Analysis of social demographic factors and its effect on work-related musculoskeletal disorders in front shovel operators of a mining company

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Abstract. Worker comfort is one important factor in the production operation. The attention to comfort in the workplace will be able to reduce the occurrence of complaints. Facilities and workplace conditions that are not ergonomic increase worker's complaints, such as musculoskeletal disorders are often experienced. Many factors affect the occurrence of work-related musculoskeletal disorders. In this research, social demographic factors retrieved and the influence its effect on musculoskeletal experienced by front shovel operators at a mining company in South Sulawesi was analyzed. This research was based on subjective questionnaires and data obtained were processed by using bivariate statistical method. Dependent and independent variables are musculoskeletal disorder, social demography factor, handgrip strength, subjective physical complaint and environmental factors (temperature, noise, vibration, lighting, and dust). Results concluded from 28 front shovel operators, they have a senior high school education background (86%), with over 3 years work (3-5 years 32%,> 5 years 39%), generally slept in a day for 5-8 hours (71%), and most operators are smokers (75%) with the number of cigarettes consumed in an average a day 4-12 sticks (57%), generally operators are having a breakfast (89%) by consuming rice and side dishes (88%). Statistical tests showed no significant relationship between social-demographic factors to muscle complaints. The influence of environmental factors has a significant relationship to subjective physical complaints but the results obtained inconsistent because the number of samples is still limited.

1. Background
Comfort at work is one important factor in the production process, and by paying attention to it will be able to reduce the occurrence of worker complaints. The complaints that arise are due to the absence of ergonomic work facilities, in accordance with the awkward posture of the worker causing them to feel less comfortable [1]. In industrial activities, exposure and risks in the workplace tend to be around the workplace and workers. Sometimes these conditions cannot always be avoided due to work demands [2]. Comfort in working is strongly influenced by the place and condition of the work environment. Uncomfortable places and working conditions can cause loss and even accidents for workers, which one of the complaints is musculoskeletal disorders.

Heavy equipment is a large-sized machine designed to carry out construction functions, such as earthwork, road construction, building construction, mining, and plantations. In the operation of heavy equipment many aspects must pay attention to, starting from tool operation procedures, aspects of work safety, operator expertise and knowledge, as well as inspection and maintenance aspects [3]. Mining company in this study as one of the largest mining companies in Indonesia has to facilitate its operational
activities using a number of heavy equipment. Several heavy equipment is used to excavate soil and rocks, for example front shovel to dig up material that is located on the surface where the machine is located. The use of heavy equipment is to facilitate humans in supporting their work, so the expected results can be achieved more easily with a relatively shorter time. Technology has brought convenience to human life, however, interactions between workers with the environment and work tools can have a negative impact on workers [4]. The most dominant factor influencing the occurrence of low back pain in mining operators operating heavy equipment is the use of static vehicles. The more often operators use static vehicles, the more likely it is to get low back pain.

The amount number and type of heavy equipment used will results in having operators to work in the area in large numbers. The number of operators who work to operate heavy equipment at the company are approximately 700 workers. The partition of operators work time are divided into 3 shifts; each work shift has 8 of work hours. Research by [5] conclude that heavy equipment operators in nickel mining may be exposed to a higher low back pain risk due to the land condition of the overburden overlying nickel deposits. There are many factors that influence the occurrence of musculoskeletal disorders due to work, one of the factors is social-demographic factors. A large number of operators certainly have different backgrounds and socio-demographic conditions. Social demographic factors pay more attention to various individual and group characteristics which include social-demographic, educational, and economic characteristics. Social and demographic characteristics include gender, age, marital status, and religion. Educational characteristics include the level of education. Economic characteristics include occupation, economic status, and income.

