ERGONOMIC RISK ASSESSMENT OF MUSCULOSKELETAL DISORDERS DURING CHEST COMPRESSION AT KNEELING, STANDING AND STEP-ON-STOOL POSITION IN RESCUER PERFORMING CARDIOPULMONARY RESUSCITATION

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AKU JANJI

Diperakui bahawa disertasi yang bertajuk **ERGONOMIC RISK ASSESSMENT OF MUSCULOSKELETAL DISORDERS DURING CHEST COMPRESSION AT KNEELING, STANDING AND STEP-ON-STOOL POSITION IN RESCUER PERFORMING CARDIOPULMONARY RESUSCITATION** merupakan kerja dan penyelidikan yang asli daripada **NURUL HUSNA BT ABD GHANI**, No. Matrik: dari tempoh 2016 hingga 2020 adalah di bawah penyeliaan kami. Disertasi ini merupakan sebahagian daripada syarat untuk penganugerahan **Sarjana Perubatan Kecemasan**, segala hasil penyelidikan dan data yang diperolehi adalah hak milik terpelihara Universiti Sains Malaysia.

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LIST OF ABBREVIATIONS

AHA	American Heart Association
BLS	Basic Life Support
ACLS	Advanced Cardiac Life Support
CPR	Cardiopulmonary Resuscitation
MSD	Musculoskeletal Disorder
REBA	Rapid Entire Body Assessment
ROSC	Return of Spontaneous Circulation
WMSD	Work-related Musculoskeletal Disorder

ABSTRAK

Pengenalan: Pelbagai kajian telah dilakukan untuk menambah baik kualiti resusitasi kardiopulmonari kepada pesakit namun hampir tiada data berkenaan kesan resusitasi kardiopulmonari kepada anggota penyelamat yang memberikan rawatan

Objektif: Untuk menilai risiko ergonomik masalah muskuloskeletal yang dihadapi oleh anggota penyelamat yang melakukan resusitasi kardiopulmonari pada 3 posisi berbeza iaitu melutut, berdiri dan berdiri di atas bangku-tangga, kualiti resusitasi kardiopulmonari pada setiap posisi dan hubungan antara keduanya.

Kaedah: Kajian rentas melibatkan simulasi menggunakan manikin, di mana pesakit mengalami denyutan jantung terhenti telah dilakukan di kalangan kakitangan perubatan di jabatan kecemasan di sebuah hospital universiti yang terletak di Kelantan, Malaysia. Skor Rapid Entire Body Assessment (REBA) telah digunakan sebagai alat universal untuk menilai ergonomik dalam kajian ini.

Keputusan: 67 peserta telah mengambil bahagian dalam kajian ini. Posisi melutut menunjukkan risiko untuk mendapat masalah muskuloskeletal yang tinggi dengan skor REBA sebanyak 9.00 (1.00), diikuti oleh posisi berdiri di atas bangku-tangga sebanyak 7.63 (1.54) dan posisi berdiri sebanyak 7.00 (1.00) yang mana termasuk dalam risiko sederhana. Perbezaan ketara dapat dilihat pada kedalaman tekanan dada antara posisi melutut dan berdiri ($p<0.001$, 95% CI), dan juga antara posisi melutut dan berdiri di atas bangku-tangga. ($p<0.001$, 95% CI) . Tiada hubungkait didapati antara risiko ergonomik dan kualiti resusitasi kardiopulmonari pada posisi berdiri dan melutut. Walaubagaimanapun, hubungkait yang ketara dilihat antara risiko ergonomik dan pendaratan dada yang lengkap pada posisi berdiri di atas bangku-tangga.

Kesimpulan: Anggota penyelamat mempunyai risiko untuk mendapat masalah muskuloskeletal apabila melakukan resusitasi kardiopulmonari pada posisi melutut, berdiri dan berdiri di atas bangku-tangga. Didapati tiada hubungkait signifikan antara risiko ergonomik kepada anggota penyelamat dan kualiti resusitasi kardiopulmonari yang dilakukan.

