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Quality of Three Chest Compression Techniques During Two-Rescuer Infant CPR: A Randomised Crossover Manikin Study

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Abstract

Aim: To evaluate the quality and ergonomic impact of three infant chest compression techniques the two-thumb encircling technique (TTHT), the cross-thumb technique (CTT), and the one-hand open-palm technique (OHT) during two-rescuer infant cardiopulmonary resuscitation (CPR) utilizing a 15:2 compression-to-ventilation ratio.

Materials and Methods: This prospective, randomized, crossover simulation study included 50 registered nurses who performed three 2-minute CPR sequences on an infant manikin, each using one of the three techniques. The primary outcomes were the depth of the compression, the percentage of target-range compressions, and the chest compression fraction (CCF). Secondary outcomes encompassed compression rate, recoil, hand position accuracy, excessive compressions, fatigue, pain, perceived difficulty, and hand slippage. We used repeated-measures statistical models to look at the data.

Results: Both thumb-based methods (TTHT and CTT) yielded significantly deeper compressions, elevated proportions of target-range compressions, increased CCF, and enhanced accuracy in hand positioning in comparison to OHT (all $p<0.01$). TTHT and CTT exhibited similar mechanical performance in all primary outcomes. However, CTT had much less fatigue, hand pain, and perceived difficulty than TTHT (all $p<0.01$). OHT caused shallower compressions, the lowest CCF, more over-depth compressions, and the highest rate of hand slippage.

Conclusion: During two-rescuer infant resuscitation, TTHT and CTT are better than OHT at biomechanical CPR quality. CTT has the same compression quality as TTHT but is more comfortable to use, making it a good choice when thumb-based techniques are feasible. OHT should only be used when it is not possible to wrap the chest. More clinical studies are needed to support these simulation results.

Keywords: Infant cardiopulmonary resuscitation, chest compression techniques, cardiopulmonary resuscitation, simulation study, compression quality, pediatric basic life support

Introduction

Infant cardiopulmonary resuscitation (CPR) is vital in emergency pediatric care and closely linked to survival and neurological outcomes. In infants, cardiac arrest usually results from respiratory failure or asphyxia, not heart disease. Thus, both proper chest compressions and effective ventilation are necessary (1-3). The American Heart Association (AHA) and American Academy of Pediatrics (AAP) recommend a 15:2 compression-to-ventilation ratio when two healthcare providers perform CPR on infants or children. This delivers more rescue breaths and aligns with the asphyxial nature of most pediatric arrests (2-4).

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Several steps must be taken to ensure high-quality CPR in infants. The correct compression depth is about one-third of the anterior–posterior chest diameter. Hands need to be placed in the correct position, on the lower third of the sternum, and kept away from the xiphoid process (5-7). The chest must fully recoil after each compression. Interruptions in compressions should be kept to a minimum. The compression rate should be 100-120·min^{-1}. Experimental and clinical evidence indicate that incomplete chest recoil, characterized by frequent and prolonged pauses, reduces coronary perfusion pressure. These factors are associated with poorer resuscitation outcomes (8,9). Therefore, any change in technique that affects depth, rate, or recoil could significantly change how well CPR works.

It is crucial to select the right method for chest compressions. The AHA and AAP now recommend the two-thumb encircling technique (TTHT) as the most effective for two-person infant CPR. This method results in deeper compressions, higher coronary perfusion pressures, and less rescuer fatigue compared to the two-finger technique. Despite this, several alternative methods have been proposed and tested in simulations and observational studies over the past decade. However, concerns remain about compression depth, hand stability, and the risk of over-compression.

Although many manikin studies and registry data show infant CPR is effective, few head-to-head comparisons of these three methods exist in realistic two-rescuer, 15:2 basic life support (BLS) scenarios (10-15). Current research suggests the one-hand technique may, under certain conditions, achieve greater depth than thumb-based methods. However, its effects on chest recoil, hand positioning, and rescuer fatigue remain unclear, especially during extended team efforts (4). Studies also show that ergonomic changes such as using a step stool, the "elbow-lock" position, or rotating compressors, can affect compression quality and reduce fatigue. However, these adjustments have not been widely tested with different infant compression techniques (4).

Due to these gaps, we needed a thorough, well-designed comparison of current infant compression techniques under conditions that reflect recommended practice. We compared the two-thumb encircling, cross-thumb, and one-hand open-palm techniques (OHT) during two-rescuer infant CPR using a 15:2 ratio.

