Malaysian Journal of Public Health Medicine 2016, Volume 16 (Suppl. 2): 61-68

**ORIGINAL ARTICLE**

# FUTURE RESEARCH ON MANUAL LIFTING TASKS IN THE AUTOMOTIVE INDUSTRY

**Mirta Widia, Siti Zawiah Md Dawal and Nukman Yusoff**

*Department of Mechanical Engineering, Faculty Engineering, University of Malaya, 50603, Lembah Pantai, Kuala Lumpur, Malaysia*

## ABSTRACT

*It is known that lifting tasks are one of the risk factors of musculoskeletal disorders in the automotive industry. Extensive research has been carried out over the years to develop guidelines and determine safe limits in which an individual can lift. For this reason, the objective of this study is to determine the significant risk factors of musculoskeletal discomfort among manual lifting task workers in the automotive industry, and propose a methodological framework for future research on manual lifting tasks. The subjects of this study comprise 211 manual material handling workers from the automotive industry. The subjects completed a set of questionnaires which are used to elicit information on their demographic characteristics, as well as physical factors and the prevalence of musculoskeletal discomfort. The Chi-Square test was used to determine the relationship between the risk factors and musculoskeletal discomfort. The findings of the study show that the following postures (trunk bent slightly forwards, hands above the knee level ($p < 0.05$), trunk twisted (over 45o) and bent sideways ($p < 0.05$) are the significant risk factors of musculoskeletal discomfort among manual lifting task workers in the automotive industry. A methodological framework on manual lifting task in the automotive industry is proposed based on the findings of this study. The framework is developed based on the need to model human lifting capabilities so that task demands can be designed to fit the workers' capacity when performing lifting tasks.*

***Keywords***: *Manual lifting task; future research; automotive industry; Malaysia*

## INTRODUCTION

Lifting task is one of the major health and safety hazards in the manufacturing industry[1]. It is also the most disabling and costly of all workplace injuries and has become a major concern in a large number of industries, including the automotive industry[2]. Human operators act as material transfer devices when loading and unloading products from machines or pallets to conveyors, or when sorting objects to and from moving conveyors. Most of the objects that are lifted in manufacturing tasks are of awkward sizes, loads and shapes, and consequently, the workers tend to adopt poor body postures. The excessive physical demands placed on human operators in such conditions are frequently shown to be a major contributor of Work-related Musculoskeletal Disorder (WRMSDs)[3,4].

Over the past four decades, ergonomics researchers have devoted considerable resources to solve problems associated with lifting tasks. Today, lifting task is still a prevailing issue which is of great interest among ergonomics researchers. One of the promising ways to minimize WRMSDs is to redesign the tasks such that the task demands are matched with the individual's or worker's capabilities. Worker's capability refers to the ability of the worker to perform a task on a safe and dependable basis[5]. Numerous studies have been carried out to determine safe human lifting capacities. A generally accepted definition for lifting capacity is the maximum acceptable weight of lift (MAWL) that can be handled safely by an individual[6,7,8,8,10,11]. Within the context of the automotive industry, the weight of the parts or materials lifted is not heavy; however, these parts or materials are lifted at a relatively high frequency since workers are required to keep up their pace with the machines or conveyors. In practice, the weight of a material cannot be changed, but the frequency can be adjusted. Hence, the frequency of the lifting task is even more crucial than the load itself[12].

In this era of industrialization and modernization, the automotive sector is one of the key players in the manufacturing industry. It is inevitable that the workers in the automotive industry, specifically those involved in manual lifting tasks, are faced with a higher risk of suffering from WRMSDs. For this reason, it is imperative to conduct a detailed investigation on manual lifting tasks of workers from the automotive industry in order to minimize the prevalence of musculoskeletal discomfort. In light of the discussion above, the objective of this study is to determine the significant risk factors of musculoskeletal discomfort among manual lifting task workers in the automotive industry and propose a methodological framework for further research on manual lifting task based on the significant risk factors.

