Delivering Chest Compressions and Ventilations With and Without Men’s Lacrosse Equipment

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**Context:** Current management recommendations for equipment-laden athletes in sudden cardiac arrest regarding whether to remove protective sports equipment before delivering cardiopulmonary resuscitation are unclear.

**Objective:** To determine the effect of men’s lacrosse equipment on chest compression and ventilation quality on patient simulators.

**Design:** Cross-sectional study.

**Setting:** Controlled laboratory.

**Patients or Other Participants:** Twenty-six licensed athletic trainers (18 women, 8 men; age = 25 ± 7 years; experience = 2.1 ± 1.6 years).

**Intervention(s):** In a single 2-hour session, participants were block randomized to 3 equipment conditions for compressions and 6 conditions for ventilations on human patient simulators.

**Main Outcome Measure(s):** Data for chest compressions (mean compression depth, compression rate, percentage of correctly released compressions, and percentage of optimal compressions) and ventilations (ventilation rate, mean ventilation volume, and percentage of ventilations delivering optimal volume) were analyzed within participants across equipment conditions.

**Results:** Keeping the shoulder pads in place reduced mean compression depth (all P values < .001, effect size = 0.835) and lowered the percentages of both correctly released compressions (P = .02, effect size = 0.579) and optimal-depth compressions (all P values < .003, effect size = 0.900). For both the bag-valve and pocket masks, keeping the chinstrap in place reduced mean ventilation volume (all P values < .001, effect size = 1.323) and lowered the percentage of optimal-volume ventilations (all P values < .006, effect size = 1.038).

**Conclusions:** For a men’s lacrosse athlete who requires cardiopulmonary resuscitation, the shoulder pads should be lifted or removed to deliver chest compressions. The facemask and chinstrap, or the entire helmet, should be removed to deliver ventilations, preferably with a bag-valve mask.

**Key Words:** sudden cardiac arrest, sudden death, emergency management, facemask, lacrosse helmet, simulation

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**Key Points**

- Leaving the lacrosse helmets and shoulder pads in place decreased the quality of cardiopulmonary resuscitation.
- Removing the shoulder pads resulted in greater chest compression depth.
- Removing the helmet chinstrap increased ventilation volume, particularly when using a bag-valve mask.

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Sudden cardiac arrest is the most common cause of sudden death in young athletes. Athletic trainers (ATs) are often the primary parties responsible for initial management of such cardiac emergencies. The National Athletic Trainers’ Association position statement on preventing sudden death in sports indicates that responders should begin cardiopulmonary resuscitation (CPR) as quickly as possible after identifying a sudden cardiac arrest and that good-quality compressions should be delivered while an automated external defibrillator is being retrieved. However, current recommendations do not address the unique challenges of equipment-intensive sports such as football, ice hockey, and lacrosse, in which protective equipment blocks access to the chest and airway. Although a few authors have examined how football equipment affects the delivery of CPR, no reports have been published on lacrosse equipment. Lacrosse shoulder pads are thinner and more flexible than football shoulder pads, and lacrosse helmets have a different shape and fit compared with football helmets. Lacrosse is the most rapidly growing interscholastic and intercollegiate sport, with more than 800,000 participants in the United States. The overall mortality rate in lacrosse is similar to that in other popular sports such as baseball, basketball, and football. Unlike these sports, however, lacrosse athletes
have a disproportionately high risk of commotio cordis, which accounts for 45% of sudden deaths in the sport; this is similar to what is observed in ice hockey. Given the sport's growing popularity and the gravity of this clinical problem, it is imperative to provide ATs with an evidence-based approach to emergency management of a lacrosse player in sudden cardiac arrest.

