

## Identification of Potentially Preventable Traumatic Injury Among Military Working Dogs Deployed During the Global War on Terror

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### ABSTRACT

**Background:** Prevention of deployment-related injury is critical for readiness of US military working dogs (MWDs). This study evaluated deployment-related injuries to determine if they were potentially preventable and identify possible abatement strategies. **Methods:** Data were collected on 195 MWD injury events that occurred between 11 September 2001 and 31 December 2018. Injuries were reviewed by a panel of veterinarians and categorized into groups based on panel consensus. The panel also established which interventions could have been effective for mitigating injuries. Multipurpose canine (MPC) and conventional MWD injury event characteristics were compared to identify meaningful differences. **Results:** Of the 195 injuries, 101 (52%) were classified as preventable or potentially preventable. Most (72%) of the potentially preventable injuries occurred in conventional MWDs, with penetrating injuries (64%) being the most common type of trauma. For the preventable/potentially preventable injuries, the most common preventative intervention identified was handler training (53%) followed by protective equipment (46%). There were differences between MPCs and conventional MWDs for injury prevention category, type of trauma, mechanism of injury, and preventative intervention (all  $p < .001$ ). **Conclusion:** The application of a preventable review process to MWD populations may be beneficial in identifying potentially preventable injuries and preventative intervention strategies.

**KEYWORDS:** military working dogs; traumatic injury; injury prevention, canine

### Introduction

Prevention of deployment-related injury is critical for the combat readiness of US military MWDs as they continue to serve alongside US Servicemembers, most recently throughout the Global War on Terrorism. Miller et al. estimated that over 2,000 MWDs were deployed in support of Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF).<sup>1</sup> Because MWDs face the same combat hazards as US Servicemembers, they are also at high risk of experiencing traumatic injury during deployment.<sup>2</sup> In one mortality study of US MWDs deployed during OEF/OIF, the majority of deaths (~77%) were due to traumatic injuries.<sup>1</sup> Despite being a leading cause of death, traumatic injury among US MWDs remains insufficiently investigated, which, in turn, hinders efforts to understand and prevent deployment-related injuries.

The existing literature on combat-related injury and death in the US Servicemember population offers an approach that can be used to investigate these same outcomes among US MWDs.<sup>3-11</sup> In 2017, the US Department of Defense (DoD) established a military trauma mortality review (MTMR) process to evaluate traumatic injury data and identify opportunities for improvement within the trauma care system, with the ultimate goal of achieving zero preventable deaths after injury.<sup>7,12</sup> Death preventability is considered an important metric, as it allows for the identification of areas that need improvement in trauma prevention and care. More notably, the concept factors in improvements for protective equipment, supply logistics, medical procedures, and other tactical issues that are essential

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for optimizing patient outcomes.<sup>12</sup> Furthermore, this MTMR process, which is based on the World Health Organization's and the American College of Surgeons Committee on Trauma's concept of trauma-related preventable death, utilizes subject matter expert (SME) review of medical records to define a trauma-related death as "preventable," "potentially preventable," or "not preventable" based on the probability of survival, trauma or injury severity score, or any combination of these.<sup>13</sup> The purpose of the MTMR process is to guide research analyzing preventable combat mortality for the strategic focus of tactical medicine, equipment, and training in order to eliminate preventable death on the battlefield.<sup>7,12</sup> The framework used to establish this process provides a guide on battlefield injury and prevention, tactical and environmental factors to consider, military definitions for preventable death categories, and SME panel composition and review process. The authors believe that the same approach that has been used to investigate trauma-related preventable death in Servicemembers can also be applied to MWDs.

Despite this promising approach, neither the concept of trauma-related preventable death nor the MTMR process has been used to assess deployment-related traumatic injuries in MWDs. This may be due, in part, to the lack of sufficient data captured in veterinary treatment records on diagnostics, treatments, and patient outcomes after a traumatic event compared with human medical records. Without detailed medical records, animal autopsy reports, injury severity scores (such as the Animal Trauma Triage score), death preventability cannot be determined.<sup>14</sup> However, many veterinary treatment records still contain extensive information on how the injury occurred for many traumatic events, making it possible to infer the preventability of the reported injury-inducing event.

The current case-series study applied the preventable death review process to identify gaps in injury prevention by evaluating injury events and determining if the injury was preventable, potentially preventable, or unpreventable among MWDs deployed to the Central Command (CENTCOM) area of responsibility (AOR). Potential interventions were also identified for injury events determined to be preventable or potentially preventable. Lastly, because multipurpose canines (MPCs) are unique MWDs assigned to US Special Operations Forces (SOF) units and are known to encounter higher risk of injury and death than conventional MWDs, injury event characteristics were compared between conventional MWDs and MPCs to determine if there were any meaningful differences by certification/unit assignment.<sup>15</sup>

## Methods

Data from a previous study on MWD trauma were collected under an exempt protocol from the Department of Defense Military Working Dog Veterinary Service Institutional Animal Care and Use Committee.<sup>15</sup> The authors of that study extracted information on traumatic injuries from official US military veterinary treatment records for MWDs who were injured while deployed to the CENTCOM AOR from 11 September 2001 to 31 December 2018. The original study identified 165 injured MWDs, some of whom experienced more than one injury at different times. In the current study, these additional injuries were considered independent of any prior injury, so there were 30 additional injuries for a total of 195 MWD injury events.

