

REGULAR ARTICLE

Randomised simulation trial found an association between rescuers' height and weight and chest compression quality during paediatric resuscitation

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Abstract

Aim: Our aim was to examine the relationship between rescuers' anthropometric data and chest compression quality during paediatric resuscitation training.

Methods: This study focused on 224 medical students (53% women) who performed 2 minutes of paediatric resuscitation at the Medical University of Vienna, Austria: 116 on a baby manikin and 108 on an adolescent manikin. Skill Reporter software measured chest compression quality by recording compression depth, frequency, hand position and complete recoil. The participants' height, weight and body mass index (BMI) were recorded.

Results: Participants with a lower BMI achieved higher total chest compression scores on both the baby and adolescent manikins than participants with a higher BMI. The latter were more likely to exceed the correct compression depth and not achieve complete chest recoil in the adolescent manikin. When it came to the baby manikin, the female participants achieved better chest recoil and the males achieved a higher number of compressions at the correct rate. Males also achieved better chest recoil with the adolescent manikins. Being tall only correlated with incomplete recoil in the adolescent manikin.

Conclusion: The results indicate that anthropometric variables were associated with chest compression quality in paediatric patients and should be considered by future education programmes.

KEYWORDS

anthropometric variables, body mass index, chest compression, paediatric resuscitation, simulated training

1 | BACKGROUND

According to the World Health Organization, cardiac events are still the leading cause of death worldwide.¹ Basic life support with high-quality cardiopulmonary resuscitation (CPR) remains the only

efficient and immediate treatment for a cardiac arrest.^{2,3} However, survival and neurological outcomes have been poor.^{4,5} Cardiac arrests are rare condition in paediatric patients, and they have been reported to occur in about 8-20 per 100 000 children per year.⁶ Survival rates are higher in adults, but cardiac events still lead to poor neurological outcomes.⁷

Abbreviations: BMI, body mass index; CPR, cardiopulmonary resuscitation.

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Cardiopulmonary resuscitation quality remains the most important determinant of a patient's outcome and survival. Therefore, it is essential that medical staff perform optimal chest compressions and ensure that the patient receives adequate ventilation. The 2015 European Resuscitation Council guideline for paediatric basic life support states that optimal paediatric CPR includes optimal hand position at the lower part of the sternum and optimal chest compression depth. This depth should be at least one-third of the anterior-posterior diameter of the chest, namely 4 cm for a baby and 5 cm for an adolescent. Furthermore, it is important to achieve an optimal chest compression rate of 100-120 per minute, with complete hand release to allow chest recoil between each compression.⁸ All of these factors are fundamental for sufficient cardiac output and coronary perfusion pressure so that the patient receives adequate oxygen.⁹

Cardiopulmonary resuscitation quality can be affected by many different factors, such as whether the rescuer feels stress or fatigue, their medical experience and the medical equipment available at the scene. Studies have reported that anthropometric variables, such as body height and weight, may influence chest compression quality to a certain extent.¹⁰⁻¹² However, the results of these studies were limited by the small number of participants and they tended to focus on basic life support for adults. It has been reported that rescuers with a lower body mass index (BMI) had more difficulties achieving a sufficient overall chest compression quality when performing basic life support on an adult manikin.^{13,14} Another study showed that rescuers with a higher body mass index (BMI) were more successful at achieving adequate compression depth.¹² Furthermore, significant kinematic differences have been observed with regard to body height, when resuscitating on a table or on the floor, but height had no impact on the rescuers' general CPR performance.¹⁵ There has been a lack of data about the effect of anthropometric variables on the influence of chest compression quality during paediatric CPR. Having a better understanding of this might optimise the resuscitation environment and management of medical staff during paediatric resuscitation.

The aim of this study was to examine the relationship between variables, such as body height, body weight and BMI, and chest compression quality during simulated CPR using an infant or adolescent manikin.

2 | METHODS

2.1 | Study design

Our study was a secondary quantitative analysis of a randomised simulation study carried out in 2017, which examined the effect of different feedback methods on CPR quality during paediatric CPR in simulation settings.¹⁶ These feedback methods were as follows: (a) feedback from a feedback device or (b) feedback from the instructor or (c) feedback from the instructor for whom measurements from the feedback device were visible. It is important to point out that we included the control condition without any feedback device in this secondary analysis. This was because we did not want to bias

Key notes

- We examined the relationship between rescuers' anthropometric data and chest compression quality when 224 medical students performed paediatric training on baby and adolescent manikins.
- Participants with a lower BMI achieved better total chest compression scores on both manikins, while a higher BMI was associated with exceeding the correct compression depth.
- The results, which also included gender differences during resuscitation, should be considered when future education programmes are developed.