Keywords: Resusitasi kardiopulmonari, Ergonomik, Masalah muskuloskeletal

ABSTRACT

Introduction: Countless research has been carried out to improve the quality of cardiopulmonary resuscitation (CPR) delivered to the patient but there is scarce data concerning health impact of CPR upon person performing it.

Objectives: The aim of this study was to determine the ergonomic risk of musculoskeletal disorders (MSD) in rescuer performing CPR at 3 different positions: kneeling, standing, standing on step-stool, quality of CPR performed at each position and their correlations.

Methods: A cross-sectional simulated-manikin study of in-hospital cardiac arrest was conducted among medical personnel of emergency department of university hospital located in Kelantan, Malaysia. Rapid Entire Body Assessment (REBA) score as a universal tool for ergonomic assessment was used in this study.

Results: In total, 67 participants took part in this study. Kneeling showed the worst mean REBA score of 9.00 (1.00) with high risk of developing MSD, followed by step-on-stool 7.63 (1.54) and standing position 7.00 (1.00) which account for moderate risk. Significant difference were observed in compression depth between kneeling and standing position ($p<0.001$, mean difference (95% CI) = 6.27 (3.26, 9.28)), and between kneeling and step-on-stool ($p<0.001$, mean difference (95% CI) = 4.35 (2.21, 6.49)). There is no evidence of significant correlation between REBA risk group and CPR quality at standing position and kneeling position, although at step-on-stool position significant correlation noted between REBA risk group and complete recoil.

Conclusion: There is notable risk of developing MSD in person performing CPR at 3 different positions although no remarkable correlation between the risk and quality of CPR performed.

Keywords: Cardiopulmonary resuscitation, Ergonomics, Musculoskeletal disorder

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Emergency doctors and paramedics are among professionals that work in hectic and demanding working environment daily. With increased in number of visits to emergency department, burden faced by emergency healthcare workers peaks. Prolonged physical exhaustion among paramedic predisposed them to burn out thus necessitate further action to avoid bad implication on the quality of emergency medical service. One of commonly performed life-saving procedure in Emergency department is cardiopulmonary resuscitation (CPR). Many literatures studied on improving delivery of high-quality CPR in order to obtain return of spontaneous circulation (ROSC) but little is known about the effect of CPR on the rescuer performing it.

Ergonomic as a science concerning human factors within the work system aims to design work system that is optimum for worker in term of efficiency, health, safety, comfort and ease of use. Data regarding application of ergonomic in health sector especially involving emergency services is still scarce. With increase of workload, ageing of workforce and economic impact of work-related musculoskeletal disorder (WMSD), it is crucial to look on this matter to reduce ergonomic mismatch.

Paramedic often needs to perform CPR in various positions due to unpredictable nature of pre-hospital care to comply with early initiation of CPR in the current guideline. In a study conducted to identify critical physical demanding task of paramedic work found that 72.3% of 183 respondents identified CPR as among highest physically demanding task to perform. Rescuer needs to push hard and fast in order to produce adequate chest compression for patient survival. Repetitive movement of joints in awkward position in addition to the force

delivered to produce high-quality chest compression contribute to fatigue and risk of work-related musculoskeletal disorder (WMSD) among paramedics.

The aim of this study is to identify the ergonomic risk factor of MSD in rescuer performing CPR at 3 different positions, quality of CPR performed and correlation between them. With the knowledge obtained from the study, we could identify the most optimum position which should be applied by rescuer when performing CPR in order to obtained effective CPR while not compromising their health. By avoiding poor ergonomic position of rescuer we hope to reduce the risk of developing WMSD in healthcare worker thus reducing the economic and social impact.

