ORIGINAL ARTICLE

EVALUATION OF DIFFERENT AUTOMOTIVE MAINTENANCE ACTIVITIES ON THE WORKER POSTURES: AN OBJECTIVE ASSESSMENT

Shukriah ABDULLAH[1*], Nor Kamaliana KHAMIS[1], Jaharah AB GHANI[1]

[1]*Department of Mechanical and Manufacturing Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia.*
** (email:shuk.kye@gmail.com)*

ABSTRACT

Vehicle maintenance workers are exposed to a variety of hazards and risks in the workplace, including physical hazards, excessive heat, heavy workload, awkward movements and also a poor psycho-social environment. These conditions can result in musculoskeletal disorders (MSDs) and injuries. In Malaysia, MSDs is among the highest occupational injury problem, accounting for 87.4%. The objective of this paper is to identify the different type of working posture which can become problematic to the workers due to ache of muscle, which can be a high risk in developing musculoskeletal disorder, due to high repetitiveness task associated with long work durations and weight force. By using electromyography method, several activities while repairing the vehicle have been chosen, based on the workers feedback.

Keywords*: Musculoskeletal disorder, automotive industry, safety and health, ergonomics in workplace, Semg SEMG.*

INTRODUCTION

The Vehicle maintenance workers work in service sectors and repair shops. They may also work for vehicle fleet operators that have their own servicing and repair garages. The responsibilities of these workers include: executing scheduled servicing and essential maintenance on cars, vans and light trucks. The workers duties and responsibilities require a familiarity with all aspects of vehicle operation and must understand the functions of the major components and systems. They must be competent at using servicing and maintenance tools and equipment, and be familiar with the different categories of lubricants and service parts in another word this type of worker need good interpersonal skills to discuss vehicle problems and solutions with car owners. The risks and hazards mainly associated with the garage environment is manual handling of the load while maintaining the vehicle. Recently the prevalence of MSDs among vehicle maintenance workers is high and mostly associated with lethargy, tiredness and discomfort on body parts (Abarougu et al., 2016, Nasaruddin et al., 2014, Moradi et al., 2017). Regarding the work task in this area, the workers are indeed in high risk of injury (López & Rubio, 2016, Monney et al., 2014, Sambo et al., 2012).

In Malaysia, based on the data updated in the second quarter of 2016, the number of motor vehicle workers registered an increase of 2.5 per cent or 6,093 compared to the corresponding quarter of the previous year (DOSM, 2017). As this type of work can be classified as an artisan which required skilled, the main factor than can be considered contributing to the MSDs problem is the posture while maintening the vehicle and this is associated with manual handling of the load. While the principle of ergonomic which states, designing the work task to fit the worker by keeping the capabilities and limitation of worker body, this type of work does not seem to be designed for this type of worker. The workers are required to fit to the task, for example, while checking a problem in the vehicle engine, the size of the vehicles are different in terms of height and width. While performing the task, workers can be seen to adjust their bodies by bending and over stretching. This type of action results in an awkward posture which can result in body ache and cause discomfort to the body.

The example of awkward posture that are present in vehicle maintenance tasks are twisting head/ body, bending, squatting, flexing, and over reaching (Abaraogu et al., 2016, Moradi et al., 2017). These types of awkward posture is associated with the following two categories of ergonomic risks, namely repetitive work and sustained position for a long period of time and can develop into MSDs among workers. There is numerous studies regarding the awkward postures that are associated with development of MSDs (Valero et al., 2016, Sarkar et al., 2016). Surface electromyography (SEMG) is a commonly used technique for measuring muscle activation and to identify poor posture while working mainly on manual handling in vehicle maintenance task.

The ability to recognize factors that affect safety and health involving humans is complicated. From literature research, there seem to be lack of material in the area of effects of health and safety in vehicle maintenance operations. The results of this study will contribute by providing much needed information, knowledge and statistical data on the occurrences of MSDs among vehicle maintenance workers. The current situation is such that maintenance depends on skilled workers without the standardization of the technique.

METHODS

Selection of Study Area

The study area is Bangi, Selangor, Malaysia. One vehicle garage was selected in this study because its suitability to show the regular activities that have been carried out by the vehicle maintenance workers. In addition, this garage provides the complete equipment and convenient working area for the study purpose.

