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Original Article

Effect of Metronome Guidance on Chest Compression Rate Adherence in Out-of-Hospital Cardiac Arrest: A Retrospective Cohort Study

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Abstract

This study sought to assess chest compression rates (CCR) during out-of-hospital cardiac arrest (OHCA) care, comparing periods when a metronome was used to periods without one. A retrospective cohort analysis was conducted on non-traumatic OHCA incidents managed by the Seattle Fire Department between January 1, 2013, and December 31, 2019. The intervention consisted of an audio metronome set to 110 beats per minute during CPR. The principal measure was the median CCR across CPR intervals performed with versus without metronome guidance. A total of 2,132 OHCA events contributed 32,776 minutes of CPR data; 15,667 minutes (48%) occurred without metronome assistance, whereas 17,109 minutes (52%) involved metronome use. In the absence of a metronome, the median CCR was 112.8 compressions per minute (IQR 108.4–119.1), with 27% of CPR minutes falling outside the 100–120 range. Under metronome guidance, the median CCR was 110.5 per minute (IQR 110.0–112.0), and fewer than 4% of minutes deviated above 120 or below 100. Compression rates of 109, 110, or 111 occurred during 62% of metronome-guided minutes compared with 18% of minutes without metronome support. Using a metronome during CPR markedly improved adherence to a predetermined compression rate, reducing variability and promoting consistent target performance.

Keywords: Metronome, Cardiopulmonary resuscitation, Chest compression rate, Chest compressions, Out-of-hospital cardiac arrest, Cardiac arrest

Introduction

High-quality CPR relies on multiple factors—rate, depth, recoil, and compression fraction [1, 2]. Prior research has demonstrated that rates below 100 or above 120 are linked with inferior outcomes compared to compressions delivered between 100–120 per minute [3-6]. Accordingly, the most recent American Heart Association recommendations specify a rate of 100–120 compressions per minute [1].

Audio or visual feedback tools have been shown to enhance compliance with recommended compression rates [7-11]. Systems that provide real-time prompts have repeatedly improved rate accuracy in simulation environments and clinical contexts for both non-clinicians and trained personnel [7]. Studies evaluating a basic auditory metronome alone have likewise shown improvements in compression metrics [8, 9]. Similar benefits have been observed in emergency department settings using standalone metronomes [10, 11]. Despite this, evidence for simple audio metronomes during real-world, prehospital CPR remains limited.

The objective of this investigation was to compare compression rates during OHCA CPR with and without an audio metronome. We predicted that metronome use would enhance the attainment of target compression rates during field resuscitation.

Materials and Methods

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Study setting, design, and data collection

This work employed a retrospective cohort design examining non-traumatic OHCA events managed by the Seattle Fire Department over a seven-year interval spanning January 1, 2013 through December 31, 2019. Approval was granted by the University of Washington Institutional Review Board, and the project adhered to STROBE recommendations for observational research.

Seattle Fire Department serves as the primary EMS organization for Seattle, Washington and operates with a tiered deployment system involving firefighter-EMTs and firefighter-paramedics. EMTs deliver basic life support (BLS) and can apply automated external defibrillators. From the beginning of the study window until January 2015, EMTs received annual OHCA-specific instruction that incorporated simulated practice emphasizing a compression target of 110 CPR compressions per minute. Beginning January 2015, a CTM-40 Tuner and Metronome (DeltaLab, Thousand Oaks, CA) preset at 110 beats per minute was stored inside each automated external defibrillator case, and EMTs were directed to activate it as early as feasible and maintain it throughout resuscitation.

All defibrillators used during the analysis captured continuous transthoracic impedance, ECG waveforms, and full audio from each response. These audio files and device outputs were extracted to assemble a comprehensive registry of OHCA incidents. A trained reviewer examined each audio file manually and documented the time the metronome became audible.

