



EVALUATION OF COMBAT ARMS EXPOSURE TO EMISSIONS FROM COPPER-BASED FRANGIBLE AMMUNITION



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Abstract

Introduction: Copper-based frangible ammunition can produce fume-containing particulates upon firing. Upper respiratory irritation, metallic taste, and nausea may result from copper fume inhalation. Due to health concerns expressed by Security Forces Combat Arms (CA) instructors, we developed a web-based survey to characterize self-reported health concerns. Survey results were used to investigate potential exposures and health outcomes related to frangible ammunition emissions.

Methods: The survey design captured symptomology and diagnoses of current active duty CA instructors and those who served since 2004 (adoption of frangible ammunition). Results were evaluated to determine an appropriate case definition based on survey analysis principles of construct, criterion, and content validity. Self-reported symptoms occurring within 4 hours of shooting were evaluated using step-wise logistic regression model building to find associations with clinical diagnoses reported on the survey.

Results: Of the 946 CA personnel receiving the survey, 419 (44.3%) responded. Furthermore, 152 survey respondents (36.3%) reported being diagnosed by a healthcare provider with at least one condition (asthma, chronic bronchitis, sleep-related breathing disorder, etc.) after becoming a CA instructor compared to 10 (2.4%) who were diagnosed prior to instructor duty. We constructed two case definitions for risk factor determination. A possible case is defined as a CA instructor self-reporting any medical diagnosis related to breathing difficulties or any symptoms within 4 hours of shooting. A probable case is a CA instructor self-reporting at least one of the three empirically validated symptoms (cough, metallic taste, or difficulty breathing) within 4 hours of shooting. In all, there were 169 possible cases (40%) and 125 probable cases (30%).

Discussion: Survey results and review of existing literature provided a basis for designing a case definition. This research presented a retrospective cohort study comparing Security Forces not serving in a CA position to those serving in a CA position at any point in time from January 2004 through May 2016. Calculated measures of association (relative risk) are presented. This study design provided a more definitive description and analysis of the health concerns experienced by the CA community.

Introduction

Copper-based frangible ammunition (FA) disintegrates into small particulates upon target impact. Respiratory issues are associated with frequent exposure to FA. Health concerns expressed by CA instructors led to the development of a web-based survey to characterize respiratory conditions. With the self-reported medical issues identified in the survey responses, we hypothesized significant results would be obtained in this comprehensive analysis of electronic medical records.

Methods

Survey results were used to characterize self-reported symptoms related to CA instruction based on the principles of construct, criterion, and content validity. Self-reported symptoms occurring within 4 hours of firing were evaluated using step-wise logistic regression model building to find associations with clinical diagnoses of interest reported on the survey. Three self-reported symptoms (cough, metallic taste, and difficulty breathing) demonstrated criterion validity for association with clinical diagnoses reported on the survey, and they had construct and content validity for initial framing of concerns and consistency with prior investigations. Thus, we constructed two case definitions (i.e., "possible case" and "probable case") for further analyses to determine risk factors. A possible case was defined as someone who self-reports any diagnosis related to breathing difficulties or who self-reports any symptoms within 4 hours of firing. A probable case was someone who self-reports at least one of the three empirically validated symptoms (cough, metallic taste, or difficulty breathing) within 4 hours of firing. There were 169 possible cases (40%) and 125 probable cases (30%). Survey results were used to investigate exposure and health outcome data related to occupational FA exposure. Negative survey outcomes were further investigated utilizing an administrative claims based database containing ICD-9/10 coded diagnoses.

We developed case definitions for sleep-related breathing disorders (SRBD), occupational asthma (OA) (Milton et al., 1998), and chronic sinusitis (SI), chosen based on previous studies concerning burn pit exposure, etc., with ICD-9/10 codes in Table 1. After applying the case definitions to the probable and possible definitions, crude odds ratios and the corresponding 95% CI were generated using logistic regression (Table 2). These results validated the case definitions for use in the retrospective cohort analysis.