Materials and Methods

Study Design and Oversight

We conducted a prospective, randomized, three-arm crossover study. It compared the quality of infant chest compressions given with three techniques: (1) two-thumb encircling, (2) cross-thumb, and (3) one-hand (open-palm). An infant manikin was used in a high-fidelity pediatric simulation setting for all scenarios. Following modern pediatric resuscitation guidelines, each sequence involved two rescuers giving BLS for two minutes with a 15:2 compression-to-ventilation ratio. Participants were randomly assigned to the order in which they performed the three techniques, using a computer-generated allocation sequence.

The Institutional Review Board of the Polish Society of Disaster Medicine reviewed and approved the protocol (approval no: 14/02/2024, date: 14.02.2024). All study procedures adhered to the Declaration of Helsinki and relevant national regulations governing research with human subjects. Volunteers received written and verbal information and provided written consent before participating. The study followed EQUATOR-aligned standards for simulation research. This included specifying prospective endpoints, detailing the simulation model and parameters, and documenting the data structure and analysis workflow.

Participants and Sample Size

The study population included 50 registered nurses. All participants were enrolled in scheduled BLS training courses, taught by AHA–certified instructors. Each participant was actively working in clinical practice and regularly cared for pediatric or neonatal patients. Eligibility required current employment as a nurse, prior completion of at least one BLS course, and willingness to participate in simulation research. Nurses who reported musculoskeletal conditions that made chest compressions unsafe were excluded. Participation was voluntary with no financial incentives. Every participant was assigned a unique ID number. All nurses performed each of the three compression techniques, using a within-subject, randomized three-period crossover design. This resulted in 150 resuscitation attempts (50 participants × 3 techniques).

Simulation Protocol

For each study condition, participants performed a standard infant BLS scenario using a dummy. Each 120-second sequence required nurses to administer chest compressions and ventilations continuously. According to the latest pediatric BLS guidelines, the compression–ventilation ratio was 15:2. Each participant delivered 15 compressions, followed by two ventilations, and repeated this cycle for the full 2 minutes.

The order of the three compression techniques was randomized in a crossover manner. ResearchRandomizer (Randomizer.org; Figure 1) was used to create a unique sequence of techniques for each participant. Allocations were made before enrollment.

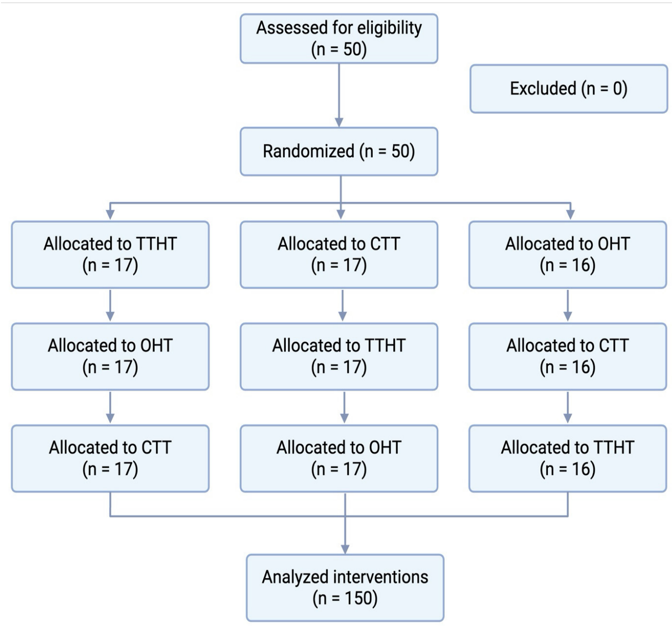

Figure 1. Randomization flow chart

TTHT: Two-thumb encircling technique, CTT: Cross-thumb technique, OHT: Open-palm technique

Participants were assigned to the following available sequence by numerical order. Each nurse performed all three techniques in a different order. This helped reduce learning fatigue and the effects of menstrual periods.

Before the event began, instructors asked participants to keep a compression rate between 100 and 120 per minute. They did not use a metronome. Instead, participants were told to "compress fast and regularly" to allow for natural variation. A second rescuer, also trained in BLS, performed bag-mask ventilation. This person gave two chest-rise breaths after each set of 15 compressions. This is similar to real-life resuscitations, where short breaks occur between compressions.

