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Lacrosse Protective Equipment and the Initiation of Cardiopulmonary Resuscitation and Time to First Automated External Defibrillator Shock

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Context: For an acute cardiac event, on-field equipment removal is suggested, although how lacrosse equipment removal may alter the time to first chest compression and time to first automated external defibrillator (AED) shock remains unknown.

Objective: To determine the time to first chest compression and first AED shock in 2 chest-exposure procedures with 2 pad types.

Design: Crossover study.

Setting: Simulation laboratory.

Patients or Other Participants: A total of 36 athletic trainers (21 women, 15 men; age = 30.58 ± 7.81 years).

Main Outcome Measure(s): Participants worked in pairs to provide 2 rescuer cardiopulmonary resuscitation (CPR) interventions on a simulation manikin outfitted with lacrosse pads and helmet. Participants completed 8 trials per pair (2 chest-exposure procedures × 2 pad types × 2 participant roles). The dependent variables were the time to first compression (seconds) and time to first AED shock (seconds). The independent variables were chest-exposure procedure with 2 levels (procedure 1: removal of the helmet while initiating CPR over the pads, followed by pad retraction and AED application; procedure 2: removal of the helmet and pads, followed by CPR and AED application) and pad type (Warrior Burn Hitman shoulder pads; Warrior Nemesis chest protector).

Results: We found a significant interaction between chest-exposure procedure and pad type for the time to first compression ($F_{1,35} = 4.66$, $P = .04$, $\omega^2_p = 0.10$), with faster times during procedure 1 for both the Nemesis pads (16.1 ± 3.4 seconds) and Hitman pads (16.1 ± 4.5 seconds) than during procedure 2 (Nemesis pads: 49.6 ± 12.9 seconds, $P < .0001$; Hitman pads: 53.8 ± 14.5 seconds, $P < .0001$).

Conclusions: Completing the initial cycle of chest compressions over either shoulder pads or a chest protector hastens the time to first chest compression without diminishing CPR quality, which may improve patient outcomes. The time to the first AED shock was not different between equipment procedures or pad types.

Key Words: emergency care, sudden cardiac arrest, shoulder pads

Key Points

- Performing the first cycle of chest compressions over either shoulder pads or a chest protector shortened the time to the first chest compression without diminishing the quality of the cardiopulmonary resuscitation.
- The time to the first automated external defibrillator shock did not differ between equipment procedures or pad types.

Cardiac arrest is one of the leading causes of sport-related deaths, with 0.76 cases per 100 000 athlete-years. Only 43.8% of these athletes survive until they have been discharged from the hospital.[1–3] Every minute of delay until defibrillation causes a 9% decrease in neurologically intact survival,[1] indicating the importance of the prompt implementation of defibrillation.[4] In a cardiac emergency, first responders must be able to perform high-quality chest compressions to improve patient outcomes and decrease the likelihood of mortality.[5] The American Heart Association[6] stressed the importance of expedient, high-quality chest compressions, which should be at least 50-mm deep at a rate of 100 to 120 per minute. In addition, expedient automated external defibrillator (AED) intervention has been found to improve patient outcomes.[4]

In equipment-intensive sports, protective equipment may interfere with the ability to perform cardiopulmonary resuscitation (CPR) and apply AED pads. Performing chest compressions with football equipment in place inhibited CPR performance due to the thickness and hard plastic coating of the shoulder pads,[7–9] despite the fact that the time to first compression was faster when the shoulder pads were left in place.[10] Manufacturers of football shoulder pads have created a quick-release system to allow expedient, high-quality chest compressions.[8] Despite the adaptation in football shoulder pads, no similar feature exists in lacrosse shoulder pads, and the thickness and

Figure 1. Chest-exposure procedures (left: pad retraction; right: pad removal).

design of lacrosse pads differ from those in football. Although the authors of 1 study[11] found a lack of high-quality chest compressions over lacrosse shoulder pads, 2 other investigations[12,13] indicated that high-quality chest compressions could be provided with lacrosse shoulder pads in place on simulation manikins. However, leaving lacrosse shoulder pads in place to improve the time to first compression may interfere with the ability to apply AED pads to patients' chests.