Table 1: Case Definition ICD Code Sets

Case Def	Diagnosis Codes
OA	(ICD-9: 490 - 494, 496, 504, 506, 507), (ICD-10: J40 - J42, J43.9, J44 - J45.2, J45.9, J47.1, J47.9, J66, J68-J69)
SRBD	(ICD-9: 327.2, 780.51, 780.53, 780.57, 786.03), (ICD-10: G47.3, R06.81)
SI	(ICD-9: 473), (ICD-10: J32)



Table 2: Internal Validity Results

Case Def	Probable	Non-Probable	Log Reg Output	95% CI
OA	25	100	2.69	(1.48, 4.90)
SRBD	21	104	1.65	(0.91, 3.00)
SI	21	104	2.17	(1.17, 4.05)

Case Def	Possible	Non-Possible	Log Reg Output	95% CI
OA	36	133	4.56	(2.38, 8.76)
SRBD	46	123	12.98	(5.69, 29.60)
SI	30	139	3.16	(1.66, 6.00)

D = Diagnosed, ND = Not Diagnosed

Data Preparation: Three cohorts were examined in this study – (1) The CA cohort (N = 842) inclusion criteria consisted of those with an Enlisted Duty Air Force Specialty Code (DAFSC) of 3P0X1B and a duty title indicative of a combat arms position on 1 Nov 2015 - (2) A Security Forces (SF) cohort (N = 22,189) which consisted of those with an Enlisted DAFSC of 3P0X1 on 1 Nov 2015 without any CA position held after 1 Jan 2004 - (3) An Aerospace Maintenance (AM) cohort (N = 16,270) consisting of those with an Enlisted DAFSC of 2A6XX on 1 Nov 2015 without any SF/CA position held after 1 Jan 2004. This cohort was selected based on size comparable to SF, similar outdoor exposures to allergens, etc., deployment cycles, demographic similarities, and permitted comparison to a group outside the SF community. All inpatient and outpatient medical visits from 1 Jan 2004 or the start date of active duty service for each individual in the SF and AM cohorts were queried for visits containing ICD 9/10 codes from Table 1. For the CA cohort, records were queried from the later of 1 Jan 2004 or their first date of service in a CA position.

Retrospective Cohort Analysis: Full cohort data analysis consisted of relative risk comparisons (Chi-squared tests) between cohorts for the three case definitions (Tables 3, 4). However, CA positions are usually held after a SF Airman gains experience in 3P0X1 career field, and they may return to SF duty after performing duty in CA. Therefore, the age and sex structure of the CA cohort differs from the SF and AM cohorts. To account for this, we used a random 2:1 match on age and sex of the CA cohort to the SF and AM cohorts. Conditional logistic regression and survival analysis techniques were used with matched cohort data (Tables 3, 4). In addition, negative binomial generalized linear models were used to examine visit rates per person year for all three case definitions among those with at least one visit.

Examination of range type exposure effects on respiratory health: An additional CA cohort was created to examine range type exposure effects on respiratory health. Any Active Duty Airman serving in a CA related position at any point from January 2009 through September 2016 was included in this longitudinal analysis (generalized linear model with generalized estimating equations). CA range type data (provided by USAFSAM/OEC and AFSFC) were linked to CA personnel by base to allow for longitudinal analysis of range type exposure effects concerning the respiratory conditions of interest (OA or SI). Actual exposure time related to CA duty was captured along with medical encounter ICD 9/10 codes satisfying the case definitions for OA or SI. Odds ratios were generated, adjusting for age and sex, comparing outdoor fully-contained, outdoor partially-contained, and non-contained impact ranges to the reference indoor fully-contained range. Results in Table 5.

Table 3: Respiratory Outcomes Among CA vs. AM (2A6) Personnel

CA (N = 842) vs. AM (N = 16270)	Case n (%)	Non-Case n (%)	RR	CI	P-Value*
OA vs. No OA	88 (4.7)	754 (5.0)	0.95	(0.72, 1.24)	1.0
SI vs. No SI	99 (4.9)	743 (4.9)	1.00	(0.78, 1.29)	1.0
SRBD vs. No SRBD	111 (7.28)	731 (4.69)	1.52	(1.19, 1.93)	<0.001

