Journal of Safety Research 88 (2024) 16–23

Contents lists available at ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

The association between safety climate and noncombat injury events among United States Air Force workers

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ARTICLE INFO

Keywords:
Safety climate
Military populations
Occupational injuries
Leading/lagging indicators

ABSTRACT

Introduction: Work-related injuries are a common lagging safety indicator whereas safety climate assessments can help identify constructs serving as leading indicators. The National Institute for Occupational Safety and Health (NIOSH) partnered with the U.S. Department of the Air Force (DAF) Safety Center to examine the association between perceptions of safety climate survey constructs and the number of injury events within the DAF workforce. *Methods:* The DAF administers voluntary, anonymous, occupation-specific safety climate surveys to DAF workers using the internal Air Force Combined Mishap Reduction System (AFCMRS). Survey responses from 2014 to 2018 provided by DAF workers and injury events in maintenance, support, and operations occupations were shared with NIOSH. Exploratory Factor Analysis revealed five constructs: Leadership and Communication; Organizational Safety Priority; Error Management; Resource Adequacy; and Deployment/Official Travel Impact. Squadron-level analysis included bivariate correlations and estimated Rate Ratios (RRs). *Results:* 1,547 squadrons administered the survey, averaging 144 workers and 15.8 reportable injuries per squadron. Higher (more favorable) squadron-level construct scores were consistently correlated with fewer reported injuries ($p < 0.001$). Controlling for the number of workers, RRs revealed significant reductions in injury rates with each one-unit increase in responses: Leadership and Communication RR = 0.40 (95%CI: 0.32–0.48); Organizational Safety Priority RR = 0.50 (95%CI: 0.40–0.64); Error Management RR = 0.37 (95%CI: 0.30–0.47); Deployment/Official Travel Impact RR = 0.36 (95%CI: 0.29–0.45). Resource Adequacy revealed a non-significant lower injury rate RR = 0.87 (95%CI: 0.73–1.04). *Conclusions:* This unique study quantified safety climate and the association with injuries across a multi-year period. While safety climate measurements may be limited by frequent turnover and the self-reported, voluntary, anonymous nature of AFCMRS, the strength of this study is in the census of injuries. *Practical Applications:* Future research should include longitudinal analyses to examine the impact on injuries when squadron leaders are provided feedback on safety climate survey results.

1. Background

Injuries remain a top concern for working populations. According to the Bureau of Labor Statistics (BLS), 2.8 million injuries and illnesses were reported by private industry employers in 2019 (BLS, 2020a) and 5,333 workers lost their life from a work-related injury in the United States (BLS, 2020b). In 2017, work-related injuries resulted in an estimated $59 billion in direct costs in the United States (Liberty Mutual Insurance, LMI, 2020).

For the military, the frequency of noncombat injuries far exceeds combat-related injuries and are a particular concern, resulting in time away from work and limiting military readiness (Grimm, Mauntel, & Potter, 2019). For example, a recent study showed that more than one-third of 30,000 soldiers injured overseas were hurt in noncombat, nonfatal incidents such as falls, motor-vehicle accidents, machinery accidents, and contact with blunt objects (Le et al., 2018). Another study showed that over 30% of medical evacuations of deployed U.S. Army soldiers resulted from noncombat injuries (Patel, Hauret, Taylor, &

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https://doi.org/10.1016/j.jsr.2023.10.004
Received 10 January 2023; Received in revised form 16 June 2023; Accepted 16 October 2023
Available online 10 November 2023
0022-4375/Published by Elsevier Ltd.

Jones, 2017), signifying the importance of injury prevention. In addition to reducing the physical hazards that increase the risk of injuries, prevention efforts should identify additional root causes of injuries to characterize and target leading indicators within an organization more accurately (Health & Safety Executive, 2006). Direct measures of work-related injuries available from medical records and safety reports are often used to prioritize prevention measures but are still considered lagging indicators. Whereas leading indicators can guide prevention efforts before injuries occur.

