Journal of Advances in Environmental Health Research

The effect of ergonomic intervention in reducing musculoskeletal disorders by Snook table method in a steel industry

Omid Giahi[1], Mansur Sarabi[2], Jamshid Khoubi[1], Ebrahim Darvishi[1]

1 Department of Occupational Health, School of Health AND Kurdistan Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran
2 Qorveh Public Health Center, Kurdistan University of Medical Sciences, Qorveh, Iran

Original Article

Abstract

The most frequent and expensive cause category of compensable loss is manual material handling (MMH). Casting workers who handle oxygen (O_2) cylinders manually are at risk for work-related musculoskeletal disorders (WMSDs). The aim of this study was to assess manual handling of O_2 cylinders by casting workers and to implement ergonomic intervention to reduce the risk of musculoskeletal disorders (MSDs). This interventional study was conducted on 30 male workers of casting unit in a steel industry. Nordic Musculoskeletal Questionnaire was used to determine the prevalence of MSDs in workers. Snook tables and its software were used to assess manual handling risk of O_2 cylinders. Manual handling of O_2 cylinders was totally excluded using the box with 16 cylinders that can be moved by crane. The most common MSDs in 1 year prior to the study were low back pain (43%), shoulders (33%), and hand/wrist and knee disorders (16%), respectively. The Snook tables' results indicated that 86% of lifting/lowering, 100% of carrying, and 50% of pulling tasks were appropriate for <10% of casting workers. About 94% of O_2 cylinders pushing were appropriate for 17% casting workers. With the implementation of ergonomic intervention, the risk of WMSDs and explosion of cylinders was decreased, and safety of workers was improved.

KEYWORDS: Manual Material Handling, Snook Tables, Ergonomics Intervention, Nordic Musculoskeletal Questionnaire, Oxygen Cylinders, Musculoskeletal Disorders

Date of submission: 30 Dec 2013, ***Date of acceptance:*** 07 Mar 2014

Citation: Giahi O, Sarabi M, Khoubi J, Darvishi E. **The effect of ergonomic intervention in reducing musculoskeletal disorders by Snook table method in a steel industry.** J Adv Environ Health Res 2014; 2(2): 65-71.

Introduction

Manual materials handling (MMH) tasks (pushing, puling, lifting, lowering, and carrying) are very common in workplaces and are carried out in most industrial plants.[1,2] MMH tasks are in many industry sectors, including manufacturing and service occupations.[3] However, the technology is developed in many industries, MMH has remained essentially the concern.[4,5] About 10% of jobs require extensive MMH.[6] The risk level of MMH depends on the load characteristics [weight, size, shape, coupling, and imbalance (i.e., changing center of gravity)], the task or method of handling (include repetitively, moving the load over large distances, accuracy and precision required because of fragile loads, hazardous movements or postures, etc.), environmental factors and workplace physical conditions (such as obstacles and floor surfaces (e.g., slippery, uneven or damaged, distance of route, temperature, lighting, and noise) and operator characteristics

Corresponding Author:
Ebrahim Darvishi
Email: darvishi.hse@gmail.com

(physical factors and psychological factors, like stress).[7,8] MMHs are the leading source of fatigue, musculoskeletal disorders (MSDs), low back pain and workers compensation claims in the workplace. MSDs often involve strains and sprains to the low back, shoulders, and upper limbs.[6] Annually, over half a million cases of MSDs reported in the United States due to MMH.[9,10] More than one-fourth of all compensable work injuries are associated with MMH tasks. National Institute for Occupational Safety and Health (NIOSH) has reported that 60% of the injury claims for low back pain is associated with MMH and 20% with pushing and pulling.[11] MMH is a frequent (36% of all claims) and costly (35% of total cost) category of compensable loss in the USA.[12]