CODESTAT review software (Version 12.0, Stryker Corporation, Kalamazoo, MI, USA) calculated the chest compression rate (CCR) for every one-minute segment by computing the average interval between compressions for that minute, excluding the lowest and highest quartile of intervals. This "trimmed mean" minimizes the effect of detection inaccuracies. The program occasionally fails to compute CCR values when the manual defibrillator is not in "paddles" mode, when too few compressions occur in the minute, or when the algorithm misses compressions. Because calculations reference the time the defibrillator was powered on, the earliest and latest compression periods usually begin or end mid-epoch due to imperfect alignment of compressions across minute boundaries and because compression cycles are not strictly two minutes in duration.

Study population, exposure, outcomes, and statistical analysis

All non-traumatic OHCAs managed by Seattle Fire Department personnel were considered for inclusion **(Figure 1)**. Exclusions were applied to: incidents without defibrillator data or missing audio; patients younger than 18; individuals who developed arrest only after EMS arrival; cases receiving ALS from non-Seattle Fire Department providers; and any situation where timestamps across devices conflicted.

Within eligible cases, individual CODESTAT minute-level epochs were omitted if they occurred after the first return of spontaneous circulation (ROSC), if a LUCAS device was used, if duplicate minutes were recorded by two devices, or if a valid compression rate could not be derived. Minutes with extreme rates—greater than 150 or below 60—were also removed because such values likely reflected measurement error. When both an automated and a manual defibrillator reported the same minute, the earliest device's data were retained, and repeated minutes from the second device were excluded.

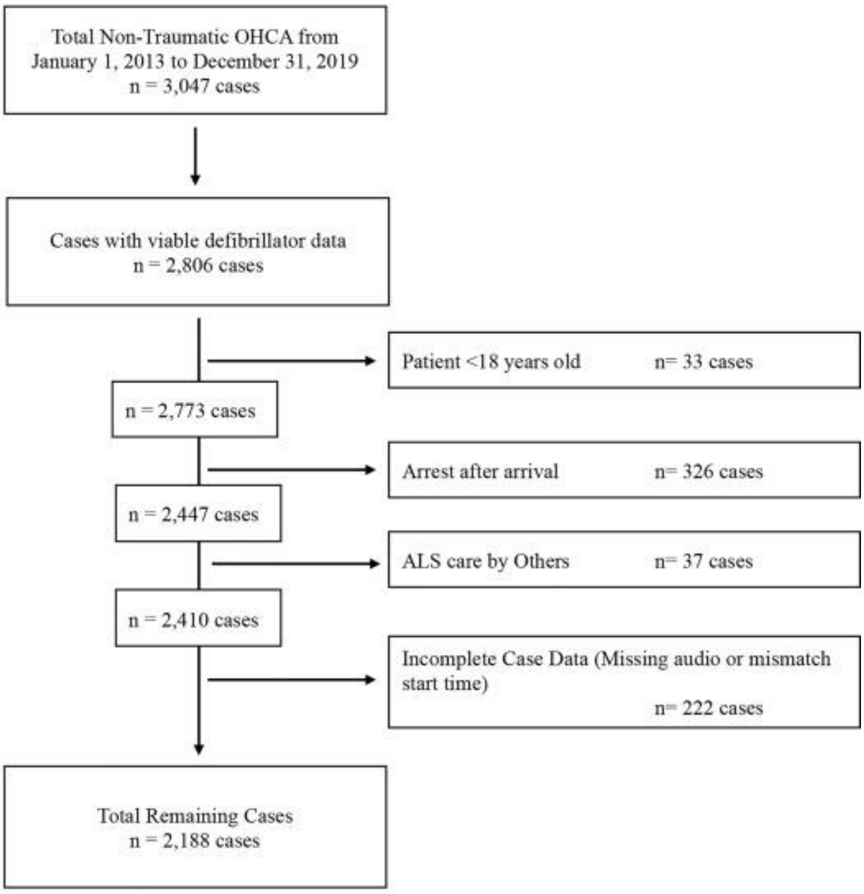
Minutes lacking an active metronome were labeled "No Metronome." Minutes in which the metronome was active for the full 60 seconds were labeled "Metronome." If the metronome became audible during the minute, that epoch was still classified as "Metronome" to avoid systematic bias.