Empirical studies have supported the use of safety climate as a leading indicator in the workplace. Broadly, safety climate is defined as an understanding of the current perceptions of safety conditions and values in the workplace with the purpose of being able to provide guidance into factors that can be positively altered (Zohar, 2010; Griffin & Curcuruto 2016). Research has demonstrated a negative relationship between employees' perceptions of their organization's safety climate and the occurrence of safety incidents (Beus, Payne, Bergman, & Arthur, 2010; Neal, Griffin, & Hart, 2000; Smith & DeJoy, 2014; Vinodkumar & Bhasi, 2009; Zohar, 2000). Other studies have focused on worker performance as the outcome variable and found similar relationships in that a strong safety climate has been associated with increased safety performance on the job (e.g., see Guldenmund, 2000; Haas, Hoebbel, & Yorio, 2020; Wiegmann, Zhang, Von Thaden, Sharma, & Mitchell, 2002; Zohar, 1980). Several meta-analyses have identified safety climate as one of the strongest predictors in workplace safety and mishap prevention (Beus et al., 2010; Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2010; Nahrgang, Morgeson, & Hofmann, 2011), reinforcing safety climate as a valid leading indicator in occupational safety and health (Haas & Yorio, 2016).

The U.S. military departments and branches (i.e., Air Force, Army, Coast Guard, Navy, Marine Corps and Space Force) are considered High Reliability Organizations (HROs) that operate complex systems and are subject to catastrophic accidents or injury events (Shrivastava, 1986). According to O'Connor, O'Dea, Kennedy, and Buttrey (2011) ongoing safety climate assessments are a common leading indicator used by HROs, including the military. For example, the Department of Navy started allocating resources as early as 2005 to improve safety climate and reduce preventable injury events (Adamshick, 2007). These efforts by the U.S. military and its respective branches have been, in part, due to their unique complexities and importance of proactively identifying hazards and mitigating risks.

Within the military and other occupational safety and health (OSH) research, leadership type and style has been a primary focus when referring to safety climate (Martinussen & Hunter, 2018). This study expands beyond leadership and focuses on a variety of safety climate indicators. Using retrospective Department of the Air Force (DAF) survey responses and injury events, researchers explored safety climate perceptions among DAF military and civilian workers in aggregate during a 5-year period, and the association of safety climate construct scores with injury rates. The following hypothesis was developed for the current study: For each survey construct measured within the overall survey, higher positive responses to each survey construct will be associated with lower rates of recorded injuries among workers who completed the safety climate survey.

2. Methods

The U.S. Air Force Safety Center (AFSEC) and the National Institute for Occupational Safety and Health (NIOSH) within the U.S. Centers for Disease Control and Prevention (CDC) formalized a collaboration in 2018 to explore the relationship between safety climate and injuries. AFSEC has administered surveys to collect safety climate perceptions since 2007; NIOSH maintains expertise in safety climate and culture and has conducted research in this area among several worker populations (Haas et al., 2020; Haas, 2020; Haas & Yorio, 2021a, 2021b, 2021c) providing an objective, mutually beneficial collaboration.

Upon formalizing the partnership with non-disclosure agreements, AFSEC provided NIOSH temporary access to their organization's anonymous safety climate survey responses and recorded injury events over the five-year period from October 1, 2013, to September 30, 2018 (i.e., federal government fiscal years, FY2014–2018). NIOSH did not support or conduct the data collection, was not engaged with study participants, and did not receive any personal identifiable information (e.g., names, contact information or medical records of the injured workers) as a part of this effort. This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy.[1] The de-identified data were securely received in 2020 using a password protected Department of Defense (DoD) file exchange website: DoD Secure Access File Exchange (safe.apps.mil).

2.1. *Department of the Air Force structure*

The Department of the Air Force (DAF) structure of organizational units is hierarchical. The largest unit is the Major Command (MAJCOM), defined by a specific, overarching mission (e.g., Air Education and Training Command). MAJCOMS have headquarters staff and subordinate organizations, typically comprising numbered air forces (NAF), wings, groups, and squadrons. Wings comprise groups. A group is comprised of two or more squadrons, which are generally the smallest level of command in the Air Force. Each squadron consists of a leadership element and two or more flights, which are the smallest hierarchical levels of a unit. Each squadron is identified by a number and function, e.g., 97th Aircraft Maintenance Squadron (U.S. DoD, 2021).

DAF workers are employed from several personnel systems including military, federal civilian, and contracts with external agencies. DAF military and civilian workers are classified according to functional area, i.e., work tasks. For this study, only workers directly enlisted or commissioned by the DAF, under the DoD (military workers), and workers employed by the federal civilian personnel systems (civilian workers) were included. Contract personnel are not included because of laws around surveying federal contractor employees.[2] Additionally, injuries among contractor employees are not routinely captured by DAF because OSHA requires the supervising employer to record injuries.[3] Survey administrations vary based on leadership priorities and timing, meaning that if a respondent moves to another unit, there may be an opportunity to take the survey again. However, there is no method to track previous administrations due to respondent and squadron anonymity.

