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Simulation and education

CPR coaching during cardiac arrest improves adherence to PALS guidelines: a prospective, simulation-based trial

Michael Buyck[a,b,*], *Yasaman Shayan*[a,b], *Jocelyn Gravel*[a,b], *Elizabeth A. Hunt*[c], *Adam Cheng*[d], *Arielle Levy*[a,b]

[a] *Department of Pediatric Emergency Medicine, Sainte-Justine Hospital University Centre, 3175 Chemin de la Côte-Sainte-Catherine, Montreal, Québec, H3T 1C5, Canada*
[b] *Université de Montreal, Montreal, Québec, Canada*
[c] *Departments of Anesthesiology and Critical Care Medicine, Pediatrics and Health Informatics, Johns Hopkins University School of Medicine, Baltimore, Maryland, United States*
[d] *Departments of Pediatrics and Emergency Medicine, University of Calgary, Calgary, Canada*

Abstract

Aim: Recent studies have shown that the integration of a trained cardiopulmonary resuscitation (CPR) Coach during resuscitation enhances the quality of CPR during simulated paediatric cardiac arrest. The objective of our study was to evaluate the effect of a CPR Coach on adherence to Paediatric Advanced Life Support (PALS) guidelines during simulated paediatric cardiac arrest.

Methods: This was a secondary analysis of data collected from a multicentre randomized controlled trial assessing the quality of CPR in teams with and without a CPR Coach. Forty paediatric resuscitation teams were equally randomized into 2 groups (with or without a CPR Coach). The primary outcome was adherence to PALS guidelines during a simulated paediatric cardiac arrest case as measured by the Clinical Performance Tool (CPT). Video recordings were assigned to 2 pairs of expert raters. Raters were trained to independently score performances using the tool.

Results: The reliability of the rating was adequate for the Clinical Performance Tool with an intraclass coefficients of 0.67 (95%CI: 0.22 to 0.84). Performance scores of the different teams varied between 51 and 84 points on the Clinical Performance Tool with a mean score of 70. Teams with a CPR Coach demonstrated better adherence to PALS guidelines (i.e. CPT score 73 points) compared to teams without a CPR Coach (68 points, difference 5 points; 95%CI: 1.0−9.3, p=0.016).

Conclusion: In addition to improving CPR quality, the presence of a CPR Coach improves adherence to PALS guidelines during simulated paediatric cardiac arrests when compared with teams without a CPR Coach.

Keywords: Pediatric, Emergency, Simulation, PALS, Resuscitation, CPR, CPR coach

Introduction

Paediatric teams struggle providing guideline compliant Cardiopulmonary resuscitation (CPR) during cardiac arrest.[1,2] Strategies implemented to enhance CPR quality, include simulation-based training,[3] CPR feedback devices,[4] and integration of a CPR Coach.[5,6] The CPR Coach is a role created at The Johns Hopkins Hospital in 2007 and iteratively refined over the past decade as reported by Hunt et al.[5] The primary objectives of the CPR Coach are to ensure high

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[*] Corresponding author.
E-mail addresses: michael.buyck@umontreal.ca (M. Buyck), yrshayan@gmail.com (Y. Shayan), graveljocelyn@hotmail.com (J. Gravel), ehunt@jhmi.edu (E.A. Hunt), chenger@me.com (A. Cheng), arielle.levy@umontreal.ca (A. Levy).

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quality Basic Life Support or CPR and to cognitively unload the resuscitation leader so they can concentrate on the more complex components of a resuscitation, such as: rhythm recognition, identifying and following the advanced life support algorithm, diagnosing and treating reversible causes, and communicating with the family.

In addition to optimizing CPR delivery, adhering to Paediatric Advanced Life Support (PALS) guidelines is essential. Critical interventions in paediatric resuscitation such as advanced airway ventilation, cardiac rhythm recognition and adequate treatment (defibrillation and/or epinephrine) have shown to add substantial survival benefit in the adult population.[7] In addition, adherence to PALS guidelines is associated with improved neurological outcomes and survival in children,[8] though simulation studies reveal major deviations in adherence to PALS.[9] The broad range of patient sizes require variations in equipment size and medication doses that creates a cognitive load unique to managing children.[10] For years, cognitive aids have been recommended[11] but showed poor efficacy[12] supporting the need for a “human cognitive aid”. A CPR Coach might be considered a human cognitive aid, as the team leader is relieved of tasks, leaving more cognitive space for advanced clinical performance.[5,13]

CPR coaching is associated with improved CPR quality, but its’ effect on general clinical performance in paediatric cardiac arrest has not been evaluated.

Objective

The objective of this study was to assess if the presence of a CPR Coach would improve adherence to PALS guidelines during simulated paediatric resuscitations.

Methods

This was a secondary analysis of data from a multicentre Randomized Controlled Trial (RCT) assessing the impact of a CPR Coach on CPR quality during simulated paediatric cardiac arrests.[6] The study was approved by research ethics boards from all study sites. Informed consent was obtained from participants. The initial study was registered at clincaltrials.gov (Id: NCT03204162). The research question of the current study was developed after completing the initial study.

Setting

The study was conducted at four Simulation Centres across North America between March 2017 and February 2018.[6] Participants were video-recorded during standardized 18-minute paediatric resuscitation scenarios (cardiopulmonary arrest from hyperkalemia with progression from pulseless ventricular tachycardia to ventricular fibrillation, then pulseless electrical activity) with identical equipment across sites (manikin Laerdal® SimJunior and a Zoll® CPR feedback defibrillator). Debriefings used the PEARLS method, and occurred at the end of simulations.[14]

Study population

Participants were senior residents, fellows or nurses with greater than five years of practice and PALS certified.[6] They were divided into 40 teams comprised of five people: CPR providers, a team leader, an airway provider, and either a CPR Coach or bedside provider depending on randomization.