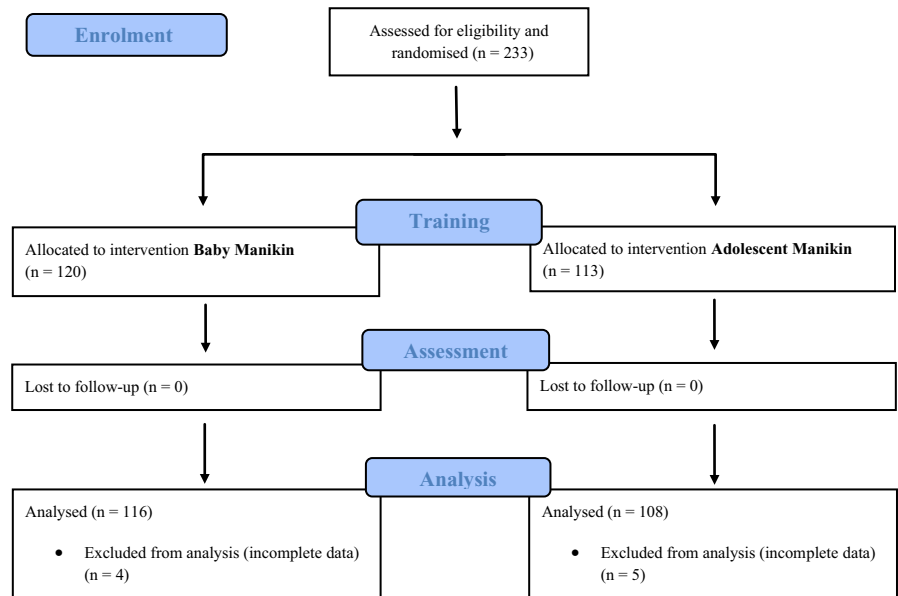
the effect of anthropometric variables by using different feedback methods.

The original study was conducted at the Paediatric Simulation Training Center at the Medical University of Vienna, Austria. It was performed according to the Consolidated Standards of Reporting Trials approach, with the extension for simulation-based research,¹⁷ and approved by the Medical University of Vienna ethics and data protection committee. The participants were third-year medical students who were attending mandatory, instructor-led paediatric basic life support training. All participants provided informed consent prior to participation and were then randomly assigned to practise CPR on either a baby or an adolescent manikin in supervised groups of 10-11 participants. The randomisation was performed using a computer-generated list of random numbers in Microsoft Excel (Microsoft Corp.). The groups were supervised by one of five instructors, who had been randomised to one of the feedback groups in advance. They were all members of the local paediatric simulation team and trained in paediatric basic life support.¹⁸ The instructors were updated on the actual guidelines before the study and were familiarised with all the details of the study procedure. They conducted the course using the four-stage technique for skills teaching, which is a standardised procedure for teaching and demonstrating paediatric resuscitation. The technique was taught in accordance with the recommendations of the European Resuscitation Council.¹⁹

2.2 | Study procedure, devices and parameters

Participants provided their anthropometric data and data on resuscitation and simulation experience. Then, they reviewed the current paediatric CPR guidelines⁸ and watched an instructor demonstrating the CPR algorithm. The participants then practised CPR in pairs, with one participant performing chest compressions using the 15:2 compression and ventilation ratio and the other participant performing mask ventilation. They then switched roles after 2 minutes of CPR practice (Figure 1).

FIGURE 1 Study groups and design



The students in the baby manikin group practised on a Resusci Baby QCPR manikin (Laerdal Medical GmbH), while the participants in the adolescent manikin group practised on a Resusci Anne QCPR manikin (Laerdal Medical GmbH). We adapted the compression spring of the Resusci Anne QCPR manikin to ensure a weight of 30 kilograms was needed for 5 cms of chest compression depth, representing the effort for an adolescent patient. We placed the manikins on a table with a standardised height of 72 cm to ensure the same height for chest compressions in all groups. Participants in the adolescent group stood on the left or right side of the thorax, while participants in the baby group stood at the feet of the manikin. Participants who felt they were too short for adequate chest compressions could use a step stool. This had a standard height of 24 cm, and any use was recorded. During the practice, participants were supervised by the instructor and the participant performing chest compressions was provided with verbal feedback on their performance. The students were allowed to choose between the two-thumb or two-finger methods of chest compression for the baby manikin but were only able to use the recommended one-hand method for the adolescent manikin.

