

**Factors Associated with Motorcycle
Traffic Crash Fatalities among Army
Soldiers, 1995–2014**

Approved for public release, distribution unlimited
General Medicine: 500A

August 2018



This page intentionally left blank.

**Clinical Public Health and Epidemiology Directorate
Injury Prevention Division**

**Factors Associated with Motorcycle Traffic Crash Fatalities among
Army Soldiers, 1995-2014**

Catherine Rappole, MPH
Michelle Canham-Chervak, PhD MPH
Bonnie Taylor, PhD
Bruce H. Jones, MD MPH

Use of trademark name(s) does not imply endorsement by the U.S. Army but is intended only to assist in the identification of a specific product.

This page intentionally left blank.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188		
<p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p>					
1. REPORT DATE (DD-MM-YYYY) 28-09-2018		2. REPORT TYPE Final		3. DATES COVERED (From – To) 1995–2014	
4. TITLE AND SUBTITLE Factors Associated with Motorcycle Traffic Crash Fatalities among Army Soldiers, 1995-2014			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
6. AUTHOR(S) Catherine Rappole, Michelle Canham-Chervak, Bonnie Taylor, Bruce H. Jones			5c. PROGRAM ELEMENT NUMBER		
			5d. PROJECT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Public Health Center, Aberdeen Proving Ground, Maryland 21010			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
8. PERFORMING ORGANIZATION REPORT NUMBER S.0047795-18			9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Public Health Center, Aberdeen Proving Ground, Maryland 21010		
10. SPONSOR/MONITOR'S ACRONYM(S) APHC			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Motorcyclists are 30 to 35 times more likely to die in a crash than other vehicle occupants. In 2012, among active duty Service members, the rate of motorcycle deaths (6.5 per 100,000 person-years) approached that of non-motorcycle motor vehicle crashes (6.7 per 100,000 person-years) despite only 15 percent of Service members reporting riding motorcycles. Purpose: The purpose of this study was (1) to describe motorcycle crash-related injuries from safety report data and (2) to assess the effect of alcohol and helmet use on risk of death due to motorcycle crash-related injuries among active duty Army personnel. Methods: Data on motorcycle traffic crashes from 1995 to 2014 were obtained from the Army Safety Management Information System and person-years were obtained from the Armed Forces Health Surveillance Branch. Trends in motorcycle injury and fatality rates, descriptive statistics, and multivariable logistic regression were calculated. Results: The rate of motorcycle traffic crashes increased from 2.7 per 100,000 person-years in 1995 to 5.8 per 100,000 person-years in 2014. Two-thirds of motorcycle traffic crashes resulted in injuries requiring a lost workday; 17% resulted in fatality. Of the fatal motorcycle traffic crashes, 79% of riders sustained injuries to the head and neck, with 60% of fatal injuries categorized as fractures, 13% concussions, and 7% abrasions/lacerations. Motorcycle traffic crashes involving operators who had used alcohol had 3 times higher odds of fatality than those who did not use alcohol (OR [95% CI]: 3.2 [2.1-4.5]), controlling for operator and crash characteristics. Operators who did not wear a helmet had 1.9 times higher odds of fatality than those who did wear a helmet (OR [95% CI]: 1.9 [1.2-2.9]), controlling for the same factors. Conclusions: There are a number of modifiable risk factors (i.e., alcohol use, helmet use, riding at night, and sleep) associated with motorcycle traffic fatalities among Soldiers. Results will help inform Soldier motorcycle policies and rider training.					
15. SUBJECT TERMS: Motorcycle, Army active duty, fatality, injury, epidemiology, prevention					
16. SECURITY CLASSIFICATION OF: Unclassified		17. LIMITATION OF ABSTRACT Unclassified	18. NUMBER OF PAGES 37	19a. NAME OF RESPONSIBLE PERSON Dr. Michelle Canham-Chervak	
a. REPORT Unclassified	b. ABSTRACT Unclassified			c. THIS PAGE Unclassified	19b. TELEPHONE NUMBER (include area code) (410)436-4655

TABLE OF CONTENTS

	<u>Page</u>
1 SUMMARY	1
1.1 Purpose.....	1
1.2 Results and Findings.....	1
1.3 Conclusions and Recommendations.....	1
2 REFERENCES	2
3 AUTHORITY	2
4 BACKGROUND	2
5 METHODS	3
5.1 Data Sources	3
5.2 Study Population and Design	4
5.3 Definitions	5
5.4 Statistical Analyses	5
6 RESULTS	6
6.1 Rates of Motorcycle Traffic Crashes, Non-fatal Injuries, and Fatal Injuries	7
6.2 Motorcycle Traffic Crash Characteristics.....	11
6.3 Non-fatal and Fatal Injuries Description	13
6.4 Unadjusted Risk of Fatality.....	15
6.5 Multivariable Analysis.....	19
7 DISCUSSION	20
7.1 Injury and Fatality.....	20
7.2 Factors associated with Fatalities	22
7.3 Limitations	25
8 CONCLUSIONS AND RECOMMENDATIONS	25

	<u>Page</u>
9 POINT OF CONTACT	26

APPENDICES

A. References	A-1
---------------------	-----

FIGURES

1. Trends in Reported Active Duty Army Solder Motorcycle Traffic Crash Rates, Non-fatally Injured Rates, and Fatally Injured Rates, Army Accident Reports, 1995–2014 (n=2,852).....	8
---	---

TABLES

1. Type of Injury Outcome for Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, 1995–2014 (n=2,852).....	7
2. Personal Characteristics of Active Duty Army Soldiers Non-fatally and Fatally Injured In Reported Motorcycle Traffic Crashes, 1995–2014 (n=2,845)	10
3. Motorcycle Traffic Crash Characteristics among Active Duty Army Soldiers, 1995–2014 (n=2,852).....	12
4. Characteristics of Non-fatal and Fatal Injuries Associated with Reported Motorcycle Traffic Crashes Among Active Duty Army Soldiers as Documented in ASMIS, 1995–2014 (n=2,852).....	14
5. Types of Fatal and Non-fatal Motorcycle Traffic Crashes among Active Duty U.S. Army Operators, Army Safety Reports, 1995–2014 (n=2,852)	15
6. Distribution of Fatal and Non-fatal Motorcycle Traffic Crash Characteristics by Age Group among Active Duty U.S. Army Operators, Army Safety Reports, 1995–2014 (n=2,852).....	15
7. Unadjusted Risk and Odds of Fatal Injury from Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, Demographics, 1995–2014	17
8. Unadjusted Risk and Odds of Fatal Injury from Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, Crash Characteristics, 1995–2014...	18
9. Adjusted Odds of Fatal Injury from Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, 1995–2014	20

PUBLIC HEALTH REPORT NO. S.0047795-18
FACTORS ASSOCIATED WITH MOTORCYCLE TRAFFIC CRASH FATALITIES
AMONG ARMY SOLDIERS, 1995–2014

1. SUMMARY

1.1 Purpose

The purpose of this study was to describe motorcycle crash-related injuries from safety report data and to assess associations between alcohol and helmet use and risk of death due to motorcycle crash-related injuries among Army Soldiers involved in motorcycle crashes.

1.2 Results and Findings

Of the 2,852 motorcycle traffic crashes that occurred over 20 years, most involved male Soldiers (97%), Soldiers ages 20–29 years (60%), Soldiers who wore a helmet (95%), and involved colliding with a vehicle, object, or person (57%); most motorcycle traffic crashes did not involve alcohol (92%) and occurred off installation (88%), while the operator was off duty (93%), and during the day (65%). Two-thirds of motorcycle traffic crashes resulted in injuries requiring a lost workday; 17% resulted in fatality. Of the fatal motorcycle traffic crashes, 79% sustained injuries to the head and neck, with 60% of fatal injuries categorized as fractures, 13% as concussions, and 6% as abrasions/lacerations.

The rate of fatal motorcycle traffic crashes increased from 2.7 per 100,000 person-years in 1995 to 5.8 per 100,000 person-years in 2014. For each advancing year from 2002 to 2014, the rate of non-fatal motorcycle traffic crashes increased by 3 per 10,000 person-years ($p < 0.01$) and the rate of fatal motorcycle traffic crashes increased by 0.2 per 10,000 person-years ($p < 0.01$).

After performing multiple imputation for missing data, a forced entry model determined the following factors to be associated with fatality: rank, alcohol use, licensure, number of hours slept in 24 hours prior to the crash, helmet use, period of day, incident off installation, incident while off duty, and collided with a vehicle/object/person. Motorcycle traffic crashes involving operators who had used alcohol had three times higher odds of fatality than those who did not use alcohol (odds ratio (OR) (95% confidence interval (CI)): 3.2 (2.1–4.5)), controlling for operator and crash characteristics. Operators who did not wear a helmet had two times higher odds of fatality than those who did wear a helmet (OR (95% CI): 1.9 (1.2–2.9)), controlling for the same factors.

1.3 Conclusions and Recommendations

This analysis indicated that there are a number of modifiable risk factors (i.e., alcohol use, helmet use, riding at night, and sleep) associated with motorcycle traffic fatalities among Soldiers. Future analyses will enable investigation of the use of other personal protective equipment (e.g., reflective apparel) and sleep deprivation on Soldier motorcyclist injury and fatality. Results will help inform Soldier motorcycle policies and rider trainings.

2. REFERENCES

Appendix A lists the references cited in this report.

3. AUTHORITY

Under Army Regulation (AR) 40-5, Section 2-19, the U.S. Army Public Health Center (APHC) is responsible for providing support for Army preventive medicine activities, including review and interpretation of surveillance data and identification and characterization of health problems as a foundation for injury prevention planning and policy efforts.

4. BACKGROUND

Motor vehicle crashes have accounted for nearly one-third of U.S. military deaths annually, and through 2009 were the leading non-war-related cause of death among U.S. military personnel (Krahl et al. 2010, Armed Forces Health Surveillance Center 2013). Motorcyclists are 30 to 35 times more likely to die in a crash than other vehicle occupants (Lin and Kraus 2009). From 1999 to 2012 there were 4,479 motor vehicle-related deaths among Service members, with the largest number of Service member deaths (n=1,158; 25.9%) being associated with motorcycle crashes (Armed Forces Health Surveillance Center 2013). Nationally, per vehicle mile traveled in 2013, motorcyclist fatalities occurred 26 times more frequently than passenger car occupant fatalities in traffic crashes (National Center for Statistics and Analysis 2015). Among men in the Army between 1990 and 1998, use of a motorcycle was the strongest behavioral predictor of fatal motor vehicle crash (Garvey Wilson et al. 2003). In 2012, among active duty Service members, the rate of motorcycle deaths (6.5 per 100,000 person-years) approached that of non-motorcycle motor vehicle crashes (6.7 per 100,000 person-years) despite only 15 percent of Service members reporting riding motorcycles (Armed Forces Health Surveillance Center 2013, Barlas 2013).

