# Evaluation of Work-related Musculoskeletal Injuries Among Coal Miner

Saleem Raza Chalgri[1], Muhammad Burhan Memon[1,2,*], Shakeel Ahmed Shaikh[3], Shafi Muhammad Pathan[1],

[1]Department of Mining Engineering, MUET, Jamshoro, Pakistan
[2]Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Malaysia
[3]Department of Industrial Engineering and Management, MUET, Jamshoro, Pakistan
[*]Corresponding author: burhan.memon@faculty.muet.edu.pk

**Abstract**

Mining work is quite tedious, and it takes the whole body into account. Underground mine environment has sensory issues, and working conditions are not ideal. It results in maximum chances for the occurrence of work-related musculoskeletal injuries (WRMSIs). WRMSIs are the conditions which affect muscles, bones, joints, nerves, vessels, and supporting system. These are the significant cost occurring disorders in the workplace. This research aims to assess the WRMSIs in Lakhra coal mines to identify critical issues. Fifty operational workers completed the self-administrated questionnaire survey. Data related to personal and work information, physical activities age, nature of job, and WRMSIs was collected. A physical wellbeing checklist and Body Part Diagram were used to know the response of the worker. The research findings show that shoulder and knee disorders occur more frequently among workers. Almost 54% of cases were reported knee pain, whereas 44% reported toe/foot disorders, 38% for a wrist disorder, 36% stuck with shoulder pain, 16% had neck pain, 10% were with elbow pain, and only 2% have the hip disorder. The study is a positive addition in the research area to carry out better health and safety measures for the miners.

**Keywords**—work-related musculoskeletal injuries; mine environment; working conditions; safety; mining

## 1 Introduction

The development and exploitation of mineral wealth are of vital importance for economic growth at the national level. Among major industrial occupations, mining industry is recognized as the most hazardous occupation by various researchers [1]. Safe mining operations in underground mines are one of the challenging issues around the world. Work-related musculoskeletal injuries (WRMSIs) are the most common injuries around the world [2]. One of the study suggests that, only musculoskeletal injury treatment costs $127.4 billion with involving longer time in recovery thus causing millions of work lost each year [3]. Therefore, it is considered as one of the critical operations because of its nature [4]. Underground miners deal with subtly dangerous risks to health and safety [5], due to manual coal mining extraction practices as shown in Fig 1 (a and b) [6].

*ISSN: 2523-0379 (Online), ISSN: 1605-8607 (Print)*
*DOI: https://doi.org/10.52584/QRJ.2001.06*


As a result, they are often exposed to a high risk of developing WRMIs [7]. Researchers came to an agreement that exposure to ergonomic risk factors such as stooping posture and continuous kneeling are major contributors to WRMSIs [8, 9]. WRMSIs are the conditions which affect muscles, bones, joints, nerves, vessels, and supporting sys-tem [10]. Miners often cannot work in standing upright position and have a limited space to change position due to muddy and uneven surfaces. Risk factors and hazards in the mining workplace include equipment and vehicle de-sign; work organization (high job demands, time pressures, lack of job rotation and long working hours without op-portunity for rest and recovery); access; duration of the task; overtime; and maintenance/breakdowns. Underground miners often work in different postures such as kneeling, squatting, and bending. Similarly, if a miner uses torque on his knee or stands on his knee, he hardly has enough space to twist or trunk. Another problem is that miners cannot transfer their load from fatigued muscles to another one because of the small height. Miners may not move from kneeling

(a) (b)