In this study, the three largest functional areas were examined, Maintenance (MX), Support (SUP), and Operations (OPS) in the Air Force at the squadron level. The MX survey is for all aircraft maintenance personnel (e.g., fabrication, materials, and specific aircraft maintenance) and the SUP survey is for all support personnel (e.g., personnel, education and training, manpower, administration, services, etc.). The OPS survey is for non-nuclear military operations workers including aircrew, missileers, and space operations workers. Comprehensive details about worker activities can be found in the Air Force Enlisted Classification Directory (AFECD, 31 October 2021) and the Air Force Officer Classification Directory (AFOCD, 31 October 2021).

2.2. *The Air Force Combined Mishap Reporting System*

The DAF safety climate survey is disseminated through the Air Force Combined Mishap Reduction System (AFCMRS), as part of the safety culture assessment tool program. This program seeks to identify organizational factors that positively or negatively impact safety

[1] See e.g., 45C.F.R. part 46; 21C.F.R. part 56; 42 U.S.C. §241(d), 5 U.S.C. §552a, 44 U.S.C. §3501 et seq.

[2] 44 U.S.C. § 3501 et seq., Paperwork Reduction Act (PRA).

[3] See 29 CFR 1904.31(b)(3), OSHA, Covered Employees.

performance (Camm et al., 2013). The original survey was composed of four dimensions: organizational processes, organizational climate, resources, and supervision, and are available in Camm and colleagues (2013) appendix of their book. In 2000, the Department of the Navy began administering an earlier version of the surveys within AFCMRS called the Command Safety Assessment (CSA) and the Maintenance Climate Assessment Survey (Schimpf 2004). This early version was initially validated in a report by Schimpf and Figlock (2006). The survey was adapted by the DAF in 2005 with some modifications to categories and others made over time, such as changes to items with reverse-Likert responses, additions and removals of items, and changes to item wording in order to tailor the language to the respondents. This study includes aggregated survey responses and mishap injury events from 2014 to 2018 since those years have the most recent and consistent format. The most recent version of the survey is publicly available from the AFCMRS website where it is also administered electronically to the workers: https://www.afcmrs.org/.

Organizational unit leaders, often commanders, are invited to administer the survey among workers in their unit according to leadership priority. Each individual worker's participation is voluntary and anonymous. Typically, surveys are open for 30 days, after such time squadron leaders are briefed on the results. All squadrons included in the analysis had the opportunity to take the survey at least one time during the 2014–2018 time period.

The safety climate survey is adapted for each of the three worker functional areas. The survey for MX functional area contains 64 items, the survey for the SUP functional area contains 49 items, and the survey for the OPS functional area contains 58 items. There were 34 common items among surveys for these three functional groups, which were the items used in the current analysis. Examples of common items include "Effective communication flow exists within my squadron"; "Workers are briefed on potential hazards associated with their assigned tasks in my squadron"; "Squadron members are comfortable approaching supervisors about personal problems/illnesses"; "Leaders/Supervisors encourage reporting safety discrepancies without fear of negative repercussions"; "Standards in my squadron are enforced"; and "My squadron has sufficient manning/assets to perform its current tasks." Response options for each item used a 5-point Likert scale (1–5), with 1

Table 1
Exploratory Factor Analysis Results of survey items after non-common and poor performing items were removed.