Anatomical location was defined by the site on the MWD body where the primary injury occurred. Body regions were selected based on previous canine injury research and further divided into specific regions of interest.<sup>15,16</sup> Survival status was determined by whether the MWD survived to hospital discharge. MWDs that were coded as "died" may have died prior to the receipt of medical care or after reaching veterinary medical care. For each variable, categories with small numbers were combined in the other/unknown category. Details of data abstraction and classification of key demographic and injury characteristics are described in detail elsewhere.<sup>15</sup>

MWD injury events were reviewed by a panel of SMEs composed of four Army veterinary specialists with deployment experience and board certification in either emergency/critical care (TE), surgery (JG), internal medicine (SK), or pathology (BS). The SME panel composition and the review process mirrored that which has been suggested as a standard for determining preventable death in US Servicemembers.<sup>12</sup> Each member of the SME panel independently reviewed the veterinary treatment records in a group setting to determine the injury prevention category. Injury events were categorized as follows: *preventable* – defined as an injury that was directly or indirectly caused from an error or true accident and could have been avoided had appropriate steps been taken; *potentially preventable* – defined as an injury suffered by an MWD that could have been prevented if they had every option of protective equipment that is available today for dogs (such as booties for feet protection, bulletproof vests, eye protection, and ear protection) and/or the most highly trained and experienced handler with extensive knowledge in canine handling in combat zones; and *unpreventable* – defined as direct injuries that would have still occurred even with a highly skilled handler and every option of protective equipment (e.g., direct explosion or blast). SME panel members could also select the category of *not enough information* if they felt there were not enough details in the veterinary treatment record to classify the injury as preventable, potentially preventable, or unpreventable. Categorization of each injury was determined based on panel consensus. If an evenly split decision was reached, a fifth Army veterinarian (JC) evaluated the record and decided the injury prevention category. Finally, two additional categories were created: (1) *preventable/potentially preventable injuries* – defined as an injury that was considered either preventable or potentially preventable and (2) *preventable/potentially preventable injuries that lead to death* – defined as death from an injury that was considered either preventable or potentially preventable.

If the SME panel determined that an injury event could have been potentially prevented, it then selected a primary intervention that may have helped to prevent or mitigate the injury. The intervention categories were as follows: improved *handler training*, improved canine *protective equipment*, and a change in *policy or doctrine*. *Not applicable* interventions are for those that were not considered preventable/potentially preventable injuries.

Because injury risk has been shown to differ between MPCs and conventional MWDs, injury event characteristics were compared between these two populations of MWDs.<sup>15</sup> For this secondary analysis, only 190 MWD injury events were included, as five veterinary treatment records lacked information on certification and unit assignment.

## Data Analysis

Descriptive statistics were calculated for demographics, injury event characteristics, and interventions by injury prevention category. Injury event characteristics were compared between MPCs and conventional MWDs using Fisher's exact test. Pairwise comparisons were completed by testing multiple sub-tables using the chi-square test or Fisher's exact test when more than 20% of the cells of a given table had an expected count of less than 5 and adjusting for multiplicity (*adjusted*  $\alpha = \alpha / \sqrt{\# \text{ pairwise comparisons}}$ ). All analyses were performed using Stata version 17.0, and  $\alpha$  was set at 0.05.<sup>17</sup>

## Results

Descriptive statistics and injury event characteristics by injury prevention category for the 195 MWD injury events are presented in Table 1. Most of the injured MWDs were intact males (64%), almost half were Belgian Malinois/Tervurens (46%), and more than one-third were certified in patrol and explosives detection (39%). The majority of injured MWDs were also conventional dogs assigned to a non-SOF unit (67%). In terms of trauma type, over two-thirds of the injuries were penetrating (68%), with knives or sharp objects (24%) being the most common mechanism of injury, followed by gunshot wounds (23%) and explosions (22%). Anatomically, many of the injuries were to the extremities (40%), with 16% of those occurring to the paw.

### Preventable Injury

Of the 195 injury events, 101 (52%) were determined to be either preventable ( $n = 37$ ; 19%) or potentially preventable ( $n = 64$ ; 33%), whereas 58 (30%) were unpreventable and 36 (18%) lacked enough information to determine an injury prevention category (Table 1). Regarding trauma type, penetrating injuries were largely considered to be preventable or potentially preventable (81% and 70%, respectively). As for mechanism of injury, sixty-eight percent ( $n=25$ ) of the preventable injuries were animal bites/scratches, while the potentially preventable injuries were most frequently caused by a knife/sharp object (59%). Injuries due to explosion were primarily deemed as unpreventable (41%), whereas injuries by gunshot wounds (64%) commonly lacked enough information to determine an injury prevention category. The most frequent preventable and potentially preventable injuries were to the head/neck (46%) and the paw (45%), respectively, whereas the most common unpreventable injuries were to the rear limb/tail (28%).

Of the 64 MWDs that died from injury, six (9%) of these deaths were classified as resulting from either a preventable or potentially preventable injury. The six deaths were caused by a gunshot wound to the thorax, a knife/sharp object to the hind limb, a fall involving the thorax, motor vehicle accidents involving the thorax (two deaths), and smoke inhalation.

### Preventative Intervention

Consensus of preventative intervention was reached by the SME panel on 84% of the 195 injury events reviewed. There was 100% agreement on primary interventions, with two injury events identified as needing both handler training and a change in policy/doctrine and one injury event as needing both handler training and protective equipment. Since the preventative intervention category of change in policy/doctrine was selected as a target intervention for only 1% of the injuries, these results are not reported.

The interventions of protective equipment and handler training – the main preventative interventions selected – are presented in Table 2 by mechanism of injury and anatomical location for the 100 injuries determined to be either preventable or potentially preventable. The intervention of change in policy/doctrine was selected for only one injury (data not shown). Handler training was selected as the preventative intervention for 54 (54%) of the injuries. Of these 54, 27 (50%) were caused by animal bites/scratches, and the head/neck (59%) were most often impacted. For the remaining 46 injuries, protective equipment was selected as the preventative intervention. Thirty-two of these 46 (70%) were caused by a knife/sharp object, and the body region primarily affected was the paw (75%).