Fig. 1: Manual Coal Mining Practices

to standing so that they may cause tissue damage due to postural limitations. Due to these factors, there is always a risk of developing these injuries [7, 11, 12].
There is no practical way to predict and calculate the reasonable cost and performance of an operator who oper-ates the machine or performs any task [13]. A decrease in working efficiency and an increase in sick leaves of the coal miners due to WRMSIs is also reported in literature [14-16]. Therefore, most of the disabled pension holders have claimed compensation due to these injuries [17, 18]. The cost of WRMSIs may vary from country to country, whether a direct or indirect cost is concerned due to the health care services across the countries are different [19].
Mining industry of Pakistan faces many challenges like low socioeconomic status, lack of proper and effective legislation, inappropriate working conditions, unawareness related to safety measures, lack of workers' safety trainings [5, 20]. For developing country like Pakistan, sustainability in mining operations is a big challenge. This emphasis on conduct of risk and safety concerns in mining industry of Pakistan. Furthermore, Pakistan underground coal working conditions prone to WRMSIs in miners. Lack of ergonomically interventions make even tougher for underground miners to cope up with WRMSIs as most of them are unaware about this injury. The aim of the research is to highlight the incident rate of WRMSIs amongst the underground miners of Pakistan coalfield. The purpose of the current study is to assess the WRMSIs amongst underground miners in Lakhra coalfield, Pakistan.

## 2 Materials and Methods

The study was conducted on coal miners working in six different underground coal mines of Lakhra coalfield, in-cluding state-owned Lakhra Coal Development Company (LCDC) and some private leasing companies, such as Habibullah Coal Mines, Irfan Coal Mines, Pedison Coal Mines, Premier Coal Mines, and Habibullah Ton Coal Mines. The Lakhra coalfield is located in the northwest part of Hyderabad, Sindh, and the western side of the Indus Valley of Sindh Pakistan as shown in Fig 2.

The total lignite reserves of Lakhra are estimated at 239.7 million tons, which are lying at a depth of 83 to 439 feet. Average seam thickness was reported to be 3.6 feet to 8.2 feet [21]. A cross-sectional quantitative study based on a questionnaire was designed. This study was conducted on underground coal miners. Miners working underground and on the surface of underground mines were investigated about WRMSIs. A physical wellbeing checklist and Body Part Diagram can be seen in figure 3 was used to understand the actual position of WRMSIs.

Researchers all over the world use questionnaires designed method for data collection of disorders, workers are asked the questions, and then data is finalized. In this research, the same method has been adapted for data collec-tion. Standardized Nordic self-reporting questions with some modifications including physical wellbeing checklist and Body Part Diagram have been adopted to carry out this study. Furthermore, the questionnaire does not further require any validation and reliability as it was adopted from literature [22, 23]. The set questionnaire was explained to the sampled workers, and they were also briefed about the purpose of this study. The survey was anonymous; respondents did not mention their identity. This study was conducted on 50 miners working in six coal mines and was randomly selected and interviewed through a convenience sampling technique on a scheduled basis. With the help of the engineers, the questionnaire was translated into the local language so that workers can respond to questions. A meeting was also held with the staff of the local government hospital "Mines Labor Welfare Ten Bedded Hospital Lakhra" situated in Indus Coal Mine, Lakhra. Each respondent had options from (1-5) using a Likert scale. The ques-tionnaire was

