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Original Article

Ergonomics Intervention in a Tile Industry: A Case of Manual Material Handling

Ali Dormohammadi (MSc)[a], Hosein Amjad-Sardrudi (MSc)[a], Majid Motamedzade (PhD)[b*], Reza Dormohammadi (BSc)[c], Saeed Musavi (MSc)[d]

[a] Department of Occupational Health, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran
[b] Department of Ergonomics, School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran
[c] Department of Mechanical Engineering, Islamic Azad University Mashhad Branch, Mashhad, Iran
[d] Department of Biostatistics & Epidemiology, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran

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** Correspondence*
Majid Motamedzade (PhD)
Tel: +98 811 8380025
Fax: +98 811 8380509
E-mail: motamedzade@yahoo.com

ABSTRACT

Background: Manual material handling is one of the major health and safety hazards in industry. This study aims to assess the lifting tasks, before and after intervention using NIOSH lifting equation and Manual Handling Assessment Charts (MAC).

Methods: This interventional study was performed in 2011 in a tile manufacturing industry in Hamadan, located in the West of Iran. The prevalence of musculoskeletal discomfort was determined using Nordic musculoskeletal questionnaire. In order to assess the risk factors related to lifting and identify the high-risk activities, MAC and NIOSH lifting equation were used. In intervention phase, we designed a load-carrying cart with shelves capable of moving vertically up and down, similar to scissor lifts. After intervention, the reassessment of risk factors was conducted to determine the success of the intervention and to compare risk levels before and after intervention using t-test.

Results: The outputs of MAC and NIOSH lifting equation assessments before intervention revealed that all activities were at high-risk level. After intervention, the risk level decreased to average level.

Conclusion: In conclusion, the results of intervention revealed a considerable decrease in risk level. It may be concluded that the given intervention was acceptable and favorably effective in preventing musculoskeletal disorders especially low back pain.

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Introduction

Manual material handling particularly lifting is one of the major health and safety hazards in industry[1]. Manual material handling consists of various activities including lifting, lowering, pushing, pulling, and carrying. According to literature, lifting is considered as the most stressful activity in manual material handling and may lead to musculoskeletal disorders among exposed workers and is one of the big concerns in many industries[2-5]. Musculoskeletal disorders is a domain of inflammatory and fatigue (wearing out) condition emerging in the forms of pain, suffering a discomfort in muscles, tendons, ligaments, joints, peripheral nerves, and blood vessels[6,7] and has considerable influence on the quality of life, lost work time, absence, increasing work constraints, changing job and work disability, impose a large number of economic effects on individual, organization, and society[6].

Despite of many work-related diseases which appear in adolescents, middle ages and elderly persons, these disorders emerging mostly in young or healthy workers[8]. In 2001, in Ontario Province, Canada, the insurance cost due to musculoskeletal disorders related to work was almost equal to $ 2500000[9]. One of the most common musculoskeletal disorders caused by manual material handling is work-related low back pain [10-14] which is considered as a high-cost and serious problem prevalent at national and international level. It is believed that over-rotation and repetitive movement of waist during manual material handling raises the hazard of being afflicted by backache significantly in workers[15]. In addition the result of several epidemiologic studies revealed that waist rotation along with bending toward sides and lifting even rather light loads are considered among important risk factors for backache[16]. Manual material handling may also lead to other musculoskeletal problems[15, 17-18] which many biomechanical and psychological studies have confirmed it[17]. Manual material handling is the main reason for damage to workforce in America and 4 out of 5 damages are related to manual material handling[19]. Around 50% of backache is due to lifting, 10% pushing and pulling, and 6% handling[20]. Accident Compensation Corporation

(ACC) statistics from 2003 to 2007 demonstrated that the number of back damages in workplaces increased nearly from 5000 to 6000 and the cost of them from $ 25000000 to $ 30000000[21]. Therefore, the cost of manual material handling is considered the most important source of compensations at work[22].

In order to prevent back disorders related to high risk manual handling activities, attempts to control these disorders should focus on assessing and redesigning the tasks of manual material handling and equipment used[23-24]. As in industrially developing countries like Iran, the problem of musculoskeletal disorders related to manual material handling are extremely serious and the working conditions are not so good and are different from developed countries, also reported studies reflecting the situation are sparse in this issue; this publication seeks to fill this research gap. This study aims to ergonomically assess the lifting tasks, before and after intervention using NIOSH lifting equation[25] and Manual Handling Assessment Charts (MAC)[26].

