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Original Article

Evaluation on Ambulance Design and Musculoskeletal Disorders Risk Factors among Ambulance Emergency Medical Service Personnel

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Abstract

Background: Injuries or pains occurred at various body's joints, ligaments, muscles, nerves, tendons, limbs, back and neck are classified as musculoskeletal disorders (MSDs). A single forceful exertion or repeated exposure to force, vibration or awkward posture can result in MSDs. This study was carried out by evaluating the relevant physical measurements of Class B ambulance used in Malaysia. The two main objectives of the study are to evaluate on the ambulance physical dimensions and workstation design and to conduct a Rapid Entire Body Assessment (REBA) to examine ambulance's emergency medical service (EMS) workers' activities and their associated MSDs risk factors.

Methods: The two methodologies adopted for the study conducted in 2014 were direct measurement of the ambulance physical dimensions and workstation layout; and in-depth interviews of five EMS workers that provides patient care during transporting patient to a public hospital in Kota Bharu, Kelantan. REBA was conducted on seven commonly performed activities by EMS workers for identifying postural risks.

Results: The study found ambulance width is too narrow and workstation layout may exposed EMS workers to MSDs risks. REBA scores for the seven commonly performed activities in the ambulance ranges from medium to very high.

Conclusion: **S**even important MSDs risk factors to be considered in the design of the Class B ambulance for performing patient care activities that may lead towards EMS workers' injury are awkward posture, bumping, instability, narrow workspace dimension, inappropriate arrangement of storage cabinet, inappropriate arrangement of medical equipment, inadequate railing and seat, and inappropriate stretcher.

Keywords: Musculoskeletal disorders, Ambulance, EMS, Workers, REBA, Risks

Introduction

Many parts of the body may be exposed to different types musculoskeletal disorders (MSDs) problems or pains, such as at the: joints, ligaments, muscles, nerves, tendons, supporting structures, limbs, neck, upper and lower back, shoulders, arms, legs, feet and hands. Emergency Medical Services (EMS) personnel are also facing the repercussion of this musculoskeletal disorders phe-

nomenon. This is due to their involvement in medical activities or emergency scenarios that will require a rapid body movement and at times have to undergo awkward postures. Ambulance personnel play an important role as the front line in EMS provider. Common activities involving ambulance personnel are lifting patients, transferring patients from lower level to higher level (i.e. ground to stretcher), transferring patients from ambulance to hospital bed (i.e. involve in pushing the stretcher) and taking medical supplies while ambulance is moving. Due to the nature of the job handled by ambulance personnel, they could face numerous medical ailments. Rodgers (1) identified three main health problems or illness that lead to early retirement among ambulance personnel, they are musculoskeletal disorders or injuries, circulatory disorders and mental disorders.

It is known the working environment in the ambulance is not conducive due to very limited space, vibration from moving vehicle (i.e. due to poor road condition), arrangement of medical items and health risks from patients. All these factors pose a continuous threat to ambulance personnel (i.e. medical officer or paramedics). This unique and specialized working environment is considered to be the most difficult area to control (2). For example, the ambulance personnel on duty has to bring up and down the stretcher during patient lifting, regardless of their height. To perform this task the arm has to be straight, and this will increase the risk of ambulance personnel to injure himself/herself, especially for those shorter personnel to support approximately 47% of the combined weight of patients and also stretcher (2). In addition, ambulance personnel have to endure high physical work demand in the ambulance, such as: lifting loads that has irregular shape and hard to hold; performing short but maximal force exertion activities such as cardiopulmonary resuscitation (CPR) in a fast moving ambulance; and working with awkward postures (3).

At present, data on MSDs among ambulance service personnel in Malaysia is scarce, this study embarks to enrich the body of knowledge by examining work place of these personnel and to see the extent of MSDs occurrences among ambulance personnel at a public hospital in Malaysia.