CHAPTER 2

OBJECTIVES

2.0 OBJECTIVES OF THE STUDY

2.1 General objective

To determine the ergonomic risk of MSD in rescuer performing CPR in kneeling, standing and step-on-stool position

5.2 Specific objectives

1. To determine mean REBA score for rescuer performing CPR in kneeling, standing and step-on-stool position
2. To compare mean difference of compression rate, depth, complete recoil and hands-off time between 3 different position of rescuer (kneeling, standing, step-on-stool) during chest compression
3. To identify the correlation between ergonomic risk of MSD and quality of CPR

CHAPTER 3

MANUSCRIPT

3.1 TITLE PAGE

Ergonomic risk assessment of musculoskeletal disorders during chest compression at kneeling, standing and step-on-stool position in rescuer performing cardiopulmonary resuscitation

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3.2 ABSTRACT

Introduction: Countless research has been carried out to improve the quality of cardiopulmonary resuscitation (CPR) delivered to the patient but there is scarce data concerning health impact of CPR upon person performing it. We conducted a study to evaluate the ergonomic risk factor of musculoskeletal disorder in rescuer performing CPR at 3 different positions of CPR, to compare the quality of CPR at 3 different positions of rescuer and to determine association of ergonomic risk factor of MSD with quality of CPR performed at 3 different positions of rescuer.

Methods: A cross-sectional simulated-manikin study of in-hospital cardiac arrest was conducted among medical personnel of emergency department of university hospital located in Kelantan, Malaysia. Each participant performed CPR at 3 different positions: kneeling, standing and standing on step-stool. Ergonomic risk at all 3 positions was determined using Rapid Entire Body Assessment (REBA) while quality of CPR performed including depth and rate of compression, hand-off ratio and complete recoil was recorded and analysed to find their correlations.

Results: In total, 67 participants took part in this study. Kneeling showed the worst mean REBA score of 9.00 (1.00) with high risk of developing musculoskeletal disorders (MSD), followed by step-on-stool 7.63 (1.54) and standing position 7.00 (1.00) which account for moderate risk. Significant difference were observed in compression depth between kneeling and standing position ($p<0.001$, mean difference (95% CI), and between kneeling and step-on-stool ($p<0.001$, mean difference (95% CI). There was no evidence of significant correlation between REBA risk group and CPR quality at standing position and kneeling

position, eventhough at step-on-stool position showed significant correlation between REBA risk group and complete recoil.

Conclusion: There is notable risk of developing MSD in person performing CPR at 3 different positions although no remarkable correlation between the risk and quality of CPR performed.

Keywords: Cardiopulmonary resuscitation, Ergonomic, Musculoskeletal diseases

3.3 INTRODUCTION

Paramedics and emergency doctors as front liners are groups of people which are predisposed to the hazard of workplace as they work in highly intense environment between life and death of patient whom they are trying to save. Physical and emotional stresses during the critical minutes, frequent and continuous exposure to death and suffering and physically demanding nature of work involving long shift and irregular working hours have predispose these front liners to occupational burn out. Among physically demanding task performed in emergency department and pre-hospital care include performing cardiopulmonary resuscitation at various circumstances such as kneeling on moving stretcher, standing in moving ambulance and standing on step-stool to accommodate person managing airway of the victim.

Chest compression is an important component of cardiopulmonary resuscitation. It is a technique of delivering external cardiac massage to generate blood flow to the heart and brain hence improve the chances of successful reperfusion[1]. CPR involves awkward postures with repeated lifting of trunk and upper body in order to deliver adequate force to produce compression across the chest wall. This exertion creates large force over L5-S1 vertebra

which is the most vulnerable region for back injury[2]. In order to achieve adequate chest deflection, rescuer need to apply force up to 530N in which the force is transmitted across the wrist causing frequently reported wrist pain after performing CPR [3]. Heavy physical work, repetitive work and awkward postures have been recognized as biomechanical risk factor for developing work-related musculoskeletal disorder (WMSD) besides individual risk factor identified like female gender, high BMI and smoker[4].