Dominant factors not related to work that have an impact on indications of failure are work environment factors such as dusty air, hot air, noise, and workplace or vibrating work tools. Most respondents indicated experiencing severe fatigue felt that they were disturbed by the work environment [6]. The quality of a good work environment and in accordance with the human condition as workers will support the work performance and productivity produced. Control and handling of work environment factors such as noise, temperature, vibration, and lighting are problems that must be dealt with seriously and continuously. Noise, hot temperatures, vibrations and poor lighting in the workplace are sources that cause work pressure and decrease work productivity [7][8]. This has become one of the factors that influence the chances of musculoskeletal disorders, due to the workload provided is not fit with the capabilities of the workers. It will not benefit for the company and either for the workers.

2. Methods
This research was conducted to the front shovel operator by purposive sampling, a mining company at South Sulawesi, Indonesia. Material handling for the excavation using seven units of front shovels and handled by 28 operators with eight working hours of each operator, excluding the rest time and departure time to and from the location.

![Front Shovel](image.jpg)

**Figure 1.** Front Shovel
Several methods of data collection are carried out, namely questionnaires, interviews and field observations. This questionnaire was given to respondents to get data on individual factors (age, years of service, smoking habits), then added factors such as rest periods and breakfast habits. The level of subjective complaints of skeletal muscle disorders felt by the operator as well as conditions around the work environment also collected. Interview by conducting questions and answer, meanwhile direct measurement of grip strength from front shovel operators were measured. Physical condition before and after doing work measured directly by the strength on the dominant hand using the handgrip dynamometer on the operator at each 1st Shift, 2nd Shift, and 3rd Shift. Measurement tool used in this study is subjective physical fatigue the Borg Scale. The Borg Scale was introduced by Gunnar Borg on a scale of 6 – 20 usually used for the diagnosis of shortness of breath, dyspnea, chest pain, and bone or muscle pain. The Borg scale, follows the heartbeat of a healthy adult by multiplying with 10. The larger the scale means the greater the energy expended [9].

3. Results and discussion
The company studied is a nickel production company in Indonesia. To meet the demand requirements, the company manufacture in 24 hours to produce ± 100,000 tons of nickel. In order to run the production process to continuously, the worker's schedule is divided into 3 work shifts, i.e. Shift 1 starts from 06.45 to 14.45, Shift 2 starts from 14.45 to 22.45, and Shift 3 starts from 22.45 to 06.45 WITA. The nickel production process starts from exploration, mining, processing to mine closure. Every shift is given a target of ± 35,000 tons production a day, with adjustment in weekly basis.

| Table 1. Participants characteristics (n=28) |
|---------------------------------------------|
| Characteristics                | Total | Percent |
|---------------------------------|-------|---------|
| Gender                          |       |         |
| Man                             | 28    | 100%    |
| Women                           | 0     | 0%      |
| Age                             |       |         |
| ≤40 years                       | 9     | 45%     |
| >40 years                       | 11    | 55%     |
| Education                       |       |         |
| Grade School                    | 1     | 4%      |
| Junior High                     | 0     | 0%      |
| Senior High                     | 24    | 86%     |
| Diploma                         | 0     | 0%      |
| University                      | 3     | 11%     |
| Employment                      |       |         |
| < 1 year                        | 0     | 0%      |
| 1-3 years                       | 8     | 29%     |
| 3-5 years                       | 9     | 32%     |
| > 5 years                       | 11    | 39%     |
| Slept                           |       |         |
| < 3 hours                       | 1     | 4%      |
| 3-5 hours                       | 5     | 18%     |
| 5-8 hours                       | 20    | 71%     |
| > 8 hours                       | 2     | 7%      |

