Facemask removal (FMR) is essential when potential cervical spine injuries occur in athletes wearing helmets. Used football helmets produce high failure rates of screw removal; however, research on lacrosse helmets is lacking. This study aimed to determine the frequency of FMR failure in lacrosse helmets worn at least 1 season. The authors collected used helmets from 4 colleges (n = 172) and 4 high schools (n = 133). A trial consisted of removing all screws (N = 1215) securing the facemask to the helmet shell using a cordless screwdriver. FMR failure rates were calculated with 95% confidence intervals (CI). Facemask removal failed in 68 of 305 helmets (22.3% [95% CI, 17.0-27.59]), whereas 96 of 1215 individual screws failed (7.9% [95% CI, 6.32-9.48]). On the basis of these results, athletic trainers should have a secondary cutting tool immediately available, and they should perform routine helmet checks throughout the season to identify faulty hardware. [Athletic Training & Sports Health Care. 2014;6(2):90-96.]

The helmet of a potential cervical spine–injured football or ice hockey athlete should remain in place, unless cervical immobilization is compromised or access to the airway is unavailable.1 Because the helmet removal process is complex, leaving the helmet in place may reduce the chances of further cervical movement, which may occur during helmet removal.2 Thus, facemask removal (FMR) is necessary to gain access to the athlete’s airway should rescue breathing be required. Health care professionals responsible for emergency care of athletes should be familiar with the equipment of their particular sport and the tools required to gain access to the airway should catastrophic injury occur.1

The majority of previous research evaluating the effectiveness of FMR tools has been completed on football helmets.3-11 Although studies suggest helmet removal as the standard of care for the potential cervical spine–injured lacrosse athlete,12,13 1 study recommends that the facemask of lacrosse helmets should be left in place to reduce cervical motion.14 Other research has shown that the amount of head motion inside a lacrosse helmet is similar to that of football and ice hockey helmets, thus supporting immobilization with the helmet left in place.15 The National Athletic Trainers’ Association position statement for the cervical spine–injured athlete1 states that health care professionals may elect to leave lacrosse equipment in place as long as an airway can be secured because it is unknown how much cervical movement occurs during equipment removal. However, the helmet and shoulder pads may need to be removed if a neutral cervical alignment cannot be maintained.1 Therefore, a consensus has yet to be reached on how to care for the potential cervical spine–injured lacrosse athlete wearing a helmet. Furthermore, lacrosse has been identified as one of the fastest growing sports in North America,16 thus raising levels of concern about FMR techniques for lacrosse helmets. Although cata-
Facemask Removal

The injury rates for men's lacrosse athletes are lower than those of football athletes, 15 high school lacrosse athletes and 11 collegiate lacrosse athletes have sustained such injuries between 1983 and 2011. Therefore, research studying FMR techniques for lacrosse helmets is warranted.

Health care providers are able to complete the task of FMR from football helmets and lacrosse helmets more quickly and easily using a cordless screwdriver, compared with popular cutting tools. Although a pruner removed the facemasks from lacrosse helmets in a manner similar to the cordless screwdriver, the time difference could be clinically significant. For these reasons, emergency response personnel should attempt FMR with a cordless screwdriver first for a facemask secured with screws before considering other tools. Screws and, in most cases, plastic loop straps are used in lacrosse helmets to attach the facemasks to the helmet shells. However, the top connection point of the facemask is often secured by a screw only (ie, there is no loop strap) and requires removal to allow for airway access. Screw removal failure for various reasons has been identified in several studies, especially in used football helmets. Failure rates for FMR using a cordless screwdriver on used football helmets have been reported to be as high as 17.6% and 16%, requiring health care professionals to be prepared with a backup cutting tool. It remains unknown whether helmet use alters FMR techniques for lacrosse helmets due to t-nut spinning, stripped screws, foreign substance embedded into screw heads, or rust. Therefore, the purpose of the current study was to evaluate the effectiveness of using a cordless screwdriver to remove facemasks from lacrosse helmets that had been worn for at least 1 season of play by determining the frequency of FMR failure.

METHOD

A cross-sectional design was used to determine the failure rate of facemask removal using a cordless screwdriver from helmets worn for at least 1 full season of play. After approval by the institutional review board of the host institution, e-mails inviting participation in the study were sent to the athletic trainers at high schools and colleges in the southern United States that sponsor male lacrosse. From these e-mails, we successfully recruited 10 certified athletic trainers from 4 colleges and 4 high schools in North Carolina and Virginia to complete this research (Table 1). We collected data on used helmets that the athletic trainers acquired from their institution's lacrosse coach or athletic director.