Many studies have been carried out to improve the quality of CPR delivered to the patient, but less concern is put on the safety and comfort of rescuer carrying out the task. Measures should be taken to address the issue in view of increasing of workload, ageing of workforce and economic impact of work-related musculoskeletal disorder (WMSD). Ergonomic is a science concerning human factors within the work system which aims to design work system that is optimum for worker in term of efficiency, health, safety, comfort and ease of use. Studies on ergonomic has long history in industrial and manufacturing sectors. Ironically implementation of ergonomic in health sector is still lacking. Few papers were published on ergonomic in dentistry and surgery, but less can be found concerning emergency service. In order to provide the best medical service to the public and at the same time not compromising the healthcare worker which is the backbone of healthcare service of the country, thorough investigation on improving safety aspect of job task and working environment is crucial. Thus, this study aim to evaluate the ergonomic risk factor of musculoskeletal disorder (MSD) in rescuer performing CPR at 3 different positions of CPR, to compare the quality of CPR at 3 different positions of rescuer and to determine association of ergonomic risk factor of MSD with quality of CPR performed at 3 different positions of rescuer.

3.4 METHODOLOGY

A cross-sectional, simulated manikin study of in-hospital cardiac arrest was carried out in Hospital Universiti Sains Malaysia, a teaching hospital in Kubang Kerian, Kelantan. The study was approved by Human Ethics Committee of Hospital Universiti Sains Malaysia. All subjects provided informed and written consent. Sixty-three emergency medical personnel comprised of 25 medical officers, 15 paramedics and 23 staff nurses voluntarily involved in the study. They have experience on doing CPR and have undergone training on high quality CPR in basic life support (BLS) course before.

The participants had no musculoskeletal pain or sprain, previous history of long bone or spine fracture, congenital abnormality of extremities and trunk, nor past history of surgery involving joints. Volunteers with chronic illness that can affect performance of high quality CPR and be exacerbated by doing CPR in the given duration of study were excluded from the study. Study was carried out in simulation room of the Department of Emergency Medicine. Each participant was enrolled when he or she had rest of at least 8 hours from previous working shift and at least 12hours from the next shift in order to minimize effect of study on working performance and status quo of the participant.

Within-subject study design was used to reduce confounding factors. Each participant was given task to perform CPR at 3 different positions: kneeling, standing and step-on-stool. At kneeling position, rescuer kneeled on the left side of manikin which was put on the floor. At standing position, rescuer stood beside the bed where the manikin was on the bed height was set at 54cm (lowest height of bed in resuscitation area). Meanwhile, for CPR in step-on-stool position, rescuer stood on the step stool which was placed beside the bed where the manikin was on. The bed height was 54cm and the step-stool height was 34cm.

Sequence of CPR was determined by drawing papers from the bowl which contained 3 piece of paper with each written different position of CPR (kneeling or standing or step-on-stool). First draw indicated the first position, second draw indicated the second position and third draw indicated the third position. Participants were not given similar sequence of CPR to reduce confounding factors of fatigue after CPR at one position that will affect performance at next position and also to avoid participant to have mental rehearsal on how they want to perform leading to failure to assess ergonomic objective.

We divided the experiment to 3 stages based on 3 positions at which CPR was performed by the participant. Manikin used in this study was Advanced CPR simulator CPEA by BT Inc. At each stage, participant performed 2 cycles of 2-minute continuous chest compression according to AHA 2015 adult BLS guideline (rate 100-120/min, depth of compression 5-6cm, allow full chest recoil, hands positioned at lower half of sternum and minimize interruption). Participants were given 2 minutes of rest between 1^{st} and 2^{nd} cycle of 2-minutes CPR to fulfil the need of rotating the compressor every 2minutes as recommended in AHA 2015 adult BLS guideline. REBA score was assessed while chest compression took place. Video recording was also taken for the purpose of ensuring accuracy of assessment. Performance data was recorded by a device attached to the manikin and data was transferred from manikin to computer via blue-tooth and analysed by using a compatible software program named RoDam. Participants were blinded from feedback on performance of CPR during the experiment. Performance data were only revealed to participant after completion of all the tasks. Performance data included average compression rate (/min), average compression depth (mm) and number of compression with complete chest recoil (%). Each

participant was given at least 1hour of rest in between stages to avoid effect of participants' fatigue on quality of CPR.