Methods

The present interventional study was performed in 2011. The population under study was workers from a tile manufacturing industry in Hamadan, located in the West of Iran. In this study all workers were male and the criterion to enter the study was lifting load alone. The prevalence of musculoskeletal discomfort of workers in all departments was determined using Nordic musculoskeletal questionnaire[27]. In order to assess the risk factors related to lifting and identify the high-risk jobs, MAC method and NIOSH lifting equation were used. Based on assessment conducted using NIOSH lifting equation and MAC method before intervention, the root cause of the outbreak of the musculoskeletal complaints in sanding, glazing, furnace, and packing units compared to molding and foundry units was attributed to using load-carrying carts with fixed shelves because the workers should do lifting tile products from the four fixed shelves of the carts 300 to 350 times per shift. For the purpose of selecting appropriate intervention toward economic and environmental conditions of this company, we designed a load-carrying cart with shelves capable of moving vertically up and down, similar to scissor lifts. Regarding its rising mechanism, pneumatic and spring ones were studied and finally spring technology selected. One of the main reasons for this selection was more cost-benefit in comparison with hydraulic and pneumatic technologies. The cart designed in such a way that while the shelves were empty, the first shelf (from bottom) was at the ergonomic height of 105 cm, according to Pheasant 1998,[28] and when four pieces of product were loaded on the first shelf, the springs shortened by 40 cm and as a result, the second shelf placed at the ergonomic height of 105 cm automatically. When the first shelf was full, the second shelf was at the height of 105 cm and the user could load four pieces of product on the second shelf in such a way that no displacement or movement occurred, and the springs could not accumulate because an stopper have been applied inside of it to prevent from shortening of the springs. Figure 1 shows an illustration from designed ergonomic load-carrying cart.

For better understanding of the designed cart mechanism, the readers may refer to Figure 2. Figure 1 shows the empty cart. In this condition, the working bench height at first shelf of the cart is 105 cm from floor. Figure 2 shows that four pieces of product are loaded on the first shelf and the working bench height at second shelf of the cart is 105 cm from floor. As springs have stopper, loading another four pieces of product in second shelf in Figure 2 will not change the cart height.

Figure 1: An illustration from designed ergonomic load-carrying cart

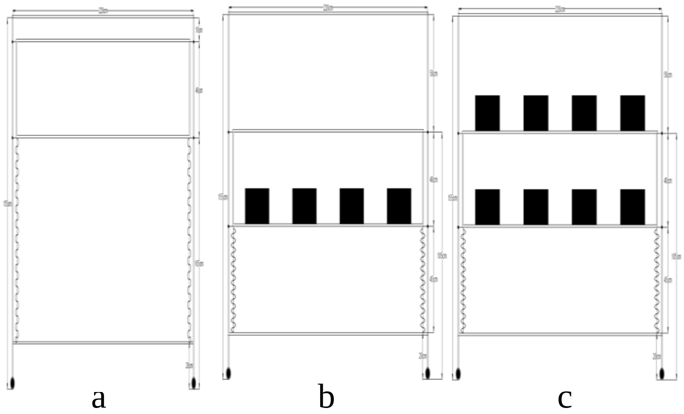

Figure 2: A graphical presentation of designed cart. a: empty, b:one shelf loaded, c: two shelves loaded

After designing the ergonomic cart (ergonomic intervention), the reassessment of risk factors was conducted in sanding, glazing, furnace, and packing units in order to determine the efficiency of the intervention, in other words, to compare the amount of risk before and after intervention using *t*-test.

Results

The numbers of manual material handling workers working in under study tile manufacturing in Hamadan were 30 married men. The results of demographic characteristics analysis of workers revealed that the mean and standard deviation of age (in year) was equal to 34.87±8.44, weight (kg) was 65.50±10.35, height (cm) was 171.1±8.05 and work history (yr) was 5.10±2.51. Results of *t*-test demonstrated that the risk levels before and after intervention were significant) $P< 0.001$), that is, intervention was significantly effective in lowering the risk. The results of analysis before and after intervention by two methods MAC and NIOSH lifting equation are presented in Table 1 and 2.

