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Review

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The Impact of CPR Position (Kneeling, Footstool and Standing Beside Bed) on Cardiopulmonary Resuscitation Quality: A Literature Review

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ABSTRACT
Background: Cardiopulmonary Resuscitation (CPR) is one of the measures to deal with emergency cardiac arrest (cardiac arrest) where the heart organ loses its function suddenly. Hence it is unable to pump blood throughout the body. CPR consists of aid in circulation (compression) and breathing (ventilation). AHA has determined guidelines for implementing CPR, especially an essential point in CPR, namely chest compression. The standing position is fundamental in the implementation of CPR, but kneeling and footstool positions can be carried out during CPR implementation. This paper aims to show the impact of standing, kneeling, and footstool positions on CPR quality.
Method: The method used is by searching journals in Science Direct, PubMed, and Google Scholar. The keywords used are CPR, Kneeling Position, Footstool, standing beside the bed Obtained eight selected journals according to the topic, then analyzed.
Results: Based on the search result, eight articles meet the criteria. The literature review results showed three positions that can be chosen when conducting CPR: standing, kneeling, and footstool. Those positions could give impact toward helper: pain level and exhaustion degree, and quality of CPR: compression strength, depth of compression, amount of compression, chest recoil, elbow movement, and movement in the lower back.
Conclusion: Three CPR positions can be done, including standing beside the bed, kneeling, and standing on stepstool footing. Each position gives impacts both to helper condition and CPR quality. Researchers recommend standing on stepstool footing due to it provides the best effect on CPR quality.

Introduction

Emergency cardiac arrest (cardiac arrest) is a condition when the heart organ loses its function suddenly marked by the cessation of the heart beating and pumping blood throughout the body and the cessation of respiratory function. This condition is a life-threatening condition that can occur anywhere, anytime, and anywhere happens to anyone, and requires immediate help (American Heart Association, 2012).

In various country, the prevalence of cardiac arrest cases is quite high. In the United States and Canada, the incidence of cardiac arrest reaches 350,000 cases per year. Whereas in Indonesia, the national prevalence of coronary heart disease was 1.5%, while the prevalence for cardiac arrest has not yet been obtained (Health Research and Development Agency, 2007). But the data shows that deaths caused by heart disease reach 4.6% by 4,552 mortality in 3 years. While the data obtained by WHO in 2002 in Indonesia, 220,372 cases of death caused by heart disease that has a high risk of sudden cardiac arrest has occurred (World Health Organization, 2014).

Cardiopulmonary Resuscitation (CPR), which has been used since 1740 (American Heart Association, 2012), is used to maintain or drain blood in those who experience cardiac arrest. Thus CPR is an essential technique in sustaining life (Mancini, 2011). CPR) consists of providing circulation assistance (Compression) and breathing (Ventilation) and is a general therapy, applied to almost all cases of cardiac arrest (Kaliammah, 2013). American Heart Association states that cardiac arrest events can occur anywhere, treating CPR at the time of the event can help reduce the risk of death. Cardiac arrest can be very deadly, but when CPR and defibrillation can be given as soon as possible, in many cases, the heart can beat again (American Heart Association, 2015).

Because mortality rate after cardiac arrest is high, and because on timely and appropriate CPR techniques can double chances of survival and reduce the number of deaths that can be avoided, further increase in the effectiveness of CPR performance is needed (Sutton, Nadkarni, & Abella, 2012). Effectiveness is an effort that is used productively for the task or goal to be achieved and effective achievement of certain results with minimum resource consumption, including physical effort. The survival rate is an important physiological parameter for determining productivity or measuring results. Basically, the higher the efficiency of CPR, the higher the rate of survival rates (American Heart Association, 2015a). The foundation in CPR is chest compression. Hess and White (2010) report that cardiac arrest's survival rate can be improved by optimizing each step (including effective chest compression) in the CPR procedure throughout the series of cardiac arrest treatments.

Effective chest compressions are critical to providing blood flow during Cardiopulmonary Resuscitation (CPR). For this reason, the 2010 American Heart Association (AHA) guidelines for CPR emphasize the "Push hard and push fast" technique, which requires compression of at least 5 cm depth at a rate of at least 100 compressions per minute. Patients with cardiac arrest in situations outside the hospital almost always undergo CPR while lying on the floor, but in cases of cardiac arrest in the hospital, chest compression is usually done with the patient lying in bed (Berg, Hemphill, Abella, C, & L, 2010). However, the depth of chest compression when done in bed is significantly shallower than in CPR performed on the floor (Jantti, Silfvast, Turpeinen, Kiviniemi, & Uusaro, 2009).

