Investigation on musculoskeletal discomfort and ergonomics risk factors among production team members at an automotive component assembly plant

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Abstract. Musculoskeletal discomfort (MSD) is very common condition in automotive industry. MSD is affecting the worker’s health, well-being and lower down the productivity. Therefore, the main objective of this study was to identify the prevalence of MSD and ergonomics risk factors among the production team members at a selected automotive component manufacturer in Malaysia. MSD data were collected by conducting structure interview with all participants by referring to the Cornell Musculoskeletal Disorder Questionnaire (CMDQ). Those production team members who achieved a total discomfort score for all body regions more than 100 was selected for job task assessment. The physical exposure risk factors of work related musculoskeletal disorders (WMSD) has evaluated by using Quick Exposure Check (QEC) techniques. The results of the study identified the severe MSD associated with production assembly team members. It is expected that the prevalence of MSD for those production assembly team members was lower back (75.4%), upper back (63.2%), right shoulder (61.4%), and right wrist (60%). The QEC analysis discovered that about 70% of job tasks had very high risks for neck posture and 60% had high risks for the back (in moving condition) and shoulder/arm postures. There were 80% of respondents have produced a high score for exposure risk to vibration. As a conclusion, the main implication of the current study is that special attention should be paid to the physical and psychosocial aspects in production team members with musculoskeletal discomfort to improve their safety, health, and well-being, maintain work ability and productivity.

1. Introduction

1.1 Research background

Nowadays, to increase the competitive market in the manufacturing industry that requires speedier time-to-market, higher quality of products [1], variety of product model, assembly processes grow into more globalized [2], and employees have good job satisfaction and well-being [3]. The manual assembly and flexibility processes have created for workers to make the assembly production survive in dynamic and uncertain market demand [4]. Manual assembly process is often required on physicality, human dexterity and cognitive capabilities of the production workers [5]. Assembly task in automotive production plant involve with repetitive motions, forceful exertions, standing postures and awkward postures. All these risk factors have exposed the workers to the risk of musculoskeletal
disorders (MSDs) [6–8]. The major health problem among industry workers is work related musculoskeletal disorders (WMSDs) [9,10]. The WMSDs can caused the prolonged pain state regularly turns into an explanation behind inability and causes weakened work capacity, nonetheless many workers with pain continue to work [11]. Moreover, a high production volume prompts high physical workload [5]. This state is potential to develop more MSDs among employees.

1.2 Increasing trend of production rate, employees turn over and accident case in an automotive component manufacturer

Figure 1 shows that the selected automotive component manufacturer in this study faces a steady deficit in production output from 2011 to 2014. The production output dramatically bounces in 2015. We extrapolate that the hazardous workload and environment such as repetitive tasks, exposure to WMSD, injuries, ill-behaviour, morbidity, mortality and similar incidents will increase. Additionally, the analysis also disclosures that poor organisation and operation management such as working overtime leads to poor individual health. This is in agreement with Nur et al. [12], Mossa et al. [5], and Niu [13].

![Figure 1](image1.png)

**Figure 1.** Assembly plant production volumes (2011–2015).

Figure 2 displays the average number of production team members who resigned per year is 20% of the total workforce of the production within five years. The turnover rate affected the productivity. One possible reason is that the workers are exposed to the ergonomically risky job task. Particularly, in 2015, the turnover is the highest as the production volume intensely increased (refer to Figure 1). During this period, the workers need to perform more repetitive and physically demanding tasks. These tasks might expose them to risks such as WMSD, low back injuries, for example. The results of this study is in agreement with the finding of Ferguson et al. [14] which found that most turnovers are due to physical demands of the job. It also supported Lavender and Marras [15] who suggested that high turnover rates could be used as supplemental incidence rates to recognize high-risk jobs for low back injury.
Figure 2. Production team members resign in last five years.

Figure 3 demonstrates that two or more accident cases are reported every year for the last five years. One possible explanation is that, as the output augmented the chances of workers to be involved in accidents due to stress, fatigue and tasks overloaded. A research conducted by Allahyari et al. [16] discovered that accidents are caused by lack of attention, interruption, and mental errors. The previous injury history were important risk factors for work-related injury and MSD.[17].

Figure 3. No of accident case reported in assembly plant.