Mounting evidence suggests that the presence of football shoulder pads and a helmet with chinstrap reduces chest compression and ventilatory quality. Whether the thinner pads used in lacrosse negatively affect compression quality is unknown, but evidence indicates that removing equipment delays the initiation of chest compressions. Therefore, if optimal compression quality can be maintained, it may be preferable to deliver compressions over the equipment and delay equipment removal until an automated external defibrillator is ready to be applied. In addition to affecting chest compression quality, equipment may interfere with delivering ventilations. One group found that the presence of a football helmet, and especially a chinstrap, reduced ventilation quality, even when the facemask was removed. Differences in pad and shell thickness, as well as helmet shape, may affect the ability to gain airway access with a lacrosse helmet in place. Moreover, the choice of airway adjunct may affect ventilation quality. Previous researchers established that using a bag-valve mask was superior to using a pocket mask, regardless of whether the helmet was in place. Given the differences in lacrosse and football helmet designs, we believed that comparing these 2 ventilation methods across various equipment conditions was warranted.

The purpose of this study was to determine the effect of men's lacrosse equipment on performing chest compressions and delivering ventilations on the Resusci Anne Simulator with SimPad (Laerdal, Wappinger Falls, NY). This patient simulator approximates a men's lacrosse player, as there is no breast tissue on the chest. By using a patient simulator in a controlled setting, we sought to inform clinicians about managing a sudden cardiac arrest in an equipment-laden lacrosse athlete. Based on previous investigations of football shoulder pads, we expected that keeping the lacrosse shoulder pads in place would decrease compression quality. We also hypothesized that leaving the chinstrap in place would reduce ventilation quality. Finally, we believed the bag-valve would provide higher-quality ventilations than the pocket mask.

**METHODS**

**Study Design and Participants**

Twenty-six certified ATs (18 women, 8 men; age = 25 ± 7 years; athletic training experience = 2.1 ± 1.6 years) licensed to practice in their jurisdictions participated in our cross-sectional study. Exclusion criteria were any history of upper extremity injury or a neurologic condition resulting in loss of arm strength. The University of North Carolina at Chapel Hill Office of Human Research Ethics approved the study of human participants. All participants provided written informed consent and completed all the procedures described herein during a single 2-hour data-collection session.

**Instrumentation**

We used the Laerdal Resusci Anne Simulator with SimPad, SkillReporter, and Quality CPR feedback to collect CPR performance metrics. We fit the simulator with Cascade R helmets (Cascade, Liverpool, NY) and STX Cell Liner II (STX, Baltimore, MD) shoulder pads per the manufacturers' guidelines. We chose these equipment options due to availability and popularity among local organizations and also because the technical and design features were consistent with equipment commonly used in men's lacrosse.

**PROCEDURES**

**Orientation**

Each participant completed a familiarization session in which he or she was oriented to the patient simulator technology, athletic equipment, and breathing apparatuses (bag-valve and pocket masks). After being oriented to the equipment by a research assistant, participants had time to handle the airway adjuncts and patient simulator. Although no time limit or minimum exposure time was imposed on the study participants, the familiarization sessions typically lasted 10 to 15 minutes. Participants then completed a CPR training session in which they viewed their CPR performance in real time using SkillReporter on a tablet wirelessly connected to the simulator. Participants were instructed to follow the 2015 American Red Cross CPR guidelines for compressions and ventilations: perform compressions for 30 seconds at a rate of 100 to 120 compressions per minute with a depth of at least 2 in (50 mm) and with full chest recoil between compressions. They were then instructed to deliver ventilations using the pocket mask for 30 seconds at a rate of 8 to 10 breaths per minute, with each ventilation lasting 1 second. The purpose of the familiarization session was to provide participants an opportunity to experience delivering chest compressions and ventilations to the patient simulator. The conditions within the task scenarios would be exclusively chest compressions or ventilations. Thus, when a participant was able to demonstrate compression and ventilation proficiency for 30 seconds (as assessed by the Laerdal SkillReporter rating of “Advanced performer”), he or she was then block randomized to one of the following task scenarios: (1) chest compressions or (2) ventilations.