Expenditures associated with work-related MSDs can be quite detrimental to both the employer and employee. From an employer point of view, increasing expenses due to high medical and replacement costs when a well-trained employee is unable to work undermines organizational financial position (4). Meanwhile, looking from employees' perspective, the downside of this phenomenon would lead to loss of income and the affected employee might undergo psychological and psychosocial disorders (4). Therefore, work-related MSDs are financially burdensome in terms healthcare costs, and loss of productivity and wages.

Burdorf & Sorock (5) have found MSDs to be the major occupational problem and a significant cause of morbidity among medical services personnel. Ambulance personnel play an important role in the healthcare system of EMS. Their primary job task includes the administration of basic medical care to ensure a patient's optimal level of vital functioning while transporting him/her to a medical facility. Knowledge and skill competencies are critical because frequently, they are only given a few minutes to evaluate a patient's condition, and at the same time, provide life-saving care. The nature of their work is reported to be physically and mentally demanding due to heavy lifting of patients, bending, kneeling and prolonged standing or any other postures as needed, adverse environmental conditions, frequent exposures to death and suffering, long shifts, and irregular working hours (6).

These physical and mental strains are believed to influence in the development MSDs during regular job performance. In addition, Johnos (7) found that force, repetition and awkward postures while performing job tasks that would lead to a variety of MSDs, comprising of epicondylitis, sciatica, low back pain, carpal tunnel syndrome and rotator cuff injuries. These working conditions exposed ambulance personnel to emotional demands which resulted in poor mental health and low quality sleep (3). Reichard and Jackson (8) in their study found high incident rates of MSDs among

medical services personnel, which affect their quality of work and detrimental effects on their safety and health. In the United States, 28% of all workplace related injuries and illnesses are classified under MSDs (9). Development of MSDs is also believed to be related to certain psychological risk factors such as: job dissatisfaction, limited job control, and monotonous work (7).

In relation to professional duties onboard of an ambulance, medical professionals' top management might have overlooked safety issues while performing patient care in an ambulance during transportation due to poor emergency vehicle design (10). This drawback would expose all occupants of emergency vehicles, providers and patients, to risk of injury (11). While the ambulance EMS personnel are focused on providing care delivery and the driver is proceeding in an emergency fashion with lights and siren, the medical service provider at the rear of the vehicle are often standing and unrestrained. A sudden stop, change direction or swerve, or crash may result in serious injury to the medical service provider and quite possibly, the patient. Ambulance personnel's workplace culture may influence patient safety (12). To-date, there is no standard protocols addressing EMS personnel and patients safety in an ambulance (13). This leads to a situation whereby the ambulance personnel unaware of body movements which are not consistent with the best practices in ergonomics.

High number businesses and occupations today are aware of the need for ergonomics programs in their workplace, and ambulance personnel is no exception. While the nature of an emergency situation can make it difficult for ambulance personnel to practice good work habits, training in the basic ergonomic principles will allow these workers to identify, reduce, and prevent hazards before they cause injury (14). Therefore, with appropriate application of ergonomics principles, many aspects of the workplace such as ambulance can be designed or modified to prevent personnel from being exposed to hazards and avoid accidental injury.

This study has two main objectives as follows: to evaluate on the ambulance physical dimensions and workstation design; and to conduct a Rapid Entire Body Assessment (REBA) to examine ambulance's EMS workers' activities and their associated MSDs risk factors.

Materials and Methods

The study was conducted in 2014 with the main purpose to investigate MSDs, EMS due to providing patient care during patient transport at a public hospital in Kota Bharu, Kelantan. The study was conducted with aim to find out the health effect among the EMS personnel. Data was collected on the dimension and design of the ambulance, and on the activities usually performed by the EMS personnel (i.e. medical doctors and emergency medical technician). The data collection was assisted by five EMS personnel who have volunteered to participate as subjects in the study.

A set of case study interview questions were formulated based on previous studies done by previous researchers. These interview questions were verbally answered by the subjects and recorded. The subjects were selected from the hospital staffs, who are performing the EMS. The interview session was carried out on five subjects to investigate and obtain detailed information about their personal feelings, perceptions and opinions on the study. Three of the subjects are medical doctors working in the emergency department, one ambulance driver and one emergency medical technician. The subjects were fully informed about the study before the procedure began.

