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An Approach to Work Design: In-Depth Audit to Determine the Modifiers of Musculoskeletal Disorder Symptom Among Vehicle Maintenance Personnel

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ABSTRACT

Vehicle maintenance personnel maintain, install, dismantle and repair as well as use hand tools in the nature of their job. A study in this domain has its complexities as there are not many research regarding the vehicle maintenance industry. The purpose of this paper was to identify the factors and their relationships towards the development of musculoskeletal disorder (MSDs) among vehicle maintenance workers. Using a self-reported questionnaire, 150 participants from workshops in Malaysia were involved in this study. They consisted of 50 workers maintain cars, 50 workers maintain four-wheel vehicles, and 50 workers maintain buses. The exclusion criterion was the participant has not been involved in accidents that caused injuries such as bone fractures as well as tears in joints, ligaments, and muscles for the past 12 months. Statistical analysis was performed to assess the impact of risk factors on MSD prevalence. Through regression analysis, it was revealed that psychosocial, temperature, and posture factors were associated with symptoms of MSD prevalence with $p < 0.05$. Age, working hours, type of vehicle repair and body mass index also showed a significant relationship with MSD prevalence. Concerning the sources of risk, related factors, mechanism of injury, and potential intervention strategies to reduce the risk, this paper will focus on the causes, nature, severity, and degree of work-relatedness of MSDs. This identification of risk factors among vehicle maintenance workers can be used to better characterise the magnitude of the problem and formulate targeted prevention strategies with improved surveillance and more accurate data collection.

Keywords: Mechanic worker; automotive; maintenance; safety; health

INTRODUCTION

There are a number of factors to be considered as work stressors among employees. The World Health Organisation mentioned that work-related conditions can be caused by work exposures and non-work factors, such as the physical, organisational and social aspects of work and the workplace (WHO 2016). The physical and social aspects of life outside the workplace may include physical activities (sports, household work) and economic (incentives and cultural value). In addition, other non-work factors due to the physical and psychological characteristics of the individual may relate to different age, gender, body mass index, personal habits which include smoking, and probably some aspects of genetically determined predispositions (Zakerian & Subramaniam, 2011; National Research Council, 2001). According to the Ministry of Domestic Trade and Consumer Affairs (KPDNKK) there are about 53,000 workshop in Malaysia in 2017, with 30,000 of them registered with KPDNKK.

For the last 20 years, MSDs have been a major cause of work-related disease in many countries (Woolf et al., 2012). MSDs are injuries and disorders that affect the human body's movement or musculoskeletal system (Daniels, 2015). The explanation for many MSD situation (working environment and repetition) could lie in a new balance between biomechanical and psycho-social factors (Gallagher & Heberger, 2013; Collins & O'Sullivan, 2015; Neupane et al., 2015; Nicolette, 2015; Bonzini et al., 2015). Work-related muscle pain is reported frequently occur at the neck and shoulder, forearm, and lower back (Top et al., 1996; Hildebrandt et al., 1996; Oliveira et al., 2012; Singh et al., 2015; Abaraogu et al., 2016). There is much confusion concerning the classification of pain and specification of diagnostic criteria. It is the corner-stone of public health and shape policy decisions and evidence-based practice by identifying the risk factors for symptoms and targets for preventive healthcare (Kuijer et al., 2012).

Work-related MSD issues among vehicle maintenance mechanics are quite prevalent and high in this work sector (Abaraogu et al., 2016). Vehicle maintenance workers mostly work in awkward postures such as kneeling, bending and flexing on a hard floor. Based on past studies, individuals who

continuously apply these postures tend to suffer from MSD pain, particularly back pain (Abaraogu et al., 2016; Nur et al., 2014). In addition, maintenance workers are involved in assembly tasks that require high focus and repetitive movements. Generally, MSDs continue to be a tremendous burden in industry due to cost of treatment and low productivity of the worker (Deros et al., 2014; Dunning et al., 2010).

The assessment and evaluation methods for different exposures, their effectiveness as well as reliability are the other problems encountered. There is a reference frame that is specific to each country and system which involves internal and external factors such as public health, norm in the society, occupational health and safety in workplace including rules and regulations, and health care system. This frame may modify the risk factors and outcome followed by differences between low- and high-income countries.

Various differing theories have been developed to explain the increasing inequality between countries, such as the culture of poverty thesis and modernity theory, modern value system and industrialising (March et al., 2014; Beer & Boswell, 2015; Ehrenberg & Smith, 2016). This affected the research developed on each country by the different results and validities obtained.