Rapid Entire Body Assessment (REBA) is a universal ergonomic assessment tool used to evaluate whole body postural risk of work-related musculoskeletal disorder (WMSD) developed by Hignett et al[5] in year 2000. It is designed for easy use and evaluator does not require advanced degree in ergonomic to do the scoring[6]. REBA is a comprehensive assessment consist of analysis of posture involving neck, trunk, legs, upper and lower arm in addition to force and load used to perform the task and consideration of dynamic of the task performed (static, repeated small range action or action causing rapid large ranges in posture or unstable base). REBA worksheet is divided into 2 body segment sections which is section A (covers neck, trunk and leg) and section B (covers arm and wrist). REBA score is obtained by analysis of both sections giving out scores from 1 to 15 that represents level of MSD risk. Scores are divided into 5 categories which determine the risk of developing MSD : negligible (score 1), low risk (score 2-3), medium risk (score 4-7), high risk (score 8-10) and very high risk (score 11+).

Figure 1 – CPR at kneeling (left), standing (middle) and step-on-stool (right) positions

All statistical analysis was done by using IBM SPSS 25. Descriptive analysis was applied to fulfill the first objective. Mean (SD) of REBA score was reported for the normally distributed data, while median (IQR) was reported for non-normally distributed data. RM ANOVA within-subject effect was done in order to determine the difference of CPR quality (compression rate, depth, complete recoil, hands-off time) between three different position of rescuer (kneeling, standing, step-on-stool) during chest compression. Assumption of compund symmetry was checked by Mauchly's test of sphericity before fitting RM ANOVA model. Significant Mauchly's test of sphericity ($p< 0.05$) indicated that assumption of compound symmetry was not met. Multivariate tests statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root) were refered when the data violated this assumption. The analysis was proceed with the pairwise comparison with confidence interval adjustment using Bonferroni when P-value of multivariates test statistics were significant ($p<0.05$). Test of sphericity was not significant when $p>0.05$, indicated the assumption was met. Test of within-subjects effects was referred when this assumption was met. If $p<0.05$, its suggested means of the groups were significantly different. Otherwise, the means were not significant and pairwise comparisons was not proceed. Mean difference with 95% confidence interval of the pairwise comparisons and p-value were reported. There was significat different of mean when p-value was significant ($p<0.05$). Spearman's correlation analysis has been done to determine the correlation between ergonomic risk of MSD and quality of CPR (compression rate, depth, complete recoil, hands-off time). Correlation coefficient (rho) and p-value of the correlations were reported as the results of the analysis. P-value < 0.05 indicated there was a significant correlation between ergonomic risk of MSD and quality of CPR.

3.5 RESULTS

There were 63 participants involved in the study with 39 (61.9%) of them were female and 24 (38.1%) were male. Twenty-five (39.7%) medical officers, 15 (23.8%) paramedics and 23 (36.5%) staff nurses participated in the study. Table 1 shows details on descriptive analysis of participants' demographics and profiles. Mean REBA score for rescuer performing CPR at kneeling, standing and step-on-stool position were shown in Table 2. The highest mean REBA score was recorded at kneeling position which belongs to high risk group for developing MSD. Meanwhile both standing and step-stool poses moderate risk to the rescuer who performed CPR.