Intervention

Teams were randomized to one of two study arms: intervention (with CPR Coach) or control. Randomization was conducted to ensure equal allocation of teams across study arms and in each centre. The CPR Coach stood close to the defibrillator and actively coached CPR providers. CPR Coaches were trained to coordinate four key tasks: initiation of CPR, provider switch and pulse/rhythm check, defibrillation, and intubation. A one-hour training session was provided to designated coaches.[6] CPR Coach training was not accessible for other participants, but participants from the intervention arm received a description of the CPR Coach role.

Outcome

The primary outcome was adherence to PALS guidelines as measured by a tailored version of the Clinical Performance Tool (CPT). The tool is a task-based scoring instrument, developed and validated by Donoghue et al.[15] and further validated by Levy et al. to evaluate clinical performance during paediatric resuscitation simulated scenarios.[16] The score is highly reliable with an intra-class coefficient of 0.95.[16] It assesses critical tasks every few minutes using a scale from 0 to 2 points (except defibrillation during non-shockable rhythm which were scored 0−1 point). We tailored the tool for the standardized 18-minute scenario giving a minimum of 0 and a maximum of 87 points.

All 40 videos were evaluated in duplicate, by two sets of independent raters. The eight raters were paediatric critical care or paediatric emergency physicians with experience in simulation. A first set of four raters was blinded to our study hypothesis and the identity of participants, but not to the study arm. The second set was not blinded to the study hypothesis and rated the same scenarios as the first set, to be used for inter-rater reliability. Each blinded rater was paired with a non-blinded rater, and IRR were calculated separately for each video. Results from non-blinded raters were not included in the main analysis. Raters were trained to score scenarios and to gather data on performances by the principal investigator. Standardized, individual training sessions initially clearly defined each item of the score and addressed how to evaluate the videos. This was followed by a scoring session of two videos, different from those they were expected to rate. Each pair of raters independently rated ten videos (five with and five without a CPR Coach, duration of three hours).

Sample size

The sample size was 40 teams (20 with and 20 without a coach), identical to the original study.[6]

Analysis

Interrater reliability was initially assessed using the intra-class coefficient for the absolute scores assigned in duplicate using a two-way mixed model. A priori, it was decided to include only items with an average coefficient higher than 0.6.

The primary analysis was the difference in mean scores for the two groups with 95% Confidence interval (95%CI) on the CPT assuming normal distribution for the scores. This was used because a Shapiro-Wilk test failed to reject normal distribution (P: 0.282). As an exploratory analysis, the difference in mean scores for each item of the tool were compared for each group.

Results

In the original study, one team was excluded because of a technical issue. The remaining 40 teams (200 participants) were equally randomized between intervention and control groups. Demographic data revealed no significant differences between study groups at baseline.[6] The reliability of the rating was adequate for the CPT with intraclass coefficients of 0.67 (95%CI: 0.22 to 0.84).[17,18]

Performance scores of the different teams varied between 51 and 84 points on the CPT, with a mean score of 70. Scenarios involving the presence of a Coach demonstrated better performances than the group without a Coach as shown in Fig. 1 (difference: 5.2 points; 95% CI: 1.0−9.3; p=0.016). This represent a large difference with a Cohen-D effect size of 0.797. Of the 45 items of the score, 8 demonstrated a statistically significant difference between the two groups. The largest difference was a significantly higher proportion of CPR providers change within the first 2 min in teams with a CPR Coach (1.85 vs. 0.95 points; p=0.001). Other major improvements for teams with a CPR Coach included better diagnosis of the first rhythm (0.4 point; p=0.027) and adequate ventilation initiation (0.2 point; p=0.04) as shown in Table 1.

Discussion

Our study demonstrates presence of a CPR Coach is associated with improved clinical performance and adherence to PALS guidelines during simulated paediatric cardiac arrests. Previous studies have demonstrated improvement in CPR metrics such as chest compression depth, rate, fraction and pauses when using a CPR Coach in adult[13] and paediatric cardiac arrests.[5,6] To our knowledge, this is the first study to show having a CPR Coach on the team is associated with better recognition of the first rhythm, a crucial step to determining the correct PALS algorithm.

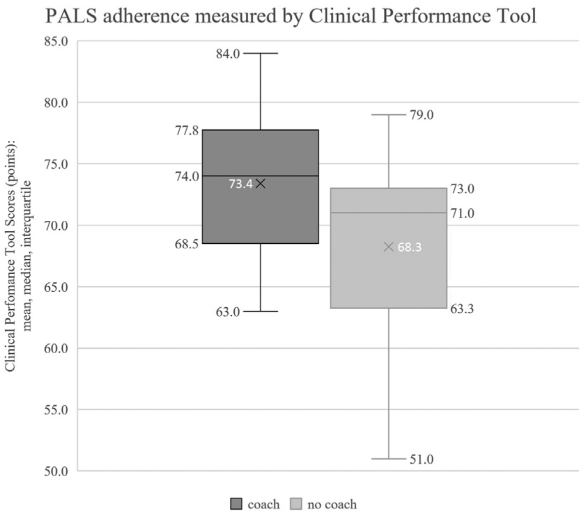

Fig. 1 – Score of PALS adherence with coach and no coach.

Previous studies showed major deviations in PALS adherence[19,20] even after simulation training.[9,21] Our results might be explained by using the concept of "divide and conquer" to provide relief in cognitive overload.[5,13] For example, teams with a CPR Coach had a better initiation of ventilation and first CPR provider change (i.e. attention to BLS) presumably because the CPR Coach made sure key elements of CPR (compressions and ventilations) occurred. Simultaneously, the Resuscitation Leader quickly assessed the initial rhythm.