Meanwhile, the observation was done on the activities usually performed by the medical doctor and EMS personnel. MSDs risk on each activity was assessed via calculating the score of REBA. It is an observational method that can be used for estimating the risks of work-related entire body disorders. In short, it provides a quick, systematic and complete assessment of the whole body postural risks to a worker. Normally, this analysis can be conducted before and after an intervention have been done to show whether the intervention has successfully lowered the risk of injury or not.

All participants have given their consent before they take part in the study.

Results

Ambulance and Equipment Design

The ambulance vehicle was studied and used in this public hospital is Class B type, based on the authors' observation and data analysis on the ambulance design in terms of its possibility to pose risk in the development of the MSDs with the assumption that the ambulance is in motion while the operation activity is in progress. Photographs and design specifications for Class B type ambulance commonly used in Malaysian public hospitals are shown in Fig.1.

Fig. 1: Photographs and design specifications for Class B type ambulance

Referring to Fig. 1, the dimensions for the Class B ambulance are as follows: a = 46 cm; b = 41 cm; c = 53 cm; d = 183 cm; e = 14 cm; f = 109 cm; g = 159 cm; h = 37 cm; i= 26 cm; j = 15 cm; k =33 cm; l = 125 cm; m = 118 cm; n = 80 cm; o = 184 cm.

In terms of the ambulance's design, several problems have been identified. Based on our interview with the subjects, it seems that the dimension of the workspace for Class B ambulance is considered as narrow. This findings is in-line with past studies (15-17) found similar problem faced by many countries ambulance service is narrow patient's compartment. This is true because many currently used ambulance vehicles were converted from ice cream small vans, therefore the same problem of narrow space happen again and again (18).

Installation of two large seats at side of the stretcher to accommodate the EMS personnel and one family member or close relative is identified to be the cause of the cramp. Furthermore, the seat cannot be adjusted or removed. Inadequate workspace may cause bumping among the emergency medical personnel and injuring the patient (19). The reason for not changing those two large seats is unknown but according to the interview, the subjects believed the reason could be due to the ambulance operating procedure that forbid any occupant to perform any major movement while the ambulance is in motion. Therefore, to prevent

and restrict the movement of all occupants in the ambulance, those two large seats are installed instead of the bench seats. In addition, according to the subjects the geographical condition of Malaysia still consist of many roads with narrow width, which most of the time will act as a shortcut route. So, to make sure the ambulance can pass through the narrow road to get to the incident place, the total dimension width of the ambulance is designed to be smaller than those in western countries.

According to Ferreira & Hignett (20) and Gilad & Bryan (21), the standard arrangement of the medical equipment inside the ambulance is not always the same. At present very little research done with respect to ergonomic principles in reducing MSDs injuries, optimize provider safety and efficiency while providing patient care within the ambulance interior. The same problem is faced by the ambulance personnel in this public hospital. Based on the interview, the authors found out that both subjects were not comfortable with the difference in the layout of the arrangement because it may cause confusion to them for not being able to familiarize with the surrounding equipment and medical items inside the ambulance and thus affecting their performance during medical service. Labeling and standardizing the arrangement of the medical equipment inside the ambulance play an important role during emergency medical service (10).

Other design specifications that increase awkward position are the railing and the seat. In Class B ambulance, it is identified that the interior design of the ambulance got no hand rail. Based on the interview, this matter can cause instability towards the body during standing since most of the time the EMS personnel need to stand in order to reach for equipment or other medical items. Meanwhile, the seat used in Class B ambulance is too large and has narrowed down the workspace's dimension. Even with only a bench seat, the access towards patient in the workspace of the ambulance is still below satisfactory level (10). In addition, placement of the captain's seat for the physician is too far from the patient and it cannot be adjusted. Due to this seat placement, the EMS personnel sometimes need to bend towards the patient even though they have already sat at the edge of the seat. This frequent motion was listed as one of the leading activities inside a moving ambulance can cause repetitive muscle strain and leads towards developing MSDs.