In analysing the posture of participant, we noticed that at step-on- stool position, taller participant tend to have their trunk bended >60 degree (score +4) . Meanwhile shorter participant need to raise their shoulder while performing CPR at standing position (score+1). At kneeling and step-on-stool position, leaning was frequent (score -1). At all position, add force score of +2 was given indicating load of >22lbs which was needed to produce adequate chest deflection. For activity score, score of +1 was given to all positions in view of chest compression involves repeated small range actions. Zero coupling score was given to all positions as CPR did not require handling of tools.

Table 3 shows decriptive analysis of CPR quality at kneeling, standing and step-on-stool position. Mean (SD) of compression rate at kneeling, standing and step-on-stool were 135.44 (20.31), 121.43 (14.87) and 128.22 (14.85), respectively. Mean (SD) of depth compression at kneeling was 52.70 (7.35), while at standing was 46.43 (11.55) and 48.35 (8.48) at step-on-stool. At kneeling position, median (IQR) of complete recoil was 100.00 (2.00), while at

standing and step-on-stool position, the median (IQR) were 100.00 (0.00) and 100.00 (1.00), respectively.

Table 1: Participants' demographic and profile (n = 63)

Variable	
Gender	
Male	24 (38.1)
Female	39 (61.9)
Mean age (years)[a]	27.00 (10.00)
Mean height (m)[b]	1.62 (0.07)
Mean weight (kg)[b]	64.75 (14.41)
Mean BMI (kg/m^2)[b]	24.49 (4.41)
CPR training level	
ALS	22 (34.9)
BLS	41 (65.1)
Duration of last training (months)	
< 6	26 (41.3)
6 – 12	15 (23.8)

> 12	22 (34.9)
Designation	
Medical officer	25 (39.7)
Paramedic	15 (23.8)
Staff nurse	23 (36.5)
Working experience (years)	
< 2	36 (57.1)
2 – 5	6 (9.5)
> 5	21 (33.3)

[a]Median (IQR), [b]Mean (SD)

Table 2: REBA score for rescuer performing CPR at kneeling, standing and step-on-stool position

Position	**Mean (SD)**
Kneeling	9.00 (1.00)[a]
Standing	7.00 (1.00)[a]
Step-on-stool	7.63 (1.54)

[a]Median (IQR)

Table 3: Descriptive analysis of CPR quality at kneeling, standing and step-on-stool position

Position	CPR quality	Mean (SD)
Kneeling	Compression rate (per minute)	135.44 (20.31)
	Depth compression (mm)	52.70 (7.35)
	Complete recoil (%)	100.00 (2.00)[a]
Standing	Compression rate (per minute)	121.43 (14.87)
	Depth compression (mm)	46.43 (11.55)
	Complete recoil (%)	100.00 (0.00)[a]
Step-on-stool	Compression rate (per minute)	128.22 (14.85)
	Depth compression (mm)	48.35 (8.48)
	Complete recoil (%)	100.00 (1.00)[a]

[a]Median (IQR)

Table 4 shows the result for comparison of mean compression rate and depth compression between three different positions of CPR. Significant differences of compression rate were found between the three different positions during CPR. Significance difference were observed between kneeling and standing position ($p<0.001$, mean difference (95% CI) = 14.02 (9.11, 18.92)), and, kneeling and step-on-stool ($p<0.001$, mean difference (95% CI) = 7.22 (1.67, 12.77)). Significance difference also was observed between standing and step-on-stool ($p = 0.006$, mean difference (95% CI) = -6.79 (-10.92, -2.67)).

Significant differences of depth compression were found between the three different positions during CPR. Significance difference were observed between kneeling and standing position

(p<0.001, mean difference (95% CI) = 6.27 (3.26, 9.28)), and between kneeling and step-on-stool (p<0.001, mean difference (95% CI) = 4.35 (2.21, 6.49)). No significant difference of depth compression observed between standing and step-on-stool (p = 0.222).