There has been limited research on factors associated with motorcycle fatalities among Army Soldiers. Risk factors associated with motorcycle traffic crash fatality among civilian studies include:

- Alcohol use (Jung, Xiao, and Yoon 2013, Lin and Kraus 2009, Hurt, Ouellet, and Thom 1981)
- Older age (Burns et al. 2015, Jung, Xiao, and Yoon 2013)
- Younger age (Lin and Kraus 2009, Langley, Samaranayaka, and Begg 2013)
- Not wearing a helmet (Burns et al. 2015, Goslar et al. 2008, Jung, Xiao, and Yoon 2013, Lin and Kraus 2009, Liu et al. 2008, Olsen et al. 2016, Norvell and Cummings 2002, Hurt, Ouellet, and Thom 1981)
- Black race (Crompton et al. 2010)
- Colliding with an object (e.g., tree) (Daniello and Gabler 2011, Jung, Xiao, and Yoon 2013)
- Riding in a state without a universal helmet law (French, Gumus, and Homer 2012, Morris 2006)
- Being ejected off the motorcycle (Jung, Xiao, and Yoon 2013)

Public Health Report No. S.0047795-18

- Truck involvement (Jung, Xiao, and Yoon 2013)
- Speeding (Lin and Kraus 2009)

Previously, a study of Air Force personnel found that speed, intoxicants, and fatigue were associated with motorcycle fatality (Marshall 2014). The largest number of Service member motorcyclist crash-related hospitalizations and deaths typically occur in May and July, with more than half occurring between May and September (Armed Forces Health Surveillance Center 2009, 2013). Among Army personnel from 2003 to 2008, for every 1 motorcycle-related death there were 5 hospitalizations and 22 outpatient visits (Dada 2015).

Between 1998 and 2008, alcohol was reported as a factor in 8.6% of all Service member motorcycle crash related deaths (per death records) (Armed Forces Health Surveillance Center 2009). Alcohol is the drug most frequently associated with motor vehicle crashes and motorcyclists specifically are more likely to have consumed alcohol than other motor vehicle drivers in fatal and non-fatal crashes (Lin and Kraus 2009). The risk of being involved in a fatal crash increases with blood alcohol content (BAC) level for all age groups (Lin and Kraus 2009). Motorcyclists that consume alcohol also have lower rates of helmet use and more severe head injuries (Lin and Kraus 2009, Brown et al. 2011). Not wearing a helmet is another important factor associated with motorcycle traffic crash fatality. A systematic review by Liu et al. pooled results from motorcycle helmet studies and calculated that helmets reduced the odds of fatality by 48% and reduced the odds of head injury by 69%, after adjusting for other person and crash factors (Liu et al. 2008).

5. METHODS

5.1 Data Sources

The data for this study originated from a larger epidemiologic study monitoring U.S. Army Soldier injuries reported in the Army Safety Management Information System (ASMIS). The U.S. Army Combat Readiness Center (ACRC) maintains the ASMIS, which comprehensively details crashes involving Army personnel (Pollack et al. 2013). All incidents reported to the ACRC are recorded in this database (Pollack et al. 2013). Reports are submitted to ACRC by unit safety officers, who are responsible for completing the requisite forms and conducting interviews with witnesses and survivors of each crash (Pollack et al. 2013). The ASMIS database includes safety reports on crashes involving privately owned vehicles, military vehicles, motorcycles, and other types of vehicles in use by Army personnel (Pollack et al. 2013). It also includes information on vehicle incidents that involve general damage to vehicles, such as those from hail or fire (Pollack et al. 2013).

The present analysis, conducted in 2015, used ASMIS safety (accident) report data from 01 January 1995 through 31 December 2014 for motorcycle traffic crashes involving active duty Army personnel. ASMIS safety report data included operator demographic information, such as date of birth, sex, and rank. Age at time of motorcycle traffic crash was calculated by subtracting date of birth from crash date. Data also contained detailed operator information, including alcohol use, helmet use, duty status, motorcycle licensure, and number of hours slept 24 hours prior to the crash. Crash information included location of the crash, on or off an Army installation, calendar season, period of day, road conditions, and whether the crash occurred on

Public Health Report No. S.0047795-18

or off a roadway or involved a collision with a vehicle, object, or person. Injury information was also obtained from the safety report data and included body part injured, type of injury, mechanism of injury, and severity of injury. Severity of injury was recorded as follows: fatality, permanent total disability, permanent partial disability, lost workdays, restricted work, medical treatment beyond first aid, and first aid.

Department of the Army (DA) Pamphlet 385-40 provides detailed instructions for completing Army safety (accident) report forms (DA Form 285 or DA Form 285-AB-R), from which data on ground accidents are imported into ASMIS (Department of the Army 2015). Forms contain a free text field describing the accident, which was reviewed and used to complete fields with missing information. Additional details regarding accident report fields on operator characteristics used in this analysis:

- *Alcohol use (yes or no)*. Defined as whether alcohol use by the individual caused or contributed to the motorcycle crash.
- *Helmet use*. Defined as 'yes' if form indicated a helmet 'was available and used.'
- *Motorcycle license (yes or no)*. Defined as whether the operator was licensed to operate the vehicle at the time of the crash; per AR 385-10, operators of government-owned and privately owned motorcycles on Army installations must be appropriately licensed to operate on public highways except where not required by the applicable local laws.

Additional details on crash characteristics obtained from accident report data and used in this analysis:

- *Location*. Exact location of the crash in a free text field, indicative of a crash occurring on an Army installation.
- *Roadway*. Determined from free text field describing accident circumstances.
- *Collision type*. Collision with a vehicle/object/person variable created by grouping collision types (i.e., going forward and colliding with a moving vehicle, going forward and colliding with a parked vehicle, collision while backing, collision with pedestrian, collision with object (other than vehicle/pedestrian), going forward and rear-ending a moving vehicle, going forward and rear-ending a parked vehicle, and collision while turning).
- *Calendar season of the motorcycle crash*. The crash was considered to have occurred during the summer if the crash date was from April to September.
- *Period of day*. Dawn and dusk were consolidated into a 'twilight' category.
- *Environmental conditions*. Wet conditions variable created by grouping categories of 'fog, condensation, frost,' 'mist, rain, sleet, hail,' and 'snow, ice' and was compared to a non-wet category (e.g., 'clear/dry; visibility unlimited').

5.2 Study Population and Design

A retrospective analysis was performed on active duty Soldiers whose cause of death or injury related medical encounter was due to a motorcycle crash. Specific inclusion criteria for this analysis included a fatal or non-fatal injury record in the ASMIS between years 1995 and 2014 with a narrative text indicating a motorcycle crash involving an active duty U.S. Army Service member. The unit of measure for this analysis was a motorcycle traffic crash. If an operator

Public Health Report No. S.0047795-18

was involved in more than one motorcycle crash over the time period of this study, then that person was included more than one time in the analysis.

5.3 Definitions

5.3.1 Motorcycle Definition

For this analysis, a motorcycle is defined as motorcycles with or without a sidecar (2- and 3-wheel; government or privately owned), mopeds, motorized bicycles, or motor scooters (also known as mopeds). This motorcycle definition excludes the following vehicles: dirt bikes, off-road motorcycles, all-terrain vehicles (ATVs), pedal bicycles, and all military vehicles that are not government motorcycles. Only motorcycle operators (i.e., persons in control of the motorcycle) were included in the analysis.

5.3.2 Motorcycle Traffic Crash Definition

According to the military NATO standardized agreement (STANAG) 2050 and the civilian ICD-9-CM coding manuals, a motor vehicle crash is defined as a traffic crash involving a motor vehicle (Military Agency for Standardization 1989, National Center for Statistics and Analysis 2015). Non-fatal motorcycle crashes are classified into two major categories: motorcycle traffic and motorcycle non-traffic. For this analysis, the definition of a traffic crash was adapted from the Fatality Analysis Reporting System as follows: crashes occurring on a paved public or private road (i.e., highway, surface street, parking lot, driveway), including U.S. Army installations, where there is a risk of interaction with fellow motorists and vehicles (National Highway Traffic Safety Administration 2016). Non-traffic crashes occur in locations other than those listed, such as off-road, on a dirt track, on a dirt or dirt bike trail, on a paved track (i.e., motorcycle/car racing track), on a dirt or unimproved road, on a gravel road, and on a military vehicle trail (e.g., tank trail).

5.4 Statistical Analyses

To assess associations of alcohol and helmet use on risk of fatality among motorcycle operators involved in a crash, descriptive statistics were generated for sociodemographic information, crash characteristics, injury types and affected body regions, and the magnitude of motorcycle traffic crash-related fatalities and injuries among active duty Soldiers in the U.S. Army from 1995 through 2014 as reported in the ASMIS. Contingency tables to test multiple proportions of potential specific risk factors across age groups were considered significant when p-values (p) ≤ 0.05 . Given the dynamic natures of the U.S. Army population, person-years were obtained from the Armed Forces Health Surveillance Branch of the Defense Health Agency and used in rate calculations. Person-years allow for more precise measurement of time in the Army considering factors such as deployments and discharges. Person-years represent all active duty Soldiers in the U.S. Army in a given year, with months deployed removed from the person-time. Rates of motorcycle crash-related fatalities and injuries were analyzed for time trends using linear regression. Univariate logistic regression was employed to calculate unadjusted OR and 95% CIs to assess the association of sociodemographic information and crash characteristics with odds of fatality, given a motorcycle traffic crash occurred. The variable level with the lowest fatality risk was selected as the reference group to compare the fatality risk at

Public Health Report No. S.0047795-18

other variable levels. Known confounders based on the literature (e.g. sex, time of day) as well as variables with $p \leq 0.25$ were selected for entry into the multivariable logistic regression.

Prior to performing multivariable logistic regression, multiple imputation using the fully conditional method (FCS) was conducted to deal with missing data. Twenty-eight percent of observations were missing alcohol use data, 15% of observations were missing data on hours slept prior to the crash, and 5% of observations were missing data on motorcycle licensure. It was methodically decided that variables with more than 50% of observations missing data would be excluded from the imputation. Therefore, variables on deployment and safety course certification could not be considered in the analysis due to more than 50% of observations missing data. Multiple imputation uses a regression-based procedure to produce multiple copies of the data set, each of which contains different estimates of the missing values (Enders 2010). FCS was chosen due to the binary outcome of the logistic model. To select terms (associated with fatality in the univariate model at overall $p \leq 0.25$) for the imputation model, a complete set of data was generated using the expectation-maximization (EM) algorithm for covariance matrices (Hendry et al. 2014). The EM algorithm is an iterative procedure that creates a complete data set in which all missing values are replaced by maximum likelihood values that are asymptotically unbiased (Hendry et al. 2014). Variables with overall $p \leq 0.10$ in the multivariable logistic regression run on the EM-generated dataset were entered into the multivariable logistic model to be run on the imputed dataset. The data augmentation algorithm in the SAS MI procedure was used to generate 60 imputed data sets. The imputation process included the 10 variables that appeared in one or more of the subsequent regression analyses. No auxiliary variables were identified therefore the imputation process did not include auxiliary variables. After creating the complete data sets, multiple logistic regression models were estimated on each filled-in data set and subsequently the parameter estimates and standard error estimates were pooled using the SAS MIANALYZE procedure into a single set of results. Methodologists currently regard multiple imputation as the best missing data technique because it improves accuracy and the power of the analyses relative to other missing data handling methods (Schafer and Graham 2002).