Apart from railing and seat, the authors have also investigated on the stretcher design. This study also showed type of stretcher used contributes to the paramedic's physical workload, especially during patient transferring and loading. It was found the activity using stretcher like transferring and loading is considered as the most frequent activities being done in EMS. Toivonen & Fagerstrom (22) showed the impact of lifting the stretcher off the ground, carrying patient, installing auxiliary equipment, and loading into the ambulance. Thus, our interview found out that most of the ambulance personnel in the public hospital are having a back pain which is caused due to frequent activities involving the use of stretcher.

Outcomes of Rapid Entire Body Assessment (REBA)

The initial body segment codes were defined through specified simple tasks were analyzed by varying the load, distance and height moved. Data collection was carried out by measuring activities performed by EMS personnel in the ambulance. Assumption that the ambulance is in motion while performing the activity is taken into consideration when calculating the REBA score. This study assessed seven activities commonly performed by EMS personnel while travelling in the ambulance.

Discussion

REBA scores for Class B ambulance for the above four activities (i.e. Fig. 2-5) showed that without the hand rail, it causes unstable situation for the EMS personnel and thus increase the coupling score and activity score. These two scores have lead towards increased in the risk of developing MSDs. Activity like retrieving medical equipment or items is considered as a frequent activity done in the ambulance, this increase repetitive stretching muscle activity since the shoulder needs to be raised up above the normal raise position; it also increase repetitive twisting and

cause instability due to the installation of the storage cabinet at one side.

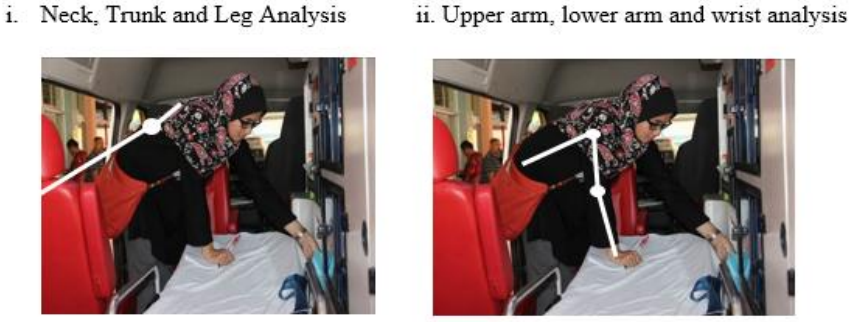

Fig. 2: EMS personnel trying to reach different parts of patient's body; the final REBA scores recorded is 9

Fig. 3: EMS personnel is trying to get the medical equipment in the upper cabinet; the final REBA scores recorded is 6

Fig. 4: EMS personnel is trying to get the medical equipment in the lower cabinet; the final REBA scores recorded is 10

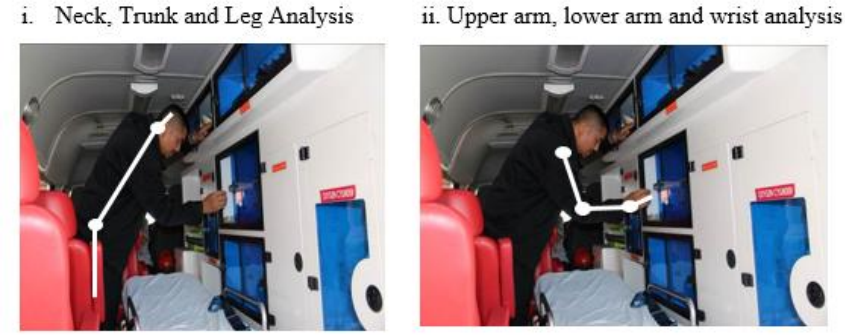

Fig. 5: EMS personnel is trying to get the medical equipment in the middle cabinet; the final REBA scores recorded is 4

The result from Class B Ambulance; Fig. 6 showed that the ambulance EMS personnel has a medium risk of developing MSDs even with just an activity of loading out the stretcher without the patient on it. Meanwhile, the result from Fig. 7 and 8, which involves loading in the stretcher back into the ambulance showed that the risk of developing the MSDs ranges about medium to high risk even with just a small kid weighing around 40 kg.