**Chest Compression Conditions**

We evaluated chest compression outcomes in 3 equipment conditions performed in a counterbalanced order: fully equipped with both lacrosse pads and helmet with facemask removed, lacrosse pads lifted with helmet on and facemask removed, and no equipment (Figure 1). Each trial lasted for 2 minutes and began when the first compression was measured by the simulator. Participants were permitted to rest outside the testing room while research assistants prepared the environment for the next condition in the randomized sequence. This usually offered participants 3 to 5 minutes of rest between conditions. We had planned to grant a longer rest period if participants expressed a need for more time. None of our participants made this request throughout the study period.
Before beginning the trial, a member of the research team read each participant a script stating that he or she had just observed an athlete collapse suddenly with no evident mechanism of injury (ie, no collision event precipitating collapse). Participants were told that the athlete was unresponsive and had no pulse, and no other life-threatening traumatic injury (ie, to the head or neck) was suspected. The participant was instructed to begin chest compressions as soon as possible after approaching the patient and not to remove any equipment. He or she was to continue chest compressions without interruption until a member of the research team ended the trial with a verbal command at 2 minutes. The participant then left the area and a member of the research team prepared the next equipment scenario on the simulator. This process was followed until each participant completed all 3 compression conditions.

Ventilation Conditions

We evaluated ventilation outcome measures in 3 lacrosse equipment conditions using a bag-valve mask: helmet removed, facemask and chinstrap removed, and facemask removed with chinstrap attached (Figure 2A–C). For each equipment condition, ventilations were administered via a 1-person pocket mask (Figure 2D–F). Thus, a total of 6 conditions were studied. Each condition lasted 2 minutes and began with the first ventilation delivered above the simulator’s minimum ventilation volume threshold (50 mL). As with the compression conditions, participants were permitted to rest outside the testing room while research assistants prepared the environment for the next condition in the randomized sequence.

As in the compression condition, participants were read a script that stated they had just observed an athlete collapse suddenly with no evident mechanism of injury. Participants were instructed to perform ventilations only; no compression or cervical spine stabilization was necessary. They were also told which method of ventilation to use (1-person pocket mask or 2-person bag-valve mask). In the 2-person bag-valve mask condition, the research assistant was responsible for compressing the bag while the participant completed the modified jaw thrust in the cephalic position and sealed the mask around the mannequin’s mouth. The cephalic position was also used in the 1-person pocket-mask scenario. The modified jaw thrust was employed to mimic procedures if cervical spine injury was suspected. The positioning for both scenarios was explained and practiced in the orientation session.

Data Analysis

We evaluated performance quality based on 4 chest compression outcome measures: (1) mean compression depth, (2) mean compression rate, (3) percentage of compressions with full chest recoil, and (4) percentage of compressions reaching optimal depth (50–61 mm). Our 3 ventilation outcome measures were (1) mean ventilation volume, (2) percentage of ventilations with optimal volume (400–700 mL), and (3) mean ventilation rate. We computed the percentage of optimal depth as the number of compressions reaching an optimal depth divided by the total number of compressions delivered. Similarly, the percentage of optimal ventilation consisted of the frequency of ventilations with optimal volume divided by the total number of delivered ventilations.

For the compression outcome measures, we calculated separate within-subjects analyses of variance with equipment condition as the independent variable. For the ventilation outcomes, we performed a 2 (ventilation method: bag-valve mask versus pocket mask) \times 3 (equipment condition) within-subjects analysis of variance. In the case of a significant omnibus F test, we conducted post hoc paired t tests with the Tukey-Kramer correction for multiple comparisons to determine pairwise differences. Rather than presenting each pairwise comparison, we provided the largest corrected P value of the pairwise tests (ie, “all P values < .001” denotes all comparisons had at most a P value < .001). Effect sizes were reported as the Cohen d. For each statistical test, we used an a priori a of .05. All statistical analyses were performed using the R Foundation for Statistical Computing software (Vienna, Austria).