Therefore, this study was performed to investigate the factors that are associated with MSDs. The prevalence of the MSD problem among workers performing repair and maintenance tasks in automotive companies, particularly in workshops is presented in this paper. The result of this study will be used to further investigate the effect of the MSD symptoms or discomfort on the workers' performance.

METHODOLOGY

This study was focused on vehicle maintenance workers in Peninsular Malaysia. There were three categories of vehicles that have been investigated in this study; cars, buses and four-wheel vehicle. Ethical approval was obtained from the Universiti Kebangsaan Malaysia ethic committees (reference series UKM PPl/111/8/JEP-2016-200).

Participants

One hundred and fifty male participants between the ages of 18–60 years, with 50 each (convenience sampling) working on a type of vehicle out of three were recruited for this study. Data was collected through a survey questionnaire which was of a cross-sectional descriptive design. A total of 20 general garages or workshops for vehicle maintenance in Peninsular Malaysia that specialised in repairing the three types of vehicles (passenger cars, multi-purpose vehicles, and buses) were chosen in this study. Most of the workers were interviewed by the researchers during the questionnaire answering session in order to avoid the bias response among them. The study population included all full-time employees at the vehicle maintenance sites. The participants were fully informed about the data collection procedures and protocol. To qualify as a participant, an individual should have worked as a mechanic with at least six months prior experience. The worker was excluded if he had a history of accidents or incidents which caused bone fractures and tears in the ligaments, joints and muscles.

Questionnaire Design

The content of the questionnaire was divided into Section A: personal information (age, height, weight and level of education), Section B: job description, Section C: general medical information, Section D: Job Content Questionnaire (JCQ), Section E: General Health Question (GHQ-12), and Section F: MSDs Nordic questionnaire. The Nordic questionnaire was adopted from Kuorinka et al. (1987) and translated into Malay. The validity and reliability of the questionnaire were sorted from different previous studies in MSD and by academic and industrial experts in the field. Figure 1 illustrates the flow of method used in this paper and Figure 2 shows part of the observation in the actual workshop.

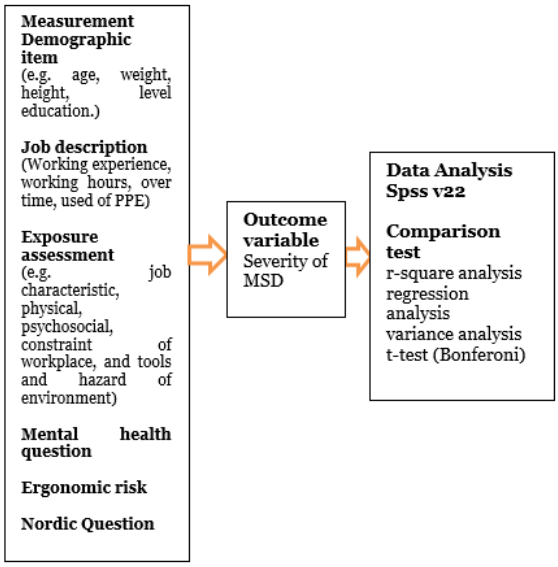

FIGURE 1. The methodology flowchart

FIGURE. 2. Observation at the workshop

Data Analysis

A cross sectional descriptive design was used in this study which employed 150 participants comprising vehicle maintenance workers. Random sampling was used where there are three populations namely passenger vehicle maintenance workers, four-wheel drive maintenance workers and bus maintenance workers. Balanced sampling is performed on condition that the refinery is a qualified worker who is not injured (Torpet, 1996; Monney et al., 2014; Moradi et al., 2017). Data analysis was carried out by using Statistical Package for Social Sciences version 22. Descriptive analysis was used to analyse the reports of demographic, job history as well as prevalence level of MSDs among workers. The t-test was performed to see the relationship between the factors associated with MSDs interference. One-way ANOVA tests were conducted to identify the differences between the variables studied. If differences were significantly apparent further tests should be performed either using the Bonferroni test (for the same variant) or the Games-Howell test (variance is not the same).