## METHODS

### Subjects

The research design used in this study is a cross-sectional survey. Ten automotive industries from two geographical clusters were identified from the list provided by the Malaysian Industrial Development Authority (MIDA), and were invited to participate in the survey based on their work process. The work process of the industries should involve major manual handling tasks such as loading and unloading materials, stamping and die-casting. However, only eight automotive industries agreed to participate in the survey, resulting in a participation rate of 80%. A total of 211 questionnaires were distributed among the manual material handling workers who fulfilled the inclusion criteria. The workers were all involved in performing material handling tasks manually.

**Data Collection Instrument**
Self-administered questionnaires were used to elicit information on the subjects' characteristics, employment history, physical risk factors at work and the prevalence of musculoskeletal discomfort. The Risk Factor Questionnaire (RFQ)[13] was used to determine the significant risk factors of musculoskeletal discomfort. The questionnaire consists of three items which assess the postures and handling activities of the subjects using an ordinal 6-point scale of duration, and three items which assess the lifting loads of the subjects using a 5-point frequency scale. A six scale rating was used, consisting of 'Never', 'Rarely', 'Sometimes', 'Moderately', 'Constantly' and 'All the time'.

Corlett and Bishop's[14] body part discomfort scale is a subjective symptom survey form that evaluates the respondent's direct experience of discomfort at different parts of the body. These questionnaires were validated by taking into account the opinions of local experts on occupational safety and health. The questionnaires were pre-tested in a pilot study, in which the Cronbach's alpha value was found to be 0.876, indicating good reliability.

**Statistical Methods**
Statistical analysis was performed using SPSS software (version 21.0). Analytical statistics was carried out using *chi-square* test. *Chi-square* test was used to assess the association between the risk factors and musculoskeletal discomfort.

## RESULTS

**Demographic Information of the Participants**
The subjects comprise 211 male workers involved in manual material handling in the automotive industry. The mean age of the participants is 28.8 years (S.D.: 9 years, range: 18–55 years) and the majority of the participants are within an age group of 21–30 years(41.2%). It is found that 34.1% of the participants have been working for less than 1 year, 46.5% of the participants have been working between 1 and 5 years, and the remaining 19.4% of the participants have been working for more than 5 years. The demographic characteristics of the participants and their relationship with musculoskeletal discomfort are summarized in Table 1 (N = 211).

**Significant risk factors of lifting task in automotive industries**
The duration of the adopted posture during daily lifting activities is shown in Figure 1. It can be seen that most of the workers adopted the following postures: trunk twisted (over 45°) and bent sideways (34.6%), as well as trunk bent slightly forwards with hands above the knee level (31.8%).

The frequency of the daily lifting task is shown in Figure 2. It can be seen that 42.2% of the subjects lift loads weighing less than 5 kg over 30 times within an hour. In contrast, 16.6% of the subjects lift loads weighing within a range of 5-14 kg over 30 times in an hour whereas the remaining 11.4% lift loads weighing more than 14 kg over 30 times in an hour. Based on the findings shown in Table 1, it can be deduced that the factors which influence musculoskeletal discomfort are the following postures: trunk bent slightly forwards with hands above the knee level ($p < 0.05$), trunk twisted (over $45^{o}$) and bent sideways ($p < 0.05$). It is somewhat astonishing that there is no significant association between lifting load, frequency of lifting task and musculoskeletal discomfort. This result contradicts the findings of[2] in which there is significant association between load and musculoskeletal discomfort. A possible explanation for this is that even though the workers do not lift the loads frequently, they will still experience discomfort because of the awkward postures that they adopt on a daily basis. Hence, it is likely that there is an association between lifting load, frequency of the lifting task and posture.

The results indicate that the current trend in manual lifting tasks in the automotive industry is gearing towards low force tasks with high repetitions in an awkward posture environment. In this case, awkward posture refers to a posture in which the trunk is bent slightly forwards with the hands above the knee level or the trunk is twisted over $45^{o}$. According to Fox [15], future studies on lifting tasks will be more focused on tasks with light loads and high repetitions. Hence, it is important to investigate the significant risk factors which will lead to musculoskeletal disorders among workers involved in manual lifting tasks, particularly those involving light loads with high repetitions. In light of this, human lifting capabilities need to be considered when designing a work system for manual lifting tasks. The results of this study highlight the need to formulate a new framework model on human lifting capabilities in order to reduce healthcare costs and loss of productivity due to musculoskeletal discomfort problems.