An improvement of 5.2 out of 87 points on CPT score might be considered slight. However, 2 points represent a timely defibrillation in a 2-minute interval (vs no defibrillation) or a correct rhythm identification. Hunt et al. showed that these elements are often delayed and may worsen outcomes. Therefore, differences of 5 points in CPT scores might indeed have an important clinical impact.[8]

Our results support the progressive implementation of CPR Coach in paediatric code teams of North America.[22] In-hospital paediatric resuscitations are usually overcrowded, so this could be re-allocation of roles. Provider confidence, satisfaction or stress[23] may be impacted by communication and teamwork. CPR Coach training must include communication tips for the CPR team and Resuscitation Leader, such that the leader truly empowers the CPR Coach to be an excellent manager of the Airway and Compressor roles and then concentrates on advanced components of the resuscitation. This should lead to faster recognition of shockable rhythms and defibrillation, faster recognition and treatment of obstructed endotracheal tubes, and diagnosis and treatment of other reversible causes. If the leader does not delegate, empower or trust their CPR Coach then the resuscitation will not improve. This requires training of the CPR Coaches as well as the Resuscitation Leaders.

Limitations

Our study has limitations. It was impossible to blind raters to the intervention. However, primary raters were blinded to the study question and hypothesis and there was an adequate inter-rater agreement between both set of assessors. The simulated setting may have influenced behaviours, but both groups had the same standardized scenario with identical resources. In some videos, the ventilation frequency or number of joules used in the defibrillation were not visible. Assessors may have given scores despite insufficient information, causing biases in results towards a smaller difference between groups. No study has defined what is a clinically significant difference using the CPT score or if all items of the score have the same clinical impact. The information from this study can be used to design future studies on how to optimize the impact of the CPR Coach on PALS.

Conclusion

In conclusion, the presence of a CPR Coach correlated with an improvement in adherence to PALS guidelines during simulated paediatric resuscitations. Emergency settings should consider adopting and implementing this new role during paediatric resuscitations.

Author contribution

Michael Buyck and Arielle Levy initiated the study and they had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Michael Buyck, Yasaman Shayan, Jocelyn Gravel, Elizabeth A. Hunt, Adam Cheng, and Arielle Levy contributed to the study design, organization of data acquisition and to interpretation of the results.

The first draft of the manuscript was written by Michael Buyck.

All authors contributed to amend it and approved the final version.

Conflicts of interest

Dr. Adam Cheng is a volunteer for the American Heart Association (Resuscitation Education Summit and Education Writing Group) and the International Liaison Committee for Resuscitation (Domain Lead, Education).

Dr. Elizabeth A. Hunt is a volunteer for the American Heart Association (Resuscitation Education Summit and Education Writing Group and ECC Science Subcommittee). She is a consultant for the Zoll Medical Corporation and has received reimbursement for travel and honoraria for speaking. She and research colleagues have patents on educational technology that they developed and have non-exclusive licenses with Zoll Medical Corporation to use that technology.

Dr. Arielle Levy is a volunteer for the American Heart Association (2020 AHA Paediatric Guidelines Education Writing Group).

The other authors (Michael Buyck, Yasaman Shayan, and Jocelyn Gravel) have no other relevant disclosures.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resplu.2020.100058.

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Effect of a Cardiopulmonary Resuscitation Coach on Workload During Pediatric Cardiopulmonary Arrest: A Multicenter, Simulation-Based Study

Nancy M. Tofil, MD[1]; Adam Cheng, MD[2]; Yiqun Lin, MD[2]; Jennifer Davidson, RN[3]; Elizabeth A. Hunt, MD, MPH, PhD[4]; Jenny Chatfield, RN[3]; Laura MacKinnon, RN[3]; David Kessler, MD, MSc[5]; for the International Network for Simulation-based Pediatric Innovation, Research and Education (INSPIRE) CPR Investigators

Objectives: Optimal cardiopulmonary resuscitation can improve pediatric outcomes but rarely is cardiopulmonary resuscitation performed perfectly despite numerous iterations of Basic and Pediatric Advanced Life Support. Cardiac arrests resuscitation events are complex, often chaotic environments with significant mental and physical workload for team members, especially team leaders. Our primary objective was to determine the impact of a cardiopulmonary resuscitation coach on cardiopulmonary resuscitation provider workload during simulated pediatric cardiac arrest.

Design: Multicenter observational study.

Setting: Four pediatric simulation centers.

Subjects: Team leaders, cardiopulmonary resuscitation coach, and team members during an 18-minute pediatric resuscitation scenario.

Interventions: National Aeronautics and Space Administration-Task Load Index.

Measurements and Main Results: Forty-one teams (205 participants) were recruited with one team (five participants) excluded from analysis due to protocol violation. Demographic data revealed no significant differences between the groups in regard to age, experience, distribution of training (nurse, physician, and respiratory therapist). For most workload subscales, there were no significant differences between groups. However, cardiopulmonary resuscitation providers had a higher physical workload (89.3 vs 77.9; mean difference, −11.4; 95% CI, −17.6 to −5.1; $p = 0.001$) and a lower mental demand (40.6 vs 55.0; mean difference, 14.5; 95% CI, 4.0–24.9; $p = 0.007$) with a coach (intervention) than without (control). Both the team leader and coach had similarly high mental demand in the intervention group (75.0 vs 73.9; mean difference, 0.10; 95% CI, −0.88 to 1.09; $p = 0.827$). When comparing the cardiopulmonary resuscitation quality of providers with high workload (average score > 60) and low to medium workload (average score < 60), we found no significant difference between the two groups in percentage of guideline compliant cardiopulmonary resuscitation (42.5% vs 52.7%; mean difference, −10.2; 95% CI, −23.1 to 2.7; $p = 0.118$).