Although immediate removal of equipment has been recommended,[14] adequate personnel may not be available to assist with the safe removal of protective equipment, forcing some to consider leaving the equipment in place until emergency medical service personnel arrive.[15] Many health care providers likely have access to an AED when covering lacrosse due to the risk of commotio cordis, which might change emergency action plans. Therefore, the purpose of our study was to determine the time to the first chest compression and first AED shock in 2 chest-exposure procedures and 2 pad types. We also wanted to determine whether performance of the first 30 compressions over shoulder pads affected the quality of CPR.

METHODS

Experimental Design

We used a prospective, randomized crossover design to measure the time to the first compression and the time to the first AED shock. In addition, we measured the ability to provide high-quality CPR using a high-fidelity manikin. The independent variables for this study were chest-exposure procedure with 2 levels (procedure 1: removal of the helmet while initiating CPR over the pads, followed by pad retraction and AED application; procedure 2: removal of the helmet and pads, followed by CPR and AED application; Figure 1) and pad type with 2 levels (Burn Hitman shoulder pads, Nemesis chest protector; Warrior Sports). Each participant completed each of the 4 combinations of the 2 independent variables as the ventilator and compressor in counterbalanced order to reduce a potential learning effect or the effects of fatigue.

Participants

A total of 36 participants (21 women, 15 men; age = 30.58 ± 7.81 years) completed our study in 18 groups of 2. To be included, participants needed to be 22 to 60 years of age, be licensed as an athletic trainer (AT) in the state in which they practiced, have had current American Heart Association CPR for Basic Life Support responder (n = 29) or American Red Cross for Basic Life Support responder (n = 7) training, and have no currently diagnosed skeletal, muscular, cardiovascular, or neurologic condition that would impair the ability to kneel and perform CPR. We obtained institutional review board approval from both the University of Lynchburg and Seton Hall University, and all participants signed an informed consent form before data collection.

Instruments

All data related to CPR quality (compression depth, mm; compression rate, No./min; adequate compression depth, %; hand-placement accuracy, %; fully recoiled compressions, %; flow fraction [the time participants were engaged in performing chest compressions or ventilations]; ventilation volume, mL; and ventilation rate, No./min) were collected using the Resusci Anne Q-CPR manikin with ShockLink chest and SimPad Reporter (QCPR; Laerdal Medical). *Flow fraction* is a representation of the time on task, performing either compressions or respirations, and is recorded by the Q-CPR as a score out of 100. A high score represents a high level of time on task, whereas a low score represents periods of inactivity when the responder is not interacting with the manikin. Previous researchers[16] concluded that the Q-CPR manikins provided reliable measures for all variables related to CPR quality. We digitally video recorded all trials on a camera (model Hero 5; GoPro, Inc) at 60 Hz. The camera was on a tripod 3 m from the feet of the manikin to capture the participants'

Figure 2. Pad types (left: Hitman; right: Warrior; Warrior Sports).

actions during the trials. All time data came from the video analysis. We used the Laerdal AED Trainer 2 (Laerdal Medical), which simulated a Phillips HeartStart AED. The AED trainer contained the ShockLink system, which dichotomously identified AED pad-placement accuracy (correct or incorrect). Two sets of new lacrosse pads were used along with the Burn Hitman shoulder pads and Nemesis chest protector, which met the National Operating Committee on Standards for Athletic Equipment (NOCSAE) commotio cordis risk-mitigation standard[17] (Figure 2). For all trials, we fit the manikin with a wicking shirt (model Battlefield Collection–BT3; Epic Sports, Inc), the appropriate pads for the trial, a lacrosse jersey (model Brine Reign On; New Balance Athletics, Inc), and a new helmet (model R; Cascade Lacrosse) fit according to the manufacturer's instructions with the chin strap fastened.

