Original Article:

The effect of increased manufacturing rate on risk of low back pain

Saeid Ahmadi[1], Sajad Zare[2*], Reza Ghanbari[3], Sahar Bahrami[1], Vida Zaroushani[1]

[1]Department of Occupational Health, School of Public Health, Qazvin University of Medical Sciences, Qazvin, Iran
[2]Department of Occupational Health, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran
[3]Department of Environmental Health Engineering, School of Public Health, Qazvin University of Medical Sciences, Qazvin, Iran

[*]Corresponding Author: email address:ss_zare87@yahoo.com (S. ZARE)

ABSTRACT

Increasing production rate in manual handling jobs can expose workers to the risk of low back pain (LBP); thus, it is necessary to investigate the relationship between manufacturing rate and the risk of the LBP in order to prevent workers from being injured. The current study was aimed to survey the effect of increased manufacturing on the risk of the LBP. This cross-sectional descriptive study was conducted in a melting and casting factory in Qazvin in 2015. The target population included seven workers with different occupational tasks. Working steps included data collection (filming, site visit and interview), classification of the occupation to tasks and subtasks, and finally analysis of manual material handling tasks by the revised NIOSH equation. The composite lifting index (CLI), frequency-independent lifting index (FILI), and single-task lifting index (STLI) of each occupation were analyzed and calculated using the manual material handling instructions of the American Institute for Occupational Safety and Health. The STLI was assessed in all the unauthorized jobs. In most of the analyzed tasks, the FILI had no significant difference with the STLI. The horizontal distance factor (HM=0.5) had much more effect on the risk of the LBP, compared with the frequency factor (FM=0.86). The tasks of alloy ingot loading in *melting and ingot* job and lifting from the highest pallet row to the visiting table in *visiting test* job acquired the highest (STLI=3.80) and lowest (STLI=0.96) STLI values, respectively. The maximum CLI was calculated for decorating and grinding job (CLI=4.96). Increased manufacturing was associated with the concept of increased lifting frequency. Accordingly, the investigations showed that lifting frequency had no role in developing the LBP, and the most critical effective parameter was the horizontal factor. By correcting the horizontal factor through education and elimination of the non-ergonomic handling habits, the risk of the LBP could be considerably reduced.

Keywords: Manual material handling; Composite lifting index; Risk of low back pain; Lifting frequency

INTRODUCTION

In common manufacturing industries, the human still plays a critical role in performing activities. The use of manual handling, due to human's high adaptability and relatively low operation cost, is more than that of machines [1]. The increasing progress of technology in the work environment has never been able to make the workplace needless of manual handling tasks. Due to the growing demand of industries for handling raw materials and portable products, manual handling can be considered as one of the most common industrial tasks, referring to lifting, lowering, pushing, and carrying with hands or body force [2]. Manual handling in industrial environments has caused great concern among industrial hygienists who are trying to reduce damages. The tasks requiring cumbersome and continuous lifting increase the risk of low back pain (LBP) and musculoskeletal diseases. The musculoskeletal diseases are injuries or agonies afflicting the joints, ligaments, muscles, nerves, tendons, and structures that support the organs, neck, and waist in the body [3]. In Europe, according to the instruction EEC 90/266, reducing the manual handling risks and training are among the commitments of employers [4]. The research by Abdillah et al. showed that prevalence of the musculoskeletal incidence was 52%, 13%, 10%, 13%, and 12% in lifting, pushing or pulling, carrying, repetitive movements, and other activities, respectively [5]. Since the manual handling tasks usually consume an enormous amount of time, work-related LBP has been recognized as the main work-related health challenge affecting the quality of life (QoL) of people in the United States [6]. The low back injuries are regarded as major problems in terms of the pain afflicting the human body and compensation costs of workers [7]. The LBP is a major public health problem with significant impact on workers [8]. Adults experience the LBP at least once in their lives [9]. One of the most common reasons for visits to doctors in developed countries is the LBP. Chronic LBPs affect the activities at home and workplace and result in an enormous economic burden [10]. Performing manual handling activities frequently or for a long period intensifies the LBP [1]. Several studies have demonstrated that various aspects of a job such as physical characteristics, lifestyle, and psychosocial factors might affect the development of the LBP. It has also been shown that the ergonomic risk factors are the main cause of low back injuries [9, 11].