Table 1: Comparison of load-lifting tasks assessments before and after intervention using NIOSH lifting equation

Type of assessment method			NIOSH					
Time of assessment			Before intervention			After intervention		
Modification action limit			LI≤1	3>LI>1	LI≥3	LI≤1	3>LI>1	LI≥3
Risk level			Low (1)	Average (2)	High (3)	Low (1)	Average (2)	High (3)
Unit	Sanding	Toilet bowl	-	-	4.34	-	1.40	-
		Wash-stand	-	-	4.05	-	1.40	-
		Wash-base	-	-	4.12	-	1.40	-
	Glazing	Toilet bowl	-	-	4.41	-	1.51	-
		Wash-stand	-	-	4.06	-	1.51	-
		Wash-base	-	-	3.95	-	1.51	-
	Furnace	Toilet bowl	-	-	4.48	-	1.55	-
		Wash-stand	-	-	4.13	-	1.55	-
		Wash-base	-	-	4.02	-	1.55	-
	Packing	Toilet bowl	-	-	5.55	-	1.84	-
		Wash-stand	-	-	5.11	-	1.84	-
		Wash-base	-	-	4.97	-	1.84	-

Table 2: Comparison of load-lifting tasks assessments before and after intervention using MAC method

Type of assessment method			MAC							
Time of assessment			Before intervention				After intervention			
Modification action limit			0≤MAC≤4	5≤MAC≤12	13≤MAC≤20	21≤MAC≤31	0≤MAC≤4	5≤MAC≤12	13≤MAC≤20	21≤MAC≤31
Risk level			Low (1)	Average (2)	High (3)	Very high (4)	Low (1)	Average (2)	High (3)	Very high (4)
Unit	Sanding	Toilet bowl	-	-	14	-	4	-	-	-
		Wash-stand	-	-	14	-	4	-	-	-
		Wash-base	-	-	15	-	4	-	-	-
	Glazing	Toilet bowl	-	-	18	-	-	8	-	-
		Wash-stand	-	-	18	-	-	8	-	-
		Wash-base	-	-	19	-	-	8	-	-
	Furnace	Toilet bowl	-	-	18	-	-	8	-	-
		Wash-stand	-	-	18	-	-	8	-	-
		Wash-base	-	-	19	-	-	8	-	-
	packing	Toilet bowl	-	-	18	-	-	8	-	-
		Wash-stand	-	-	18	-	-	8	-	-
		Wash-base	-	-	19	-	-	8	-	-

Discussion

The results of MAC method and NIOSH lifting equation assessment before intervention revealed that sanding, glazing, furnace and packing units had a high-risk level. The reason for the high risk level in these units was that individuals should do lifting loads from the four fixed shelves of material handling carts and as these four shelves were at different and non-ergonomic heights (21, 69, 115, 166 cm), thus workers imposed inappropriate postures so as to be able to lift loads from above-mentioned heights or put loads on. As a result, to reduce the risk levels and to reduce the musculoskeletal disorders rate, a material handling cart with shelves capable of dynamic vertical movement was designed and tested. It should be noted that this cart was economic and its testing result based on designing computation proved to be a success.

The NIOSH lifting equation assessment result after engineering ergonomic intervention revealed that (Table 1) risk levels in all units, that is, sanding, glazing, furnace and packing ones, declined from high risk (level 3) to average risk (level 2).

The result of MAC method assessment after engineering ergonomic intervention also demonstrated (Table 2) that the risk levels of load lifting in sanding unit reduced from high (level 3) to low (level 1) and the risk levels for load lifting in glazing, furnace and packing units reduced from high risk (level 3) to average risk (level 2). The general results of present study showed that designing a new cart with the capability of vertical dynamic movement as an engineering ergonomic intervention reduced the risk level of load lifting significantly in all units (P<0.001), resulting in a decrease in the risk of being afflicted by musculoskeletal disorders especially reducing damages to waist or back. The result of Snook study revealed that one way to reduce the back inabilities related with work is to design workplace ergonomically[29]. In 2010, Hess et al.[30] studied the effect of different kinds of lifting-tools and handling wooden boards on back and concluded that lifting wooden boards by two people using J-handle reduces the risk of backache and this point indicates that ergonomic designing of load-lifting tools and manual material handing has an important role in reducing musculoskeletal risks especially backache risk. Hess et al.[31] designed skid plates for easier movement of concrete injection hose on steel bars and the results after intervention showed significant reduction in low back disorders.