Survey Items	Leadership and Communication	Organizational Safety Priority	Resource Adequacy	Deployment/Official Travel Impact	Error Management
1. My squadron adequately reviews and updates safety standards and operating procedures.		0.768			
2. My squadron adequately trains personnel to safely conduct their jobs.		0.747			
3. Standards in my squadron are clearly defined.		0.692			
4. Standards in my squadron are enforced.		0.722			
5. Safety decisions are made at the proper levels by the most qualified personnel.		0.732			
6. Personnel in my squadron must possess the appropriate experience and skills to receive increased responsibility.		0.578			
7. Anyone intentionally violating SOPs or safety rules is swiftly corrected.		0.723			
8. Official guidance (e.g., AFI's, T.O.'s) is incorporated into day-to-day safety decisions in my squadron.		0.707			
9. Squadron members, from the top down, incorporate risk management into daily activities.		0.620			
10. Effective communication flow exists within my squadron.	0.603				
11. Squadron members are comfortable approaching supervisors about personal problems/illness.	0.679				
12. Individuals in my squadron are willing to report safety violations, unsafe behaviors, or hazardous conditions.	0.433				
13. Members of my squadron work effectively as a team.	0.635				
14. Morale in my squadron is high.	0.765				
15. Leaders/Supervisors encourage reporting safety discrepancies without fear of negative repercussions.	0.562				
16. Leaders/Supervisors in my squadron set a good example for compliance with policies, rules, and instructions.	0.779				
17. Leaders/Supervisors in my squadron discourage cutting corners to get a job done.	0.627				
18. Leaders/Supervisors in my squadron react well to unexpected changes.	0.858				
19. Leaders/Supervisors in my squadron care for members' quality of life.	0.927				
20. Leaders trust subordinates to manage routine operations. (MX and OPS only).	0.772				
21. I am provided adequate resources (e.g., time, staffing, budget, and equipment) to accomplish my job.			0.720		
22. My squadron has sufficient manning/assets to perform its current tasks.			0.816		
23. The level of our squadron's operational demands permits members to obtain sufficient rest to perform their jobs.			0.512		
24. Additional duties do not adversely affect organizational safety in my squadron.			0.342		
25. Violations of operating procedures are rare in my squadron.					0.562
26. Our squadron reports all adverse incidents.					0.736
27. Work performance is the same quality when away from home base.				0.465	
28. Temporary Duty (TDY) deployment rates for the last year have not created safety problems in my squadron.				0.777	

being the strongest negative response and 5 being the strongest positive response. Options for "N/A" (0) and "Don't Know" (6) were available to respondents but excluded from this analysis during the data cleaning process. Most responses for Leadership and Communicatio n, Organizational Safety Priority, and Resource Adequacy had less than 15 percent of "N/A" or "Don't Know" responses (1.5– 14.5%). However, Error Management (9.1–21.4%) and Deployment/Official Travel Impact (24.7–54.2%) had a higher percentage of "N/A" or "Don't Know" responses. This would be expected due to the nature of the items for those constructs (defined below). For example, a portion of workers may not be able to answer questions about violations, adverse incidents, along with work performance and safety problems during deployment or official travel.

2.3. Survey psychometric properties

NIOSH researchers aggregated survey responses by squadron to identify and understand which constructs served as significant leading indicators and their weighted impact on injuries. The AFSEC groups their survey items under four categories: organizational processes, organizational climate, resources, and supervision. The four original categories represent Likert-scale statements with 5 option levels of agreement. The organizational processes category included items related to communication, safety enforcement and competence, management commitment/trust, hazard identification, training, and risk assessment (Table 1, items 1–10 and 27). The organizational climate category included items related to morale, teamwork, and safety violation reporting (Table 1, items 11–14, 25, and 26). The resources category included items related to the adequacy of time, staffing, budget, and equipment and other resources to perform work tasks (Table 1, items 21–24, and 28). The supervision category included items related to the fairness, reactions, and attitudes of the leadership and supervisors within the respondent's squadron (Table 1, items 15–20). More information can be found at the AFCMRS website, https://www.afcmrs.org, including sample surveys.

To ensure we could identify accurate leading indicators of injuries, NIOSH researchers conducted an exploratory factor analysis (EFA) on the 34 survey items that were shared among the three surveys (MX, SUP, and OPS). The EFA allowed researchers to identify potentially new safety climate constructs measured across functional groups. The 34 items were subject to a maximum likelihood extraction EFA using direct oblimin rotation to reduce the number of items into meaningful factors as well as demonstrate statistical support for the theoretical constructs. The optimal number of factors was determined through the combined use of the scree plot, Eigenvalues, parallel analysis, and fit statistics (Costello & Osborne, 2005; Fabrigar, Wegener, MacCallum, & Strahan, 1999). Factor loadings less than 0.32 were considered below the minimum threshold and omitted/suppressed. Using this threshold eliminates items that cross load or share more than 10% of their variance with another possible factor (Tabachnick, Fidell, & Ullman, 2007). Based on the initial EFA, six items were excluded because they either loaded on multiple constructs or did not sufficiently load on any. The remaining 28 items were subject to the same EFA and confirmed their loading into homogenous subsets. This step was imperative to ensure that inferences made in the analyses were reliable and valid. Refer to Table 1 for the item text, factor loadings, and construct groupings.

