# RISK ANALYSIS OF VIBRATION AND POSTURE TO MUSCULOSKELETAL DISCOMFORTS OF UNDERGROUND MINE DRILLING WORKERS CASE STUDY: PT. KARYA SAKTI PURNAMA

# *ANALISIS RISIKO GETARAN DAN POSTUR TUBUH TERHADAP* MUSCULOSKELETAL DISCOMFORTS *PADA PEKERJA PEMBORAN TAMBANG BAWAH TANAH STUSI KASUS: PT. KARYA SAKTI PURNAMA*

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**Abstract:** Undergound drilling workers who used jeg leg drill machine have musculoskeletal discomfort risk due to exposure of vibration and ergonomy factors. The purpose of this research is to analyze the risk of vibration and posture to musculoskeletal discomfort of drilling workers.Vibration measurement using Human Vibration Meter based on ISO 5349-2. Posture observation using BRIEF and QEC survey. musculoskeletal complaints by Cornell Musculoskeletal Discomfort Questionnaire. The measurement result showed that the average value of daily vibration exposure were exceed the threshold by range 11.0 to 21.62 $m/s^2$. Hbeam installation was the highest risk task based on BRIEF and QEC survey .The prevalence of complaints of the drilling workers was greater (100%) than controls (55%). Musculoskeletal discomfort were include discomfort, tingling, cramps, numbness and pain. The most complaints in hand was in A (62.5%) and B (45.8%) right hand area, and for the body was low back (62.5%). The frequency of complaints was generally 1-2 times last week (48.5%). Total of 57.1% of complaints are categorized as slightly uncomfortable and 85.7% the workers stated that the discomfort did not interrupt their job. According to statistical analysis, age and years of work have a significant correlation to musculoskeletal discomfort on hand and body. Based on statistical analysis, it could be concluded that the regression equation for musculoskeletal discomforts on hand using BRIEF and QEC methods were qeuialent, while the assessment of musculoskeletal discomforts on body need more homogenous group of age.

**Keywords**: vibration, posture, musculoskeletal dicomforts, drilling workers

***Abstrak:*** *Pekerja pemboran tambang bawah tanah yang menggunakan jeg leg drill machine memiliki risiko ketidaknyamanan muskuloskeletal (*musculoskeletal discomforts*) karena paparan getaran dan faktor ergonomi. Tujuan dari penelitian ini adalah untuk menganalisis risiko paparan getaran dan postur tubuh terhadap ketidaknyamanan muskuloskeletal pada pekerja pemboran. Pengukuran getaran menggunakan* Human Vibration Meter *berdasarkan ISO 5349-2. Pengamatan postur tubuh pekerja menggunakan BRIEF* survey *dan QEC* survey. *Keluhan muskuloskeletal berdasarkan* Cornell Musculoskeletal Discomfort Questionnaires. *Hasil pengukuran menunjukkan bahwa nilai rata-rata getaran harian yang diterima pekerja melebihi ambang batas dengan besar antara 11,0 – 21,62 $m/detik^2$. Evaluasi postur tubuh berdasarkan BRIEF dan QEC didapatkan bahwa pekerjaan dengan risiko tertinggi adalah pemasangan Hbeam. Prevalensi MSDs pada pekerja (100%) lebih banyak dibanding kelompok kontrol (75%). Keluhan MSDs yang dirasakan pekerja meliputi rasa nyeri, kesemutan, kram, kaku, mati rasa dan pegal-pegal. Keluhan pada tangan yang paling banyak dirasakan adalah pada area A kanan (62,5%), dan B kanan (45,8%), sedangkan badan adalah nyeri pinggang (62,5%). Frekuensi keluhan umunya dirasakan 1-2 kali pada minggu lalu (48,5%). Sebanyak 57,1% keluhan termasuk kategori sedikit tidak nyaman dan 85,7% pekerja menyatakan bahwa keluhan tidak mengganggu mereka saat bekerja. Berdasarkan analisis statistik dapat disimpulkan bahwa persamaan regresi untuk ketidaknyamanan muskuloskeletal pada tangan menggunakan metode BRIEF dan QEC menunjukkan hasil yang hampir setara sedangkan untuk penilaian ketidaknyamanan muskuloskeletal pada badan dibutuhkan pembatasan usia responden yang lebih homogen.*

***Kata kunci:*** *getaran, postur tubuh,* musculoskeletal discomforts, *pekerja pemboran*

# INTRODUCTION

The mining industry worldwide is currently experiencing an economic boom that is contributing to econimic recovery and social progress in many countries. In addition, public pressure to ensure safe and responsible mining is huge challages of any business or government. In a highly complex and uncertain environment, rigorous management risk remains indispensable in order to repel threats to the success of mining, include health risk for the miners. Risk analysis is nevertheless one of the biggest concern in the mining industry (Badri et al., 2013).