To prevent fatigue and minimize the mixing of techniques, participants rested for at least 30 minutes between sequences. They took breaks in the simulation room. However, they did not practice compressions or receive extra coaching. This approach ensured that subsequent attempts were based on random technique allocation, not ongoing instruction or warm-up. Before data collection, an AHA-certified instructor demonstrated each technique to all participants. There was a brief practice session. Instructors did not give corrective feedback during recorded attempts.

Three chest compression techniques were used during the study:

- **TTHT:** The rescuer stood at the baby's feet. Both thumbs pointed up, side by side, on the lower third of the sternum. The fingers wrapped around the thorax to support the back. To compress, both thumbs pressed straight down while the hands encircled the chest. This allowed for full chest recoil after each compression.
- **Cross-thumb technique (CTT):** The rescuer stood beside the manikin. Both thumbs were on the lower half of the sternum, with one crossing over the other at the midline. The fingers of both hands wrapped around the thorax for stability. The overlapping thumbs applied vertical pressure. The focus was on vertical compression, full release between compressions, and no lateral movement.
- **One-hand (open-palm) technique:** The rescuer stood next to the mannequin. The heel of one hand was on the lower sternum. Fingers were held up to avoid the ribs and abdomen. The second hand could rest on the forearm or chest for support, but added no force. Compressions were given using the heel of the hand, pressing straight down to about one-third of the chest depth. The hand fully recoiled after each compression (Figure 2).

Figure 2. Chest compression techniques used during two-rescuer infant cardiopulmonary resuscitation (CPR) with a 15:2 compression-to-ventilation ratio: (A) two-thumb encircling technique (TTHT), (B) cross-thumb technique (CTT), and (C) one-hand open-palm technique (OHT)

For all techniques, participants were instructed to minimize interruptions, avoid leaning between compressions, and maintain their focus on maintaining the correct rate, depth, and 15:2 sequence. During the experimental phase, a different neonatal simulator (Laerdal Medical SimBaby, Laerdal Medical, Stavanger, Norway) was used to ensure standardization of resuscitation.

Outcomes

All outcomes were predetermined and based on objective measurements obtained from the manikin, supplemented by concise post-scenario self-reports from participants. To clarify the outcomes, they were divided into two groups: primary measures of the quality of chest compressions and secondary measures of the mechanics of compressions, hemodynamic surrogates, ergonomics, and technical performance.

Primary Outcomes

The average compression depth, measured in millimeters, was the most critical sign of compression quality. The manikin recorded the depth of each compression for every 2-minute sequence. The average value for that sequence was used in the analysis. Since guidelines recommend that compressions should be at least one-third of the anterior-posterior chest diameter in babies, we also counted how many were within the target range of 40-50 mm. This percentage indicates the frequency with which a rescuer achieved a clinically acceptable depth, not just the average. The chest compression fraction (CCF) was the third primary outcome. It shows how much of the 2 minutes was spent giving compressions. Lower values indicate more time spent in pauses, for example, during ventilations or repositioning.

Secondary Outcomes

We initially looked at the compression rate — the number of compressions per minute averaged over two minutes—to understand how chest compression's function. Additional variables assessed compression technique performance. Full chest recoil was the proportion of compressions where the chest returned to neutral without tilting. According to pediatric BLS standards, the correct hand posture was the proportion of compressions with the thumbs or heel centered on the bottom half of the sternum. We tracked the percentage of "over-depth compressions," or compressions deeper than 50 mm, to assess if the force was excessive. Participants rated their fatigue and hand pain on a 0-10 visual analogue scale immediately after each sequence and the perceived difficulty of the technique on a 5-point Likert scale (1 =very easy to 5 =very difficult) to assess the ergonomic burden of each technique. The nurses' subjective judgments were used to estimate each method's physical and technical demands. Finally, we included measures of safety and technical strength. The hand slippage count revealed how often the compressing hand or thumbs left the sternum during a sequence. This variable had a Poisson-like count distribution.

Sample Size

Based on randomized crossover trials of baby chest compression techniques on manikins (10,16), the sample size was chosen. These investigations showed mean compression depth variations of 2-3 mm and within-subject standard deviations (SDs) of 2.5 mm between approaches, indicating a medium effect magnitude. The primary endpoint for sample size calculation was compression depth (mm).

