results indicate that it is a safe lifting task. So, an important inference in this case study is the non-applicability of revised NIOSH lifting equation in estimating the safe load limit. In the next phase, to assess the effects of job experience on the degree of risk involved in the lifting task, another set of experiments are performed taking 7 non-workers (male, age range 20-32 years) with no job experience. On comparing the results of post-test heart rate of workers and non-workers, it is suggested that the job habit reduces the degree of risk involved in the manual task significantly.

1 Introduction

Lifting is a commonly found manual materials handling (MMH) task in the manufacturing and service industries of developing countries including India. The stressfulness of a MMH task is evaluated by comparing job demands to human abilities or scientific norms established in the literature. Manual lifting has been recognized as a major source of low back pain by researchers and organizations. In 1981, National Institute of Occupational Safety and Health (NIOSH) first published a Lifting Equation to compute the Recommended Weight Limit (RWL) [11]. It was revised in 1991 to apply to a larger percentage of lifting tasks, and the resulting equation was published as Revised NIOSH Lifting Equation [12], which computes RWL as illustrated be-low.

$$RWL = LC \times HM \times VM \times DM \times FM \times AM \times CM \quad (1)$$

Where,

$$LC(Load\ Constant) = 23\ \text{kg}$$

$$HM(Horizontal\ Multiplier) = \frac{25}{\text{H}}$$

$$VM(Vertical\ Multiplier) = 1 - (.003\ |\ \text{V} - 75\ |)$$

$$DM(Distance\ Multiplier) = .82 + \left(\frac{4.5}{\text{D}}\right)$$

$$AM(Asymmetric\ Multiplier) = 1 - (.0032)A$$

ISBN 978-93-5258-836-7 HWWE 2015

All distances are measured in centimeters and angle is measured in degrees. Frequency Multiplier (FM), and Coupling Multiplier (CM) are noted from the standard tables. Notations stand for their usual meanings. LC is the safe load limit of 23 kg under optimal conditions. Value of each multiplier ranges from 0 to 1. There are instances in the literature wherein questions have been raised on the applicability of revised NIOSH lifting equation especially for non-western population [5, 9, 10]. Owing to limitations of applicability of this equation another lifting equation has been proposed to evaluate maximum load limit for Indian female workers (10).

Manual lifting workers are at a higher risk of cardiovascular diseases due to physical and mental stress induced by higher job demands placed on them [4], which could lead to adverse physiological conditions such as increased heart rate, elevated blood pressure levels, excessive sweating and higher intake of oxygen. Heart rate (HR) is one of the most commonly measured and monitored signs among others (respiration rate, blood oxygen saturation, arterial blood pressure etc.) [1]. The body responds by increasing the heart rate such that any kind of task that goes on for an extended period of time can cause stress to the level of heart failure. Laboratory assessment of oxygen saturation provides an important indicator of a worker's cardio-respiratory status. Pulse oximeters monitor arterial blood oxygen saturation, which is referred to as SpO2 [15]. During physical exercise, the heart rate and cardiac output are linearly related to oxygen consumption [1]. A study shows that the arterial oxygen saturation remains within normal limits during exercise in sedentary subjects while a decrease in arterial oxygen saturation at maximal exercise has however been observed in athletes [13].

The present study is concerned with asymmetric lifting of hand-pump body (HPB), formally called water tank cylinder and stand assembly, in an industrial unit in Agra. A HPB, weighing 16 kg, has a circumferential width as 35.56 cm, and its shape is typical with three legs pointing outward.