RESULTS

Personal and job characteristics of participants

A total of 150 workers who maintained passenger cars (50 respondents maintained passenger cars), four-wheel drives (50 respondents), and buses (50 respondents maintained buses) were included in this study. Workers with a history of accidents at work or at home, during exercise, or on-road which caused injuries such as bone fractures, tears in joints, tendons, ligaments, and muscles, and broken limbs were excluded. Table 1 illustrates the demographic data and job description. The respondents' age are between 18–60 years old, 51.3% of the workers have a certificate of education, and the monthly incomes of car maintenance workers in Malaysia is between RM 900–1500 (74%). 72% of the workers have a normal weight, receive work incentives (80%), 50.7% are smokers, while the rest are called passive smokers as all the workshops contain smokers. On average, the workers smoke 5 cigarettes per day (80%) and have smoked for over 5 years (78.7%). Most of the employees did part time jobs (52.7%) and work for ≤ 8 hours per day (88.7%). Most workers did not use the personal protective equipment as provided. There were no chronic symptoms reported among them, except for one person who was suffering from diabetes.

TABLE 1. Personal and job characteristics

	n	%
Age (years)		
<30	96	64.0
31-41	35	23.3
>40	19	12.7
Daily working hours		
8 hours	133	88.0
>8 hours	17	11.3
Marital status		
Single	83	55.3
Married	61	40.7
Divorce	6	4.0
Educational level		
PMR	4	2.7
SPM	28	18.7
STPM/ Skill Certified	77	51.3
Diploma	38	25.3
Degree	3	2.0
BMI		
Underweight	8	5.3
Normal weight	108	72.0
Overweight	31	20.7
Class 1 obese	3	2.0
Ergonomic risk		
Twisting head/ body	125	83.3
Bending	144	96.0
Squatting	136	90.7
Flexing	147	98.0
Over reaching	138	92.0
Repetitive movement	136	90.7
Sustained position for a long time	139	92.7
Manual handling		
Lift load	150	100.0
Push load	149	99.3
Pull load	147	98.0

For the job content section, 86% of the employees agreed that their work is a day-to-day repetition and 90.7% said that their job requires basic skills. About 94.7% of the employees claimed that they did not have enough time to complete their task and 94.7% of them stated that their task requires a high level of focus. Most workers (69.3%) stated that their employers care about them, but some complained that they are not happy with their employers. Colleagues play an important role of which 92.7% claimed their colleagues are friendly, thus helps in the development of a positive workplace culture.

Relationship analysis (psychosocial, temperature, and posture)

The effects of psychosocial, temperature, and posture towards the severity of MSDs among vehicle maintenance workers were analysed. The psychosocial factor was divided into six groups which were 1) work and task with 10 items, 2) psychology demand with 9 items under it, 3) employer with 4 items, 4) colleagues with 5 items under it, 5) work expectation with 6 items, and 6) job satisfaction with 5 items. There were 39 sub-items with 5 Likert scale ranging from strongly agree to strongly disagree. The temperature factor applied two conditions which were working in hot and cold conditions. Four frequency scales were used, 1 = never, 2 = one to two times, 3 = three to five times, and 4 = always (which is more than five times a day). Posture factors are the head or body twisting, bending, squat, kneeling, reaching, flexing, lifted, pushing and pulling a load, working in a static position for a certain time (long hours), and working in a narrow space. This factor used a frequency scale similar to the temperature factor. The determination coefficient (R-squared) test was performed to determine the sum of variables of the dependent variable as described by the independent variables (psychosocial, temperature, and posture).

A one-way ANOVA test (Table 2) was conducted to identify the difference between psychosocial, temperature, and posture to the severity and nature. The results show that there is a significant difference between psychosocial, temperature, and posture on the severity and the nature (df 2,147 = 9,220, $p < 0.05$). In conclusion, there is a difference between psychosocial, temperature, and position on the severity and the nature.

TABLE 2. Variance analysis (ANOVA test)

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	2.034	3	.678		
Residual	18.584	146	.127	5.328	.002 [b]
Total	20.618	149			

The results from the double regression analysis (Table 3) clearly demonstrate the beta value and overall importance of each variable in this study. $\beta 0 = 3.252$ indicates that when there is no change in the independent variables (position, temperature, and psychosocial), the dependent variable will remain at the level of 3.252. Based on Figure 4, $\beta 1 = 0.210$ shows that for every unit increase in position, the risk of skeletal muscle pain will increase by 0.210. Coefficient $\beta 1$ is significant ($t = 3.073$, df 2.147 = 9.220, $p < 0.05$). Next, $\beta 2 = -0.237$ indicates that for each unit increase in temperature, it will cause the risk of skeletal muscle symptom to increase by 0.237. Coefficient $\beta 2$ is significant ($t = 2.263$, df 2.147 = 9.220, $p < 0.05$). The values of $\beta 3 = 0.017$ indicates that in every social psychiatric increase, there is an increased risk of skeletal muscle symptom by 0.017. Coefficient $\beta 3$ is not significant ($t = 0.243$, df 2.147 = 9.220, $p > 0.05$).