RESULTS

Chest Compressions

We observed an effect of equipment condition on compression mean depth ($F_{2,50} = 29.695$, $P < .001$), the
percentage of correctly released compressions \( (F_{2,50} = 4.373, P = 0.02) \), and the percentage of compressions with optimal depth \( (F_{2,50} = 14.493, P < .001) \). The condition with shoulder pads in place had a lower mean depth (all \( P \) values < .001, effect size = 0.835) and lower percentage of optimal-depth compressions (all \( P < .003 \), effect size = 0.900) compared with the other conditions. The percentage of correctly released compressions was lower for the fully equipped condition compared with the no-equipment condition \( (P = .04 \), effect size = 0.579) \. We did not observe any differences between the pads-lifted and pads-removed conditions for any of the compression outcomes.

Descriptive and inferential statistics for all compression outcomes are presented in Table 1.

### Table 1. Chest Compression Outcome Measures

| Outcome Measure         | Compression Condition (Mean ± SD) | F Statistic | Effect Size\( a \) | \( P \) Value\( b \) |
|-------------------------|-----------------------------------|-------------|---------------------|-------------------|
| Mean depth, mm          | Fully Equipped 45.2 ± 7.2 51.4 ± 8.1 51.5 ± 7.3 | 26.695      | 0.835               | <.001             |
| Rate, compressions/min  | Fully Equipped 107.1 ± 15.8 109.7 ± 16.6 110.3 ± 13.9 | 2.545       | -0.189              | .09               |
| Correct release, %      | Fully Equipped 67.7 ± 29.5 78.1 ± 26.3 83.0 ± 23.3 | 4.373       | 0.579               | .02               |
| Adequate depth, %       | Fully Equipped 32.1 ± 37.8 65.5 ± 37.3 65.4 ± 37.8 | 14.493      | 0.900               | <.001             |

\( a \) Effect sizes compare the unequipped and pads-lifted conditions with the fully equipped condition.  
\( b \) \( P \) values reflect the omnibus \( F \) test for main effects.

### Ventilations

We noted a main effect of equipment condition on the mean volume of ventilations \( (F_{2,125} = 44.435, P < .001) \) and the percentage of ventilations with optimal volume \( (F_{2,125} = 22.791, P < .001) \). For both the bag-valve and pocket masks, the condition with the chinstrap in place had a lower mean ventilation volume (all \( P \) values < .001, effect size = 1.323) and lower percentage of optimal...
ventilations (all $P$ values < .006, effect size = 1.038) than either the facemask-and-chinstrap–removed or the helmet-removed condition. A significant interaction between equipment condition and ventilation method was observed for the number of ventilations ($F_{2,125} = 3.722, P = .03$). For the pocket mask only, the chinstrap-in-place condition had a lower mean number of ventilations than the other 2 conditions (all $P$ values < .008, effect size = 0.722). Using the bag-valve mask, the participants produced a similar number of ventilations across equipment conditions. For all 3 outcomes, the facemask-and-chinstrap–removed condition and the helmet-removed condition were similar.

We demonstrated a main effect of ventilation method on mean ventilation volume ($F_{1,150} = 9.590, P = .002$) and percentage of optimal ventilations ($F_{1,150} = 23.772, P < .001$). With the chinstrap in place, the bag-valve mask resulted in greater mean ventilation volume as compared with the pocket mask ($P < .001$, effect size = 0.598); for the 2 conditions in which the chinstrap was removed, the mean volumes were similar between the 2 methods. The bag-valve was associated with a greater ventilation rate (all $P$ values < .003, effect size = 0.575) and a greater percentage of optimal ventilations (all $P$ values < .002, effect size = 0.671) than the pocket mask across all equipment conditions. Descriptive and inferential statistics for all ventilation outcomes are presented in Table 2.