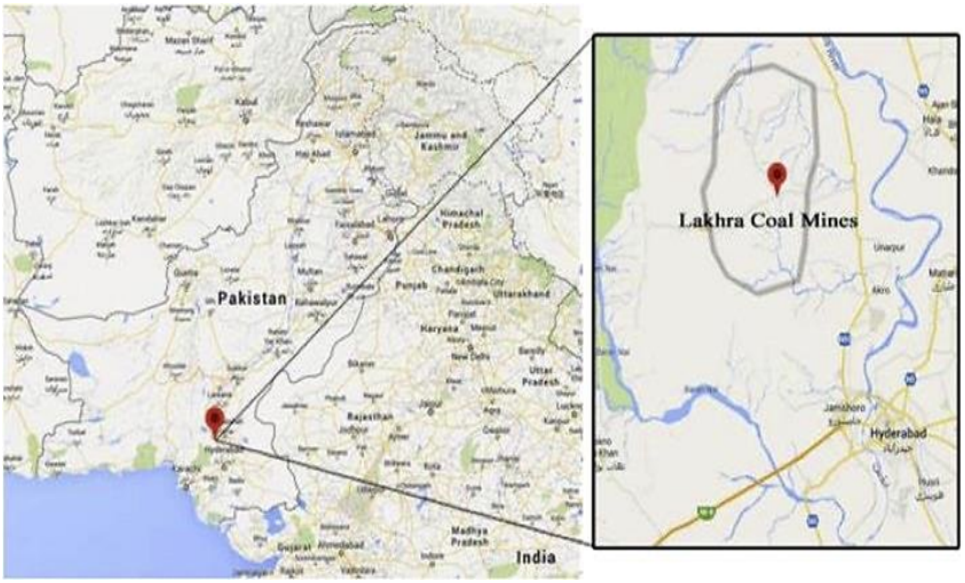


Fig. 2: Location of Lakhra Coalfield [24]

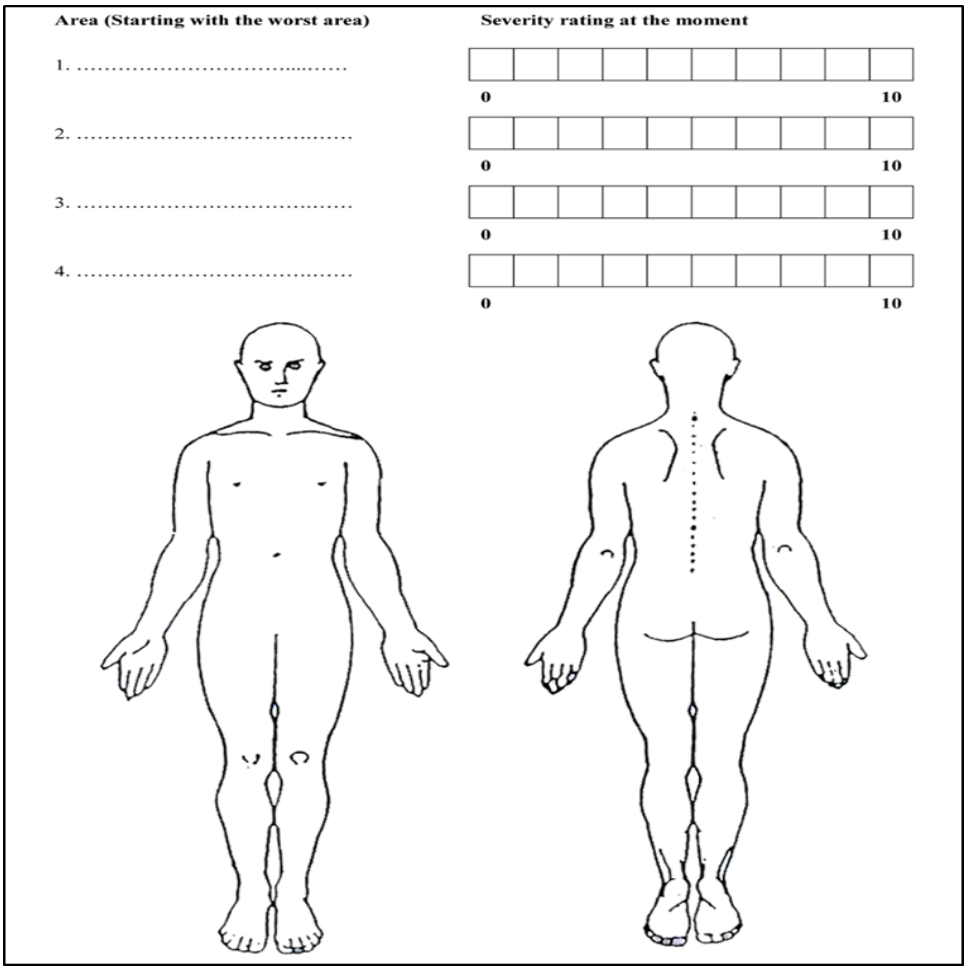


Fig. 3: Physical well-being checklist and Part Diagram

TABLE 1: Reliability Statistics

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N |
|---|---|---|
| 0.569 | 0.668 | 50 |

highlighting three major areas for assessing WRMSIs complaints. The questions include demographic information, work experience, nature of the job, questions regarding injuries, and work condition. The aim of this study is to identify the working conditions causing WRMSIs. However, for comparing the data table, some basic sta-tistical tools were used using SPSS 19 software.