CA vs. Sex-Age Matched** AM	Case n (%)	Non-Case n (%)	OR	CI	P-Value*
OA vs. No OA	88 (25.7)	754 (34.8)	0.64	(0.45, 0.92)	0.007
SI vs. No SI	99 (25.4)	743 (34.8)	0.63	(0.45, 0.88)	0.002
SRBD vs. No SRBD	111 (36.2)	731 (32.9)	1.17	(0.82, 1.65)	1.0

*Chi-squared test; **Age-sex matching 2:1; Conditional logistic regression (all P-Values and CIs adjusted for multiple comp)

Table 4: Respiratory Outcomes Among CA vs SF Personnel

CA (N = 842) vs. SF (N = 22189)	Case n (%)	Non-Case n (%)	RR	CI	P-Value*
OA vs. No OA	88 (4.6)	754 (3.6)	1.28	(0.97, 1.68)	0.108
SI vs. No SI	99 (5.7)	743 (3.5)	1.60	(1.23, 2.06)	<0.001
SRBD vs. No SRBD	111 (8.2)	731 (3.4)	2.34	(1.83, 2.99)	<0.001

CA vs. Sex-Age Matched** SF	Case n (%)	Non-Case n (%)	OR	CI	P-Value**
OA vs. No OA	88 (28.6)	754 (34.0)	0.77	(0.54, 1.10)	0.337
SI vs. No SI	99 (32.0)	743 (33.5)	0.93	(0.65, 1.33)	1.0
SRBD vs. No SRBD	111 (35.4)	731 (33.1)	1.12	(0.78, 1.59)	1.0

*Chi-squared test; **Age-sex matching 2:1; Conditional logistic regression (all P-Values and CIs adjusted for multiple comp)

Table 5: CA Population (Jan 2009 – Sep 2016) Respiratory Outcomes Stratified by Shooting Range Type

	Odds Ratio	95% CI	P-Value*
All Airmen serving in CA position anytime from January 2009 through September 2016 (N = 1377)			
OA (Indoor Fully Contained was Reference Group (18 bases))			
Non-Contained Impact Range (18 bases)	0.97	(0.46, 2.02)	0.922
Outdoor Fully-Contained (16 bases)	1.88	(0.81, 4.37)	0.188
Outdoor Partially Contained, Baffled (22 bases)	1.39	(0.60, 3.23)	0.747
SI (Indoor Fully Contained was Reference Group (18 bases))			
Non-Contained Impact Range (18 bases)	2.65	(1.16, 6.03)	0.016
Outdoor Fully-Contained (16 bases)	2.36	(0.88, 6.33)	0.103
Outdoor Partially Contained, Baffled (22 bases)	1.55	(0.57, 4.19)	0.655

