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The Combined Tool Approach for Face Mask Removal During On-Field Conditions

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Context: An effective approach to emergency removal of the face mask (FM) from a football helmet should include successful removal of the FM and limitation of both the time required and the movement created during the process. Current recommendations and practice are to use a cutting tool to remove the FM. Researchers recently have suggested an alternate approach that combines the use of a cordless screwdriver and a cutting tool. This combined tool approach has not been studied, and FM removal has not been studied in a practical setting.

Objective: To investigate the effectiveness and speed of using a combined tool approach to remove the FMs from football helmets during on-field conditions throughout the course of a football season.

Design: Randomized multigroup design.

Setting: Practice field of 1 National Collegiate Athletic Association Division II football college.

Patients or Other Participants: Eighty-four members of 1 football team.

Intervention(s): We used a battery-operated screwdriver for FM removal and resorted to using a cutting tool as needed.

Main Outcome Measure(s): We tracked FM removal success and failure and trial time and compared results based on helmet characteristics, weather variables, and the seasonal timing of the removal trial.

Results: Of the 84 players, 76 were available for data-collection trials. Overall, 98.6% (75/76) of FM removal trials were successful and resulted in a mean removal time of 40.09 ± 15.1 seconds. We found no differences in FM removal time throughout the course of the season. No differences in effectiveness or trial time were found among helmet characteristics, weather variables, or the timing of the trial.

Conclusions: Combining the cordless screwdriver and cutting tool provided a fast and reliable means of on-field FM removal in this Division II setting. Despite the excellent overall result, 1 FM was not removed in a timely manner. Therefore, we recommend that athletic trainers practice helmet removal to be prepared should FM removal fail.

Key Words: football injuries, protective equipment, emergency management, cervical spine, airway access

Key Points

- The combination of the cordless screwdriver and cutting tool quickly and reliably enabled on-field face mask removal.
- A total of 98.6% of face masks were removed successfully with the combined tool approach.
- Athletic trainers should use the cordless screwdriver as the primary tool for face mask removal and should carry an appropriate backup cutting tool for use if the screwdriver fails.

The face mask (FM) of a football helmet is a barrier to airway treatment in the emergency management of an injured football athlete. However, researchers[1–3] have reported that spinal alignment can be disrupted if the football helmet is removed without the concurrent removal of the shoulder pads. Therefore, the Inter-Association Task Force for the Appropriate Care of the Spine-Injured Athlete[4] (IATF) recommended that, to gain access to the injured athlete's airway, the rescuer should remove the FM from the helmet before transporting the athlete to the hospital. The IATF further recommended that the best FM removal tools should limit the time required for, and movement created during, the FM removal process. Because quick management is essential in respiratory emergencies and limitation of head and neck movement is imperative when addressing a potential injury to the spine, these 2 elements of FM removal are critical performance factors. Recently, researchers[5,6] investigated several FM removal techniques, including the use of various cutting tools. Their results indicated that cutting tools did not always enable successful FM removal within a clinically reasonable amount of time (4 minutes or less)[5,6] and that cutting tools could fail.[6] Furthermore, compared with data reported for a manual[7] and a cordless screwdriver (CSD),[6,8] data from research on cutting tools have demonstrated longer removal times,[5,6,9,10] increased difficulty for the rescuer removing the FM,[6] more torque placed on the helmet,[10] and significantly more helmet movement created during the task.[6,9,11] Based on its superior performance in those studies, the CSD appears to be a better FM removal tool than the manual screwdriver and cutting tools that have been tested to date.

However, before 2004, research on FM removal was limited to laboratory-based settings where new football equipment was used, and it left the reliability of employing the CSD on used equipment in question. Since then, researchers[8,12] have investigated the failure rate for CSD FM removal in used football equipment. Those studies revealed significantly different screwdriver effectiveness among football teams, with the best results for successful

FM removal as high as 90% to 100% and the worst results as low as 47%.[12] Because excellent results are possible with the CSD and because use of the CSD can limit time and limit head and neck movement, Swartz et al[12] and Decoster et al[8] recommended a combined tool approach for emergency FM removal. In this approach, the CSD is the athletic trainer's primary tool for FM removal, and an appropriate backup cutting tool is immediately available for use in case of CSD failure. No one has investigated or validated this combined tool approach. In addition, no one has investigated FM removal during on-field situations with athletes.

