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Sex Representation in CPR Training Manikins and Its Impact on Resuscitation Performance: A Randomized Crossover Simulation Study

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Abstract

Female patients face a significantly lower probability of receiving bystander or in-hospital cardiopulmonary resuscitation (CPR) than male patients, contributing to poorer post-arrest survival outcomes. Traditional resuscitation pedagogy relies heavily on training simulators that replicate lean, white, male anatomy. This project analyzes whether the physical sex characteristics of a training manikin affect clinical performance during simulated cardiac emergencies. We designed a randomized, prospective, crossover simulation experiment involving 52 internal medicine residents. Each subject managed two distinct ventricular fibrillation scenarios, featuring a male-bodied and a female-bodied simulator, in an alternating sequence (distributed via 1:1 allocation to either a female-first or a male-first track), separated by a 4 h intervention-free interval. The primary endpoint was the time from the onset of ventricular fibrillation to the administration of a shock. In contrast, secondary endpoints tracked the elapsed time to initial chest compressions, pad application, and rhythm diagnosis, as well as objective CPR quality metrics (depth, rate, and compression fraction). Linear mixed-effects statistical models were applied to analyze the data, adjusting for participant sex and clinical background. Trainees assigned to the female-first track demonstrated delayed time to defibrillation (28.05, $P < 0.006$), lengthened time to compressions (12.08 s, $P = 0.007$), prolonged pad application (14.58 s, $P < 0.001$), and slower identification of ventricular fibrillation (17.79 s, $P = 0.004$) when managing the female simulator compared to colleagues in the male-first track. Furthermore, the duration spent within the optimal compression depth range was lower for the female-first cohort (11.02%, $P = 0.027$). Resuscitation quality was compromised when providers encountered the female simulator at the beginning of testing, revealing an asymmetrical improvement curve, which indicates that presentation sequence alone cannot account for the performance gap. Incorporating female-presenting simulators early and routinely into medical education curricula could optimize cognitive readiness and help eliminate sex-based disparities during real-world resuscitations.

Keywords: Cardiopulmonary resuscitation, Cardiac arrest, Resuscitation training, Simulation-based education, Implicit bias, Sex disparities

Introduction

Gender-based discrepancies in cardiac arrest interventions are widely established across pre-hospital and in-hospital medical settings. Women who suffer an Out-of-Hospital Cardiac Arrest (OHCA) are far less likely to be given bystander CPR [1], an inequality that intensifies within public spaces [2, 3]. Furthermore, female OHCA patients are less likely to undergo defibrillation [4]. During active emergency medical services transport, women receive epinephrine doses and electrical shocks less frequently than men [5]. This pattern persists for In-Hospital Cardiac Arrest (IHCA), where female patients experience lower rates of defibrillation despite presenting with identical initial shockable rhythms and undergoing comparable durations of active CPR [6, 7].

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As a result, determining whether the educational environment itself fosters these clinical discrepancies is essential. Prior studies indicate that implicit biases are present among healthcare professionals [8, 9] and that these biases can alter the management of male versus female patients during acute emergencies like sudden cardiac arrest [10]. Given these systemic imbalances, it is crucial to analyze the current CPR training framework, particularly the impact of simulator diversity [11].

The vast majority of resuscitation manikins feature white, lean, male-presenting body types [11]. Even widely implemented simulators like the Laerdal Resusci Anne/Little Anne—which utilize a female name and facial features—possess anatomically neutral, flat chests that fail to represent the broader population at risk for cardiac arrest [8]. Standard resuscitation courses (such as the American Heart Association Advanced Cardiac Life Support (AHA ACLS) [12, 13] and the European Resuscitation Council (ERC) [14]), along with quantitative CPR research, generally depend on a solitary type of simulator, typically torso-only models (Laerdal's LittleAnne®) or full-body systems (SimMan®). These "realistic models of real patients" completely omit the physiological attributes of female patients (e.g., breast tissue), which can hinder a trainee's ability to locate physical landmarks and deliver high-quality chest compressions [13]. Additionally, a lack of demographic diversity among training models may reinforce implicit biases within lay responders [3].

We hypothesize that the physical attributes of a simulator can influence medical professionals when they resuscitate a female versus a male victim during an acute cardiac arrest scenario. This project evaluates how a manikin's designated sex alters objective CPR quality metrics within a simulated clinical environment.