* Age and Sex Adjusted Longitudinal modeling; adjusted for multiple comparisons

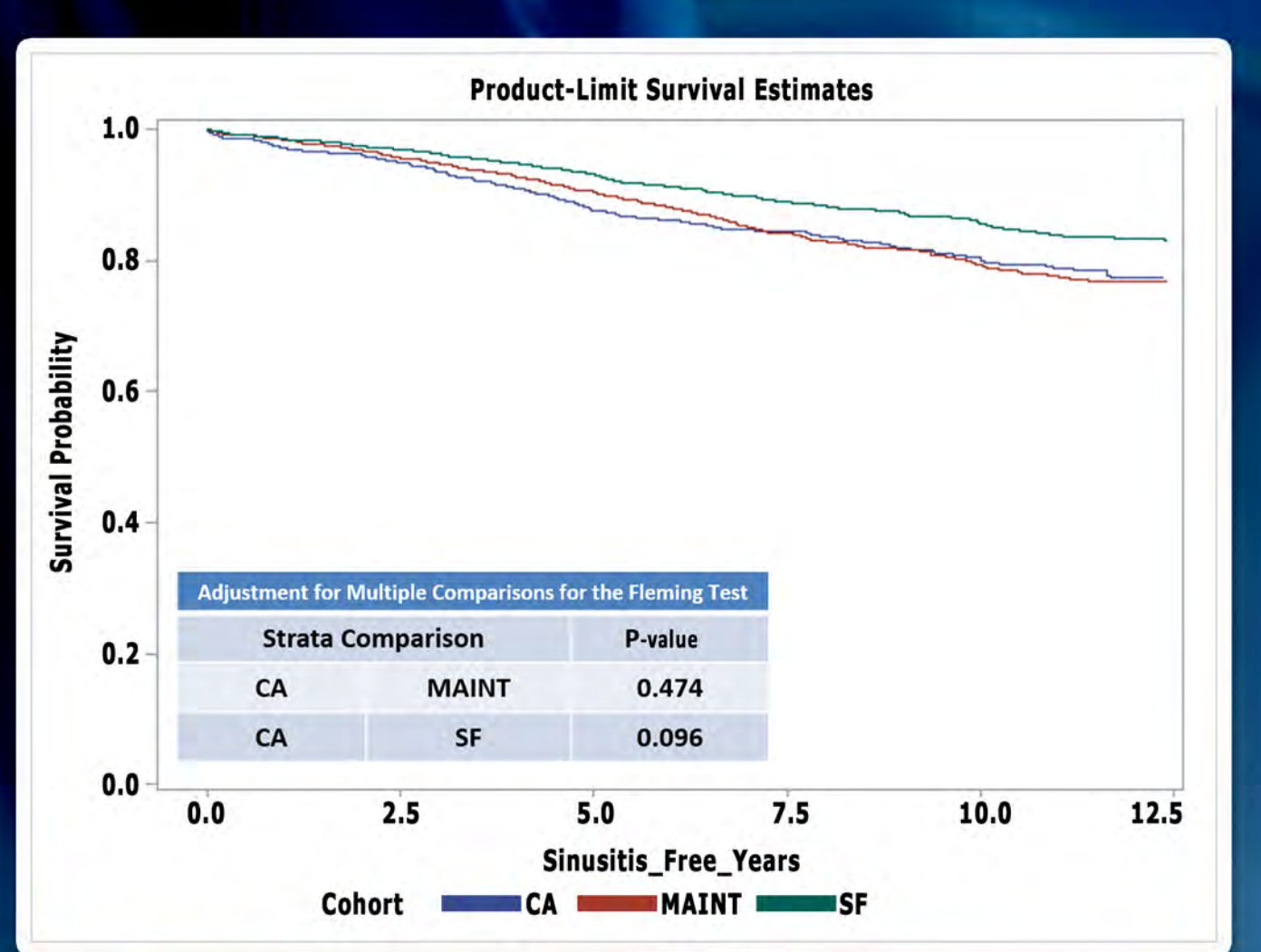


Figure 1: SI Survival Analysis Summary, 2:1 Match on Age and Sex

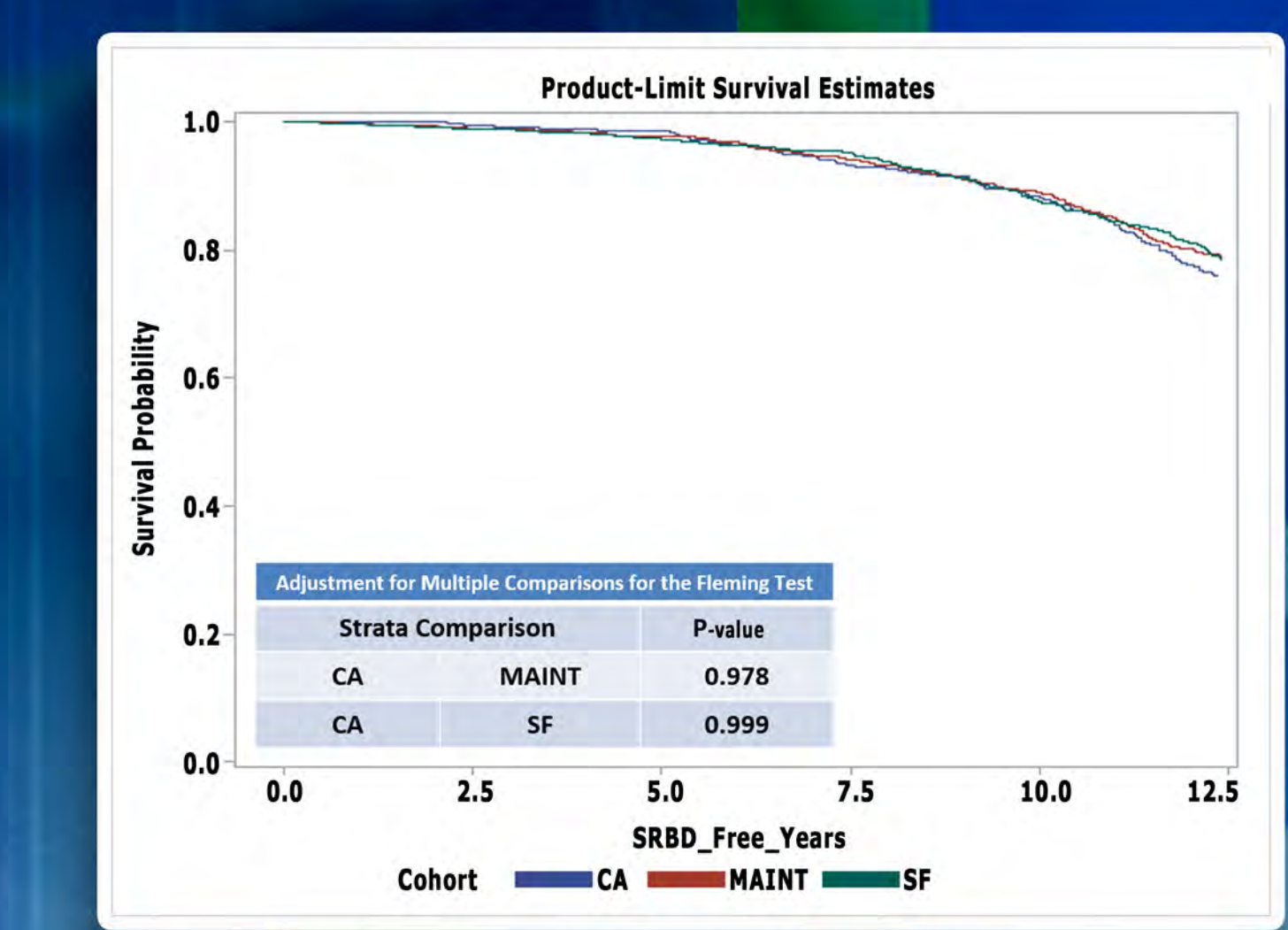


Figure 2: SRBD Survival Analysis Summary, 2:1 Match on Age and Sex