**Table 1 – Association between risk factor and musculoskeletal discomfort**

| Risk factors (n) | Musculoskeletal discomfort | | Statistics | Significance |
|---|---|---|---|---|
| | Discomfort (n=174)% | None (n=37)% | Chi square | |
| Age | | | | |
| <20 (16) | (15)7.11 | (1)0.47 | $x^2$ = 1.08, d*f* = 3 | P > 0.05 |
| 21-30 (87) | (75)35.55 | (12)5.69 | | |
| 31-40(78) | (66)31.28 | (12)5.69 | | |
| >40 (30) | (25)11.84 | (5)2.37 | | |
| Job tenure | | | | |
| <1 year (72) | (57)27.01 | (15)7.1 | $x^2$ = 4.5, d*f* = 2 | P > 0.05 |
| 1-5 years (98) | (86)40.75 | (12)5.69 | | |
| >5 years (41) | (38)18 | (3)1.4 | | |
| Trunk bent slightly forwards, hands above the knee level | | | | |
| Never (39) | (27)12.79 | (12)5.69 | $x^2$ = 11.7, d*f* = 5 | P < 0.05* |
| Rarely (41) | (35)16.59 | (6)2.84 | | |
| Sometimes (26) | (24)11.37 | (2)0.95 | | |
| Moderately (23) | (21)9.95 | (2)0.95 | | |
| Constantly (15) | (14)6.63 | (1)0.47 | | |
| All the time (67) | (60)28.44 | (7)3.32 | | |
| Trunk bent slightly forwards, hands below the knee level | | | | |
| Never (59) | (45)21.33 | (16)7.58 | $x^2$ = 9.49, d*f* = 5 | P > 0.05 |
| Rarely (61) | (55)26.06 | (6)2.84 | | |
| Sometimes (23) | (21)9.95 | (2)0.94 | | |
| Moderately (21) | (20)9.48 | (1)0.47 | | |
| Constantly (9) | (9)4.27 | (0)0 | | |
| All the time (38) | (31)14.69 | (7)3.32 | | |
| Trunk twisted (over 45°) and bent sideways | | | | |
| Never (33) | (23)10.90 | (10)4.74 | $x^2$ = 14.31, d*f* = 5 | P < 0.05* |
| Rarely (46) | (44)20.85 | (2)0.95 | | |
| Sometimes (29) | (24)11.37 | (5)2.37 | | |
| Moderately (17) | (16)7.58 | (1)0.47 | | |
| Constantly (13) | (13)6.16 | (0)0 | | |
| All the time (73) | (61)28.91 | (12)5.69 | | |
| Lifting loads weighing less than 5 kg | | | | |
| Almost never (62) | (50)23.70 | (12)5.69 | $x^2$ = 2.7, d*f* = 4 | P >0.05 |
| Less than once in an hour (9) | ( 8)3.79 | (1)0.47 | | |
| 1-10 times in an hour (27) | (24)11.37 | (3)1.42 | | |
| 11-30 times in an hour (24) | (18)8.53 | (6)2.84 | | |
| Over 30 times in an hour (89) | (74)35.07 | (15)7.11 | | |
| Lifting loads weighing from 5 to 14 kg | | | | |
| Almost never (133) | (104)49.29 | (29)13.4 | $x^2$ = 6.76, d*f* = 4 | P > 0.05 |
| Less than once in an hour (20) | (17)8.06 | (3)1.42 | | |
| 1-10 times in an hour (21) | (20)9.48 | (1)0.47 | | |
| 11-30 times in an hour (2) | (1)0.47 | (1)0.47 | | |
| Over 30 times in an hour (35) | (32)15.17 | (3)1.42 | | |
| Lifting loads more than 14 kg | | | | |
| Almost never (156) | (127)60.19 | (29)13.74 | $x^2$ = 0.53, d*f* = 4 | P > 0.05 |
| Less than once in an hour (19) | (16)7.58 | (3)1.42 | | |
| 1-10 times in an hour (11) | (10)4.74 | (1)0.47 | | |
| 11-30 times in an hour (1) | (1)0.47 | (0)0 | | |
| Over 30 times in an hour (24) | (20)9.48 | (4)1.9 | | |