Materials and Methods

Study design and setting

Following institutional review board approval (STUDY00001649), we executed a randomized, prospective, crossover simulation trial within a major academic medical center in Southern California. Data collection occurred in a dedicated Intensive Care Unit (ICU) simulation bay that replicated the equipment placement, crash cart layout, and monitoring infrastructure of an authentic medical-surgical floor **(Figure 1)**. All acquired metrics were compiled and stored on a de-identified cloud storage platform accessible exclusively to the research team. This study is reported in compliance with CONSORT guidelines [15], including the specific frameworks recommended for simulation-based research design.

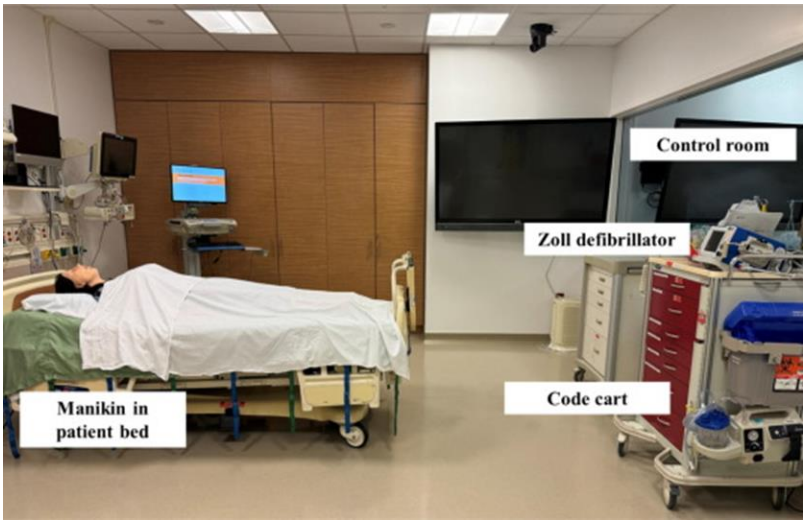


Figure 1. Scenario set-up in ICU room.

Participants

Trainees were recruited from an introductory clinical training intensive designed for incoming internal medicine residents. Participation was entirely optional, and all subjects received a water bottle (valued at $25) as reimbursement for their time.

Randomization: sequence generation and implementation

A pre-established block allocation matrix was generated by the study statistician (who remained completely uninvolved in participant consent or active data collection) to randomize subjects. This allocation sequence was unveiled the day before each simulation session, enabling the specialist (E.E.) to prepare the appropriate initial manikin (female- or male-bodied) for the following day. Every resident scheduled on a specific date was exposed to the same initial manikin type, followed by the alternate-sex model after a 4-h washout interval had passed.

Study procedure

Upon arrival, ACLS-certified participants were briefed on the study context by the facilitators (T.C. and P.N.). Following electronic consent completion, trainees listened to a standardized pre-brief script detailing the primary clinical goals: (1) identifying the electrocardiogram rhythm; (2) placing the defibrillator pads in the correct positions; and (3) administering CPR according to established ACLS protocols [12]. This orientation included a demonstration of the Zoll training defibrillator pads, their integrated feedback mechanism, and the rhythm simulator box (to establish suspended disbelief), along with a tour of the room layout and a description of one of the two clinical cases.

Participants remained completely blind to the specific research questions. The roles and responsibilities of the embedded research assistants (P.N. and E.E.) were strictly defined (E.E. was responsible for providing the Zoll defibrillator pads, activating the Zoll monitor, and delivering electrical shocks upon direct instruction from the participant; P.N. was responsible for operating bag-mask ventilation when requested by the participant. Both E.E. and P.N. participated across all simulation sessions [16].

Scenario design

Both testing scenarios simulated a sudden ventricular fibrillation (VF) arrest utilizing low-fidelity, 40-year-old male and female manikins (Lifecast Body Simulation, London, UK). Upon entering the simulation bay, participants encountered a patient (either the male or female model, clothed exclusively in a standard hospital gown) in the patient bed, a crash cart equipped with a Zoll defibrillator, pads, and a rigid backboard **(Figure 1)**. The crash cart organization and the location of the defibrillation equipment mirrored the actual clinical environment. Each testing session concluded exactly two minutes after active CPR metrics began recording, defined as 2 min following the placement of the Zoll feedback device.