**DISCUSSION**

Current National Athletic Trainers’ Association recommendations for providing care during sudden cardiac arrest events are unclear regarding the removal of protective equipment in collision sports. An interassociation task force statement on the management of sudden cardiac arrest in athletic programs was similarly vague in its recommendations: the only explicit mention of equipment removal was for an athlete with a cervical spine injury who was in cardiac arrest. For the acute management of a patient with sudden cardiac arrest in an equipment-intensive sport, ATs must have clear instructions on what equipment should be removed before initiating CPR. Researchers have explored the effects of football shoulder pads on compressions, and 1 group examined how a football helmet affected ventilations, but to date, no published studies have assessed lacrosse equipment. Therefore, the purpose of our study was to determine the effect of men’s lacrosse equipment on the performance of chest compressions and delivery of ventilations to a men’s lacrosse athlete, as simulated by the Laerdal Resusci Anne.

We found that chest compression quality was compromised by the presence of lacrosse shoulder pads. The effect size we observed for compression depth was large (>0.8) when the shoulder pads were in place. However, our participants were able to reach optimal compression depth in only about one-third of their compressions. This resulted in a mean compression depth reduction of 5 mm. Our chest compression results are consistent with previous reports on the effect of football shoulder pads on CPR quality. Mihalik et al noted that football shoulder pads reduced the mean compression depth and lowered the percentage of compressions with optimal depth. As one would expect, the stiffer football pads resulted in greater reductions in chest compression efficacy than did the lacrosse equipment; the

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**Table 2. Ventilation Outcome Measures**

| Ventilation Condition (Mean ± SD) | No. of ventilations | Volume, mL | Optimal volume, % |
|-----------------------------------|--------------------|-----------|-------------------|
| Facemask and Chinstrap in Place | 23.5 ± 4.6 | 397.6 ± 85.3 | 48.3 ± 4.6 |
| Facemask Removed | 24.5 ± 5.0 | 404.7 ± 91.7 | 48.7 ± 4.6 |
| Chinstrap Removed | 25.5 ± 6.0 | 431.4 ± 182.0 | 46.4 ± 4.6 |

| Comparison | Ventilation Method | F | P | Effect Statistic | Values | Effect Sizea | Values | Values | Effect Sizeb |
|------------|--------------------|---|---|-----------------|--------|---------------|--------|--------|---------------|
| Helmet Removed | Bag-Valve | 6.124 | < .001 | 25.002 | < .001 | 0.575 | 3.772 |
| Chinstrap Removed | Bag-Valve | 22.791 | < .001 | 23.772 | < .001 | 0.671 | 0.071 |

* a Compares the helmet-removed and facemask-and-chinstrap–removed conditions with the chinstrap-in-place condition, collapsing across ventilation methods.
* b Compares the bag-valve mask with the pocket mask, collapsing across equipment conditions.
authors of the previous study showed that only 15% of compressions reached optimal depth when the pads were left in place, with a mean depth reduction of approximately 7 mm in the fully equipped condition. Similarly, Waninger et al observed a 6.5-mm reduction in median compression depth in the equipped condition with football shoulder pads in place.

Although lacrosse pads are more flexible and thinner than football pads, they nevertheless present a barrier to chest compression quality. A 5-mm reduction in compression depth may not seem large. However, the quality of chest compressions was frequently substandard, with providers typically performing compressions that were too shallow, and thus, even a small impediment to compression depth is problematic. Further, converging evidence indicates a survival benefit with a 5-mm increase in mean compression depth. Taken together, our findings strongly suggest that the pads should be lifted or removed to expose the chest before initiating compressions.