### Comparison of SOF MPCs and Conventional MWDs

Type of trauma, mechanism of injury, injury prevention category, and preventive intervention were all statistically associated ( $p < .001$ ) with dog subpopulation (Table 3). For injury prevention, 72% of conventional MWD injuries were preventable (27%)/potentially preventable (45%), whereas only 10% of SOF MPC injuries were preventable (2%)/potentially preventable (8%) ( $p < .001$  for both preventable and potentially preventable injuries). The majority of SOF injuries (52%) lacked enough information to determine an injury prevention category compared to just 3% for conventional MWD injuries ( $p < .001$ ). When considering type of trauma, conventional MWDs experienced predominately penetrating (64%) or blunt (21%) trauma compared to 78% and 2% of injuries in SOF MPCs ( $p = .07$  for penetrating trauma and  $p < .001$  for blunt trauma). Mechanisms of injury also differed between dog subpopulations. Thirty-four percent of injury events among conventional MWDs were from a knife/sharp object and 23% from animal bites/scratches, while only 3% of SOF MPC injuries were from a knife/sharp object ( $p < .001$ ) and no SOF MPC injuries were from traumatic animal bites/scratches ( $p < .001$ ). In contrast, the majority of injuries sustained by SOF MPCs were from gunshot wounds (67%) whereas just 4% of conventional MWD injuries were caused by gunshot wounds ( $p < .001$ ). Lastly, handler training and protective equipment were selected as the prevention intervention for 40% and 31% respectively, of the injuries among conventional MWDs compared to 2% and 8%, respectively, of injuries among SOF MPCs ( $p < .001$  for both handler training and protective equipment).

## Discussion

This is the first study to apply the US DoD's preventable death review process to MWDs deployed to a combat zone to identify potentially preventable injury events and identify potential prevention interventions for this unique population. Over half of the 195 injury events analyzed were determined to be either preventable or potentially preventable using this process. Of these preventable/potentially preventable injuries, six were found to have led to the death of the MWD. The most common preventative intervention selected was handler training followed by protective equipment. There were significant differences in injury event characteristics by certification/unit assignment, with many of the injuries in our sample occurring in conventional MWDs. More notably, there were more conventional MWDs than MPCs in our sample, and the true number of all MWDs deployed during this time is unknown. Collectively, these findings indicate that deployed MWDs may