Limitations and acceptable loads in MMH have been analyzed using a wide spectrum of techniques including physiological, psychophysical, subjective, biomechanical, observational, postural analysis and a combination of the above. "Snook tables" were developed at Liberty Mutual Insurance Company and described by Snook.[13] Snook tables are based on psychophysical measurements rather than biomechanical. They have more general use rather than the revised NIOSH lifting equation because they are applied in many of tasks.[13,14] Snook tables have been used in various studies and industries, including agriculture, mines, and construction sites.[10,15,16] Furthermore, these tables have been used in order to survey physiological and psychophysical responses in handling maximum acceptable weights (MAWs) in male Chinese workers performing combined MMH tasks, the effects of box size, vertical distance, and height on lowering tasks for male and female industrial workers.[17-19] Scientific studies indicate that effective ergonomic interventions can decrease the physical demands of MMH tasks, as a result lowering the prevalence and severity of the musculoskeletal discomfort.[2] Their potential to reduce discomfort associated with costs alone makes the ergonomic interventions useful tool for improving a product quality, company's productivity and overall business competitiveness. The best ergonomic intervention measure is to remove the need for workers to carry out MMH tasks.[17,18]

Mechanical handling devices or aids can often remove the task itself or facilitate the demands on the worker. Hence, it is not possible for MMH tasks to be designed base on to the workers' capabilities. Workers are facing with ergonomics hazards such as overload in manual handling of O_2 cylinders tasks in blast furnace unit, which expose them to risk of work-related musculoskeletal disorders (WMSDs). Thus, the aim of this study was to evaluate prevalence of WMSDs and to investigate MMH tasks by Snook tables among casting workers and ergonomics intervention in manual handling of O_2 cylinders in a steel industry.

Materials and Methods

The current experiment is an intervention study that was conducted on 30 male workers of the casting unit in a steel industry. All the subjects dressed in the same working overalls. They were provided with similar shoes to ensure consistent coefficients of friction on the ground. All the subjects examined by an occupational medicine specialist to identify people had experienced significant low back pain or other MSDs.

In steel industry, purified O_2 is used to take the hot metal out of the blast furnace and conduct it into the cauldron and casting molds to produce steel ingots. O_2 reduces the viscosity of the hot metal flow. Thus, O_2 consumption in steel industry is very high. In the studied steel industry, 40 rechargeable O_2 cylinders with weight and dimensions of 153 pounds (70 kg) and 146 cm × 23 cm, respectively, were used per day. Workers performed 14 variations of Lifting, carrying, lowering, pushing and pulling of cylinders, manually (MMH). O_2 cylinders were placed horizontally on each other in a truck and were carried to the company. Workers lifted cylinders and carried it vertically to 2 m in the truck, then lowered to 1 m onto ground. In most cases, this necessitated some degree of body twisting during lifting and lowering (Figure 1). The lifting and lowering tasks were performed at frequencies of 2 and 1/min. Workers carried the O_2 cylinders from the floor to body height distances of 2.1 m. Combination of The lifting, carrying and lowering task was performed at frequency rate of 1/min. Pulling tasks were performed at a distance of 2.6 m and at frequency of 0.2 and 1/min. A 1.1 m pushing task was performed 1/min. Workers pushed and pulled at a height midway between knuckle and elbow height (88.1 cm).