OR and 95% CI from the forced entry multivariable analysis on the imputed data were calculated and reported. Factors at the $p \leq 0.05$ were considered statistically significant in the multivariable model. The analysis was performed using SPSS 21.0 (SPSS Version 21.0 for Windows, 2012; SPSS, Chicago, Illinois) and SAS Enterprise Guide 6.1 (Statistical Analysis System Version 6.1; SAS Institute Inc., Cary, North Carolina).

6. RESULTS

There were 2,852 motorcycle traffic crashes reported in ASMIS among active duty Army operators from 1995 through 2014. An additional 147 records were removed from the dataset for the following reasons:

- One hundred and twenty-one records did not meet the definition of motorcycle traffic crash.
- Seventeen records were reports on supervising personnel.
- Six records were reports on motorcycle passengers.
- Two records were reports on bystanders.

Public Health Report No. S.0047795-18

- One record was a hand receipt.

Every motorcycle traffic crash reported in the dataset sustained at least one injury, with varying degrees of severity (Table 1). Two-thirds of motorcycle traffic crashes resulted in injuries that required a lost workday, while 17% resulted in fatality.

Table 1. Type of Injury Outcome for Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, 1995–2014 (n=2,852)

Type of Injury Outcome	Number Injured (%)
Fatal	470 (16.5)
Permanent Total Disability	38 (1.3)
Permanent Partial Disability	103 (3.6)
Lost Workday Case	1,881 (66.0)
Restricted Work	255 (8.9)
Medical Treatment Beyond First Aid	95 (3.3)
First Aid	10 (0.4)
Total	2,852

6.1 Rates of Motorcycle Traffic Crashes, Non-fatal Injuries, and Fatal Injuries

The rate of reported motorcycle traffic crashes resulting in fatal injuries increased from 2.7 per 100,000 person-years in 1995 to 5.8 per 100,000 person-years in 2014 (Figure 1). The rate of motorcycle traffic crashes resulting in non-fatal injuries increased from 14.4 per 100,000 person-years in 1995 to 51.8 per 100,000 person-years in 2014. From 1995 through 2014, the average rate of motorcycle traffic crashes resulting in fatal injuries was 5.3 per 100,000 person-years, and the average rate of motorcycle traffic crashes resulting in non-fatal injuries was 26.4 per 100,000 person-years. The fatal and non-fatal crash rates did not significantly change from 1995 through 2001 (fatal rate $p=0.98$; non-fatal rate $p=0.87$). From 2002 through 2014, the rate of fatal motorcycle traffic crash injuries showed a non-statistically significant ($p=0.18$) average increase of 0.2 per 100,000 person-years each year, while the rate of non-fatal motorcycle traffic crash injuries increased by an average 3 per 100,000 person-years each year during this time period ($p<0.01$).

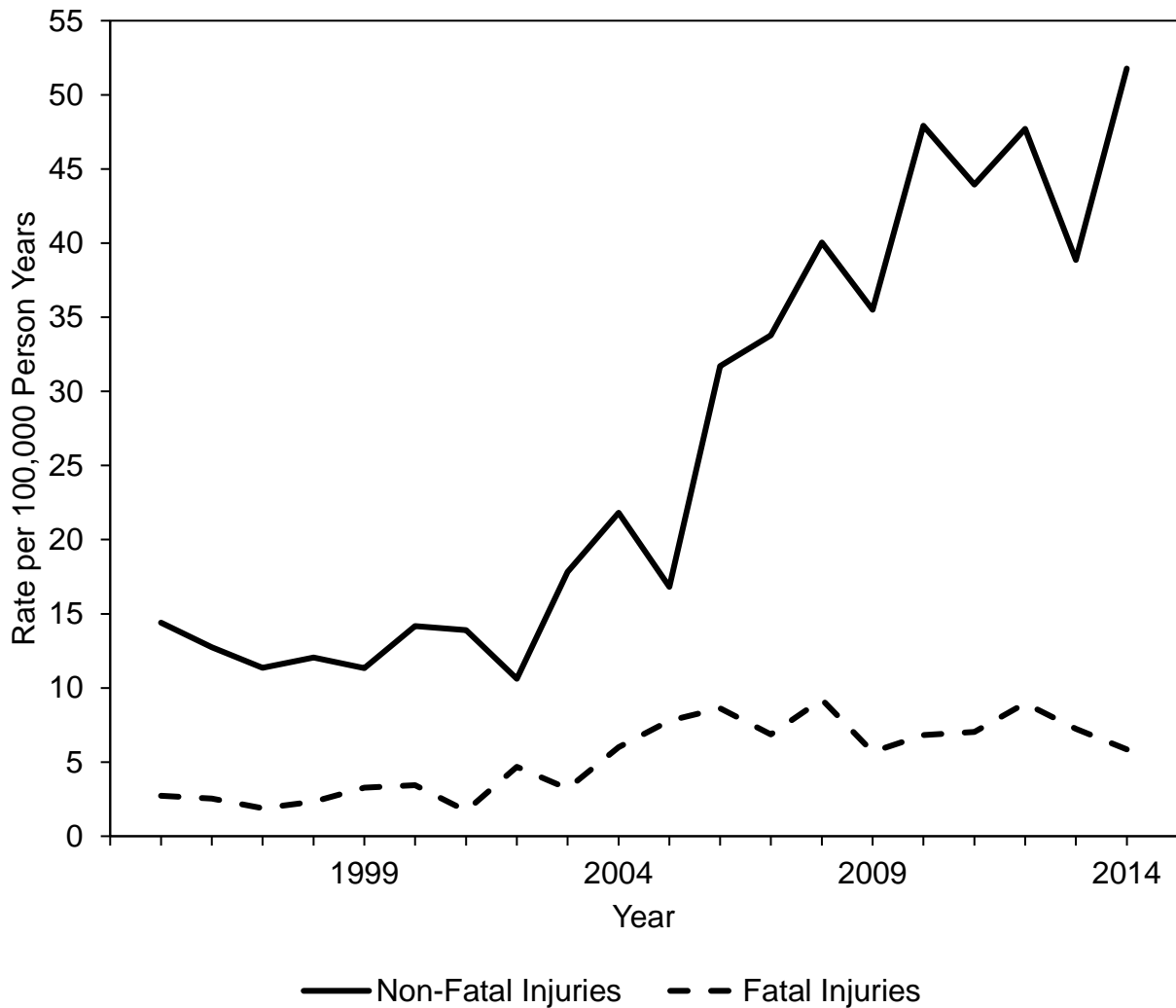


Figure 1. Trends in Reported Fatal and Non-fatal Motorcycle Traffic Crash Rates among Active Duty Army Operators, Army Safety Reports, 1995–2014 (n=2,852)

Rates of motorcycle traffic crashes, non-fatally injured, and fatally injured were examined by sex, age group, and rank groups (Table 2).

- Males had 8.8 times the rate of fatal motorcycle traffic crashes (95% CI: 4.6–17.1) and 4.7 times the rate of non-fatal motorcycle traffic crashes (95% CI: 3.8–5.9) than females ($p < 0.01$).
- Soldiers under 20 years old had the lowest rate of fatal (0.2 per 100,000 person-years) and non-fatal (0.9 per 100,000 person-years) motorcycle traffic crashes. Soldiers ages 30–34 years had the highest rate of fatal motorcycle traffic crashes (0.6 per 100,000 person-years). Soldiers ages 25–29 years had the highest rate of non-fatal motorcycle traffic crashes (3.1 per 100,000 person-years).

Public Health Report No. S.0047795-18

- Soldiers in ranks E1–E4 had a rate of fatal motorcycle traffic crashes 82% higher than officers and warrant officers (OR (95% CI): 1.8 (1.3–2.6)). Soldiers in ranks E5–E9 had 3.6 times the rates of fatal motorcycle traffic crashes compared with officers and warrant officers (95% CI: 2.5–5.2).

Table 2. Personal Characteristics of Active Duty Army Soldiers Non-fatally and Fatally Injured in Reported Motorcycle Traffic Crashes, 1995–2014 (n=2,845)

Characteristic	Fatal			Non-fatal			Total			
	n (%)	Rate ^a	Relative Rate (95% CI)	n (%)	Rate ^a	Relative Rate (95% CI)	n (%)	Rate ^a	Relative Rate (95% CI)	
Sex	Male	461 (98.1)	6.0	8.83 (4.57–17.09)	2,291 (96.5)	29.7	4.70 (3.78–5.85)	2,752 (96.7)	35.7	5.10 (4.15–6.28)
	Female	9 (1.9)	0.7	1.00	84 (3.5)	6.3	1.00	93 (3.3)	7.0	1.00
Age Group	< 20	11 (2.4)	1.7	0.40 (0.21–0.74)	56 (2.4)	8.5	0.39 (0.29–0.51)	67 (2.4)	10.2	0.39 (0.30–0.50)
	20–24	144 (31.3)	5.2	1.25 (0.96–1.62)	731 (31.9)	26.6	1.22 (1.08–1.37)	875 (31.8)	31.9	1.22 (1.10–1.36)
	25–29	124 (27.0)	6.0	1.43 (1.09–1.88)	638 (27.9)	31.1	1.42 (1.26–1.60)	762 (27.7)	37.1	1.42 (1.27–1.59)
	30–34	92 (20.0)	6.3	1.50 (1.12–2.00)	402 (17.6)	27.5	1.26 (1.10–1.44)	494 (18.0)	33.8	1.30 (1.15–1.46)
	≥ 35	89 (19.3)	4.2	1.00	463 (20.2)	22.0	1.00	552 (20.1)	26.1	1.00
Rank	E1–E4	163 (34.7)	4.0	1.82 (1.26–2.63)	886 (37.3)	21.8	1.24 (1.09–1.43)	1,049 (36.9)	25.8	1.31 (1.15–1.49)
	E5–E9	273 (58.1)	8.0	3.60 (2.52–5.15)	1,218 (51.3)	35.5	2.03 (1.78–2.31)	1,491 (52.4)	43.5	2.20 (1.95–2.49)
	O1–W5	34 (7.2)	2.2	1.00	270 (11.4)	17.5	1.00	304 (10.7)	19.7	1.00

Note:

^a Rate is calculated per 100,000 person-years

6.2 Motorcycle Traffic Crash Characteristics

Table 3 represents the following characteristics of motorcycle traffic crashes:

- Ninety-six percent of motorcycle traffic crashes involved men, one-third involved Soldiers between ages 20 and 24 years old, and approximately half involved Soldiers in ranks E5–E9.
- The majority of motorcycle traffic crashes did not involve alcohol (92%) and operators were wearing helmets (95%).
- Twenty-nine percent of fatal motorcycle traffic crashes involved alcohol use, while only 5% of non-fatal motorcycle traffic crashes involved used alcohol use.
- Nine percent of fatal motorcycle traffic crashes involved Soldiers who did not wear a helmet, while only 4% of non-fatal motorcycle traffic crashes involved Soldiers who did not wear a helmet.
- A majority of fatal and non-fatal motorcycle traffic crashes occurred while the Soldiers were off duty (93%).
- Fifteen percent of fatal motorcycle traffic crashes involved Soldiers without a valid motorcycle license, while only 8% of non-fatal motorcycle traffic crashes involved Soldiers without a valid motorcycle license.
- Approximately 58% of fatal motorcycle traffic crashes involved Soldiers who had slept less than 8 hours within the 24 hours prior to the crash.
- A majority of fatal and non-fatal motorcycle traffic crashes occurred off installation (88%).
- Two-thirds of fatal and non-fatal motorcycle traffic crashes occurred during the summer (April to September).
- The incidence of motorcycle traffic crashes resulting in non-fatal or fatal injuries was highest during the daytime (65%) and conditions were dry (94%).
- Seventy-three percent of fatal motorcycle traffic crashes involved colliding with a vehicle, object, or person.