For a one-way repeated-measures ANOVA with three levels (TTHT, CTT, OHT), $\alpha = 0.05$, 80% power, and $f = 0.25$, G^* Power 3.1 suggests 40 participants are sufficient. We planned to enroll 44 individuals to cover dropouts and missing data. Fifty participants completed all three approaches once recruitment exceeded this minimum aim to increase estimate accuracy and secondary outcome power. This final sample size has at least 80% power to detect clinically relevant differences in compression depth and sufficient power to detect secondary outcomes (compression rate and rescuer fatigue).

Statistical Analysis

Statistics were based on each participant's three resuscitation attempts (one for each procedure). Intra-subject variables included technique (TTHT, CTT, OHT). The primary analyses used one-way repeated-measures models with technique as a fixed effect and a random intercept for individuals, similar to repeated-measures ANOVA for this balanced design. The overall impact of the strategy on each outcome was tested using F-tests. Pairwise comparisons between approaches were performed using estimated marginal means, with Holm-Bonferroni adjustment for multiple testing when the omnibus test was significant.

Residual plots, Shapiro-Wilk, and Levene's tests were used to assess normality and homogeneity of variance. Greenhouse-Geisser corrected p-values were reported when Mauchly's test indicated non-sphericity. For non-normal or ordinal outcomes such as fatigue, pain, perceived difficulty, and hand slippage frequency, we used nonparametric Friedman tests and Wilcoxon signed-rank tests with Benjamini–Hochberg correction as sensitivity analyses. These yielded the same statistical significance as the primary models and are not discussed. For symmetric continuous data, the mean ± SD is used, whereas skewed variables are summarized as the median interquartile range. Effect sizes are reported using partial eta-squared (η^2p) for omnibus testing and Cohen's d for significant pairwise contrasts. All tests were two-sided and had a significance level of α=0.05.

All statistical analyses were performed using Python 3.11 (Python Software Foundation, Wilmington, DE, USA) with Pandas, NumPy, and SciPy/statsmodels libraries for data management and modeling, and Matplotlib for figure creation.

Results

Participants and Dataset

Fifty registered nurses working in acute care settings participated in the study, and all of them adhered to the protocol. Each participant executed three resuscitation sequences, one utilizing each chest compression technique, yielding 150 analyzable sequences (50 per technique). There were no missing or excluded observations, and no participant withdrew or deviated from the protocol. This means that all recorded sequences were kept for the final analyses. At the time of the study, all the nurses were undergoing a BLS training session certified by the AHA. They had all already taken at least one accredited BLS course. The research component was optional and separate from the course assessment, and it did not affect completion of the course or certification status.

Chest Compression Quality

Table 1 presents descriptive statistics for all compression variables. There was a big difference in the compression rate between the two methods (F =3.70, p=0.027). TTHT and CTT had almost the same rates, but OHT had a slightly lower rate. In pairwise tests, TTHT and CTT were different from OHT (p=0.019 and p=0.040, respectively), but TTHT and CTT were not (p=0.661; Figure 3).

The CCF was high in all groups, but it varied depending on the method (F =9.34, p<0.001). CTT produced the highest CCF, TTHT produced an intermediate value, and OHT produced the lowest. There was no difference in CCF between the two thumb-based techniques (p=0.085), but both were better than OHT (TTHT vs OHT p=0.008; CTT vs OHT p<0.001).