Fig. 6: EMS personnel is pulling out the stretcher from the ambulance; the final REBA scores recorded is 7

Fig. 7: EMS personnel is pushing in/out with the patient on the stretcher; the final REBA scores recorded is 4

Fig. 8: EMS personnel is lifting up for pushing further the stretcher in the ambulance with the patient; the final RE-BA scores recorded is 8

This study has investigated the inadequacy in ergonomic and safety of ambulance. It discusses the associated MSDs problems to those who are involved in ambulance services. The current seat design in ambulance is not adjustable and inflexible, which limit the movement of the EMS personnel to attend the patient care in transit. In addition, safety belt was not provided to protect EMS personnel from being thrown around in the ambulance compartment. These problems indicate that it will be better if the current seat design is changed to bench designed with segmented cushions like a sofa, place on a platform that able to move backward and forward. This design concept is not only improving the flexibility but also allow the seated EMS personnel to slide backward and forward; and easy to access the patient while using safety belt (23).

EMS personnel are required to perform activities such as lifting, moving and carrying patients using stretcher and the physical load factors comprise in lifting and moving heavy objects may results in awkward working postures (24). Improving work ergonomics, such as use of auxiliary equipment can prevent MSDs occurrence. Ergonomic design approach for manual handling equipment such as stretcher can reduce the physically demanding work of transporting patient. In addition, equipment accessibility inside the ambulance is also an important factor that can contributes many problems faced by EMS personnel.

Presently, location of equipment within the ambulance is not standardized. Thus, this condition forces the EMS personnel to repetitively open multiple drawers or cabinets to search for the equipment or supplies. Therefore, by labeling will help to reduce the possibility of repetitively opening the drawers and maintaining the standardization in all ambulance will promote familiarity (10).

The study found most of the time EMS personnel need to stand to reach medical equipment; they always experienced instability because there is no proper lace for the EMS personnel to hold or grip while working in Class B ambulance. Thus, hand railing need to be provided so that it can provide a place for them to hold or grip and reduce the awkward position due to instability.

Conclusions

Evaluation of the ambulance EMS personnel's activities has been successfully studied. A total of seven activities have been assessed. The range of risk to develop MSDs among all the seven activities ranges between medium to very high. The risk factors to MSDs in the design of the Class B ambulance were successfully examined. Among the factors identified are narrow workspace dimension, inappropriate arrangement of storage cabinet, inappropriate arrangement of medical equipment, inadequate railing and seat, and inappropriate stretcher. All these factors are deemed important because they can cause problems for performing patient care activities in the ambulance such as: awkward posture, bumping, instability, and event that may lead towards personal's injury.

Ethical considerations

The authors have completely observed all ethical issues which include plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission and redundancy.

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References

1. Rodgers IM (1998). A five year study comparing early retirements on medical grounds in ambulance personnel with those in other groups of health service staff, part II: causes of retirement. *Occup Med*, 48(2): 119-132.
2. Boocock MG, Gray MI, Williams S (2002). *Patient handling in the ambulance services: case study investigations*. CRC Press, 2002. *Pp:* 33- 38.