At the end of the course, the participants had to perform 2 minutes of CPR while the Skill Reporter software (Laerdal Medical) was connected to their respective manikin. The participants did not receive any feedback on their chest compression performance during this CPR.

2.3 | Statistical analysis

We analysed the performance of each participant using a range of factors. These included the percentage of chest compressions that were performed with the correct hand position and the percentage that were correctly released. We also recorded the average depth of the chest compressions in millimetres, the percentage that had the correct depth, the average chest compression rate per minute and the percentage of chest compressions at the correct rate. Finally, we

recorded the total chest compression score, which was the composite score calculated by the Skill Reporter software. This consisted of the correct hand position, adequate depth, compression rate and complete release for each 2-minute CPR cycle. Participants received 100% for each variable if the guideline criteria were executed accurately. Any deviation decreased the score as low as 0% along a S-curve, depending on the number of deviations. Small deviations reduced the score less than large deviations. More detailed information on the software scoring is provided on the manufacturer's website.²⁰ The recorded results were correlated to the participants' anthropometric variables, such as body weight, height and their BMI, which were calculated by dividing weight in kilograms by height in square metres.

The data were analysed using Shapiro-Wilk tests to verify the normality of the distribution. Parameters with a skewed data distribution were log-transformed before the analysis. To ensure homogeneity of the two manikin groups, the Student *t* test for independent samples was conducted on the participants' age, height, weight, BMI and experience. In addition, the chi-square test was used to compare the distribution of men and women across the groups. The relationships between CPR parameters and anthropometric data, namely body weight, height and BMI, were evaluated using the Pearson correlation coefficient. The height of the step stool was added to the participants' body height when they used it. For significant correlations, we stratified our sample into the bottom 25% (25th percentile), middle 50% and top 25% (75th percentile) for height, weight and BMI to describe and interpret the results. Unless otherwise indicated, the data are presented as means and standard deviations (SD). An a priori sample size calculation with G*Power²¹ revealed that a sample size of 82 or more participants in a manikin group would provide sufficient power (0.80) to detect a significant correlation at an alpha level of .05. The two-tailed level of significance was set at $P \leq .05$. All statistical analyses were performed with SPSS version 24.0 (IBM Corp.).

3 | RESULTS

A total of 233 participants completed the study, but nine had to be excluded from the analysis due to incomplete data. This means that 224 participants (53% women) provided data for the final analysis: 116 in the baby manikin group and 108 in the adolescent manikin group. Their average weight was 173.9 cm (range 150-198), average weight was 67.6 kg (range 47-115) and mean BMI was 22.2 kg/m² (range 17.3-41.2). Table 1 presents the anthropometric variables for men and women.

There was no significant difference between the manikin groups when it came to the participants' age, experience, anthropometric variables and gender distribution (Table 1). We found that 37 (34%) of the students in the adolescent manikin group used a step stool and that they had a shorter mean body height than those who did not (170.7 cm vs 175.5 cm, $t = 2.87$, $P < .01$). Participants who used the stool demonstrated a lower mean chest compression rate than those who did not (108 vs 114 per minute, $t = 4.16$, $P < .001$).

Men and women did not differ with regard to the reported CPR parameters, except for the percentage of chest compressions carried out at the correct rate and the percentage of correctly released chest compressions. Men performed more chest compressions at the correct rate (67%) than women (58%), but only in the baby manikin group ($t = 2.44$, $P < .05$). With regard to the percentage of correctly released chest compressions, men (90%) performed better than women (80%) in the baby manikin group ($t = 2.55$, $P < .05$) and women (56%) performed better than men (38%) in the adolescent manikin group ($t = 3.48$, $P < .01$). Controlling for gender in the further analyses did not substantially change the results.

Correlation coefficients between the anthropometric variables and CPR parameters are presented in Table 2. The mean values for the significant CPR parameters for the stratified sample are presented in Table 3. The total chest compression score was negatively associated with BMI in both manikin groups ($P < .05$). In general, participants with a BMI of under 20.3 kg/m² had chest compression scores that were 10-30 points higher than those with a BMI of over 24 kg/m². The same association was found for the percentage of chest compressions with the correct hand position, but only when using the baby manikin ($P < .01$). The percentage of chest compressions with correct recoil was correlated with both body weight and height ($P < .05$), but the direction of the relationship varied depending on which manikin was being used. Participants who were heavier (>76 kg) and taller (>181 cm) were less likely to achieve a complete chest recoil with the adolescent manikin, but the opposite was found when they used the baby manikin. Compression depth was only correlated with body weight in the adolescent manikin group ($P < .05$). Heavier participants (>76 kg) were more likely to exceed the correct depth of 50 mm and performed 10% more chest compressions with incorrect depth than participants with a lower BMI (<58 kg). Finally, compression rate did not correlate with any anthropometric variable with either manikin.