Mining is long recognized as being arduous and liable to injury and disease. One health risk in mining is musculoskeletal disorders. Musculoskeletal disorders inculde a goup of condition that involve the nerves, tendon, muscles, and supporting structures such as intervertebral disks. There is compelling evidence that work-related musculoskeletal disorders affect mineworkers to a greater degree than workers in other industries. A cross-sectional study has shown that India coalminers complaint about the development of musculoskeletal disorders at different body parts,like neck, shoulder, low back, wrist, and leg, as the result of ergonomic exposure (Bandyopadhyay et al., 2012). Musculoskeletal disorders required medically diagnosis therefore in this research musculoskeletal aches and pains assessed as musculoskeletal discomforts.

Musculoskeletal discomforts risk factors that are common to mining include awkward postures, forceful exertions (heavy or frequent lifting), forceful gripping, highly repetitive motions, jolting/jarring, vibration exposure (hand and arm), and contact stress (Wiehagen and Turin, 2004). There were significant associations between musculoskeletal injuries and ergonomic risk factor, such as working with the back bent and grasping an unsupported object (Kunda et al., 2013). Symptoms of vibration white finger were found in miners who operate vibration equipment for 14 years (Narini et al., 1993). Musculoskeletal discomfort risk also effected by individual characteristic. Mbutshu et al. (2014) have found that among vibration-exposed African cassava and corn millers who smoking have 2.4 times higher experiencing musculoskeletal symptoms than non smoking millers. The symptoms is 7.4 higher in young millers (10-17 years old) than in older millers.

Hagberg et al. (2006) stated that there was associations between vibration exposure among plant and machinery operators and the musculoskeletal symptoms. The prevalence of hand-arm vibration syndrome (HAV) in South African vibration-exposed gold miners was 15% with a mean latent period of 5,6 years (Nyantumbu et al., 2007). The prevalence and severity of different vibration-related pathologies are highly dependent on several factors, the main one being the vibration dose received, which depends on the intensity of vibration and the daily and cumulative duration of exposure (Gauthier et al., 2012).

Drilling is an important stage in undergound mine tunnel development. The objective is to open up an additional free face as first hole are detonated to improving the effectiveness and efficiency of the blasting (Hartman, 1897). In drilling process, PT. Karya Sakti Purnama (PT. KSP) workers used jack leg drill machine that cause mechanical vibration. The purpose of this research is to analyze the risk of vibration and posture to MSDs of drilling workers. The result can be used to control the vibration exposure and improve work posture in order to reducing the musculoskeletal discomfort risk at workers.

# METHODOLOGY

## Research Place Execution

This study was conducted in gold mine belongs to PT. Antam UBPE Pongkor. The mining use undergound method, consist of drilling, blasting, hauling, transportation, and backfilling. PT. KSP is one of PT. Antam's work partner that perform manual drilling.

**Research Tools and Materials**

Tools and materials used in this study include Human Vibration Meter, camera, BRIEF survey form, QEC survey form, Cornell Musculoskeletal Discomfort Questionnaires and worker questionnaire.

**Research Stages**

Respondents consist of 24 PT. KSP drilling workers and 24 other workers as control group who fulfill criteria as man, among 20-55 years old, and have minimal 6 months work experience. The total vibration measuring time should be at least one minute. A number of shorter duration samples should be taken in preference to single log duration measurement. For each operation, at least three samples should be taken as recomendation by ISO 5349-2 (2001) about Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration.

Posture measurement using BRIEF and QEC survey. BRIEF survey emphasizes on posture, force, duration and frequency. While QEC survey has worker assessment consist of work duration, visual needs, the use of vibration vehicle or tools, as well as the working difficulties. Posture was observed when workers perform drilling, scaling, and support installation.