Table 3. Motorcycle Traffic Crash Characteristics among Active Duty Army Soldiers, 1995–2014 (n=2,852)

Characteristic		Fatal Crash n (%)	Non-fatal Crash n (%)	Total n (%)
Operator Characteristics				
Sex	Male	461 (98.1)	2,291 (96.5)	2,752 (96.7)
	Female	9 (1.9)	84 (3.5)	93 (3.3)
	Missing	0	7	7
Age Group (Years)	< 20	11 (2.4)	56 (2.4)	67 (2.4)
	20–24	144 (31.3)	731 (31.9)	875 (31.8)
	25–29	124 (27.0)	638 (27.9)	762 (27.7)
	30–34	92 (20.0)	402 (17.6)	494 (18.0)
	≥ 35	89 (19.3)	463 (20.2)	552 (20.1)
	Missing	10	92	102
Rank	Enlisted (E1–E4)	163 (34.7)	886 (37.3)	1,049 (36.9)
	Enlisted (E5–E9)	273 (58.1)	1,218 (51.3)	1,491 (52.4)
	Officer or Warrant Officer	34 (7.2)	270 (11.4)	304 (10.7)
	Missing	0	8	8
Alcohol Use	Yes	75 (29.4)	101 (5.2)	176 (7.9)
	No	180 (70.6)	1,859 (94.8)	2,039 (92.1)
	Missing	215	422	637
Helmet Use	Yes	428 (91.1)	2,289 (96.1)	2,718 (95.3)
	No	42 (8.9)	92 (3.9)	135 (4.7)
	Missing	0	1	1
Off Duty	Yes	459 (97.7)	2,175 (91.5)	2,634 (92.5)
	No	11 (2.3)	202 (8.5)	213 (7.5)
	Missing	0	5	5
Motorcycle License	Yes	347 (85.0)	2,107 (91.6)	2,454 (90.7)
	No	61 (15.0)	192 (8.4)	253 (9.3)
	Missing	62	83	145
Hours Slept 24 Hours Prior to Incident	≥ 8 hours sleep	139 (41.6)	1,589 (73.9)	1,728 (69.6)
	< 8 hours sleep	195 (58.4)	560 (26.1)	755 (30.4)
	Missing	136	233	369

Public Health Report No. S.0047795-18

Crash Characteristics				
On an Army Installation	Yes	27 (5.7)	327 (13.8)	354 (12.4)
	No	443 (94.3)	2,048 (86.2)	2,491 (87.6)
	Missing	0	7	7
Summer	Yes	310 (66.0)	1,555 (65.3)	1,865 (65.4)
	No	160 (34.0)	827 (34.7)	987 (34.6)
	Missing	0	0	0
Period of Day	Day	254 (54.0)	1,588 (66.7)	1,842 (64.6)
	Night	204 (43.4)	647 (27.2)	851 (29.8)
	Twilight	12 (2.6)	146 (6.1)	158 (5.5)
	Missing	0	1	1
Wet Conditions	Yes	20 (5.8)	106 (6.1)	126 (6.0)
	No	324 (94.2)	1,634 (93.9)	1,958 (94.0)
	Missing	126	642	768
On Roadway	Yes	470 (100)	2,284 (95.9)	2,754 (96.6)
	No	0 (0)	97 (4.1)	97 (3.4)
	Missing	0	1	1
Collided with Vehicle/Object/Person	Yes	343 (73.0)	1,258 (53.9)	1,601 (57.1)
	No	127 (27.0)	1,075 (46.1)	1,202 (42.9)
	Missing	0	49	49

6.3 Non-fatal and Fatal Injuries Description

Safety reports contained the following injuries (Tables 4–6):

- Of the fatal motorcycle traffic crashes, 79% sustained injuries to the head and neck. The lower and upper extremities were the most frequently injured body areas in non-fatal motorcycle traffic crashes (35% each).
- Among all motorcycle traffic crashes, over half of the injuries sustained were fractures (60%), followed by abrasions/lacerations (21%), and sprains/strains (9%).
- Among fatal motorcycle traffic crashes, 60% of injuries sustained were fractures, 13% were concussions, and 6% were abrasions/lacerations.
- A motorcyclist being struck by or against something was the leading mechanism of fatal (65%) and non-fatal (42%) injuries, followed by the Soldier being thrown from a motorcycle (32% fatal and 35% non-fatal).
- Examining the crash type more closely, 23% involved the motorcycle going forward and colliding with a moving vehicle, while 21% involved colliding with an object other than a vehicle or pedestrian. An additional 21% of crashes involved a motorcycle overturning and 12% involved a motorcycle running off the road (non-collision type crashes) (Table 5).

Public Health Report No. S.0047795-18

- There were differences across age groups in the proportion of Soldiers whose crash occurred while riding off duty, off an Army installation, or without a motorcycle license (Table 6).

Table 4. Characteristics of Non-fatal and Fatal Injuries Associated with Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers as Documented in ASMIS, 1995–2014 (n=2,852)

Characteristic		Fatal Crash n (%)	Non-fatal Crash n (%)	Total n (%)
Body Area Injured	Head and Neck	160 (79.2)	298 (14.1)	458 (19.8)
	Torso	31 (15.3)	311 (14.7)	342 (14.8)
	Lower Extremity	7 (3.5)	747 (35.4)	754 (32.6)
	Upper Extremity	4 (2.0)	753 (35.7)	757 (32.8)
	Missing	268	273	541
Type of Injury	Fractures	136 (60.4)	1,215 (53.7)	1,351 (59.7)
	Concussion	29 (12.9)	107 (4.7)	136 (6.0)
	Contusion (Bruise, Hematoma)	15 (6.7)	100 (4.4)	115 (5.1)
	Abrasions/Lacerations	14 (6.2)	456 (20.2)	470 (20.8)
	Puncture, Perforation or Penetration	8 (3.6)	20 (0.9)	28 (1.2)
	Amputation	7 (3.1)	41 (1.8)	48 (2.1)
	Herniation/Rupture	7 (3.1)	14 (0.6)	21 (0.9)
	Burns (Chemical and Thermal)	3 (1.3)	9 (0.4)	12 (0.5)
	Unconsciousness/Coma	3 (1.3)	11 (0.5)	14 (0.6)
	Dislocation	2 (0.9)	87 (3.8)	89 (3.9)
	Sprains and Strains	0 (0)	197 (8.7)	197 (8.7)
	Other ^a	1 (0.4)	5 (0.2)	6 (0.3)
	Missing	245	119	364
Mechanism of Injury	Struck By/Against	205 (65.1)	956 (41.9)	1,161 (44.7)
	Thrown From	101 (32.1)	793 (34.7)	894 (34.4)
	Fell from Elevated or Same Level	3 (1.0)	143 (6.3)	146 (5.6)
	Other ^b	6 (1.9)	391 (17.1)	397 (15.3)
	Missing	155	99	254

Notes:

^a “Other” types of injury included: hemorrhage, paralysis, and repeated trauma disorder.

^b “Other” mechanisms of injury included: rubbed/abraded, bodily reaction, overexertion, exposure, external contact, and inhalation.

Table 5. Types of Fatal and Non-fatal Motorcycle Traffic Crashes among Active Duty Army Operators, Army Safety Reports, 1995–2014 (n=2,852)

Type of Crash	Fatal Crash n (%)	Non-fatal Crash n (%)	Total n (%)
Going forward and collided with moving vehicle	168 (35.7)	462 (19.8)	630 (22.5)
Collision with object other than vehicle/pedestrian	137 (29.1)	446 (19.1)	583 (20.8)
Overtaken	65 (13.8)	512 (21.9)	577 (20.6)
Ran off road	59 (12.6)	280 (12.0)	339 (12.1)
Going forward and rear-ended moving vehicle	15 (3.1)	47 (2.0)	62 (2.2)
Collision while turning	5 (1.1)	103 (4.4)	108 (3.9)
Going forward and collided with parked vehicle	4 (0.9)	35 (1.5)	39 (1.4)
Going forward and rear-ended parked vehicle	2 (0.4)	39 (1.7)	41 (1.5)
Collision with pedestrian	2 (0.4)	2 (0.1)	4 (0.1)
Jackknifed	0 (-)	7 (0.3)	7 (0.2)
Collision while backing	0 (-)	3 (0.1)	3 (0.1)
Other	13 (2.8)	397 (17.0)	410 (14.6)
Missing	0	49	49

Table 6. Distribution of Fatal and Non-fatal Motorcycle Traffic Crash Characteristics by Age Group among Active Duty U.S. Army Operators, Army Safety Reports, 1995–2014 (n=2,852)

Characteristic	Age Group (Years) n (%)					X ² p-value	
	<20	20–24	25–29	30–34	35–64		
Helmet Use	Yes	56 (87)	750 (91)	664 (92)	422 (92)	478 (93)	0.24
	No	8 (13)	77 (9)	54 (8)	36 (8)	33 (6)	
Alcohol Use	Yes	3 (6)	58 (8)	55 (9)	27 (7)	27 (6)	0.51
	No	43 (93)	621 (91)	558 (91)	355 (93)	401 (94)	
Hours Slept 24 Hours Prior to Incident	≥ 8 hours sleep	40 (68)	528 (69)	468 (71)	300 (69)	344 (70)	0.95
	< 8 hours sleep	19 (32)	237 (31)	193 (29)	134 (31)	149 (30)	
Off Duty	Yes	63 (94)	820 (94)	716 (94)	448 (91)	494 (89)	< 0.01
	No	4 (6)	54 (6)	45 (6)	46 (9)	58 (11)	
On an Army installation	No	53 (79)	746 (85)	663 (87)	441 (89)	501 (91)	< 0.01
	Yes	14 (21)	127 (15)	96 (13)	52 (11)	50 (9)	
Motorcycle License	Yes	46 (74)	712 (86)	657 (91)	446 (94)	516 (97)	< 0.01
	No	16 (26)	118 (14)	67 (9)	26 (6)	16 (3)	