Table 1. Chest compression outcomes

Outcome	TTHT	CTT	OHT	TTHT vs. CTT	TTHT vs. OHT	CTT vs. OHT	ANOVA
Compression rate	112 (110-113)	111.0 (110-113.5)	109 (107-110)	0.661	0.019	0.040	F (2.147)=3.70; p=0.027
	112 (5.0)	111.6 (4.54)	109.4 (6.1)				
Chest compression fraction	0.712 (0.706-0.720)	0.720 (0.715-0.728)	0.702 (0.691-0.708)	0.085	0.008	<0.001	F (2.147)=9.34; p<0.001
	0.712 (0.021)	0.720 (0.025)	0.701 (0.023)				
Compression depth	42.64 (41.86-43.27)	41,18 (40.38-42.22)	39.49 (37.52- 40.68)	0.074	<0.001	0.005	F (2.147)=10.97; p=0,000036
	42.23 (2.42)	31.38 (2.33)	39.42 (4.15)				
Percentage of compression with target depth range 40-50 mm	52.3 (44.-56.6) %	43.1 (36.3-47.4)%	35.0 (35-35) %	0.051	<0.001	<0.001	F (2.147)=21.59; p<0.001
	53.2 (15.2) %	47.4 (14.0)%	37.1 (5.7) %				
Percentage of compressions with full chest recoil	96.6 (96.2-97.2)	97 (96.8-97.2)	95 (94.45-95.30)	0.232	<0.001	<0.001	F (2.147)=40.16; p<0.001
	96.69 (1.29)%	96.98 (1.14)%	94.75 (1.59)%				
Correct hand placement	99.0 (98.9-99.3)	98.9 (98.7-99.1)	97.2 (96.5-97.4)	0.192	<0.001	<0.001	F (2.147)=88.62; p<0.001
	99.1 (0.60)%	98.9 (0.54)%	97.2 (1.10) %				
Percentage to deep over 50mm	2.4 (1.6-2.8)	2.2 (1.5-2.5)	3.35 (3.0-3.9)	0.454	<0.001	<0.001	F (2.147)=13.18; p<0.001
	2.24 (1.39)%	2.05 (1.19)%	3.39 (1.64) %				
Rescuer fatigue	4.3 (4.0-4.7)	3.25 (2.8-3.5)	4.6 (4.2-5.05)	<0.001	0.034	<0.001	F (2.147)=31.86; p<0.001
	4.25 (0.93)	3.19 (0.82)	4.70 (1.13)				
Rescuer hand pain	3.5 (3.3- 3.75)	3.1 (2.8-3.4)	4.3 (3.95-4.6)	0.002	<0.001	<0.001	F (2.147)=33.75; p<0.001
	3.54 (0.67)	3.06 (0.83)	4.31 (0.80)				
Technique difficulty	2.5 (2.25-2.70)	2.2 (2.0-2.35)	2.9 (2.6-3.25)	0.017	<0.001	<0.001	F (2.147)=18.26; p<0.001
	2.48 (0.55)	2.20 (0.61)	2.97 (0.78)				
Hand slippage count	0 (0-1)	0 (0-1)	1 (1-1)	0.863	<0.001	<0.001	F (2.147)=10.30; p<0.001
	0.50 (0.58)	0.52 (0.58)	1.02 (0.77)				

TTHT: Techniques the two-thumb encircling technique, CTT: Cross-thumb technique, OHT: One-hand open-palm technique

Compression depth varied by technique (F =10.97, p<0.001). TTHT and CTT produced deeper compressions than OHT (TTHT vs OHT p<0.001; CTT vs OHT p=0.005); TTHT and CTT did not differ significantly (p=0.074).

There was a significant difference between the techniques in the percentage of compressions within the target depth range (40-50 mm) (F =21.59, p<0.001). Both thumb-based methods achieved a higher percentage of target-depth compressions than OHT (all p<0.001). The only difference between TTHT and CTT was very small (p=0.051). The proportion of excessive compressions (>50 mm) was minimal but markedly greater with OHT compared to TTHT or CTT (F =13.18, p<0.001; both comparisons vs OHT p<0.001); TTHT and CTT exhibited no significant difference (p=0.454).

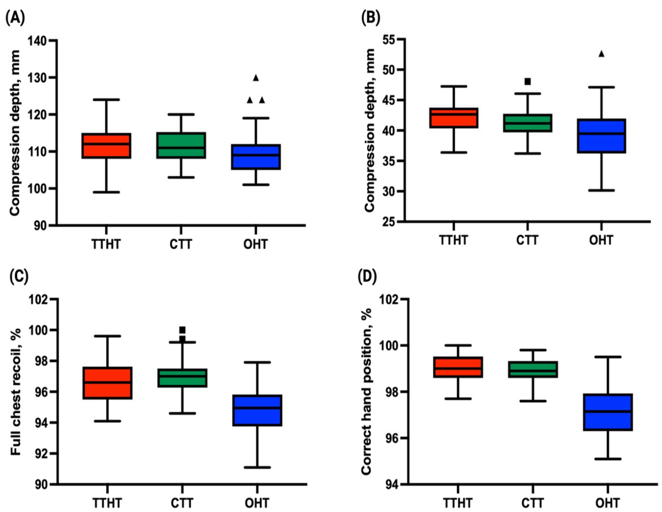

Figure 3. Comparison of chest compression quality parameters between the three infant chest compression techniques: two-thumb encircling technique (TTHT), cross-thumb technique (CTT), and one-hand open-palm technique (OHT). Data are presented as box-and-whisker plots showing median, interquartile range, and minimum/maximum values

Table 1 shows that all techniques achieved nearly full chest recoil, but OHT had slightly less. The technique had a strong effect (F =40.16, p<0.001): TTHT and CTT were similar (p=0.232), both of which were higher than OHT (both p<0.001).