TABLE 3. Double regression analysis

Model	Unstandardised Coefficients		Standardised Coefficients	*t*	Sig.
	B	SE	Beta		
(Constant)	3.25	.32		10.17	.000
MEAN_POSTURE	.21	.07	.244	3.07	.003
MEAN_TEMP	.24	.11	.179	2.26	.025
MEAN_PSYCHO_SOCIAL	.02	.07	.019	.24	.808

a. Dependent Variable: MEAN_MSDs Risk

Age Impact on MSD risk

An independent t-test was conducted (Table 4) to identify the relationship between age and risk of skeletal muscle symptom. The results show that there is a significant relationship between age and risk of skeletal muscle symptom (df 2.147 = 9.220, $p < 0.05$). The results show that the risk of skeletal muscle symptom among respondents below 30 years old (2.59 ± 0.42) is lower than of those in the 31–40 age bracket (2.87 ± 0.17) and those above 40 years old (2.81 ± 0.18). In view of this, it is concluded that the older the worker, the higher the risk for skeletal muscle symptom.

TABLE 4. Variance analysis on age

Age (years old)	*N*	Mean	*SD*	Sig.
Less than 30	96	2.59	0.42	
31–40	35	2.87	0.17	
Above 40	19	2.81	0.18	0.000
Total	150	2.68	0.37	

df = 2,147

Analysis on ratio comparison of risk-based muscular symptoms based on age

The results of the analysis (Table 5) indicate that the risk of skeletal muscle symptom is influenced by age. Only a few items are significantly less than at 30 years *31–40 years old (p-value = 0.00, < 0.05), less than 30 years *above 40 years old (p-value = 0.047, < 0.05) and 31–40 years old *(p-value = 0.00, < 0.05).

TABLE 5. Crosstab analysis

(I) Age (years old)		M D (I-J)	*SE*	Sig.	95% Confidence Interval	
					LB	UB
Less than 30	31–40	-.276*	.070	.000	-.445	-.108
	Above 40	-.216*	.089	.047	-.431	-.002
31–40	Less than 30	.276*	.070	.000	.108	.445
	Above 40	.059	.101	1.000	-.184	.303
Above 40	Less than 30	.216*	.089	.047	.002	.431
	31–40	-.059	.101	1.000	-.303	.184

*The mean difference is significant at the 0.05 level.

Effects of working hours on the risk of muscular symptoms

An independent t-test was carried out (Table 6) to assess the relationship between the risk of skeletal muscle pain and duration of work. The independent t-test results show that there is a significant relationship between working period and skeletal muscle disease risk (df 2,147 = 9,220, $p < 0.05$). Respondents who worked more than 8 hours (2.90 ± 0.13) are found to have a higher risk than respondents who worked for up to 8 hours (2.65 ± 0.38). In conclusion, the skeletal muscle symptom is related to the duration of working hours, where the longer the working time, the higher the risk of skeletal muscle symptom.

TABLE 6. T-test analysis

Severity	*N*	Mean	*SD*	*t*	*df*	Sig.(2 tailed)
8 hours	133	2.65	0.38	-5.19	59.97	.000
>8 hours	17	2.90	0.13			

Impact of vehicle type on the risk of muscular symptoms

The F-test was conducted to identify the relationship between the type of vehicle being maintained and the risk of skeletal muscle symptom. The test results (Table 7) show that there is a significant correlation between the type of vehicle being maintained and the risk of skeletal muscle symptom (df 2.147 = 22.523, $p < 0.05$). The results from the Bonferroni test analysis show that the risk of skeletal muscle symptom among respondents who maintain buses (2.45 ± 0.41) was significantly lower than those who maintain passenger cars (2.71 ± 0.29) and four-wheel drives (2.89 ± 0.26). In view of this, it is concluded that the differences in the type of vehicle being maintained are contributing to the risk of skeletal muscle symptom.