*$x^2$ = Chi square, df = degrees of freedom*
** p< 0.05 = statistically significant at 5% level ** p < 0.01 = statistically significant at 1% level*

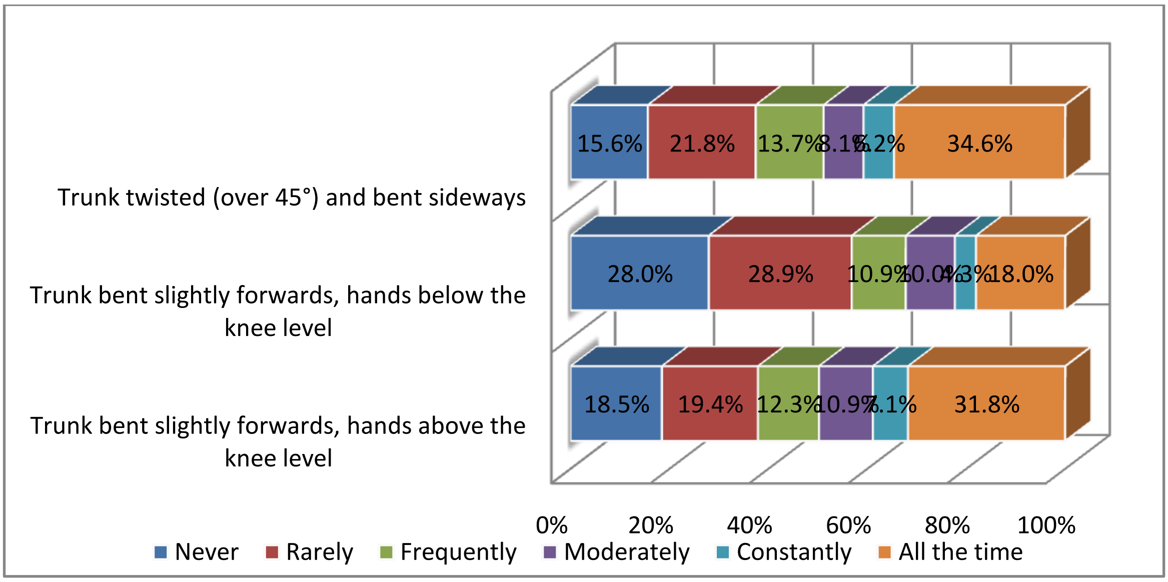


***Figure 1 - Physical risk factor in lifting task***

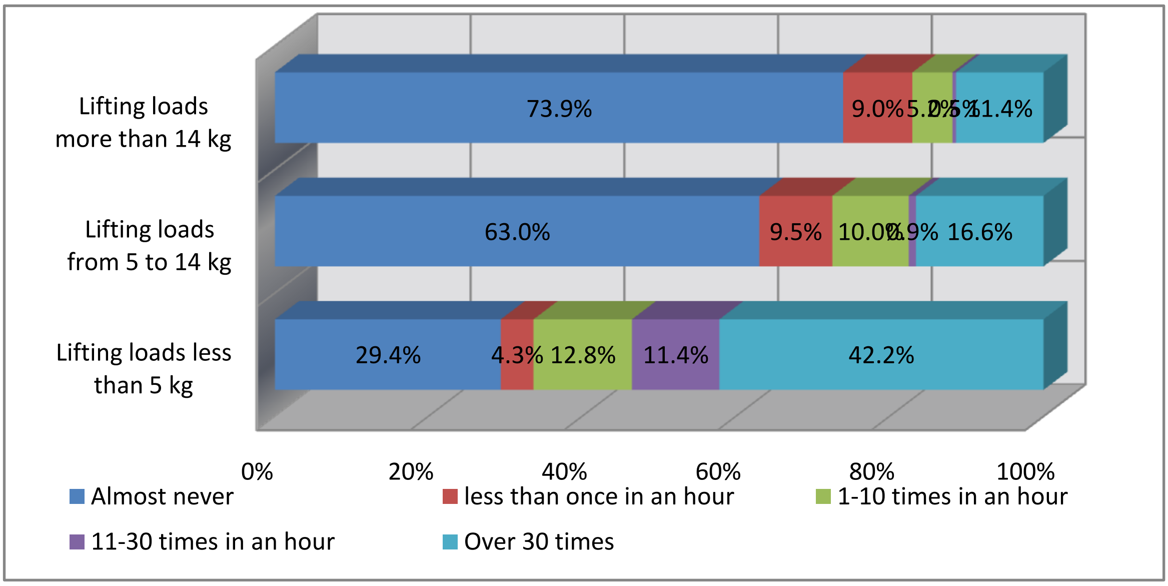


***Figure 2 - Lifting frequency***

**Methodological framework on human lifting capabilities**

The proposed methodological framework used to determine human lifting capabilities shown in Figure 3. The framework was adapted fromDempsey[16], Council[17] and Karwowski[18]. The Dempsey model[16] is basically a systems approach used to define the task demand to worker capacity ratio for manual material handling systems. The model consists of two basic elements as well as the factors which play a key role in manual material handling tasks. These factors need to be considered when optimizing the system.