The primary exposure variable was whether a metronome operated during EMS CPR. The main outcome was the median compression rate for "Metronome" versus "No Metronome" epochs. Additionally, the total number of minutes exceeding 120 CPM and the number under 100 CPM were reported separately for the two exposure categories.

At the patient level, baseline characteristics were contrasted between cases in which metronome use occurred at any point and those without any use. Categorical variables were assessed using chi-square tests, and continuous variables with the Wilcoxon rank-sum test. At the minute level, compression rates in "Metronome" and "No Metronome" groups were compared using the Wilcoxon rank-sum test. The proportions of "Minutes over 120 CPM" and "Minutes under 100 CPM" were evaluated with chi-square tests. Compression rates by year were compared using the Kruskal-Wallis statistic. Statistical significance was defined as $p < 0.05$. Normality was checked via skewness and kurtosis tests. All analyses were executed using Stata version 17 (StataCorp, College Station, TX).

Results and Discussion

A total of 3,047 OHCA incidents occurred during the study period, of which 2,806 contained usable defibrillator information. An additional 618 incidents were removed as outlined in **Figure 1a**. The remaining 2,188 cases produced 41,514 CPR minutes. After excluding 8,738 minutes deemed ineligible **(Figure 1b)**, the final dataset included 32,776 CPR minutes across 2,132 cases. Of these, 15,667 minutes (48%) occurred without metronome use, and 17,109 minutes (52%) occurred with metronome use.



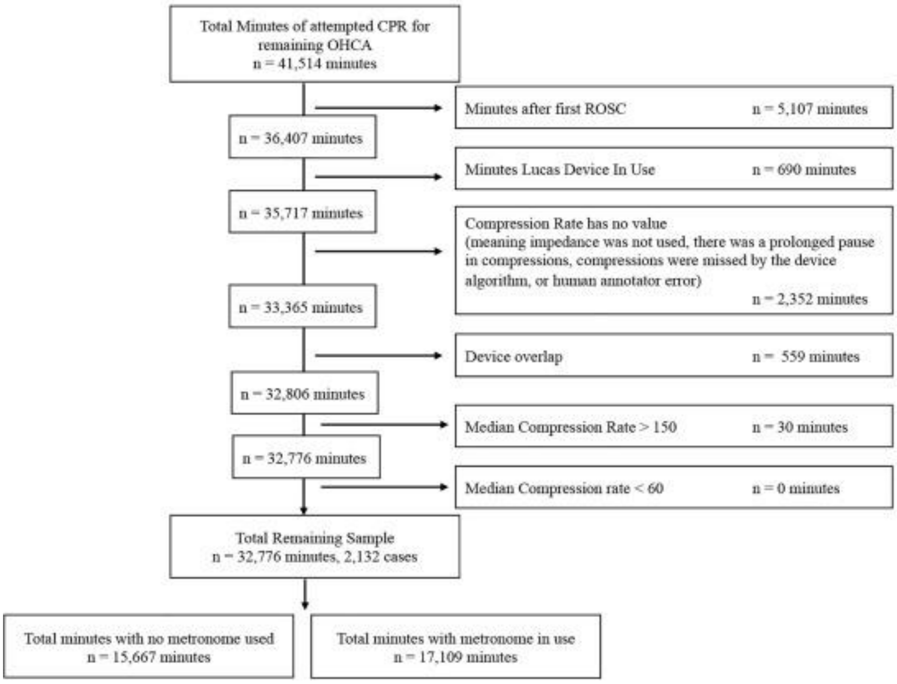


Figure 1. a. Case Exclusions: Count of cases removed according to each exclusion rule. **b. Minute Exclusions:** Specific minutes were omitted whenever they met any exclusion requirement
Abbreviations: OHCA: out-of-hospital cardiac arrest; ALS: advanced life support; ROSC: return of spontaneous circulation.

Metronome utilization increased steadily over the study timeframe. In the year directly following metronome rollout, only 32% of cases incorporated a metronome, whereas by 2019 this proportion had risen to 88%. The metronome was activated early during resuscitation; across all cases using one, the median delay from EMS CPR initiation to metronome activation was 1.3 minutes **(Table 1)**. This activation delay consistently improved, falling from 3.2 minutes in 2015 to 0.7 minutes in 2019.