For this analysis, we describe the following construct groupings on the same 5-point Likert scale: Leadership and Communication (Table 1, items 10–20), Organizational Safety Priority (Table 1, items 1–9), Error Management (Table 1, items 25 and 26), Resource Adequacy (Table 1, items 21–24, and Deployment/Official Travel Impact (Table 1, items 27 and 28). The names of these constructs closely reflect the item themes, with one construct that included both leadership and communication and two new themes that emerged on Deployment/Official Travel Impact and Error Management. An administration of the survey is defined as a point in time when squadron members are solicited via email to complete the survey. The survey was administered to some squadrons multiple times, and all squadrons included in the analysis had the survey administered at least one time during the 2014–2018 time period.

2.4. Air Force safety Automated System (AFSAS)

According to the Department of Defense Instruction 6055.07, all noncombat injury events resulting in medical care beyond first aid are required to be investigated, and for the DAF they are recorded in the Air Force Safety Automated System (AFSAS). Mishap events which lead to an injury of one or more on-duty workers with some associated monetary cost, from FY2014–2018 were included in this study. A mishap injury event may include one or more people. Mishap injury events (rather than individual worker injuries) were aggregated at the squadron level and linked to the aggregate survey responses. Due to the aggregate nature of the data in this analysis, no individual workers or injury events were identifiable.

2.5. Data management and analysis

Each of the survey items were aggregated using the mean response across individual respondents within a squadron, for each survey administration, during FY2014–2018, while injury data were summed for the same period. This aggregated dataset provided the total number of noncombat injuries per squadron along with the average perceptions during the same time. Additionally, due to the anonymous nature of the safety climate survey case database, it was not possible to directly match survey responses to an injury event. Because of the anonymous nature of the survey and changes in leadership and the workforce over time, we did not adjust for repeated measures.

Before aggregation across the 5-year period, zero injuries were imputed for years where no injuries were recorded, but a survey was administered. However, if no survey was administered, zeroes were not imputed due to the possibility of a change in a squadron (re-named, moved, removed, etc.).

The distribution of injuries indicated some level of overdispersion (the standard deviation was twice that of the mean), therefore negative binomial regression models were used to examine the relationship between injuries and each of the survey constructs. Goodness of fit statistics (deviance, log likelihood, Akaike's information criterion, Bayesian information criterion) confirmed that, within the total sample of squadrons, negative binomial models were more appropriate than Poisson models. Given the logical association between squadron size and the number of injuries reported, squadron size was included as a control variable in the statistical models. With the inclusion of squadron size as a control variable, the interpretation of the exponentiated regression coefficient [exp(B)] is the multiplicative adjustment in squadron level injuries for a single unit increase in the squadron's measurement scale related to the construct while controlling for the effect of squadron size. Within SPSS Version 25, researchers calculated bivariate correlations and estimated Rate Ratios (RRs) using negative binomial regression.

A total of 2,601 DAF units were considered for this study. After review by a DAF military expert, 825 units were identified as a different organizational size than a squadron and therefore excluded. Another 229 squadrons were excluded based on surveys that were administered before FY2014. A final total of 1,547 squadrons had at least one completed survey from FY2014–2018. The mean number of total reportable, on-duty injuries per squadron during the five-year period was 15.8 (SD = 29.27, Mode = 0 (n = 273), Minimum = 0, Maximum = 524).

3. Results

Table 2 describes the survey administration by functional area. A total of 2,439 squadron-level survey administrations were considered

Table 2
Description of safety climate survey administration among military and civilian workers in the Department of the Air Force by functional area for 1,547 squadrons, fiscal years 2014–2018.