The musculoskeletal discomfort questionnaire was based on Cornell Musculoskeletal Discomfort Questionnaries (CMDQ). The question about aches, pains, and discomfort assessed musculoskeletal pain in right and left hand, and also 11 different body regions (neck, shoulders, upper arms, elbows, forearms, upper back, lower back, hips/thighs/buttocks, knees, feet, and ankle. For all body parts, respondents were asked how often had experienced discomfort in that body part during the past week, how uncomfortable the region was (slightly, moderately, or very), and whether the discomfort interfered with wok activities. Beside that, interview and questionnaire were held to know individual characteristis such as age, years of work, body mass index, smoking and exercise habits.

**Analysis Stages**

The vibration total value was defined as **Equation 1** (ISO 5349-1, 2001).

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \qquad \textbf{(Equation 1)}$$

Where $a_{hv}$ is vibration total value (m/s$^2$) and $a_{hwx}$, $a_{hwy}$, $a_{hwz}$ is acceleration value for the x-, y-, and z-axes (m/s$^2$). The vibration during tools operation have different magnitude, the average vibration magnitude of a series N vibration magnitude samples is given by **Equation 2** (ISO 5349-2, 2001).

$$a_{hw} = \sqrt{\frac{1}{T}\sum_{j=1}^{N} a_{hvj}^2 t_j} \quad \text{as} \quad T = \sum_{j=1}^{N} t_j \qquad \textbf{(Equation 2)}$$

Where $A_{hw}$ is average vibration magnitude (m/s$^2$), $a_{hvj}$ is the measured vibration magnitude for sample j (m/second$^2$), dan $t_j$ measurement duration of sample j (second).

In posture assessment using BRIEF survey, each factor that fulfill the criteria of posture, force, duration, and frequency was given 1 score. More score obtained meaning that the task has more risk. Meanwhie the assessment using QEC, observation in body like back, shoulders, wrists, and neck was refer to worker assessment include the weight tools, work duration, and other risk. Every option has different score.

The result of CMDQ was calculated based on the guidelines (White, 2013). Frequency scores were assigned: never = 0, 1-2 times a week = 1.5; 3-4 times a week = 3.5; daily = 5; several times a day = 10. Discomfort score were assigned: slightly uncomfortable = 1; moderately uncomfortable = 2; very uncomfortable = 3. Working interference score were assigned: not at all = 1; slightly interfered = 2; substantially interfered = 3. Pain severity was obtained by multiplying the frequency, discomfort, and interference scores for each body part. Total body pain severity for an individual was obtained by summing all the body pain severity scores for that individual. Total hand pain scores were obtained by summing the hand pain severity scores for that individual. Total overall pain scores were obtained by summing the hand pain and body pain scores for that respondent.

**Analysis Stages**

The statistical analysis used is Mann Whitney test, correlation and regression test. Correlation is used to determine the effect of each individual characteristics of MSDs perceived by workers. While multiple regression was to determine the direction of the relation between independent and dependent variables.

## RESULTS AND DISCUSSIONS

**Characteristics of Respondents**

Test was conducted to determine te characteristics of respondent quality various attributes possessed by drilling workers and control group. Individual characteristics consist of age, years of work, body mass index (BMI), smoking habits, and excercise habits. Based on the Mann Whitney test result, all the p-value for all individual characteristics were > 0,05. Those value indicated that the average value of both goups are not significantly different (equivalent).

**Vibration Exposure**

Vibration exposed workers when drill a blast hole at the tunnel and rockbolt support installation. A group of 2-3 workers doing the job together so the average of duration exposure fos one workers was 1.9 hours per day. Daily vibration exposure were obtained by calculate measurement result using **Equation 1** dan **Equation 2**. Summary of daily exposure can be seen in **Table 1**.

**Table 1**. Summary of daily exposure ($a_{hw}$)

| No. of Respondents | $a_{hw}$ (m/s$^2$) | No. of Respondents | $a_{hw}$ (m/s$^2$) | No. of Respondents | $a_{hw}$ (m/s$^2$) |
|---|---|---|---|---|---|
| 1 | 13.60 | 9 | 11.03 | 17 | 17.44 |
| 2 | 12.77 | 10 | 14.42 | 18 | 16.82 |
| 3 | 13.12 | 11 | 14.02 | 19 | 18.45 |
| 4 | 14.56 | 12 | 14.94 | 20 | 21.62 |
| 5 | 16.40 | 13 | 16.20 | 21 | 12.54 |
| 6 | 14.28 | 14 | 13.99 | 22 | 15.35 |
| 7 | 15.45 | 15 | 11.00 | 23 | 13.66 |
| 8 | 13.96 | 16 | 18.05 | 24 | 16.29 |