Procedures

Orientation and Training Session. We recruited potential participants through professional networks via email. Each recruit who met the eligibility criteria was paired with another recruit and scheduled for training and data-collection sessions. The training session began with an informational video that the research team had prepared explaining how the manikin worked and how high-quality CPR is correctly performed based on the American Heart Association guidelines.[6] In addition, the equipment used in the study (AED trainer, helmet, and pads) was explained. The ATs then completed a 2-minute CPR proficiency test on the Q-CPR manikin without equipment. We used the same methods and an 80% overall CPR score as determined by the Q-CPR manikin to define *proficiency* as in previous studies.[12,13,18] The SimPad device that recorded data from the Q-CPR manikin provided the overall CPR score, which was calculated using an algorithm that took into account incorrect compression depth, incorrect compression rate, incomplete recoil, inaccurate hand placement, flow-time fraction, incorrect ventilation volume, and incorrect ventilation rate. If participant pairs failed to reach 80%, they remediated by watching an additional video on how to improve their performance, followed by practicing with the manikin and SimPad in practice mode. Once a score of 80% was achieved by each person in the first role (compressor or ventilator), the individuals switched roles and repeated the procedure to ensure proficiency in both roles. Six groups required remediation. All 6 achieved a score $\geq$80% after 1 remediation session.

Data-Collection Session. Approximately 7 days (5.94 $\pm$ 2.74 days) after the initial session, participants returned for the second session for all data-collection trials. We placed the Q-CPR manikin on the floor with a base wicking shirt, helmet, pads, and lacrosse jersey. Yoga mats around the manikin provided participants with a comfortable kneeling environment. The scenario was described to the study participants: "A lacrosse athlete wearing full athletic protective equipment collapses during practice. There was no evidence of trauma during the incident, and the athlete appears unconscious. Rescuers should determine if resuscitation and AED shock are needed to manage the athlete's

condition. Begin." Participants stood within 1 m of the manikin at the start of every trial. Each trial lasted 3 minutes. Participants were required to initiate their response while either leaving the pads in place and performing pad retraction or removing them (Figure 1). The trial procedures follow.

- Procedure 1: Leaving the pads in place and removing the helmet. Rescuer 1 performs the primary survey and determines CPR is necessary. Rescuer 2 assists by removing the helmet as rescuer 1 begins chest compressions on top of the jersey and pads. Rescuer 2 retrieves the AED, cuts the jersey and wicking shirt off the manikin, retracts the pads by flipping them superiorly over the manikin head, and places the AED pads on the chest. Rescuer 1 continues chest compressions after the AED shock, and rescuer 2 provides ventilations.
- Procedure 2: Removing the pads and helmet. Rescuer 1 performs the primary survey and determines CPR is necessary. Rescuer 2 assists by removing the helmet as rescuer 1 cuts the jersey, unfastens the hook-and-loop straps that attach the pads, and cuts the wicking shirt. Both rescuers slide the pads off the manikin. Rescuer 1 begins chest compressions. Rescuer 2 retrieves the AED and places the pads on the manikin chest. Rescuer 1 provides another round of chest compressions after AED shock, and rescuer 2 provides ventilations.

Cutting of the jersey and base wicking shirt was performed using EMT shears (model Stainless Steel Medical Bandage Scissors; Gainwell Technologies), starting at the neck and moving toward the waist. The standard 2-rescuer American Heart Association CPR protocol[6] was followed (30 compressions followed by 2 ventilations for each cycle) using a standard pocket mask (Laerdal Medical). The AED trainer was located 10 m from the manikin to simulate retrieval from the sideline. The AED pads were placed in the pocket of the AED trainer case before each trial. All groups had new pads for their trials. After the AED pads were applied, we used a scenario that involved a single shockable rhythm and then cycles of CPR until the scenario ended. Participants took a 3-minute rest period between trials. Each person performed all trials in 2 roles (as compressor or ventilator), resulting in 8 total trials for each group in a counterbalanced order. The *time to first compression* was defined as the time from the start of the session when the research team member stated, "Begin," until the time the first chest compression was delivered. The *time to first AED shock* was from the time when the research team member stated, "Begin," until the time the first AED shock was delivered.