All groups did a great job of placing their hands correctly on the lower half of the sternum; however, the thumb-based methods were more effective (F =88.62, p<0.001). TTHT and CTT were not significantly different from each other (p=0.192), but both were more accurate than OHT (both p<0.001).

Ergonomic Outcomes and Hand Stability

Self-reported fatigue differed by technique (F =31.86, p<0.001; Table 1). CTT had the lowest scores, TTHT was intermediate, and OHT had the highest. CTT caused less fatigue than TTHT and OHT (both p<0.001), and TTHT less than OHT (p=0.034; Figure 4).

Hand pain exhibited a comparable trend (F =33.75, p<0.001): CTT < TTHT < OHT. Pairwise comparisons revealed reduced pain with CTT compared to TTHT (p=0.002) and OHT (p<0.001), as well as diminished pain with TTHT relative to OHT (p<0.001).

The perceived difficulty, rated on a 1-5 scale, also differed by technique (F =18.26, p<0.001). CTT was the easiest, TTHT was a little harder, and OHT was the hardest. The ratings for CTT were lower than those for TTHT and OHT (p=0.017 and p<0.001, respectively), and the ratings for TTHT were lower than those for OHT (p<0.001).

Lastly, the number of times a hand slipped per attempt was low, but technique had a significant effect on it (F =10.30, p<0.001). The number of slippages was similar for TTHT and CTT (p=0.863) but higher for OHT. Both thumb-based techniques had significantly fewer slippages than OHT (both p<0.001).

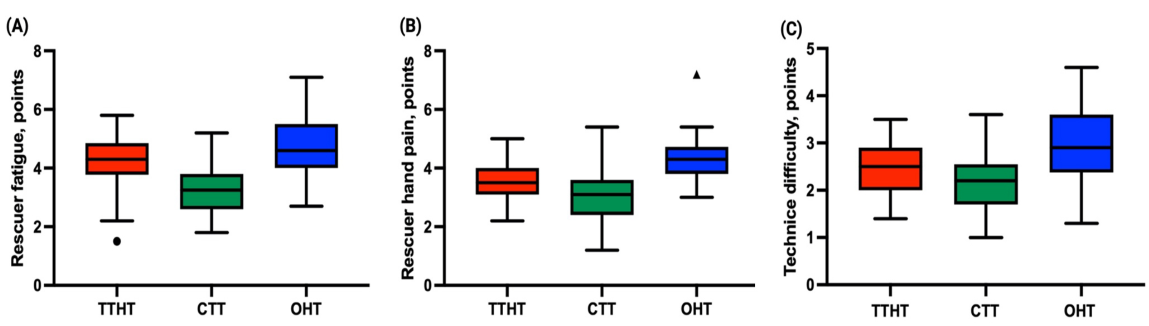

Figure 4. Comparison of ergonomic and subjective outcomes associated with the three infant chest compression techniques: two-thumb encircling technique (TTHT), cross-thumb technique (CTT), and one-hand open-palm technique (OHT). Data are presented as box-and-whisker plots showing median, interquartile range, and minimum/maximum values

Discussion

This randomized crossover simulation study evaluated three infant chest compression techniques –two-thumb encircling hands, cross-thumb, and one-hand open-palm chest– administered by nurses during 2-minute, two-rescuer CPR with a 15:2 ratio. In all core biomechanical outcomes, both thumb-based techniques produced better compressions than OHT. CTT, on the other hand, had similar mechanical performance but much better ergonomic profiles.

Chest Compression Performance and Alignment with Current Guidelines

Our findings support existing resuscitation guidelines, which favor TTHT for baby compression, especially with two rescuers. In our study, TTHT and CTT yielded comparable compression rates and CCF, both considerably higher than OHT. The average TTHT and CTT compression depth was 41-42 mm. OHT made shallower compressions and had the lowest target range compression rate of 40–50 mm (13,14).

These findings confirm earlier manikin and animal studies that TTHT provides greater depth, more consistent compressions, and higher coronary perfusion pressures than the two-finger technique (4,15). Recently, Solecki et al. (16) completed a meta-analysis and narrative review. Due to its better depth accuracy than lateral or two-finger approaches, TTHT is still the best way to perform CPR on babies and neonates. We also found that TTHT beats OHT in a 2-rescuer, 15:2 scenario that follows AHA/AAP baby CPR standards.