Conclusions: The addition of a cardiopulmonary resuscitation coach increases physical workload and decreases mental workload of cardiopulmonary resuscitation providers. There was no change in team leader workload. (*Pediatr Crit Care Med* 2020; 21:e274–e281)

Key Words: cardiopulmonary arrest; National Aeronautics and Space Administration-Task Load Index; pediatric; simulation; team roles; workload

Despite recent advances in the instructional design of basic and advanced life support courses, deficiencies continue to exist in cardiopulmonary resuscitation (CPR) performance during pediatric cardiac arrest (1–5). Suboptimal CPR performance is a major contributor to poor survival outcomes for infants and children suffering from in- and out-of-hospital cardiac arrest (6–8). Hunt et al (8) integrated the role of a CPR coach into resuscitation teams, whose primary task is to focus on the mechanics, timing, and communication of the elements of CPR. Studies have recently demonstrated improved compliance with American Heart Association guidelines for CPR in both simulated and actual cardiac arrest teams involving the CPR Coach Role (8, 9). One potential explanation for how and why a CPR coach helps improve CPR performance is through improved distribution of resuscitation team workload (10, 11).

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[1]University of Alabama at Birmingham, Birmingham, AL.

[2]Cumming School of Medicine, University of Calgary, Calgary, AB, Canada.

[3]Alberta Children's Hospital, Calgary, AB, Canada.

[4]Johns Hopkins University School of Medicine, Baltimore, MD.

[5]Columbia University Vagelos College of Physicians and Surgeons, New York, NY.

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Crisis resource management principles promote appropriate distribution of workload so as not to overwhelm any individual team member (TM) (9, 12, 13). Workload can be assessed using the National Aeronautics and Space Administration-Task Load Index (NASA-TLX), a multi-dimensional tool designed to assess workload that has been validated in multiple settings (14, 15). This tool has six domains separated into two sections: 1) Workloads imposed on participants (mental demand, physical demand, and temporal demand) and 2) Interaction of participant with the task (performance, effort, and frustration). High workload is defined as a score greater than 60, moderate workload 40–60, and low workload as a score less than 40.

Overall workload and the relative workload of TMs and team leaders (TLs) has been studied during a simulated pediatric sepsis and cardiac arrest (10, 11). In both studies, TL reported high workload in all categories except physical demand. Identifying strategies to reduce TL workload during resuscitation may help to improve TL performance and overall clinical care. Furthermore, CPR providers were found to have the highest physical workload among TMs during simulated cardiac arrest, with the degree of physical workload associated with CPR quality.

Although Brown et al (11) first described the workload distribution during pediatric cardiac arrest, it is unknown how workload may be re-distributed with the integration of new technology and/or roles within resuscitation teams. Specifically, it is not known if the introduction of a CPR coach changes workload distribution among pediatric resuscitation teams with access to a CPR feedback defibrillator. Our primary objective was to determine the impact of a CPR coach on CPR provider workload during simulated pediatric cardiac arrest. Our secondary objectives were to compare the workload of CPR coaches to TLs and the impact of workload on quality of CPR.

MATERIALS AND METHODS

We conducted secondary analysis of data collected from a previously published prospective, multicenter, randomized controlled trial assessing the impact of a CPR coach on CPR performance during an 18-minute pediatric CPR scenario (9). In this study, we evaluated the workload of all TMs using the NASA-TLX. Institution Review Board approval was obtained for all study sites and informed consent was acquired from all participants. Previously published guidelines for designing and reporting simulation-based research were used to guide the design and execution of the study (16, 17).

Pediatric healthcare providers were recruited in teams of five from four institutions. Team roles included two CPR providers, a TL, an airway provider and a CPR coach or bedside provider. Specific criteria for inclusion/exclusion can be found in the original study (9). Randomization occurred at the level of the team with an online randomization tool (www.randomize.net), was stratified by study site, and conducted in blocks of two to ensure equal numbers of teams and participants across study arms. For the intervention group, the CPR coach received a training session using rapid cycle deliberate practice just prior to the scenario (18). Training focused on optimizing CPR utilizing a defibrillator with real-time rate and depth feedback and coordinating CPR actions including pulse checks, switching compressors, defibrillation, and intubation (19, 20). The control arm resuscitation teams had the same team composition and size, except the CPR coach role became a bedside provider role.

Teams performed an 18-minute pediatric cardiopulmonary arrest scenario (i.e., hyperkalemic cardiac arrest with progression from pulseless ventricular tachycardia [6 min] → ventricular fibrillation [6 min] → pulseless electrical activity [6 min]) with CPR quality parameters collected from a Zoll R-Series Defibrillator (Zoll Medical, Chelmsford, MA). Teams in both arms received visual CPR feedback provided by the defibrillator. All recruitment sites used the identical pediatric manikin (SimJunior; Laerdal Corporation, Wappinger Falls, NY), specifically designed and calibrated for CPR training (spring constant 4.46 kg/cm; 22.3 kg of force required to press to 5 cm; maximum compression depth of 7 cm) (21). The simulation scenario was tightly standardized using a scenario template with highly scripted actor roles and patient progression. Examples of roles the actor would play included: drawing up medications only at the order of the team, providing laboratory analysis as the request of the team, etc. All roles were scripted and at no time did the actor assist the team with patient care. At the completion of the scenario, all participants completed a demographic survey and the NASA-TLX tool. Once these were completed, a formal debriefing of the team performance in the scenario was conducted by a trained facilitator using the Promoting Excellence and Reflective Learning in Simulation (PEARLS) framework and direct review of defibrillator summary feedback for the CPR quality metrics collected during the case. Additional methodologic details are described in the main study publication (9, 22).