Therefore, the primary purpose of our study was to investigate the effectiveness (FM removal success or failure) and speed (time to complete the task) of a combined tool approach to removing the FMs from football helmets during on-field conditions throughout the course of a football season. Information relative to helmet brand, helmet model, hardware components (screw and loop-strap types), and weather conditions (temperature and humidity) was collected to enable further exploration, when appropriate, of the relationship with FM removal success and time. We developed 3 research hypotheses to guide the statistical approach: (1) Frequency of FM removal failures and the mean times to complete FM removal would increase as the season progressed. (2) Differences in FM removal failure and time to complete FM removal would exist between selected helmet characteristics. (3) No relationship would exist between the success of FM removal or time to complete FM removal and the dry-bulb temperature or percentage of relative humidity during the removal attempt.

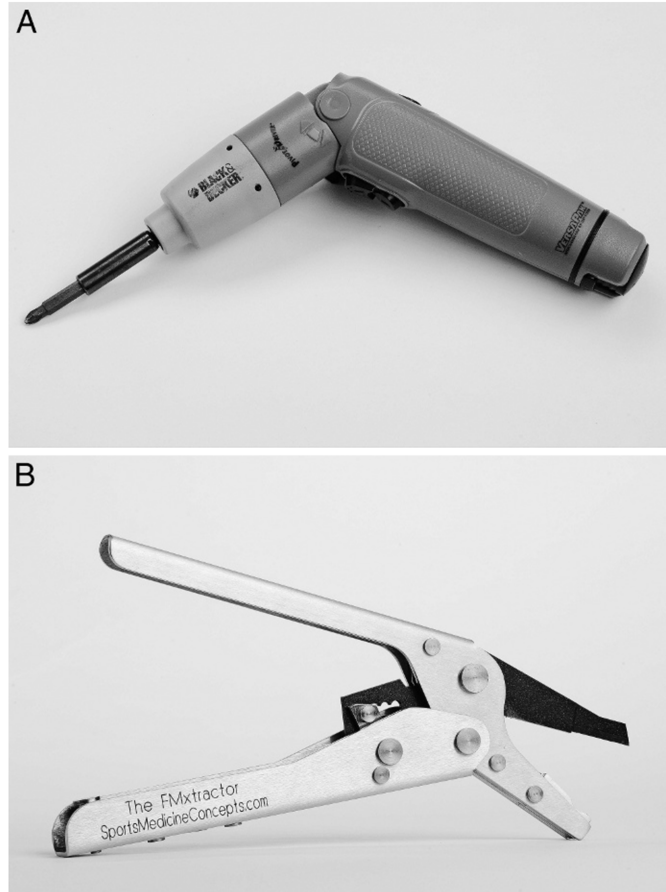


Figure 1. Removal tools. A, Cordless screwdriver. B, Cutting tool.

METHODS

Participants

The subject pool included 84 National Collegiate Athletic Association Division II football players from 1 team at a local New England college; however, only 76 players (90.5%; age = 19 ± 1.2 years, height = 182.7 ± 6.3 cm, mass = 96.7 ± 14.5 kg) were available for data collection. Before the first practice, participants signed an informed consent form. We set no other specific inclusion or exclusion criteria for participation in the study. The study was approved by the college's institutional review board.