6.4 Unadjusted Risk of Fatality

Unadjusted risk ratios and odds ratios suggested the same variables were potentially associated with fatal injuries from motorcycle traffic crashes (Table 7 and 8). When univariate logistic regression was conducted, the following variables were seen to be associated with fatality ($p \leq 0.25$): male sex, enlisted rank, alcohol use, no helmet use, less than 8 hours' sleep, off duty (Table 7), not occurring on an Army installation, period of day (night time), and colliding with a vehicle, object, or person (Table 8). The unadjusted odds ratios for operator and crash characteristics were as follows:

Public Health Report No. S.0047795-18

- Motorcycle traffic crashes involving male Soldiers had an 88% higher odds of fatality from motorcycle traffic crashes involving females (OR (95% CI): 1.9 (0.9–3.8), $p=0.08$).
- There was no significant difference in risk or odds of fatality when comparing motorcycle traffic crashes involving the younger age groups to the crashes involving the oldest age group.
- Motorcycle traffic crashes involving Soldiers in ranks E1–E4 had 46% higher odds of fatality than crashes involving officers and warrant officers (OR (95% CI): 1.5 (1.0–2.2), $p=0.06$).
- Motorcycle traffic crashes involving Soldiers in ranks E5–E9 had 78% higher odds of fatality than crashes involving officers and warrant officers (OR (95% CI): 1.8 (1.2–2.6), $p<0.01$).
- Motorcycle traffic crashes involving Soldiers who used alcohol had 4.8 times the odds of fatality compared to those that did not involve alcohol (OR (95% CI): 4.8 (3.9–6.02), $p<0.01$).
- Motorcycle traffic crashes involving Soldiers who did not wear a helmet had 2.5 times the odds of fatality compared to those that did wear a helmet (OR (95% CI): 2.5 (1.7–3.6), $p<0.01$).
- Motorcycle traffic crashes involving Soldiers riding off duty had 3.4 times the risk of fatality compared to those that were riding on duty (OR (95% CI): 3.4 (1.9–6.1), $p<0.01$).
- Motorcycle traffic crashes involving Soldiers who were not licensed had 71% higher risk of fatality than those who were licensed (OR (95% CI): 1.7 (1.4–2.2), $p<0.01$).
- Motorcycle traffic crashes involving Soldiers who were not licensed had 93% higher odds of fatality than those who were licensed (OR (95% CI): 1.9 (1.4–2.6), $p<0.01$).
- Motorcycle traffic crashes involving Soldiers who had slept less than 8 hours had 4.0 times the odds of fatality compared to those that had 8 or more hours of sleep (OR (95% CI): 4.0 (3.1–5.1), $p<0.01$).

Table 7. Unadjusted Risk and Odds of Fatal Injury from Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, Operator Characteristics, 1995–2014

Characteristic		Injured N (% fatal)	Risk Ratio (95% CI)	Odds Ratio (95% CI)	X ² p-value	Overall X ² p-value
Sex	Male	2,752 (16.8)	1.73 (0.93–3.24)	1.88 (0.94–3.76)	0.08	0.08
	Female	93 (9.7)	1.00	1.00		
Age Group (Years)	< 20	67 (16.4)	1.02 (0.57–1.81)	1.02 (0.52–2.03)	0.95	0.81
	20–24	875 (16.5)	1.02 (0.80–1.30)	1.02 (0.77–1.37)	0.87	
	25–29	762 (16.3)	1.01 (0.79–1.30)	1.01 (0.75–1.36)	0.94	
	30–34	494 (18.6)	1.16 (0.89–1.51)	1.19 (0.86–1.64)	0.29	
	≥ 35	552 (16.1)	1.00	1.00		
Rank	Enlisted (E1–E4)	1,049 (15.5)	1.39 (0.98–1.97)	1.46 (0.99–2.16)	0.06	< 0.01
	Enlisted (E5–E9)	1,491 (18.3)	1.64 (1.17–2.29)	1.78 (1.22–2.60)	< 0.01	
	Officer and Warrant Officer	304 (11.2)	1.00	1.00		
Alcohol Use	Yes	176 (42.6)	7.67 (5.48–10.73)	4.83 (3.87–6.02)	< 0.01	< 0.01
	No	2,039 (8.8)	1.00	1.00		
Helmet Use	Yes	2,717 (15.8)	1.00	1.00		
	No	135 (31.9)	2.02 (1.56–2.63)	2.50 (1.72–3.64)	< 0.01	< 0.01
Off Duty	Yes	2,635 (17.5)	3.88 (2.10–7.18)	3.38 (1.89–6.05)	< 0.01	< 0.01
	No	213 (5.20)	1.00	1.00		
Motorcycle License	Yes	2,454 (14.1)		1.00		
	No	253 (24.10)	1.71 (1.35–2.17)	1.93 (1.42–2.63)	< 0.01	< 0.01
Hours Slept 24 Hours Prior to Incident	≥ 8 hours sleep	1,728 (8.0)	1.00			
	< 8 hours sleep	755 (25.8)	3.21 (2.63–3.92)	3.98 (3.14–5.05)	< 0.01	< 0.01

Note: Bold numbers indicate significant p-value

Public Health Report No. S.0047795-18

- Motorcycle traffic crashes involving Soldiers riding off an Army installation had 2.3 times the odds of fatality compared to those that were riding on an installation (OR (95% CI): 2.3 (1.6–3.4), p<0.01).
- Motorcycle traffic crashes involving Soldiers riding during the summer did not have significantly different odds of death than those crashes that did not occur in the summer (OR (95% CI): 1.0 (0.8–1.3), p=0.86).
- Motorcycle traffic crashes involving Soldiers riding during the night had 2.0 times the odds of death compared to those that were riding during the day (OR (95% CI): 2.0 (1.6–2.4), p<0.01).
- Motorcycle traffic crashes involving Soldiers riding during the twilight had 0.6 times the odds of fatality compared to those that were riding during the day (OR (95% CI): 0.6 (0.3–1.0), p=0.05).
- Motorcycle traffic crashes involving Soldiers riding in wet conditions did not have higher odds of fatality compared to those that were riding in dry conditions (OR (95% CI): 1.0 (0.6–1.6), p=0.85).
- Motorcycle traffic crashes involving colliding with a vehicle, object, or person had 2.3 times the odds of death compared to those that did not (OR (95% CI): 2.3 (1.9–2.9), p=0.01).

Table 8. Unadjusted Risk and Odds of Fatal Injury from Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, Crash Characteristics, 1995–2014

Characteristic		Injured N (% fatal)	Risk Ratio (95% CI)	Odds Ratio (95% CI)	X ² p-value	Overall X ² p-value
On an Army Installation	Yes	354 (7.6)	1.00	1.00		< 0.01
	No	2,491 (17.8)	2.33 (1.61–3.38)	2.33 (1.61–3.38)	< 0.01	
Summer	Yes	1,867 (16.6)	1.02 (0.83–1.25)	1.02 (0.85–1.21)	0.86	0.86
	No	985 (16.4)	1.00	1.00		
Period of Day	Day	1,842 (13.8)	1.00	1.00		< 0.01
	Night	851 (24.0)	1.74 (1.47–2.05)	1.97 (1.61–2.42)	< 0.01	
	Twilight	159 (8.2)	0.59 (0.35–1.01)	0.56 (0.31–1.00)	0.05	
Wet Conditions	Yes	126 (15.9)	0.95 (0.58–1.56)	0.96 (0.63–1.45)	0.85	0.85
	No	1,958 (16.6)	1.00	1.00		
Collided with Vehicle/Object/Person	Yes	1,601 (21.4)	2.31 (1.85–2.87)	2.03 (1.68–2.45)	< 0.01	< 0.01
	No	1,202 (10.6)	1.00	1.00		

Note: Bold numbers indicate significant p-value

6.5 Multivariable Analysis

After analysis of variables in the EM-generated data, the following variables were included in the final multivariable logistic regression model run on the imputed dataset: sex, rank, alcohol use, helmet use, duty status, licensed to operate motorcycle, hours slept 24 hours prior to the crash, crash location, period of day, and collision type (Table 9). The adjusted odds ratios for operator and crash characteristics that were significantly associated with fatality were as follows:

- Motorcycle traffic crashes involving Soldiers who used alcohol had 3.1 times the odds of fatality than Soldiers who did not use alcohol (OR (95% CI): 3.1 (2.2–4.5), $p < 0.01$).
- Motorcycle traffic crashes involving Soldiers who did not wear a helmet had 1.9 times the odds of fatality than Soldiers who did wear a helmet (OR (95% CI): 1.9 (1.2–2.9), $p < 0.01$).
- Motorcycle traffic crashes involving Soldiers riding off duty had 2.4 times the odds of fatality than Soldiers riding on duty (OR (95% CI): 2.4 (1.3–4.6), $p < 0.01$).
- Motorcycle traffic crashes involving Soldiers who had slept less than 8 hours had 2.3 times the odds of fatality than Soldiers who had slept 8 or more hours (OR (95% CI): 2.3 (1.8–2.9), $p < 0.01$).
- Motorcycle traffic crashes involving Soldiers riding off installation had 2.2 times the odds of fatality than Soldiers riding on installation (OR (95% CI): 2.2 (1.4–3.4), $p < 0.01$).
- Motorcycle traffic crashes involving Soldiers who collided with a vehicle, object, or person had 2.2 times the odds of fatality than Soldiers who did not collide with something (OR (95% CI): 2.2 (1.7–2.7), $p < 0.01$).