### 2.1 Physical Well-Being Checklist

1) Do you have at the moment any discomfort, ache, or pain (not including headaches or eye strain) in any part of your body?

(A) No (B) Yes

If YES, carefully shade the area(s) in which you feel this discomfort, ache, or pain on the diagram and then name each area, rate the severity experienced on the scales (Fig. 3). Reliability analysis was carried out to justify whether the sample size was enough to analyze the data further. Cronbach alpha, in this regard, was found to be 0.668 (approx. 0.7) for 50 items, as shown in Table 1.

## 3 Results and Discussion

This research aimed to identify the risk factors pertinent to musculoskeletal injuries in miners working at Lakhra coal mines. Since no or very little research has been carried out, especially in Sindh province [4, 5, 7]. Therefore, it was necessary to identify and evaluate the risk factors in miners in order to improve the quality of working life as well as enhancing the productivity for the organization. Data were collected from 50 male respondents (underground min-ers) using the physical wellbeing checklist and Body Part Diagram. As far as the working conditions were concerned, it was expected a high prevalence of musculoskeletal injuries among miners. Table 2 shows the frequency distribution along with mean (SD) for the age 3.82 (2.04), work experience 2.88 (1.56), and nature of the job.

Based on the data collected on the Physical Well-being Checklist, the results showed that 42 out of 50 respond-ents/patients had no complaint about the neck having mean (SD) 0.16(0.37). It is also witnessed that that Twenty-three respondents did not stick with knee disorder, and 27 suffered from the knee disorder 0.54 (0.503), only one re-spondent has hip pain. Whereas 18 workers complained about shoulder pain while performing hauling activities. Almost 45 respondents replied with the answer no when asked about elbow pain, and only five complained about the above-said disorder, 31 workers did not have wrist/-hand issue, but 19 responded with yes. Twenty-two stuck with foot/toe disorder, and 28 reply was no. WRMSIs problems were there with the mine workers continuously in-volved in the coal extracting, cutting, loading, and hauling practices (Fig. 4).

TABLE 2: Frequency Distribution Table for Age Group, Work experience and Nature of job

| Variables | N (%) |
|---|---|
| Age Groups (Years) | |
| 15 to 19 | 3 (6) |
| 20 to 24 | 15 (30) |
| 25 to 29 | 8 (16) |
| 30 to 34 | 7 (14) |
| 35 to 39 | 7 (14) |
| 40 to 44 | 4 (8) |
| 45 to 49 | 1 (2) |
| Greater than 50 | 5 (10) |
| Work Experience (Years) | |
| 1 to 3 | 11 (22) |
| 4 to 6 | 12 (24) |
| 7 to 9 | 12 (24) |
| 10 to 12 | 7 (14) |
| 13 to 15 | 3 (6) |
| Greater than 15 | 5 (10) |
| Nature of Job | |
| Coal Cutter | 11 (22) |
| Drill Operator | 8 (16) |
| Haulage Operator | 1 (2) |
| Haulage + Cutter | 7 (14) |
| Loading | 7 (14) |
| Mine Sirdar | 4 (8) |
| Pump Operator | 6 (12) |
| Surface Collie | 2 (4) |
| Underground Transporter | 4 (8) |

Table 3 provides an assessment of age and WRMSIs. It consists of a comparison of age with neck, knee, hip, elbow, wrist/ hand, shoulder, and foot/toe. It shows miners between the age of 35-39 stuck with knee, elbow, feet/toe dis-order.

Table 4 shows the disorder division based on work experience. Also, it can be witnessed from the table that miners with work experience of 1-3 and 7-9 years have disorders more frequently.