	Maintenance (MX)	Support (SUP)	Operations (OPS)	Combined Total
Number of squadron-level survey administrations	465 (19.1%)[a]	1,377 (56.7%)	597 (24.6%)	2,439
Number of completed, individual worker survey responses[b]	58,959 (28.1%)	121,737 (58.1%)	28,962 (13.8%)	209,658
Number of workers requested to participate in at least one survey administration[c]	74,700 (32.3%)	135,200 (58.4%)	21,400 (9.2%)	231,300

[a] Percentages may not add to 100 due to rounding or overlap between squadrons and years. Each squadron could have workers from MX, SUP, or OPS, that's why we had to aggregate at the squadron level.
[b] A completed survey response included only the common items of the safety climate survey since the aggregated analysis combines MX, SUP, and OPS.
[c] This number is estimated by squadron leadership at the time of the survey administration. Full demographic characteristics of the Department of the Air Force working population is available from: https://www.afpc.af.mil/About/Air-Force-Demographics/.

for this study across the 1,547 squadrons. Over the five-year study period, the average number of times the survey was administered within a squadron was 1.57 (SD = 0.93, Mode = 1 (n = 952), Minimum = 1, Maximum = 12). The final sample had an average number of squadron workers of 144.3 (SD = 140.9, Mode = 100 (n = 33), Minimum = 5, Maximum = 1675). To understand the overall worker response rate, we divided the number of completed responses by the number of workers requested to participate in at least one survey administration (Table 2). The combined number of completed, individual worker survey responses was 209,658 representing an overall response rate of 90.6%.

The bivariate correlation between squadron level injuries, squadron size, Organizational Safety Priority, Leadership and Communication, Resource Adequacy, Error Management, and Deployment/Official Travel Impact are shown in Table 3. The bivariate correlations between each of the constructs and squadron level injuries are negative and range from small to medium in effect size. The relationship between squadron size and squadron level injuries was positive and strong.

Table 4 reports the results of the Negative Binomial regression models. In the base model, only the number of workers within a squadron was used to predict squadron level reported injuries. The base model suggests that squadron size was a strong, positive predictor of squadron level reported injury events, which is consistent with the bivariate correlation and the reasoning for including squadron size, and therefore modeling injury rates. Except for resource adequacy, each of the constructs was significantly related to squadron level injury rates.

Higher scores for the survey constructs were consistently correlated with fewer injuries ($p < 0.001$). After controlling for the number of workers in each squadron, the estimated RRs consistently revealed significantly lower injury rates with a unit increase in each survey construct score. For example, a one point increase in the 5-point Likert scale responses for the Leadership and Communication construct revealed a 60% decrease in reported injuries (RR = 0.40, 95%CI: 0.32–0.48). A single point increase in Organizational Safety Priority revealed a 50% decrease in reported injuries (RR = 0.50, 95%CI: 0.40–0.64); A single point increase in Error Management revealed a 63% decrease in reported injuries RR = 0.37 (95%CI: 0.30–0.47); A single point increase in Deployment/Official Travel Impact revealed a 64% decrease in injuries (RR = 0.36 95%CI: 0.29–0.45). A single point increase in Resource Adequacy revealed a non-significant injury rate reduction of 13% (RR = 0.87 95%CI: 0.73–1.04).

4. Discussion

Previous research has argued that workers in various organizational positions are likely to have different perceptions of safety climate because of their unique experiences (Zohar, 2010). While we did not assess differences among the functional areas or squadrons, this study advanced traditional analyses of the data by aggregating the survey responses over a five-year time period to understand the impact of squadron-level safety climate perceptions (i.e., leadership and communication, error management, resource adequacy, and deployment/official travel impact) on the overall injury rates during the same time period. Although each construct differed in terms of the relative magnitude of their association with the injury rate, positive perceptions of safety climate constructs were consistently associated with lower injury rates during the five-year period. These results illustrate the advantages of using safety climate constructs as a valid leading indicator during a longer period. In other words, it takes leadership and patience to see the benefits of safety management activities. However, these results not only provide ample feedback and direction for application in the military but also for other industries and workgroups who operate in high-hazard environments.

Active-duty military personnel generally change positions every two to three years based on DAF priorities and policies (Department of the Air Force Instruction (DAFI) 36-2110, 2 August 2021), which may increase the challenges faced by a unit commander working to assess safety climate and implement improvements. These study results indicate the importance of leadership and communication practices among squadrons, especially considering the level of personnel movement that can occur across squadrons. When moving among different units, it is important to have operational management practices and communication mechanisms in place so there is no question about the squadron's priority toward safety. Positive measures of leadership and safety communication have been associated with reductions in injury rates in

Table 3
Bivariate correlations of safety climate constructs and study measures, FY2014–2018.