Table 1. Out-of-hospital cardiac arrest patient characteristics

Characteristic	All Patients	No Metronome Used	Metronome Ever Used	p-value
	n = 2,132	n = 1,043	n = 1,089	
Demographics				
Age, years, median (IQR)	63 (50–75)	63 (50–75)	63 (50–75)	0.95
Male sex, n (%)	1,412 (66.3%)	682 (65.4%)	730 (67.0%)	0.45
Clinical Features				
Presumed aetiology, n (%)				0.19
Primary cardiac	1,673 (78.5%)	826 (79.2%)	847 (77.9%)	
Primary respiratory – non-toxic	109 (5.1%)	50 (4.8%)	59 (5.4%)	
Primary respiratory – toxic	208 (9.8%)	111 (10.6%)	97 (8.9%)	
Other medical	120 (5.6%)	47 (4.5%)	73 (6.7%)	
Other / unknown	22 (1.0%)	9 (0.9%)	13 (1.2%)	
Location of arrest, n (%)				0.043
Home / residence	1,304 (61.2%)	603 (57.8%)	701 (64.4%)	
Public place	565 (26.5%)	308 (29.5%)	257 (23.6%)	
Healthcare facility	249 (11.7%)	126 (12.0%)	123 (11.3%)	
Other / unknown	14 (0.7%)	6 (0.6%)	8 (0.7%)	
Bystander witnessed, n (%)	785 (36.8%)	381 (36.5%)	404 (37.1%)	0.13
Bystander CPR performed, n (%)	1,283 (60.2%)	593 (56.8%)	690 (63.4%)	<0.0001
Initial rhythm on EMS arrival, n (%)				0.24
Ventricular fibrillation / VT	502 (23.6%)	263 (25.2%)	239 (21.9%)	
Pulseless electrical activity (PEA)	482 (22.6%)	235 (22.5%)	247 (22.7%)	
Asystole	1,052 (49.4%)	505 (48.4%)	547 (50.3%)	
Non-shockable (other)	43 (2.0%)	14 (1.3%)	29 (2.7%)	
Pulses present on first check	36 (1.7%)	16 (1.5%)	20 (1.8%)	
Unknown	17 (0.8%)	10 (1.0%)	7 (0.6%)	
Case Timing Features				
Call to dispatch interval, min, median (IQR)	0.63 (0.47–0.88)	0.62 (0.47–0.85)	0.65 (0.48–0.92)	0.0006
Call to first EMS chest compressions, min, median (IQR)	6.7 (5.6–8.1)	6.5 (5.4–7.9)	6.8 (5.7–8.2)	0.0006
Total resuscitation duration, min, median (IQR)	30.3 (22.2–39.4)	30.0 (20.8–38.9)	30.5 (23.4–39.7)	0.012
Time from EMS compressions to metronome start, min, median (IQR)*	—	—	1.3 (0.6–3.2)	—

Significant between-group differences were identified for Arrest Location, Bystander CPR provision, Call-to-Dispatch interval, Call-to-EMS Compression interval, and overall duration of resuscitation. No other comparisons demonstrated statistically significant variation.
Missing data included: Age (10 cases), Call-to-Start EMS Compressions (21 cases), Resuscitation Duration in minutes (32 cases), and EMS Compressions-to-Metronome Start (7 cases).
Abbreviations: CPR: cardiopulmonary resuscitation; EMS: emergency medical services; VF/VT: ventricular fibrillation/ventricular tachycardia; PEA: pulseless electrical activity.

The median age of the study cohort was 63 years, with an interquartile spread from 50 to 75. An estimated 78.5% of arrests were judged to be of cardiac origin, and 23.6% presented with an initially shockable rhythm. The median resuscitation duration—defined as the time from EMS CPR onset until termination of efforts or hospital arrival—was 30.0 minutes for cases without metronome involvement and 30.5 minutes for cases where a metronome was used **(Table 1)**.