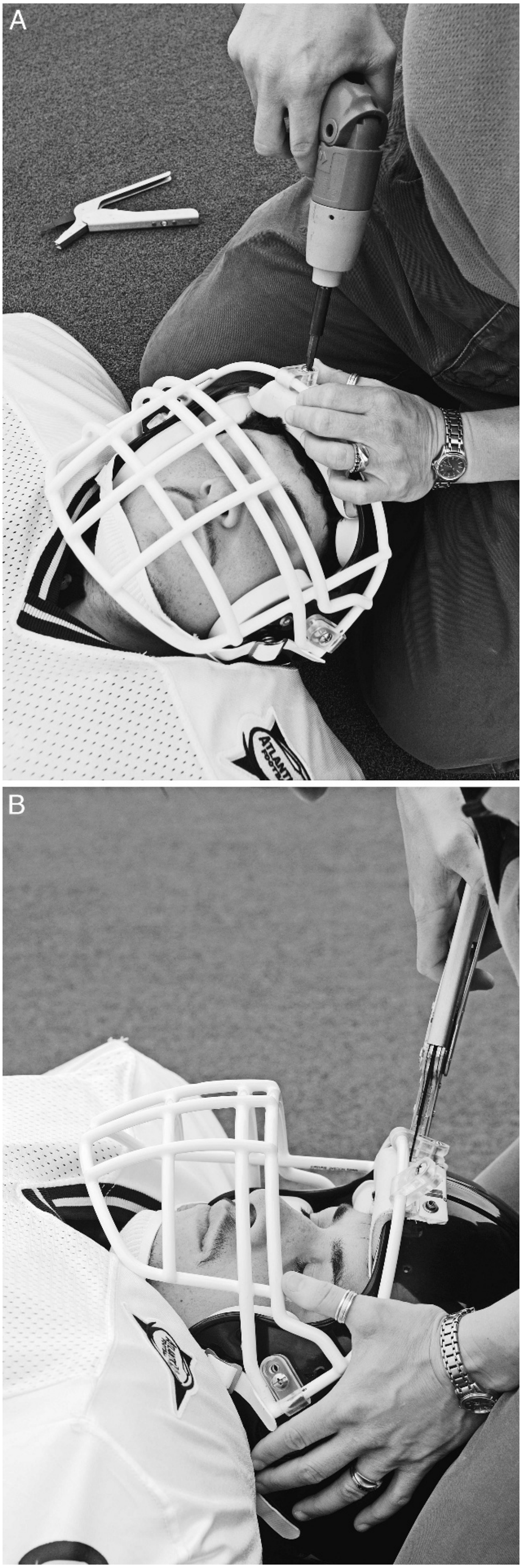
Instrumentation

An SP100FR sling psychrometer (Mannix Testing and Measurement, Chicago, IL) was used to measure wet-bulb and dry-bulb temperature and relative humidity on each day of data collection. One rechargeable, battery-operated CSD (3.6-V pivot driver; Black & Decker, Towson, MD) was used for all FM removal trials (Figure 1A). One screwdriver battery was used throughout the study, and it was stored in a charger between data-collection sessions, resulting in a minimum of a 6-day charge before each session. We used the Phillips head bit that was packaged with the CSD. An FMxtractor (FMX; Sports Medicine Concepts, Inc, Geneseo, NY) that was new before the start of data collection was the cutting tool used in all trials where the CSD failed to remove all loop-strap screws (Figure 1B). A digital stopwatch was used to time all trials.

Testing Procedure

The football team's season began August 11, 2005, and ended November 5, 2005, resulting in a total of 12 separate weeks for data collection. Before the start of the season, we used a computer-generated list (version 3.0; Research Randomizer, Middletown, CT) to randomly assign all participants to a testing date during 1 of the 12 weeks of the season. Beginning with the first practice and ending the last week of the season, 2 investigators traveled once each week to the football practice field to collect environmental data and attempt FM removal on players assigned to that week. Recorded environmental data included wet-bulb and dry-bulb temperature and percentage of relative humidity. To obtain the temperatures, the primary investigator used the sling psychrometer according to the manufacturer's instructions. Percentage of relative humidity was determined according to the scale provided by the manufacturer.

Following environmental measurements, the first subject assigned to that day of data collection was identified and invited into the data-collection area. The investigators recorded individual helmet demographics (helmet brand, helmet brand, screw color, and loop-strap type) and subject demographics (age, height, mass, year in school, and football position). Participants were instructed to lie motionless and not to resist or assist motion at the head



or neck during the data-collection procedure. Each player then assumed a supine position on the ground with his arms by his sides or clasped across the abdomen and with his legs extended in readiness for the beginning of the trial.