Statistical Analysis

We calculated means with SDs and medians with ranges for all continuous variables and categorical variables, respectively. We analyzed the data using separate 2×2 repeated-measures analyses of variance to assess differences in each of the continuous dependent variables (time to first compression, time to first AED shock, and CPR quality [mean compression depth, mm; mean compression rate, No./min; mean ventilation volume, mL]; mean ventilation rate, No./min) between the chest-exposure procedure and pad type using SPSS (version 26; IBM Corp). The SimPad recorded all CPR quality data and presented it in Session Viewer (Laerdal Medical) files for analysis.

Because adequate depth, adequate recoil, and flow-fraction data are reported as percentages, we used nonparametric analyses (Wilcoxon signed rank tests) to determine differences. However, nonparametric approaches do not allow multiple independent variables to be analyzed simultaneously. Therefore, we analyzed each independent variable separately. We originally planned to also compare compression hand-placement accuracy using the same approach, but there was little variability (123 of 144 trials had hand-placement scores of 100%). In addition, we conducted a logistic regression analysis for AED pad-placement accuracy (correct or incorrect) with the chest-exposure procedure and pad type as the independent variables. We calculated the odds ratio and a 95% CI to determine the association between chest-exposure procedure and pad type with AED pad-placement accuracy.

Finally, we separately analyzed the CPR compression quality data (compression depth, mm, and compression rate, No./min) from only the first 30 compressions to account for the differences in performing compressions over pads or on the bare chest using 2×2 repeated-measures analyses of variance. The first 30 compressions during procedure 1 occurred on top of the pads before retraction, whereas the remaining compressions occurred on the bare chest after retraction. To identify the quality of the first 30 compressions, data from the SimPad Session Viewer files were exported to Excel (Office 365; Microsoft Corp) for further analysis. In Excel, raw data for compression depth, compression rate, adequate depth, hand-placement accuracy, and adequate recoil were extracted from the full data set so that a mean score for only the first 30 compressions could be calculated.

Before all analytic procedures, we conducted assumption testing for normality, linearity, and sphericity. Greenhouse-Geiser corrections were applied for any violations of sphericity. The level of statistical significance was set a priori to .05. We calculated partial ω squared (ω^2_p) or Cohen *d* as estimates of effect size.

RESULTS

Complete Trials

Our 36 participants completed 4 trials each, for a total of 144 trials. All descriptive statistics can be seen in Table 1, and statistical results can be seen in Table 2. We found a significant interaction between chest-exposure procedure and pad type for the time to the first compression ($F_{1,35} = 5.48$, $P = .03$, $\omega p^2 = 0.11$). Procedure 1 (pad retraction) was faster for both the Nemesis (16.08 ± 3.41 seconds) and Hitman (16.03 ± 4.39 seconds) pads than procedure 2 (pad removal; Nemesis pads: 49.58 ± 12.89 seconds, $P < .0001$, Cohen $d = 3.55$; Hitman pads: 53.94 ± 14.42 seconds, $P < .0001$, Cohen $d = 3.56$). No difference was evident between pads during the retraction procedure ($P = .922$). No other significant interactions were noted for the remaining continuous dependent variables (time to the first AED shock, compression rate, compression depth, ventilation rate, and volume; Table 2).