Compression-rate findings are summarized in **Table 2**. For minutes without metronome guidance, the median rate was 112.8, accompanied by an interquartile range of 108.4–119.1. In contrast, minutes with metronome support had a median rate of 110.5 and a narrower interquartile range of 110.0–112.0. Among all metronome-guided minutes, 62% recorded compression rates of 109, 110, or 111, compared with only 18% of minutes without metronome use **(Figure 2)**. Of the no-metronome minutes, 21.8% exceeded 120 CPM and 5.4% fell below 100. With the metronome running, only 3% surpassed 120 CPM and just 0.7% were below 100 (Table **2; Figure 2 and 3)**.

Table 2. Overall Compression Rates

Chest Compression Rate Characteristics	No Metronome	Metronome Used	p-value
Total analysed minutes	15,667	17,109	—
Median compression rate, per minute	112.8	110.5	<0.0001
Interquartile range (IQR)	108.4 – 119.1	110.0 – 112.0	—
Minutes with rate >120/min, n	3,413	513	<0.0001
Minutes with rate >120/min, %	21.8%	3.0%	—
Minutes with rate <100/min, n	846	128	<0.0001
Minutes with rate <100/min, %	5.4%	0.7%	—

Displays median compression rates for all minutes without metronome use versus those with metronome use. **Abbreviation:** CPM: compressions per minute.