### Table 1

<table>
<thead>
<tr>
<th>INSTITUTION</th>
<th>MEN</th>
<th>WOMEN</th>
<th>YEARS CERTIFIED</th>
<th>LACROSSE EXPERIENCE (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school</td>
<td>2</td>
<td>2</td>
<td>12.00 ± 6.36</td>
<td>6.40 ± 8.20</td>
</tr>
<tr>
<td>College</td>
<td>3</td>
<td>3</td>
<td>8.08 ± 6.05</td>
<td>1.83 ± 1.47</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>5</td>
<td>9.86 ± 6.22</td>
<td>3.91 ± 5.80</td>
</tr>
</tbody>
</table>

Data collection occurred in an open area (typically the athletic training clinic) at either the host institution or the institution providing the helmets. The recruited athletic trainers signed informed consent and completed a demographic form. The athletic trainers participating performed facemask removal using a cordless screwdriver (Ryobi model #HP41LK; Ryobi Technologies Inc., Anderson, South Carolina) on each used helmet. The lead investigator (T.G.B.) properly fitted all helmets and chinstraps to an individual serving as a model simulating an injured athlete lying supine. The model was given instructions not to speak or move. The participants positioned themselves with the helmet between their knees to stabilize the model's head and minimize motion of the helmet and cervical spine during FMR. This position was selected to simulate the worst case scenario of a single rescuer stabilizing the head and removing the facemask simultaneously.

An athletic trainer from the institution providing the used helmets performed the FMR trials. We collected data at 1 college and 1 high school in consecutive years because a different athletic trainer performed the second round of data collection due to a different staff member covering men’s lacrosse the second season. Before the first FMR trial began, 2 of the authors (T.G.B., J.A.C.) instructed the athletic trainers about how to perform FMR with the cordless screwdriver.
for each helmet and allowed him or her time to become acquainted with the task. During this time, the lead investigator allowed the participants to inspect the helmets and to practice FMR using the cordless screwdriver to ensure that they understood the procedure.

Data collection was started only after the participants understood how to remove the facemasks from the helmets. We used a standard stopwatch (Sportline; EB Sport Group, Yonkers, New York) to time each facemask removal trial. A trial started when the participant picked up the cordless screwdriver and it stopped when the participant removed the facemask from the helmet. One trial consisted of removing either 3 (n = 155 helmets; Figure 1) or 5 (n = 150 helmets; Figure 2) screws, depending on the helmet style. The screwdrivers were fully charged before the start of each data collection session and were adjusted to the maximum torque setting. If more than 25 trials were attempted during a single data collection session, an additional fully charged cordless screwdriver was used after the 25th trial. Participants who removed the facemasks of more than 15 helmets during 1 data collection session were required to rest for 5 minutes before resuming.

The brand and model of each helmet, the location of each screw removal failure and success, and the reason for each screw failure (eg, t-nut spinning, the screw being fused to the t-nut because of corrosion, a stripped screw, or another reason) were recorded. The lead investigator verified every unsuccessful trial by attempting to take out the screws that failed removal and documented the reason for each screw failure. The athletic trainer who performed the trial rated the ease of using the cordless screwdriver on a 5-point Likert scale (0 = extremely hard, 5 = extremely easy) at the end of each trial. Some helmets of 1 high school (n = 49) and 1 college (n = 7) had been reconditioned prior to the start of the spring season of play that directly preceded data collection. All remaining helmets used for data collection received maintenance on an as-needed basis but had never been sent to a refurbishing facility.

We also collected samples of 2 screws and 2 t-nuts from each helmet style encountered during each data collection session for subsequent metallurgical analysis. The hardware samples were sent to the New Hampshire Materials Laboratory Inc (Somersworth, New Hampshire) for a full chemical composition analysis, using inductively coupled plasma spectroscopy (SpectroFlame M120E spectrometer; Spectro Analyticals, Kleve, Germany) to determine the materials used to construct each piece of hardware. All of the hardware we encountered (screws and t-nuts) were composed of carbon steel, regardless of color, except those from 1 helmet, which were stainless steel and silver.
Black screws had zinc plating, with subsequent chromate finish for added corrosion resistance.

**Statistical Analysis**
Demographic data were gathered for each helmet, including the number of weeks it was worn during practice and the number of games it was worn, and the facemask removal failure rate and the screw removal failure rate was calculated with 95% confidence intervals (CIs) using Microsoft Excel, 2007 version (Microsoft Corp, Redmond, Washington). We also used Excel to calculate the failure rates for each screw location, each failure reason, and the metallurgical composition with 95% CIs and a failure ratio between the 5- and 3-screw helmet models.