Guidelines issued by the American Heart Association (AHA) on Cardiopulmonary Resuscitation (CPR) emphasize the importance of chest compression. However, this guideline does not contain specific criteria for rescuers' location to perform effective chest compression, because most helpers who perform CPR are done with the victim lying on the floor. However, most CPR in hospitals is done with patients lying in bed. Therefore, chest compression's effectiveness can differ according to the correlation between the height of the savior and the bed's height. It is difficult to control the height of the bed to match the height of the medical staff which varies every time a resuscitation is needed, and a bed with a

high height still makes the quality of chest compressions difficult for those of short stature (Lee, Kim, Kim, & Lee, 2012). Although the standing position is a crucial position for CPR in cases of cardiac arrest in the hospital, footstool and kneeling position can also be done when performing CPR in hospital, to be able to adjust height to bed height and is expected to affect the quality of compression (Foo, Chang, Lin, & Guo, 2010).

Footstool position is a position where the helper stands on the footing can be a ladder that can adjust the helper's height to the bed and maximize the position in doing compression. Kneeling position is a position where the helper can kneel on the stairs or on the patient's bed (a stable place) right beside the patient. Standing on the floor often occurs when footstool is not available, and rescuers usually stand beside the bed on tiptoes trying to keep the upper limbs perpendicular to the chest wall of the patient. The right position can prevent rescuers from the risk of injury and reduce fatigue during compression (Foo et al., 2010).

The phenomenon found in the Emergency Department in one hospital varies in the use of positions in performing CPR. Where health workers, both doctors, and nurses, there are still some who perform CPR in a standing position beside the bed with a tiptoe, while in the resuscitation room most use footstool where the helper stands on the stairs while performing compression besides the patient's bed, not a few of them immediately kneel climbed onto the patient's bed. This position difference has no clear standard on which position is best when seen from the risk of injury, the quality of the compression, and the effects of fatigue that arise.

Method

This literature review search used search engines: Science Direct, PubMed, Google Scholar, and the National Center for Biotechnology Information (NCBI). The keywords used are CPR, Kneeling Position, Footstool, standing beside the bed. The choice of topics used in the literature review is generally about CPR, and specifically, the topic used is about the effectiveness of positions in conducting CPR. The inclusion criteria in this literature review were the publication of articles for the last ten years between 2010-2020, articles available in full text and free form, articles on CPR, and the effectiveness of positions in conducting CPR. The exclusion criteria in this literature review were articles that were only published in abstract form, articles published before 2015.

Results

Based on a search on the PubMed and google scholar sites, 19 PubMed results were obtained, and six articles based on inclusion and exclusion criteria were selected. On google scholar, 137 were obtained, and then screening based on inclusion and exclusion criteria were obtained three articles. The total articles used are nine articles, but one article excluded due to its objective was not appropriate. Finally, eight articles met the criteria in this review literature. These articles are in the form of full-text articles and discuss specifically the position when carrying out CPR and its influence on CPR quality.

Flow analysis and the system can be seen in the figure:

Figure 1. Flowchart of article selection results

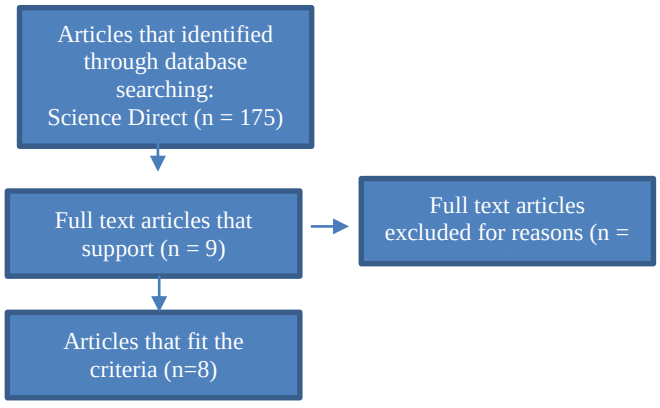

Table 1. Result of articles review

No	Article	Objective	Design	Sample	Result
1	The Most Effective Rescuer's Position For Cardiopulmon ary Resuscitation Provided To PatientsOn Beds: A Randomized, Controlled, Crossover Mannequin Study (Hong et al., 2014)	This research aim was Comparing chest compressions performed on the bed using three different savior positions: standing, using a footstool, or kneeling in bed.	A Randomized, Controlled, Crossover Mannequin Study	38 students	1. Strength of Compression the level of strength in compression with a standing position is 97.0, kneeling 138.6, and footstool 144.6 with p-value<0.001. So the position of Kneeling and Footstool can provide adequate compression strength. The amount of adequate compression strength is significantly greater for the kneeling and footstool than the standing position. Still, there is no significant difference for this size between the kneeling position and the footstool. 2. Total Compression a sufficient total amount of compression performed for 2 minutes is higher when compression is carried out either in kneeling or pedestal positions than in standing position results of standing 230, kneeling 238, and footstool 243. 3. Fatigue Level The severity of fatigue is lower for kneeling and footstool than standing, but there is no significant difference between pedestal and kneeling position for this size 4. Depth of compression The average depth of compression with a standing position is 43.9, and kneeling position is 49.4 and footstool position 49.0 with a p-value<0.00. So that the Kneeling and Footstool positions can provide adequate depth.
2	Effects of rescuer position on the kinematics of cardiopulmonary resuscitation (CPR) and the force of delivered compressions (Chi, Tsou, & Su, 2010)	To evaluate the three savior positions in influencing the kinematics of CPR and the strength of compression given during CPR	The experiment was conducted using A cross over, randomized-to-order design.	18 health care providers	There were significant differences in the head, shoulders, lower trunk, hip, and knee angles between the three methods (kneeling on the floor, standing bedside a table 63, and 37 cm). The resting heart rate, systolic blood pressure, MAP, and oxygen saturation between the three positions are similar. Kinematics CPR differs significantly in several helper positions. This difference does not affect the compression force and depth of compression.

3	Effect of Chest Compression with kneeling on the bed in cinical situation. (Hasegawa et al., 2019)	To see the effect of compression quality with the knee position on the bed.	Pre – post experiment.	15 students	The results showed that underfoot conditions on the floor could cause the upper body to be unstable and not optimal in the movement of muscle strength needed during compression.
4	Rescuer fatigue and cardiopulmon ary resuscitation positions: A randomized controlled crossover trial (Foo et al., 2010)	To compare fatigue when CPR is in various positions.	Randomized controlled trial.	24 health providers (nurses and doctors)	Adequate compression in 10 minutes 73.2 ± 28% when kneeling, 67.4 ± 28% when standing on a stool, 59.1 ± 29% when standing on the floor (p=0.029). The effectiveness of kneeling compression was significantly higher compared to the standing position on the floor (p=0.036). Values of the lower back ROM are 14.0 ± 4.8◦ in the kneeling position, 12.0 ± 3.2◦ in the standing position on the stool, and 18.1 ± 6.3◦ in the standing position on the floor (p<0.001). The lower back ROM value in the kneeling position (p <0.001) and the standing position above the stool (p<0.001) were significantly lower compared to the standing position on the floor. The elbow ROM value is 19.3 ± 6.6◦ in the kneeling position, 20.5 ± 8.4◦ in the standing position on the stool, and 26.4 ± 12.8◦ in the standing position on the floor (p=0.024). The elbow ROM value in the kneeling position was significantly lower compared to standing on the floor (p=0.049). The value of the pain score in standing position on the floor was significantly higher than standing on the stool within 24 hours after CPR (p<0.001). The value of social disturbances in standing position on the floor was also significantly higher kneeling and standing on the stool (p=0.004). CPR is more effective in kneeling position beside the patient's bed, and to minimize fatigue. It is recommended to alternate every 2 minutes doing compression.
5	Chest compression with kneeling posture in hospital cardiopulmon ary resuscitation: A randomised crossover simulation study (Oh, Chee, Lim, Cho, & Kim, 2014)	To find out the chest compression in the kneeling posture using a bench and standing on the stool.	Randomized controlled crossover trial	38 participants	The chest compression posture is a critical factor for cardiopulmonary resuscitation (CPR). A recommends position is 'kneeling' posture. Kneeling position requires that the rescuer kneel as close as possible to the patient, place his body directly above the patient's chest, straighten both arms, and place your heel on the bottom of the sternum. In hospitals usually use a 'standing posture', which requires rescuers to stand next to the patient. Proper posture may be important to reduce the potential for injury and minimize fatigue.