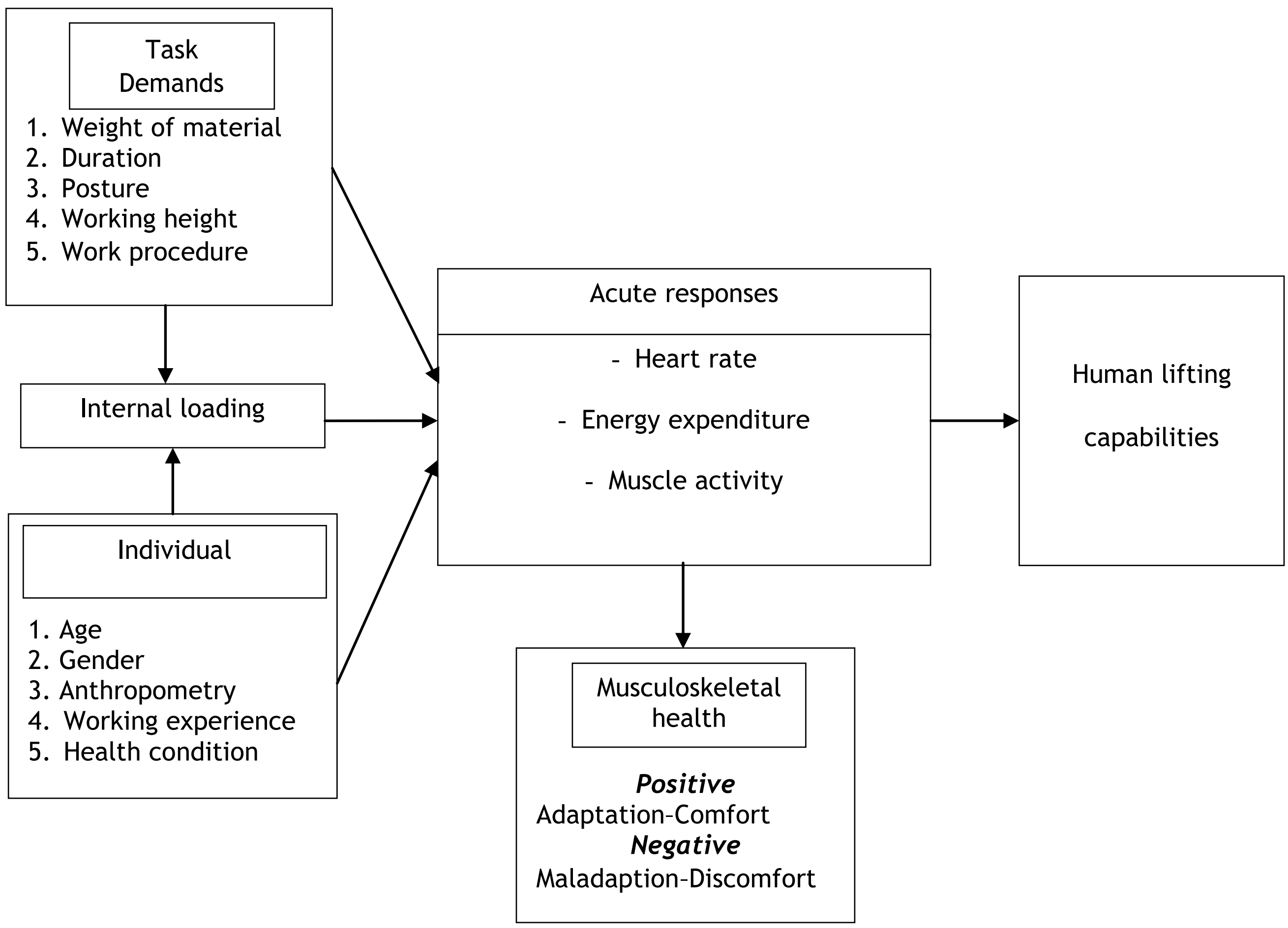


***Figure 3- Methodological framework on human lifting capabilities***

However, this model does not indicate the pathways and factors that contribute towards musculoskeletal health. On the other hand, the National Research model[17] is rather generic and therefore, it is not specific to particular job or task. Even though this conceptual framework indicates the pathways and factors that contribute towards WMSDs, it does not explicitly represent human capabilities in the system and how a certain task is performed (i.e. the postures adopted by the workers. The Karwowski model[18] shows the importance of human capabilities and limitations which should be considered in systems design. However, this model is rather complex and its application is more on systems design.

The methoological framework in Figure 3 serves as a basis of the methodology used to validate the hypotheses in this study. It shall be noted that the several elements involved in the analysis of the activities proposed in the methodology are based on our previous studies[19,20,21]. This framework shows the relationship between the elements, which provides insight on how the elements may be used effectively to determine human lifting capabilities. In this model, the task demand is centered on five significant variables: (1) load, (2) frequency (repetitiveness), (3) posture, (4) working height and (5) work procedure. It is perceived that the combination of these variables will largely determine whether a work situation will increase or decrease the risk of musculoskeletal health. The whole concept is simple. If the lifting load is extreme, this leads to an immediate injury to the worker. However, if the load is low, the onset of injury is dependent on the number of times per day the person is exposed to the lifting load. Awkward postures, combined with lifting loads and repetitions, will further accelerate injuries compared to postures that are more natural or neutral. It is understood that as the load of an object increases, the amount of mechanical work also increases. Assuming that the efficiency of