**TABLE 1** Military Working Dog and Injury Event Characteristics by Injury Category (N = 195)

| Characteristic                           | Total<br>N = 195 | Injury Prevention Category             |                                   |                                                |                                 |                                                                     |                                                                                       |
|------------------------------------------|------------------|----------------------------------------|-----------------------------------|------------------------------------------------|---------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                                          |                  | Not<br>Enough<br>Information<br>n = 36 | Unpreventable<br>Injury<br>n = 58 | Potentially<br>Preventable<br>Injury<br>n = 64 | Preventable<br>Injury<br>n = 37 | Preventable &<br>Potentially<br>Preventable<br>Injuries*<br>n = 101 | Preventable &<br>Potentially<br>Preventable<br>Injuries That<br>Led to Death<br>n = 6 |
| Age in years <sup>†</sup> (mean, SD)     | 4.6 (1.8)        | 4.4 (0.2)                              | 4.8 (0.3)                         | 4.7 (0.2)                                      | 4.5 (0.3)                       | 4.7 (0.2)                                                           | 6.3 (1.0)                                                                             |
| <b>Sex</b>                               |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Male, intact (No., %)                    | 124 (64%)        | 33 (92%)                               | 37 (64%)                          | 28 (44%)                                       | 26 (70%)                        | 54 (53%)                                                            | 4 (67%)                                                                               |
| Male, castrated (No., %)                 | 37 (19%)         | 0 (0%)                                 | 13 (22%)                          | 20 (31%)                                       | 4 (11%)                         | 24 (24%)                                                            | 2 (33%)                                                                               |
| Female, spayed (No., %)                  | 34 (17%)         | 3 (8%)                                 | 8 (14%)                           | 16 (25%)                                       | 7 (19%)                         | 23 (23%)                                                            | 0 (0%)                                                                                |
| <b>Dog breed</b>                         |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Belgian Malinois/Tervuren (No., %)       | 90 (46%)         | 23 (64%)                               | 30 (52%)                          | 28 (44%)                                       | 9 (24%)                         | 37 (37%)                                                            | 1 (17%)                                                                               |
| German Shepherd (No., %)                 | 54 (28%)         | 3 (8%)                                 | 15 (26%)                          | 23 (36%)                                       | 13 (35%)                        | 36 (35%)                                                            | 4 (67%)                                                                               |
| Labrador Retriever (No., %)              | 38 (19%)         | 3 (8%)                                 | 8 (14%)                           | 13 (20%)                                       | 14 (38%)                        | 27 (27%)                                                            | 0 (0%)                                                                                |
| Dutch Shepherd <sup>‡</sup> (No., %)     | 6 (3%)           | 4 (11%)                                | 2 (3%)                            | 0 (0%)                                         | 0 (0%)                          | 0 (0%)                                                              | 0 (0%)                                                                                |
| Other/Unknown <sup>§</sup> (No., %)      | 7 (4%)           | 3 (8%)                                 | 3 (5%)                            | 0 (0%)                                         | 1 (3%)                          | 1 (1%)                                                              | 1 (17%)                                                                               |
| <b>Certification</b>                     |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Explosives Detection (No., %)            | 27 (14%)         | 1 (3%)                                 | 4 (7%)                            | 9 (14%)                                        | 13 (35%)                        | 22 (22%)                                                            | 0 (0%)                                                                                |
| Multipurpose Canine (No., %)             | 58 (30%)         | 30 (83%)                               | 22 (38%)                          | 5 (8%)                                         | 1 (3%)                          | 6 (6%)                                                              | 2 (33%)                                                                               |
| Patrol/Explosives (No., %)               | 76 (39%)         | 1 (3%)                                 | 17 (29%)                          | 39 (61%)                                       | 19 (51%)                        | 58 (57%)                                                            | 4 (67%)                                                                               |
| Specialized Search (No., %)              | 11 (5%)          | 0 (0%)                                 | 1 (2%)                            | 7 (11%)                                        | 3 (8%)                          | 10 (10%)                                                            | 0 (0%)                                                                                |
| Other/Unknown <sup>¶</sup> (No., %)      | 23 (12%)         | 4 (11%)                                | 14 (24%)                          | 4 (6%)                                         | 1 (3%)                          | 5 (5%)                                                              | 0 (0%)                                                                                |
| <b>SOF<sup>†</sup></b>                   |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Yes (No., %)                             | 58 (30%)         | 30 (83%)                               | 22 (38%)                          | 5 (8%)                                         | 1 (3%)                          | 6 (6%)                                                              | 2 (33%)                                                                               |
| No (No., %)                              | 132 (68%)        | 4 (11%)                                | 33 (57%)                          | 59 (92%)                                       | 36 (97%)                        | 95 (94%)                                                            | 4 (67%)                                                                               |
| Unknown (No., %)                         | 5 (2%)           | 2 (6%)                                 | 3 (5%)                            | 0 (0%)                                         | 0 (0%)                          | 0 (0%)                                                              | 0 (0%)                                                                                |
| <b>Geographical location</b>             |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Iraq (No., %)                            | 83 (43%)         | 11 (31%)                               | 11 (19%)                          | 38 (59%)                                       | 23 (62%)                        | 61 (60%)                                                            | 3 (50%)                                                                               |
| Afghanistan (No., %)                     | 83 (43%)         | 22 (61%)                               | 31 (53%)                          | 18 (28%)                                       | 12 (32%)                        | 30 (30%)                                                            | 2 (33%)                                                                               |
| CENTCOM** (No., %)                       | 29 (14%)         | 3 (8%)                                 | 16 (28%)                          | 8 (13%)                                        | 2 (5%)                          | 10 (10%)                                                            | 1 (17%)                                                                               |
| <b>Type of trauma</b>                    |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Blunt (No., %)                           | 29 (15%)         | 1 (3%)                                 | 9 (16%)                           | 14 (22%)                                       | 5 (14%)                         | 19 (19%)                                                            | 3 (50%)                                                                               |
| Penetrating (No., %)                     | 133 (68%)        | 24 (67%)                               | 34 (59%)                          | 45 (70%)                                       | 30 (81%)                        | 75 (74%)                                                            | 2 (33%)                                                                               |
| Both Blunt and Penetrating (No., %)      | 28 (14%)         | 11 (31%)                               | 14 (24%)                          | 1 (2%)                                         | 2 (5%)                          | 3 (3%)                                                              | 0 (0%)                                                                                |
| Other/Unknown <sup>††</sup> (No., %)     | 5 (3%)           | 0 (0%)                                 | 1 (2%)                            | 4 (6%)                                         | 0 (0%)                          | 4 (4%)                                                              | 1 (17%)                                                                               |
| <b>Mechanism of injury</b>               |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Explosion (No., %)                       | 43 (22%)         | 12 (33%)                               | 24 (41%)                          | 7 (11%)                                        | 0 (0%)                          | 7 (7%)                                                              | 0 (0%)                                                                                |
| Gunshot Wound (No., %)                   | 46 (23%)         | 23 (64%)                               | 19 (33%)                          | 3 (5%)                                         | 1 (3%)                          | 4 (4%)                                                              | 1 (17%)                                                                               |
| Fall (No., %)                            | 13 (7%)          | 0 (0%)                                 | 4 (7%)                            | 7 (11%)                                        | 2 (5%)                          | 9 (9%)                                                              | 1 (17%)                                                                               |
| Knife/Sharp Object (No., %)              | 47 (24%)         | 0 (0%)                                 | 4 (7%)                            | 38 (59%)                                       | 5 (14%)                         | 43 (43%)                                                            | 1 (17%)                                                                               |
| Animal Bite/Scratch (No., %)             | 30 (15%)         | 0 (0%)                                 | 3 (5%)                            | 2 (3%)                                         | 25 (68%)                        | 27 (27%)                                                            | 0 (0%)                                                                                |
| Other/Unknown <sup>††</sup> (No., %)     | 16 (8%)          | 1 (3%)                                 | 4 (7%)                            | 7 (11%)                                        | 4 (11%)                         | 11 (11%)                                                            | 3 (50%)                                                                               |
| <b>Anatomical location</b>               |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| <b>Extremities</b>                       |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Front Limb (No., %)                      | 20 (10%)         | 1 (3%)                                 | 5 (9%)                            | 9 (14%)                                        | 5 (14%)                         | 14 (14%)                                                            | 0 (0%)                                                                                |
| Rear Limb/Tail (No., %)                  | 23 (12%)         | 0 (0%)                                 | 16 (28%)                          | 6 (9%)                                         | 1 (3%)                          | 7 (7%)                                                              | 1 (17%)                                                                               |
| Paw (No., %)                             | 32 (16%)         | 0 (0%)                                 | 0 (0%)                            | 29 (45%)                                       | 3 (8%)                          | 32 (31%)                                                            | 0 (0%)                                                                                |
| Unspecified Limb (No., %)                | 4 (2%)           | 1 (3%)                                 | 1 (2%)                            | 1 (2%)                                         | 1 (3%)                          | 2 (2%)                                                              | 0 (0%)                                                                                |
| Head/Neck (No., %)                       | 35 (18%)         | 2 (6%)                                 | 13 (22%)                          | 3 (5%)                                         | 17 (46%)                        | 20 (20%)                                                            | 0 (0%)                                                                                |
| Ear (No., %)                             | 10 (5%)          | 0 (0%)                                 | 1 (2%)                            | 7 (11%)                                        | 2 (5%)                          | 9 (9%)                                                              | 0 (0%)                                                                                |
| Thorax (No., %)                          | 17 (9%)          | 3 (8%)                                 | 5 (9%)                            | 6 (9%)                                         | 3 (8%)                          | 9 (9%)                                                              | 4 (67%)                                                                               |
| Two or More Sites <sup>§§</sup> (No., %) | 17 (9%)          | 5 (14%)                                | 10 (17%)                          | 0 (0%)                                         | 2 (5%)                          | 2 (2%)                                                              | 1 (17%)                                                                               |
| Unknown (No., %)                         | 37 (19%)         | 24 (67%)                               | 7 (12%)                           | 3 (5%)                                         | 3 (8%)                          | 6 (6%)                                                              | 0 (0%)                                                                                |