6	The impact of a step stool on cardiopulmonary resuscitation: across-over mannequin study (Edelson, Call, Yuen, & Hoek, 2013)	To evaluate the impact of using step stool on CPR.	A cross-over design, simulated study	50 rescuers	94% of rescuers believed that their compression was deep when done on a step stool, compared with 64% of rescuers without stepstools ($p<0.001$). They also report emphasizing a more appropriate level and feel more comfortable and not too tired when doing compression on the step stool. Step stool did not affect their perception of imperfect recoil ($p=0.36$). The use of step stool causes the average compression depth to increase by 4 mm and 18% to increase in incomplete recoil. The use of step stools when performing CPR causes a trade-off between increasing the depth of compression and increasing incomplete recoil.
7	The impact of the use of a footrest on the quality of chest compressions. A prospective, randomized, cross-sectional study (Majer, Pyda, Ladny, Rodriguez- Nunez, & Szarpak, 2018)	To evaluate the effect of usage "Footrest" on the quality of chest compression when CPR simulations are performed in a hospital	A Prospective randomized cross-sectional observational study	55 active doctors in the emergency unit and experienced in CPR.	Frequency of compression without using the footrest is 128 CPM, and using footrest is 126 CPM. The median of the value of compression depth without using footrest is 43 mm and 48 mm using a footrest. The truth is chest recoil without using footrest 30.5% and 52% using a footrest. The correctness of hand position when compression without using footrest is 72%, and using footrest is 89%. The use of footstool statistically improves the quality of CPR in the depth of compression, the correctness of the chest recoil, and the correct position of the hand when performing compression.
8	Use of Step Stool during resuscitation improved the quality of chest compression in simulated resuscitation (Lee, Kim, Kim, & Lee, 2012)	To determine the effect of using the step stool technique in performing chest compression on a mannequin at the height of a hospital bed	Experimental – simulation	74 medical students	Participants who are higher or equal to 171 cm shows the right depth of compression, which is around 4-5 cm. However, participants whose height is less than 170cm is not enough to do the compression with the proper depth. By using a step stool, the level of compression depth increased from 34.62% ± 34.16% (not using stepstool) to 48.91% ± 38.46% (after using step stool). Participants who did not use step stool showed chest compression rates decreased from 28.58% and 40.36% to 7.68% and 20.51%. The number of inaccuracies in compression location appears to be reduced when using stepstool compared to those not using a step stool.

Based on several journals that have been analyzed, the compression position in performing CPR can be conduct in three ways: standing beside the bed, kneeling position, and standing position using stepstool footing. These three positions affect the performance of compression, both on the helper or the patient. Compression position could give impacts:

1. Compression position affects helper quality

a. Pain Level

Based on the results of the literature, it shows that the pain that arises after chest compression is low back pain. Based on the results of research conducted by Hong et al., (2014), the severity of low back pain that arises after one day of chest compressions in kneeling position and using stepstool is lighter than when standing beside the bed. Whereas according to (Foo, Chang, Lin, & Guo, 2010) explained that the value of the pain score that appears after doing compression with standing position tends to be higher than when kneeling or using a stepstool.

b. Level of fatigue

The level of fatigue that arises in the helper due to the compression position by kneeling or using stepstool tends to be lower than standing beside the bed. However, there is no difference in the fatigue level between kneeling and using stepstool (Hong et al., 2014). More than 70% of helpers prefer to kneel posture compared to a standing posture, because of the lower level of fatigue (Oh, Chee, Lim, Cho, & Kim, 2014). Similar to research conducted by Edelsona, Call, Yuena, & Hoekc, (2012) which states that the level of fatigue is not severe when compressing the chest with a step on the stepstool.

2. Compression position affects the quality of the CPR

a. Compression strength

Using mixed models in a study conducted by Hong et al., (2014), that the level of strength in compression with standing position has lower results compared to the other two positions that is 97, then followed by kneeling position, which is 138 and the highest is grounded using footstool/step stool which is 144.6.

b. Depth of compression

Based on the mixed model analysis, the average results of compression depth with standing position have the lowest result (the result of 43.9) compared to the kneeling position (the result of 49.4) or using the footing (the result of 49). So kneeling position and using the footing tend to provide adequate depth during compression but are not significant (Hong et al., 2014). It was also mentioned by Oh et al., (2014) who stated that the presentation of accurate compression depth in the kneeling position was 52.7% while the standing position was 50.3%.