The data obtained by Sheahan et al. showed that frequent, short, and standing rest might help to reduce the symptoms of LBP; however, these are merely temporary solutions [12]. Santos et al. investigated the relationship between job rotation, working speed, and muscular fatigue of the upper limbs in repetitive tasks. The study yielded no consistent results regarding the effect of job rotation on muscular activities however, the increase in working speed caused higher muscular load in certain muscles [13]. The present study was conducted in a melting and casting factory manufacturing various car cylinders in Qazvin. According to the statements of industrial hygiene experts involved in this industry and the available medical records, the LBP is very prevalent in this industry. Despite the current conditions, the production managers decided to increase the manufacturing rate; accordingly, they planned to reduce the manufacturing time of each component so that they can require the workers to manufacture a greater number of components in the entire working shift. In the current study, there were jobs which had several manual material handlings. Increasing manufacturing rates means more frequent manual material handlings, which can be the main factor in increasing the LBP. Thus, with regard to these explanations, the present study was aimed to investigate the relationship between the number of manufactured components, manufacturing time, and risk of manual handling. Evaluation of the manual handling risk is commonly performed using various methods such as snook tables, manual handling assessment charts, revised NIOSH lifting equation, psychophysical capacity data, and so on. In this study, the revised NIOSH lifting equation was used to evaluate manual handling. In a survey, Varmaziar et al. examined three palletizer operators to determine the weight limit in manual handling in batching lines in a factory in Qazvin. The results in their study showed that the minimum value of the lifting index (LI) was at the point, the horizontal lifting distance of which was less than that of other points [14]. Yet, another study was conducted by Faqih et al. on 50 workers using snook tables to evaluate manual handling in a casting factory in Hamadan. As shown by the results, the maximum load lowering weight was affected by the horizontal distance from body and thermal stress rather than by the lowering height; further, reduction of the weight limit in some tasks was caused by their high frequency during the working shift [2]. Cirillo (2003) conducted a study on eight male industrial workers in 15 various lifting tasks. The obtained results showed that frequency significantly affected the maximum acceptable load [15]. Moreover, Afshari et al. conducted a research to evaluate the complex LI in Ahvaz soft drink industry. The results revealed that the frequency-independent load weight limit for each class was higher than the FIRWA load weight, and the frequency-independent load lifting index was smaller than one (FILI<1). Furthermore, the results showed that by ignoring the lifting frequency, no worker would undergo physical stress during load lifting [16]. In Waters et al.'s study conducted on the accuracy of measurement of the revised NIOSH equation, the horizontal distance was the most important parameter [17]. Maria conducted a research in a spare car parts manufacturing company on lifting and lowering steel sheets in order to attain a better understanding of the revised NIOSH equation. In Maria's research, the LI in origin and destination was higher than 1, and the effective parameters were the horizontal distance and elbow angle [18]. Chang's study was conducted in a refractory brick production company with a high prevalence of low back injuries to analyze lifting tasks using the revised NIOSH lifting equation. According to the obtained results, in the majority of the tasks, the lifting weight was recommended to be higher than the weight limit [19].]. All in all, concerning previous studies, it appears that the horizontal distance in manual handling is a more efficient parameter in determining the composite lifting index (CLI). The aim and novelty of this study were to investigate the relationship between increasing production and its effect on the LBP risk in manual handling tasks in a melting and casting factory.