1.3 Research aims and objectives
Although established studies have recognized MSD in several occupational, but there is still less information for an exact determination the prevalence of MSD and exposure risk level among production team members who performed high physical demand job task in challenging working environment. Furthermore various intervention studies encourage the adequacy of participatory ergonomics (PE) intervention as a method for decreasing exposure to biomechanical and psychosocial well-being risk factors [18–20]. Surprisingly PE method is seldom applied in assessing the ergonomics risk factors in workplace. In this study the PE has practiced by the involvement of production employee from different position and department as observer to conduct the job task assessment, and the selected production team members who has direct experience of the job task. The aim of this study was to identify the prevalence of MSD and ergonomic risks factors in an automotive component assembly plant. The specific objectives of this research were to recognize the prevalence musculoskeletal discomforts among production team members, to identify the job task exposure risk level, and to determine the ergonomics physical and psychosocial risk factors.
2. Method

2.1 Identification of prevalence musculoskeletal discomforts

2.1.1 Respondents. The study was conducted in an automotive component assembly plant in Malaysia. Respondents were production assembly team members from various assembly lines in the assembly plant including Line Model A (32%), Line Model B (27%), Line Model C (20%), Line Model D (5%) and Line Model E (15%). The sample size for this study was 40% from the total production assembly team members who worked in the different shift including normal shift (13%), day shift (41%) and night shift (46%).

2.1.2 Use of Cornell Musculoskeletal Discomforts Questionnaire. Data were collected by conducting structure interview with all participants by referring to the Cornell Musculoskeletal Disorder Questionnaire (CMDQ) [21]. The interview session has conducted in group, and each group consists of 7 to 8 respondents. There are 54 questionnaire items related to the prevalence of musculoskeletal pain or discomfort in 18 body regions (neck, shoulders, upper back, upper arm, lower back, forearm, wrists, hip/buttocks, thighs, knees, and lower legs). During the interview the respondents were required to indicate the frequency of discomfort on an ordinal scale from 0(never) to 4 (several times every day) and the severity of discomfort from 1(slightly uncomfortable) to 3(very uncomfortable). A pain level of at least “moderately uncomfortable” was selected as a severity threshold for determining prevalence and frequency. Moreover, the level at which the discomfort interfered with assembly task was scored from 0 (no interference) to 2 (substantial interference). Total discomfort score was calculated by using the following formula.

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\text{Discomfort score} = \text{Frequency of discomfort} \times \text{Severity of discomfort} \times \text{Interference}
\]  

2.2 Job task assessment

2.2.1 Subjects. The participants in this study were recruited through a screening process using CMDQ. Those production team members who achieved a total discomfort score for all body regions more than 100 was selected for job task assessment. Production team members worked on a different shift, attached to a different workstation and assembly line, vary in numbers of the task and work output per hour (refer Table 1). There were six observers appointed for job task assessment including 2 persons each from safety, health and environment department and engineering department, and 1 person each from production assembly department and university researcher. This group of the observer has mixed background and experiences. Nine workstations were selected based on workstation’s worker total discomfort score in exposure WMSD assessment using CMDQ.

2.2.2 Use of Quick Exposure Check techniques. The QEC was one of the observational methods and developed for ergonomists, health and safety practitioners in order to investigate musculoskeletal risk factors in workers [22–24]. In this study, the job task assessment was executed by applying the QEC technique. QEC has been previously applied to production team members and includes assessment of four body regions, namely the back, shoulder/arm, wrist/hand, and neck, with regards to postures and repetitive movements. This technique also assesses several psychosocial risk factors including driving, vibration, work pace and stress. The exposure levels for body regions and psychosocial factors are categorized into four exposure categories; low, moderate, high, and very high (refer Table 2).
### Table 1. Summary of workstation and job task for exposure to musculoskeletal risk factors.

| Production Team Member (PTM) | Total discomfort score | Assembly Line | Workstation | No of task | No of spots/length welding | Target output (pcs/hour) |
|------------------------------|------------------------|---------------|-------------|------------|---------------------------|--------------------------|
| PTM 1                        | 163                    | Model A       | Workstation 1 | 1          | 4                         | 45                       |
| PTM 2                        | 144                    | Model A       | Workstation 2 | 3          | 6                         | 30                       |
| PTM 3                        | 110                    | Model B       | Workstation 3 | 4          | 15cm                      | 40                       |
| PTM 4                        | 117                    | Model B       | Workstation 4 | 3          | 8                         | 17                       |
| PTM 5                        | 120                    | Model C       | Workstation 5 | 2          | 7                         | 35                       |
| PTM 6                        | 110                    | Model D       | Workstation 6 | 4          | 9                         | 20                       |
| PTM 7                        | 186                    | Model D       | Workstation 7 | 4          | 6                         | 25                       |
| PTM 8                        | 118                    | Model D       | Workstation 8 | 4          | 9                         | 20                       |
| PTM 9                        | 111                    | Model E       | Workstation 9 | 2          | -                         | 40                       |