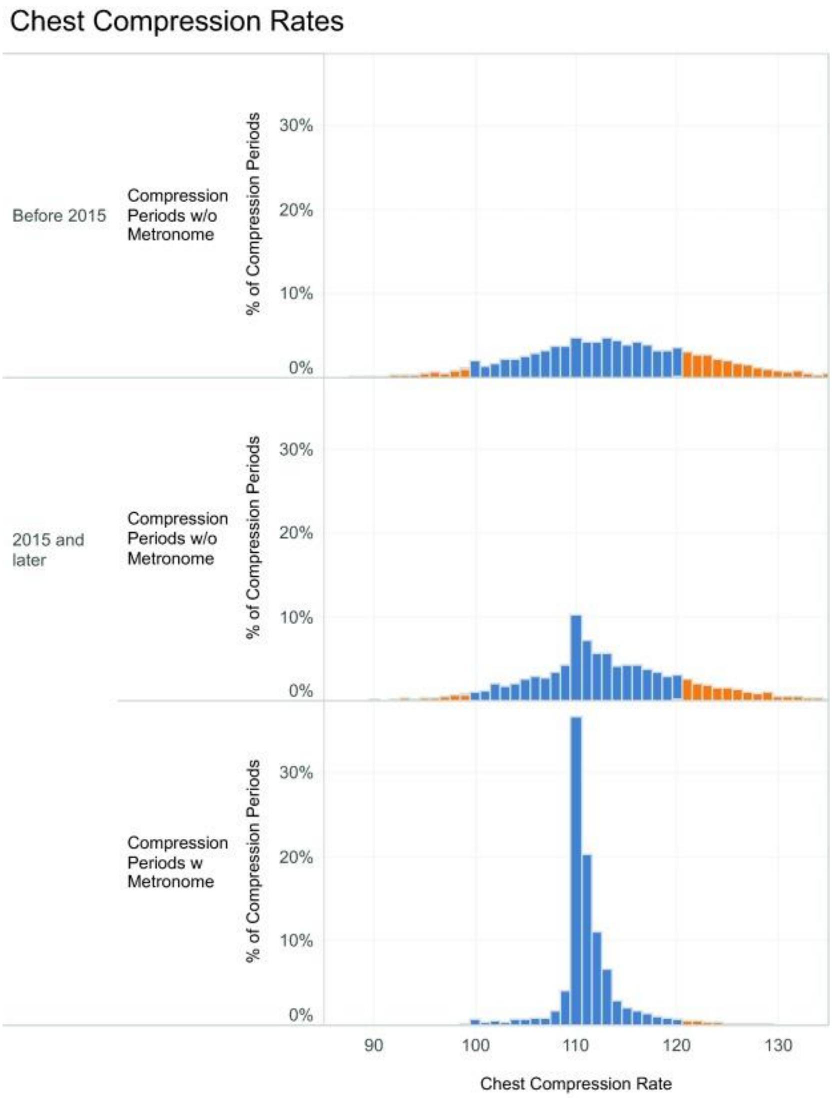


Figure 2. Overall Chest Compression Rates

This histogram depicts the distribution of compression rates during intervals without a metronome prior to 2015, intervals without a metronome after 2015, and intervals with an active metronome. The figure demonstrates a pronounced clustering at approximately 110 CPM when the metronome was used, in contrast to a much broader range during periods without metronome guidance.