Pad-retraction (median = 51%, range = 34%–65%) and pad-removal (median = 46%, range = 3%–57%) procedures ($z = -5.527$, $P < .0001$) and the Nemesis (median = 49%,

Table 1. Descriptive Statistics for Outcome Variables During Complete Data-Collection Sessions

Outcome Variable	Procedure and Pad[a]			
	1: Retraction		2: Removal	
	Nemesis	Hitman	Nemesis	Hitman
	Mean ± SD			
Time to first compression, s	16.08 ± 3.41	16.03 ± 4.39	49.58 ± 12.89	53.94 ± 14.42
Time to first automated external defibrillator shock, s	88.81 ± 11.94	91.61 ± 16.61	90.83 ± 16.11	95.19 ± 14.53
Compression depth, mm	56.47 ± 4.21	56.83 ± 4.91	57.36 ± 4.21	56.97 ± 4.65
Compression rate, compressions/min	117.69 ± 8.60	119.53 ± 16.36	118.83 ± 7.64	117.56 ± 7.28
	Median (Range)			
Adequate-depth compressions, %	94.5 (20–100)	98 (5–100)	98.5 (34–100)	97.5 (37–100)
Fully recoiled compressions, %	54 (3–100)	48.5 (4–100)	57.5 (3–100)	54.5 (2–100)
Compression hand-placement accuracy, %	100 (41–100)	100 (97–100)	100 (81–100)	100 (74–100)
Flow fraction	51.5 (38–65)	49.5 (34–65)	47 (27–57)	44.5 (3–57)
Ventilation volume, mL	618.31 ± 183.05	584.00 ± 171.69	571.86 ± 204.07	603.08 ± 182.11
Ventilation rate, ventilations/min	2.47 ± 0.61	2.33 ± 0.76	2.33 ± 0.99	2.36 ± 0.64

[a] Warrior Sports.

range = 27%–65%) and Hitman (median = 47%, range = 3%–65%; $z = 2.376$, $P = .0017$) pads did not differ for flow fraction. Neither depth nor recoil was different (P values > .05). The interaction of chest-exposure procedure and pad type was not significantly associated with AED pad-placement accuracy (odds ratio = 0.80, 95% CI = 0.21, 3.10).

First 30 Compressions

Descriptive statistics for the first 30 compressions are shown in Table 3. The interaction between chest-exposure procedure and pad type for compression depth ($F_{1,35} = 2.436$, $P = .128$, $\omega p^2 = 0.04$) and compression rate ($F_{1,35} = .008$, $P = .928$, $\omega p^2 < 0.001$) was not significant. No differences occurred between chest-exposure procedure or pad type for adequate depth or recoil (P values > .05).

DISCUSSION

Our main finding was that the time to the first chest compression differed based on the procedure and pad type. We also observed no difference in the time to the first AED shock between the chest-exposure procedures regardless of which pads were in place, a critical outcome because early AED intervention decreases patient mortality.[4] Procedure 1 (performing the first round of compressions on top of the pads) allowed approximately 35 seconds' faster initiation of chest compressions. Although the increased speed came with a statistically significant decrease in compression depth during retraction when the Nemesis chest protector was in place (compression depth main effect for chest-exposure procedure; Table 2), we do not believe this difference was clinically significant. The mean for chest-compression depth during the first 30 compressions that occurred over the Nemesis chest protector was 56.15 mm, and it remained above the American Heart Association recommended depth of 50 mm.[6] Therefore, completing the chest compressions over either pad type did not reduce CPR compression quality to a clinically meaningful level.

More recently, a study[19] of compression-only CPR and AED interventions by lay responders on individuals wearing Kendo equipment was performed. Similar to our methods, the researchers[19] used 2 conditions (1 in which the protective equipment was fully removed first and 1 in which the equipment was left in place until the AED arrived) and determined that fully removing equipment slowed the time to the first compression. Consistent with our results, the time to the first AED shock was no different between their 2 chest-access procedures. The similarities in the studies demonstrate that whether the equipment is taken off before or after the CPR intervention has started will not affect the time to the first AED shock.