Table 5 gives a clue that the nature of work was also one of the significant components of the disorder. There is al-ways a high possibility that coal cutters were likely to be victims of WRMSIs.

The above analysis inconsistent with the effects of WRMSIs have been identified in many tasks such as awkward postures during assembly operations [25], upper limb disorders due to manual material handling

TABLE 3: Assessment of WRMSIs with age groups

| Age (Years) | Neck | | Knee | | Hip | | Elbow | | Wrist/Hand | | Shoulder | | Foot/Toe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes |
| 1 to 3 | 3 | 0 | 0 | 3 | 3 | 0 | 2 | 1 | 2 | 1 | 0 | 3 | 0 | 3 |
| 4 to 6 | 14 | 1 | 9 | 6 | 15 | 0 | 15 | 0 | 10 | 5 | 12 | 3 | 10 | 5 |
| 7 to 9 | 7 | 1 | 6 | 2 | 8 | 0 | 8 | 0 | 7 | 1 | 6 | 2 | 4 | 4 |
| 10 to 12 | 6 | 1 | 5 | 2 | 7 | 0 | 7 | 0 | 5 | 2 | 6 | 1 | 5 | 2 |
| 13 to 15 | 5 | 2 | 1 | 6 | 7 | 0 | 4 | 3 | 3 | 4 | 5 | 2 | 3 | 4 |
| 15 | 2 | 2 | 1 | 3 | 3 | 1 | 3 | 1 | 2 | 2 | 1 | 3 | 4 | 0 |
| 45 to 49 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 50 | 4 | 1 | 0 | 5 | 5 | 0 | 5 | 0 | 1 | 4 | 1 | 4 | 1 | 4 |

TABLE 4: Assessment of WRMSIs with work experience

| Experience (Years) | Neck | | Knee | | Hip | | Elbow | | Wrist/Hand | | Shoulder | | Foot/Toe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes |
| 1 to 3 | 11 | 0 | 5 | 6 | 11 | 0 | 10 | 1 | 8 | 3 | 8 | 3 | 6 | 5 |
| 4 to 6 | 10 | 2 | 6 | 6 | 12 | 0 | 12 | 0 | 8 | 4 | 8 | 4 | 9 | 3 |
| 7 to 9 | 10 | 2 | 8 | 4 | 11 | 1 | 11 | 1 | 10 | 2 | 10 | 2 | 7 | 5 |
| 10 to 12 | 6 | 1 | 3 | 4 | 7 | 0 | 6 | 1 | 3 | 4 | 3 | 4 | 5 | 2 |
| 13 to 15 | 0 | 3 | 0 | 3 | 3 | 0 | 1 | 2 | 0 | 3 | 1 | 2 | 1 | 2 |
| 15 | 5 | 0 | 1 | 1 | 5 | 0 | 5 | 0 | 2 | 3 | 2 | 3 | 0 | 5 |

TABLE 5: Assessment of WRMSIs with job nature

| Job Nature | Neck | | Knee | | Hip | | Elbow | | Wrist/Hand | | Shoulder | | Foot/Toe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes |
| Coal cutter | 8 | 3 | 2 | 9 | 11 | 0 | 7 | 4 | 6 | 5 | 5 | 6 | 4 | 7 |
| Drill Operator | 4 | 4 | 4 | 4 | 8 | 0 | 8 | 0 | 0 | 8 | 2 | 6 | 8 | 0 |
| Haulage Cutter | 7 | 0 | 6 | 1 | 7 | 0 | 7 | 0 | 6 | 1 | 7 | 0 | 7 | 0 |
| Loading | 7 | 0 | 2 | 5 | 7 | 0 | 7 | 0 | 7 | 0 | 7 | 0 | 6 | 1 |
| Mine Sirdar | 4 | 0 | 0 | 4 | 4 | 0 | 4 | 0 | 0 | 4 | 0 | 4 | 0 | 4 |
| Pump Operator | 6 | 0 | 6 | 0 | 6 | 0 | 6 | 0 | 6 | 0 | 6 | 0 | 0 | 6 |
| Surface Collie | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 2 | 0 |
| Underground Transporter | 4 | 0 | 0 | 4 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 0 | 4 |