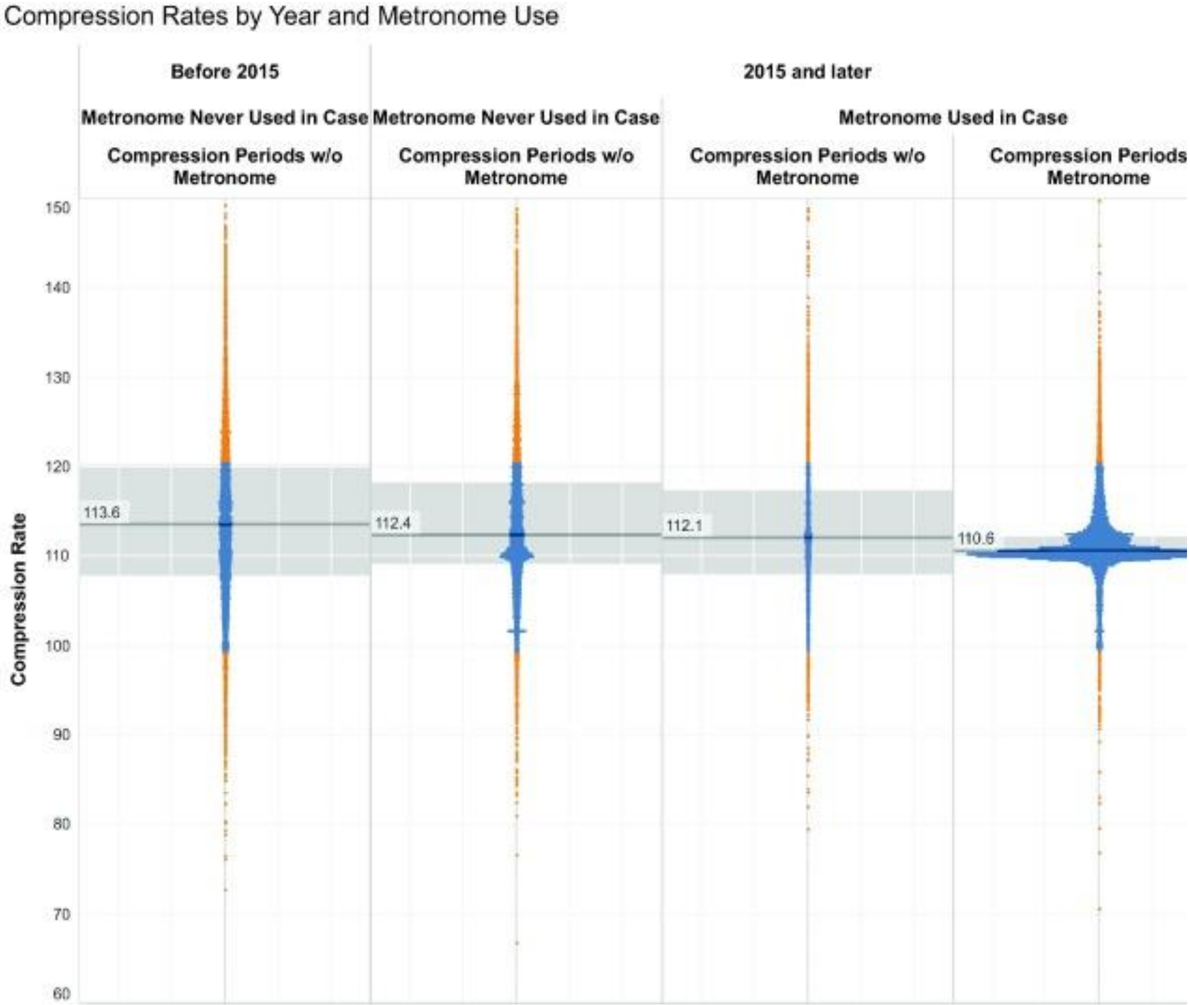


Figure 3. Compression Rates by Year and Metronome Use

Each dot represents the actual compression rate for one minute of CPR. Data are grouped into periods before 2015 (all without metronome) and periods after 2015. Post-2015 data include: cases with no metronome used at any point, minutes without metronome during cases in which the metronome was later activated, and minutes with active metronome guidance. A minor clustering near 110 CPM appears in post-2015 minutes lacking metronome activation. This may reflect undetected metronome use during review or improved provider accuracy in targeting 110 CPM even without audio cues—both representing potential study limitations.

In this seven-year retrospective review of OHCA incidents, we found that EMS crews consistently incorporated a basic audio metronome into resuscitation efforts. Its use corresponded with chest compression rates that aligned much more closely with the intended target of 110 compressions per minute. When the metronome was active, deviations from this benchmark were minimal, and fewer than 4% of minutes fell outside the recommended 100–120 compressions-per-minute range.

The improved precision and narrower variability associated with metronome-guided CPR suggest that it serves as an important aid in optimizing compression delivery. Limiting rates above 120 may have clinical relevance, as excessively rapid compressions may shorten diastolic intervals and diminish both cardiac output and coronary perfusion [12]. Compression rate may also affect depth, with quicker rates sometimes resulting in suboptimal compression depth [13, 14].

Determining the ideal chest compression rate remains an active area of investigation [5]. Because the metronome provides a reliable way to standardize specific rates, its use offers a practical method for evaluating how different frequencies may influence survival outcomes that matter to patients.

Beyond its effectiveness, the metronome's simplicity and affordability support straightforward integration into EMS protocols. The devices used here cost roughly $25 each and can be adjusted easily to any desired tempo. Adoption occurred quickly and continued to rise over the study period.

Reported drawbacks of metronome use are minimal. One earlier simulation-based project suggested that compression depth might decrease when following a metronome, possibly because attention shifts primarily to rate [15]. A subsequent study proposed that using a slightly faster target, such as 120 compressions per minute, mitigated this reduction in depth seen at 100–110 [15, 16]. These findings, however, were drawn from individuals with less CPR experience than many EMTs and paramedics.

Some improvement in compression rates during intervals without metronome use **(Figure 2 and 3)** may reflect a training effect. Research on layperson CPR training found that practicing with a metronome enhanced the ability to achieve guideline-consistent rates even in later sessions without auditory cues [17]. This learning effect is advantageous—functioning as ongoing reinforcement of the correct rate—but it also introduces a limitation: as providers improve on their own over time, the measured impact of metronome use may be underestimated.

This study includes several limitations. All participating EMTs and paramedics were proficient in high-performance CPR [18], potentially enabling them to maintain near-target rates even without metronome assistance, which may restrict generalizability. Although minutes involving a LUCAS device were excluded, recurring observations of a 101.75 rate likely represent undocumented periods when the LUCAS device was operating. Metronome activation time was logged once audio reviewers could clearly hear it on the recording, so earlier activation on the scene may have gone undetected, leading to misclassification of some CPR minutes. This could explain the minor clustering near 110 CPM in **Figure 3** among minutes labeled as no-metronome in the post-2015 group. The study did not explore the relationship between metronome use and patient outcomes or survival, nor did it evaluate CPR quality metrics other than compression rate. Relying on a metronome to fix the rate may also influence other performance elements such as depth. These considerations must be weighed alongside the study's strengths: a relatively large dataset, detailed event documentation, and highly resolved timing measurements.

In summary, an audio metronome represents a low-cost, flexible, and effective means of promoting a consistent target chest compression rate during CPR, with minimal variability from that target.