The flow fraction was higher for pad retraction than for pad removal, indicating that responders were able to spend more time on task performing CPR and preparing the AED during the retraction procedure. Equipment removal initially took time away from providing compressions, whereas participants started chest compressions immedi-

Table 2. Interactions and Main Effects for Dependent Variables During Complete Data-Collection Sessions[a]

Outcome Variable	Interaction			Chest-Exposure Procedure Main Effect			Pad-Type Main Effect		
	$F_{1,35}$ Value	P Value	ω^2_p Effect Size	$F_{1,35}$ Value	P Value	ω^2_p Effect Size	$F_{1,35}$ Value	P Value	ω^2_p Effect Size
Time to first compression, s	4.655	.038	0.09						
Time to first automated external defibrillator shock, s	0.260	.614	<0.001	1.5	.229	0.01	2.917	.096	0.05
Compression depth, mm	1.538	.223	0.01	1.311	.260	0.008	0.001	.971	<0.001
Compression rate, compressions/min	1.660	.206	0.02	0.076	.784	<0.001	0.072	.790	<0.001
Ventilation volume, mL	0.989	.327	<0.001	0.074	.787	<0.001	2.002	.166	0.03
Ventilation rate, ventilations/min	0.593	.446	<0.001	0.186	.669	<0.001	0.28	.60	<0.001

[a] Main effects are not provided for significant interactions.

Table 3. Descriptive Statistics for Outcome Variables During the First 30 Compressions Only

Outcome Variable	Procedure and Pad[a]			
	1: Retraction		2: Removal	
	Nemesis	Hitman	Nemesis	Hitman
	Mean ± SD			
Compression depth, mm	55.39 ± 4.44	57.84 ± 4.17	57.16 ± 5.30	57.56 ± 4.30
Compression rate, No./min	106.48 ± 23.35	115.00 ± 8.28	116.65 ± 9.30	115.20 ± 7.77
	Median (Range)			
Adequate-depth compressions, %	94.5 (20–100)	98 (10–100)	98.5 (35–100)	97.5 (37–100)
Compression hand-placement accuracy, %	100 (59–100)	100 (100–100)	100 (94–100)	100 (67–100)
Compressions fully recoiled, %	54 (3–100)	48.5 (3–100)	52 (3–100)	57.5 (2–100)

[a] Warrior Sports.

ately during the retraction procedure. Although they stopped to retract the equipment once the AED arrived and after completing the first set of compressions, retraction was faster than full equipment removal, thus improving flow fraction. During trials, we manually started the SimPad after reading the scenario script and stating, "Begin," leaving a long inactive period during the equipment-removal trials when nothing happened to the manikin. Rather than the timer starting with the first compression, the SimPad included the inactive period, which likely explains our findings. Initiating CPR, followed by a pause, appears to be better than delaying CPR for a long inactive period. Unfortunately, we were unable to compare flow-fraction data because no previous research on CPR and athletic equipment included those results.

We initially intended to compare hand placement between the independent variable levels, but the data lacked sufficient variability for useful statistical tests to be conducted. Therefore, we do not believe that hand placement meaningfully differed by procedure or pad type. Earlier authors[12] identified more accurate hand placement when 2 minutes of chest compressions were performed on the bare chest as opposed to on top of the 2 types of lacrosse shoulder pads. Although the chest protector and shoulder pads cover the sternum where chest compressions need to be applied, participants were able to correctly position their hands when performing chest compressions. This outcome was important given that correct hand position is a component of high-quality CPR. Similarly, retracting the equipment did not hinder the participants' ability to correctly apply the AED pads because the odds of correct AED pad placement were not associated with the combinations of procedure and pad type.