2 Methodology

A preliminary survey in a hand-pump manufacturing unit in Agra shows that lifting of HPB is one of the difficult MMH tasks among others. It is carried out in a shift of 8 hours with 45 minutes flexible lunch break. Shape of a HPB is typical with its three legs pointing outward for its support (cylinder length = 89cm, cylinder diameter = 15cm, leg length = 50cm, leg angle = 40 degree, discharge = 375 ml/stroke per minute, and stroke length =12.5cm±0.4cm) (Fig 1a). Task involves lifting of HPB from ground and placing them horizontally over vertically-positioned HPB on ground (Fig 1b & Fig. 1c).

a b c

Fig. 1 (a) A hand-pump body at factory site, (b) stack of hand-pump body, (c) lifting of HPB at factory site

Experiments are performed in the Industrial Kinesiology (IK) Lab, DEI, on two sets of healthy subjects: (1) 8 workers (male, age range: 28-42 years, 5 years minimum work experience of MMH tasks) and (2) 7 non-workers (male, age range: 20-32 years) having no work experience. Subjects are given a brief demonstration of equipment for measuring heart rate (BioHarnessTM Physiology Monitoring System with AcqKnowledge® Software, BIOPAC® Systems, Inc., Goleta, CA) and oxygen saturation (Pulse Oximeter, RMS Chandigarh, India), procedures and experimental risks prior to investigations. A signed consent is taken from each subject. Anthropometric and other data is noted down viz. age, height, weight and job experience in years. Factory site HPB lifting is simulated in the IK Lab by recording actual values of task variables of revised NIOSH lifting equation such as H, V, D, A, and F (Fig. 2a & Fig. 2b). Environmental parameters are also simulated. Each subject participated in repetitive free style lifting of HPB of 10 minutes duration. Pre-test and post-test heart rate and oxygen saturation (SpO_2) are measured. A test involves lifting of HBP for 10 minutes duration by a subject.