(continues)

TABLE 1 *Cont.*

| Characteristic                       | Total<br>N = 195 | Injury Prevention Category             |                                   |                                                |                                 |                                                                     |                                                                                       |
|--------------------------------------|------------------|----------------------------------------|-----------------------------------|------------------------------------------------|---------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                                      |                  | Not<br>Enough<br>Information<br>n = 36 | Unpreventable<br>Injury<br>n = 58 | Potentially<br>Preventable<br>Injury<br>n = 64 | Preventable<br>Injury<br>n = 37 | Preventable &<br>Potentially<br>Preventable<br>Injuries*<br>n = 101 | Preventable &<br>Potentially<br>Preventable<br>Injuries That<br>Led to Death<br>n = 6 |
| Intervention                         |                  |                                        |                                   |                                                |                                 |                                                                     |                                                                                       |
| Handler Training (No., %)            | 54 (28%)         | 0 (0%)                                 | 0 (0%)                            | 17 (27%)                                       | 37 (100%)                       | 54 (54%)                                                            | 4 (67%)                                                                               |
| Protective Equipment (No., %)        | 46 (23%)         | 0 (0%)                                 | 0 (0%)                            | 46 (72%)                                       | 0 (0%)                          | 46 (45%)                                                            | 1 (17%)                                                                               |
| Policy/Doctrine (No., %)             | 1 (1%)           | 0 (0%)                                 | 0 (0%)                            | 1 (2%)                                         | 0 (0%)                          | 1 (1%)                                                              | 1 (17%)                                                                               |
| Not Applicable <sup>¶</sup> (No., %) | 94 (48%)         | 36 (100%)                              | 58 (100%)                         | 0 (0%)                                         | 0 (0%)                          | 0 (0%)                                                              | 0 (0%)                                                                                |

\*Preventable and potentially preventable injuries are the preventable injuries and potentially preventable injuries combined.

<sup>†</sup> Age data were missing for two MWDs.

<sup>‡</sup> Includes long— and short-haired Dutch Shepherds.

<sup>§</sup> Other category includes one Springer Spaniel.

<sup>||</sup> Other category includes four combat tracker dogs, two mine detection dogs, and one patrol and drug detection dog.

<sup>¶</sup> MWD was owned by a Special Operations Forces unit.

<sup>\*\*</sup> CENTCOM is for injuries that occurred anywhere in US Central Command's Area of Operations other than Iraq or Afghanistan.

<sup>††</sup> Other category includes three events involving a burn, electrical, or chemical exposure.

<sup>††</sup> Other category includes three motor vehicle accidents, three crush/pinch injuries, two electrical injuries, and one fire injury.

<sup>§§</sup> Injuries involving the abdomen were included in the category of two or more sites.

<sup>¶¶</sup> Not applicable – potential interventions were not identified for injuries determined to be unpreventable or that did not have enough information.

TABLE 2 *Mechanisms of Injury and Anatomical Locations of Injury by Interventions for Preventable and Potentially Preventable Injuries (N = 100)\**

| Anatomical Location                         | Mechanism of Injury                         |                  |                       |                                |                                         |         |                  |                       |                                |
|---------------------------------------------|---------------------------------------------|------------------|-----------------------|--------------------------------|-----------------------------------------|---------|------------------|-----------------------|--------------------------------|
|                                             | Protective Equipment <sup>†</sup><br>n = 46 |                  |                       |                                | Handler Training <sup>†</sup><br>n = 54 |         |                  |                       |                                |
|                                             | Explosion                                   | Gunshot<br>Wound | Knife/Sharp<br>Object | Other/<br>Unknown <sup>§</sup> | Animal<br>Bite                          | Fall    | Gunshot<br>Wound | Knife/Sharp<br>Object | Other/<br>Unknown <sup>§</sup> |
| Head/Neck (No., %)                          | —                                           | —                | —                     | —                              | 16 (59%)                                | —       | —                | 3 (27%)               | 1 (17%)                        |
| Ear (No., %)                                | 6 (86%)                                     | —                | —                     | —                              | 2 (7%)                                  | —       | —                | 1 (9%)                | —                              |
| Thorax (No., %)                             | 1 (14%)                                     | 2 (67%)          | 1 (3%)                | —                              | 1 (4%)                                  | 2 (22%) | —                | —                     | 1 (17%)                        |
| Front Limb (No., %)                         | —                                           | —                | 5 (16%)               | —                              | 4 (15%)                                 | 5 (56%) | —                | —                     | —                              |
| Rear Limb/Tail (No., %)                     | —                                           | —                | 2 (6%)                | —                              | —                                       | 2 (22%) | —                | 3 (27%)               | —                              |
| Paw (No., %)                                | —                                           | —                | 24 (75%)              | 4 (100%)                       | 2 (7%)                                  | —       | —                | 1 (9%)                | 1 (17%)                        |
| Unspecified Limb<br>(No., %)                | —                                           | —                | —                     | —                              | —                                       | —       | —                | 1 (9%)                | 1 (17%)                        |
| Two or More Sites <sup>  </sup><br>(No., %) | —                                           | —                | —                     | —                              | —                                       | —       | —                | 1 (9%)                | 1 (17%)                        |
| Unknown (No., %)                            | —                                           | 1 (33%)          | —                     | —                              | 2 (7%)                                  | —       | 1 (100%)         | 1 (9%)                | 1 (17%)                        |
| Total                                       | 7                                           | 3                | 32                    | 4                              | 27                                      | 9       | 1                | 11                    | 6                              |