The main focus of present study and above studies are on the engineering ergonomic intervention toward reducing musculoskeletal disorders caused by load-lifting and manual material handling. The results of the present study were congruent with those of above-mentioned studies. In addition to engineering ergonomic intervention, managerial and environmental interventions also play an important role in reducing the risk level of being afflicted by musculoskeletal disorders and backache damages. For this reason, in addition to engineering intervention, this study made recommendations regarding environmental interventions such as installing local and public ventilation, leveling floor surface, increasing the light of the environment and managerial interventions including education and forcing work and leisure time which in case of meeting above-mentioned criteria, the risk level of affliction by musculoskeletal and backache would reduce. The results after ergonomic intervention plans by Poosanthanasarn et al.[32] revealed that the mean score of general discomfort of body and waist muscular discomfort was decreased significantly and the distribution rate of damages was 65.46%, the intensity rate of damages 41.2% and medical costs 42.79% and a significant reduction was observed in muscular load of back. The study by Verbeek et al.[33] also showed the preventive influence of education on back pains caused by manual material handling. Multi-component intervention such as purchasing elevator and appropriate transportation equipment for the purpose of reducing biomechanical incidents and conducting educational programs toward correct handling of load and right application of the equipment together will decrease musculoskeletal damages significantly[34]. One of the important aspects in the discussion of damages related to manual handling of material is the costs caused directly by them. Ergonomic interventions play a significant role in reducing direct costs due to manual handling of material[34,35]. An advantage of ergonomic intervention is the reduction in the rate of protection paid to workers[36].

Conclusion

The results of intervention revealed a considerable decrease in risk level and it may be concluded that the given intervention was acceptable and favorably effective in preventing musculoskeletal disorders specially backache.

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Conflict of interest statement

Authors have no conflicts of interest.

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References

1. Lin CJ, Wang SJ, Chen HJ. A Field Evaluation Method for assessing whole body biomechanical joint stress in manual lifting tasks. *Ind Health*. 2006;44(4):604-612.
2. Faber GS, Kingma I, Bakker AJ, van Dieën JH. Low-back loading in lifting two loads beside the body compared to lifting one load in front of the body. *J Biomech*. 2009;42(1):35-41.
3. Mital A, Ramakrishnan A. A comparison of literature-based design recommendations and experimental capability data for a complex manual materials handling activity. *Int J Ind Ergon*. 1999;24:73-80.
4. Straker L. *A Critical Appraisal of Manual Handling Risk. Assessment Literature*. Louisville: The International Ergonomics Association Press; 1997.
5. Andersson ER. Economic evaluation of ergonomic solutions: part I-guidelines for the practitioner. *Int J Ind Ergon*. 1992;10:161-171.
6. Tinubu BM, Mbada CE, Oyeyemi AL, Fabunmi AA. Work-related musculoskeletal disorders among nurses in Ibadan, South-west Nigeria: a cross-sectional survey. *BMC Musculoskelet Disord*. 2010;11:12.
7. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J Electromyogr Kinesiol*. 2004;14(1):13-23.
8. Waters TR, Putz-Anderson V, Baron S. Methods for assessing the physical demands of manual lifting: a review and case study from warehousing. *Am Ind Hyg Assoc J*. 1998;59(12):871-881.
9. Workers Safety and Insurance Board. *Annual Report*. Toronto: WSIB; 2001.
10. Kao HW, Yu DS, Wu CJ, Lai CC, Lee MS, Lo CP, et al. Work-related musculoskeletal disorders among medical staff in a radiology department. *J Med Sci*. 2009;29(3):119-124.
11. Reid CR, McCauley Bush P, Karwowski W, Durrani SK. Occupational postural activity and lower extremity discomfort: A review. *Int J Ind Ergon*. 2010; 40(3):247-256.
12. Kuiper JI, Burdorf A, Verbeek JHAM, Frings-Dresen MHW, Beek AJ, Viikari-Juntura ERA. Epidemiologic evidence on manual materials handling as a risk factor for back disorders: a systematic review. *Int J Ind Ergon*. 1999;24:389-404.
13. Lei L, Dempsey P, Xu J, Ge L, Liang Y. Risk factors for the prevalence of musculoskeletal disorders among Chinese foundry workers. *Int J Ind Ergon*. 2004;35:197-204.
14. Broniecki M, Esterman A, May E, Grantham H. Musculoskeletal disorder prevalence and risk factors in ambulance officers. *J Back Musculoskelet Rehabil*. 2010;23(4):165-174.
15. Trevelyan FC, Legg SJ. Back pain in school children—Where to from here? *Appl Ergon*. 2006;37(1):45-54.
16. Plouvier S, Gourmelen J, Chastang JF, Lanoë JL, Leclerc A. Low back pain around retirement age and physical occupational exposure during working life. *BMC Public Health*. 2011;11:268.
17. Punnett L, Fine LJ, Keyserling WM, Herrin GD, Chaffin DB. Back disorders and non neutral trunk postures of automobile assembly workers. *Scand J Work Environ Health*. 1991;17(5):337-346.
18. Kuiper JI, Burdorf A, Verbeek JHAM, Frings-Dresen MHW, Beek AJ, Viikari-Juntura ERA. Epidemiologic evidence on manual materials handling as a risk factor for back disorders: a systematic review. *Int J Ind Ergon*. 1999;24:389-404.
19. Heran-Le Roy O, Niedhammer I, Sandret N, Leclerc A. Manual materials handling and related occupational hazards: a national survey in France. *Int J Ind Ergon*. 1999;24:365-377.
20. U.S. Department of Labor, Occupational Safety and Health Administration. *OSHA Technical Manual*. Washington; 2011 [cited 17 December, 2011]; Available from: http://www.osha.gov/dts/osta/otm/otm_vii/otm_vii_1.html
21. Stephen BA. A guide to manual materials handling and back safety. NC Department of Labor Occupational Safety and Health Di-