Based on **Table 1**, the average value of daily vibration received by drilling workers ranged 11.0 to 21.62 m/s$^2$. That value has exceeded the threshold based on Kepmenaker No. 51 Tahun 1999 Tentang Nilai Ambang Batas Faktor Fisika Di Tempat Kerja, that threshold for exposure time of 1 hour and less than 2 hours per working day is 8 m/s$^2$. The difference of vibration exposure received by workers depend on workers ability, drilling infrastructure such as drilling machine, drill rod, and compressor. Beside, the worse quality of rocks need longer duration of drilling process.

### Workers Posture Evaluation

During drilling, there were three main posture that distinguished by drill hole positions, namely high, medium, and low hole. High hole drilling (PLT) was hole positions parallel with the head of workers or higher. Medium hole drilling (PLS) was hole positions parallel with chest and abdoment workers, while low hole drilling (PLR) was the position of lower hole of abdome to feet. In addition to drilling, the workers also have task of scaling (S) and supporting installation, like rockbolt (PR) and Hbeam (PH).

Scaling is tunnel roof cleaning by banging the roof and wall to drop vurnerable rocks that could be danger for the workers bellow ar around it. Rockbolt supporting installation basically has the same process with high hole drilling. The rockbolt was inserted into the drill rod then drilled into the hole that was previously made, therefore the risk assessement for rockbolt installation was same with high hole drilling. As for Hbeam supporting, installation was performed in goups of worker and also used heavy equipment like wheel loader to reposition the Hbeam in right location. Example of BRIEF score were cantained in **Table 2** and example of QEC score can be seen in **Table 3**.

**Table 2.** Example of BRIEF score

| No. | Body Parts | | Score | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Left | Right | PLT | PLS | PLR | S | PR | PH |
| 1 | Hand/wrist | Hand/wrist | 0-2 | 0-2 | 0-2 | 2-2 | 0-2 | 2-2 |
| 2 | Elbow | Elbow | 2-2 | 0-0 | 2-2 | 0-0 | 2-2 | 2-2 |
| 3 | Shoulder | Shoulder | 2-2 | 0-0 | 0-0 | 2-2 | 2-2 | 2-2 |
| 4 | Neck | | 2 | 2 | 2 | 2 | 2 | 2 |
| 5 | Back | | 2 | 2 | 2 | 0 | 2 | 0 |
| 6 | Leg | | 0 | 0 | 1 | 0 | 0 | 0 |
| **Total Score** | | | 14 | 6 | 11 | 10 | 14 | 14 |

**Table 3.** Example of QEC score

| No | Criteria | PLT | PLS | PLR | S | PR | PH |
|---|---|---|---|---|---|---|---|
| 1 | Back | 14 | 10 | 18 | 14 | 14 | 16 |
| 2 | Shoulder/ Arm | 26 | 22 | 22 | 22 | 26 | 28 |
| 3 | Hand / Wrist | 20 | 20 | 20 | 20 | 20 | 22 |
| 4 | Neck | 8 | 4 | 6 | 6 | 8 | 6 |
| 5 | Driving | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | Vibration | 4 | 4 | 4 | 1 | 4 | 1 |
| 7 | Working speed | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | Stress | 1 | 1 | 1 | 1 | 1 | 1 |
| **Total Score** | | 75 | 63 | 73 | 66 | 75 | 76 |

In BRIEF assessment, a score of 2 was include in medium risk category. Right hand and neck were the body part that always had medium risk in every task. The back also have the same score except on scaling process. While the result of QEC assessment shown that shoulder/are was body part that had moderate exposure level on all task. Based on BRIEF and QEC evaluation, Hbeam installation had the highest ergonomic risk.