c. Amount of compression

Based on research from Hong et al. (2014), an adequate amount of compression is carried out for 2 minutes. Research Oh, Chee, Lim, Cho, & Kim (2014) stated that the average amount of compression is around 106 times per minute when kneeling and 105 times per minute when standing up, the two positions do not have a different effect on the amount of compression performed. This study is similar to Chi, Tsou, and Su's (2010) study in kneeling on the floor, standing above a 63 cm bed, and a standing position on a 37 cm bed. The research showed an average amount of compression of 117.9 times per minute, 116.6 times per minute, and 108.8 times per minute. One research (Majer, Pyda, Ladny, Rodriguez-Nunez, & Szarpak, 2018) showed no significant difference between compression without using a footrest that is 128 CPM and using a footrest that is 126 CPM.

d. Chest recoil

One research (Majer et al., 2018) explains the results of chest recoil without using footrest was 30.5% and 52% using a footrest. This result shows that the footrest position has a higher chest recoil compared to the position without footrest.

e. Elbow movement

The results of the study of Foo, Chang, Lin, and Guo (2010) show the value of elbow movement has a value of 19.3 ± 6.6◦ in the kneeling position, 20.5 ± 8.4◦ in the standing position on the stool, and 26.4 ± 12.8◦ in the standing position on the floor ($p = 0.024$). This

result shows that the value of elbow movement in the kneeling position is significantly lower than standing on the floor. In helping the victim, the elbow's movement in a kneeling position beside the patient's bedside can minimize fatigue from the amount of elbow movement during compression.

f. Movement in the lower back

Research by Foo, Chang, Lin, and Guo (2010), obtained the results of lower back movements 14.0 ± 4.8◦ in the kneeling position, 12.0 ± 3.2◦ in the standing position on the stepstool, and 18.1 ± 6.3◦ in the standing position on the floor. Lower back movements in the kneeling position have a lower level, causing fatigue in the helper. This position relates to the resulting less movement than in the other two positions: the standing position and the standing position on the floor.

Discussion

1. Compression position affects helper quality

a. Pain level

CPR position is an essential factor that influences CPR success. For effective CPR, it is crucial to maintain the body position, including straight arms and back perpendicular to the patient's chest. This position requires high strength in the lumbar and spinal areas to cause pain and cause fatigue, which can reduce the quality of CPR.

It was stated that the kneeling position and the position using the footing had lower back and waist pain than the standing position. This condition happens because - within 9 or 10 minutes helpers with standing positions tend to use the back and elbows stronger to maintain the quality of compression (Hong et al., 2014). However it is different from the research conducted by Wahab, Ghani, & Othman, (2019) which states that the CPR in the kneeling position shows the most ergonomic position for the helper, although this position can achieve excellent quality chest compressions.

Research conducted by Cobo-Vázquez, De Blas, García-Canas, & Gasco-García, (2018) shows that fatigue in the spinal and lumbar muscles in the CPR position appears after 2 minutes of CPR activity. This study shows that duration is the only factor that affects fatigue and pain during CPR. So this study recommends replacing rescuers when performing CPR every 2 minutes.

b. Degree of exhaustion

The position of compression can also influence not much different from the level of pain, the level of helper fatigue. The level of fatigue and pain level that appears on the back or elbow helper can occur due to excessive efforts to maintain the quality of CPR (Hong et al., 2014). In standing position beside the bed, the helper will try harder to straighten the elbow position and back so that it is perpendicular to the patient's chest, and this effort can make the helper feel tired more quickly than when kneeling or using a stepstool. By some literature which states that the level of fatigue is lower with a kneeling position or using a foothold compared to a standing position (Edelsona et al., 2012; Oh et al., 2014).

2. Compression position affects the quality of the CPR

a. Compression strength

Based on the literature analysis results, the adequate level of compression strength is standing using the stepstool footing compared to the other two positions, namely the kneeling position and the standing position. The compression strength can occur because the kneeling position above the patient's bed can make the body out of balance. Also, the condition of beds in the emergency room tends to use a cage which tends to have no room to kneel on the bed. By research conducted by Hasegawa, Okane, Ichikawa, Inukai, & Saito (2020), the position of the body that does not step on the floor can cause the upper body is unstable and not optimal in the movement of muscle strength needed during compression. Whereas when compressed in a standing position, the body tends not to be much higher than the position of the anchor so the hands cannot be upright 90o to do the compression, which the CPR process will not be maximized, which is following research

conducted by Lee, Kim, Kim, & Lee, (2012). It was explained that a helper with a body that was higher or equal to 171 cm showed proper compression, which was around 4-5 cm. However, the helper whose height is less than 170 cm is not enough to do the compression with the right strength and depth. The study recommended using a step with a step stool so that the body position, especially the arms, can be upright and not bent. The recommendation is to maximize the strength of compression in performing CPR.