The purpose of analyzing the first 30 compressions was to compare the data with those of previous investigators who evaluated CPR quality over lacrosse equipment and on a bare manikin chest. However, we concede that examining only 30 compressions may not have provided a comprehensive view of CPR quality. We noted no differences, indicating that CPR quality was similar, regardless of whether the compressions were performed over 1 of the 2 pad types or on the bare chest of the manikin. Our results contradict those of other authors[7–9] who assessed chest-compression quality over football pads. Football shoulder pads are much thicker than lacrosse pads, which may explain the discrepancy. Previous research[12,13] on lacrosse pads revealed adequate chest-compression quality, whereas a separate study[11] demonstrated inadequate chest-compression depth with equipment in place. Our participants, as well as those in earlier studies,[12,18] were required to pass a CPR skill proficiency test before data collection; we speculate that may explain the differences between findings. In addition, our ATs provided only 30 chest compressions on top of the lacrosse pads, and pad types vary widely in the sport, which may have also accounted for the different outcomes. Whereas it might be possible to perform 30 quality compressions over pads, such performance would not be sustainable over several cycles of CPR, especially with the commotio cordis plate on the Nemesis pads. Therefore, we believe that early AED application and retracting the lacrosse pads may be prudent. Regardless, we think it is important for health care providers to practice CPR with a feedback manikin if they plan to perform chest compressions over protective equipment to ensure high-quality execution.

It is crucial to note our use of the Warrior Nemesis chest protector as 1 pad type. The Nemesis was the only goalie chest protector that met the new NOCSAE standard for mitigating the risk of commotio cordis[17] at the time of this study. To our knowledge, no authors have examined the ability to provide quality chest compressions over any pad that meets the NOCSAE commotio cordis standard. The additional breastplate over the chest protector[18] did not alter chest-compression depth or rate. However, our participants noticed a difference when performing chest compressions over these pads. Perhaps they compensated appropriately by pressing harder during chest compressions to ensure adequate depth.

Immediate removal of protective equipment on the field should be performed by ATs[14,20] because they are likely the most highly trained personnel and familiar with sports equipment.[15,20] Despite this, many ATs would not have adequate trained medical personnel available to immediately remove equipment on the field and would choose to supply immediate care with the equipment in place or retracted until additional medical providers arrive to assist with full equipment removal.[15] Our results suggest that high-quality CPR can be rendered with the equipment retracted. Nonetheless, we agree that the equipment will need to be removed at some point, and sooner may be better than later in situations when immediate care would be compromised.[20]

Limitations and Future Directions

We believe our work is an important step in studying CPR and AED interventions among athletes wearing lacrosse equipment. Yet we studied only 2 pairs of lacrosse pads. We attempted to select a model representative of that worn by field players and a model worn by goalies that met the NOCSAE commotio cordis standard. We acknowledge that a wide variety of shoulder pads and chest protectors is available, and others may produce different results. Similarly, we used the Laerdal AED Trainer 2, which simulated a Phillips HeartStart AED, and did not ask participants to choose between adult and pediatric AED pads. Familiarity with a particular AED and having to determine the appropriateness of adult or pediatric AED pads could affect the results. We recommend that future researchers examine different models of shoulder pads and other AED trainers to improve generalizability. We selected 2 chest-exposure procedures that we thought first responders would use when responding to acute on-field cardiac emergencies, but we understand that the order of events may vary in real-life situations. Our investigation was conducted in a contrived laboratory setting and, therefore, whether these results would translate to more sport-specific locations such as turf or grass fields remains unknown. Given that participants were fully aware of the scope of the study due to reading and signing the informed consent form, they may have hastened their initial assessment and initiation of CPR. Before data collection, we tested the CPR proficiency of our ATs on the manikin with a bare chest. Although the proficiency tests added to the internal validity of the research by ensuring that our CPR quality findings could be attributed to the presence of equipment and not a poor skill level, it also threatened the external validity and overall generalizability of the findings. It would be interesting to replicate this study on a field with clinicians who have not recently practiced CPR to simulate more realistic conditions.

CONCLUSIONS

Completing the initial round of chest compressions over either a chest protector with a NOCSAE–approved commotio cordis plate or shoulder pads shortened the time to the first chest compression, which improved patient outcomes. The time to the first AED shock was consistent, regardless of the chest-exposure procedure and pad type. The chest-compression depth was shallower on top of the chest protector with the commotio cordis plate, but the quality was not clinically different because the compressions met the American Heart Association standard, whether they were performed over the chest protector or shoulder pads or directly on the bare chest.

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