Data collection

Chronological tracking was managed by a pair of qualified investigators (F.K., acting as a Human Factors Engineer, and T.C., serving as a Human Factors Scientist). This team documented the exact intervals required to begin cardiac compressions, achieve proper pad positioning (defined as an antero-lateral configuration that circumvented mammary tissue while placing the lateral pad along the mid-axillary line [14], verified by consensus between the embedded confederates, E.E. and P.N.), achieve vocalized rhythm recognition of VF by the subject, and deliver a shock (measured from the initial onset of VF to actual defibrillation) during the recorded testing sessions. Objective performance metrics were monitored and logged directly via the defibrillator hardware interface (utilizing OneStep training pads manufactured by Zoll Medical, MA, USA), which recorded chest compression depth, frequency, and overall compression fraction. Interrater consistency was verified by ensuring F.K. and T.C. maintained strict alignment on event durations throughout the active scenarios (ICC > 0.8), with all video assets and time-stamped annotations subsequently validated by PN.

Outcomes

The primary endpoint for this trial was the time to defibrillation, measured in seconds, from the precise moment of VF onset (marked by the candidate entering the testing space) to shock delivery. Secondary endpoints tracked the time (in seconds) to initiate compressions (spanning from VF onset to the first downward stroke), the time to achieve pad attachment (spanning from VF onset to verified proper pad positioning), the time to recognize VF (spanning from VF onset to the subject's spoken identification of the rhythm), and overall CPR efficiency. This clinical efficiency was measured by calculating the percentage of time that compression depth and frequency remained within the target thresholds established by the AHA [12] and ERC [17] frameworks (specifically a depth of 5–6 cm and a speed of 100–120 compressions per minute), as well as the percentage of time spent without active compressions (with a target chest compression fraction of 80%).

Statistical analysis

Continuous variables were evaluated using linear mixed-effects regression to account for the crossover trial's repeated-measures design properly. Each statistical model included a random intercept for each participant, along with fixed effects for simulator anatomy (female vs male), presentation order (female-first vs male-first), and the interaction between simulator anatomy and presentation order. We constructed both unadjusted frameworks and fully adjusted models that controlled for the additional covariates of participant gender and medical specialty. Descriptive observations are reported as mean ± standard deviation, whereas regression outcomes are stated as β coefficients accompanied by 95% confidence intervals and two-sided p-values. For endpoints featuring significant interaction variables, order-dependent dynamics were interpreted as the female-versus-male variance within the female-first sequence (representing the main sex effect) and within the male-first sequence (calculated as the main sex effect aggregated with the interaction term). The target sample size was determined based on the primary endpoint, which tracked the duration from VF onset to shock delivery. A historical study by Hunt *et al.* [18] demonstrated a mean time to defibrillation of 244 s with an SD of 165 s. Factoring in these metrics alongside an

anticipated pool of roughly 50 residents attending the training intensive, a sample size of n = 48 yields 80% statistical power to verify mean discrepancies of 68 s or greater under a significance criterion of $P < 0.05$.

Results and Discussion

A cohort of 52 internal medicine residents participated in this investigation (comprising 21 females and 31 males). Within this group, 1 resident had previously switched training tracks and possessed > 1 year of clinical experience, while 3 participants were primary neurology residents. Upgrades to the training center's audiovisual infrastructure during the study altered the recording process, leading to isolated missing data points **(Table 1)**. After controlling for participant gender, years of residency experience, and medical specialty, subjects in the female-first sequence exhibited a delayed time to defibrillation when managing the female model relative to the male model (β 28.05 s for female vs male, p = 0.006, main sex effect), **Figure 2**. Conversely, within the male-first sequence, the duration to defibrillation on the female model shortened by 4.38 s compared to the male model (interaction β −32.43 s, net effect 28.05 +(−32.43) = −4.38, interaction p = 0.027, factoring the main sex effect alongside the interaction term), **Table 2**.

Table 1. Descriptive statistics for all outcomes stratified by manikin sex present descriptive statistics for all outcomes stratified by manikin sex. Mean (SD) and mean differences are provided. Note: P-values shown are unadjusted and do not account for the repeated measures design.