Outcome Measures

After each scenario, before debriefing, workload was assessed for all TMs by completion of the NASA-TLX (14, 15). Scores range from 0 to 100 with low workload defined as less than 40, moderate workload ranging from 40 to 60, and greater than 60 signifying high workloads. There are six subscales representing independent dimensions of workload: mental, physical, temporal, effort, frustration, and performance (14, 15). Our primary outcome measure was the NASA-TLX average score across all six dimensions. The secondary outcome measures were the NASA-TLX score for each dimension.

Statistical Analysis

NASA-TLX data were summarized using descriptive statistics (mean and SD) in both the control and intervention arm. NASA-TLX scores were compared with two-sample *t* test between groups. Comparison between CPR coach and TLs were conducted with paired *t* tests. All tests were two-tailed with a significance level of 0.05.

RESULTS

Study Population

Forty-one teams (205 participants) were recruited from March 22, 2017, to February 26, 2018. One team (five participants) was excluded from the study due to technical issues (e.g., palpable pulse when simulated patient should have been pulseless) that resulted in violation of the study protocol. Data from the remaining 40 teams (200 participants) were included in the analysis. Demographic data revealed no significant differences between the control and intervention groups and can be found in the original article (9).

Effect of CPR Coaches on Provider Workload

Table 1 shows the summary of the average scores as well as six dimensions of the NASA-TLX for both the control and intervention groups which is subdivided by TM's role. We found that compared with control group, CPR providers with a coach had a lower mental demand (40.6 vs 55.0; mean difference [MD], 14.5; 95% CI, 4.0–24.9; $p = 0.007$) but significantly higher physical workload (89.3 vs 77.9; MD, –11.4; 95% CI, –17.6 to –5.1; $p = 0.001$) and higher effort scores (80.9 vs 74.5; MD, –6.5; 95% CI, –13.2 to 0.3; $p = 0.059$; **Fig. 1*A***). TLs in the groups with a CPR coach had a trend toward lower mental demand scores but this was not significant (75.0 vs 82.3; MD, 7.4; 95% CI, –4.1 to 18.8; $p = 0.20$; **Fig. 1*B***). There was no difference between groups for the airway provider in any of the

TABLE 1. National Aeronautics and Space Administration-Task Load Index Domain Analysis Showing Between Group Differences for Each Role

Role	National Aeronautics and Space Administration Domain	Noncoach Team, Mean (SD)	Coach Team, Mean (SD)	Mean Difference (95% CI)	*p*
Team leader	Mental	82.3 (18.1)	75.0 (17.7)	7.4 (−4.1 to 18.8)	0.203
	Physical	8.0 (12.9)	14.3 (16.1)	−6.3 (−15.6 to 3.0)	0.179
	Temporal	67.8 (16.5)	68.5 (14.4)	−0.8 (−10.7 to 9.2)	0.879
	Performance	45.0 (19.3)	50.8 (19.4)	−5.8 (−18.2 to 6.6)	0.349
	Effort	68.7 (15.9)	64.3 (20.1)	4.4 (−7.2 to 15.9)	0.452
	Frustration	52.8 (26.8)	43.3 (24.6)	9.5 (−7.0 to 25.9)	0.252
	Average	54.1 (9.8)	52.7 (11.6)	1.4 (−5.5 to 8.3)	0.686
Airway	Mental	56.2 (20.8)	56.0 (22.2)	0.2 (−13.5 to 14.0)	0.971
	Physical	28.9 (20.4)	38.5 (30.2)	−9.6 (−26.0 to 6.9)	0.248
	Temporal	59.6 (19.1)	49.5 (20.5)	10.2 (−2.5 to 22.8)	0.114
	Performance	39.3 (23.0)	29.3 (18.1)	10.0 (−3.2 to 23.2)	0.135
	Effort	56.6 (20.5)	55.9 (25.6)	0.7 (−14.1 to 15.6)	0.919
	Frustration	37.7 (28.4)	28.0 (24.3)	9.7 (−7.2 to 26.6)	0.253
	Average	46.4 (14.8)	42.8 (17.4)	3.5 (−6.8 to 13.9)	0.492
Cardiopulmonary resuscitation providers	Mental	55.0 (23.3)	40.6 (23.4)	14.5 (4.0–24.9)	0.007
	Physical	77.9 (18.0)	89.3 (8.5)	−11.4 (−17.6 to −5.1)	0.001
	Temporal	53.5 (20.3)	52.7 (17.6)	0.9 (−7.6 to 9.3)	0.837
	Performance	36.3 (16.4)	39.0 (21.2)	−2.8 (−11.2 to 5.7)	0.514
	Effort	74.5 (15.0)	80.9 (15.2)	−6.5 (−13.2 to 0.3)	0.059
	Frustration	34.2 (25.3)	31.1 (24.6)	3.2 (−7.9 to 14.3)	0.571
	Average	55.2 (11.2)	55.6 (9.1)	−0.4 (−4.9 to 4.2)	0.877
Coach/bedside provider	Mental	62.5 (22.3)	73.9 (15.6)	−11.4 (−23.8 to 1.0)	0.07
	Physical	38.2 (34.2)	13.1 (23.6)	25.1 (6.1–44.2)	0.011
	Temporal	51.8 (21.9)	53.0 (18.1)	−1.2 (−14.1 to 11.7)	0.851
	Performance	47.1 (21.4)	40.5 (22.7)	6.6 (−7.6 to 20.7)	0.354
	Effort	54.6 (26.3)	69.9 (14.0)	−15.4 (−29.0 to −1.7)	0.028
	Frustration	32.7 (21.9)	33.9 (28.6)	−1.2 (−17.5 to 15.2)	0.887
	Average	47.8 (16.9)	46.2 (9.6)	1.6 (−7.3 to 10.5)	0.714