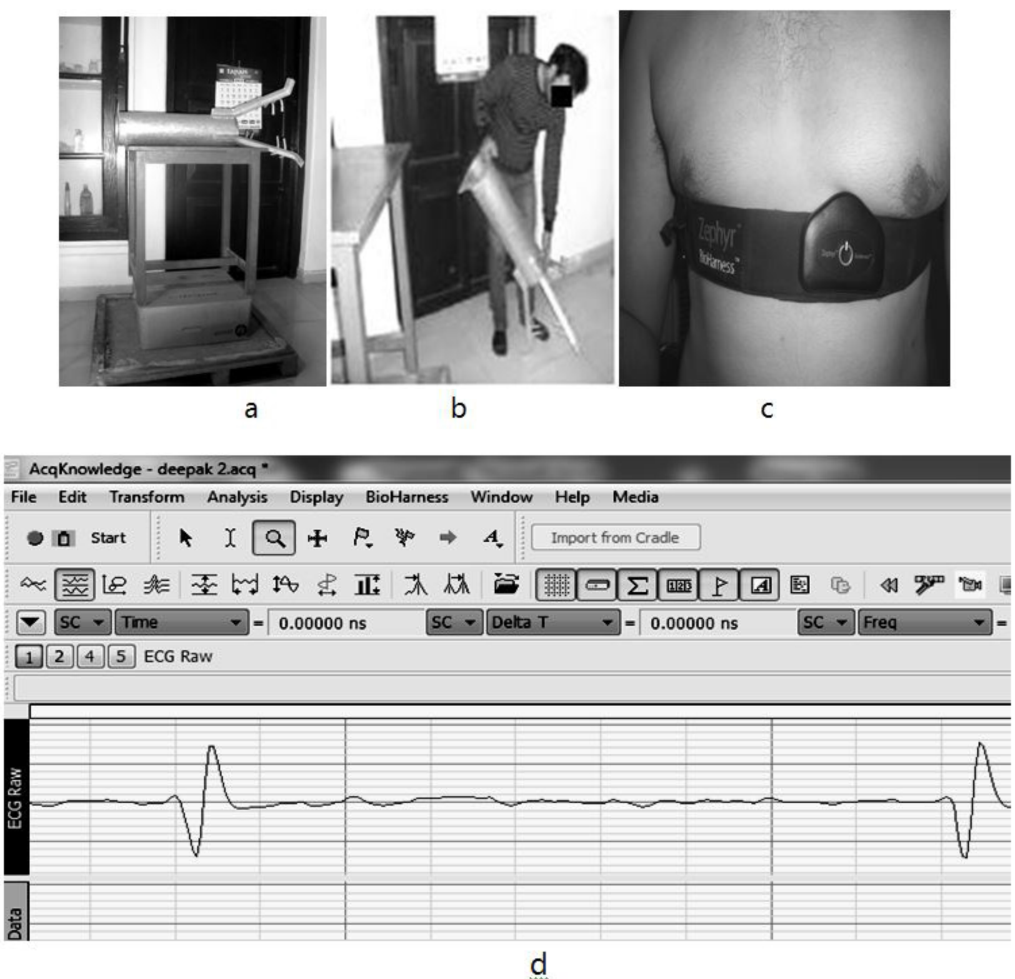

Fig. 2 (a) A HPB at IK lab, (b) Simulated lifting of HPB, (c) Heart rate recording using BioHarness™, (d) A snapshot of ECG Raw post experiment

ISBN 978-93-5258-836-7 2015 HWWE

3 Results

Value of each task variable of revised NIOSH lifting equation is noted down from the factory site: H=63 cm, V=60 cm, D=122 cm, A=80 degree, Coupling Type=Fair. Lifting frequency for workers varied from 61 lifts to 85 lifts per 10 minutes, whereas for non-workers, it varied from 52 to 76 lifts per 10 minutes. Corresponding value of each multiplier is as follows: HM=0.328, VM=0.96, DM=0.86, AM =0.73, CM=0.95. FM varied from 0.6 to 0.75 for workers and 0.6 to 0.8 for non-workers. Accordingly, for workers, lifting index varied from 4.34 to 7.4, and for non-workers, it ranged from 4.06 to 5.85. The average lifting index is 5.46 for workers and 5.14 for non-workers (Table 1). These results clearly spell out that HPB lifting is a highly unsafe task.

Table 1 Average value of lifting index for workers and non-workers

	Workers	Non-Workers
Average Lifting Index	5.46±0.92	5.14±0.60

Table 2 Pre-test and post-test heart rate and oxygen saturation (SpO2)

	Workers		Non-Workers	
Parameters	Pre-test	Post-test	Pre-test	Post-test
HR (in bpm)	74.42±9.13	107.9±19.6	94.7±19.8139.19±21.8	
SpO2 (in %)	98.375±0.51	98±0.92	97.7±0.75	96.6±0.53

To reduce lifting index for both cases, HPB lifting task can be redesigned. It is evident that a very low value of HM (i.e. 0.328) contributed significantly to high lifting index. But HM could not be improved due to high circumferential width of HPB. There is only a little scope of improving upon the value of AM. Therefore, as per revised NIOSH lifting equation, lifting of HPB would remain a highly unsafe task even after redesigning it. For workers, pre-test heart rate varied from 61.5 bpm to 90.4 bpm, while post-test heart rate varied from 74.52 bpm to 139.61. For non-workers, variation in pre-test heart rate is from 82 bpm to 119.8 bpm and variation in post-test heart rate is from 98.66 bpm to 151.81 bpm respectively. For both sets of subjects, the average value of post-test heart rate is less than 110 bpm (it is 107.9 bpm for workers and 139.2 bpm for non-workers) (Table 2). Results also show that post-test oxygen saturation reduces for both set of subjects-workers as well as non-workers. However, this reduction is higher in non-workers in comparison to workers (Table 2). Therefore it can be inferred from the physiological results that both, post-test heart rate, and decrease in oxygen saturation level are higher for non-workers in comparison to workers.