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Ethics statement: None.

References

1. Merchant RM, Topjian AA, Panchal AR, Cheng A, Aziz K, Berg KM, et al. Part 1: Executive summary: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2020;142:S337-57.
2. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Donnino MW, et al. Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association [published correction appears in Circulation. 2013;128(8):e120; published correction appears in Circulation. 2013;128(20): e408]. Circulation. 2013;128:417-35.
3. Perkins GD, Travers AH, Berg RA, Castren M, Considine J, Escalante R, et al. Part 3: Adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Resuscitation. 2015;95:e43-69.
4. Idris AH, Guffey D, Pepe PE, Edelson DP, Becker LB, Ornato JP, et al. Chest compression rates and survival following out-of-hospital cardiac arrest. Crit Care Med. 2015;43:840-8.
5. Idris AH, Guffey D, Aufderheide TP, Brown SP, Spaite DW, Nichol G, et al. Relationship between chest compression rates and outcomes from cardiac arrest. Circulation. 2012;125:3004-12.
6. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder H, et al. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005;111:428-34.
7. Kirkbright S, Finn J, Tohira H, Bray JE, Stub D, Smith K, et al. Audiovisual feedback device use by health care professionals during CPR: a systematic review and meta-analysis of randomised and non-randomised trials. Resuscitation. 2014;85:460-71.
8. Çalışkan D, Bildik F, Aslaner MA, Kılıçaslan I, Keleş A, Demircan A. Effects of metronome use on cardiopulmonary resuscitation quality. Turk J Emerg Med. 2021;21:51-5.

9. Kern KB, Stickney RE, Gallison L, Hartsell S, Lee M, Heidenreich J, et al. Metronome improves compression and ventilation rates during CPR on a manikin in a randomized trial. Resuscitation. 2010;81:206-10. Doi:10.1016/j.resuscitation.2009.10.015
10. Rainey K, Birkhoff S. Turn the beat on: an evidenced-based practice journey implementing metronome use in emergency department cardiac arrest. Worldviews Evid Based Nurs. 2021;18:68-70.
11. Khorasani-Zadeh A, Krowl LE, Chowdhry AK, Link MS, Byrne DW, Lewis RJ, et al. Usefulness of a metronome to improve quality of chest compressions during cardiopulmonary resuscitation. Proc (Bayl Univ Med Cent). 2020;34:54-5.
12. Harris AW, Kudenchuk PJ. Cardiopulmonary resuscitation: The science behind the hands. Heart. 2018;104:1056-61.
13. Agostinucci JM, Weisslinger L, Marzouk N, Kramer-Johansen J, Merchant RM, Meaney PA, et al. Relation between chest compression rate and depth: the ENFONCE Study. Eur J Emerg Med. 2021;28:352-4.
14. Monsieurs KG, De Regge M, Vansteelandt K, Calle PA, Bossaert LL, Herck I, et al. Excessive chest compression rate is associated with insufficient compression depth in prehospital cardiac arrest. Resuscitation. 2012;83:1319-23.
15. Oh JH, Lee SJ, Kim SE, Lee KJ, Choe JW, Kim CW. Effects of audio tone guidance on performance of CPR in simulated cardiac arrest with an advanced airway [published correction appears in Resuscitation. 2009 Mar;80(3):390]. Resuscitation. 2008;79:273-7.
16. Chung TN, Kim SW, You JS, Cho YS, Chung SP, Park I. A higher chest compression rate may be necessary for metronome-guided cardiopulmonary resuscitation. Am J Emerg Med. 2012;30:226-30.
17. Hafner JW, Jou AC, Wang H, Bleess BB, Tham SK. Death before disco: the effectiveness of a musical metronome in layperson cardiopulmonary resuscitation training. J Emerg Med. 2015;48:43-52.
18. Hanisch JR, Counts CR, Latimer AJ, Rea TD, Yin L, Sayre MR, et al. Causes of chest compression interruptions during out-of-hospital cardiac arrest resuscitation. J Am Heart Assoc. 2020;9:e015599.