Workstation Evaluation Regarding Ergonomic Awareness and Work-Related Musculoskeletal Disorders Among Coal Mine Workers

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Abstract-Mining is often associated with the risk of Work-Related Musculoskeletal Disorders (WRMSDs). Despite being a coal-rich country, Pakistan's mining sector stays behind in terms of occupational health and safety. Only a few research studies have been conducted on ergonomics in the mining industry. The current study aimed at evaluating workstations for WRMSDs and ergonomic factors among coal mine workers. Survey data were gathered from a total of 103 workers using a structured questionnaire. Information on the incidence of musculoskeletal disorders was obtained using the Standardized Nordic Questionnaire. The questions about ergonomics awareness, workstation, environment, demands, and risks were based on the available literature studies. The association between the incidence of WRMSDs and age was explored using chi-square analysis. The results showed a high rate of uneducated workers with a lack of ergonomics awareness. Back, shoulders, and legs were the most vulnerable body areas to WRMSDs. A significant association between workers' age and WRMSDs was found. The workers' opinion towards workstation was at a very low level. The current work conditions were found to have risks of potential hazards and economic losses. Ergonomic interventions are suggested to be developed and implemented to improve workplace conditions..

Keywords-musculoskeletal disorders; coal mine workers; ergonomics; workstation evaluation; work environment; work demands

I. INTRODUCTION

Any engineering project encounters several risks during its life cycle [1]. Risk management is based on the management of health, safety, and the environment of the personnel. Risk is a process that has an uncertain and unknown outcome in each field [2]. Longwall mining is a highly automated, very powerful and productive way to mine. In the absence of longwall mining, other technologies can be applied, named highwall mining or coal mining of flat-laying coal seam technology which solves the same problem as high wall mining, but does not require any specialized equipment [3]. Mining is often associated with high rates of Work-Related Musculoskeletal Disorders (WRMSDs) that have adverse effects on the health of workers. Coal is a major energy source of the economic development of a country [4-5]. However, its mining is believed to be a dangerous task, as it poses many health problems to workers [6-9]. The health issues include manual tasks, working in awkward postures, and for long durations, increasing the risk of developing WRMSDs [10]. WRMSDs are one of the major cost occurring disorders [11] and are related to discomforts in muscles, joints, nerves, blood vessels, and supporting structure. They include both work-related and non-work exposures [12, 13]. WRMSDs have become one of the most serious problems in industries, causing one-third of the total sickness absenteeism [14]. Regardless of the work nature and the involvement of high physical efforts, WRMSDs are very common in virtually all job categories and are among the major causes of workers' pain, disability, absenteeism, low productivity, and high financial costs [15-20].

Studies suggest a causal relationship between WRMSDs with occupational and non-occupational physical risk factors. Numerous mining-related physical risk factors such as manual material handling, repetitive movements, high exertion, working in awkward postures, and changes of workplace circumstances are some reasons for the development of WRMSDs [21, 22]. WRMSDs are contributed by many risk factors in the mining industry, and a variety of positions and postures like kneeling, squatting, and stooping can enhance the occurrence of musculoskeletal disorders [23]. From an

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ergonomic perspective, disorders or injuries are caused by carrying out the activities incorrectly. The risks and hazards in the mining comprise of the design of equipment and vehicles, high job demands, work pressure, job rotation, overtime, improper rest, recovery time, and breakdowns [24]. Working in low working heights (in low-seam mines) causes multiple forms of discomforts and injuries attributed to working in kneeling and squatting postures [25, 26]. The workers are often exposed to these risks, therefore risk potential should be identified and reduced [27]. In Pakistan, the coal is still being extracted using conventional mining methods, thus WRMSDs have become the most common health problems [28, 29] in this industry. The mining industry in Pakistan is not technologically advanced [30]. Therefore, the present study has been carried out to evaluate ergonomic factors and assess WRMSDs with the aim to address the key issues that contribute in their development. The focus of this study is the assessment of a representative sample of Pakistan's coal mining industry workforce. The study will help the government and mining enterprises to promote the health of workers by developing and implementing proper ergonomic interventions.