TABLE 7. F-test for the type of vehicle being maintained

Severity	***N***	**Mean**	***SD***	**Sig.**
Bus	50	2.45	0.41	0.00
Car	50	2.71	0.29	
Four-wheel drive	50	2.89	0.26	
Total	150	2.68	0.37	

Relationship between body mass index (BMI) and risk of muscular symptoms

The one-way ANOVA test was done to determine the impact of BMI on the risk of skeletal muscle symptom. The results in Table 8) show that there is a significant correlation between BMI and skeletal muscle symptom risk (df 3.146 = 3.328, $p < 0.05$). It indicates that the BMI factor is an important factor in describing the risk of skeletal muscle symptom among respondents. Based on the comparative test, the risk of skeletal muscle disease among overweight respondents (2.86 ± 0.27) is significantly higher than respondents with normal weight (2.63 ± 0.39).

TABLE 8. ANOVA analysis for BMI

BMI	*N*	Mean	*SD*	Sig.
Underweight	8	2.60	0.35	.009
Normal weight	108	2.63	0.39	
Overweight	31	2.86	0.27	
Class 1 obese	3	2.93	0.13	
Total	150	2.68	0.37	

Df = 3.146

DISCUSSION

The prevalence of MSDs based on vehicle maintenance group were found to be 69% for passenger vehicle workers, 82% for four-wheel drive maintenance workers, and 83% for bus maintenance workers. The high prevalence among vehicle maintenance workers in Malaysia has been reported previously (Nasaruddin et al., 2014). There was a significant relationship found in the psychosocial factor relating to the interrelation of social factors and individual thoughts and behaviour which are closely related in developing MSDs among workers. The same result was reported by past research regarding the relationship among them (Oliveira et al., 2012).

The ergonomic risk in the workplace was found to be high at more than 80% and classified as awkward positions such as twisting, bending,

squatting, flexing and over reaching. There was a significant relation found between MSDs and factors like psychosocial, working posture and high environmental temperature.

In work task factors which was described as the body's position and manual handling while working, most of the workers agreed that their work requires them to lift a load (86.7%) and in awkward positions (89.3%). Most of them suffer from skeletal disorders within 12 months, but there are also symptoms as early as 7 days, indicating that skeletal muscle symptom is rapid and gradual.

There was a significant relation found between age and MSDs, where workers aged more than 30 years old are at a slightly high risk compared to workers in their 20s. Vyas et al. (2011) reported that age plays an important role in developing MSDs either by medical explanation in association with the bone as well as from physical load mostly from manual handling in the workplace. Body mass index can be categorised similarly to age which is a personal factor with the results concluding that heavier workers are more at risk to get MSDs. Previous research had identified the effect of weight regarding MSDs (Oakman et al., 2016).

In Malaysia, vehicle maintenance workers work up to 8 hours per day. As reported by (Abaraogu et al., 2016), those who work up to 5 hours a day have a high risk of developing MSDs. The type of vehicle being maintained has also been proven to have a significant relationship with MSDs as workers that maintain four-wheel drive vehicles have a higher risk compared to those who work on buses but nearly the same when compared with passenger car maintenance workers. This is due to the appearance of each vehicle which is different in shape and height, where buses are classified as utility vehicles and are not produced in high numbers compared to the other two types.

A conclusion that can be drawn from the interviews carried out among the workers is that pain in the waist occurs among workers that repair four-wheel drives, while upper back pain occurs among workers that repair passenger cars. All factors mentioned are significantly related to MSD risk. Age, duration of work, and BMI are among the factors which give significant results $p < 0.05$, and have been discussed in previous studies (Abaraogu et al., 2016; Oakman et al., 2016; Faghri et al., 2014).

Self-report prevalence in this study may prone to recall bias. Again this cross sectional study as best to explained the relationship regarding MSDs risk with this type of jobs.

CONCLUSIONS

Related factors such as psychosocial, working posture, environmental temperature, age, body mass index, working hours, and type of vehicle being maintained have been identified as related to the development of MSDs among vehicle maintenance workers. To our knowledge there are limited studies on the different types of vehicle being maintained which is one of the factors contributing to musculoskeletal symptoms among vehicle maintenance workers. The results show that type of vehicle produces different effects on workers' health. In addition, automotive maintenance personnel in Malaysia are likely to be exposed to a variety of ergonomic hazards and risk factors. Therefore, ergonomics awareness among employers and employees with training and information sharing should be increased to reduce the prevalence of MSDs. In future muscle study should be carried out to related between posture of this type of work with MSDs risk.

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