### Table 2. Priority levels for Quick Exposure Check scores [25].

| Exposure factor     | Exposure level | Low  | Moderate | High  | Very high |
|---------------------|----------------|------|----------|-------|-----------|
| Back (static)       |                | 8 - 14 | 16 - 22  | 24 - 28| 30 – 40   |
| Back (moving)       |                | 10 - 20 | 21 - 30  | 32 - 40| 42 – 56   |
| Shoulder/arm        |                | 10 - 20 | 21 - 30  | 32 - 40| 42 – 56   |
| Wrist/hand          |                | 10 - 20 | 21 - 30  | 32 - 40| 42 – 56   |
| Neck                |                | 4 - 6   | 8 - 10   | 12 - 14| 16 – 18   |
| Driving             |                | 1       | 4        | 9      | -         |
| Vibration           |                | 1       | 4        | 9      | -         |
| Work pace           |                | 1       | 4        | 9      | -         |
| Stress              |                | 1       | 4        | 9      | 16        |

### 3. Results

The prevalence of MSDs and assembly activity performance among assembly plant team members were investigated using the percentages of responses, mean value, and standard deviation given on the frequency discomfort, severity discomfort, and assembly performance interference scales. Table 3 shows the frequency distribution of responses across body parts. Four body parts with MSD prevalence rates about equivalent and above 60% were included in ergonomics risk factors investigations. These body parts were the lower back (75.4%), right shoulder (61.4%), right wrist (60%) and upper back (63.2%). These four body parts involved the highest assembly process performance interference with rates of 70.1%, 50.6%, 50.6% and 54.4%, respectively.
3.1 The prevalence musculoskeletal discomforts among production team members