The primary investigator (S.D.G.) performed all removal trials from a position behind the subject's head while maintaining stabilization with her knees (Figure 2A). The CSD and FMX were placed on the ground to the right of the investigator. Each trial was timed with a digital stopwatch by a second investigator. Timing started when the primary investigator picked up the CSD and stopped when the FM was removed completely from the helmet. The primary investigator used the same removal order for each helmet: she removed the screw securing the FM loop strap (1) near the right ear, (2) near the left ear, (3) at the right forehead, and (4) at the left forehead. After those 4 CSD attempts were completed, if 1 or more of the 4 screws had not been removed successfully, the FMX was used to cut away the loop strap or straps associated with the screw or screws that could not be removed (Figure 2B).

Following each trial, data for successful or failed removal and for completion time were recorded. The next subject was invited to the data-collection area, and the procedure was repeated until data on all participants and trials for that day were collected. Upon return to the office, we entered and stored the trial data on a computer-based spreadsheet (Excel 2003; Microsoft Corp, Redmond, WA).

Operational Definitions

A trial was classified as a success if the FM was removed completely with the CSD or through the combined use of the CSD and the backup FMX within 3 minutes. If the FM could not be removed, we classified the trial as an overall failure. The use of the 3-minute time limit represents a slight departure from previous research[6] in which a 4-minute maximal trial time was used. We decided to reduce the allowed trial time after considering the time required to respond to an injured athlete on the field, perform an assessment, and perhaps roll the athlete into a supine position before actually starting the process of FM removal. Because 4 minutes represents a marker when permanent brain damage may occur in an anoxic individual, we believed that the time available for FM removal actually would be less than 4 minutes.

In addition, when we encountered individual screw removal failures, we classified the reasons for those failures. Specific reasons for failure at individual screw sites included the following categories: (1) screw stripped (damage was pre-existing or was caused when the CSD did not turn the screw and stripped the screw head[8] during the trial), (2) T-nut spinning (the CSD caused the screw head to turn but did not loosen the screw from the underlying T-nut on the inside of the helmet),[8] (3) screw stuck (the CSD failed to turn the screw or T-nut), and (4) other (foreign substances were embedded in the screw head).

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Figure 2. Face mask removal procedure. A, The researcher first attempted to remove all 4 screws with the cordless screwdriver. B, If 1 or more of the screws could not be removed with the cordless screwdriver, the cutting tool was used to complete face mask removal.

Statistical Analysis

At the completion of the study, data were transferred to SPSS (version 13.0; SPSS Inc, Chicago, IL) for analysis. The independent variables included helmet (helmet brand, helmet model, screw color, loop-strap type) and environmental (dry-bulb temperature and percentage of relative humidity) characteristics. Helmet-characteristic data were transformed into nominal values for inclusion in statistical analysis. Two dependent variables were included in the statistical analysis: (1) success or failure of FM removal and (2) time to completion of FM removal. The overall success or failure of FM removal and the failure of the CSD for each of the 4 categories were transformed into nominal values for inclusion in statistical analysis. We created frequencies for overall success and failure of FM removal and the failure of the CSD for each of the 4 characteristics. Means (±SDs) were calculated for the removal time for each week of data collection and for the overall season. We used univariate analysis of variance (ANOVA) to test for differences in time for removal among each of the weeks of the season, and we conducted post hoc Scheffé testing as necessary. Independent-samples *t* tests were used to detect differences in removal time between selected helmet characteristics. Pearson product moment correlations were used to examine relationships between removal time and the environmental characteristics. The α was set a priori at ≤.05 for all tests. The confidence interval (CI) was 95%.

RESULTS

The 76 helmets worn by the participants who completed the study included 50 Riddell VSR4 (Elyria, OH), 25 Riddell Revolution, and 1 Schutt Air (Litchfield, IL). Based on a report from the football coach, all helmets had been reconditioned before the start of the season, and all screws (n = 304) were stainless steel. A variety of equipment-appropriate loop straps were encountered.