vision; 2009.

22. Grimes PH. Case Study: Ambulance paramedic low back injury and workplace rehabilitation. OHSIG Web Site; 2012 [cited 17 December, 2011]; Available from: http://www.ohsig.org.nz/documents/library/OHSIG%20Case%20 Study.pdf

23. Patrick GD. Utilizing criteria for assessing multiple-task manual materials handling jobs. *Int J Ind Ergon*. 1999;24:405-416.

24. Vincent MC, Stover HS, Lobat H, John C. Distributions of manual materials handling task parameters. *Int J Ind Ergon*. 1999;24:379-388.

25. Waters TR, Putz-Anderson V, Garg A. Applications manual for the revised NIOSH lifting equation. Cincinnati: National Institute for Occupational Safety and Health; 1994.

26. Monnington SC, Pinder AD, Quarrie C. Development of an inspection tool for manual handling risk assessment. HSE Web Site; 2002. [cited 17 December, 2011]; Available from: http://www.hse.gov.uk/research/hsl_pdf/2002/hsl02-30.pdf

27. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon*. 1987;18(3):233-237.

28. Pheasant S. Bodyspace. Anthropometry, Ergonomics and the Design of Work, 2nd Ed, London: Taylor & Francis, 1998.

29. Snook SH. Work-related low back pain: secondary intervention. *J Electromyogr Kinesiol*. 2004;14(1):153-160.

30. Hess JA, Kincl LD, Davis K. The impact of drywall handling tools on the low back. *Appl Ergon*. 2010;41(2):305-312.

31. Hess JA, Hecker S, Weinstein M, Lunger M. A participatory ergonomics intervention to reduce risk factors for low-back disorders in concrete laborers. *Appl Ergon*. 2004;35(5):427-441.

32. Poosanthanasarn N, Lohachit C, Fungladda W, Sriboorapa S, Pulkate C. An ergonomics intervention program to prevent worker injuries a metal autoparts factory. *Southeast Asian J Trop Med Publ Health*. 2005;36(2):512-522.

33. Verbeek JH, Martimo KP, Karppinen J, Kuijer PP, Viikari-Juntura E, Takala EP. Manual material handling advice and assistive devices for preventing and treating back pain in workers. *Cochrane Database Syst Rev*. 2011;(6):CD005958.

34. Tullar JM, Brewer S, Amick BC, Irvin E, Mahood Q, Pompeii LA, Wang A, Van Eerd D, Gimeno D, Evanoff B. Occupational safety and health interventions to reduce musculoskeletal symptoms in the health care sector. *J Occup Rehabil*. 2010;20(2):199-219.

35. Chhokar R, Engst C, Miller A, Robinson D, Tate RB, Yassi A. The three-year economic benefits of a ceiling lift intervention aimed to reduce healthcare worker injuries. *Appl Ergon*. 2005;36(2):223-239.

36. Goggins RW, Spielholz P, Nothstein GL. Estimating the effectiveness of ergonomics interventions through case studies: Implications for predictive cost-benefit analysis. *J Safety Res*. 2008;39(3):339-344.