\*Change in policy/doctrine was selected for only one MWD and is not included here.

<sup>†</sup> No animal bites or falls were considered preventable by protective equipment.

<sup>‡</sup> No explosions were considered preventable by handler training.

<sup>§</sup> Other category includes three motor vehicle accidents, three crush/pinch injuries, two electrical injuries, and one fire injury.

<sup>||</sup> Injuries involving the abdomen were included in the category of two or more sites.

Percentages were rounded and may not total to 100.

often experience potentially preventable injuries and suggest that improved handler training and use of innovative protective equipment could possibly help prevent traumatic injury in MWDs during deployment.

Although a majority of MWD injury events were determined to be preventable or potentially preventable, there were some injury events related to specific mechanisms of injury that were determined to be mostly unpreventable, namely explosions and gunshot wounds. Among MWDs who experienced an explosion-related injury, very few of those injuries were determined to be either preventable or potentially preventable injuries. However, ruptured tympanic membranes from an explosion-related injury were deemed as potentially

preventable injuries for six MWDs, where protective equipment was selected to be an intervention for all these injuries. In Servicemembers, earplugs have been proven to lower the overpressure in the ear canal after a blast, significantly decreasing the chance of tympanic membrane rupture and hearing loss.<sup>19</sup> More research is needed to determine the effectiveness of evolving protective equipment for hearing protection designed for MWDs, but this novel protective equipment could reduce tympanic membrane injury and hearing loss in MWDs that experience blast-related injuries.<sup>20</sup>

Similar to explosion-related injuries, very few gunshot wounds were determined to be preventable or potentially preventable after considering availability and use of protective equipment.

**TABLE 3** Injury Characteristics, Preventable Injury Category, and Interventions of Military Working Dog Injuries by Certification/Unit Assignment (N = 190)\*

| Characteristic                    | Conventional<br>Military Working Dogs<br>n = 132 | Special Operations Forces<br>Multipurpose Canines<br>n = 58 | P†      |
|-----------------------------------|--------------------------------------------------|-------------------------------------------------------------|---------|
| <b>Type of Trauma</b>             |                                                  |                                                             | < 0.001 |
| Blunt (No., %)                    | 28 (21%)                                         | 1 (2%)                                                      |         |
| Penetrating (No., %)              | 85 (64%)                                         | 45 (78%)                                                    |         |
| Blunt and Penetrating (No., %)    | 14 (11%)                                         | 12 (20%)                                                    |         |
| Other/Unknown‡ (No., %)           | 5 (4%)                                           | 0 (0%)                                                      |         |
| <b>Mechanism of Injury</b>        |                                                  |                                                             | < 0.001 |
| Explosion (No., %)                | 25 (19%)                                         | 16 (28%)                                                    |         |
| Gunshot Wound (No., %)            | 5 (4%)                                           | 39 (67%)                                                    |         |
| Knife/Sharp Object (No., %)       | 45 (34%)                                         | 2 (3%)                                                      |         |
| Fall (No., %)                     | 12 (9%)                                          | 1 (2%)                                                      |         |
| Animal Bite/Scratch (No., %)      | 30 (23%)                                         | 0 (0%)                                                      |         |
| Other/Unknown§ (No., %)           | 15 (11%)                                         | 0 (0%)                                                      |         |
| <b>Injury Prevention Category</b> |                                                  |                                                             | <0.001  |
| Preventable (No., %)              | 36 (27%)                                         | 1 (2%)                                                      |         |
| Potentially Preventable (No., %)  | 59 (45%)                                         | 5 (8%)                                                      |         |
| Unpreventable (No., %)            | 33 (25%)                                         | 22 (38%)                                                    |         |
| Not Enough Information (No., %)   | 4 (3%)                                           | 30 (52%)                                                    |         |
| <b>Intervention</b>               |                                                  |                                                             | <0.001  |
| Protective Equipment (No., %)     | 41 (31%)                                         | 5 (8%)                                                      |         |
| Handler Training (No., %)         | 53 (40%)                                         | 1 (2%)                                                      |         |
| Policy/Doctrine (No., %)          | 1 (1%)                                           | 0 (0%)                                                      |         |
| Not Applicable¶ (No., %)          | 37 (28%)                                         | 52 (90%)                                                    |         |

\*Five dogs excluded as unit association and certification was unknown.

†p-value for Fisher's exact test of  $k \times k$  table.

‡Other category includes three events involving a burn, electrical, or chemical exposure.

§Other category includes three motor vehicle accidents, three crush/pinch injuries, two electrical injuries, and one fire injury.