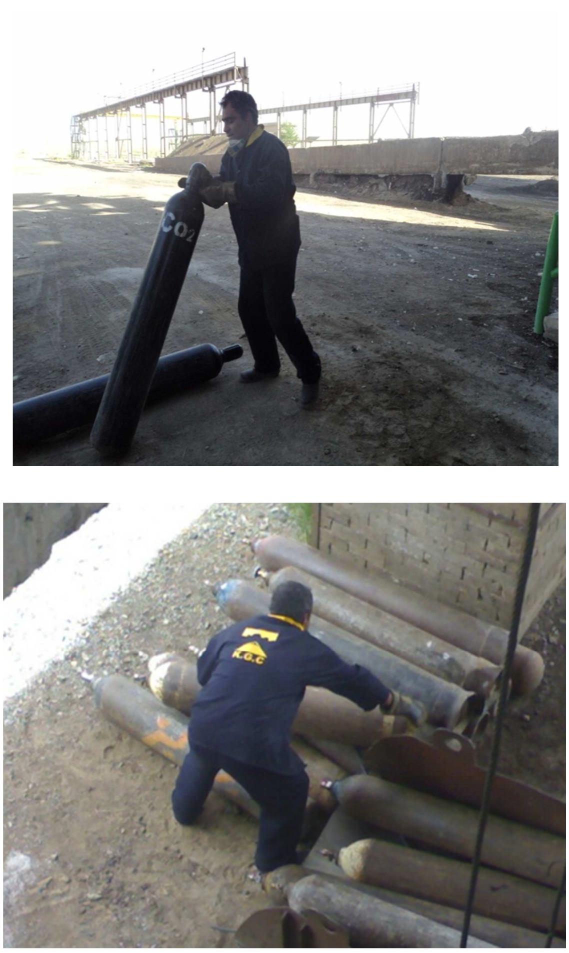

Figure 1. Lifting and lowering of O2 cylinders tasks

By unloading the truck, the O_2 cylinders were laid horizontally on the ground and on each other (Figure 2). Cylinders must be connected to the valve and oxygen consumption device that are used separately. Cylinders loading have been done manually for recharging in the factory after discharging. Workers complained of MMH tasks because they had to handle many cylinders daily.

Figure 2. Oxygen cylinders position before the intervention

Nordic Musculoskeletal Questionnaire (NMQ) was used to determine the prevalence of MSDs in workers. NMQ included questions about risks and discomfort during the last 12 months and 1 week before the study.[20]

Furthermore, the psychophysical methodology described by Ciriello and Snook[14] and Ciriello and Snook[18] was used in this experiment. This methodology includes measurement of oxygen consumption, heart rate, and anthropometric characteristics. This methodology is well-known as Snook tables. These tables are based on controlled experiments using psychophysical evaluation, and can be used to find the percent of an industrial population capable of sustaining the efforts tabulated in lifting, lowering, pushing, pulling, and carrying. These tables included 20 tables for MAW for lifting, lowering, pulling, pushing and carrying tasks. These tables are presented separately for males and females. The result is specified as a percentage of the population of males and females who are able to carry out manual handling tasks. MMH tasks must be designed for more than 75% of the female or male work population to be able to do it. Designing these manual tasks for more than 90% of the female work population will offer a more appropriate level of protection from manual handling injuries. The force exerted to lifting/lowering, pushing/pulling, and carrying cylinders tasks were measured using a model of FG-5100 potentiometer. These tasks were evaluated using the software Snook.

Ergonomics intervention (designed box and handling mechanization of the cylinders)

Among the different options to improve a particular MMH task, it is important to choose the one, which will work best for that task. In the current study, a cubic rectangular box was designed to eliminate the manual handling of cylinders. Box dimensions were 150 × 150 × 170 cm. Box frame was made of steel. Sixteen O_2 cylinders were fixed inside the box vertically. The cylinders were connected to each other using copper pipes. Finally, inlet and outlet in the cylinders were designed for O_2 consumption and charging, respectively. Regulator and manometer were installed at the inlet and outlet of the cylinders. Two hooks were installed in the top of the box for connection of the crane. There were overhead cranes in all the units with the application of O_2 cylinders (Figure 3).

Results and Discussion

Mean (± SD) of 30 studied male workers' age, height, body weight, and work experience were 35.8 (± 5.5) years, 175.8 (± 4.2) cm, 65.0 (± 5.6) kg, and 14.5 (± 5.5) years, respectively.

The results of NMQ showed that 84% of workers had experienced pain at least once in one of the organs during the 12 months before the study. The most common MSDs were low back pain (43%), shoulders (33%) and hand/wrist and knee disorders (16%), respectively, in 1 year prior to the study (Table 1). Furthermore, four of them had suffered significant musculoskeletal injuries.

The measurements included finding the percentage of male workers population for O_2 cylinder lifting/lowering.

O_2 cylinder weights were 153 pounds (70 kg). Hand distances away from the body of 7 in. an initial hand height at the start of 10 and 15 in. O_2 cylinders were lifted once every 1, 5, and 480 min.