The percentage of over-deep compressions (>50 mm) was low across all procedures, except OHT. This shows that providers may overshoot when trying to compensate for one-handed depth. OHT also has the lowest target range compressions, thus it does not offer the best depth or safety. These findings imply that OHT should not be routinely employed when TTHT or CTT are practicable, even though the most recent pediatric BLS recommendations recommend the one-hand technique when the chest cannot be ringed (17).

Cross-thumb Technique Versus Two-Thumb Encircling

A significant contribution of this study is the direct comparison between TTHT and the more recent CTT in a two-rescuer context. We discovered that CTT attained compression rates, CCF, depths, target-depth proportions, and over-depth rates that were statistically indistinguishable from those of TTHT. These results are very similar to those found by Joyner et al. (9) in their randomized manikin study. They found that CTT and TTHT had similar depth and guideline-compliant compression rates, both of which were much better than the two-finger technique (4). Recent comparative data also demonstrate that CTT provides comparable or marginally enhanced mechanical performance while enabling the rescuer to maintain a lateral position, which could be beneficial in confined spaces.

Our findings reveal a significant distinction: despite the mechanical equivalence of TTHT and CTT, CTT was consistently associated with reduced fatigue, diminished hand pain, lower perceived difficulty, and no increase in hand slippage. This ergonomic advantage is clinically significant, as rescuer fatigue is known to degrade CPR quality over time and may be especially detrimental during extended pediatric resuscitation. CTT may be a good alternative to TTHT because it offers both high-quality compressions and reduced physical strain. This is especially true when the compressor must remain next to the patient (for example, in transport incubators, crowded ED bays, or limited workspace around an infant bed).

Nonetheless, it is crucial to underscore that the current evidence for CTT, including our own, is limited to simulation studies. There are no clinical outcome data available to show that CTT is better than or even as satisfactory as TTHT in real cases of infant cardiac arrest. Until such evidence surfaces, TTHT should remain the standard technique endorsed by guidelines, while CTT should be regarded as a promising adjunct or alternative in particular circumstances.

One-hand Technique in the Context of Emerging Evidence

Recent research has rekindled interest in one-handed techniques for infant CPR. Smereka et al.(18) found that the one-hand open-palm technique (OPT) on an infant manikin produced greater depth and was rated as easier than standard two-finger or two-thumb methods. However, the absolute depths still did not consistently meet AHA targets. In a two-rescuer 15:2 scenario, however, our results show that OHT is inferior to TTHT and CTT in several ways: it has shallower compressions, a lower CCF, a significantly lower percentage of target-depth compressions, and a higher percentage of over-deep compressions.

This apparent discrepancy likely stems from differences in how the studies were designed and what they examined. The OPT studies focused on single-rescuer CPR and primarily compared OHT with the two-finger technique, which is commonly acknowledged as inadequate due to its limitations in depth and fatigue. In that context, OHT might be a better option. In our study, OHT was compared to two highly effective thumb-based methods in a two-rescuer scenario, revealing its relative deficiencies. These results support the cautious stance of recent guideline updates, which position the one-hand technique as an option when the provider cannot adequately encircle the chest, rather than as a first-line approach.

Ergonomics and Technical Stability

The ergonomic outcomes in our study provide further insight into the practical trade-offs among techniques. CTT had the lowest scores for fatigue and pain, as well as the lowest perceived difficulty. TTHT was in the middle, and OHT always scored the worst on these measures (13,19).

These results are similar to earlier data, which showed that two-thumb techniques require less rigorous work than two-finger compressions, both in terms of subjective ratings and physiological measures (20). There weren't many instances when hands slipped, but there were significantly more with OHT than with either of the thumb-based methods.

This could be due to the smaller contact area and less stable leverage of the heel of one hand on a small chest. From a patient-safety standpoint, heightened slippage may result in more frequent off-target compressions, especially on compliant infant ribs or in the presence of fluids or gel, although this remains conjectural in the absence of clinical evidence. Our results suggest that OHT may be less forgiving in terms of technical stability, especially for providers with limited pediatric experience, because there are more over-deep compressions.