Characteristic	P-value[b]	Female (n = 52)[a]	Male (n = 52)[a]
Overall scenario duration (s)[c]	0.3	197 ± 24	191 ± 19
Interval until defibrillation (s)[c]	0.13	115 ± 47	103 ± 44
Time required to initiate chest compressions (s)	>0.9	49 ± 29	47 ± 24
Time to apply defibrillation pads (s)[c]	0.3	60 ± 22	54 ± 17
Time to identify ventricular fibrillation (s)[c]	0.10	84 ± 29	76 ± 28
Percentage of chest compressions delivered within the recommended depth range (50–60 mm)	0.4	16 ± 20	20 ± 24
Percentage of chest compressions performed within the target rate range (100–120 compressions/min)	0.8	56 ± 36	59 ± 36
Chest compression fraction (%) representing periods without compressions	0.8	27 ± 18	26 ± 14
Mean number of defibrillation shocks administered	0.4	1.54 ± 0.98	1.67 ± 0.86

[a]: Mean ± SD.
[b]: Wilcoxon rank sum test; p-values shown are unadjusted and do not account for the repeated measures design.
[c]: Due to a transition in the simulation center recording system, 1 recording of pad placement and 23 recordings of time to VF recognition were not saved, preventing maintenance of interrater reliability; therefore, these data were excluded from analysis.

a) b)

Figure 2. Influence of manikin order-specific effects (main sex effect) on time to defibrillation and time to compression.

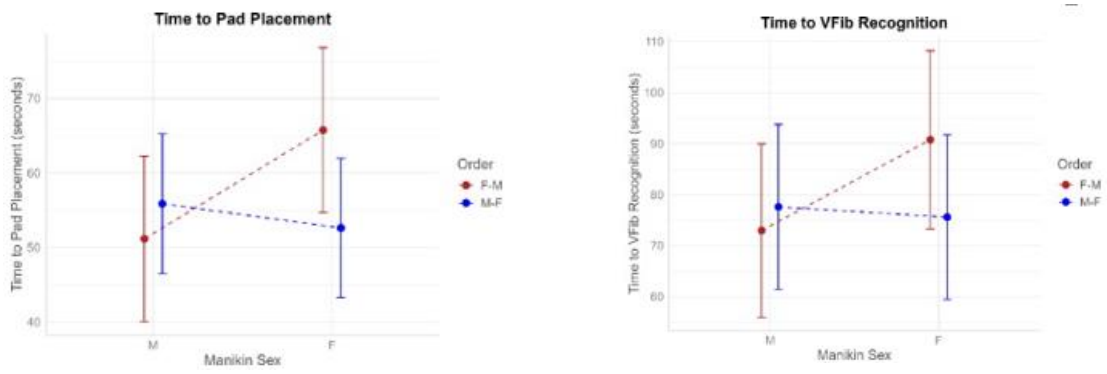
Table 2. Fully adjusted models: main effects and interactions with all covariates.

Outcome measure	P-value	Incremental effect in the male–female sequence (interaction β, 95% CI)	P-value	Effect of female manikin in the female–male sequence (β, 95% CI)
Duration until defibrillation (s)	0.027	−32.43 (−60.09, 4.78)	0.006	28.05 (9.40, 46.69)
Time elapsed before initiating chest compressions (s)	0.002	−19.01 (−30.52, −7.51)	0.007	12.08 (3.64, 20.53)
Time required for defibrillator pad application (s)	0.001	−17.84 (−27.80, −7.76)	<0.001	14.58 (7.29, 21.88)

Time to identify ventricular fibrillation (VF) (s)	0.029	−19.79 (−36.79, −2.63)	0.004	17.79 (6.29, 29.30)
Percentage of chest compressions within the recommended depth range (50–60 mm)	0.045	13.58 (0.67, 26.49)	0.027	−11.02 (−20.50, −1.55)
Percentage of chest compressions within the target rate range (100–120 compressions/min)	0.714	3.69 (−15.92, 23.29)	0.491	−5.09 (−19.48, 9.30)
Chest compression fraction (%) representing intervals without active compressions	0.422	−3.21 (−10.97, 4.56)	0.421	2.36 (−3.34, 8.06)

Note: All models adjusted for resident sex, years of experience, and specialty in addition to manikin sex, order, and their interaction. For time-based outcomes (rows 1–4), positive β values indicate longer times/delays, and negative β values indicate shorter times/faster performance. For CC quality outcomes (rows 5–7), positive β values indicate better performance (a higher % in the target range), and negative β values indicate poorer performance.

Female body types were associated with a longer interval before starting compressions (β = 12.08 s, P = 0.007) **(Table 2; Figure 2)** and a longer duration before achieving pad attachment (β = 14.58 s, P < 0.001) when encountered as the initial scenario **(Figure 3)**. Significant negative sex-by-order interactions were observed for both compression initiation (β = −19.01, 95% CI = −30.52 to −7.51, P = 0.002) and pad placement (β = −17.84, 95% CI = −27.80 to −7.76, P = 0.001) **(Figures 2 and 3)**.