The participants included 33 freshman, 15 sophomore, 17 junior, and 11 senior players who participated in the following positions: center (2), cornerback (1), defensive back (9), defensive end (6), defensive line (2), defensive tackle (6), kicker (1), linebacker (9), offensive line (13), quarterback (3), running back (6), safety (4), tight end (4), and wide receiver (10).

With the combined tool approach, the FM was removed successfully from 75 of 76 (98.6%) helmets. The FMs were removed successfully with the CSD from 70 of 76 (92.1%) helmets. In the 6 cases in which the FM was not removed with the CSD, only 1 screw failed per helmet. This created a screw failure rate of 2.0% (6 of 304 total screws). Of those 6 screws that could not be removed using the CSD, 3 failed because of a foreign substance embedded in the screw head; 2 because of T-nut spinning; and 1 because of a stripped screw head. Of the 6 CSD failures, 5 of the 6 FMs were removed successfully with the backup FMX. One Riddell Revolution side loop strap could not be removed within the 3-minute time limit and represented the 1 overall trial failure. Other planned analyses to examine failure rates throughout the course of the season, and relationships those failure rates may have held with helmet and weather variables were not deemed appropriate because of insufficient failure episodes (n = 1).

Table. Time for Face Mask Removal(s)

Week	n	Time Mean ± SD
1	8	39.02 ± 11.58
2	9	37.70 ± 9.01
3	7	34.55 ± 8.71
4	6	31.87 ± 6.62
5	4	38.32 ± 4.05
6	6	49.88 ± 40.54
7	6	50.83 ± 19.32
8	7	46.94 ± 14.43
9	7	40.62 ± 7.30
10	6	38.67 ± 6.13
11	6	36.08 ± 6.36
12	3	34.36 ± 6.12
Total	75	40.09 ± 15.12

Mean removal time for the 75 FMs was 40.09 ± 15.12 seconds (range = 24.8–132.0 seconds, 95% CI = 36.70, 43.49). The mean FM removal times for each week are provided in the Table. The ANOVA results indicated no significant differences in mean FM removal time throughout the course of the season ($F_{11,74} = 0.991$, $P = .465$, effect size = 0.147, observed power = .492). The independent-samples *t* test indicated no significant difference in FM removal time between helmet models (VSR4 = 38.6 ± 16.8 seconds, Revolution = 43.6 ± 10.8 seconds; $t_{72} = -1.016$, $P = .131$). No other helmet demographic was deemed appropriate for further statistical comparison of removal time or failure. No significant correlations were found between time required for FM removal and relative humidity ($R = -0.141$, $P = .226$) or dry-bulb temperature ($R = 0.109$, $P = .352$).

DISCUSSION

The results of our study demonstrated that the combination of CSD and FMX provided a fast (mean = 40.09 seconds) and reliable (success = 98.6%) means of on-field FM removal in a Division II collegiate football team with no differences based on the timing of the removal attempt. Three research hypotheses were tested in this project: (1) Frequency of FM removal failures and the mean times to complete FM removal would increase as the season progressed. (2) Differences in failure to remove the FM and time to complete FM removal would exist among selected helmet characteristics. (3) No relationship would exist between the success of FM removal or time to complete FM removal and the dry-bulb temperature or percentage of relative humidity. Based on the analyses allowed by the data, the time elements of the 2 hypotheses were rejected, and the time element of the third hypothesis was accepted.

Success and Removal Time Over the Football Season

The primary objective of our study was to determine the success rate and time to complete FM removal using a combined tool approach during the course of a football season. During the development of this study, we suspected that time and success of FM removal might change over the course of the season as helmets were exposed to the environment and daily wear and tear. Our results did not support this supposition, and this hypothesis was rejected. However, the relatively small sample size combined with the very small failure rate prevented us from drawing strong conclusions about the effect of season progression on FM removal success. A larger sample with more failures might reveal different results. The lack of change in removal time over the season is a statistically stronger result. Because of the lack of differences, all success and time findings are considered as a whole for purposes of comparison to past literature in this discussion.