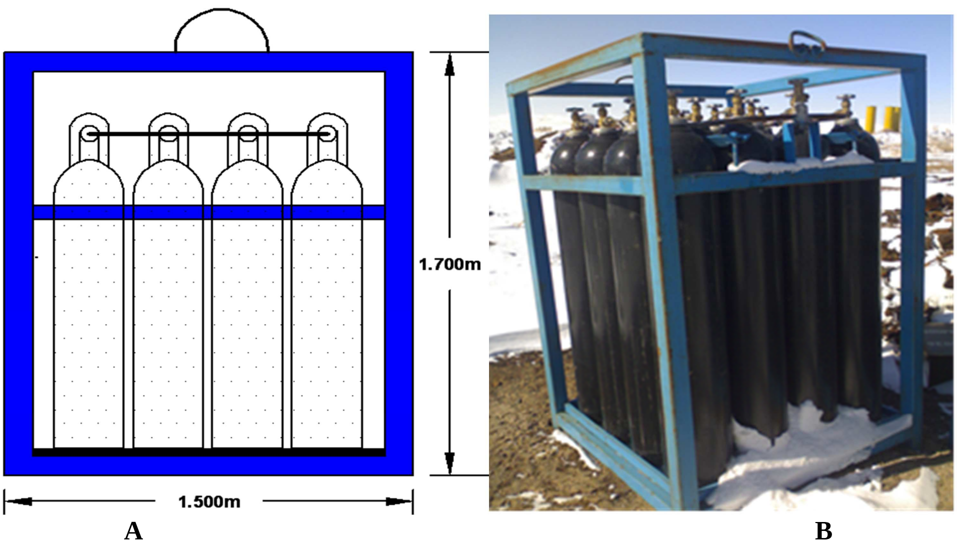

Figure 3. (A) Cylinder box plan. (B) Made cylinder box

Table 1. Musculoskeletal symptoms in various body regions during the 12 months and 1 week before the study

Organs	Musculoskeletal disorders	
	Frequency during the last 1 week (%)	Frequency during the last 12 months (%)
Neck	3 (10.0)	4 (13.0)
Shoulders	5 (16.0)	10 (33.0)
Elbow	1 (3.3)	2 (6.6)
Hand/wrist	1 (3.3)	5 (16.0)
Low Back	10 (33.0)	13 (43.0)
Thigh/hip	0 (0.0)	1 (3.3)
Knee	3 (10.0)	5 (16.0)
Foot	1 (3.3)	3 (10.0)

The percentages of population capable of sustaining the efforts of lifting/lowering were estimated using the software Snook for 30 workers (Table 2).

The results of the carrying O_2 cylinder tasks are presented in table 3.

The percentage male workers able to perform these tasks (lifting, lowering, and carrying of O_2 cylinders) were very low. MAWs and forces were appropriate for < 10% of them.

Maximum hands and lifting/lowering distances were 15 and 20 in., respectively. Most lifting and lowering tasks were performed in the frequency of 1 and 5 min and least of them were performed once every 8 h.

Table 4 contains the population percentage estimated for pushing/pulling O_2 cylinder tasks and maximum acceptable forces of push/pull of the subjects.

Table 2. Population percentage estimated for lifting/lowering O2 cylinder tasks and maximum acceptable lifting/lowering weights for workers (kg)

States	Lifting/lowering						
	Frequency states	Force exertion (kg/p)	Hand distance (cm/in.)	Distance (cm/in.)	Frequency once every	Percentage population	Maximum acceptable weights
1	0.330	(38/84)	(38/15)	(51/20)	1 min	Less than 10	13
2	0.130	(38/84)	(25/10)	(51/20)	1 min	Less than 10	13
3	0.400	(38/84)	(38/15)	(51/20)	5 min	Less than 10	13
4	0.033	(38/84)	(25/10)	(25/10)	5 min	22	14
5	0.066	(38/84)	(25/10)	(25/10)	1 min	17	14
6	0.033	(38/84)	(25/10)	(25/10)	8 h	48	17

Table 3. Population percentage estimated for carrying O2 cylinder tasks and maximum acceptable carrying weights for workers (kg)

Carrying states	Frequency states	Force exertion to carrying (kg/p)	Hand height (cm/in.)	Carrying distance (m/feet)	Frequency one carrying every	Percentage population	Maximum acceptable weights
1	0.86	(70/153)	(84/33)	(4.3/14)	30 s	Less than 10	13
2	0.14	(70/153)	(84/15)	(8.5/28)	1 min	Less than 10	13

