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TRENDS AND DEVELOPMENTS IN MILITARY SAFETY PERFORMANCE: A COMBINED SCIENTOMETRIC AND SCOPING STUDY

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ABSTRACT

Safety performance is extremely important in a military context as it directly affects the protection of soldiers and the successful completion of missions. This study aims to examine military safety performance through a combination of scientometric and scoping review methods. The research emphasizes the crucial roles played by safety leadership, culture, and technological advancements. To analyze the data, bibliographic databases such as Scopus and WoS were examined, and advanced data analysis tools like ScientoPy and VOSviewer were used for data processing and visualization. The analysis produced a list of the top ten keywords including safety, safety standards, safety performance, safety culture, software safety, military, flood risk, risk assessment, laser safety, and safety measures. These keywords highlight the impact of effective safety leadership on soldiers' perception of risk and operational success, as well as the importance of technologies like smart wearables for monitoring health and location. The study also identifies various stressors that affect safety such as job burnout and PTSD and emphasizes the need for targeted interventions. The scientometric analysis shows a growing interest in academic research on military safety performance, while the scoping review identifies gaps in current studies and suggests areas for future research. By integrating continuous training, technological advancements, and adaptive leadership, the study proposes a comprehensive approach to improve military safety and operational effectiveness. The findings underscore the importance of cultivating a strong safety culture and the need for ongoing research to address the evolving challenges in military environments.

Keywords: military, safety leadership, safety performance, scientometric, scoping review

INTRODUCTION

In the military, personnel effectiveness and readiness depend heavily on safety performance. Factors such as safety leadership, culture, and technological advancements all impact safety performance. Previous research has shown that effective safety leadership enhances soldiers' perception of risk, which is crucial for operational success (Wei & Kuo, 2023). The use of safety performance indicators in civil aviation and other fields further emphasizes the wide applicability and importance of systematic safety management (Chen et al., 2021). Additionally, implementing technologies like smart wearables to monitor soldiers' health and location plays a crucial role in enhancing safety and operational effectiveness (Kodam et al., 2020). By integrating these elements, we can develop a comprehensive approach to improving safety and overall military effectiveness. This approach emphasizes the need for high safety and reliability standards, as seen in critical systems such as nuclear power plant systems (Kumar et al., 2020). Overall, these aspects highlight the fundamental role of safety performance in bolstering the strategic and operational efficacy of military forces.

Adapting safety performance in military environments is a multifaceted and intricate task due to the dynamic nature of modern operations. Numerous challenges must be addressed including ever-evolving threats such as cyber-attacks, and unconventional warfare. These challenges demand a flexible approach to safety. The incorporation of new technologies also presents ongoing challenges, as it often requires adaptation and learning that may challenge traditional safety paradigms (Radzi et al., 2024b). Striking a balance between safety and operational effectiveness requires a nuanced approach to risk management. Furthermore, rapid technological changes can lead to gaps in training and education, further complicating safety efforts (Noor Arzahan et al., 2024). Ensuring interoperability in a networked environment and managing cultural resistance to new safety measures are also significant issues that need to be tackled. Additionally, resource constraints can limit the implementation of effective safety measures. To effectively address these challenges, a comprehensive strategy is indispensable, encompassing continuous training, technological enhancements, fostering a robust safety culture, and adaptive leadership.

The issue of safety performance among military personnel is complex. One aspect involves the influence of factors such as job burnout, time pressure, and Effort-Reward Imbalance (ERI) stress on driving behaviors, which can increase the risk of road accidents (Rosenbloom, 2022). Another aspect relates to the impact of operational stressors, such as sleep deprivation and caloric restriction, on perception-action coupling, performance, and safety in military environments (LaGoy et al., 2022). In addition, safety behaviors associated with insomnia and post-traumatic stress disorder (PTSD) can perpetuate anxiety and psychosocial impairment. This highlights the need for interventions that address underlying issues such as insomnia, PTSD, and nightmares to improve safety behaviors associated with PTSD (Bui et al., 2023; Radzi et al., 2024a). Overall, addressing these various factors is crucial in enhancing safety performance and reducing risks among military personnel.