4 Discussion and Conclusion

An important conclusion of the present work is the non-applicability of revised NIOSH lifting equation in deciding the safe limits of HPB lifting. Due to the larger circumferential width of HPB (width as 35.56 cm with protruding edges), it is not possible to improve upon horizontal multiplier in the revised NIOSH lifting equation [12]. This resulted in very high value of lifting index for both sets of subjects, which in turn may suggest that lifting of HPB is associated with extreme risks. It may also be noted that since HPB is in one unit so its weight cannot be reduced. Reducing angle of asymmetry is not much helpful to bring down lifting index value. Other multipliers are already close to one. A workload of 33% of the aerobic capacity is recommended as the maximum energy expenditure for an eight hour work day [2, 8]. Its corresponding heart rate is 105 bpm with a range of 95 to 115 bpm [7]. Other studies suggest that the average heart rate over an eight hour industrial work shift should not exceed 110 bpm [3, 6, 14]. Therefore the results of physiological approach based on post-test heart rate criterion suggest that lifting of HPB is safe for workers. On comparing the results of post-test heart rate of workers and non-workers it is clear that that job habit plays a crucial role to determine the amount of risk involved in the job.

Acknowledgement

This work is supported by UGC, New Delhi, under Grant F. No. 3-38/2012(SAP-II) dated 02/10/2012, and by DST, New Delhi, under Grant Dy. No. 100/IFD/2563/2012-2017 dated 20/07/2012.

References

1. Astrand,P.O., et.al (1964). Cardiac output during submaximal and maximal work. Journal of Applied Physiology, 19, 268-274.
2. Authier, M., Lortie, M., Micheline, G.(1996). Manual handling techniques: Comparing novices and experts. International Journal of Industrial Ergonomics, 17, 419-429.
3. Ayoub, M.M., (1992). Problems and solutions in manual material handling, the state of art. Ergonomics, 35, 713-728.
4. Chany, A.M., Parakkat, J., Yang, G., Burr, D.L. and Marras, W.S. (2006). Changes in spine loading patterns throughout the workday as a function of experience, lift frequency, and personality. The Spine Journal, 6, (3), 296-305.
5. Evans, W. A. (1990). The relationship between isometric strength of Cantonese male and the US NIOSH Guide for manual lifting. Applied Ergonomics, 21,135 – 42.
6. Garg, A. and Beller, D. (1994). A comparison of isokinetic lifting strength with static strength and maximum acceptable weight with special reference to speed of lifting. Ergonomics. 37, 1363–1374.
7. Garg, A., and Banaag, J. (1988). Maximum acceptable weights, heart rates and RPEs for one hour's repetitive asymmetric lifting. Ergonomics, 36(1), 77-96
8. Garg, A., and Saxena, U. (1979). Effects of lifting frequency and technique on physical fatigue with special reference to psychophysical methodology and metabolic rate. American Industrial Hygiene Association Journal, 40(10), 894-903
9. Lee, Y. H., Wu, S. P. and Hsu, S. H.(1995). The psychophysical lifting capacities of Chinese subjects. Ergonomics, 38,671 – 83.
10. Maiti, R., & Ray, G.G. (2004). Manual lifting load limit equation for adult Indian women workers based on physiological criteria. Ergonomics, 47(1), 59-74.
11. National Institute of Occupational Safety and Health, NIOSH. (1981). Work practices

guidance for manual lifting. NIOSH. Technical report No. 81-122. (US Department of Health and Human Services, National Institute of Occupational Safety and Health, Cincinnati, OH).
12. NIOSH (National Institute for Occupational Safety and Health). (1991). Work practices guide for manual lifting. NIOSH Technical Report Draft, US Department of Health and Human Services, Cincinnati, OH.
13. Rowell L. B, Taylor H. L, Wang Y & Carlson W. S (1964). Saturation of arterial blood with oxygen during maximal exercise. J. Appl. Physiology, 19(2), 284-286.
14. Saha, P. N., Datta, S.R., Banerjee P. K., & Narayane, G. G. (1979). An acceptable workload for Indian workers. Ergonomics, 22(2), 1059 – 71.
15. Shannon, H. (2006). Oxygen Saturation- A Guide to Laboratory Assessment. Clinical Laboratory News.