Clinical and Educational Implications

Our data collectively substantiate multiple pragmatic conclusions for clinical practice and education. First, they support the guidelines that state TTHT should be the standard method for infant CPR when two rescuers are available. Second, they suggest that CTT can be safely regarded as a distinct thumb-based technique that functions mechanically just as well but is more comfortable to use. For teams that frequently revive babies in settings where the compressor must remain near the patient, it may be beneficial to incorporate CTT into local training programs, provided that students also learn TTHT and are aware that it remains the standard (11,21). Third, our results suggest that OHT should not be used when high-quality thumb-based compressions are possible. OHT is useful when the chest can't be encircled, such as with larger babies, unusual body types, or certain situations where the baby can't move. However, our data show that for normal-sized babies and in controlled settings, OHT leads to shallower compressions, less time spent in compression, more technical errors, and increased workload for the rescuer. This nuance may be especially significant as recent consensus documents broaden the application of one-hand techniques in pediatric BLS (22). From an educational standpoint, the substantial influence of technique on both objective quality metrics and subjective workload underscores the imperative of deliberate practice coupled with feedback (1). Training that utilizes simulations to teach students various techniques, focusing on depth, recoil, and minimizing pauses, may help them adjust to different patient sizes, environments, and team compositions without compromising the quality of their care.

Study Limitations

Strengths and Limitations

This study has several strengths. The randomized crossover design, wherein each participant acts as their control, diminishes inter-subject variability and facilitates significant comparison of techniques under uniform conditions. We used a two-rescuer, 15:2 scenario that followed current pediatric guidelines. We also used a group of nurses who had recently completed BLS training and were fairly similar, which makes the results more reliable. There was no missing data in any of the sequences, so the dataset was complete for analysis.

However, significant limitations must be recognized. First, this was a simulation study conducted on an infant manikin; the degree to which observed differences correlate with clinically significant outcomes (return of spontaneous circulation, survival, neurological status) in actual infants remains uncertain. Second, our participants were practicing nurses from a single institution, which may not encompass the full spectrum of pediatric resuscitation experience. Third, we looked at 2-minute bouts of CPR. Rescuer fatigue and technique degradation may differ over longer periods or during more complex resuscitations that involve multiple tasks. Fourth, we examined a single configuration for each technique; alternative configurations, including over-the-head TTHT or adjusted hand positions for CTT, were not investigated. Finally, making multiple comparisons across various endpoints increases the likelihood of committing a Type I error. However, the consistency and magnitude of the effects we observed—especially for OHT versus thumb-based techniques—make it unlikely that our main conclusions are merely random.

Future Directions

Subsequent research must extend beyond the use of manikins to assess these techniques in authentic environments, preferably through multicenter observational registries or pragmatic trials that measure CPR quality metrics during actual infant resuscitations. The incorporation of high-fidelity manikins that can estimate hemodynamic surrogates alongside real-time feedback devices may elucidate whether the ergonomic benefits of CTT result in enduring quality during prolonged resuscitations. Moreover, research contrasting these methodologies in solo-rescuer contexts, during transit, and in restricted settings would enhance the precision of their ideal applications. Finally, cost-effectiveness and learning-curve analyses could help determine the most effective way to incorporate CTT and OHT into pediatric life support courses without compromising important skills in TTHT.

Conclusion

In this randomized crossover simulation of two-rescuer infant CPR, both TTHT and CTT yielded superior chest compression quality compared to the one-hand OHT, demonstrating increased depth, enhanced target-range compressions, and improved recoil and hand positioning. CTT had similar mechanical performance to TTHT, but it caused less fatigue and pain in the hands and was perceived as easier, suggesting that it could be a practical and more comfortable alternative when thumb-based methods are possible. OHT should still be an option when the chest can't be encircled. Further clinical studies are needed to determine whether the benefits of simulations translate into improved patient outcomes.

Ethics

Ethics Committee Approval: The Institutional Review Board of the Polish Society of Disaster Medicine reviewed and approved the protocol (approval no. 14/02/2024, date: 14.02.2024). All study procedures adhered to the Declaration of Helsinki and relevant national regulations governing research with human subjects. Volunteers

Informed Consent: Volunteers received written and verbal information and provided written consent before participating.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.S., Concept: M.S., Design: M.S., Data Collection or Processing: M.S., H.K., L.S., B.M., W.W., Analysis or Interpretation: M.K., M.S., L.S., B.M., W.W., Literature Search: M.K., M.S., H.K., L.S., B.C., B.M., A.C., W.W., Writing: M.K., M.S., H.K., L.S., B.C., B.M., A.C., W.W.

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