Prior research has established a link between safety leadership, risk perception, safety culture, and safety performance (Wei & Kuo, 2023). Psychological empowerment, encompassing psychological safety and safety performance, has a significant impact on the physical and mental well-being of individuals, job satisfaction, and overall effectiveness (Hwang & Park, 2022). A secure work environment not only enhances productivity but also fosters motivation and confidence among employees (Sauri et al., 2022). Furthermore, safety performance indicators play a crucial role in evaluating organizational performance and can contribute to improved work quality and operational continuity (A et al., 2022). Therefore, by

prioritizing safety practices and cultivating a culture of safety, military personnel can experience heightened morale, productivity, and overall performance levels.

The significance of safety performance within the military is of utmost importance, regardless of the presence of conflict or a state of peace. Its role in preventing accidents within the military environment cannot be overstated. To ensure the credibility of findings and reference sources in this field, the implementation of evidence synthesis and scoping reviews is imperative. Thus, the objective of this study is to analyze pertinent information on safety performance within the military context, using a scientometric approach and scoping review. Consolidating existing literature on this subject is significant. It is worth noting that there is a lack of prior research using this methodology to synthesize publication output concerning safety performance in the military context.

METHOD AND ANALYSIS DESIGN

Scientometric Analysis

Scientometric analysis is a well-established method for analyzing and understanding large amounts of scientific data. It allows us to gain a deeper understanding of how a field develops (Donthu et al., 2021). The use of scientometric parameters to evaluate the quality of research output is increasing. Researchers use scientometric analysis for various purposes such as identifying emerging trends and evaluating journal performance (Struck et al., 2021). They also use it to examine collaboration patterns and research components (Wachsmann et al., 2019), study publication trends within a research domain (Abdullah, 2021a) and explore the intellectual structure of a specific area in published works (Abdullah, 2021b; Simao et al., 2021). In this study, we use scientometric analysis to observe patterns of research publications on safety performance, identify countries actively involved in publishing, and analyze the themes and subthemes conveyed through authors' keywords.

Scoping Analysis

The primary aim of scoping reviews is to systematically gather and document a wide range of available evidence (Munn et al., 2018). Consequently, the objective of this study is to comprehensively analyze the essential facets pertaining to safety performance in military publications and synthesize the existing literature in this field of research. This scoping review was conducted to identify areas necessitating further investigation and gaps in knowledge. The study adhered to the established five-step scoping review framework developed by Arksey and O'Malley (2005):

1) Establishing the research question.
2) Identifying relevant studies.
3) Selecting studies.
4) Data charting.
5) Reporting results.

Establishing Research Question

The following research question serves as the basis for scoping analysis in this study:
Based on the SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research Type) tool (Cooke et al., 2012), what are the key findings from past studies on safety performance in military environments?

Identifying Relevant Studies

Database

To access scientific journal publications, institutional repositories, archives, and other collections of materials, databases and search engines are necessary (Abdullah et al., 2020). For this study, we used the Scopus and Web of Science (WoS) databases to analyze scientometric and scoping indicators. These databases were chosen because they place more importance on document citations compared to others (Vieira & Gomes, 2009). Furthermore, adjustments were made to improve the validity of the coverage analysis, including enhancing metadata accuracy, document category classification, and discipline assignment. Therefore, Scopus and WoS prioritize these factors (Stahlschmidt & Stephen, 2022).

Search Strategy

Once the keywords have been identified, an encyclopedia is used to find synonymous terms. Table 1 shows the search strings that were used to obtain publication lists from the Scopus and WoS databases. The search was conducted in July 2024 and included titles, abstracts, and keywords from both databases. No restrictions were placed on the retrieved data during this process such as date, publication type, or language.

Table 1

Search Strategy for Extracting Data from the Web of Science and Scopus Databases.