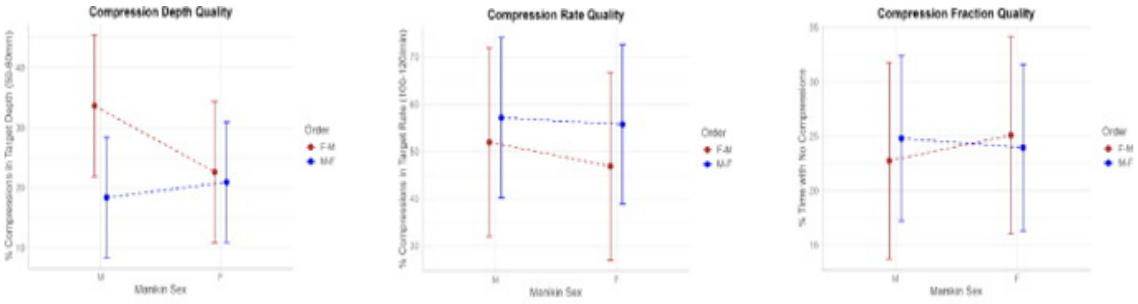


a) b)

Figure 3. Influence of manikin order-specific effects (main sex effect) on time to pad placement and time to ventricular fibrillation (VFib).

Regarding the VF recognition endpoint, a major interaction was observed between simulator sex and presentation sequence (P = 0.029) **(Table 2)**. When the female model was evaluated first, rhythm diagnosis was delayed by 17.79 s compared with the male model (P = 0.004), resulting in a 23% increase in detection time (baseline male manikin mean = 76 s). This lag was completely mitigated when residents managed the male model first (M-F sequence, net effect: −2.00 s) (interaction P = 0.029) **(Figure 3)**. Participant gender and previous simulation exposure did not emerge as significant predictors within any of the statistical models.

A significant interaction between simulator anatomy and presentation order was also identified regarding the accuracy of chest compression depth (P = 0.045) **(Figure 4)**. When facing the female model first, residents maintained the target compression depth range (50–60 mm) for a lower proportion of the scenario relative to the male model (−11.02%, p = 0.027). Conversely, when the male model was managed first, compression depth accuracy on the female model improved, yielding a 2.56% higher proportion of time within the target depth boundaries (net effect: −11.02 + 13.58 = +2.56%) **(Table 2)**. No statistically significant variances were detected concerning compression frequency or compression fraction **(Table 2; Figure 4)**.



a) b) c)

Figure 4. Influence of manikin order-specific effects (main sex effect) on chest compression depth quality, rate quality, and compression fraction quality.

This study demonstrated meaningful variances in AHA [12] and ERC [17] CPR metrics tied to the presentation sequence of simulator sex during simulated resuscitations. When subjects engaged with the female model before the male model, their performance on the female simulator was consistently degraded. Intervals to defibrillation, chest compression start, pad application, VF diagnosis, and accurate compression depth were all significantly worse on the female model within the female-first cohort.

Simulation pedagogy is designed to familiarize students with the settings, patients, and practical variables they will encounter in clinical practice; however, the overwhelming prevalence of male-presenting simulators in CPR education [11] may compromise psychological preparedness and procedural comfort with female anatomy during active resuscitations. A 2024 analysis reviewed CPR training models commercially available worldwide, noting that of 20 identified simulators, 95% feature flat chests and structurally align with male anatomy [8]. More specifically, 90% of accessible CPR simulators present as lean, white, and morphologically androgynous [8].

The pronounced interaction identified across these outcome measures offers a novel perspective on how bias manifests in clinical execution. This pattern implies that once a student interacts with a male-bodied simulator, subsequent engagement with a female-bodied model becomes "normalized," thereby diminishing treatment lags and execution challenges. The cognitive psychology framework of schema activation may clarify this trend; specifically, learners rely on internalized prototypes and past experiences to interpret environmental cues and respond [9]. When a clinical marker deviates from a prototypical baseline schema (i.e., a female physique rather than a male physique), schema activation can be slowed or incomplete, resulting in a "schema mismatch" that slows down recognition and response times [10]. For participants in the male-first cohort, their pre-existing schema was triggered immediately ("resuscitation is occurring on a male-presenting model") and continued to guide pattern matching and task sequencing during the subsequent female scenario, facilitating a more efficient performance [11].