the human body is constant, more energy will be needed to perform the additional work. Several researchers[7,8,11,22,23] have studied load and its relationship to metabolic and cardiovascular responses. They concluded that an increase in metabolic energy expenditure results from an increase in the load to be lifted. Hence, it is the combination of lifting load, frequency of the lifting task and posture that contributes to musculoskeletal health. In manual lifting tasks, load, frequency, posture, working height and work procedure change constantly. Thus, workers who adopt unusual or restricted postures while working often experience higher rates of musculoskeletal injury. If awkward postures are unavoidable in a workplace, then the tasks should be designed to match the lifting capabilities observed in these postures. With this in mind, it is deemed beneficial to use the variables identified in the proposed methodological framework when describing a system in future studies. In general, it can be expected that task demands will produce external loads (e.g. from lifting light loads with a high degree of repetitiveness) and this results in the transmission of muscular activity to the tendons and articulations[24]. This transmission consists of internal loads (biomechanical forces). These internal loads induced from task demands within the human body results in acute physiological and psychological responses, which may exceed the physiological and psychological tolerance of the worker. The acute physiological and psychological responses represent the workload during work as well as several hours after performing the work. Such responses may include short-term development of fatigue, discomfort or pain. When acute responses occur over a longer term, this will have an adverse effect on musculoskeletal health. Westgaard and Winkel[25] classified acute responses into two categories: physiological and psychological responses. Physiological responses include muscle activity, heart rate and energy expenditure, whereas psychological responses are perceived fatigue and the level of comfort experienced by the workers.