**Musculoskeletal Complaints**

Musculoskeletal complaints were reported include discomfort, tingling, cramps, numbness and pain. The prevalence of musculoskeletal discomfort in drilling workers (100%) was higher than control group (75%), with odd ratio of 3 for discomfort on hand and 1.5 on body. **Figure 1** shows the prevalence of musculoskeletal complaints on the hand. The most complaints area were A (62.5%) and B (45.8%) on right hand. Complaints on the right hand was higher because right hand is used as the main hand for working, especially in holding drill machine, while the left hand only direct the positions. Pain on those areas are symptoms that usually appear as carpal tunnel syndrome (CTS). However, to make sure the symptoms required expert medical examination. Force, repetition, exposure to cold, and segmental vibration have all been shown to be work-related risk factor for CTS. Exposure to more than one of these factors synergistically increase the risk of developing CTS. Symptoms usually appear in the dominant hand or the hand suffering the most musculoskeletal load. Bilateral CTS is also possible, but in that case the symptoms are rarely of the same intensity in both hand (Patry et al., 1998).

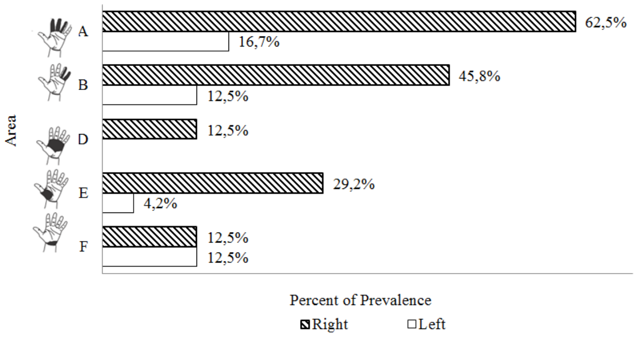


**Figure 1**. Prevalence of musculoskeletal complaints on hand

The highest discomfort on body part was low back (62,5%). Low back pain was the most common musculoskeletal disorders (Dias, 2014). Prevalence of low back pain is often higher among those exposed to handtransmitted vibration. It is possible that the vibration is transmitted through the arm and to the lumbar spine to directly cause the injury (Mansfield, 2005). **Figure 2** shown the prevalence of musculoskeletal discomfort On body.

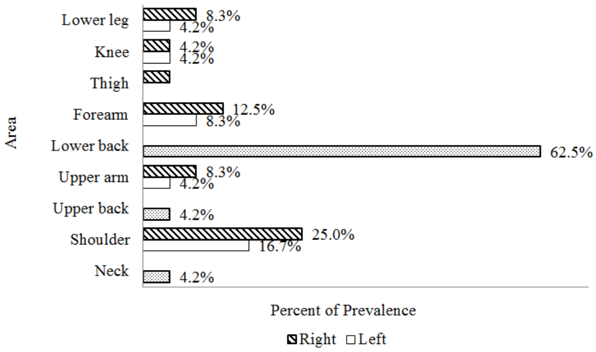


**Figure 2**. Prevalence of musculoskeletal discomfort on body

Based on **Figure 2**, besides low back, the second highest prevalnce is shoulders (25.0% for right shoulder and 16.7% for left shoulder). This can be result of using shoulders at many tasks, like drilling and scaling. Out of 55 coalminers in India, the maximum pain was identified at lower back. The presence of lower back pain was observe among 58.18% of miners. The repetitive operations and awkward posture were the risk factors for the development of work related musculoskeletal disorders in neck, shoulder and upper limb. Moreover, the repetitive operation of moving heavy substance and stoping posture continously were related significantly with the development of lower back pain at lower limb due to the long standing awkward posture. The miner in drill operation mostly complained about wrist and shoulder trouble (Bandyopadhyay et al., 2012).

Not all the musculoskeletal discomfort were felt every day. Most complaints occur 1-2 times last week (48.4%). The frequency of complaints of 3-4 times last week were 45.1%, and for once everyday were 6.6%. As the musculoskeletal discomfort severity, there were 57.1% of complaints that included in slightly uncomfortable category, moderately uncomfotable were 37.4%, and 5.5% were very uncomfortable. Differences in severity assisted by consulting the company doctor, for example, complaints of cramps and tingling with short duration was categorized as slightly uncomfortable. If the workers need to take a break after felt the complaints, it were categorized as moderately uncomfortable. Very uncomfotable categorize was the pain that made the workers took sick permit.

Many workers stated that musculoskeletal discomfort did not interfere their work (85.7%) because the complaint was felt at night, while 14.3% of workers feel disturbed during working. If the complaint was felt during working, the worker would take a rest then continue their work in order to achieve work target.