With regard to ventilations, we observed that a chinstrap was a major detriment to ventilation quality. The ventilation volume effect size exceeded 1.3, which was considerably greater than the effect size of the ventilation method on volume that we demonstrated (approximately 0.6). When the chinstrap was left in place, only half of the ventilations reached optimal volume using a bag-valve mask and only a quarter using a pocket mask. The helmet itself did not present a barrier to ventilations, as the condition with the helmet in place and chinstrap removed was similar to the helmet-removed condition. The chinstrap made it exceedingly difficult to maintain an airtight seal over the mannequin’s mouth, resulting in a smaller volume being delivered to the lungs. We also found that the 2-person bag-valve mask was superior to the pocket mask in every equipment scenario. This result corroborated a previous study using football equipment, wherein the authors used similar methods. Conversely, reports of nonhelmeted settings have shown superior performance of the pocket mask over the bag-valve mask. We suspect the 2-person approach used in our study may have contributed to the greater volumes achieved with the bag-valve mask. In the 2-person scenario, the participant was responsible only for creating a seal over the simulator’s mouth; in the 1-person scenario, the participant had to both seal the mask and provide ventilations. The ability to focus only on creating an airtight seal may confer a major benefit to ventilation quality.

**Limitations**

A primary limitation to our study is the controlled environment in which it was conducted. All of the emergency scenarios were staged and participants were prepared for each scenario with the initial primary survey findings. Although this study represents a basic level of simulation, more intensive simulation would be open ended and supply participants with less information before initiating a patient care simulation. Given that orientation and practice do not typically occur in the period immediately preceding a cardiac arrest, our participants’ performance may be superior to what could be expected in a real-life setting. The patient simulator approximates an injured athlete, yet differences in the overall body size, texture of skin, and resistance and shape of the jaw limit ecologic validity. Nevertheless, even in this ideal setting, differences in CPR quality across conditions were stark, with medium to large effect sizes for several comparisons despite the relatively large variability in some of our compression (percentage correctly released and percentage with optimal depth) and ventilation (ventilation volume and percentage achieving optimal volume) variables. It is unclear to our scientific team why we observed large variabilities in these measures, but they may reflect participants’ previous experience and training. Additionally, future authors should explore group differences (eg, skilled rescuers versus beginners) as well as training effects (eg, pretraining versus posttraining) to better understand the broader picture of emergency care for athletes in equipment-intensive sports.

Equipment constituted another possible limitation, as we included only 1 type of shoulder pad and 1 helmet-and-facemask combination. Men’s lacrosse equipment is manufactured by several companies. The equipment we used in this study had technical and design features consistent with equipment common in men’s lacrosse. Importantly, we did not require participants to remove equipment and thus cannot comment on the time it takes to remove shoulder padding or the helmet. The trade-off between minimizing time to CPR initiation and maximizing CPR quality requires more in-depth exploration. Lastly, our examination of ventilation quality was limited to 2 popular methods of establishing airway access in emergency athletic training settings and does not represent all possible airway adjuncts that may be available to ATs. Previous researchers found that alternative airway adjuncts, such as standard endotracheal intubation and a laryngeal mask airway, are viable options for establishing airway access in helmeted athletes, though it is unclear if the chinstrap was left in place while using these adjuncts. Because the chinstrap resulted in lower ventilation volumes, it is possible there were more attempted ventilations than we could record with the simulator (ie, ventilations below the threshold of 50 mL were not counted by the instrument). Future investigations would be improved by video recording the ventilation attempts to determine the frequency of ventilations that fail to reach the simulator’s detection threshold.

**CONCLUSIONS**

Our results suggest that chest compressions and ventilation delivery were compromised during equipment-laden conditions in men’s lacrosse. In the case of suspected sudden cardiac arrest in a men’s lacrosse athlete, the shoulder pads should be lifted or cut away to expose the chest before delivering chest compressions. Additionally, the facemask and chinstrap should be removed to access the airway and deliver maximal-quality ventilations. Lastly, a bag-valve mask with 2 responders resulted in higher-quality ventilations as compared with a 1-person pocket mask; thus, a bag-valve mask should be used if available.

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