Results regarding the combined tool approach cannot be compared directly with previous research because investigations into this technique have not been reported. However, the results for the success rate of FM removal for the CSD in our investigation can be compared with results reported in 2 previous studies. Our removal success rate (92.1%) for the CSD is similar but superior to the overall results obtained by Decoster et al[8] (82.4%) and Swartz et al[12] (84%), who reported data collected from used high school helmets. The origin and makeup of the samples in those studies were quite different from the samples in our study; in both of the previous studies, multiple teams were included in the analyses, and comparison of the individual team results indicated significant differences among teams. Compared with our single college team, some of the high school teams previously tested had inferior removal success rates (as low as 47%), some had similar rates, and some had superior rates (up to 100%).[12] In those earlier studies, a larger, more heterogeneous sample of helmet brands and models and a greater variety of metal hardware components were encountered. Authors[8,12] from both studies suggested that the differences in metal composition of the screws and T-nuts encountered in their samples were likely important factors in the disparity found in removal success rates. In our study, the metal hardware was the same in all helmets.

Regardless of tool, technique, or approach, the time required to remove the FM is a critical element of our study that can be compared with previous research. Our mean combined tool removal time (40.09 ± 15.12 seconds, 95% CI = 36.70, 43.49) was at the faster end of CSD removal times reported by Swartz et al,[6] who noted that means for various combinations of helmet and hardware ranged from 42.1 seconds to 68.8 seconds. The mean CSD removal time reported by Decoster et al[8] (26.9 seconds) was faster than our time. However, the authors[8] theorized that conditions better representing real-life situations might increase the time required to remove the FMs. Therefore, times in our study may better represent actual FM removal times because we collected the data on athletes during the season. Our results for the time to remove the FM in the combined tool trials are also faster than previously reported times in cutting-tool trials. According to Swartz et al,[6] the mean time required to remove the FM using the original FM Extractor (Sports Medicine Concepts, Inc) ranged from 63.08 seconds to 203.33 seconds. In a 2003 study, Swartz et al[5] found the following mean (±SD) times for FM removal using various cutting tools: anvil pruner = 96.2 ± 41.6 seconds, polyvinyl chloride pipe cutter = 155.9 ± 63.8 seconds, and Trainer's Angel (Trainer's Angel, Riverside, CA) = 102.2 ± 39.8 seconds. Clearly, FM removal times using the CSD or the combined tool approach are considerably faster.

Although the overall success rate of this combined tool approach was higher than any other reported in the literature, it was still not 100% successful. Swartz et al[12] showed that 100% removal success was possible in subpopulations, but we found that failure was still possible. Therefore, we agree with previous recommendations[8,12] that athletic trainers should use a CSD as their primary tool for FM removal and use a backup cutting tool if the CSD fails to remove the FM. However, we further recommend that athletic trainers should practice helmet removal to prepare themselves in case that becomes necessary.

Success and Removal Time Based on Helmet Characteristics

Our second hypothesis also was rejected because no difference existed in the success rate or time needed to remove the FM between 2 common models of football helmets. We had based this hypothesis on the results of previous studies[6,12] of heterogeneous samples that showed significant differences in FM removal success and time based on helmet brand, helmet model, loop-strap type, and metal hardware. The homogeneity of our sample did not enable us to make comparisons other than between helmet models. Consequently, although we rejected the second hypothesis, we drew this conclusion only for a comparison between 2 models of Riddell helmets; we could not make any conclusions regarding the effect of different helmet brands, loop-strap types, or screw types.

Although we hypothesized a difference in the time required to unscrew the FM from different helmet models, our failure to find one is not unique. In a previous study, Swartz et al[6] found no significant differences in the time required to unscrew the FM from different helmet models. In another study, the researchers[12] reported a moderate correlation between helmet brands and the success of CSD FM removal. Swartz et al[6] also reported differences in removal time and success with cutting tools among helmet brands. Importantly, a review of pertinent literature[6,8,12] shows that, regardless of helmet characteristics, even the longest mean times associated with CSD FM removal appear to be clinically acceptable. This provides support for the use of the CSD as a primary FM removal tool.