The prevalence of musculoskeletal discomforts among production team members

| Body regions | Frequency Discomfort | Severity Discomfort | Interference with assembly activities | Discomfort score |
|--------------|----------------------|---------------------|---------------------------------------|-----------------|
|              | Never n (%)          | 1-2 times last week n (%) | 3-4 times last week n (%) | Once every 6 days n (%) | Several times every day n (%) | Slight n (%) | Moderate n (%) | Severe n (%) | Not at all n (%) | Slight n (%) | Substantially n (%) | Mean (SD) |
| Lower        | 14 (24.6)            | 19 (33.3)           | 9 (15.8)       | 10 (17.5)       | 5 (8.8)       | 17 (29.8)       | 13 (22.8)       | 13 (22.8)       | 3 (5.3)       | 29 (50.9)       | 11 (19.3)       | 5.16 (7.24) |
| Back         | 22 (12)              | 13 (21.1)           | 8 (14)        | 3 (5.3)        | 16 (28.1)     | 14 (24.6)      | 5 (8.8)         | (10.8)          | 21 (37.9)     | 7 (12.6)         | 3.09 (5.33)     |
| Leg R        | 28 (50)              | 12 (14.3)           | 6 (8.8)       | 12 (18.7)      | 13 (23.2)     | 10 (17.9)      | 5 (8.9)         | (7.1)           | 30 (44)       | 5 (12.5)         | 5.47 (5.47)     |
| Wrist R      | 23 (40.4)            | 16 (21.4)           | 8 (12.5)      | 11 (18.7)      | 15 (23.2)     | 10 (17.9)      | 5 (8.9)         | (7.1)           | 30 (44)       | 5 (12.5)         | 2.72 (4.58)     |
| Lower        | 28 (13)              | 13 (22.4)           | 9 (15.8)       | 7 (11.8)       | 14 (24.1)     | 11 (19.0)      | 5 (8.6)         | (7.1)           | 27 (44)       | 9 (13.8)         | 2.70 (5.35)     |
| Leg R        | 21 (48.3)            | 21 (36.8)           | 6 (10.5)      | 4 (6.7)        | 26 (36.3)     | 13 (22.8)      | 14 (24.0)       | (8.8)           | 47 (44)       | 7 (13.0)         | 5.01 (5.01)     |
| Upper        | 24 (36.8)            | 12 (14.8)           | 9 (16.7)       | 1 (1.8)        | 14 (25.9)     | 12 (22.2)      | 4 (7.4)         | (1.1)           | 33 (44)       | 11 (22)          | 2.58 (4.81)     |
| Wrist L      | 39 (47.4)            | 27 (26.3)           | 8 (14.0)      | 10 (15.5)      | 11 (19.3)     | 15 (26.3)      | 4 (7.0)         | (7.0)           | 36 (38)       | 5 (8.8)          | 3.27 (3.27)     |
| Knee L       | 34 (69.6)            | 15 (41.3)           | 7 (5.4)       | 3 (5.4)        | 7 (12.5)      | 8 (14.3)       | 2 (3.6)         | (3.6)           | 13 (3)        | 7 (2.8)          | 2.02 (7.48)     |
| Lower        | 36 (58.6)            | 10 (20.7)           | 7 (8.6)       | 3 (8.6)        | 2 (3.4)       | 9 (13.8)       | 4 (6.9)         | (6.9)           | 25 (5.6)      | 8 (5.6)          | 1.83 (4.03)     |
| Arm R        | 36 (63.2)            | 17 (17.5)           | 5 (12.3)      | 3 (5.3)        | 9 (15.8)      | 10 (17.5)      | 2 (3.5)         | (2.5)           | 47 (22)       | 7 (4.7)          | 1.46 (3.47)     |
| Knee R       | 37 (46.6)            | 22 (37.9)           | 4 (6.9)       | 6 (6.9)        | 1 (1.7)       | 17 (29.3)      | 11 (18.9)       | 3 (5.2)         | (10.0)        | 36 (5.5)         | 3.17 (3.17)     |
| Neck         | 35 (66.1)            | 10 (16.9)           | 5 (8.5)       | 8 (6.8)        | 1 (1.7)       | 17 (29.3)      | 11 (18.9)       | 3 (5.2)         | (10.0)        | 36 (5.5)         | 1.36 (3.17)     |
| Upper        | 33 (55.9)            | 17 (28.8)           | 4 (6.8)       | 8 (8.5)        | 0 (18.7)      | 11 (18.7)      | 4 (6.8)         | (9.2)           | 33 (31)       | 1 (1.8)          | 3.07 (3.07)     |
| Arm L        | 30 (51.7)            | 19 (32.8)           | 5 (8.6)       | 3 (5.2)        | 1 (1.7)       | 15 (25.9)      | 11 (19.0)       | 2 (3.5)         | (10.7)        | 32 (3.2)         | 1.26 (3.00)     |
| Thigh L      | 36 (64.3)            | 12 (21.4)           | 5 (8.9)       | 3 (3.6)        | 1 (1.8)       | 9 (16.1)       | 10 (17.9)       | 1 (1.8)         | (13.6)        | 32 (3.2)         | 1.01 (2.50)     |
| Hip/Buttocks | 45 (78.9)            | 6 (10.5)            | 3 (5.3)       | 1 (1.8)        | 2 (3.5)       | 5 (8.8)        | 6 (10.6)        | 1 (1.8)         | (13.6)        | 7 (1.5)          | 0.77 (3.30)     |
| Thigh R      | 38 (67.9)            | 9 (16.1)            | 6 (10.7)      | 2 (3.6)        | 1 (1.8)       | 9 (16.1)       | 8 (14.3)        | 1 (1.8)         | (13.6)        | 7 (1.5)          | 3.1 (1.00)      |

3.2 The exposure risk level among production team members

In accordance with the exposure levels for body regions in Figure 4, the job task assessment result reveals that 70% had very high exposure risk to worker’s neck, and 60% had high exposure risk to worker’s back (moving), shoulder and arm. Meanwhile out of the tasks evaluated, 80% had medium exposure risks to the wrist and hand.
3.3 *Ergonomics physical and psychosocial risk factors in an automotive component assembly plant*

Figure 5 is displaying the exposure risk level for ergonomics physical and psychosocial risk factors. The QEC analysis discovered that 80% of respondents have produced a high score for exposure risk to vibration and each 10% of respondents the exposure risk to vibration were low and medium. Work pace scores in 60% of the respondents were medium, in 30% of the respondents were high, and 10% of them were low. While the stress scores of respondents in 60% were medium, the scores were high in 30% and were very high in 10% of them. However, driving score is low for all workers because driving is not part of their job task.

4. Discussions

4.1 *Prevalence and assembly task performance interference of MSD*

The current study explored the prevalence and assembly task performance interference of musculoskeletal discomfort, among production assembly team members in the automotive component assembly plant. The study contributed additional evidence to literature about the considerable prevalence of musculoskeletal discomfort among automotive component production team members. The results of the study identified the severe musculoskeletal discomfort associated with production team members. The findings of this study are consistent with established studies conducted by Roquelaure [26], Farioli et al., [27], Yu et al., [17] which showed that musculoskeletal disorders are main causes of work disability among the employees and also can give very serious effects on employee’s health and efficiency.