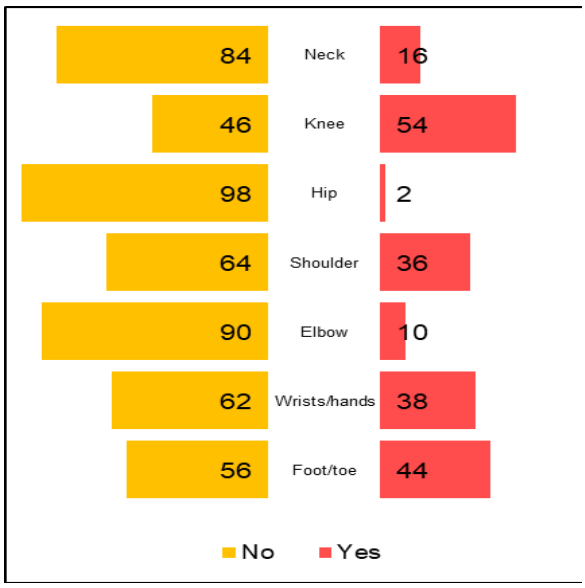


Fig. 4: Incidences of WRMSIs

and cumulative trauma disorders due to repetitive tasks awkward postures during assembly operations, manual material handling [26]. From the acquired results, the analysis for the frequent disorder has also been done, which is shown in Fig. 5.

The findings indicate that almost 54% cases stuck with the knee pain respectively, whereas, 44% reported toe/foot disorders, 38% for the wrist disorder, 36% had shoulder disorder, 16% stuck with neck pain, 10% with elbow pain and only 2% had the hip disorder. Ergonomics intervention strategies need to be focused so that disorders can be reduced to a certain level. Hence, it is observed that cases of the knee, foot/toe, and wrist/hands are frequently oc-curring in Lakhra coalfield. Therefore, there is an urgent need to address these injuries. Table 6 elaborates on the working conditions and activities of miners while performing their assigned work.

TABLE 6: Working conditions and activities of workers

| Work Conditions and Activities | Percentage | | |
|---|---|---|---|
| | Almost Never | Sometimes | Almost Always |
| Overhead reaching for load, tools, mining equipment | 28 | 20 | 52 |
| Bending at the waist to handle loads, tools or mining equipment | 8 | 34 | 58 |
| Twisting at the waist to handle loads, tools or mining equipment | 24 | 42 | 34 |
| Carrying, lifting or lowering loads of more than 25 kg repeatedly | 28 | 12 | 60 |
| Climbing up or down the stairs or ladder with loads, tools/equipment | 40 | 24 | 36 |
| Pushing loads, tools or mining equipment | 30 | - | 70 |
| Pulling loads, tools, or mining equipment | 38 | 16 | 46 |
| Working with the hands above shoulder height | 24 | 28 | 48 |
| Operating equipment or tools above shoulder height | 42 | 38 | 20 |
| Working in tunnels where you cannot stand up straight | 26 | 28 | 46 |
| Kneeling or squatting | 54 | 42 | 4 |
| Repeated bending and straightening of your elbow | 54 | - | 46 |
| Using vibratory tools such as rock drills | 84 | 16 | - |