¶Not applicable – potential interventions were not identified for injuries determined to be unpreventable or that did not have enough information. Values in bold signify statistical differences ( $p < .01$ ) between conventional MWDs and SOF MPCs within a row.

The reason may be that most gunshot wounds occurred in anatomical locations that are not covered by body armor, which mainly covers only the thorax, an uncommon location of gunshot wounds in this study. Baker et al. evaluated gunshot wounds in a small subset of MWDs deployed from 2003 to 2009 and concluded that even with protective gear available at the time, those dogs who suffered from thoracic gunshot wounds would not have been protected due to its limited coverage.<sup>21</sup> Additionally, Reeves et al. evaluated traumatic injury interventions in eleven MWDs deployed from February 2008 to December 2014 and determined that 37.5% of MWDs who sustained gunshot wounds were mortally wounded.<sup>22</sup> The authors suggested that their findings are likely a result of gun fire from high velocity weapons and at close-range. The largest study of trauma in deployed MWDs observed that only 23.9% of 46 dogs with gunshot wounds survived.<sup>15</sup> Currently, the use of bulletproof vests is uncommon in MWD populations, as it can lead to heat exhaustion and is not ideal for desert environments.<sup>21–23</sup> More funding is needed to create protective equipment, such as bulletproof vests, that provides adequate coverage that is lightweight and flexible yet effective for MWDs.<sup>23</sup>

Improved handler training was selected as the primary intervention for over half of the preventable/potentially preventable injuries. Handlers are responsible for the health and safety of their MWDs. Although handlers do not intentionally harm their MWDs, this study identified instances in which handlers could have acted differently and potentially prevented a common injury to their MWD, such as animal bites and scratches,

many of which were the result of fights with other MWDs. Thus, training on the importance of MWD separation and awareness of other MWDs could help decrease these types of injuries. Furthermore, of the six preventable/potentially preventable injuries that led to death, the SME panel determined four were caused by handler errors. Therefore, it is plausible that improved handler training and experience could have potentially prevented these deaths. It is unknown if the MWDs included in this study were wearing any protective equipment at the time of injury. Common practice during the period these MWDs were deployed make it unlikely that protective equipment was being used.<sup>21,22</sup> Nevertheless, the use of protective equipment was selected as a primary intervention for almost half of the preventable/potentially preventable injuries, most of which were injuries to the paw from a knife/sharp object (largely from concertina wire). The use of canine protective footwear could help reduce these paw injuries. As canine protective footwear continues to improve, paw injuries due to knives/sharp objects may be prevented.

In contrast to improved handler training and use of protective equipment, a change to policy or doctrine was selected as the primary intervention for only one MWD injury event, which was caused by smoke inhalation from a fire in the living quarters. Importantly, handler training was also identified by the panel as an important intervention for this injury event. While more specific details of this injury event are unknown, a change or update in policy was proposed to ensure that no other MWDs are left behind in an event such as this. Generally,

however, the lack of preventable/potentially preventable injuries and deaths that require a change to policy or doctrine for prevention indicates that the policies already in place may be sufficient for protecting MWDs from injuries.

Type of trauma, mechanism of injury, injury prevention category, and selected intervention were all associated with dog subpopulation (i.e., SOF MPCs and conventional MWDs). SOF MPCs more frequently operate as part of higher risk missions in more austere environments, and a 2021 study by Edwards et al. confirmed that these dogs were more likely to sustain mortal injuries compared to conventional MWDs.<sup>15</sup> Thus, the finding that injuries among SOF MPCs were significantly different from those sustained by conventional MWDs was unsurprising. Importantly, in SOF MPCs, there were few applicable interventions because 38% of injuries were unpreventable and over half of the injury events (52%) did not have sufficient information in the veterinary treatment records for the SME panel to determine an injury prevention category. This is likely due to the high risk and confidential nature of the work these MPCs perform. Further study focusing on preventative injury specific to SOF MPCs would be beneficial to reduce the burden of injury in these highly trained and extremely valuable MWDs.

This study is the first application of the DoD's MTMR process to review traumatic injury in an MWD population. Nonetheless, this study has some important limitations. First, the sample size was rather small and only included 195 injury events for MWDs who were deployed to the CENTCOM AOR between 2001 and 2018. The total number of dogs injured in combat zones and the total number of dogs deployed during this time is unknown. Yet, the sample size of this study was far larger than other studies that have evaluated traumatic injury in deployed MWDs.<sup>21,22</sup> Second, selection bias is a concern as those MWDs who were identified as having experienced a traumatic injury had to have a veterinary treatment record or medical after action review available to the authors to be included in the study. Additionally, our sample was mostly composed of conventional MWDs (68%). Without knowing the ratio of conventional MWDs to SOF MPCs, the sample in this study may not be representative. Furthermore, over half of the injuries that occurred to SOF MPCs did not have enough information to determine an injury prevention category. This limitation may skew the relevance of the findings in this study to the SOF community. Third, the lack of injury details and missing animal autopsy reports in the veterinary treatment records may have led to some misclassification. Because determination of injury category was based only on the information provided in the veterinary treatment record, which frequently contained limited information on the conditions surrounding the injury, the panel could not determine if any given injury was truly and completely preventable. Despite these limitations, all available injury data documented in the veterinary treatment record, including after-action reports and evacuation logs, were used to best classify each injury and better understand the types of injuries MWDs experience. The findings of this study should not be misinterpreted as handlers and/or veterinary/medical personnel being unable or unwilling to render proper care to deployed MWDs. Certainly, in the fog of war, mistakes are inevitable and can result in unintended injuries to both humans and animals. However, studies such as this are essential to identifying gaps in care and information and evaluating processes that can be improved to minimize injuries even in dangerous situations.