MATERIALS AND METHODS

This cross-sectional descriptive study was conducted in a casting factory manufacturing various car cylinders in Qazvin in 2015. The target population of the research included seven workers employed at different sections of the factory. Data collection was in accordance with the ethical committee of the Qazvin university of medical science, Qazvin, Iran. Ethics approval was made for this research. Most of the workers were committed to producing different numbers of components during a working shift. In order to produce each component in various occupations, a certain working cycle was determined, and the number of components to be generated by these workers was selected based on the 8-hour working shift and the shift duration. Handling the components (spare parts), repeating the movements, applying force, and various working postures are a major part of each working cycle. The jobs evaluated in this study included decorating and grinding, shot blasting, ingot and melting, cutting, testing and visiting, bearing cap, and mould changing. These jobs were selected according to the HSE expert and the high risk of exposure to musculoskeletal diseases. The working steps in this study included: 1) field visit of the factory and data collection through the films (photography), observations, and interviews with workers and supervisors; 2) classification of the occupations to tasks, sub-tasks, activities, and movements; and 3) analysis of manual material handling using the revised NIOSH equation. To analyze manual material handling using the revised NIOSH equation, first, the numerical values of H (horizontal distance of load between ankle and hands), V (vertical distance between hands and ground), D (vertical distance from the start to the end of the displacement distance), A (asymmetric angle or angle factor between the midpoint of ankles and midpoint of hands), F (lifting frequency [the average repetition of lifting per minute in the entire process of lifting]; this factor is calculated considering the lifting duration) and C (coefficient of coupling of hands and load), as well as the load weight in each task were measured. Then, their coefficients were extracted from the relevant tables. Subsequently, in the next step, the frequency-independent recommended weight index (FIRW), single-task recommended weight limit (STRWL), frequency-independent lifting index (FILI), and single task lifting index (STLI) were calculated according to the following equations. Finally, for occupations with multiple lifting tasks, the NIOSH CLI was calculated. The CLI is shown considering the set of calculated lifting tasks and the combined effect of all the lifting tasks. The index is determined by adding up the highest STLI of each occupation and the FILI per task.

Formula1: $FIRWL = 23 \times HM \times VM \times DM \times AM \times CM$

Formula2: $\mathrm{STRWL} = \mathrm{FIRWL} \times \mathrm{FM}$

Formula3: $\mathrm{FILI} = \mathrm{L} \div \mathrm{FIRWL}$

Formula4: $\mathrm{STLI} = \mathrm{L} \div \mathrm{STRWL}$

Formula5: $\mathrm{CLI} = \mathrm{STLI}_1 + \Delta\mathrm{FILI}_2 + \Delta\mathrm{FILI}_3 + \Delta\mathrm{FILI}_4 + \cdots$

RESULTS

The present study was conducted in a head cylinder melting and casting factory on seven occupations with 22 occupational tasks of manual material handling. Table (1) shows job characteristics and lifting indices in various occupations including occupation titles, total production, lifting tasks, load weight, FILI, single-task lifting index (STLI) and STRWL. The FILI in all the analyzed jobs (except for the lifting task from the highest pallet row to the visiting table in the visiting test job) was calculated as equal to or higher than 1. Moreover, the results showed that the load weight was at an ideal and permitted level only in the visiting test job (the task of lifting from the highest pallet row to the visiting table). In most of the analyzed occupational duties, there were no significant difference between the FILI and STLI. The variables affecting lifting (CM, AM, DM, VM, HM) and the average values of them are shown in Table (2). According to this table, HM and DM obtained the lowest and highest mean values of 0.51 and 0.93, respectively.

Moreover, the CLI and maximum single task lifting index values in the occupation are shown in table (3). Investigating the CLI in the analyzed occupations revealed that the decorating and grinding job with the CLI of 4.96 as well as the deburring and grinding with the CLI of 2.16 had the highest and lowest index values, respectively (Table-3).