Heavy equipment operators especially front shovel machine was total of 28 people, all of them are man (100%). As can be seen in Table 1 that 3% of operators have an elementary education background, 11% have university degrees, and 86% have a high school education background. Based on the length of work, 29% of operators have worked for 1-3 years, 32% for 3-5 years and 39% for> 5 years. The data shows that more than all operators have worked for more than 1 years in operating the front shovel. Operators were having rest periods <3 hours (4%), 7% of operator slept for> 8 hours, 18% of operator slept for 3-5 hours, and most operators have a rest periods ranging from 5-8 hours (71%).
Table 2. Participants lifestyle characteristics (n=28)

| Characteristics | Total | Percent |
|-----------------|-------|---------|
| Smoking         |       |         |
| Yes             | 21    | 75%     |
| No              | 7     | 25%     |
| Number of Cigarettes |       |         |
| 4-12 sticks    | 12    | 43%     |
| >12 sticks      | 9     | 32%     |
| Breakfast       |       |         |
| Yes             | 25    | 89%     |
| No              | 3     | 11%     |
| Breakfast menu  |       |         |
| Rice and side dishes | 22    | 79%     |
| Bread/bakery    | 3     | 11%     |
| Sickness Prior  |       |         |
| Yes             | 24    | 86%     |
| No              | 4     | 14%     |
| Discomfort      |       |         |
| Yes             | 16    | 57%     |
| No              | 12    | 43%     |

As many as 75% of operators consume cigarettes every day shown in Table 2, also that 43% of operators who smoke consume >12 cigarettes per day and 57% of operators consume 4-12 cigarettes/day. Most operator (89%) having a breakfast and 11% of operators did not, while most of them (88%) were consume rice when having breakfast and 12% consume bread/bakery. Most of operator (86%) have experienced sickness/pain prior this research and 57% felt discomfort in work.

Table 3. Operator front shovel handgrip strength (n=20)

| Descriptive | Age | 1st Shift | 2nd Shift | 3rd Shift |
|-------------|-----|-----------|-----------|-----------|
|             |     | Pre      | Post      | Pre      | Post      | Pre      | Post      |
| Mean        | 40,50 | 50,18 | 40,01 | 48,17 | 37,62 | 46,62 | 29,14 |
| Min         | 37,00 | 42,40 | 32,90 | 40,60 | 30,20 | 40,10 | 22,60 |
| Max         | 43,00 | 59,20 | 48,30 | 55,80 | 44,60 | 56,40 | 37,60 |
| Stdv        | 1,96 | 5,36 | 4,03 | 5,33 | 4,74 | 5,20 | 4,47 |

Based on the handgrip strength data, it can be seen in Table 3 and Figure 2 that there is a decrease in the grip strength of each operator before (pre) and after work (post). On the average, operator subjective physical fatigue experience was increased in 2nd Shift and 3rd Shift compared to 1st Shift, which the biggest difference on the 3rd Shift. Overall, the handgrip strength category was decrease from level good (46,5 - 55,5 kg) to moderate (36,5 - 46,0 kg) [10] after work.

Subjective physical fatigue is tiredness that felt by the operator after doing work or activity presented in a scale, as seen in Figure 3. The result accordance with handgrip strength which the 3rd Shift is the most cause fatigue in front shovel operator, with the highest Borg Scale of all.

Risk factors that are not related to work and are associated with indications of fatigue are environmental influences [6]. The environmental factors subjectively studied were temperature, noise, vibration, lighting, and dust of workplace; whom the operator fills in the questionnaire based on what they felt about their environmental conditions.
Figure 2. Handgrips strength each shift of front shovel operator

Figure 3. The subjective operator fatigue measured with Borg Scale

Figure 4. Subjective measure of environment conditions (a) Temperature and (b) Noise
The operator's work environment is in the front shovel cabin, where each unit is equipped with air conditioning. As seen in Figure 4a, the cabin was in neutral level for two Shifts and get chilly at 3rd Shift, even though some participant felt warm at 2nd Shift. Figure 4b shown the sounds surround workplace felt noisy at all Shifts and more operators perceived noisier at 2nd Shift.

![Figure 5. Subjective measure of environment conditions (a) Vibration and (b) Dust](image)

Figure 5a shown the vibration felt at all shifts comply with the study by [11], suggest measuring vibration levels to identify and assessment the risk of equipment is needed. On the other hand, seen in Figure 5b that the work environment was slightly dusty in 1st Shift but became dusty in 2nd Shift.