Postural Analysis Assessment

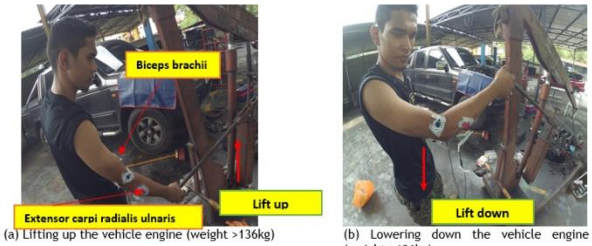
Five different regular maintenance activities have are focused in this study, as shown in Table 1. The workere were asked to do different types of activities that involves selected muscle. This muscle was selected based on recommendation by Surface Electromyography for Non-Invasive Assessment of Muscle (somethng is missing here as **non-invasive of muscles** does not sound right - found it below. Please confirm if it is Assessment) [SENIAM, 2016, Florimond, 2009].

Table 1 Type of activity and muscle involve

Code	Activity	Muscle
A1	Engine lift up and lift down using auxiliary support	Biceps brachii Extensor carpi radialis ulnaris
A2	Manual handling (>136kg engine), use two worker	Biceps brachii Extensor carpi radialis ulnaris
A3	Manual handling (≤ 5kg)	Erector spinae (L) Erector spinae (R)
A4	Hand tool spanner (assemble and dissemble)	Flexor carpi radialis Extensor carpi radialis brevis
A5	Hand tool screw driver (thick diameter, thin diameter)	Flexor carpi radialis Extensor carpi radialis brevis

Subjects and experimental setup

Figure 1 to Figure 5 illustrate the view of these activities. Figure 1 shows the A1 activity. The worker need to lift up and lift down the engine by using the auxiliary support. Two muscles were selected for this kind of activity, extensor carpi radialis ulnaris and biceps brachii. Selection of these muscles is due to interaction between both these muscle with lifting up and lowering down activity. Figure 2 illustrates the A2 activity. There are two workers involve in this activity. It is called as team lifting. Both workers need to lift the vehicle engine up manually, weighs more than 136 kilograms. Referring to Figure 3, the worker need to lift up and lower down the cam pulley with weight less than 5 kilograms. In this activity, left and right erector spinae were selected. Figure 4 shows tightening and loosening a screw by using spanner. Extensor carpi radialis brevis and flexor carpi radialis were chosen to be record in electromyography assessment. The last figure, Figure 5 illustrates tighten activity by using two different diameters of screwdriver. Selected muscle for this activity was the same with activity in Figure. 4



(a) Lifting up the vehicle engine (weight >136kg) (b) Lowering down the vehicle engine (weight >136kg)

Figure 1: Lifting up and lowering down the vehicle engine using auxiliary support

Figure 2: Lifting up the vehicle engine manually (weight >136kg)

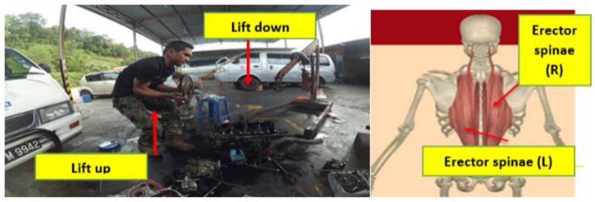


Figure 3: Lifting up and lowering down cam pulley weight ≤5kg

(a) Tighten up the screw using spanner (b) Loosening screw using spanner

Figure 4: Tightening and loosening screw using spanner

(a) Tighten up using screw driver ø 5cm (b) tighten up using screw driver ø 2cm

Figure 5: Tightening a screw using screw driver with different diameter

Surface Electromyography Procedure
Surface electromyography (SEMG) measurement was used in this study to investigate the muscle activity or contraction according to the different types of maintenance activities. A Megawin ME6000-T4 was used to collect these analog data of muscle activity with sample rate up to 1000 Hz interfaced with two channel signal amplifier. Figure 6 illustrates the Megawin set.

Figure 6: MEGAWIN set

The surface myo-electrical signal was converted to the analog data which later converted to digital data by the signal analysis personal computer interface. SEMG measurement was performed by placing electrodes on the skin's surface and electrical activity underneath of the selected muscle was recorded. The data collection procedure on the selected muscle was according to the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) recommendations.