**Associations between Workers Characteristics and Musculoskeletal Discomfort**

The correlation of worker characteristics toward musculoskeletal discomfort was obtained by Spearman test using SPSS. Based on the result of the test, p-value between age and musculoskeletal discomfort On hand and body is 0.004 ($p<0.05$). That means there was a significant correlation between the variable of age with musculoskeletal discomfort symptoms in hands and body. For variable year of work, there was also a significant association to musculoskeletal discomfort in hand and also in body. The result of the test was obtained p-value was 0.010 ($p<0.05$). Similar result was found for musculoskeletal discomfort on the body, p-value was 0.005 ($p<0.05$).

By Spearman correlation analysis for body mass index (BMI), smoking habits and exercise habits variable had no real relationship between toward musculoskeletal discomfort on hand and musculoskeletal discomfort on body. On **Figure 3** can be seen that the complaints of 20-29 years old worker who had ≥ 5 years of work (6) were higher than the complaints of workers who had ≤ 2 years of work (5) at the same age group. Total varioation of musculoskeletal discomfort in 40-49 years old workers increase along with the years of work. The group of 50-55 years old workers had ≥ 5 years of work and reported the most variation complaints of body part that had musculoskeletal discomfort. This result showed that group of 50-55 years old workers had the highest risk of musculoskeletal discomfort.

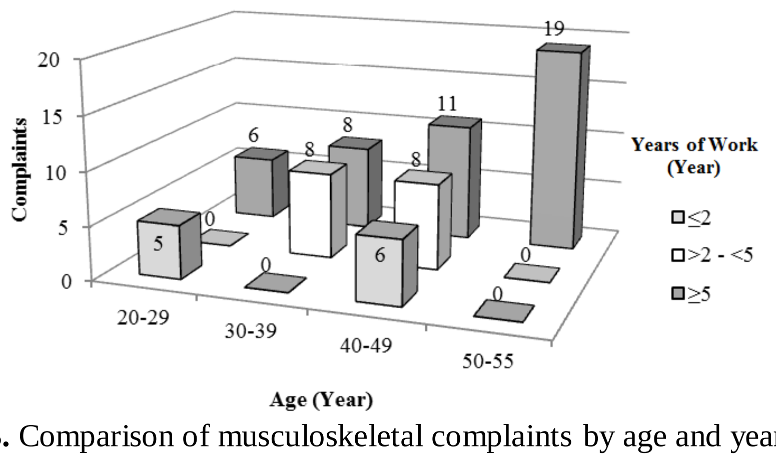


**Figure 3.** Comparison of musculoskeletal complaints by age and year of work

**Effect of Vibration and Posture in Musculoskeletal Discomfort**

Muscles exposed to vibration can be exhibit a tonic vibration reflex (TVR) in the form of a gradually increaseing involuntary contraction. If a muscle moderately active, vibrating its tendon cause a gradual increase in its activity and stimultaneous decrease in the activity of its antagonists. The result are either slow joint movement or a corresponding change in active tension (Amstrong et al., 1987). The muscle contracts as long as the mucle is in contact with the vibrating souce. Workers may use higher grip force to accomplish a job because of the influence of the TVR and decreased tacticle sensation in the finger as a result of prolonged exposure (Sanders, 2004). The awkward wrist posture combined with an increased muscle effort and a vibration exposure higher than the standart, may be an indication a particular risk of developing musculoskeletal discomfort in the wrist (Gauthier et al., 2012).

Multiple regression was used to determine the effect of vibration and posture in musculoskeletal discomfort simultaneously. Analysis was conducted on high hole drilling posture because it had the higest task score on the assessment of BRIEF and QEC survey. In addition to vibration and posture, the age and year of work variables were also included in the regression analysis because it have been shown had a significant relatioship to musculoskeletal discomfort on hand and bosy. Result of the analysis can be found in **Table 4**.