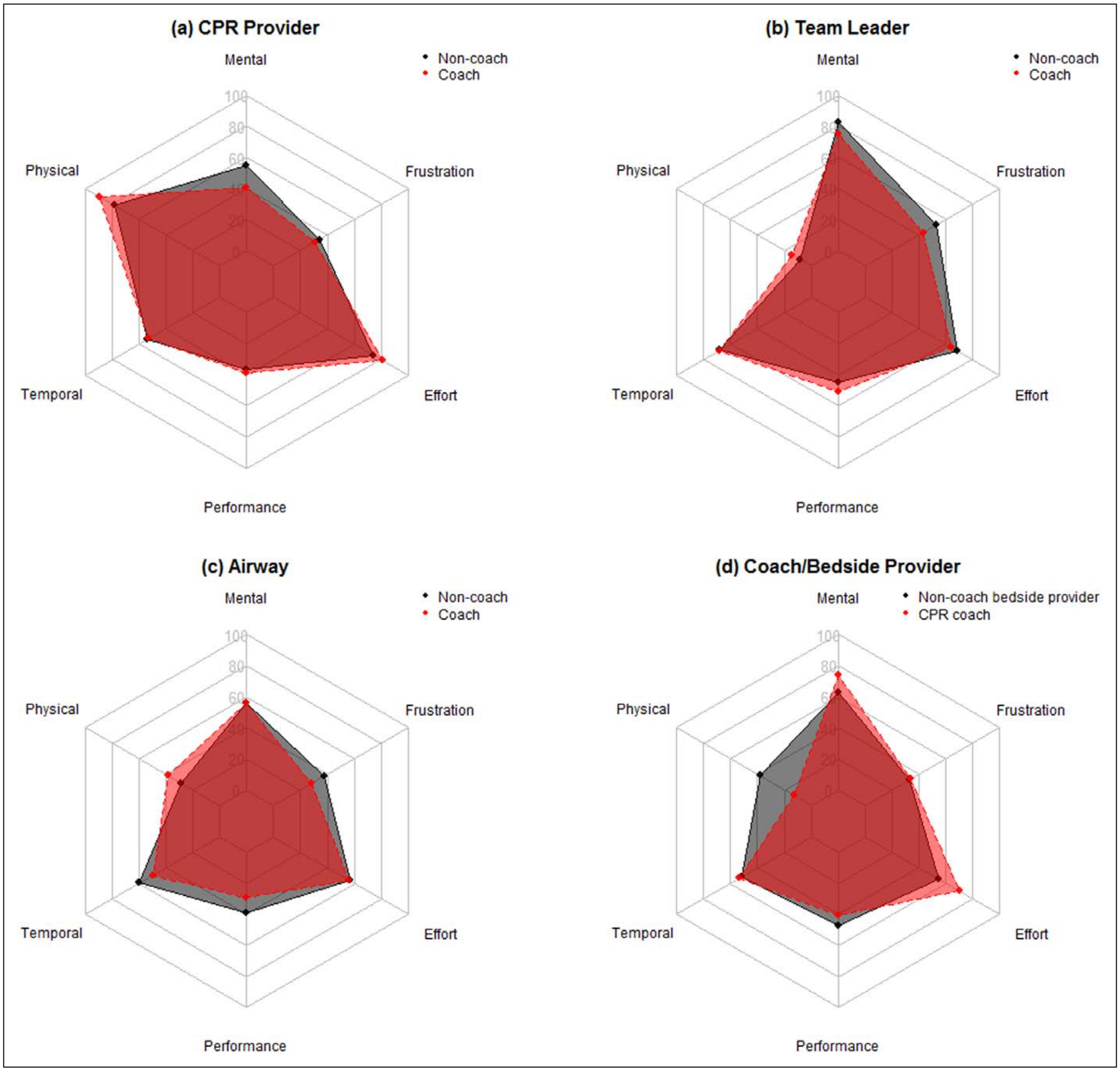

Figure 1. Workloads of different roles between noncoach and coach teams. CPR = cardiopulmonary resuscitation.

six domains of the NASA-TLX score (**Fig. 1*C***). Compared with the regular bedside providers, CPR coaches have similar average workload (47.8 vs 46.2; MD, 1.6; 95% CI, –7.3 to 10.5; *p* = 0.714), but higher mental demand (62.5 vs 73.9; MD, –11.4; 95% CI, –23.8 to 1.0; *p* = 0.07), significantly higher effort scores (54.6 vs 69.9; MD, –15.4; 95% CI, –29.0 to –1.7; *p* = 0.028) and lower physical demand (38.2 vs 13.1; MD, 25.1; 95% CI, 6.1–44.2; *p* = 0.011; **Fig. 1*D***).

Comparing the Workload of Team Leaders and CPR Coaches

Table 2 shows the average scores and scores of six domains between TL and Coaches for the intervention group. Both the TL and coach had similarly high mental demand in the intervention group (75.0 vs 73.9; MD, 0.10; 95% CI, –0.88 to 1.09; *p* = 0.827). Both TL and coaches had very low physical workload scores. The TL had significantly higher average scores than the CPR coach role (53.2 vs 46.2; MD, 7.1; 95% CI, 1.1–13.0; *p* = 0.022). Compared with TL, coaches had significantly lower temporal scores (68.5 vs 53.0; MD, 15.5; 95% CI, 7.2–23.8; *p* = 0.001) (**Fig. 2**).

We compared the CPR quality of providers with high workload (average score > 60) and low to medium workload (average score < 60) and found no significant difference between two groups in percentage of guideline compliant CPR (42.5% vs 52.7%; MD, –10.2; 95% CI, –23.1 to 2.7; *p* = 0.118).