Table 9. Adjusted Odds of Fatal Injury from Reported Motorcycle Traffic Crashes among Active Duty Army Soldiers, 1995–2014

Characteristic		Odds Ratio (95% CI)	p-value
Operator Characteristics			
Sex	Male	1.48 (0.72–3.04)	0.28
	Female	1.00	
Rank	Enlisted (E1–E4)	1.14 (0.75–1.73)	0.55
	Enlisted (E5–E9)	1.46 (0.98–2.18)	0.06
	Officer or Warrant Officer	1.00	
Alcohol Use	Yes	3.14 (2.17–4.53)	< 0.01
	No	1.00	
Helmet Use	Yes	1.00	
	No	1.89 (1.24–2.89)	< 0.01
Off Duty	Yes	2.44 (1.28–4.63)	< 0.01
	No	1.00	
Motorcycle License	Yes	1.00	
	No	1.34 (0.94–1.91)	0.11
Hours Slept 24 Hours Prior to Incident	≥ 8 hours sleep	1.00	
	< 8 hours sleep	2.30 (1.80–2.92)	< 0.01
Crash Characteristics			
On an Army installation	Yes	1.00	
	No	2.18 (1.41–3.37)	< 0.01
Period of day	Day	1.00	
	Night	1.20 (0.93–1.53)	0.16
	Twilight	0.60 (0.33–1.09)	0.09
Collided w Vehicle/Object/Person	Yes	2.17 (1.72–2.73)	< 0.01
	No	1.00	

Note: Bold numbers indicate significant p-value

7. DISCUSSION

7.1 Injury and Fatality

The current study found that motorcycle traffic crash and related fatality rates have increased since 1995. The rate of non-fatal motorcycle traffic crashes has increased relatively more than fatal crashes, with a significant increase beginning in 2002. This trend is reflected when examining military motorcycle-related injuries and fatalities from other data sources. The Armed Forces Health Branch also found that motorcycle traffic crash and motorcycle fatality rates among active component Army Soldiers has been on the rise since 1995 (Armed Forces Health Surveillance Center 2013). A prior analysis of medical examiner data similarly found that

Public Health Report No. S.0047795-18

motorcycle traffic fatality rates among active component Army personnel, 1999–2012, began increasing in 2002, with a subsequent peak in 2008 at approximately 7.5 motorcycle deaths per 100,000 person-years (Armed Forces Health Surveillance Center 2013). The same study found that active component, those ages 20–24 years, males, whites, and non-Hispanics have the largest numbers of motorcycle-related deaths among military members (Armed Forces Health Surveillance Center 2013). Similarly, males and those ages 20–24 years had the highest number of motorcycle traffic crash fatalities in the current study.

No statistically significant change in fatal crash rates was observed in the current study. However, a prior analysis of Defense Medical Surveillance System (DMSS) data reported that motorcycle traffic crash non-fatal injury hospitalization rates increased among Army personnel from 1998 to 2008, with the highest reported rate in 2008 (Armed Forces Health Surveillance Center 2009). DMSS data showed the rate of motorcycle hospitalizations and fatalities combined to be 27 per 100,000 person-years in 1998 and 47 per 100,000 person-years in 2008 (Armed Forces Health Surveillance Center 2009). Given that safety data may include non-fatal injuries treated on an outpatient basis as well as hospitalizations, these rates are not directly comparable, but serve to validate observed trends. Fatal and non-fatal motorcycle crash rates in the general U.S. population peaked around 2007 and have since remained stable (National Center for Statistics and Analysis 2016). For comparison to DMSS and civilian data, future investigations into these rates should use denominators that adjust for temporal changes in ridership and/or vehicle miles traveled (Dada 2015).

The significant rise in non-fatal motorcycle traffic crashes occurred at a time when deployments to Afghanistan and Iraq were beginning and/or ongoing. Noticing the trend, the Services responded with aggressive safety campaigns (Armed Forces Health Surveillance Center 2009, 2011) that could have influenced motorcycle crash fatality and non-fatal injury rates; however, an evaluation of the campaigns was not conducted. Unfortunately, the safety data did not contain complete information on deployment. For that reason, the relationship between deployment and motorcycle crash injury could not be assessed in this analysis. Although motor vehicle-related injuries are not generally a focus of deployment health outcome assessments (Institute of Medicine 2010), consideration should be given to monitoring this in the future, given previous associations of deployment with the risk of fatal motor vehicle accidents among Gulf War veterans (Hooper et al. 2006). As reported in a Medical Surveillance Monthly Report, the underlying cause of the increasing motorcycle traffic non-fatal crash rate from 2002 to 2014 remains unclear (Armed Forces Health Surveillance Center 2013). Programs and policies, such as a motorcycle safety course requirement, are already in place but a reduction in crashes have yet to be seen (Armed Forces Health Surveillance Center 2013).

Approximately two-thirds of fatalities were due to the Soldier being struck by or against something and one-third was due to being thrown from the motorcycle. The majority of fatal crashes involved injury to the head and neck; while in non-fatal crashes, the lower extremities and the upper extremities accounted for about one-third of non-fatal injuries. In fatal and non-fatal crashes, fractures were the most common type of injury. These results are similar to prior studies of civilian and military motorcycle-related fatalities and non-fatal injuries (Lin and Kraus 2009, Dada, Canham-Chervak, and Jones 2015, Coben, Steiner, and Miller 2007). A study using a nationwide inpatient database found that motorcycle crash injuries were most commonly fractures of the lower limbs, fractures of the upper limbs, and intracranial injuries (Coben,

Public Health Report No. S.0047795-18

Steiner, and Miller 2007). Among Army personnel from 2003 to 2008 the most common injuries requiring hospitalization were fractures of the lower and upper extremities followed by traumatic brain injuries (Dada 2015). A review of motorcycle injuries found that head injuries were the leading cause of death in motorcycle crashes and injury to the lower extremity is most common among non-fatal motorcycle crashes (Lin and Kraus 2009). As seen in other populations, the proportion of some potential risk factors for motorcycle crashes vary across age groups in this Army population (Bell et al. 2000, Crompton et al. 2010, Jung, Xiao, and Yoon 2013).

7.2 Factors Associated with Fatalities

The current study found that modifiable factors were significantly associated with motorcycle traffic fatality, given that a crash occurred. While controlling for other factors, modifiable individual risk factors such as alcohol use, helmet use, and hours slept were more strongly associated with fatality risk than non-modifiable personal characteristics (i.e., sex, rank).

7.2.1 Alcohol Use

Alcohol use was found to approximately triple the odds of death due to motorcycle traffic crash, similar to previous studies of alcohol use and driving (motor vehicle or motorcycle) (Lin and Kraus 2009). Mayhew et al. determined that the risk of being involved in a fatal motorcycle crash increases with increased BAC levels for all age groups (Mayhew et al. 1986). A study of motorcycle crashes in California from 1995 to 2009 found that alcohol/drug influence had the strongest effect on motorcyclist fatalities across all age groups studied (Jung, Xiao, and Yoon 2013). A study of French data from 1996 to 2005 calculated that motorcycle riders with an illegal BAC of between 0.5 and 0.8 grams/liter had 3.7 times higher risk of being involved in a crash compared with riders who were not over the legal limit (Moskal, Martin, and Laumon 2012). The study additionally determined that beyond this level of intoxication while operating a motorcycle the risk of a crash increased with alcohol dose (Moskal, Martin, and Laumon 2012). A prior study of motor vehicle crashes based on ASMIS data from 1999 to 2006 found that the odds of medically-severe injury was doubled when alcohol was involved compared with no alcohol involved (Pollack, Gibbons, and Canham-Chervak 2009). It has previously been suggested that motorcycle operators are more vulnerable than other motor vehicle drivers are to alcohol's effects on balance, motor coordination, and judgement that are needed to safely operate a motorcycle (Colburn et al. 1993, Sun, Kahn, and Swan 1998). A study of motor vehicle injury hospitalizations among active duty Army personnel determined there was an interaction between age and alcohol; younger respondents were at higher risk of motor vehicle-related injuries than older respondents across all levels of alcohol consumption, but the difference in risk was smallest among the heaviest drinkers (Bell et al. 2000). Age was not found to interact with alcohol use in the current study.

The enforcement of legal limits of BAC is an effective intervention to reduce alcohol-related motorcycle deaths (Villaveces et al. 2003). There are already Army policies regarding alcohol use and motor vehicle operation (including motorcycles) (Department of the Army 2006). An installation commander or designee may suspend privately-owned vehicle driving privileges on an installation if a Soldier is determined to be operating a motor vehicle with a BAC of 0.08 g/dl or higher or incurs an arrest report for intoxicated driving while on or off an installation (Department of the Army 2006). However, the majority of motorcycle traffic crashes occur off

Public Health Report No. S.0047795-18

installation, suggesting policies on installation are not preventing Soldier motorcyclists' injuries and fatalities off installation.

7.2.2 Helmet Use

Not wearing a helmet is an important modifiable factor associated with motorcycle traffic crash fatality. There is conclusive civilian evidence of helmet effectiveness for preventing severe injury and death during a motorcycle crash (Liu et al. 2008, Jung, Xiao, and Yoon 2013, Abbas, Hefny, and Abu-Zidan 2012, Goslar et al. 2008, Lawrence 2002, Lin and Kraus 2009, Liu et al. 2015, National Center for Statistics and Analyses 2014b, Olsen et al. 2016, Norvell and Cummings 2002, Burns et al. 2015). A systematic review by Liu et al. pooled results from motorcycle helmet studies and calculated that helmets reduce odds of fatality by 48% (OR (95% CI): 0.58 (0.50, 0.68)) and reduced the odds of head injury by 69% (OR (95% CI): 0.31 (0.25, 0.38)), after adjusting for other factors (Liu et al. 2008). A review of risk factors for motorcycle injuries also found that un-helmeted riders are more likely to have head injuries, die, require longer hospitalization, and have higher medical costs compared to helmeted riders (Lin and Kraus 2009). An analysis by the National Highway Traffic Safety Administration (NHTSA) estimated that helmets are 37% effective in preventing fatal injuries to motorcycle riders and 41% effective for motorcycle passengers (National Center for Statistics and Analyses 2014b). A study of the Crash Outcome Data Evaluation System Network (a collection of states partially support by NHTSA) found that un-helmeted riders had between 1.1 and 1.9 increase for moderate to severe head/face injury or death (Olsen et al. 2016); this is similar to the 2 time increase estimated by the current study. Similarly, among 1,200 motorcycle crash patients at a Galveston trauma facility, those who did not wear a helmet had 2.3 times the odds of death after adjusting for patient demographic data (Burns et al. 2015).

Helmet use is significantly higher in states with laws requiring all motorcyclists to be helmeted than in states that do not (National Center for Statistics and Analyses 2014a, Olsen et al. 2016); state (as a proxy for state helmet law) was not controlled for in the multivariable analysis. All of the references above examined associations between helmet use and fatality in civilian populations. It appears that Soldiers have similar risk of death when riding un-helmeted and are involved in a motorcycle crash.

7.2.3 Riding Off Duty and Off an Army Installation

In the current study, off-installation motorcycle traffic crashes and crashes that occurred while the driver was off duty were significantly associated with fatality. Soldier motorcyclists are required to follow the regulations in AR 385-10, *The Army Safety Program*, including completing at least the Motorcycle Safety Foundation Basic Rider Course ((Department of the Army 2013). This training is required to be completed within 30 duty days of the request for training for new riders, and at least every 5 years as a refresher (Department of Defense 2009). The ACRC contains information on Soldier motorcyclist regulations, the Motorcycle Mentorship Program, and information for leaders of Soldier motorcyclists (U.S. Army Combat Readiness Center 2016). Despite these motorcycle policies and programs, riders may choose to not comply with Army motorcycle regulations or ride more recklessly while off installation. Further investigation is needed to address the higher non-fatal injury rates attributable to riding off duty and off installation.