Table 4. Population percentage estimated for pushing/pulling O2 cylinder tasks and maximum acceptable forces of push/pull for workers (kg)

Task	States	Frequency states	Initial force (kg/p)	Sustained forces (kg/p)	Hand height (cm/in.)	Frequency one every	Percentage population	Maximum Acceptable (kg)	
								Initial forces	Sustained forces
Pulling	1	0.260	(43/95)	(52/115)	(94/37)	5 min	29	44	36
	2	0.166	(43/95)	(52/115)	(94/37)	1 min	20	43	31
	3	0.500	(43/95)	(52/115)	(94/37)	30 s	Less than 10	44	31
	4	0.080	(43/95)	(52/115)	(94/37)	8 h	60	45	36
Pushing	1	0.944	(46/100)	(53/116)	(145/57)	30 s	17	44	30
	2	0.066	(46/100)	(53/116)	(145/57)	1 min	15	53	36

The results indicated that 84% of workers have experienced musculoskeletal discomfort in the low back, shoulders, hands, and wrists in the year prior to the study. These discomforts were due to extra weight cylinders, forceful exertions and awkward postures during tasks, repetitive and forceful movements, poor workstation design and the MMH tasks. High prevalence of wrist, low back, shoulders, and neck disorders in casting workers in the steel plant have been reported by Armstrong et al.[21]

The results of the assessment of manual handling of O_2 cylinders tasks in the casting workers showed that these tasks were appropriate for < 10%. More than 90% of casting workers confronted with the risk of suffering from MSDs, especially in the low back. About 86% of cylinders lifting/lowering tasks were appropriate for < 10% of workers and MAW for cylinders lifting/lowering was 13 kg, which was more than the recommended limit. The low percentage of workers population in lifting, lowering, and carrying cylinders tasks were due to weight factor. The study of manual material handling assessment by Snook tables in casting workshops in Iran has been studied by Faghih et al. The Snook tables' results indicated that in most of the cases exerted loads exceeded suggested weights.[22] Therefore, the results showed the significant decreases in MAWs with cylinders weight. About 50% of cylinders pulling tasks were appropriate for <10% of workers population and maximum acceptable initial and sustained forces to pull cylinders were 44 and 31 kg, respectively. About 94% of cylinders pushing tasks were appropriate for 17% of workers population and maximum acceptable initial and sustained forces to push them were 43 and 30 kg, respectively. Results of a study on Indian male and female workers showed that the maximum acceptable forces to pull and push agricultural equipment, and loads were high.[12] Cylinders carrying tasks was appropriate for < 1% of workers population and maximum acceptable carrying weights for them was 12 kg.

Hence, ergonomic intervention must be taken to resolve this problem quickly. Ergonomic intervention was based on using the cylinders mechanical handling instead of their individual manual handling. Thus, manual handling of O_2 cylinders was totally excluded by designing and building a box and mechanizing these tasks. One of the limitations of this intervention was high consumption of oxygen that made it impossible to place fewer numbers of cylinders in the box. Before the intervention, the cylinders were placed horizontally on each other and the probability of their falling and colliding was high. Furthermore, cylinders were connected to the oxygen device separately and workers were forced to replace empty cylinders with full cylinders in short intervals. Therefore, probability of human error was high. High opening and closing of cylinders connections increased corrosion and the probability of oxygen leakage. Moreover, opening and closing of cylinders connections with greasy hands increased the risk of an explosion. Therefore, manual handling of cylinders was excluded and all loading, unloading and handling of cylinders tasks were performed by crane. Finally, safety factor and workers safety against the risk of an explosion was increased.

Conclusion

The results showed that in most cases, the MMH tasks were inappropriate for the workers and the high prevalence of MSDs in the working population can be associated with it. Thus, by designing and building a box and mechanizing handling tasks, risk of suffering from MSDs caused by manual handling of O_2 cylinders was removed.

Conflict of Interests

Authors have no conflict of interests.

Acknowledgements

Hereby, the authors thank the Zagroos steel Company for technical support of this study.