TABLE 2. National Aeronautics and Space Administration-Task Load Index Domain Comparison Between Team Leader and Cardiopulmonary Resuscitation Coach (Intervention Group Only)

National Aeronautics and Space Administration Domain	Team Leader, Mean (SD)	Cardiopulmonary Resuscitation Coach, Mean (SD)	Mean Difference (95% CI)	p
Mental	75.0 (17.7)	73.9 (15.6)	1.0 (−8.8 to 10.9)	0.827
Physical	12.5 (14.5)	13.1 (23.6)	−0.5 (−13.0 to 12.0)	0.931
Temporal	68.5 (14.4)	53.0 (18.1)	15.5 (7.2–23.8)	0.001
Performance	50.8 (19.4)	40.5 (22.7)	10.3 (−4.5 to 25.0)	0.162
Effort	64.3 (20.1)	69.9 (14.0)	−5.6 (−16.5 to 5.3)	0.296
Frustration	43.3 (24.6)	33.9 (28.6)	9.5 (−8.6 to 27.5)	0.286
Average	53.2 (11.6)	46.2 (9.6)	7.1 (1.1–13.0)	0.022

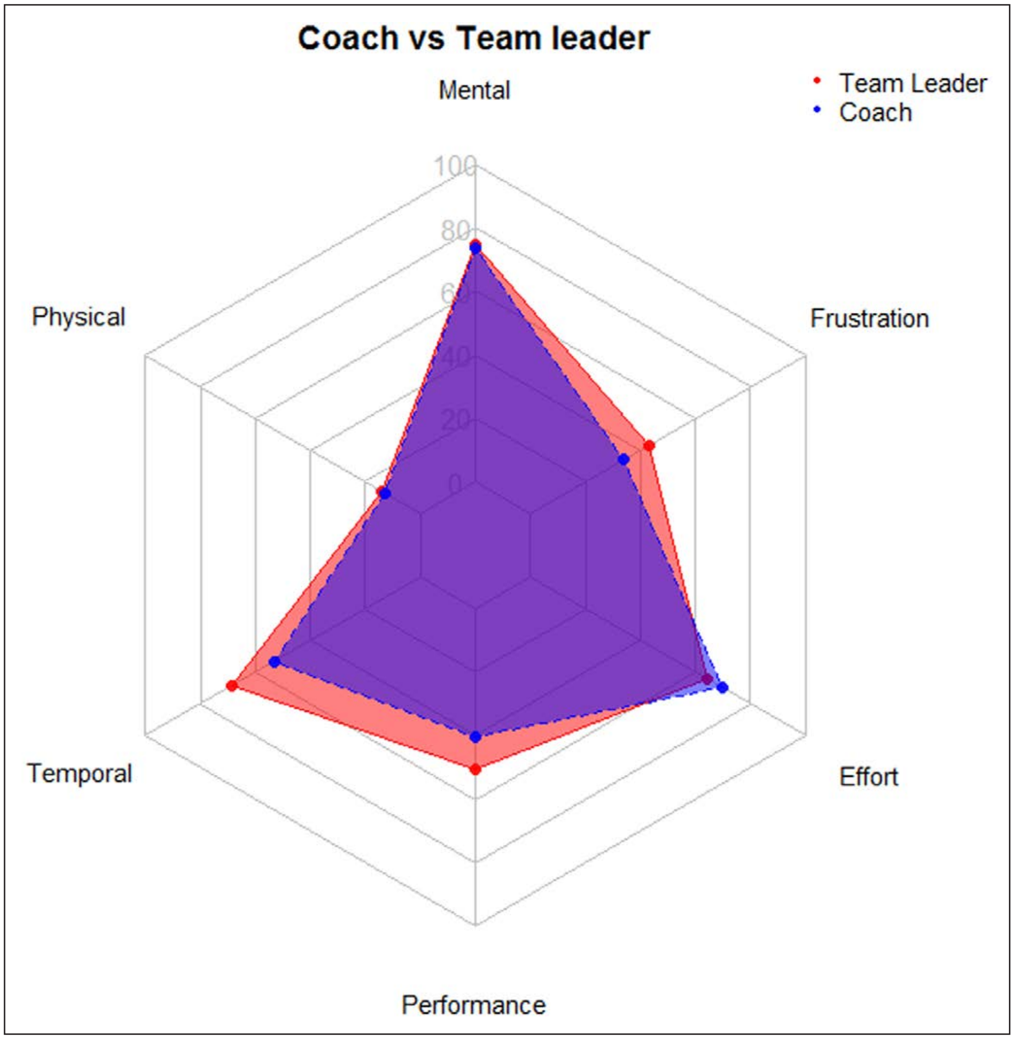

Figure 2. Radar chart of team leader and coach with six domains of National Aeronautics and Space Administration-Task Load Index.

DISCUSSION

Overall, we found that CPR providers with a coach had a lower mental demand but higher physical load than did the CPR providers in teams without a CPR coach. TL and CPR coaches had very high mental workloads at 82.3 and 75.0, respectively, with greater than 60 being defined as high workload. Overall, the TL in the intervention group with a CPR coach had a trend toward lower mental demand scores. Although a coach did not significantly decrease the mental load for the TL, the CPR providers did have a lower mental load. Likely, the coach facilitated teamwork allowing CPR providers to focus solely on compressions. In addition, the coach allowed CPR providers the luxury to only focus on the chest of the patient and not having to switch focus between CPR feedback device and chest of the patient.

The NASA-TLX instrument originally developed in 1988 to study workload in aviation has expanded with use in many fields including medicine and medical simulation (14). Brown et al (11) found in a simulated pediatric arrest scenario that the TL had significantly higher workloads in the mental, temporal, performance-related and frustration domains, and CPR providers had higher physical workloads. Interestingly, they found that with real-time CPR feedback, providers had significantly higher workloads than without feedback. They also found that higher workloads were associated with better quality CPR in regard to guideline-compliant CPR depth. Our study revealed that the addition of a coach resulting in significantly higher physical demand and effort score. This is important because it suggests that highly trained (and certified) CPR providers may be able to increase their exertion and thus improve their CPR quality when a CPR coach is present.