## 4 Conclusion and Recommendations

Lakhra coalfield was developed many years ago. However, unfortunately considering working characteristics has been the issue in almost every organization, whether local or multinational, especially in developing countries, be-cause labor is less expensive. This research was, therefore, a step to highlight the working conditions that prevalent WRMSIs, resulting in less productivity and doubtfully affecting the quality of working life. Findings and discussion showed that workers face many problems regarding the unergonomic environment related to the working condition causing a number of health issues. Another cause while observing the underground mine, it was found that due to the low coal seam thickness, the mining height was very short, which resulted in the occurrence of many health and safety-related problems as well. The research work also aimed to provide workplace awareness and ensure the safety of workers for the organization to pay adequate attention to the worker's health and safety. Nature of work plays a vital role; for example, Mine Sirdar, drill operators, and coal cutters, who are mainly engaged in exerting muscular effort while carrying the mine work. They were regular complainers of WRMSIs caused by kneeling, bending, and small mining height. Therefore, workers must be given a specific time for the muscle's rest so that continuous work may not influence. Apart from the physical factors, which was the main area in this research, organizational, psycho-social issues can also impact WRMSIs, which need to be highlighted in future research. The research outcome may not only be limited to the coal industry of Pakistan but also for the general industry's employees in the country for setting the future health and safety policies for the mining and other industry of Pakistan.

## References

[1] Jeripotula, Sandeep Kumar, Aruna Mangalpady, and Govinda Raj Mandela. "Ergonomic assessment of musculoskeletal disorders among surface mine workers in India." Mining, Metallurgy Exploration 38, no. 2 (2021): 1041-1046.

[2] Okello, Alfred, Solomon Tsebeni Wafula, Deogratias K. Sekimpi, and Richard K. Mugambe. "Prevalence and predictors of work-related musculoskeletal disorders among workers of a gold mine in south Kivu, Democratic Republic of Congo." BMC musculoskeletal disorders 21, no. 1 (2020): 1-10.

[3] Palazzo, Clémence, Jean-François Ravaud, Agathe Papelard, Philippe Ravaud, and Serge Poiraudeau. "The burden of musculoskeletal conditions." PloS one 9, no. 3 (2014): e90633.

[4] Jiskani, Izhar Mithal, Jonhatan Magno Norte Da Silva, Saleem Raza Chalgri, Paras Behrani, Xiang Lu, and Ebelia Manda. "Mine health and safety: influence of psychosocial factors on musculoskeletal disorders among miners in Pakistan." International Journal of Mining and Mineral Engineering 11, no. 2 (2020): 152-167.

[5] Jiskani, Izhar Mithal, Barkat Ullah, Kausar Sultan Shah, Sher Bacha, Niaz Muhammad Shahani, Muhammad Ali, Ahsan Maqbool, and Abdullah Rasheed Qureshi. "Overcoming mine safety crisis in Pakistan: An appraisal." Process safety progress 38, no. 4 (2019): e12041.

[6] Shahani, Niaz Muhammad, Muhammad Jawad Sajid, Xigui Zheng, Manzoor Ali Brohi, Izhar Mithal Jiskani, Fawad Ul Hassan, and Abdullah Rasheed Qureshi. "Statistical analysis of fatalities in underground coal mines in Pakistan." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects (2020): 1-16.

[7] Jiskani, Izhar Mithal, Zhou Wei, Saleem Raza Chalgri, Cai Qingxiang, Paras Behrani, and Raheel Aziz. "Prevalence of musculoskeletal disorders and assessment of workplace factors: A case of coal mine in Pakistan." In Thirty-Fifth Annual International Pittsburgh Coal Conference, Xuzhou, China. 2018.

[8] Aghillinejad, Mashallah, Elaheh Kabir Mokamelkhah, Mohammad Nassiri-Kashani, Mohammad Kazem Nouri, Narges Noorian, and Amir Bahrami-Ahmadi. "Musculoskeletal disorders among Iranian coal miners at 2014." Iranian Journal of Health, Safety and Environment 3, no. 1S (2016): 466-471.

[9] Kunda, Richard, Josè Frantz, and Farhana Karachi. "Prevalence and ergonomic risk factors of work-related musculoskeletal injuries amongst underground mine workers in Zambia." Journal of occupational health 55, no. 3 (2013): 211-217.

[10] Buckle, Peter W., and J. Jason Devereux. "The nature of work-related neck and upper limb musculoskeletal disorders." Applied ergonomics 33, no. 3 (2002): 207-217.