**Table 4.** Multivariate regression equation of musculoskeletal discomfort

| | **Equation** | |
|---|---|---|
| Musculoskeletal discomforts on hand | | |
| BRIEF : | Y = -19,953 + 0,087 X1 + 0,277 X2 + 1,076 X3 + 0,544 X4 (**Equation 3**) | Y = Discomforts on hand<br>X1 = Age<br>X2 = Year of work<br>X3 = Vibration<br>X4 = Posture |
| QEC : | Y = -18,295 + 0,106 X1 + 0,328 X2 + 1,107 X3 + 0,075 X4 (**Equation 4**) | |
| Musculoskeletal discomforts on body | | |
| BRIEF : | Y = -13,494 + 0,254 X1 + 0,444 X2 + 0,665 X3 + 0,054 X4 (**Equation 5**) | Y = Discomfort on body<br>X1 = Age<br>X2 = Year of work<br>X3 = Vibration<br>X4 = Posture |
| QEC : | Y = -41,854 + 0,155 X1 + 0,338 X2 + 0,278 X3 + 0,553 X4 (**Equation 6**) | |

The results of regression analysis to musculoskeletal discomfort on hand using BRIEF and QEC method shown similar result, that four independent variables (age, year of work, vibration and posture) had significant influence conjuctly. On **Equation 3** and **Equation 4**, it showed taht the constants of age, year of work, vibration and posture variable using BRIEF and QEC methods had equivalent value. If the highest of year of work variables (12 years) was calculated on both equations, assuming other variables to be zero, the score obtained for musculoskeletal discomfort on hand were almost similar (scoreof 3.32 for BRIEF method and 3.94 for QEC method). Similar results were also obtained in the calculation of age and vibration variables. While for posture variables, the discomfort score of BRIEF (8.7) was slightly higher than QEC (5.63). The coefficient of determination on BRIEF method (0.473) also did not much differ compared to QEC method (0.467). Therefore, both BRIEF and QEC methods were relevant to measured the musculoskeletal discomforts on hand.

Based on coefficient of determination for musculoskeletal discomfort on body (**Equation 5** and **Equation 6**), percentage of influence for age, years of work, vibration and BRIEF posture variables respectively were 23.1%, 11.4%, 14,5% and 0.6%. The calculation on QEC method also showed a high percentage age variables influence, as 14.2%. age affect strength and endurance of muscle (Tarkawa et al, 2004 in Purnama, 2015). It wasin line with **Figure 3** where the number of body part with musculoskeletal complaints increase as the older worker on group of more tha 5 years of work. In this regression model, the age variables causing the influence of other variables less visible, so it was necessary to decided the restriction of workers age group in the study of musculoskeletal discomforts on body. For example, using a group of 40-49 years old workers where had clear difference of musculoskeletal complaints based on year of work (**Figure 3**).

If the higest value in posture score inserted in **Equation 5** and **Equation 6**, assuming other variables to zero, then the results were a score of 0.86 on musculoskeletal discomforts using BRIEF method and 41.48 using QEC method. The difference was caused by different factors of assessment. Assessment on BRIEF method just depend on four factors, that was posture, force, duration and frequency, resulting not much different score. While QEC method had more detailed categories, for example on back posture was devided into categories 'almost neutral' ($<20^0$), 'slightly flexed' ($20^0$-$60^0$) and 'excessively flexed' ($>60^0$) so the value obtained more represent worker's posture. Therefore QEC method was better in measurement posture to assess the musculoskeletal discomforts on body.

## CONCLUSIONS

The average value of daily vibration received by drilling workers ranged 11.0 to 21.62 $m/s^2$. That value has exceeded the threshold based on Kepmenaker No. 51 Tahun 1999 Tentang Nilai Ambang Batas Faktor Fisika Di Tempat Kerja. Based on BRIEF and QEC evaluation, Hbeam installation had the highest ergonomic risk. The most area with musculoskeletal complaints in hand were A (62.5%) and B (45.8%) on right hand. Beside, the highest complaints on body part was low back (62.5%).

The result of the correlation test shown that there are a significant correlation of age and year of work. For age variable, p-value between musculoskeletal discomfort in hand and body is 0.004 ($p < 0.05$). Meanwhile for variable year of work, the test was obtained p-value of 0.010 ($p < 0.05$) for musculoskeletal discomfort in hand and 0.005 ($p < 0.05$) for musculoskeletal discomfort in body. Whereas there are no real relationship between other variables (BMI, smoking habits, and exercise habits) with musculoskeletal discomfort in hand as well as on body.

The result of bivariate correlation showed that age and years of work variables had significant relationship to musculoskeletal discomfort on hand and body. Based on statistical analysis it could be concluded that the regression equation for musculoskeletal discomforts on hand using BRIEF and QEC method showed equivalent results, while for the musculoskeletal discomforts on body need more homogen age group of respondents.

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