Human lifting capability refers to an individual's ability to perform a lifting task in a safe and dependable manner[5]. Biomechanical, physiological and psychophysical approaches will be used to establish the recommended human lifting capabilities. Biomechanical exposure plays a key role in musculoskeletal disorder causation and this has been highlighted by a number of researchers[26,27,28]. However, recent studies have begun to unravel systematic links between biomechanical, psychophysical and physiological approaches. A recent study by Fisher and Dickerson[29] reveals that there are important links between biomechanical limitations and psychophysical force acceptability as well as between perceived effort and moment loading at the shoulder. These findings support the ongoing use of psychophysical and biomechanical methods and implore future developments to improve their use to establish the recommended human lifting capabilities. Human lifting capabilities are related to the workers' diagnosed conditions and the broad clinical picture of their biomechanical, neurological and musculoskeletal capacities that can be obtained by initial observations with the workers. Such knowledge will provide us with useful insight regarding the workers' potential for change as well as the precautions which need to be considered as feedback during intervention. Human lifting capabilities should be integrated with the design of lifting tasks and equipment in order to ensure safe and effective operation.

## CONCLUSION

This study contributes to the existing knowledge by addressing two important issues. Firstly, the following postures (trunk bent slightly forwards with hands above the knee level, and trunk twisted over $45^{o}$), as well as low loads with high frequency of repetitions are the significant risk factors of musculoskeletal disorders among workers involved in manual lifting tasks in the automotive industry. A methodological framework has been proposed based on the findings in this study, and it can be used to determine human lifting capabilities while accounting for the significant risk factors of musculoskeletal disorders among workers involved in manual lifting tasks in the automotive industry. This methodological framework serves as a basis for future studies on manual lifting tasks in the automotive industry in order to minimize musculoskeletal discomfort.

## ACKNOWLEDGEMENTS
This work is financially supported by the Ministry of Higher Education Malaysia under the High Impact Research Grant UM.C/HIR/MOHE/ENG/35 (D000035-16001).

## COMPETING INTERESTS
There is no conflict of interest.

## REFERENCES

1. Chiuhsiang J, Lin SJ, WaHJC. A Field Evaluation Method for Assessing Whole Body Biomechanical Joint Stress in Manual Lifting Tasks. *Industrial Health* 2006;44:8.

2. Faber GS, Kingma I, Bakker AJ, van Dieen JH. Low-back loading in lifting two loads beside the body compared to lifting one load in front of the body. *Journal of Biomechanics* 2009;42(1):35-41.

3. Ferguson SA, Marras WS, Allread WG, Knapik GG, Splittstoesser RE. Musculoskeletal disorder risk during automotive assembly: current vs. seated. *Appl Ergon* 2012;43(4):671-678.

4. Marras WS, Parakkat J, Chany AM, Yang G, Burr D, Lavender SA. Spine loading as a function of lift frequency, exposure duration, and work experience. *Clinical biomechanics* 2006;21(4):345-52.

5. Tamkin P. Measuring the Contribution of Skills to Business Performance: A summary for Employers. Brighton BN1 9

RF, UK: Institute for Employment Studies, Mantell Building, Falmer, 2005.

6. Punnett L, Fine LJ, Keyserling WM, Herrin GD, Chaffin DB. Shoulder disorders and postural stress in automobile assembly work. *ScandinavianJournal of Work, Environment & Health* 2000;26(4):283-291.

7. Ciriello VM. The effects of container size, frequency and extended horizontal reach on maximum acceptable weights of lifting for female industrial workers. *Appl Ergon* 2007;38(1):1-5.

8. Ciriello VM. The effects of box size, frequency and extended horizontal reach on maximum acceptable weights of lifting. *International Journal of Industrial Ergonomics* 2003;32(2):115-20.