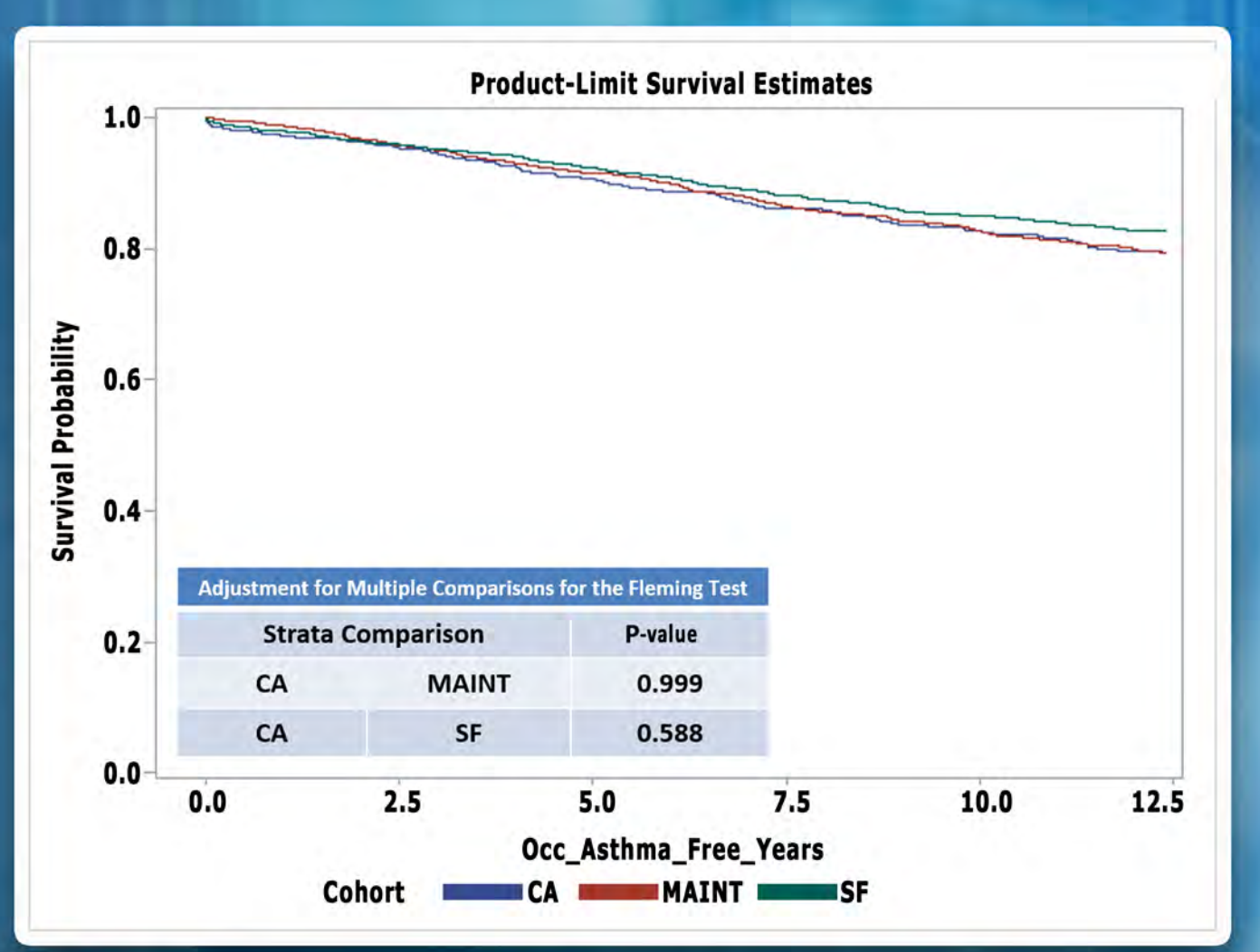
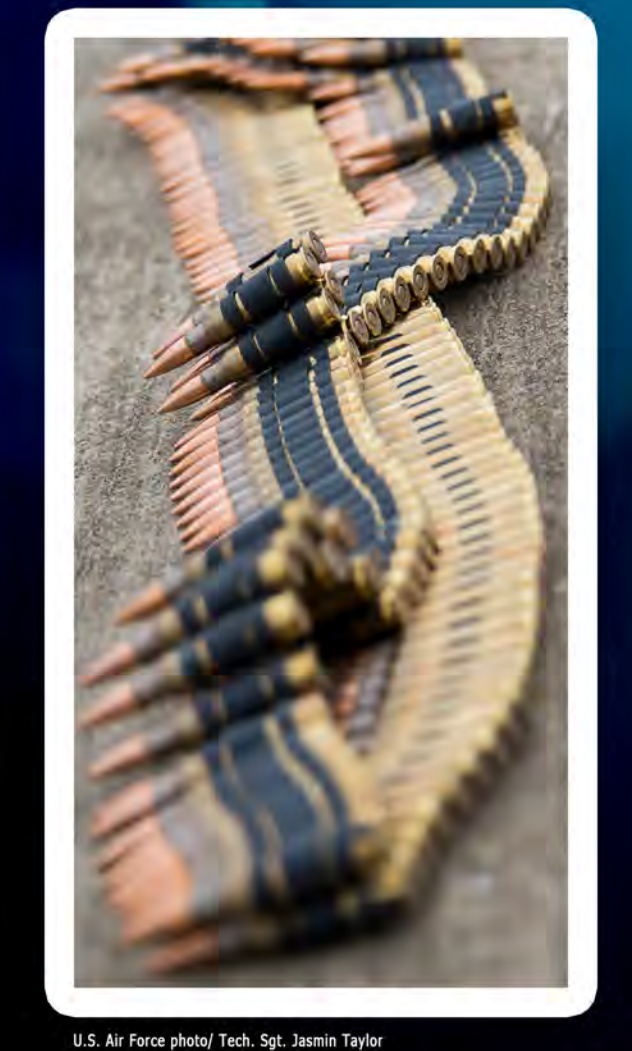


Figure 3: OA Survival Analysis Summary, 2:1 Match on Age and Sex



U.S. Air Force photo by Staff Sgt. Scott Hines

Discussion

This investigation was initiated by request of the Air Force Security Forces Center to address health concerns expressed by CA instructors during small arms range weapon qualification. The collection and analysis of health data by USAFSAM was for the purpose of protecting the health of the CA community; thus, this investigation is deemed public health practice, and not considered human subjects research.