4 | DISCUSSION

To the best of our knowledge, this was the first study to examine the relationship between rescuers' anthropometric variables, such as body weight, body height and BMI, and the quality of their performance during simulated paediatric cardiopulmonary resuscitation using a baby or adolescent manikin. The study had four key findings. First, participants with a lower BMI had significantly higher chest compression scores during CPR for both manikins. Second, participants with lower BMIs demonstrated a higher percentage of chest compressions with the correct hand position, but only with the baby manikin. Third, participants were more likely to achieve the correct depth when performing CPR on the adolescent manikin. Fourth, the relationship between anthropometric variables and sufficient chest recoil varied across groups, as heavier and taller participants were less likely to achieve complete chest recoil when using the adolescent manikin. The opposite was observed in the baby manikin group.

While the relationship between the rescuers' anthropometric variables and chest compression quality during adult resuscitation has been well established, there has been a lack of data about these relationships in paediatric resuscitation. In the current study, a lower BMI was associated with better overall chest compression quality. This contradicts previous evidence that participants with a lower BMI were less likely to achieve sufficient chest compression performance.^{13,14} This means that a lower BMI may even be beneficial during paediatric resuscitation.

However, we did identify a positive correlation between body weight and chest compression depth, but only when using the adolescent manikin, which confirmed previous adult manikin studies. This might be explained by the fact resuscitating an adolescent is technically and physically similar to an adult procedure, as the rescuers' body is next to the patient and they tend to use their own body weight for compressions. We were more concerned by the finding that heavier participants were more likely to exceed the chest compression depth threshold, which worsened the chest compression quality. Our results showed no correlation between weight and compression depth in the baby manikin group. This was presumably because of the different and less demanding physical requirements needed to achieve sufficient depth in a baby than an adolescent or adult.

Complete chest recoil during external chest compression ensures that the heart refills, which provides sufficient perfusion pressure to the coronary arteries.⁹ Contri et al¹¹ compared participants with a greater and lower BMI and found that those with a heavier BMI were less likely to achieve complete chest recoil in the adolescent manikin group. This finding is not surprising, as rescuers who are resuscitating adolescents are usually positioned vertically to the patient's chest and use their body weight and gravity to achieve sufficient compression. This leads to insufficient decompression. Interestingly, we observed the opposite effect in the baby manikin group, as BMI and body height were positively correlated with complete chest recoil. This might be because it was easier to reach the baby manikin's chest and taller participants

TABLE 1 Characteristics of the study participants

	Baby manikin (n = 116)	Adolescent manikin (n = 108)
Gender		
Female	63 (54%)	56 (52%)
Male	53 (46%)	52 (48%)
Physical characteristics (Female/male)		
Age (y)	22.6 ± 3.4/23.5 ± 2.3	22.3 ± 1.9/23.0 ± 1.7
BMI (kg/m ²)	20.7 ± 2.3/23.2 ± 2.7	21.9 ± 3.7/23.3 ± 2.2
Height (cm)	167.6 ± 6.4/181.6 ± 7.7	167.5 ± 6.8/180.7 ± 6.0
Weight (kg)	58.1 ± 7.3/76.7 ± 11.2	61.5 ± 10.9/76.2 ± 9.1
Experience		
Number of adult resuscitation training sessions before the study	3.5 ± 0.7	3.3 ± 0.8
Number of paediatric resuscitation training sessions before the study	0.8 ± 1.3	0.7 ± 1.3
Number of medical simulation training sessions before the study	0.6 ± 1.3	0.7 ± 1.3
Step stool		
Used	0 (0%)	37 (34%)
Not used	116 (100%)	71 (66%)

Note: Data on physical characteristics and experience are presented as means and SDs. Data on gender and the use of step stool are presented as numbers and percentages.

TABLE 2 Correlations between CPR parameters and anthropometric data

Parameter	Baby manikin (n = 116)			Adolescent manikin (n = 108)		
	Weight	Height	BMI	Weight	Height	BMI
Total CC score	-.17	-.05	-.21*	-.23*	-.08	-.20*
Correct hand position	-.24**	-.17	-.22**	-.01	-.07	.05
Full recoil	.17*	.25**	.06	-.30**	-.22*	-.11
Mean CC depth	-.08	-.03	-.08	.20*	.01	.16
CCs with correct depth	-.01	.05	-.05	-.19*	-.13	-.16
Mean CC rate	.07	.05	.06	.11	.07	.02
CCs with correct rate	.06	.12	.01	.04	.14	.01

Note: Significant correlations are marked in bold.