Table 1. Job characteristics and lifting indices in various occupations

No.	Occupation	Total production, components /shift	Lifting tasks	Weight of the load, Kg	FILI	STLI	STRWL
1	Decorating and grinding	250	1.1. Lifting Pride and Nissan components from the conveyor belt to the decorating table	12	2.06	2.55	4.70
			1.2. Lifting Paykan components from the conveyor belt to the pallet	10	2.01	2.48	4.03
			1.3. Lifting components from the decorating table to the decorating machine	12	1.51	1.86	6.43
			1.4. Lifting components from the decorating machine to the decorating table	12	1.67	2.07	5.79
			1.5. Lifting components from the decorating table to the grinding table	12	1.20	1.49	8.04
			1.6. Manual handling and displacement of components from the grinding table to the pallet	12	1.71	2.12	5.66
2	Shot blasting	650	2.1. Lifting cylinders from the pallet to the universal joint, origin	11	1.96	2.11	5.20
			2.2. Lifting shot blasted cylinders from the universal joint to the origin table	11	2.14	2.49	4.41
			2.3. Lifting cylinders from the table to the highest pallet row	11	1.57	1.69	6.98
			2.4. Lifting cylinders from the table to the lowest pallet row	11	1.67	1.67	6.58
3	Ingot melting	352	3.1. Loading aluminum ingot to the highest row	23	3.02	3.02	7.60
			3.2. Loading aluminum ingot to the lowest row	23	2.30	2.30	9.60
			3.3. Loading alloy ingot	23	3.80	3.80	5.91
4	Cutting	650	4.1. Lifting components from the pallet to the edge of the saw on the ground (8 rows, 8 tasks)	11	2.6	3.17	5.70
			4.2. Lifting components from the ground to the saw table	11	1.97	2.68	4.10
			4.3. Lifting the components cut by the saw	11	1.54	1.81	6.06
5	Visiting test	400	5.1. Lifting components from the lowest pallet row to the visiting table	11	1.75	2.060	5.32
			5.2. Lifting from the highest pallet row to the visiting table	11	0.82	0.96	11.39
			5.3. Lifting components from the visiting table to the leakage table	11	1.38	1.73	6.35
6	Bearing cap	245	10.1. Lifting ladle filled with molten from cauldron to machine	7	1.21	1.49	4.67
7	Template changing	1	11.1. Manual handling of Paykan template (mould)	43	3.58	3.58	12.10
			11.2. Manual handling of side template	60	3.40	3.40	17.6

Table 2. Average of the variables affecting lifting

Occupation	HM	FM	VM	DM	AM	CM
Decorating and grinding	0.45	0.81	0.85	0.92	0.91	0.90
Shot blasting	0.43	0.93	0.79	0.91	0.93	0.90
Ingot and melting forge	0.49	1	0.84	0.93	0.85	0.97
Cutting	0.45	0.80	0.84	0.92	0.86	0.90
Visiting	0.56	0.82	0.89	0.94	1	0.90
Bearing cap	0.40	0.81	0.90	0.90	0.86	0.90
Template (mould) changing	0.81	1	0.82	1	1	0.92
Mean	0.51	0.88	0.58	0.93	1	0.91

HM: Horizontal multiplier, FM: Frequency multiplier, VM: Vertical multiplier, DM: Distance multiplier, AM: Asymmetric multiplier, CM: Coupling multiplier

Table 3. Composite lifting index and maximum single task lifting index values in the occupations

No.	Occupation	CLI	STLI max
1	Decorating and grinding	4.96	2.55
2	Shot blasting	2.66	2.49
3	Ingot & melting forge operator	3.88	3.80
4	Cutting	3.73	3.17
5	Visiting	2.46	2.06
6	Bearing cap	_	1.49
7	Template (mould) changing	3.58	3.58