3. Hansen C, Rasmussen K, Kyed M, Nielson KJ, Anderson JH (2012). Physical and psychosocial work environment factors and their association with health outcomes in Danish ambulance personnel- a cross-sectional study. *BMC Public Health,* 12(1): 5 - 34.
4. Fisher TF, Wintermeyer SF (2012). Musculoskeletal disorders in EMS: Creating employee awareness. *Professional Safety,* 57(07): 30-34.
5. Burdorf A, Sorock G (1997). Positive and negative evidence of risk factors for back disorders. *Scand. J. Work. Environ. Health*, 23(4): 243-256. *Scand J Work Environ Health,* 23(4): 243 – 256.
6. Bost N, Crilly J, Wallis M, Patterson E, Chaboyer W (2010). Bost, C. J., Wallis, M., Patterson, E., & Chaboyer, W. 2010. Clinical handover of patients arriving by ambulance to the emergency department. *Int Emerg Nurs,* 18(4): 210 – 220.
7. Johnos WMS (2011). Prevalence of Upper Extremity Musculoskeletal Disorders. *Musculoskeletal Disorders,* 5(2): 187-190.
8. Reichard AA, Jackson LL (2010). Occupational injuries among emergency responders. *Am J Indust Med,* 53(1): 1 – 11.
9. Bureau of Labor Statistics (2010). Non-fatal occupational injuries and illnesses requiring days away from work, 2009 (pp. 1-37). Retrieved from www.bls.gov/iif/oshednew.htm.
10. Biesbroek S, Teteris E (2012). Human factors review of EMS ground ambulance design. *Symposium on Human Factors and Ergonomics in Health Care* 1: 95 – 101.
11. Brice JH, Studnek JR, Bingham BL, Martin-Gill C, Custalow C, Hawkins E, Morrison LJ (2012). EMS provider and patient safety during response and transport: Proceedings of an ambulance safety conference. *Prehospital Emerg Care,* 16(1): 3 – 19.
12. Patterson PD, Huang DT, Fairbanks RJ, Simeone S, Weaver M & Wang HE (2010). Variation in emergency medical services workplace safety culture. *Prehospital Emerg Care,* 14(4): 448 – 460.
13. Tomas S, Chanovas M, Roqueta F, Toranzo T (2012). Patient safety in emergency medicine: report on 4 years' implementation of a program designed for the Spanish Society of Emergency Medicine (SEMES). *Emergencias,* 24: 225 – 233.
14. Jellad A, Lajili H, Boudokhane S, Migaou H, Maatallah S, Frih ZBS (2013). Musculoskeletal disorders among Tunisian hospital staff: Prevalence and risk factors. *Egypt Rheumatol,* 35: 59 – 63.
15. Levick N, Grzebieta R (2007). Crash worthiness analysis of three prototype ambulance vehicles. *Int Enhanced Safety Vehicles Technical Paper, 07-0249.*
16. Levick N, Li G, Yannaccone J (2001). Development of a dynamic testing procedures to assess crashworthiness of the rear patient compartment of ambulance vehicles. *Enhanced Safety of Vehicles, Technical Paper Series. Paper, 454.*
17. Levick N, Shelew WB, Blatt A (2001). Occupational injury hazards in ambulance transport, findings from full vehicle crash testing. *Academic Emerg Med,* 8(5): 5 - 27.
18. Dirk G, Kawakami K, Shimizu H (2005). Design concept of electrical vehicle ambulance. *J Asian Electric Vehicl,* 3(1): 713 – 719.
19. Sanddal ND, Albert S, Hansen JD (2008). Contributing factors and issues associated with rural ambulance crashes: Literature review and annotated bibliography. *Prehospital Emerg Care,* 12(2): 257 – 267.
20. Ferreira J, Hignett S (2005). Reviewing ambulance design for clinical efficiency and paramedic safety. *Appl Ergon,* 36(1): 97 – 105.
21. Gilad I, Bryan E (2007). Ergonomic evaluation of the ambulance interior to reduce paramedic discomfort and posture stress. *Human Factors,* 49(6): 1019 – 1032.
22. Toivonen R, Fagerstrom V (2011). The effect of patient transport stretchers on work ergonomics among paramedics. Helsinki, Finland: Finnish Institute of Occupational Health.
23. Kibira D, Lee YT, Dadfarnia M (2012). Enhancing performance and safety in ambulance through improved design standard. USA: National Institute of Standard and Technology, Department of Commerce.
24. Videman T, Ojajarvi A, Rihimaki H, Troup JDG (2005). Low back pain among nurses, a follow up beginning at entry to the nursing school. *Spine,* 30(20): 2334 – 2341.