Figure 7 shows the flow chart of SEMG data analysis. Matlab and Microsoft Excel software are two main operatoring systems in processing and analysing EMG (is this ENG or SEMG) data in this study. All data was gathered in 1000 Hz frequency. Before starting the experiment, the signal from the selected muscle was tested to determine whether the muscle is working properly according to the maintenance activity. The muscle signal is displayed in the Megawin software. If the muscle works as predicted, then the experiment can be started. All raw data from the software are in the form ASCII file. These file need to be transferred to the Matlab software for further analysis as shown in Figure 7.

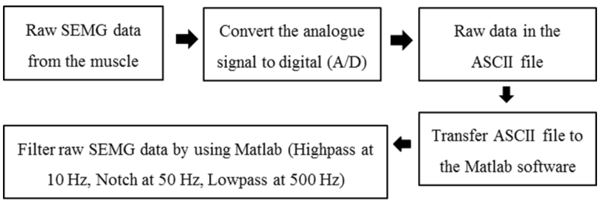


Figure 7: Flow chart of SEMG data analysis

All data is filtered since the raw data has unnecessary noise and artefact (? Not sure is this the correct word to be used here) from movement of the electrode. All raw SEMG signal were filtered via the band pass and notch filter process. Most of the power in the EMG (EMG or SEMG) signal is in the frequency range of 5 to 500 Hz (Soderberg & Knutson, 2000). This filter setup was based on recommendation from SENIAM and previous studies. There were two types of band pass filter, namely the high-pass and low-pass Butterworth filters. It is used to reduce the source of SEMG signal noise. In this study, the high-pass and low-pass Butterworth filters of the fourth order were used at cut-off frequencies of 10 Hz and 500 Hz respectively, while the notch filter was set at 50 Hz. 10 (for consistency) Hertz was setup as cut off frequencies at the high-pass to ensure the signal was adjusted to zero line first. Consequently, it can reduce the unwanted noise and artefact (? Not sure is this the correct word to be used here).

Meanwhile, 500 Hz was the next setup as cut-off frequency at the low-pass. This frequency was used to reduce the biological artefact (? Not sure is this the correct word to be used here) such as from the body fat which cannot be recognized by the EMG (EMG or SEMG) signal. Therefore, according to SENIAM recommendation, this setup was necessary to reduce the noise due to this type of artefact (? Not sure is this the correct word to be used here). Then, 50 Hz was the setup for the notch filter. This frequency was used to reduce the noise signal from any electrical device such as computer or hand phone that is used near the experiment location.

Amplitude Analysis was carried out to determine muscle activity according to maintenancetasks, either in contraction form or rest form. The value of muscle activity is in Root Mean Square (RMS). If the RMS of muscle activity is below 5 microvolt (μV), it means that the muscle is in the rest form (Florimond, 2009). Basically, the Amplitude Analysis was performed at time domain and the amplitude unit is μV. Amplitude analysis was conducted at the stipulated epoch (not sure if epoch is the correct word here) (Gerdle et al., 1999). The RMS equation in discrete time is defined in Equation. 1.

$$R.M.S = \sqrt{\frac{1}{N}\sum_{n=1}^{n} EMG\,[n]^2} \tag{1}$$

Where N is the number of data and n is the EMG (EMG or SEMG) data

RESULTS AND DISCUSSION

EMG (EMG or SEMG) analysis
Table 2 shows RMS value for lifting up and lowering the engine by using auxiliary support. For both activity, lifting up (u) and lowering down (d), the RMS value are marginally different. The RMS value while lowering down the vehicle engine are slightly higher compared to lifting up of the load. Biceps brachii muscle shows active contraction while doing this kind of activity. However, extensor calpi radialis ulnaris is at the rest condition with both activities shows RMS

value less than 5 microVolt. Relevant stands in performing tasks associated with the ankle for this type of activity (Need to clarify the last sentence).

Table 2: RMS value for activity 1

Muscle	RMS(u)	RMS (d)
Biceps brachii muscle	5.68	6.77
Extensor calpi radialis ulnaris	2.89	3.20

Table 3 shows RMS value for manual task lifting the vehicle engine which needed two workers. The increase in muscle activity in line with the continuous increase in trials, by handling a heavy load. Repetitive task can increase the value of muscle activity. The posture while handling this type of task is bending forward and slightly squatting.