	Total Number of Surveys Administered	Injuries	Squadron Size	Organizational Safety Priority	Leadership and Comm.	Resource Adequacy	Error Management
Injuries	−0.001						
Squadron Size	−0.072*	0.70*					
Organizational Safety Priority	0.21*	−0.31*	−0.40*				
Leadership and Communication	0.19*	−0.37*	−0.44*	0.91*			
Resource Adequacy	0.011	−0.10*	−0.086*	0.43*	0.46*		
Error Management	0.20*	−0.39*	−0.46*	0.90*	0.91*	0.40*	
Deployment/Official Travel Impact	0.086*	−0.28*	−0.35*	0.740*	0.74*	0.54*	0.73*

* Correlation is significant at the 0.01 level (2-tailed).

Table 4
Negative Binomial regression models for safety climate constructs and work-related injuries, controlling for squadron size, fiscal years 2014–2018.

	Estimate	Std. Error	Wald Chi-Square	P-value	Rate Ratio (RR)	RR 95% CI lower bound	RR 95% CI upper bound
	Base Model						
Squadron Size	0.007	0.002	822.17	<0.001	1.007	1.007	1.008
	Models for each construct while controlling for squadron size						
Leadership and Communication	−0.93	0.11	81.8	<0.001	0.40	0.32	0.48
Organizational Safety Priority	−0.69	0.12	32.0	<0.001	0.50	0.40	0.64
Error Management	−0.98	0.11	74.7	<0.001	0.37	0.30	0.47
Resource Adequacy	−0.14	0.09	2.37	0.12	0.87	0.73	1.04
Deployment/Official Travel Impact	−1.02	0.11	91.2	<0.001	0.36	0.29	0.45

Note: Given multicollinearity (VIF > 4) between each of the perceptual constructs, each construct was entered with the squadron size as the control variable individually. Within the base models, squadron size was used to individually predict squadron level injuries. In all models the predictive effects of squadron size remained a significant predictor of squadron level injuries at $p < 0.001$. Estimate and std. error is the regression coefficient and standard error of the estimate derived from the generalized linear negative binomial regression models. Exp(B) is the exponentiated regression coefficient and represents the multiplicative effect on expected injuries for a single unit increase in the scale related to each of the constructs.

other high-risk industries as well such as mining (Haas, 2020) and construction (Pandit, Albert, Patil, & Al-Bayati, 2018; Schwatka, Hecker, & Goldenhar, 2016; Schwatka & Rosecrance, 2016), also supporting the need to further examine the leadership and communication measures used within this survey to help identify where unit commanders can improve.

The five-factor model used for the common AFCMRS items requires further investigation to understand the completeness of item measurement by the Resource Adequacy and the Deployment/Official Travel Impact constructs. The lack of a significant association between the Resource Adequacy and injury events may be a result of the overlap between items in AFCMRS, and the shared variance between resource items and leadership items, another aspect of what makes the factor structure challenging to assess.

4.1. Limitations and strengths

Although this study presents tangible findings, it is not without limitations. First, the safety climate survey is voluntary for squadron commanders to initiate and workers to complete. Therefore, results may be subject to non-response bias. However, the anonymous nature of the survey encourages workers to be as honest as possible and may reduce non-response bias. Similarly, because the surveys were not systematically administered to all organizational units across the Air Force, the data available for analysis may be biased toward leaders and workers who value safety the most. Also due to the nonsystematic implementation of the survey, we were unable to conduct a cohort study to understand the longitudinal effects of safety climate on a static military workforce. To assess this potential source of bias, future studies in this population should administer surveys to a random sample of squadrons. Also, safety climate survey responses from AFCMRS and injury counts from AFSAS were linked by name of the squadron. Although rare, there are situations over time where a squadron may change its name or change organizational structure. At the time of survey administration, squadron leaders estimated the number of workers available to take the survey which specifically includes federal and military workers. Injury and safety climate information is not collected for workers of other personnel systems such as contract workers. This analysis aggregated across three major functional areas (MX, OPS, SUP) in order to understand the broad implications of safety climate during the four year period and does not assess the temporality of injuries and impact on safety climate constructs.