9. Determination of the Maximum Acceptable Weights in Non-Standard Positions. 13th Annual International Conference on Industrial Engineering Theory, Applications and Practice; 2008 7-10 September; Las Vegas, Nevada.

10. Lee T-H. Effects of Range and Mode on Lifting Capability and Lifting Time. International *Journal of Occupational Safety and Ergonomics (JOSE)* 2012;18(3):5.

11. Vincent M. Ciriello RVM, Patrick G. Dempsey and Niall V. O'Brien. Gender differences in psychophysically determined maximum acceptable weights and forces for industrial workers observed after twenty years. *International archives of occupational and environmental health* 2011;84:6.

12. Fox RR, Smith JL. A psychophysical study of high-frequency arm lifting. *International Journal of Industrial Ergonomics* 2014;44(2):238-45.

13. Halpern,M.R.H, M. Nordin, D. Goldsheyder, M. Crane. The test-retest reliability of a new occupational risk factor questionnaire for outcome studies of low back pain. *Applied Ergonomics* 2001;32:7.

14. Corlett EN BR. A technique for measuring postural discomfort. *Ergonomics* 1976;9:7.

15. Smith JL, Fox RR. Self-Paced High Frequency Lifting of Light Loads. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 2000;44(29):1-4.

16. Dempsey P.G. A critical review of biomechanical, epidemiological, physiological and psychophysical criteria for designing manual materials handling tasks. *Ergonomics* 1998;41(1):15

17. Council NR. National Research Council. Work-related musculoskeletal disorders: report, workshop summary, and workshop papers. Washington DC, 1999.

18. Karwowski W. Ergonomics and human factors: the paradigms for science, engineering, design, technology and management of human-compatible systems. *Ergonomics* 2005;48(5):27.

19. M.M. Ayoub WK, P.G. Dempsey. Manual materials handling. 2nd Ed ed: John Wiley, New York, 1996.

20. CHARLES-OWABA SOIaOE. A Review of Manual Load Lifting Models. Leonardo *Journal of Sciences* 2010;16:12.

21. Pinder ADJ, Boocock MG. Prediction of the maximum acceptable weight of lift from the frequency of lift. *International Journal of Industrial Ergonomics* 2014;44(2):225-37.

22. Lee T-H. Maximum Symmetric and Asymmetric Isoinertial Lifting Capabilities from Floor to Knuckle Height. *Industrial Health* 2009;47:5

23. Li KW, Yu R-f, Gao Y, Maikala RV, Tsai H-H. Physiological and perceptual responses in male Chinese workers performing combined manual materials handling tasks. *International Journal of Industrial Ergonomics* 2009;39(2):422-427.

24. Lanfranchi JB, Duveau A. Explicative models of musculoskeletal disorders (MSD): From biomechanical and psychosocial factors to clinical analysis of ergonomics. *Revue Européenne de PsychologieAppliquée/European Review of Applied Psychology* 2008;58(4):201-213.

25. Westgaard RH &Winkel J. Guidelines for occupational musculoskeletal load as a basis for intervention: a critical review. *Applied Ergonomics* 1996; 27(2): 79-88.

26. Waters T, Yeung S, Genaidy A, Callaghan J, Barriera-Viruet H, Deddens J. Cumulative spinal loading exposure

methods for manual material handling tasks. Part 1: is cumulative spinal loading associated with lower back disorders? *Theoretical Issues in Ergonomics Science* 2006;7(2):113-30.

27. Xu X, Chang CC, Faber GS, Kingma I, Dennerlein JT. Estimation of 3-D peak L5/S1 joint moment during asymmetric lifting tasks with cubic spline interpolation of segment Euler angles. *Appl Ergon* 2012;43(1):115-20.

28. Coenen P MS, Kingma I, Boot CRL, Bongers PM, van, JH D. The effect of the presence and characteristics of an outlying group on exposure–outcome associations. *Scandinavian Journal of Work, Environment& Health* 2015;41(1):9.

29. Steven L. Fischer CRD. Applying psychophysics to prevent overexposure: On the relationships between acceptable manual force, joint loading, and perception. *International Journal of Industrial Ergonomics* 2014;44:8.