Unlike Brown et al (11) who found a positive association between workload and quality CPR, we found a trend toward negative association between excellent CPR proportion and physical demand score in the intervention group (i.e., those who reported higher score perform poorer). We do not know exactly why this occurred. One possible explanation is that the CPR coach pushed the CPR providers so hard that they reached a point of physical exhaustion earlier than usual, thus resulting in fatigue and lower performance. This could allow for future training of CPR coaches to focus on quality CPR parameters while switching CPR providers when necessary (and not just at the 2-min mark) if some providers are demonstrating signs of physical fatigue.

In an earlier study, our research team compared different workloads of TL and TM during a simulated pediatric sepsis scenario (10). We found that TL had significantly higher overall workloads then TM and that TL were under high workloads (> 60) in both mental demand and effort subscales. We concluded that taking some of the workload off TL may lead to better performance. A CPR coach could potentially have this effect. Our current study did not find the TL mental workload to be decreased in the presence of a CPR coach. This could potentially be explained by the fact that the scenario was intentionally designed to be very difficult, requiring a high mental workload to manage multiple medical issues. Thus, perhaps there was more "work to be done" if the CPR coach was able to cognitively unload the leader. (i.e., management of cardiac arrest and hyperkalemia). In this case, the CPR coach may not have been associated with a lower mental workload for the TL but may have cognitively unloaded the TL to be able to shift more of their mental energy from the Basic to the Advanced Life Support concepts (i.e., following the algorithm, diagnosing and treating the reversible causes) This is in fact one of the goals of the coach (8). This hypothesis requires more study in the context of different types of cardiac arrest scenarios.

CPR providers with a coach did have a lower mental demand. This makes sense because with the facilitation of a coach, CPR providers do not have to keep an eye on the feedback device in order to receive the feedback nor do they have to focus on switching roles both a cause of mental workload. The CPR coach will provide coaching and/or reminders to perform these tasks. However, the physical demand is significantly higher, likely because the coach pushed CPR providers to work harder during CPR. Our study also found that CPR coaches reported high mental demand and efforts scores in comparison to other TMs. This suggests that 1) TMs and TLs should not underestimate the effort required to effectively perform the CPR coach role and 2) that the pros and cons of adding more tasks to the CPR coach should be carefully considered before modifying the role as changes may impact mental demand and effort.

Pediatric cardiac arrests are complex and understanding team dynamics and workload distributions among TMs may help performance and ultimately patient outcome. In both Tofil et al (10) and this study, the TL has highest average workload. The CPR coach attempts to offload this workload, especially in the cognitive domain. In all three pediatric resuscitation studies including this study, the mental load on the TL remains very high at over 75 regardless of intervention, be it the addition of a CPR feedback device or a CPR coach (10, 11). In order to achieve better team distribution of labor, future studies should explore adjusting TM tasks, roles, and/or team composition. Alternatively, perhaps the TL will always have a high mental workload and the main goal is to ensure that they are able to spend their mental energy on the advanced cognitive tasks for which they have received the most training. Simultaneously, the other TMs can concentrate on tasks for which they have or can receive the most training (i.e., CPR coach ensuring high-quality CPR, documenter ensuring accurate time keeping, medication nurse ensuring medications are delivered safely) Ultimately, perhaps the goal is the optimal distribution of tasks, both in quantity of workload and also in terms of matching existing skill sets and/or training.

The broader human performance literature provides some guidance on the interpretation of this study's findings and future research directions. Specifically, prior research demonstrated interactive effects between physical and mental demands on perceived workload and task performance outcomes (23). A concurrent mental demand impedes performance on a physical task and likewise adding a concurrent physical task results in deteriorated performance on a mental task (24, 25). This suggests that there may be benefits to overall team performance by creating roles based at least in part on the type of task demands (i.e., creating roles that perform primarily physical or primarily mental tasks). Maintaining the same overall level of perceived workload while redistributing it across types of workload demands (i.e., focusing workload on similar tasks) may have a net performance benefit. As illustrated in Figure 1, the introduction of a CPR coach had this general effect. In the no-coach condition, the overall amount of perceived workload within roles tended to be distributed across more dimensions of workload, whereas in the coach condition workload for each role tended to be concentrated in fewer dimensions. It should also be noted that workload within the team was measured at the individual level in this study. The need to coordinate within the team presents its own set of workload demands and changes to how tasks are distributed across team roles will impact the amount of team level workload (26, 27). Future research should investigate jointly optimizing individual-role level and team-level workload.

This study has important limitations. We had four study sites in an effort to generalize findings, but all institutions were pediatric tertiary care centers. This could potentially influence the generalizability of the study. Our study limited the resuscitation team to only five members with very specific roles. In many CPR patient scenarios in the hospital, there are more than five members which introduce complexity but also increase the number of individuals available to perform CPR. Although we were able to compare the NASA-TLX scores of CPR providers with clinically important outcome of CPR performance parameters at the team level, we could not separate each individual provider. The measurement of workloads in our study, although validated and widely used, is a reported physical demand score, which is subjective and a perception not an objective workload such as pounds of force. Further studies could consider using more objective methods (i.e., physiologic parameters [heart rate variabilities], performance of secondary tasks). In addition, this is a simulated study and it is not certain how well tests of cognitive function reflect the load in actual patient resuscitation events.

CONCLUSIONS

The addition of a CPR coach increases physical workload and decreases mental workload of CPR providers. There was no significant change in TL workload. Better understanding of workload distribution during pediatric resuscitations may help improve team performance.

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For information regarding this article, E-mail: ntofil@peds.uab.edu

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