II. METHODOLOGY

The study has been carried out to explore WRMSDs and to evaluate workstations for ergonomic conditions in Lakhra Coal Mines, Sindh, Pakistan. The data were obtained from the workers of 18 different underground coal mine sites. The study sample consisted of 103 underground coal mine workers, which were selected with randomize sampling technique. The data were gathered through a structured questionnaire. The prevalence of musculoskeletal disorders was measured using the Nordic Musculoskeletal Questionnaire [31]. The questions regarding ergonomic awareness, workstation evaluation, work environment, work demands, and risks at work were based on the contents of [32-34]. A 5-point Likert scale was used, from 1 for strongly disagree to 5 for strongly agree. SPSS version 23 was used for data analysis. Data obtained from the workers were summarized in frequency, percentage, mean, and standard deviation. The association between the prevalence of WRMSDs and the age of coal mine workers was evaluated with the Chi-square test. The alpha (α) level was set at 0.05.

III. RESULTS

A. Demographic Data

The demographic description of the respondents is presented in Table I. The study sample comprised of only males, as women do not work in the mining industry in Pakistan.

B. Work-Related Musculoskeletal Disorders

According to the data on pain during the last 12 months, the results show that a high number of workers were suffering from WRMSDs. The overall measurement results are summarized in Table II. Figure 1 shows the percentage of WRMSDs among workers. The prevalence of WRMSDs complaints during the last 12 months was significantly associated with workers' age. The back-pain complaint (88%) was the most commonly reported and leading complaint among the workers and it was highly significantly associated with the workers' age ($p < 0.001$). Shoulder pain (76%) and leg pain (67%) were ranked as the second and third most commonly reported WRMSDs. The prevalence of WRMSDs was found consistently associated with age.

TABLE I. DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Variable	Description	(%)
Age (years)	18–33	38 (36.9)
	34–49	36 (35.0)
	≥50	29 (28.2)
Marital status	Single	12 (11.7)
	Married	78 (75.7)
	Other	13 (12.6)
Education level	Uneducated	55 (53.4)
	Primary	36 (35.0)
	Secondary	12 (11.7)
Nature of job	Coal cutter	21 (20.4)
	Hand trolley man	9 (8.7)
	Haulage operator	14 (13.6)
	Worker	28 (27.2)
	Loader	11 (10.7)
	Surface collie	7 (6.8)
	Underground transporter	13 (12.6)
Total experience (years)	<1	5 (4.9)
	1–10	17 (16.5)
	11–20	45 (43.7)
	21–30	28 (27.2)
	>30	8 (7.8)

TABLE II. MSDS AND THEIR ASSOCIATION WITH AGE

Body Part	Prevalence (%)	Mean	(SD)	p
Shoulder	76.7	3.79	(0.75)	0.008*
Forearm	48.6	3.36	(0.93)	<0.001*
Back	88.4	3.94	(0.50)	0.045*
Legs	67.0	3.57	(0.94)	<0.001*
Foot / toe	63.1	3.58	(0.99)	0.011*

*Significant at $p < 0.05$ level

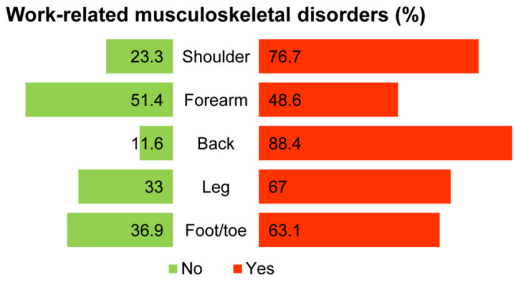

Fig. 1. Percentage of WRMSDs among workers.

C. Ergonomic Awareness

Table III presents information about ergonomics awareness among the workers. More than 86% of them were unaware of the ergonomic body of knowledge in their daily work. Only 32% of the survey population realized the effects of neglecting ergonomics in their life. Besides that, only 7.8% of the total respondents ever attended an ergonomic seminar.

D. Workstation Evaluation

The ergonomic analysis showed a low level of respondents' perception of their workstation. The results presented in Table IV are the responses to questions on workstation evaluation. More than 59% of the respondents reported that the

workstation was not clean and comfortable to work. The majority (72%) of the respondents stated that the workstation did not have suitable space to carry out routine work. Most (64%) of the respondents felt uneasy to work due to the congested workspace. More than 50% of the respondents were not provided with the necessary equipment.