[11] Gallagher, Sean. "Physical limitations and musculoskeletal complaints associated with work in unusual or restricted postures: a literature review." Journal of Safety Research 36, no. 1 (2005): 51-61.

[12] Bhattacherjee, Ashis, Jean-Pierre Bertrand, Jean-Pierre Meyer, Lahoucine Benamghar, Carmen Otero Sierra, Jean-Pierre Michaely, Apurna Kumar Ghosh et al. "Relationships of physical job tasks and living conditions with occupational injuries in coal miners." Industrial health 45, no. 2 (2007): 352-358.

[13] Laring, J., Mikael Forsman, Roland Kadefors, and Roland Örtengren. "MTM-based ergonomic workload analysis." International journal of Industrial ergonomics 30, no. 3 (2002): 135-148.

[14] Palmer, Keith T., Michael Calnan, David Wainwright, Jason Poole, Claire O'Neill, Anna Winterbottom, Chris Watkins, and David Coggon. "Disabling musculoskeletal pain and its relation to somatization: a community-based postal survey." Occupational Medicine 55, no. 8 (2005): 612-617.

[15] Ryall, C., D. Coggon, R. Peveler, J. Poole, and K. T. Palmer. "A prospective cohort study of arm pain in primary care and physiotherapy—prognostic determinants." Rheumatology 46, no. 3 (2007): 508-515.

[16] Bhuttoa, Ghulam Mehdi, Jawaid Daudpotoa, and Izhar Mithal Jiskanib. "Development of a wearable safety device for coal miners." International Journal 7, no. 4 (2016).

[17] Lipton, James A., and Joseph J. Marbach. "Ethnicity and the pain experience." Social Science Medicine 19, no. 12 (1984): 1279-1298.

[18] Aptel, Michel, Agnès Aublet-Cuvelier, and Jean Claude Cnockaert. "Work-related musculoskeletal disorders of the upper limb." Joint bone spine 69, no. 6 (2002): 546-555.

[19] Baldwin, Marjorie L. "Reducing the costs of work-related musculoskeletal disorders: targeting strategies to chronic disability cases." Journal of Electromyography and Kinesiology 14, no. 1 (2004): 33-41.

[20] Jiskani, Izhar Mithal, Shuai Han, Atta Ur Rehman, Niaz Muhammad Shahani, Muhammad Tariq, and Manzoor Ali Brohi. "An integrated entropy weight and grey clustering method–based evaluation to improve safety in mines." Mining, Metallurgy Exploration 38, no. 4 (2021): 1773-1787.

[21] Ghani, M. A., Robert Lee Harbour, Edwin R. Landis, and William Kebblish. Geology and coal resources of the Lakhra coal field, Hyderabad area, Pakistan. No. 75-553. US Geological Survey„ 1975.

[22] Kuorinka, Ilkka, Bengt Jonsson, Asa Kilbom, Henrik Vinterberg, Fin Biering-Sørensen, Gunnar Andersson, and Kurt Jørgensen. "Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms." Applied ergonomics 18, no. 3 (1987): 233-237.

[23] Dias, Belinda. "Musculoskeletal Disorders in the South Africa Mining Industry." PhD diss., University of the Witwatersrand, Faculty of Health Sciences, 2014.

[24] Shahani, N. M., Z. Wan, M. Ali, and B. Ullah. "Detection and monitoring of underground coal mine gases at Lakhra Coal Mines, Pakistan." In 35th Annual International Pittsburgh Conference, pp. 1-8. 2018.

[25] Shaikh, S., S. V. G. Cobb, D. Golightly, J. I. Segal, and C. M. Haslegrave. "Investigating the effects of physical and cognitive demands on the quality of performance under different pacing levels." Work 41, no. Supplement 1 (2012): 1625-1631.

[26] T. a. S. D. Ministry of Labour. Prevent Musculoskeletal Disorders (MSDs) in Mines. (2012). Available: https://www.labour.gov.on.ca/english/hs/hs_disclaimer.php