These insights offer actionable takeaways for ACLS and related resuscitation training curricula. Deploying exclusively male-presenting models in early educational stages may inadvertently reinforce a male-centric cardiac arrest schema, precipitating performance drops when students later face diverse body types in real-world environments. Conversely, the enhanced performance on the female-bodied model following prior male-bodied exposure implies that deliberate task sequencing and educational scaffolding could effectively normalize demographic diversity [11], for example, by alternating male and female models across the baseline stages of instruction.

The 2025 ERC [14] and AHA [19] frameworks emphasize simulator fidelity, authentic patient representation, and deliberate practice as foundational pillars of successful resuscitation pedagogy. The 2025 AHA Guidelines [13] for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care specifically highlight an ongoing knowledge gap: "Which educational interventions most impact real-world performance and clinical outcomes, as opposed to educational outcomes or performance in training?" These benchmarks underscore that simulator fidelity is a critical component driving educational efficacy. Introducing female-bodied simulators alongside explicit learning goals early in training tracks could improve the cognitive readiness required to deliver CPR across a broader patient demographic. The clear execution delays observed on a female-bodied model—particularly when encountered first in our study—demonstrate that not only the model type but also the specific sequence in which students encounter diverse anatomies can affect the acquisition and execution of critical ACLS skills.

This study is subject to several limitations. First, data collection was conducted at a single academic medical facility. It focused exclusively on internal medicine residents, limiting the generalizability of these findings to clinicians with different levels of training or medical expertise. Second, the experimental design utilized two specific models from a single manufacturing source; though highly realistic, these models depict only a singular anatomical representation of "female" and "male" patient body types. Additionally, an upgrade to our institution's video recording infrastructure occurred during the investigation, which resulted in missing data variables that may have influenced the tracked outcomes.

Furthermore, while subjects were aware that the trial investigated CPR execution on male and female simulators, they were not explicitly informed that manikin sex and presentation sequence served as the primary variables under investigation. Nevertheless, this general awareness alongside the distinct physical differences between the simulators could have induced a Hawthorne effect or introduced expectation bias. To balance the practical constraints of the resident training camp with established guidelines for crossover simulation frameworks, a 4 h washout interval was integrated between testing sessions [20-22]. However, this timeframe might not have been long enough to eliminate the influence of skill acquisition or schema activation.

Resuscitation quality improved during the second trial irrespective of the simulator's sex, a finding that aligns with a standard practice or carryover effect. Crucially, this optimization was not balanced: performance gains were far more notable when the female simulator was managed second, whereas performance on the male model derived less benefit from previous trial exposure **(Figures 2, 3, and 4a)**. This distinct asymmetry implies that a basic learning effect cannot fully account for the recorded trends. Instead, the data point to a combination of a carryover effect and a distinct performance drop unique to the sequence in which the female simulator was

evaluated first; unfortunately, the crossover framework prevents us from completely separating these underlying mechanisms.

It should also be noted that while the recorded delays in administering a shock, starting compressions, positioning pads, and diagnosing VF were statistically significant, their direct clinical significance—amounting to approximately 10–20 s per task—remains unproven and should be interpreted conservatively. Finally, we did not systematically document the exact accuracy of pad layout relative to mammary tissue or precise hand positioning throughout the compression cycles. This omission prevents us from directly linking the variations in timing and depth to specific technical mistakes in pad or hand placement.

Ultimately, while simulation serves as a robust methodology for assessing clinical actions under standardized parameters, it cannot perfectly replicate the complex psychological and environmental stressors present during live cardiac arrest emergencies. Nonetheless, given our findings regarding the influence of simulator sex sequence on CPR metrics, we maintain that female-presenting models should be systematically and early integrated into resuscitation curricula.

Conclusion

Resuscitation quality during educational tracking was affected by both the simulator's sex and the sequence of exposure. The uneven scale of performance improvement across different testing tracks means that the sex-based disparity cannot be attributed solely to the sequence of presentation. Implementing early, routine, and compulsory female manikin representation within resuscitation training courses represents a foundational step toward dismantling clinical barriers to managing female patients and closing the performance gap identified in simulator presentation sequencing.

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Conflict of interest: None

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Ethics statement: The study was approved by the Cedars-Sinai Medical Center Institutional Review Board (STUDY00001649). All participants provided informed consent before participation.

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