![Figure 6. Subjective measure of environment conditions of lighting/lumination](image)

Far away terrain, straight, and saturated requires operators to always be in high concentration when working (vigilance), especially when working at night. In addition to the risk terrain, continuous high concentrations are also caused by a lack of lighting at the worksite [6]. The result corresponded those study as seen in Figure 6, shown that 3rd Shift at the cabin was slightly dark. This could be one of the reasons the physical fatigue increased in 3rd Shift.
Table 4. Comparison of environment subjective measurement of the front shovel operators

| Variable | 1st Shift | 2nd Shift | 3rd Shift |
|----------|-----------|-----------|-----------|
| Temperature | 68% neutral | 64% neutral | 55% slightly cold |
| Noise | 50% noisy | 66% noisy | 63% noisy |
| Vibration | 57% vibrate | 78% vibrate | 75% vibrate |
| Lighting | 53% neutral | 41% neutral | 61% slightly dark |
| Dust | 60% slightly dusty | 72% dusty | 50% dusty |

Overall measurement of subjective environmental conditions can be seen in Table 4 to compare the results of the commonly perceived by operators. Based on [12], the condition of moderate workload and 8 hours of work is recommended to have a temperature of 28°C, a noise threshold of 85 dB, a whole-body vibration threshold of 0.8661 m/sec², with 100 lux of lighting. This results in Table 4 are accordingly with [6], most of the respondents who indicated experiencing severe fatigue felt that they were disturbed by the work environment. Work environment factors such as dusty air, hot air, noise, and workplace or vibrating work tools have an impact on indications of fatigue; especially related to the distance and breadth of eyesight if the road is not visible due to dust will interfere with driving ability. Operators who are exposed to noise more than 85 dB have a risk of 0.198 times higher of fatigue [13], and there is a positive association between whole-body vibration and low back disorders [11].

Table 5. Binary logistic regression analysis of variable handgrip strength and demographics

| Variables      | Coef. | Std. Err. | z      | P>|z| Sig. |
|----------------|-------|-----------|--------|-------|
| Employment     | -.0988| .5006     | -0.20  | 0.844 |
| Sleep time     | -.9412| .7951     | -1.18  | 0.236 |
| Smoking Habit  | -.2426| .9363     | -0.26  | 0.796 |
| Breakfast      | .7612 | .6753     | 1.13   | 0.260 |
| Constant       | 2.9332| 2.9875    | 0.98   | 0.326 |

Regression analysis of handgrip strength and demographics variable can be seen in Table 5. The results of bivariate statistical analysis showed that there was no significant relationship between handgrip strength and social demographic factors of the operators. The smoking habit result is comply the study by [4], there was no significant relation with muscle pain. However, on the contrary employment and sleep time have the indication of fatigue on other studies [6][13]. Participants who were indicated to have severe fatigue were work within 1 - 3 years, with a risk of 1.195 times higher for fatigue. Based on the results of those study, whose work duration was 1 - 3 years did not yet have a good rest period. If an adult has less than 5 hours sleep it will decrease the mental ability and have an impact on work performance, with a risk of 4.09 times greater for fatigue.
Eventhough the regression analysis did not conclude a significant relationship, there were very weak correlations between numbers of cigarettes and Borg scale (16.8%) and numbers of cigarettes and handgrip difference (15.1%) The positive correlation between numbers of cigarettes with both is possibly due to fatigue, because there are correlations between stress level with smoking behavior [14], psycological distress with smoking habit [15], and stress level with risk of musculoskeletal pain [4]. There was also weak correlation between age and handgrip difference (19.5%). The bigger handgrip differences mean the strength between pre-post work is significantly decreased; thus, the older operators will be higher strength differences. Low correlation between Borg scale and handgrip differences (42.6%) also be seen in the study; the higher strength differences will be higher perceived fatigue. Participants mean age were 40,5 years, and [16] concluded that after about the age of thirty the chances of developing a musculoskeletal disorder remain fairly consistent regardless of age. Nonetheless, according to [13] operators who have more than 10 years of work experience or who have aged over 40 years have a smaller incidence rate.