Table 5 shows the results of Spearman's correlation analysis in order to determine the correlation between REBA score risk group and CPR quality.Spearman's correlation analysis showed no evidence of significance correlation between REBA score risk group and CPR quality at kneeling position since p-value > 0.05. The analysis also found no significant correlation between REBA risk group and CPR quality at standing position (p>0.05). At step-on-stool position, it was also no evidence of significant correlation determined between REBA risk group with compression rate and depth compression (p>0.05). However, there was a significant correlation between REBA risk group and complete recoil (p = 0.006). The obeserved correlation coefficient, Spearman's rho was 0.34, which suggested positive fair correlation.

Table 4:Comparison for mean difference of CPR quality between three different positions

CPR quality	**Comparison**	**Mean difference (95% CI)**	**p-value**
Compression rate	Kneeling – Standing	14.02 (9.11, 18.92)	<0.001
	Kneeling – Step-on-stool	7.22 (1.67, 12.77)	0.006
	Standing – Step-on-stool	-6.79 (-10.92, -2.67)	<0.001
Depth compression	Kneeling – Standing	6.27 (3.26, 9.28)	<0.001
	Kneeling – Step-on-stool	4.35 (2.21, 6.49)	<0.001

	Standing – Step-on-stool	-1.92 (-4.52, 0.68)	0.222

Table 5: Correlation between CPR quality and REBA risk group at different position during CPR

Position	**CPR quality**	**Correlation coefficient (rho)**	**p-value[a]**
Kneeling	Compression rate	-0.11	0.413
	Depth compression	0.03	0.830
	Complete recoil	-0.00	0.991
Standing	Compression rate	0.13	0.328
	Depth compression	-0.15	0.243
	Complete recoil	0.19	0.135
Step-on-stool	Compression rate	0.03	0.848
	Depth compression	-0.17	0.186
	Complete recoil	0.34	0.006

[a]Spearman's correlation analysis; significant at p-value ≤ 0.05

3.6 DISCUSSION

This study presents ergonomic risk of developing MSD at 3 different positions of CPR: kneeling, standing and step-on-stool position, quality of CPR at each position and how they affect each other.

Previous studies reported on impact of CPR on rescuer in various aspect such as vital parameters, kinematic, and muscular fatigue[7,8] . Heart rate increase significantly after each external chest compression and there were significant differences in rescuer motion at kneeling and standing position[7]. Electromyography study showed that fatigue started at 2min of chest compression[8]. In order to maintain effective compression, rescuer exert compensatory force which lead to poor posture predisposing him to musculoskeletal pain and long-term injury. The knowledge obtained from the previous studies were used to improve the quality of resuscitation delivered to the patient. For example, latest recommendation by American Heart Association for Advanced Cardiac Life Support in 2015 which advocate changing of rescuer every 2 minutes to maintain the effectiveness of compression. Musculoskeletal pain and fatigue experienced by rescuer should be look into seriously. In a study conducted to identify critical physical demanding task of paramedic work found that 72.3% of 183 respondents identified CPR as among highest physically demanding task to perform[9]. Work-related musculoskeletal disorders (WMSD) contribute to reduction in performance of emergency medical services besides adding to the economic and social burden in term of treatment and rehabilitation.

In this study we employed REBA score to determine the risk of developing MSD. It is divided into 5 groups of risk : negligible, low, moderate, high and very high risk depending on number of score. From our study, we found that all 3 different positions of CPR posed ergonomic risk to the rescuer in which kneeling position possessed high risk of developing

MSD while standing and step-on-stool position imply moderate risk to the rescuer. Kneeling while doing CPR required the rescuer to flex his knees and hips next to the victim while bending his back to put both hands in straight line with shoulder and elbow in order to produce adequate forceful compression to the chest. At standing position, rescuer stands by the side of victim while putting both hand on chest for compression. Shorter rescuer often needs to lift his shoulder and tiptoe to make sure his arm is in straight position to produce adequate compression force. As for step-on-stool position, taller rescuers need to bend their back further to have a comfortable height for adequate compression. Report by Gallagher et al[10] said that prevalence of lower back symptoms increases significantly while performing task at awkward posture including stooped, squatting and kneeling due to increase load on the spine. Sustenance of flexed hips and knees exert high pressure between thigh and lower leg gastrocnemius[11]. Kneeling and squatting contribute to degenerative meniscial lesion which lead to MSD of knee and lower back[12]. Repititive strain injury can be caused by repetitive forceful motions and awkward posture[13]. Unfortunately all of these factors can be found in postures during CPR.