7.2.4 Sleep

The current study estimated that Soldiers who sleep less than 8 hours in the 24 hours prior to the motorcycle traffic crash are about 2 times more likely to be involved in a fatal crash. A previous study of motor vehicle crashes reported in ASMIS from 1996 to 2006 found that zero hours of sleep was significantly associated with medically-severe injury after a motor vehicle crash (OR: 2.3, 95% CI: 1.7–3.2) (Pollack, Gibbons, and Canham-Chervak 2009). Hours of sleep was not a significant predictor of hospitalization after a motorcycle crash in the Pollack et al. study but the population of their multivariable model was smaller than the current study (Pollack, Gibbons, and Canham-Chervak 2009). The current study may have had more power to detect the significance of hours slept and the outcome was motorcycle traffic fatality, which may also explain the difference from the Pollack et al. analysis. The NHTSA has previously found that the following are at increased risk for motor vehicle drowsy driving crashes: young people (ages 16–29 years), males, shift workers, and people with untreated sleep disorders (NCSDR/NHTSA Expert Panel on Driver Fatigue and Sleepiness). Soldiers involved in fatal motorcycle traffic crashes in the current study were overwhelmingly male and almost two-thirds were below 29 years old, putting them in a population that is at especially high risk of drowsy driving crashes in any motor vehicle. There was not sufficient information on hours worked in the 24 hours prior to the crash in the dataset to examine its potential association with motorcycle traffic crash fatality, but Military personnel often have long and atypical work hours, compromising their ability to obtain sleep (Lentino et al. 2013a). Adequate sleep has already been identified as a priority for Soldier health, as demonstrated by its inclusion in the Performance Triad (Army Medicine 2015, Lentino et al. 2013b). The findings of this study further support focusing on improving Soldiers sleep patterns to reduce risk of injury and fatality while riding a motorcycle.

7.2.5 Collision with Vehicle, Object, or Person

Colliding with something was estimated to double the odds of fatality in the population under study. The risk of motorcycle fatality has previously been found to increase when motorcyclists depart the roadway and collide with roadside objects such as trees, poles, or traffic barriers (Daniello and Gabler 2011). Using motorcycle crash data from the Fatality Analysis Reporting System and the General Estimates System, Daniello and Gabler found that roadside objects are overrepresented in fatality risk and that motorcycle-tree collisions had the highest fatality risk, followed by collisions with signs and utility poles (Daniello and Gabler 2011). This is also reflected in the univariate and multivariable analysis results of the current analysis. Collision type has also previously been associated with motorcycle fatalities in the Statewide Integrated Traffic Records System of California (Jung, Xiao, and Yoon 2013). A study of motorcycle crashes in California from 1995 to 2009 found that collision type was one of the strongest factors to increase motorcyclist fatalities across the studied age groups (Jung, Xiao, and Yoon 2013). The study determined head-on collisions increased fatalities by 96% for motorcycle riders under 25 years old, 301% for motorcycle riders 35–44 years old, and 445% for motorcycle riders 45–54 years old (Jung, Xiao, and Yoon 2013). The study also found that the impacts of broadside and hit object collisions were stronger in increasing the probability of fatalities in the under 25 year old age group (Jung, Xiao, and Yoon 2013). This finding further supports the

importance of Soldiers being aware of their surroundings and avoiding collisions with other vehicles as best as possible.

7.3 Limitations

The current study accounted for the effects of potentially important factors such as licensure, time of year or day, and weather conditions to determine what factors are most important with regard to motorcycle traffic fatalities. A limitation of this study was that the rates were calculated using a population-based denominator, that is, person-years of all active duty Army personnel. A more accurate denominator for assessment of trends in motorcycle fatalities would be person-years of motorcycle operators, number of registered vehicles, or vehicle miles traveled. Rates calculated based on the entire Army population do not reflect changes in motorcycle ridership that may influence the rates of fatal and non-fatal motorcycle traffic crashes. Another limitation was the inability to examine race and motorcycle traffic fatalities. A study using motorcycle crashes recorded in the National Trauma Data Bank determined that after controlling for confounders, blacks had a 58% higher risk of dying compared with whites with equivalent injuries (Crompton et al. 2010). Unlike the current study, this study did not control for crash factors such as time of day and involvement of other vehicles, which may have contributed to the higher risk of deaths seen among black motorcyclists (Crompton et al. 2010). We also did not examine whether Soldier motorcyclists were riding in states with universal helmet laws (UHL). A study using the National Highway Traffic Safety Administration's Fatality Analysis Reporting System determined that states without a UHL have 34% more motorcycle fatalities than states with UHL (French, Gumus, and Homer 2012). A study employing the Healthcare Cost and Utilization Project's State Inpatient Databases found that motorcycle crash cases from states without UHLs were 41% more likely to sustain the most severe forms of traumatic brain injury (Coben, Steiner, and Miller 2007). Another limitation was the inability to examine speed as a factor associated with motorcycle traffic crash fatality. Speeding is responsible for approximately two-thirds of motorcycle deaths in single-vehicle crashes, but there was not enough data on speeding to examine it as a factor in this Soldier population (Lin and Kraus 2009). Vehicle speed needs to be collected on every safety report. Future investigations will examine qualitative data to capture speed, as it is not a unique question on the safety report. There was also not enough data regarding deployment to examine recent return from deployment as a risk factor for motorcycle crash fatality in this study. Soldiers returning from the Gulf War were found to have higher risk of fatal motor vehicle crashes (Hooper et al. 2006), so future studies using safety data should be linked to databases with deployment information, if possible. This analysis also suggests that certain risk factors for motorcycle crashes vary by age in this Army population, which warrants further investigation. A methodological limitation was a lack of sensitivity analyses; future studies will include sensitivity analysis. Lastly, witness interviews were used to collect some fatal motorcycle traffic crash details; therefore, some fatal crash characteristics, such as hours slept in the past 24 hours, may be less accurate than for non-fatal crashes, where the operator could be interviewed.

8. CONCLUSIONS AND RECOMMENDATIONS

Despite required training and equipment use, motorcycle traffic crashes have been on the rise since 2002 and remain an important preventable cause of military personnel injury. Modifiable risk factors such as alcohol use, helmet use, and hours slept prior to riding should continue to

Public Health Report No. S.0047795-18

be addressed by Army motorcycle safety policies. With this information, Army safety officers and leadership can be better prepared to address modifiable risk factors for motorcycle traffic crash fatalities. As noted by Bullock et al., education and leadership support are critical components of a successful injury prevention program (Bullock et al. 2010). Leadership should encourage and counsel their troops to utilize the required safety measures during off duty, off-installation activities, and at night. Leadership should continue to ensure fully trained personnel are riding operationally safe motorcycles and complete all mandatory motorcycle training as required under the Progressive Motorcycle Program per AR 385-10 (Department of the Army 2013). The ACRC has pertinent information and materials for leadership and motorcyclists to help them address the modifiable risk factors associated with motorcycle traffic crash fatalities.

9. POINT OF CONTACT

The APHC Injury Prevention Division is the point of contact for this project, e-mail usarmy.apg.medcom-phc.mbx.injuryprevention@mail.mil, or phone number 410-436-4655, DSN 584-4655. Specific questions may be directed to author(s) listed at the front of this report.

Approved:

Bruce H. Jones, MD MPH
Division Chief
Injury Prevention Division

Appendix A

References

- Abbas, Alaa K., Ashraf F. Hefny, and Fikri M. Abu-Zidan. 2012. "Does wearing helmets reduce motorcycle-related death? A global evaluation." *Accident Analysis & Prevention* 49:249-252. doi: <http://dx.doi.org/10.1016/j.aap.2011.09.033>.
- Armed Forces Health Surveillance Center. 2009. "Motorcycle accidents, active component, U.S. Armed Forces, 1998-2008." *Medical Surveillance Monthly Report* 16 (6).
- Armed Forces Health Surveillance Center. 2011. "Motorcycle and other motor vehicle accident-related deaths, U.S. Armed Forces, 1999-2010." *Medical Surveillance Monthly Report* 18 (3).
- Armed Forces Health Surveillance Center. 2013. "Update: motor vehicle-related deaths, active and reserve components, U.S. Armed Forces, 1999-2012." *Medical Surveillance Monthly Report* 20 (11).
- Army Medicine. 2015. "The Performance Triad." Department of the Army. <http://armymedicine.mil/Pages/performance-triad.aspx>.
- Barlas, FM, Higgins, WB, Pflieger, JC, Diecker, K. 2013. 2011 Health Related Behaviors Survey of Active Duty Military Personnel. edited by Department of Defense. Fairfax, VA: ICF International.
- Bell, Nicole S., Paul J. Amoroso, Michelle M. Yore, Gordon S. Smith, and Bruce H. Jones. 2000. "Self-reported risk-taking behaviors and hospitalization for motor vehicle injury among active duty Army personnel." *American Journal of Preventive Medicine* 18 (3, Supplement 1):85-95. doi: [http://dx.doi.org/10.1016/S0749-3797\(99\)00168-3](http://dx.doi.org/10.1016/S0749-3797(99)00168-3).
- Brown, Carlos V. R., Kelli Hejl, Eric Bui, Gaylen Tips, and Ben Coopwood. 2011. "Risk Factors for Riding and Crashing a Motorcycle Unhelmeted." *The Journal of Emergency Medicine* 41 (4):441-446. doi: <http://dx.doi.org/10.1016/j.jemermed.2009.07.024>.
- Bullock, Steven H., Bruce H. Jones, Julie Gilchrist, and Stephen W. Marshall. 2010. "Prevention of Physical Training-Related Injuries: Recommendations for the Military and Other Active Populations Based on Expedited Systematic Reviews." *American Journal of Preventive Medicine* 38 (1, Supplement):S156-S181. doi: <http://dx.doi.org/10.1016/j.amepre.2009.10.023>.
- Burns, ST, Z Gugala, CJ Jimenez, WJ Mileski, and RW Lindsey. 2015. "Epidemiology and patterns of musculoskeletal motorcycle injuries in the USA." *F1000Research* 4:114. doi: 10.12688/f1000research.4995.1.
- Coben, Jeffrey H., Claudia A. Steiner, and Ted R. Miller. 2007. "Characteristics of motorcycle-related hospitalizations: Comparing states with different helmet laws." *Accident Analysis & Prevention* 39 (1):190-196. doi: <http://dx.doi.org/10.1016/j.aap.2006.06.018>.
- Colburn, N., R. D. Meyer, M. Wrigley, and E. L. Bradley. 1993. "Should motorcycles be operated within the legal alcohol limits for automobiles." *J Trauma* 35 (2):183-6.
- Crompton, Joseph G., Keshia M. Pollack, Tolulope Oyetunji, David C. Chang, David T. Efron, Elliott R. Haut, Edward E. Cornwell Iii, and Adil H. Haider. 2010. "Racial disparities in motorcycle-related mortality: an analysis of the National Trauma Data Bank." *The American Journal of Surgery* 200 (2):191-196. doi: <http://dx.doi.org/10.1016/j.amjsurg.2009.07.047>.
- Dada, EO, Canham-Chervak, M, Jones, BH. 2015. Epidemiology of Army motor vehicle related fatal and nonfatal injuries, 2003-2008. edited by Department of the Army: U.S. Army Public Health Center (Provisional).
- Dada, Esther, Michelle Canham-Chervak, and Bruce H. Jones. 2015. "Motorcycle and Motor Vehicle (Non-Motorcycle) Occupant-Related Fatal and Nonfatal Injuries in the U.S. Army." *Annals of Epidemiology* (9). doi: 10.1016/j.annepidem.2015.06.054.
- Daniello, Allison, and Hampton C. Gabler. 2011. "Fatality risk in motorcycle collisions with roadside objects in the United States." *Accident Analysis & Prevention* 43 (3):1167-1170. doi: <http://dx.doi.org/10.1016/j.aap.2010.12.027>.
- Department of Defense. 2009. DoD Traffic Safety Program. edited by Department of Defense.