| Correlation          | Education | Employment | Slept | Smoking | Number of Cigarettes | Breakfast | Breakfast Menu | Age | Borg Scale |
|----------------------|-----------|------------|-------|---------|---------------------|-----------|----------------|-----|-------------|
| Borg Scale           | -0.384    | 0.097      | -0.035| -0.126  | 0.168               | 0.035     | 0.064          | -0.132|             |
| Handgrip difference  | -0.190    | 0.327      | 0.013 | -0.237  | 0.151               | -0.144    | -0.024         | 0.195| 0.426       |

Statistical test results shown by Table 7, working environment and their effect on the handgrip strength of the front shovel operators on every shift showed there were no significant relationship on the influence of the work environment on the handgrip strength of the operators. Statistical testing linear regression also conducted to determine the relationship between working environment conditions and their effects on subjective physical fatigue experienced by operators.
Table 8. Results of the Borg Scale and environmental factors linear regression

| Variable   | 1st Shift | 2nd Shift | 3rd Shift |
|------------|-----------|-----------|-----------|
|            | Sig.      | Sig.      | Sig.      |
| (Constant) | 0.096     | 0         | 0         |
| Temperature| 0.020     | 0.291     | 0.087     |
| Noise      | 0.728     | 0.895     | 0.523     |
| Vibration  | 0.813     | 0.614     | 0.040     |
| Lighting   | 0.067     | 0.321     | 0.706     |
| Dust       | 0.020     | 0.526     | 0.825     |

The results obtained from analysis shown on Table 8 that in 1st Shift which are significant and have an effect on subjective physical fatigue were temperature (p value = 0.02) and dust (p value = 0.02). This could be due to the first shift at 06.45 to 14.45 WITA, with known temperature in the morning was 27°C, afternoon 29°C, night 23°C, and maximum temperature was 31°C [17]. A hot condition above 30°C causes decreased consciousness and generally experience fatigue [13]. However, in 2nd Shift can be seen that there is no influence of the five factors on subjective physical fatigue. The 3rd Shift shows that only vibrations that affect subjective physical fatigue felt by workers after doing work (p value = 0.04). Driving these heavy machines in mine workings involve uneven terrain, changing slopes on haul road, needs careful speed control etc. all of which can influence level of exposures [11]. Bio-mechanical factors, vibration and heat stress were highlighted contributed to the health risks caused by poor ergonomics [18].

Musculoskeletal disorder place a significant burden on mining company finances, but in many cases largely preventable through workplace design, usage of correct tools, proper housekeeping and equipment modifications [16]. Based on this study, improvements need to be made so that operator’s comfort will increase. The results obtained from the overall data are still visible inconsistent results between environmental conditions against subjective physical fatigue, most likely due to the limited number of samples and differences in operator’s perceived their work condition. For further research, it is advisable to increase the number of samples, posture analysis, body discomfort/pain mapping, and measure the environmental conditions with quantitative data to improve a mining workers quality of life.

4. Conclusion
The results of this study indicate that in 28 front shovel operators have a high school education background (86%), with a work period of > 5 years (39%), the rest time is generally within 5-8 hours a day (71%), and 75% is smokers with the average number of cigarettes consumed in a day is 4-12 cigarettes (57%), generally having breakfast in the morning (89%) by consuming rice and side dishes (88%). The average strength of the operator's handgrip decreased from 48.32 kg (good) then after work was 35.58 kg (moderate); with a Borg scale after work was 13.25 (slightly heavy). The results of bivariate statistical analysis showed that there was no significant relationship between social demographic factors and muscle complaints experienced by the operator. However, there is a low correlation between Borg scale and handgrip strength (42.6%).