Meanwhile in term of quality of CPR, kneeling position produced deeper compression depth that met the quality of CPR recommended. Furthermore, at kneeling and step-on-stool position, positioning the rescuer's shoulder perpendicular to patient's chest produce greater compression force compared to standing which depends on rescuer's height. The use of step-stool improved the compression depth as it minimized the effect of height and enhanced effect of chest compression in short rescuer[14]. In term of rate of compression, kneeling also produced higher rate of compression although all 3 positions exceeded the recommendation rate. Less effort is needed in term of producing adequate compression depth at kneeling and

step-stool position as the force is partly contributed by the weight of the rescuer, thus effort is shifted more to producing quicker compression. Previous study by Hong et al on how postures affect the quality of compression showed that kneeling and step-stool produced greater mean compression depth and number of adequate compression[15]. Meanwhile Perkins et al and Chi et al found that no significant effect of rescuer's position on the quality of CPR although there was kinematics difference at different positions of the rescuer[7,16].

Despite poor ergonomic of CPR, the quality of CPR was not affected given by no significant correlation between REBA score and quality of CPR except for complete recoil at step-on-stool position. This finding proved that experienced rescuer was able to utilize strategies to maintain compression quality at various positions. It was concurrent with study by Chi et al in which there were no different in levels of exertion, force applied to the chest or compression depth in different manikin position[7]. Nonetheless, finding of this study may be contributed by the short duration of chest compression as rescuer usually experienced muscular pain and fatigue after prolonged duration of chest compression which might further affect the quality of CPR delivered. Further study should also be carried out on correlation between REBA score and muscular discomfort experience by rescuer at different positions of CPR to support findings of ergonomic risk.

Although we failed to prove the correlation of CPR ergonomics and CPR quality in this study, the findings of ergonomic risk posed by CPR on rescuer should not be taken lightly. From long term perspective, improving the technique of delivering CPR which favour the posture of rescuer while at the same time maintaining the quality of CPR could save us a lot in term of cost in treating work-related MSD. CPR at kneeling position has commonly taught in training courses eventhough in real life we seldom need to perform CPR at kneeling

position. In view of the high risk it caused on the rescuer, it is recommended to avoid advocating kneeling position in CPR training courses technique. Regarding the use of step-stool, the design can be improved by making it easily adjustable with the height of rescuer to maximise the benefit in producing deeper compression. Alternatives such as mechanical compression device should be taken into considerations in view of metaanalysis has showed that there was no difference in outcome of patient recieving conventional or mechanical CPR[17].

There are few limitations of the study. Firstly, it only involved small group of healthcare workers in emergency department of a single university hospital which may not represent whole emergency rescuer in general. Secondly, it was a simulated manikin study in which the elasticity of manikin's chest wall may not accurately similar to human's chest. However the manikin used is standardized for all participants so that it diminished inter-participants variability. Thirdly, the height of the stretcher is set at 54cm for all participants while in real situation the rescuer has the option to adjust it. However by fixing the stretcher's height, any postural disadvantage would apply to all study groups.

Conclusion

CPR cause significant risk of developing MSD in rescuer performing it. Further studies should be carried out concerning assessment of musculoskeletal discomfort experienced by rescuer after performing CPR. Appropriate action should be taken to minimize the risk such as developing more ergonomic way to provide chest compression to the victims or consideration on expanding the usage of mechanical device to reduce the risk exposure.

3.7 REFERENCES