Table 3: RMS value for activity 2

Muscle	RMS 1st	2nd	3rd	4th
Bicep brachii	6.10	7.52	10.50	10.41
Extensor calpi radialis ulnaris	3.34	2.38	1.50	2.38

Table 4 shows the RMS value for lifting up and lowering down a cam pulley. The right muscle shows a noticeable increase when lowering (d) the object than when lifting (u) the object. While for the left muscle there is not much change. The signal polar on both muscles shows an increase. The activity of handling heavy equipment over 5kg is usually perform in maintenance vehicle. The muscle activity on the right is higher and this is because the participants in this activity are more focused on the right hand side than the left hand. The result of a poor mechanics and a biased position can be seen. Bias causes more pressure to be administered on one side of the body and the balance of the manual handling cannot be achieved. Type of poor posture existed is bending forward and squatting. (is bias position = poor posture, if yes then need to standardize the terminology)

Table 4: RMS value for activity 3

Muscle	RMS (u) 1st 2nd		RMS (d) 1st 2nd	
Erector spinae (R)	2.27	7.89	7.05	19.85
Erector spinae (L)	1.87	5.78	8.17	4.61

(The table need to improved – 1st and 2nd to be aligned with the data)

Table 5 shows the RMS value for activity handling a hand tool which is a spanner to tighten and loosen a screw. At the first attempt to tighten the extensor muscle seen giving a much different value compared to the flexor muscles and extensor muscle compared to the reading on the second attempt. This is due to unwanted effect signal by extensor muscle that is 32% - 50% flexibly operated by the wrist hands (Kong et al., 2010). The RMS value for flexor muscle activity increases for the use of hand tools in tightening the screws. According to Mogk & Keir, 2003, the mean value of muscle can determine if the activity is related to the change of hand position. The mean value of both loosening and tightening the screw are not much different with tightening muscle flexor (6.20), extensor (6.32), and loosening flexor (3.00), extensor (3.06). With the result activity 4 did not associated with hand posture.(please check the last sentence, could not make sense of it)

Table 5: RMS value for activity 4

Muscle	RMS 1st 2nd		RMS 1st 2nd	
Flexor carpi radialis	3.93	9.10	3.60	4.63
Extensor carpi radialis brevis	26.89	8.16	8.25	4.38

(The table need to improved – 1st and 2nd to be aligned with the data)

Table 6 shows the RMS value for activity using a screw driver with different diameter to tighten up the screw in vehicle part component. From the RMS result it is shown that the use of thin-diameter screwdriver generates higher motor signals than the use of thick-diameter screwdriver, similar pattern obtained by (12 – please list the reference). Mean value for flexor muscle while using thick screw driver (2.05) compared to thin (5.98), while extensor muscle mean value while using thick (2.4), thin (2.0), was not much different. As for the posture, the elbow is in a poor position while conducting the task. There is a possibility that the awkward posture resulted in slightly higher mean value for flexor muscle.

Table 6: RMS value for activity 5

Diameter	Muscle	RMS
5cm	Flexor carpi radialis	4.24
	Extensor carpi radialis brevis	3.48
2cm	Flexor carpi radialis	10.59
	Extensor carpi radialis brevis	2.37

Control of the position of the human body depends largely on the correct muscle pattern (Mann et al., 2010). From the A1 to A5 activity, several positions during the, tasks performed primarily in manual handling are seen to be risky resulting in the occurrence of MSDs. Important considerations during the SEMG study was that the active muscular identification during the activity was not easy (Winter, 2017). It should be noted that the study conducted at vehicles workshop, the workers were exposed to hot weather and they were sweating during the activity. SEMG can be used to identify muscles that may have a role in developing different pattern due to tiredness and discomfort to the body. But according to Huber et al. (2016), the activation of skeletal muscles of different body parts can be a hallmark for a particular position (Huber et al., 2016) (please check if hallmark is the correct word to be used here). While from SEMG studies, emphasis is placed on muscles for one body only for each activity (please check this sentence). Therefore, the description is more to the type of activity in relation to positioning.

CONCLUSION

This study has highlighted the awkward and extreme postures in vehicle maintenance industry and the muscles involved with possible onset of work related musculoskeletal disorder. The findings show that manual handling in the maintenance activity is the most high risk task as it involves extreme postures which required trunk to bend and twisted while arms are sometimes above shoulder height. Maintenance activity is also considered as high risk for it requires prolonged, repetitive and awkward postures.