Abbreviation: CC, chest compression.

* $P \leq .05$ and

** $P \leq .01$.

were able to achieve a more comfortable hand position around the thorax.

With regard to achieving the correct hand position during chest compressions, we observed a negative correlation with BMI and body weight in the baby manikin group, but no correlation in the adolescent manikin group.

Significant gender differences were found with regard to chest release and the number of compressions with correct compression rate. Interestingly, men performed more chest compressions with the correct rate on the baby manikin, which contradicts previous evidence. In resuscitation studies on adult manikins, researchers observed that women performed CPR with higher compression rates

than men.^{10,22} In our study, the males achieved better complete chest recoil with the baby manikin than females. In contrast, the females achieved better complete chest release with the adolescent manikin. This was in line with the findings reported by Contri et al,¹¹ who found that female subjects were more likely to achieve correct compression than males during simulated adult resuscitation.

Finally, we did not find that using a step stool had any effect on the chest compression quality, with the exception of the mean chest compression rate per minute. Although, the participants who used a step stool had a significantly lower mean chest compression rate than those who did not, the mean chest compression rates were within the recommended range for both of these options. Our results contradict

TABLE 3 Mean values of the significant CPR parameters for the two manikin groups and the stratified weight, height and BMI groups

	Weight (kg)			Height (cm)			BMI (kg/m ²)		
	<58	59-75	>76	<167	168-180	>181	<20.3	20.4-23.9	>24.0
Baby manikin									
Number	37	54	25	37	55	24	32	56	28
Total CC score (%)							89.2	81.0	75.4
Correct hand position (%)	97.5	86.1	83.7				94.5	88.7	82.3
Full recoil (%)	81.8	85.3	86.7	75.7	87.2	89.0			
Adolescent manikin									
Number	28	50	30	19	59	30	28	55	25
Total CC score (%)	80.7	85.4	69.0				89.0	79.8	60.8
Full recoil (%)	59.5	46.4	36.4	58.8	48.2	31.2			
Mean CC depth (mm)	54.4	56.8	57.2						
CCs with correct depth (%)	62.3	64.0	49.1						

Note: The sample was stratified into bottom 25% (25th percentile), middle 50% and top 25% (75th percentile) for weight, height and BMI.

Abbreviation: CC, chest compressions.

previous data that reported a significant improvement in chest compression depth and overall chest compression quality when step stools were used, especially in shorter participants.^{23,24} However, our results might be due to differences in study designs. Previous investigators used a cross-over design and compared chest compression performance with and without the use of the step stool. In contrast, the participants in our study decided whether or not they wanted to use a step stool. It is also important to consider possible differences in chest compression quality based on healthcare professionals' clinical experience and other parameters, such as fitness and fatigue. Therefore, further studies to investigate any associated implications are needed.

4.1 | Strengths and limitations

The strengths of the current study were the large sample size and the simultaneous measurement of various chest compression parameters. However, there were also several limitations and these need to be considered when interpreting the results. The distribution of BMI in our sample did not reflect Western countries²⁵ as most of our participants (80%) were in the normal BMI range (18.5-25 kg/m²) and only 20% were either underweight (<18.5 kg/m², 7%) or overweight (25-30 kg/m², 11%) or obese (>30 kg/m², 2%). Furthermore, all the participants only performed CPR for 2 minutes. Even though a 2-minute trial is adequate for a simulation scenario,²⁶ it still remains unclear how chest compression quality changes over a longer time period or during real-life resuscitation. Unfortunately, it was not possible to control for physical fitness or fatigue, which may also influence CPR quality. We did not evaluate the quality of ventilation, which remains a cornerstone of high-quality CPR in paediatric patients. While the recruitment of third-year medical students reduced possible bias, it may not be possible to generalise the data to other groups, such as rescuers who are not medically qualified or healthcare professionals who have completed their training.

5 | CONCLUSION

The rescuers' anthropometric data influenced chest compression quality when they performed 2 minutes of CPR on baby and adolescent manikins. Participants with a lower BMI achieved higher total chest compression scores with both manikins than those with a higher BMI. Gender difference was also noted. As resuscitation teams contain people with different body compositions and genders, education programmes should provide individualised teaching, by focusing on the anthropometric differences in their resuscitation teams. Furthermore, feedback devices for measuring chest compression quality should be implemented during resuscitation training sessions.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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