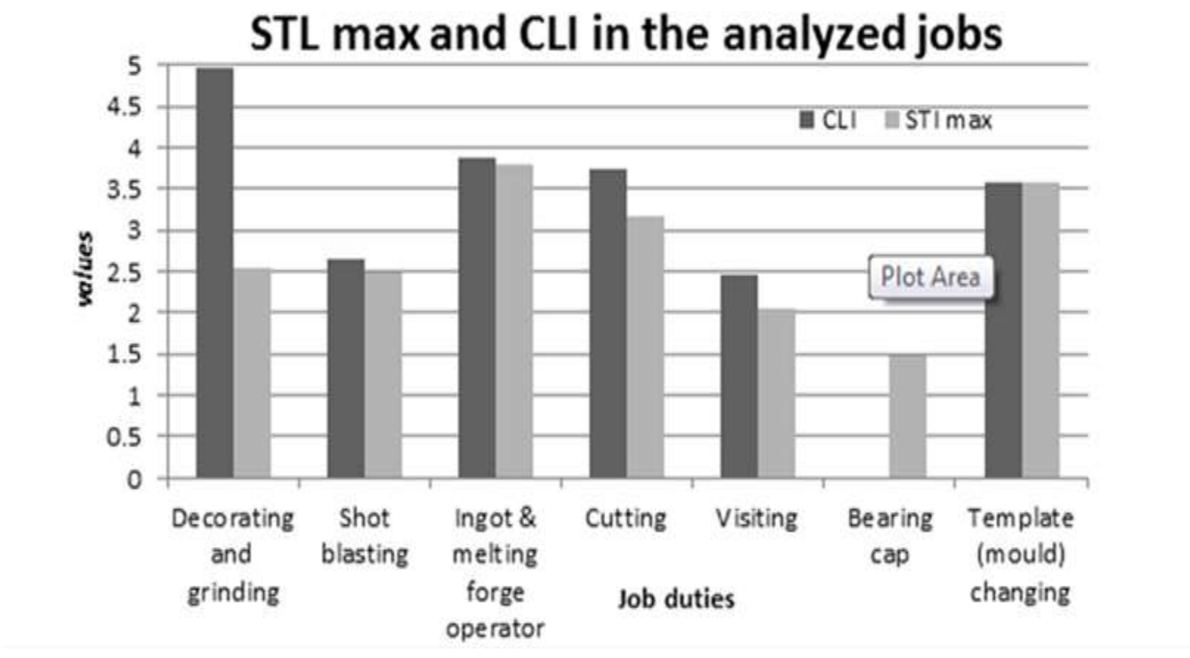

Figure 1. STL $_{max}$ and CLI in the analyzed job

DISCUSSION

In the present study, the number of lifted components in each task did not solely lead to the risk of LBP**.** The horizontal factor, compared to the other effective parameters, had the highest effect on the LI in the occupations**.** The FILI was calculated to be higher than one in all the tasks except for the task (2) (lifting from the highest row pallet to the visiting table) of the visiting test job. The index showed that the lifting frequency or the number of lifted components in each task did not solely lead to the risk of LBP. However, Afshari et al. calculated the FILI to be lower than 1 (1> FILI). The present study, in contrast to Afshari's, showed that disregarding the lifting frequency would lead to the risk of LBP (Table-1) [16]. According to the results, in all the tasks except for the task (2) (lifting from the highest pallet row to the visiting test) of the visiting test job, the load weight was much higher than the recommended weight limit. In Faqih et al.'s study, the findings of the Snook tables indicated a significant difference between the weight limit and applied weight ($P <0.05$); accordingly, in most of the cases, the applied weight was higher than the recommended weight [2]. Similarly, in Chang's study, the load weight was higher than the recommended weight limit in most of the cases [19]. Our study was consistent with the studies of Faqih and Chang. Thus, it is concluded that the load weight should be reduced (Table-1). In most of the tasks, there was no significant difference between the FILI and STLI, indicating that the lifting frequency could not be an effective factor. According to Table (2), HM and DM with values of 0.51 and 0.93 had the lowest and highest mean values, respectively. The horizontal factor, compared to other effective parameters, had the most significant effect on the LI in the occupations (Table-2). According to Varmaziar et al., the lowest LI value was at the point with lower horizontal lifting distance H compared to the other points. In Waters' study, the horizontal distance was the most critical parameter; thus, our study is consistent with the studies of Varmaziar and Waters (Table-2) [14.17]. In Maria's study, the LI in origin and destination was higher than 1, and the effective parameters were the horizontal distance and elbow angle. In the present study, similar to Maria's research, the horizontal distance was an effective factor while, in contrast, the elbow angle was an ineffective parameter. Investigating the CLI in the analyzed occupations showed that the decorating and grinding job with the CLI of 4.96 and deburring and grinding job with the CLI of 2.16 had the highest and lowest indices, respectively. Since the CLI results from the effect of the number of lifting tasks in the maximum STLI, the significant difference between the two indices in decorating and grinding job indicated that multiple lifting tasks in this occupation were a critical factor and this job should be performed by various people. Furthermore, the FILI was calculated to be higher than 1 in all the occupation tasks, indicating that frequency had no effect on the risk of LBP. Thus, the high value of the CLI in this occupation was due to a significant number of lifting tasks, but not the frequency (Table-3).

CONCLUSION

In conclusion, the present study showed that the frequency of lifting was not a factor affecting the LBP, and the influential factors included the horizontal distance, non-ergonomic lifting habits, and lack of training.

"The authors declare no conflict of interest"

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