ACKNOWLEDGEMENTS

This project is partly funded by the grant of Fundamental of Research Grant Scheme under the Ministry of Higher Education, Malaysia (Grant No: FRGS/1/2018/TK03/UKM/03/2) and also supported by Universiti Kebangsaan Malaysia

COMPETING INTERESTS

There is no conflict of interest.

REFERENCES

Abaraogu, U. O., Ezema, C. I., Igwe, S. E., Egwuonwu, A. V., & Okafor, U. C. (2016). Work-related back discomfort and associated factors among automotive maintenance mechanics in Eastern Nigeria: A cross sectional study. Work, 53(4), 813-823.

Nasaruddin, A. F. A., Tamrin, S. B. M., & Karuppiah, K. (2014). The prevalence of musculoskeletal disorder and the association with risk factors among auto repair mechanics in Klang Valley, Malaysia. Iranian Journal of Public Health, 43(3), 34-41

Moradi, M., Poursadeghiyan, M., Khammar, A., Hami, M., Darsnj, A., & Yarmohammadi, H. (2017). REBA method for the ergonomic risk assessment of auto mechanics postural stress caused by working conditions in Kermanshah (Iran). Annals of Tropical Medicine and Public Health, 10(3), 589.

López-Arquillos, A., & Rubio-Romero, J. C. (2016). Analysis of workplace accidents in automotive repair workshops in Spain. Safety and health at work, 7(3), 231-236.

Monney, I., Bismark, D. A., Isaac, O. M., & Kuffour, R. A. (2014). Practices among vehicle repair artisans in an urban area in Ghana. J Environ Occupational Science Apr-Jun, 3(3), p.147.

Sambo, M. N., Idris, S. H., & Shamang, A. (2012). Determinants of occupational health hazards among roadside automobile mechanics in Zaria, North Western Nigeria. Borno Medical Journal, 9(1), 5-9.

Department of Statistics, Malaysia (DOSM 2017) yearly report. https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=QUJRUm4xMHdLZ0xaeDcvRDNYbUlSUT09.

Valero, E., Sivanathan, A., Bosché, F., & Abdel-Wahab, M. (2016). Musculoskeletal disorders in construction: A review and a novel system for activity tracking with body area network. Applied Ergonomics, 54, 120-130.

Sarkar, K., Dev, S., Das, T., Chakrabarty, S., & Gangopadhyay, S. (2016). Examination of postures and frequency of musculoskeletal disorders among manual workers in Calcutta, India. International journal of occupational and environmental health, 22(2), 151-158.

Kong, Y. K., Hallbeck, M. S., & Jung, M. C. (2010). Crosstalk effect on surface electromyogram of the forearm flexors during a static grip task. Journal of Electromyography and Kinesiology, 20(6), 1223-1229.

Mogk, J. P., & Keir, P. J. (2003). Crosstalk in surface electromyography of the proximal forearm during gripping tasks. Journal of Electromyography and Kinesiology, 13(1), 63-71.

Yoo, W. G. (2013). Effects of the different screwdriver handle sizes on the forearm muscles activities and wrist motion during screw-driving work. Journal of physical therapy science, 25(7), 885-886.

Mann, L., Kleinpaul, J. F., Moro, A. R. P., Mota, C. B., & Carpes, F. P. (2010). Effect of low back pain on postural stability in younger women: Influence of visual deprivation. Journal of bodywork and movement therapies, 14(4), 361-366.

Winter, D. (2017). EMG interpretation. In Electromyography in ergonomics (pp. 109-126). Routledge.

SENIAM. (2016). Surface electromyography for non-invasive measurement (SENIAM). www.seniam.org. [19 May 2016].

Florimond, V. (2009). Basics of surface electromyography applied to physical rehabilitation and biomechanics, Volume 1, Montreal, Canada: Thought Technology Ltd.

Soderberg, G.L., & Knutson, L.M. 2000. A guide for use and interpretation of kinesiologic electromyographic data. Physical Theraphy, 80: 485-498.

Gerdle, B., Karlsson, S., Day, S. and Djupsjöbacka, M., 1999. Acquisition, processing and analysis of the surface electromyogram. Modern techniques in neuroscience research, Springer Berlin Heidelberg. 705-755.

Huber, J., Lisiński, P., Ciesielska, J., Kulczyk, A., Lipiec, J., & Bandosz, A. (2016). Surface electromyography studies in standing position confirm that ankle strategy remains disturbed even following successful treatment of patients with a history of sciatica. Journal of physical therapy science, 28(2), 563-568