First, a major strength of this study is the large number of survey responses and the census of injuries (rather than a sample). This analysis provides a unique opportunity to examine safety climate responses in relation to injury counts over a 5-year period. All on-duty injuries resulting in medical care beyond first aid are required to be reported and recorded within AFSAS. Other strengths of this study include that it advances upon research that has already made the connection between a positive safety climate and a reduction in severe workplace injuries by aggregating data over a period of years. Specific to the military, research has assessed such perceptions among unit divisions (Ciavarelli, Figlock, Sengupta, & Roberts, 2001; Ciavarelli & Crowson, 2004; Roberts, 1990; Shappell & Wiegmann, 2000). For example, the U.S. Navy has been using a command safety assessment survey since 2000 to measure the climate of aviation squadrons (O'Dea, O'Connor, Kennedy, & Buttrey, 2010). O'Dea and colleagues found that this survey can serve as a predictor of future injury events among Navy personnel. However, to date, analyses have occurred with one specific data set or time point examining responses of each unit one time, and analyses are often limited to medical data only. Medical data typically have very little information about circumstances and risk factors associated with a work-related injury. Cumulative data collected over many years, such as the five years of this study, has not been used to assess trends in safety climate perceptions and the impact of those trends on unit injury rates. To validate these links even further and advance the body of knowledge on safety climate, future research should examine the impact of safety climate on injuries by occupational groups. Additionally, future research should examine the longitudinal impact on injury rates after providing feedback to leadership on safety climate scores. Such analyses may allow the DAF to revise the current surveys to include the most pertinent constructs (Hahn & Murphy, 2008).

4.2. Conclusions

Research continues to suggest that safety climate models can support root cause analyses and trends, particularly to identify vulnerable areas within an organization (Griffin & Curcuruto, 2016; Reason, 2016). Therefore, despite the limitations of this study there are major strengths to consider for future applications. We examined safety climate as both a leading and lagging indicator of safety, recognizing that safety climate can truly be both (Yorio et al. 2020; Haas & Yorio, 2016; Payne et al., 2009, 2010). Specifically, Payne et al. (2009, 2010) argue that safety climate is both a leading and lagging indicator because it can be influenced by major safety events. We note that some major strengths of this study included the large number of survey responses and the census of injuries. By comparison, many national estimates of work-related injury are based on samples or surveys, such as the National Electronic Injury Surveillance System – Occupational Supplement, which is a national probability-based sample of U.S. hospital emergency department records (CPSC, 2001) or the Bureau of Labor Statistics Survey of Occupational Injuries and Illnesses (BLS, 2020c). It would be prohibitive to link the available work-related injury data to any safety climate survey.

4.3. Practical applications

Assessing organizational safety climate has been operationally useful in providing DAF leadership with the current perceptions of their respective organizational units. Results are made available to squadron leaders to share with among the chain of command, including the workforce, to communicate priorities to improve safety. The findings of this study can be applied in other high-hazard industries. The DAF and other HROs can use the results of this study to tailor and support the implementation of health and safety management programs. Options for future survey administration and interpretation may be to (1) explore revising the safety climate surveys to implement shorter scales (Hahn & Murphy 2008) to improve rates of survey completion; (2) include longitudinal analyses to examine the impact of safety climate as a leading and/or lagging indicator of injuries by occupational groups and detailed injury variables, such as injuries related to falls, fatigue, or hand/wrist injuries; and (3) aim to implement the survey at different time points to assess perceptions at different snapshots in time such as during routine operations or following a major injury or incident. Recording some of the environmental indicators during the time of survey completion may allow for a more ecological view of what may impact worker perceptions of safety climate over a multi-year period of time. Trends in these results could help industries further refine their health and safety management systems.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was funded intramurally through the National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda (NORA). The study represents a collaborative effort between NIOSH and the U.S. Air Force. NIOSH owes a debt of gratitude to the U.S. Air Force for their hard work to make this project a reality. The Air Force Safety Center (AFSEC) is to be commended for their innovative efforts to improve safety culture. The authors wish to recognize the following for their insightful review of the manuscript: Jennifer Bell (NIOSH/DSR), Scott Schneider (Laborers' Health and Safety Fund of North America (retired)), Michelle Canham-Chervak (Army Public Health Center); and for review and clearance of the manuscript by Susan Moore (NIOSH/NPPTL), Christine Schuler (NIOSH/DSR), and Legal Judge Advocate (AFSEC).

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC) or the U.S. Department of the Air Force (DAF). Mention of any company or product does not constitute endorsement by NIOSH, CDC, or DAF. In addition, citations to websites external to NIOSH or DAF do not constitute NIOSH or DAF endorsement of the sponsoring organizations or their programs or products. Furthermore, neither NIOSH nor DAF are responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.

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