Success and Removal Time Based on Weather Characteristics

Differences in ambient weather conditions could have an effect on the ability to remove screws from the FM. For example, exposure to humid or rainy conditions might facilitate screw rusting or preclude proper function of the CSD. In our study, success rate or removal time appeared to have no relationship with the weather variables of dry-bulb temperature and percentage of relative humidity, leading us to accept our final hypothesis. We found no relationship between removal time and the environmental conditions studied. The only other research investigating weather considerations as they affect FM removal was retrospective,[12] and the authors looked at the cumulative effects of weather conditions over the course of a football season. The authors[12] theorized that the effects of differences in weather characteristics across 5 regions of the country could have a strong effect on FM removal. However, as in our study, they did not find a strong relationship between weather characteristics and FM removal.

Minimization of Movement

In addition to the effectiveness and time required to remove the FM, minimization of head and neck movement during the task is also an important consideration. Researchers have investigated the amount of movement or torque created during the process of both FM removal and retraction. Using various methods, Ray et al,[7] Knox and Kleiner,[9] Jenkins et al,[10] and Swartz et al[6] found that the CSD approach created less movement or torque than cutting techniques created. We did not analyze movement in the current study, but extrapolation from that previous research leads us to conclude that the combined tool approach created less movement than a pure cutting approach because the combined tool approach only required the use of a cutting tool for 6 of 304 loop straps.

Limitations

Because we tested the combined tool technique of FM removal in a practical, on-field setting, we did not have the luxury of choosing a research design with stronger controls for threats against internal validity. For example, to better control for potential confounding factors, such as differences encountered in helmet brands, helmet models, and hardware types, we would have had to assign participants prospectively into specific equipment groups. However, this presents a challenge in the football setting, where equipment worn by participants is chosen based on multiple factors, inhibiting external control. Furthermore, often throughout the season, the equipment that a participant is wearing is changed for a variety of reasons. Therefore, we tested participants on the date to which they were randomly assigned in the equipment in which they presented. This represented the actual position of an athletic trainer during a real-life situation. Although our chosen research design may have been susceptible to threats to internal validity, it had greater external validity than previous studies[5,6,12] performed in the laboratory setting.

Another clear limitation of this study was the small sample size and the resulting lack of generalizability to settings other than that of a Division II college football team using similar helmet brands and hardware and playing in the Northeast. The final limitation was related to the FM removal trials being performed by 1 investigator. Certainly an entry-level certified athletic trainer is qualified to perform this task, but, as previous research[6] suggests, the cutting task is more difficult for some athletic trainers than for others. The sole investigator was a recent graduate who had limited practice with the combined-tool approach (CSD and cutting tool). The use of multiple investigators performing the data-collection process on a more heterogeneous sample would further increase generalizability.

CONCLUSIONS

Our results demonstrated that the combination of CSD and FMX represents a fast and reliable means of on-field FM removal in this Division II setting. Based on the results of this and other studies, we recommend that athletic trainers use a CSD as their primary tool for FM removal and carry an appropriate backup cutting tool for use if the CSD fails. Finally, because even the combined tool approach may fail to remove the FM in a timely manner, we further recommend that athletic trainers practice the skill of helmet removal to prepare themselves in case they need to use it.

Future researchers should repeat the methods of our study with a larger and more heterogeneous sample. Further research efforts might be expended to attempt to improve current procedures and equipment or to identify a single emergency procedure that would enable the athletic trainer to successfully gain access to the athlete's airway quickly and with limited head and neck movement.

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Stephanie D. Gale, MEd, ATC, participated in conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Laura C. Decoster, ATC, and Erik E. Swartz, PhD, ATC, participated in conception and design; acquisition and analysis and interpretation of the data; and critical revision and final approval of the article.

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