References

1. Li KW, Yu RF, Han XL. Physiological and psychophysical responses in handling maximum acceptable weights under different footwear--floor friction conditions. Appl Ergon 2007; 38(3): 259-65.
2. Way Li K, Yu RF, Gao Y, Maikala RV, Tsai HH. Physiological and perceptual responses in male Chinese workers performing combined manual materials handling tasks. International Journal of Industrial Ergonomics 2009; 39(2): 422-7.
3. Sadeghi Naeeni H. Ergonomic principles in the design of transport systems for handheld products. Tehran, Iran: Fanavaran Publication; 2009. [In Persian].
4. Abdoliermeki M. Body mechanics and principles of work station design. Tehran, Iran: Omid Majd Publication; 2000. [In Persian].
5. Division of Workers' Compensation. Manual Material Handling An Ergonomic Approach. Texas, TX: The Texas Department of Insurance, Division of Workers' Compensation; 2004.
6. Ciriello VM, Dempsey PG, Maikala RV, O'Brien NV. Revisited: Comparison of two techniques to establish maximum acceptable forces of dynamic pushing for male industrial workers. International Journal of Industrial Ergonomics 2007; 37(11-12): 877-82.
7. Industrial Accident Prevention Association. Manual Materials Handling. Mississauga, Ontario: IAPA; 2008.
8. Dempsey PG, Maynard W. Manual Materials Handling: Using the Liberty Mutual Tables to Evaluate These Tasks. Professional Safety 2005; 50(5): 20-5.
9. NIOSH. Ergonomic Guidelines for Manual Material Handling the California Department of Industrial Relations [Online]. [cited 2007]; Available from: URL: http://www.dir.ca.gov/dosh/dosh_publications/mmh.pdf
10. Ciriello VM. The effects of box size, vertical distance, and height on lowering tasks. International Journal of Industrial Ergonomics 2001; 28(2): 61-7.
11. National Institute for Occupational Safety and Health. Work practices guide for manual load lifting. Cincinnati, OH: NIOSH; 1981.
12. Tiwari PS, Gite LP, Majumder J, Pharade SC, Singh VV. Push/pull strength of agricultural workers in central India. International Journal of Industrial Ergonomics 2010; 40(1): 1-7.
13. Snook SH. Psychophysical Tables: Lifting, Lowering, Pushing, Pulling, and Carrying. In: Stanton NA, Hedge A, Brookhuis K, Salas E, Hendrick HW, Editors. Handbook of Human Factors and Ergonomics Methods. New York, NY: CRC Press; 2004. p. 128-50.
14. Ciriello VM, Snook SH. Survey of manual handling tasks. International Journal of Industrial Ergonomics 1999; 23: 149-56.
15. Ciriello VM. The effects of box size, frequency and extended horizontal reach on maximum acceptable weights of lifting. International Journal of Industrial Ergonomics 2003; 32(2): 115-20.
16. Ciriello VM. The effects of box size, vertical distance, and height on lowering tasks for female industrial workers. International Journal of Industrial Ergonomics 2005; 35(9): 857-63.
17. Ciriello VM. The effects of container size, frequency and extended horizontal reach on maximum acceptable weights of lifting for female industrial workers. Appl Ergon 2007; 38(1): 1-5.
18. Ciriello VM, Snook SH. A study of size, distance, height, and frequency effects on manual handling tasks. The Journal of the Human Factors and Ergonomics Society 1983; 25(5): 473-83.
19. Gallagher S, Kotowski S, Davis KG, Mark C, Compton CS, Huston RL, et al. External L5-S1 Joint Moments When Lifting Wire Mesh Screen Used to Prevent Rock Falls in Underground Mines. Int J Ind Ergon 2009; 39(5): 828-34.
20. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon 1987; 18(3): 233-7.
21. Armstrong TJ, Marshall MM, Martin BJ, Foulke JA, Grieshaber DC, Malone G. Exposure To forceful exertions and vibration in a foundry. International Journal of Industrial Ergonomics 2002; 30(3): 163-79.
22. Faghih M, Motamedzadeh M, Mohammadi H, Habibi Mohraz M, Bayat H, Arassi M, et al. Assessment of Manual Material Handling by Snook tables in Hamadan casting manufactories. Iran Occup Health 2013; 10(1): 60-9. [In Persian].