Public Health Report No. S.0047795-18

- Department of the Army. 2006. Motor Vehicle Traffic Supervision. edited by Department of the Army. Washington, DC: Department of the Army.
- Department of the Army. 2013. The Army Safety Program. edited by Department of the Army. Washington, DC: Department of the Army.
- Department of the Army. 2015. Pamphlet 385-40: Army Accident Investigations and Reporting. Washington, DC.
- Enders, CK. 2010. *Applied Missing Data Analysis*. Edited by Todd D. Little, *Methodology in the Social Sciences*. New York, NY: The Guilford Press.
- French, Michael T., Gulcin Gumus, and Jenny F. Homer. 2012. "Motorcycle fatalities among out-of-state riders and the role of universal helmet laws." *Social Science & Medicine* 75 (10):1855-1863. doi: <http://dx.doi.org/10.1016/j.socscimed.2012.06.022>.
- Garvey Wilson, Abigail L., Jeffrey L. Lange, John F. Brundage, and Robert A. Frommelt. 2003. "Behavioral, Demographic, and Prior Morbidity Risk Factors for Accidental Death among Men: A Case-Control Study of Soldiers." *Preventive Medicine* 36 (1):124-130. doi: <http://dx.doi.org/10.1006/pmed.2002.1054>.
- Goslar, P. W., N. R. Crawford, S. R. Petersen, J. R. Wilson, and T. Harrington. 2008. "Helmet use and associated spinal fractures in motorcycle crash victims." *J Trauma* 64 (1):190-6; discussion 196. doi: 10.1097/TA.0b013e3180f62eec.
- Hendry, G. M., R. N. Naidoo, T. Zewotir, D. North, and G. Mentz. 2014. "Model development including interactions with multiple imputed data." *BMC Med Res Methodol* 14:136. doi: 10.1186/1471-2288-14-136.
- Hooper, Tomoko I., Samar F. DeBakey, Kimberly S. Bellis, Han K. Kang, David N. Cowan, Andrew E. Lincoln, and Gary D. Gackstetter. 2006. "Understanding the effect of deployment on the risk of fatal motor vehicle crashes: A nested case-control study of fatalities in Gulf War era veterans, 1991-1995." *Accident Analysis & Prevention* 38 (3):518-525. doi: <http://dx.doi.org/10.1016/j.aap.2005.11.009>.
- Hurt, HH, JV Ouellet, and DR Thom. 1981. Motorcycle Accident Cause Factors and Identification of Countermeasures. edited by Traffic Safety Center. Los Angeles, CA: University of Southern California.
- Institute of Medicine. 2010. "Returning Home from Iraq and Afghanistan: Preliminary Assessment of Readjustment Needs of Veterans, Service Members, and Their Families." In. Washington, DC: The National Academies Press. <https://www.nap.edu/read/12812/chapter/1#ii>.
- Jung, Soyoung, Qin Xiao, and Yoonjin Yoon. 2013. "Evaluation of motorcycle safety strategies using the severity of injuries." *Accident Analysis & Prevention* 59:357-364. doi: <http://dx.doi.org/10.1016/j.aap.2013.06.030>.
- Krahl, P. L., C. J. Jankosky, R. J. Thomas, and T. I. Hooper. 2010. "Systematic review of military motor vehicle crash-related injuries." *Am J Prev Med* 38 (1 Suppl):S189-96. doi: 10.1016/j.amepre.2009.10.024.
- Langley, John, Ari Samaranayaka, and Dorothy J. Begg. 2013. "Age, period and cohort effects on the incidence of motorcyclist casualties in traffic crashes." *Injury Prevention* 19 (3):153-157. doi: 10.1136/injuryprev-2012-040345.
- Lawrence, B.A., Max, W., Miller, T.R. 2002. Costs of Injuries Resulting from Motorcycle Crashes: A Literature Review. edited by Department of Transportation. Washington, DC: National Highway Traffic Safety Administration.
- Lentino, C. V., D. L. Purvis, K. J. Murphy, and P. A. Deuster. 2013a. "Sleep as a component of the performance triad: the importance of sleep in a military population." *US Army Med Dep J*:98-108.
- Lentino, Cynthia V, Dianna L Purvis, Kaitlin J Murphy, and PA Deuster. 2013b. "Sleep as a Component of the Performance Triad: The Importance of Sleep in a Military Population." *The United States Army Medical Department Journal*.
- Lin, Mau-Roung, and Jess F. Kraus. 2009. "A review of risk factors and patterns of motorcycle injuries." *Accident Analysis & Prevention* 41 (4):710-722. doi: <http://dx.doi.org/10.1016/j.aap.2009.03.010>.

Public Health Report No. S.0047795-18

- Liu, BC, Rebecca Ivers, Robyn Norton, Soufiane Boufous, Stephanie Blows, and Kai Lo Sing. 2008. Helmets for preventing injury in motorcycle riders. *Cochrane Database of Systematic Reviews* (1). doi:10.1002/14651858.CD004333.pub3.
- Liu, H. T., C. C. Liang, C. S. Rau, S. Y. Hsu, and C. H. Hsieh. 2015. "Alcohol-related hospitalizations of adult motorcycle riders." *World J Emerg Surg* 10 (1):2. doi: 10.1186/1749-7922-10-2.
- Marshall, Alan J. 2014. "Why riders die ... Qualitative analysis of Air Force motorcycle fatalities." 12.
- Mayhew, D. R., A. C. Donelson, D. J. Beirness, and H. M. Simpson. 1986. "Youth, alcohol and relative risk of crash involvement." *Accid Anal Prev* 18 (4):273-87.
- Military Agency for Standardization. 1989. Standardized Classification of Diseases, Injuries, and Causes of Death. In *STANAG 2050*: North Atlantic Treaty Organization.
- Morris, C. Craig. 2006. "Generalized linear regression analysis of association of universal helmet laws with motorcyclist fatality rates." *Accident Analysis & Prevention* 38 (1):142-147. doi: <http://dx.doi.org/10.1016/j.aap.2005.08.004>.
- Moskal, Aurélie, Jean-Louis Martin, and Bernard Laumon. 2012. "Risk factors for injury accidents among moped and motorcycle riders." *Accident Analysis & Prevention* 49:5-11. doi: <http://dx.doi.org/10.1016/j.aap.2010.08.021>.
- National Center for Statistics and Analyses. 2014a. Motorcycle Helmet Use in 2013—Overall Results. edited by Department of Transportation. Washington, DC: National Highway Traffic Safety Administration.
- National Center for Statistics and Analyses. 2014b. Motorcycles. edited by Department of Transportation. Washington, DC: National Highway Traffic Safety Administration.
- National Center for Statistics and Analysis. 2015. Motorcycles: 2013 Data. In *Traffic Safety Facts*. Washington, DC: National Highway Traffic Safety Administration.
- National Center for Statistics and Analysis. 2016. Motorcycles: 2015 Data. In *Traffic Safety Facts*. Washington, DC: National Highway Traffic Safety Administration.
- National Highway Traffic Safety Administration. 2016. Fatality Analysis Reporting System (FARS) Analytical User's Manual 1975-2015.
- NCSDR/NHTSA Expert Panel on Driver Fatigue and Sleepiness. Drowsy driving and automobile crashes. edited by Department of Transportation: National Highway Traffic Safety Administration.
- Norvell, Daniel C., and Peter Cummings. 2002. "Association of Helmet Use with Death in Motorcycle Crashes: A Matched-Pair Cohort Study." *American Journal of Epidemiology* 156 (5):483-487. doi: 10.1093/aje/kwf081.
- Olsen, Cody S., Andrea M. Thomas, Michael Singleton, Anna M. Gaichas, Tracy J. Smith, Gary A. Smith, Justin Peng, Michael J. Bauer, Ming Qu, Denise Yeager, Timothy Kerns, Cynthia Burch, and Lawrence J. Cook. 2016. "Motorcycle helmet effectiveness in reducing head, face and brain injuries by state and helmet law." *Injury Epidemiology* 3:8. doi: 10.1186/s40621-016-0072-9.
- Pollack, KM, L Gibbons, and ML Canham-Chervak. 2009. Defense Safety Oversight Council Initiative: Causes and Risk Factors for Military and Privately Owned Vehicle Accidents. Baltimore, MD: Johns Hopkins University Bloomberg School of Public Health.
- Pollack, KM, Nathan Yee, Michelle Canham-Chervak, Lauren Rossen, Kathleen E. Bachynski, and Susan P. Baker. 2013. "Narrative text analysis to identify technologies to prevent motor vehicle crashes: Examples from military vehicles." *Journal of Safety Research* 44:45-49. doi: <http://dx.doi.org/10.1016/j.jsr.2012.10.013>.
- Schafer, J. L., and J. W. Graham. 2002. "Missing data: our view of the state of the art." *Psychol Methods* 7 (2):147-77.
- Sun, S. W., D. M. Kahn, and K. G. Swan. 1998. "Lowering the legal blood alcohol level for motorcyclists." *Accid Anal Prev* 30 (1):133-6.
- U.S. Army Combat Readiness Center. 2016. "Off Duty: PMV-2." Department of the Army. <https://safety.army.mil/OFF-DUTY/PMV-2.aspx>.
- Villaveces, Andrés, Peter Cummings, Thomas D. Koepsell, Frederick P. Rivara, Thomas Lumley, and John Moffat. 2003. "Association of Alcohol-related Laws with Deaths due to Motor Vehicle and

Public Health Report No. S.0047795-18

Motorcycle Crashes in the United States, 1980–1997." *American Journal of Epidemiology* 157 (2):131-140. doi: 10.1093/aje/kwf186.