E. Work Environment

The results of overall perception towards work environment are shown in Table V. Around 52.5% of the respondents reported the problem of gases in mines and 65% complained about improper lighting. The workers did not extensively report any difficulty to work due to noise, temperature, and humidity, and 71% of them reported the problem of coal dust and more than half (56%) were not satisfied with the overall ventilation system of the mine.

F. Work Demands

From the results shown in Table VI, we can see that a low percentage of the workers work overtime (40%). According to 58% of the respondents, their job involved a high degree of repetitiveness. The muscular strength requirement was high for 66% of the respondents, the work of 54% of the respondents was done manually, 52% of the respondents required bending and twisting, most of the respondents (68%) were dealing with carrying, lifting, or lowering heavy physical loads, 51% of the respondents required pushing/pulling/dragging the material with no aid of machinery, 47% had to climb up or down and 41% had to kneel or squat to perform their work.

G. Risks at Work

The data in Table VII indicate that errors in work are associated with risks of personal injury and economic losses. About 91% of the respondents were at risk of personal injury and 86% stated that their work is associated with risk of economic losses.

IV. DISCUSSION

This study was carried out in order to analyze the rate of WRMSDs and their associations with respondents' age. In addition, ergonomics awareness at work was considered. Workers' perception towards workstation, work environment, and work demands was analyzed. The risks associated with work were also explored. The results showed that more than half of the respondents were uneducated (53%), 35% had primary education, and less than 12% had secondary education. The back pain complaint was mostly reported, and it was found significantly associated with workers' age. The back pain became more prevalent with the increase of age. Pain in shoulders and legs ranked second and third respectively. The likelihood of developing body pain was caused by the adoption of uneasy working positions. The prevalence of all WRMSDs complaints was significantly associated with the age of the workers. Lack of ergonomic knowledge was observed and at the moment there was no safety and health program running at the workplaces. The majority of the respondents were unaware of the ergonomic issues. This implies that they had no knowledge of ways to avoid the WRMSDs. Approximately 68% of the respondents even did not realize the effects of ergonomics on their health, implying that the mine management was inefficient in providing ergonomic awareness. Only 7.8% of the respondents stated that they have been informed about ergonomics before the conduct of this survey.

The respondents' opinion towards workstation was at a very low level. Workstations were reported as unclean and uncomfortable, space was not suitable for routine activities and the workers felt uneasy to move during their work. The appropriate equipment was not provided to many of the workers, which could also be a factor of causing WRMSDs. There was a moderate level between satisfaction and dissatisfaction of the workers towards mine environment. The coal mines were having adequate air, comfortable temperature and humidity with a reduced level of noise. The presence of gases, improper lighting, and dust were the most reported problems, therefore, the workers' opinion towards overall ventilation was not satisfactory. The ventilation is the fundamental element involved in Occupational Safety and Health (OSH) of the workers. The current state of work demands was found to have potential health hazards. Although a low percentage of workers work overtime, the problems of manual material handling and the requirement of high muscular strength were common. A high percentage of the workers had to repeatedly bend and twist, push, pull, drag, climb, kneel, squat, and carry heavy physical loads. The results show that errors in work were associated with the risk of personal injury and economic losses. The analysis of risk factors showed a mean score of 3.96 and a standard deviation of 0.84. There is no doubt that coal miners are engaged in a heavy and repetitive task and they carry out monotonous work, which makes them highly vulnerable to WRMSDs, which is reflected in the prevalence of WRMSD rates in this study.

TABLE III. WORKERS' PERCEPTION TOWARDS ERGONOMIC AWARENESS

Item	Yes n (%)	No n (%)	Mean (SD)
Ergonomic knowledge	14.0 13.6	89 86.4	1.86 (0.34)
Knowing the effects of neglecting ergonomics	33 32	70 68	1.68 (0.47)
Attended ergonomic training	8 7.8	95 92.2	1.92 (0.27)
Overall	-	-	1.82 (0.36)