This cohort study examined associations between CA exposures and medically diagnosed respiratory outcomes with comparison to SF (not assigned a CA position during the study period) and AM (2A6XX Duty AFSC). Three types of cohort comparison analyses were conducted to examine (1) whether or not cohort members ever had a medical visit meeting one of the pre-defined case definitions (Occupational Asthma, Chronic Sinusitis, and Sleep-Related Breathing Disorders), (2) the time to first occurrence of a case-defined medical visit, and (3) the number of case-defined medical visits during the surveillance or investigative period for those with at least one medical visit.

When comparing the three cohorts with analysis (1), several significant differences were detected between CA and both comparison cohorts. Relative risks of SRBD for the CA cohort and corresponding 95% confidence intervals were 1.52 (1.19, 1.93) and 2.34 (1.83, 2.99) when compared to AM and SF respectively. Additionally, relative risk of SI for the CA cohort was 1.60 (1.23, 2.06) when compared to the SF cohort. However, the age/sex structure within CA is not directly comparable to AM and SF since the CA cohort members are usually between the ages of 22 to 40 whereas AM and SF are usually between 18 and 49. In addition, the CA cohort had 82 females (9.7%) while AM had 1,075 (6.6%) and SF had 3,552 (16%). These differences may have distorted the relative risk results. After the 2:1 sex and age matching the comparison cohorts to the CA cohort, these results were no longer significant and the adjusted association showed an opposite direction of association, suggesting age/sex confounding was explanatory.

Effects of CA range type were also observed. CA personnel assigned to bases with outdoor fully-contained or outdoor partially-contained, baffled ranges experienced greater odds of occupational asthma-related diagnoses when compared to those stationed at bases with indoor fully-contained ranges. Similarly, CA personnel stationed at bases with any type of outdoor range had greater odds of chronic sinusitis diagnoses when compared to those stationed at bases with indoor fully-contained ranges.

Analysis of time to first occurrence of a case-defining medical visit (2) was conducted on the age and sex matched data. Only time to first medical visit for chronic sinusitis between the CA and SF cohorts was marginally significant with a P-value of 0.096. This result would suggest that CA personnel may be experiencing earlier onset of chronic sinusitis issues than their SF counterparts. Interpretation of the time to event estimates suggest that, after five years of CA duty, approximately 13% of the cohort were clinically diagnosed at least once with chronic sinusitis whereas approximately 7% of the SF cohort were diagnosed at least once.

For analysis of visit rates per person-year (3) adjusting for age and sex, significant differences were detected among all three case definitions. CA had the highest visit rate per person year for occupational asthma, chronic sinusitis, and sleep-related breathing disorders. These results may suggest those in the CA cohort may seek medical care more often for these health outcomes than the comparison cohorts.

To bridge the gap between the self-reported and medical encounter data, a five-year prospective/cross sectional cohort study may be beneficial. This type of study would allow for standardization of diagnoses for exposure-related medical outcomes, capture more specific exposure information (duration of exposure, range-type, frequency of firing, etc.), control the primary and secondary data collection, and facilitate evaluation of long-term respiratory health effects associated with CA duty. The overall cost of the prospective study has yet to be determined and the estimated time to complete analysis is one year after the five-year data collection period. In addition, respiratory health of CA instructors (i.e., methacholine challenge test results) could be measured before and after range instruction in a variety of range, instruction time, weapon, and environmental configurations. This design, coupled with bioenvironmental sampling data will address this study's limitations (incomplete exposure information and medical diagnosis coding) and improve the evaluation of the Combat Arms community's health concerns. Approximate time to complete this study, after IRB approval, is two years, and the associated cost has yet to be determined.

References: Milton et al. (1998). Risk and incidence of asthma attributable to occupational exposure among HMO members. American Journal of Industrial Medicine, 33, 1-10.



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