**RESULTS**
Data were collected on a total of 305 helmets (average seasons worn = 2.00 ± 0.88, average number of games worn = 30.89 ± 13.73, average weeks of practice worn = 29.26 ± 16.45). Table 2 shows the helmet styles used in this study. For helmets requiring the removal of 3 screws, participants completed FMR in 24.70 ± 7.75 seconds on average, whereas removal of 5-screw facemasks took an average time of 57.66 ± 23.37 seconds. Participants gave the cordless screwdriver an ease of use score of 4.15 ± 1.04 of 5.

The failure rates and 95% CIs are shown in Table 3. We found an overall facemask removal failure rate—failure of at least 1 screw—of 22.3% (95% CI, 17.0-27.59), as facemask removal failed on 68 of 305 helmets. Ninety-six of 1215 individual screws failed to be removed, for a failure rate of 7.9% (95% CI, 6.32-9.48). The majority of the screw failures occurred due to spinning of the t-nut (83 of 96, 86.46% [95% CI, 67.86-100]). Most screw failures occurred at the lateral location of helmets with 3 screws (27 of 155, 17.42%, [95% CI, 10.89-23.99]; Figure 1) and at the bottom positions of the helmets with 5 screws (53 of 300, 17.67% [95% CI, 12.91-22.42]; Figure 2). Of 1215 total screws, 1002 were black (82.47%) and 213 were silver (17.53%). Eighty-six zinc-plated (black) carbon steel screws could not be removed (8.58% [95% CI, 6.77-10.44]), and only 6 carbon steel screws without zinc plating (silver) could not be removed (2.82% [95% CI, 0.56-5.07]). Three silver stainless steel screws were removed successfully. Helmets with 5 screws were more likely to fail than helmets with 3 screws, for a failure ratio of 2.31 (95% CI, 1.38-3.86), and zinc-plated screws were more likely to fail than those without plating, resulting in a failure ratio of 3.02 (95% CI, 1.32-6.9).

**DISCUSSION**
The mean facemask removal time using the cordless screwdriver in the current study (39.03 ± 23.20 seconds) is within the range of times reported in the literature for lacrosse (32.32 seconds) and football helmets (34.1 to 68.8 seconds). Ease of cordless screwdriver use score in the current study (4.15 ± 1.04) is also similar to previous research (4.94 ± 0.30). We discovered a larger FMR failure rate—22.3%—compared with 17.6% and 16% but a similar screw removal failure rate (7.6% versus 6%, 7%, 8%, and 9.16%) compared with results examining facemask removal with a cordless screwdriver from used football helmets. Due to the high failure rates in the current study, we agree with previous authors who recommended that athletic trainers should carry a backup cutting tool to remove the facemask of lacrosse helmets when screw removal fails. Previous work has suggested that pruners should be the backup tool for lacrosse helmet FMR, based on speed of removal.

In the current study, the most common reason for screw removal failure was spinning of the t-nut. T-nut spinning occurred in 86.46% of the failures in the current study, compared with 71.7% reported previously with football helmets. Of note, the company providing refurbishing services of helmets obtained from 1 high school (n = 49) placed washers between the t-nuts and the helmet shell at the bottom-screw position, but the refurbished helmets worn by col-
college lacrosse athletes (n = 7) did not have such washers. When trying to remove the screws with washers, the t-nut spun easily due to a lack of friction between the t-nut and the washer, leading to a failure rate of 23.47% (23 of 98). We found no failures at the other screw locations for these helmets and believe the washers were the cause of the high failure rates. Washers should not be used between t-nuts and the helmet shell to reduce the possibility of t-nut spinning when screw removal is attempted. Football helmet manufacturers
have introduced a molded t-nut wall\(^3\) into the inside of the helmet shell to prevent t-nut spinning when the screw is turned. Lacrosse helmet manufacturers should consider adding a similar feature to help prevent t-nut spinning.