TABLE IV. WORKERS' PERCEPTION TOWARDS WORKSTATION

Item	n (%)	n (%)	n (%)	n (%)	n (%)	Mean (SD)
Clean and comfortable work pace	3 2.9	14 13.6	44 42.7	35 34	7 6.8	3.28 (0.89)
Suitable space for routine activities	18 17.5	33 32	23 22.3	26 25.2	3 2.9	2.64 (1.13)
Ease of movement in work space	8 7.8	26 25.2	32 31.1	31 30.1	6 5.8	3.01 (1.05)
Appropriate aid equipment provided	2 1.9	6 5.8	44 42.7	44 42.7	7 6.8	3.47 (0.79)
Overall						3.1 (0.97)

TABLE V. WORKERS' PERCEPTION TOWARDS WORK ENVIRONMENT

Item	n (%)	n (%)	n (%)	n (%)	N (%)	Mean (SD)
Mine gases	10 9.7	7 6.8	32 31.1	44 42.7	10 9.7	3.36 (1.07)
Lighting	14 13.6	17 16.5	36 35	28 27.2	8 7.8	2.99 (1.14)
Noise	3 2.9	14 13.6	16 15.5	51 49.5	19 18.4	3.67 (1.02)
Temperature and humidity	4 3.9	15 14.6	20 19.4	48 46.6	16 15.5	3.55 (1.05)
Dust	12 11.7	11 10.7	50 48.5	27 26.2	3 2.9	2.98 (0.98)
Overall ventilation	19 18.4	16 15.5	23 22.3	34 33	11 10.7	3.02 (1.29)
Overall						3.26 (1.09)

TABLE VI. WORKERS' PERCEPTION TOWARDS WORK DEMAND

Item	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**Mean (SD)**
Working overtime	3 2.9	24 23.3	35 34	33 32	8 7.8	3.18 (0.98)
Tasks with a high degree of repetitiveness	3 2.9	8 7.8	32 31.1	52 50.5	8 7.8	3.52 (0.86)
Muscular strength requirements	2 1.9	12 11.7	21 20.4	54 52.4	14 13.6	3.64 (0.93)
Manual material handling	7 6.8	8 7.8	32 31.1	49 47.6	7 6.8	3.40 (0.97)
Bending and twisting	12 11.7	12 11.7	25 24.3	41 39.8	13 12.6	3.30 (1.19)
Heavy Physical Load (carrying, lifting or lowering loads)	2 1.9	10 9.7	21 20.4	58 56.3	12 11.7	3.66 (0.88)
Pushing/ Pulling/ Dragging	10 9.7	13 12.6	28 27.2	44 42.7	8 7.8	3.26 (1.09)
Climbing up or down	2 1.9	11 10.7	31 30.1	54 52.4	5 4.9	3.48 (0.83)
Kneeling or squatting	3 2.9	14 13.6	44 42.7	35 134	7 6.8	3.28 (0.89)
Overall						3.41 (0.96)

TABLE VII. WORKERS OPINION ABOUT RISKS ASSOCIATED WITH WORK

Item	**1 n (%)**	**2 n (%)**	**3 n (%)**	**4 n (%)**	**5 n (%)**	**Mean (SD)**
Are errors in your work associated with a risk of personal injury?	2 1.9	3 2.9	4 3.9	69 67	25 24.3	4.09 (0.76)
Are errors in your work associated with the risk of economic losses?	5 4.9	7 6.8	2 1.9	75 72.8	14 13.6	3.83 (0.92)
Overall						3.96 (0.84)

V. CONCLUSION

This study aimed to assess WRMSDs and analyze the ergonomic conditions at workstations associated with underground coal mine workers in Pakistan. The results showed that back, shoulders, and legs were the most exposed body regions to WRMSDs. Every respondent was found with at least one MSD, while the workers themselves had a very low level of ergonomic awareness. Inefficient organization setting and low-technology environment are the main reasons for the high prevalence of WRMSDs. It is recommended that the current mining method employed should be investigated and immediate changes should be applied. Concentrated steps should be taken, and proper strategies must be developed and implemented to control WRMSDs among the workers. This study can be generalized because the ergonomic settings and health and safety scenarios in underground coal mines are similar throughout the country. The findings of this study will not only help the management to take better measures for the health of mine workers, but they will also help policy makers in forming better ergonomics awareness plans.

VI. STUDY LIMITATIONS

The current study is cross-sectional. A longitudinal study is suggested in order to research the long-term effects of occupational factors on the prevalence of WRMSDs. A qualitative study is also recommended in order to acquire a deeper understanding of other ergonomic risk factors.

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