## Conclusion

Traumatic injury prevention among deployed MWDs is critical, as it reduces the time an MWD is unable to perform their essential missions of safeguarding the force and neutralizing enemy combatants. Many of the injuries identified in this population were minor – such as small lacerations to the paw pad or minor abrasions after a dog fight – and likely required only short recovery times, allowing the MWDs to return to duty quickly. Nonetheless, this study has demonstrated that deployed MWDs experience preventable and potentially preventable injuries, some of which are severe. Improvements in handler training and development of innovative protective equipment specific for MWDs may significantly reduce the number of traumatic injuries experienced on the battlefield.

## Author Contributions

JC and THE conceived the study concept. THE obtained funding. THE and LFFS coordinated and collected the data. JC and LFFS analyzed the data. JC wrote the first draft, and all authors read and approved the final manuscript

## Disclosure

The authors have nothing to disclose.

## Disclaimer

The views expressed in this manuscript are those of the authors and do not reflect the official policy or position of the U.S. Army Medical Department, the Department of the Army, DoD, or the US Government.

## References

1. Miller L, Pacheco GJ, Janak JC, et al. Causes of death in military working dogs during Operation Iraqi Freedom and Operation Enduring Freedom, 2001–2013. *Mil Med.* 2018;183(9–10):e467–e474.
2. Baker JL, Truesdale C, Schlanser J. Overview of combat trauma in military working dogs in Iraq and Afghanistan. *US Army Med Dep J.* 2009;33–37.
3. Belmont LPJ, Schoenfeld MAJ. Epidemiology of combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom: orthopaedic burden of disease. *J Surg Orthop Adv.* 2010;19(1):6.
4. Butler FK, Blackburne LH. Battlefield trauma care then and now: a decade of Tactical Combat Casualty Care. *J Trauma Acute Care Surg.* 2012;73(6):S395–S402.
5. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg.* 2012;73(6):S431–S437.
6. Holcomb JB, McMullin NR, Pearce L, et al. Causes of death in U.S. Special Operations Forces in the Global War on Terrorism: 2001–2004. *Ann Surg.* 2007;245(6):986–991.
7. Janak J, Stockinger Z, Mazuchowski E, et al. Military preventable death conceptual framework: a systematic approach for reducing battlefield mortality. *Mil Med.* 2018;183(suppl\_2):15–23.
8. Kotwal RS. Eliminating preventable death on the battlefield. *Arch Surg.* 2011;146(12):1350.
9. Kotwal RS, Scott LLE, Janak JC, et al. The effect of prehospital transport time, injury severity, and blood transfusion on survival of US military casualties in Iraq. *J Trauma Acute Care Surg.* 2018;85(1S):S112–S121.
10. Kotwal RS, Howard JT, Orman JA, et al. The effect of a Golden Hour Policy on the morbidity and mortality of combat casualties. *JAMA Surg.* 2016;151(1):15.
11. Mazuchowski EL, Kotwal RS, Janak JC, et al. Mortality review of US Special Operations Command battle-injured fatalities. *J Trauma Acute Care Surg.* 2020;88(5):686–695.
12. Janak JC, Mazuchowski EL, Kotwal RS, et al. Establishing an enduring military trauma mortality review: misconceptions and lessons learned. *J Trauma Acute Care Surg.* 2020;89(2S):S16–S25.

13. Hakkenbrak NAG, Mikdad SY, Zuidema WP, et al. Preventable death in trauma: a systematic review on definition and classification. *Injury*. 2021;52(10):2768–2777.
14. Rockar RA, Drobatz KS, Shofer FS. Development of a scoring system for the veterinary trauma patient. *J Vet Emerg Crit Care*. 1994;4(2):77–83.
15. Edwards TH, Scott LLF, Gonyeau KE, et al. Comparison of trauma sustained by civilian dogs and deployed military working dogs. *J Vet Emerg Crit Care*. 2021;31(4):498–507.
16. Mey W, Schuh-Renner A, Anderson MK, et al. Risk factors for injury among military working dogs deployed to Iraq. *Prev Vet Med*. 2020;176:104911.
17. Capak H, Brkljac Bottegato N, et al. Review of 166 gunshot injury cases in dogs. *Top Companion Anim Med*. 2016;31(4):146–151.
18. StataCorp. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC.
19. Ritenour AE, Wickley A, Ritenour JS, et al. Tympanic membrane perforation and hearing loss from blast overpressure in Operation Enduring Freedom and Operation Iraqi Freedom wounded. *J Trauma Inj Infect Crit Care*. 2008;64(2):S174–S178.
20. U.S. Army CCDC Army Research Laboratory Public Affairs. 26 November 2019. [https://www.army.mil/article/230018/innovative\\_hearing\\_protection\\_may\\_safeguard\\_military\\_working\\_dogs](https://www.army.mil/article/230018/innovative_hearing_protection_may_safeguard_military_working_dogs). Accessed 10 October 2022.
21. Baker JL, Havas KA, Miller LA, et al. Gunshot wounds in military working dogs in Operation Enduring Freedom and Operation Iraqi Freedom: 29 cases (2003–2009). *J Vet Emerg Crit Care*. 2013;23(1):47–52.
22. Reeves L, Mora A, Field A, Redman TT. Interventions performed on multipurpose military working dogs in the prehospital combat setting: a comprehensive case series report. *J Spec Oper Med*. 2019;19(3):90–93.
23. Pickrell R. The Army wants to outfit dogs with tiny cameras and other advanced gear to make them even more effective in combat. *Task Purpose*. 19 December 2019. <https://taskandpurpose.com/news/army-military-working-dog-gear/>. Accessed 10 October 2022.