Most of the screw failures (55.21%) occurred at the bottom position of the helmets with 5 screws. These positions are just posterior and inferior to the ears where the chin guard is attached to the helmet shell. As discussed, we believe the findings at this position were likely due to the high failure rate found with the refurbished helmets with washers placed between the helmet shell and the t-nuts. An additional 37.5% of the screw failures occurred at the lateral location of the facemask where it is attached to the helmet shell laterally and inferiorly to the athletes’ eyes. This screw location occurs in helmets with both 3 and 5 screws. These results are similar to those found in previous studies.\(^5\)\(^,\)\(^21\) We believe these screw positions are most vulnerable to corrosion from sweat, rain, and water from the athlete drinking during games and practices because of their location (Figures 1-2). Further, blows to the facemask may cause the helmet to bow outward, stressing these lateral attachments and potentially altering FMR. Of importance, 7 of 96 (7.29%) screw removal failures occurred at the top of the helmet at the visor location. In several popular helmet models currently on the market, screw removal is required at this location, as no loop strap exists or the loop strap is in a location that does not allow for cutting. Although the overall failure rate for the visor screw was low, the athlete’s helmet would need to be removed if screw removal fails because a cutting tool cannot be used due to its location. Helmet manufacturers should consider altering the attachment of the facemask to the helmet shell at the top position of the visor to allow for FMR if screw removal fails due to the risk of altering spinal stabilization when the helmet is removed.

After inspection of 2 pieces of hardware from each helmet type by an independent laboratory to determine their metallurgical composition, almost all of the helmets encountered (n = 304) had screws and t-nuts constructed of carbon steel. However, stainless steel is more resistant to rust corrosion than carbon steel\(^9\) and previous authors have recommended encouraging the use of stainless steel hardware only.\(^22\) Future research should determine the best hardware materials to use in helmets based on the resiliency of the metallurgical properties to water exposure and extreme cold or hot temperatures.

**LIMITATIONS AND FUTURE DIRECTIONS**

All of the helmets from which we collected data came from the same geographic location (southern United States). Significant differences have been found for FMR from football helmets of 5 different geographic locations, with the highest failure rates found in the northeastern and southern US regions.\(^9\) Using the geographic classifications of that previous study,\(^9\) all the helmets used in the current study came from the southern US region. Screw corrosion can be accelerated by profuse sweating, humidity, and temperature changes, among other factors, possibly leading to higher screw failure rates, particularly in the southern US region. Perhaps screw removal failure rates would be different for lacrosse helmets from different regions. Also, the helmets in our study came from schools whose personnel volunteered to participate. The participating athletic trainers were familiar with the equipment and FMR techniques. It is possible that these schools devoted more than average attention to their equipment maintenance. We do not suspect that the condition of the equipment was substantially worse than that typically worn. Also, the age of the helmet was self-reported by an equipment manager, the lacrosse coach, or the athletic director. Although we do not believe the age of the helmet was reported inaccurately, this is a possibility. We also believe that the helmets the participants acquired were not selected based on how they were expected to perform in the study. To our knowledge, we tested all of the helmets used at a particular institution. However, it is possible that some helmets were not made available. Finally, some of the helmets we encountered had been refurbished prior to the start of the previous season. It is possible that our results may have been different, especially for those helmets with washers installed, had they not been refurbished.

Future research should continue to determine a standard of care for the potential cervical spine–injured helmeted lacrosse athlete. Cervical alignment while wearing different combinations of lacrosse helmets and shoulder pads should be examined, as cervical alignment should be maintained during immobilization.\(^1\) Head motion inside a lacrosse helmet has been found to be similar to head motion that occurs inside football and ice hockey helmets, suggesting that cervical immobilization should occur with the lacrosse helmet in...
place. However, because poor helmet fit appears to be a problem in men’s lacrosse, the ability of lacrosse helmets to adequately immobilize the cervical spine should continue to be determined. The movement that occurs in the cervical spine while removing lacrosse equipment should also be studied. If equipment removal results in movement of the cervical spine, leaving the equipment in place may be the most appropriate action. Finally, cervical movement created by FMR of lacrosse helmets should be quantified, as motion would be counterproductive to maintaining neutral cervical alignment.

IMPLICATIONS FOR CLINICAL PRACTICE

Based on the results of the current study, the use of a cordless screwdriver only to perform facemask removal on used lacrosse helmets is unreliable. We recommend that athletic trainers carry a cordless screwdriver as well as a cutting tool in case FMR is required and the cordless screwdriver fails. Practice sessions should be held regularly to identify an appropriate backup cutting tool that will allow for prompt FMR should catastrophic injury occur. Health care providers should remain familiar with the lacrosse helmets on the market, as design modifications frequently alter FMR. We encourage lacrosse helmet manufacturers to consider the implications that design modifications have on FMR as football helmet manufacturers have done. Helmets should be inspected frequently by an equipment manager or athletic trainer to identify hardware that impedes FMR or conditions that may make FMR difficult with a cordless screwdriver. Subsequent helmet maintenance should ensure that screws securing the facemask to the helmet shell are properly functioning to allow quick and efficient FMR. Finally, emergency personnel should gain and maintain experience with equipment removal should FMR fail.

REFERENCES