The environmental factors mostly felt by operators were neutral temperature, noisy, vibrate, neutral lighting, and dusty categories. The results of statistical analysis show that environmental factors at 1st Shift temperature and dust have a significant effect on the Borg scale, whereas on 3rd Shift only vibrations have a significant effect on the Borg scale. It can be concluded that environmental factors have a significant relationship with subjective physical fatigue, even though there was no significant effect on handgrip strength.
References

[1] Nazlina, Buchari and Ria S I 2008 Usulan Perancangan Postur Kerja dengan Menggunakan Pendekatan Biomekanika dan Fisiologi pada Aktivitas Pencetakan Batu Bata Seminar Nasional Teknik Industri dan Kongres BKSTI V

[2] Raliby, Widodo E M and Aman M 2008 Studi Intervensi Ergonomi dan Penilaian Tingkat Resiko Terhadap Pengrajin Pahat Batu di Sentra Industri Pahat Batu Prumpung Semin. Nas. Tek. Ind. dan Kongr. BKSTI V

[3] PT. Karya Master Mandiri Indonesia 2019 Pelatihan dan Sertifikasi Operator Front Shovel

[4] Basuki K 2009 Faktor Risiko Kejadian Low Back Pain Pada Operator Tambang Sebuah Perusahaan Tambang Nickel Di Sulawesi Selatan Indones. J. Heal. Promot. 4 115–21

[5] Yassierli 2017 Implementation of ergonomic programs to reduce sick leave due to low back pain among nickel mining operators Int. J. Ind. Ergon. 61 81–7

[6] Susilowati I H, Syaaf R Z, Satrya C, Hendra H and Baiduri B 2013 Pekerjaan Nonpekerjaan, dan Psikologi Sosial sebagai Penyebab Kelelahan Operator Alat Berat di Industi Pertambangan Batu Bara Kesmas Natl. Public Heal. J. 8 91

[7] Suma’mur P K 1987 Hiperkes, keselamatan kerja dan ergonomi (Jakarta: Muara Agung Dharma Bhakti)

[8] Tarwaka, Bakri S and Sudiajeng L 2004 Ergonomi untuk keselamatan, kesehatan kerja, dan produktivitas (Indonesia: UNIBA Press)

[9] Bridger R S 2008 Introduction to Ergonomics, Third Edition. (CRC Press)

[10] Fenanlampir A and Faraq M M 2015 Tes dan Pengukuran Dalam Olah Raga (Yogyakarta: CV. Andi Offset (Penerbit ANDI))

[11] Mandal B B and D. Manwar V 2017 Prevalence of musculoskeletal disorders among heavy earth moving machinery operators exposed to whole-body vibration in opencast mining Int. J. Community Med. Public Heal. 4 1566

[12] Indonesia M K R 2018 Peraturan Menteri Ketenagakerjaan Republik Indonesia Nomor 5 Tahun 2018 Tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja (Indonesia)

[13] Mulyani T 2012 Faktor-Faktor Yang Berhubungan Dengan Keluhan Fatigue Pada Operator Unit Hauling Coal Dan Overburden Di Pt Buma, Mitra Kerja Pt Berau Coal Lati Tanjung Redeb Kalimantan Timur Tahun 2012 (Universitas Indonesia)

[14] Arniati L N 2019 Hubungan Antara Tingkat Stres Dengan Perilaku Merokok Perawat Pria di RSUD Sukoharjo (Universitas Muhammadiyah Surakarta)

[15] Considine R, Tynan R, James C, Wiggers J, Lewin T, Inder K, Perkins D, Handley T and Kelly B 2017 The contribution of individual, social and work characteristics to employee mental health in a coal mining industry population PLoS One 12 1–15

[16] Weston E, Nasarwanji M F and Pollard J P 2016 Identification of Work-Related Musculoskeletal Disorders in Mining. J. safety, Heal. Environ. Res. 12 274–83

[17] Anon Prediksi BMKG, Cuaca Malili Pagi dan Siang Cerah Berawan, Malam Hujan - Tribun Timur

[18] Schutte P C 2005 Ergonomics in the South African mining industry J. South African Inst. Min. Metall. 105 369–72