b. Depth of compression

From the results of the literature analysis that has been done, that the results of the average depth of compression performed by standing have a lower result (43.9) compared to using a step (49) or kneeling (49.4). In this case, the kneeling position tends to have the most effective compression depth results with a score of 49.4, although the results show not much difference. Similar to the study conducted by Oh et al., (2014), the presentation of accurate compression depth in the kneeling position was 52.7% while the standing position was 50.3%. The effectiveness of the depth of compression when kneeling and when using the footing is caused by the position of the body that is perpendicular to the chest of the patient can produce greater compressive force. That result follows the statement of Hong et al., (2014) that kneeling footstool position can provide greater compressive force during the CPR process. According to Foo et al., the kneeling position results in better performance during compression within 5 minutes.

c. Amount of compression

This literature review showed that the amount of compression is between 105 -117 times per minute. In line with the algorithm of the American Heart Association guidelines (American Heart Association, 2015b) explains the recommendation rate at chest compression is 100-120 times per minute. Thus, from the kneeling position aside on the floor, the standing position does not significantly differ from the amount of compression produced. According to Mullin, Lydon, & Connor (2019), there is no difference in the amount of compression between standing and sitting positions. Giving sitting position compression is safer for rescuers but reduces the quality of chest compressions given to the patient. Meanwhile, the standing position has a more optimal quality of chest compression to the patient but risks endangering the helper (Mullin et al., 2019).

d. Chest recoil

Several studies show that the footrest position has a higher chest recoil compared to the position without footrest. According to Chu (2016), the chest recoil is to let the chest return to its normal position after chest compression. This recoil allows full chest blockage to increase venous return because it rests on the chest, preventing the heart from overloading with blood. Thus, the footrest position will increase the chest recoil during compression by the patient.

e. Elbow movement

The kneeling position becomes the position that has the smallest elbow movement compared to the standing position on the footstool and standing position on the floor. According to Bucki, Waniczek, Michnik, et al. (2019), elbow movements are common when compressing the chest. This is related to the helper is possible not to keep his arms straight so that it will form movement in the elbow area. Bucki et al. (2019) explain that movement in the elbow area does not affect the quality of the maneuver during compression. This research shows that the movement of a small elbow can reduce fatigue during chest compression procedures. The position of the mink becomes the position that has the smallest elbow movement.

f. Movement in the lower back

Specific postures can cause high biomechanical loads that work through the lower back and shoulder joints. Postures such as flexion, lateral arches, and axial rotation of the stem can increase the amount of compression and / or sliding through the lower back leading to an increased risk of getting a low back injury (Dainty, 2015). The kneeling position is significantly higher for lower back compression and discomfort than the sitting position. The

research analysis results found that the kneeling position has a lower back movement higher than the standing position on the stepstool. This indicates that the kneeling position is uncomfortable, and there is a risk of injury to the lower back.

Conclusions

Three CPR positions can be done, including standing beside the bed, kneeling, and standing using stepstool footing. Seeing the pain level, kneeling and using the footing position has a lower waist and back pain than the standing position, as well as the level of helper fatigue. When viewed from the strength of compression, standing position using stepstool footing is the maximum level of compression in performing CPR. Seen from the depth of compression, the kneeling position using the stepstool footing also has a more effective compression depth than the standing position. Based on the amount of compression from various positions performed, the results do not show significant differences, but several studies have shown that the position using stepstool will further increase the chest recoil when doing compression. Elbow movement of the kneeling position is significantly lower compared to standing on the floor and seen from the lower back movement in the kneeling position has a lower level, causing fatigue in the helper. From the results of the analysis of several articles from various journals, it was found that the position of the helper standing using the stepstool footing has higher effectiveness compared to standing beside the bed.

Hospitals can make the appropriate standard position of a helper when carrying out CPR assistance by considering standing position using stepstool footing. In addition to increasing effectiveness while carrying out CPR, it can also make the same positions for health workers to be applied when carrying out CPR.

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