Production team members have involved with demanding material manual handling works such as moving, handling and lifting heavy tools like welding spot gun. It is expected that the prevalence of
musculoskeletal discomfort for those production assembly team members was lower back (75.4%), upper back (63.2%), right shoulder (61.4%), and right wrist (60%). Several similar type studies have shown a variety of results which is comparable and contrast to the present study. The highest prevalence of WMSD among assembly workers in Malaysia occurs at the shoulder, feet, lower leg and lower back [28]. According to Zare et al. [29] the prevalence of musculoskeletal symptoms among truck assembly plant workers are different based on cycle time, for cycle time A were shoulders (67%), elbows (53%), and wrists (47%), and for cycle time B the prevalence of shoulder (35%), elbow (40%) and wrist (40%) symptoms respectively. In contrast, the study by Nur et al.[30] indicated that the prevalence of musculoskeletal symptoms among workers in Malaysian automotive manufacturing companies is highest for the neck (49.3%), followed by hand/wrist (48.0%), shoulder (46.7%), upper back (33.6%), lower back (21.7%), knee (15.8%), thigh/hip (14.5%), elbow 8.7%) and ankle (1.3%).

4.2 The exposure risk level among production assembly team members

This job task assessment was performed exposure risk levels for WMSDs among production assembly team members in assembly plant of an automotive component manufacturer was analysed. Working in an automotive assembly plant is known as a demanding task that requires a high level of strength and attention in order to cope with the demands of the job demands, production volume, quality of component, and variable of tasks. Most of the automotive component manufacturer's workers had significant exposure to ergonomics risk factors [31].

The results of the study indicated that about 70% of job tasks in an automotive component assembly plant had very high risks for neck posture and 60% had high risks for the back (in moving condition) and shoulder/arm postures. Current study results support the previous finding by several researchers which found that the most affected body regions for WMSDs among automotive industry's workers are the neck, shoulder, arm, and back [30,32–34]. In addition, a study conducted by de Cassia and team members [35] have found that the musculoskeletal comorbidity was high, varying between 72.2% for lower back to 90.5% for neck pain.

4.3 Ergonomics physical and psychosocial risk factors

The QEC analysis discovered that 80% of respondents have produced a high score for exposure risk to vibration. The high score for exposure risk to vibration among respondents may have been due to their job tasks applied manually hand tools, equipment and machines to complete assembled the components. The findings of this study are consistent with Burstrom et al., [36] who had reported that manual work involving vibrating power tools has been related to musculoskeletal disorders. Established studies had reported that manual handling of the tools and vibration were associated with increased prevalence of body pain among the workers [33,37,38]. The job task assessment analysis also exposed that 30% each of respondents have produced a high score for exposure risk to work pace and stress. This finding has support latest study conducted by Bao et al. [39] who have found that the work pace had significant effects on all biomechanical stressors and psychosocial variables. In other study conducted by Bosh et al. [40] has suggested that high work pace will cause fatigue on the workers and lead more errors, finally affect production quality. According to Thye [41] work stress in the workplace is common due to the demands of the current work environment. Authors also reported that the physical health issues and musculoskeletal disorders begun by the prolonged stress. The psychosocial risk factors like high work stress lead to the development of musculoskeletal discomforts among workers [42]. This ergonomics risk assessment study has found that the job task performed by production team members has exposed them to the physical and psychosocial risk factors.

5. Conclusions

The study explored the prevalence, severity discomfort and assembling task performance interference of MSD among production team members in an automotive component assembly plant in Malaysia. There are four body parts with MSD prevalence rates about equivalent and above 60% were included in ergonomics risk factors investigations. The prevalence of pain in the upper back, lower back, right shoulder and right wrist have been reported to be higher in comparison with pain in other parts of the
body. The study results demonstrated that job tasks in automotive component assembly plant have been exposed to very high of WMSD risk at worker’s neck, followed to a high of WMSDs risk at worker’s back (in moving condition) and worker’s shoulder/arm. This study also found that in the psychosocial factors, the exposure level is high for vibrations, work pace and stress in most of the workstations. Although the results found are constructive as a preliminary study, the inexperience of observer’s assessment could lead to the misinterpretation. Moreover, the way on how inexperience assembly workers have to estimate the weight of tools and objects, and the force that existed in assembly process activities is questionable due to their limited knowledge in ergonomics. However, this job task assessment is a decent to begin for the company to actualize the participatory ergonomics program among the production employees. The main implication of the current study is that special attention should be paid to the physical and psychosocial aspects in production team members with musculoskeletal discomfort to improve their safety, health, and well-being, maintain work ability and productivity.

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