Database	Search Strategy	Records
Web of Science	Topic: ("Safety performance" OR "Safety record" OR "Safety outcomes" OR "Safety achievements" OR "Safety results" OR "Safety standards compliance" OR "safety participation" OR "safety compliance" OR "Safety behavior" OR "Safety standard" OR "Safety indicators" OR "Safety accomplishments" OR "Safety effectiveness" OR "Safety ratings" OR "Safety metrics") AND ("Military" OR "armed forces" OR "army" OR "Navy" OR "Air force" OR "defence forces" OR "soldiers" OR "Defense sector" OR "Armed services" OR "Military branches" OR "Military personnel" OR "Military operations" OR "military environments" OR "Military organization" OR "defence" OR "military service")	104
Scopus	Article Title, Abstract, Keywords: ("Safety performance" OR "Safety record" OR "Safety outcomes" OR "Safety achievements" OR "Safety results" OR "Safety standards compliance" OR "safety participation" OR "safety compliance" OR "Safety behavior" OR "Safety standard" OR "Safety indicators" OR "Safety accomplishments" OR "Safety effectiveness" OR "Safety ratings" OR "Safety metrics") AND ("Military" OR "armed forces" OR "army" OR "Navy" OR "Air force" OR "defence forces" OR "soldiers" OR "Defense sector" OR "Armed services" OR "Military branches" OR "Military personnel" OR "Military operations" OR "military environments" OR "Military organization" OR "defence" OR "military service")	680

Software

ScientoPy and VOSviewer are two commonly used research tools in academic settings. ScientoPy, a Python script, is designed to extract valuable information from research articles, including main subjects, authors, countries, and associated documents. By utilizing author-provided keywords,

ScientoPy generates insights and helps reduce potential biases that might arise from separate investigations (Ruiz-Rosero et al., 2017). However, it is important to acknowledge that analyzing studies based on author names may still introduce bias, especially when name similarities occur (Ruiz-Rosero et al., 2017). Additionally, ScientoPy's analysis of theories is limited to those explicitly mentioned in abstracts, keywords, and titles. As a result, theories not cited by previous authors may remain undetected by the software. Nevertheless, identifying these theories offers fresh insights into the topics and highlights relevant theories for future research.

VOSviewer is a software application that facilitates co-occurrence analyses of keywords, particularly in the context of safety performance in the military domain. It employs sophisticated mapping techniques to transform CSV data into visually informative diagrams or clusters (Abdullah, 2022). These mapping strategies hold considerable potential benefits for researchers who wish to analyze specific data points such as authors' keywords (Abd Aziz et al., 2021; Abdullah & Othman, 2022).

Selecting Studies

Publications Merge and Removal of Duplicates

The data from both databases was compiled and processed using ScientoPy. During this stage, the data underwent standardization procedures such as substituting commas in the author's name with semicolons, removing dots, commas, and unique formatting from the author's name, and eliminating duplicate entries with identical titles and authors. This methodological approach serves to improve the accuracy and reliability of the datasets. The outcomes of the pre-processed data are illustrated in Diagram 1.

The preprocessing script utilized in ScientoPy assigns greater priority to WoS documents in contrast to Scopus documents. Figure 1 shows the preprocessing of documents in a study on military safety performance. The figure reveals that out of the 100 documents acquired from WoS, no duplicates were eliminated. However, 14% of the 680 documents from Scopus were identified and removed as duplicates. Diagram 1 supplements this information by indicating that the source dataset comprises 784 papers from both the WoS and Scopus databases. ScientoPy automatically classifies publications into various categories such as conference papers, articles, reviews, proceedings papers, and press pieces. Consequently, 61 documents, including books, letters, and errata, were excluded. Following the process of data reconciliation, this study employed a total of 636 entries from both databases, consisting of 103 papers from WoS and 533 from Scopus. Furthermore, 87 duplicate entries from Scopus and 13 from WoS were eliminated.

Diagram 1
Flow Diagram of Research of Databases and Registers

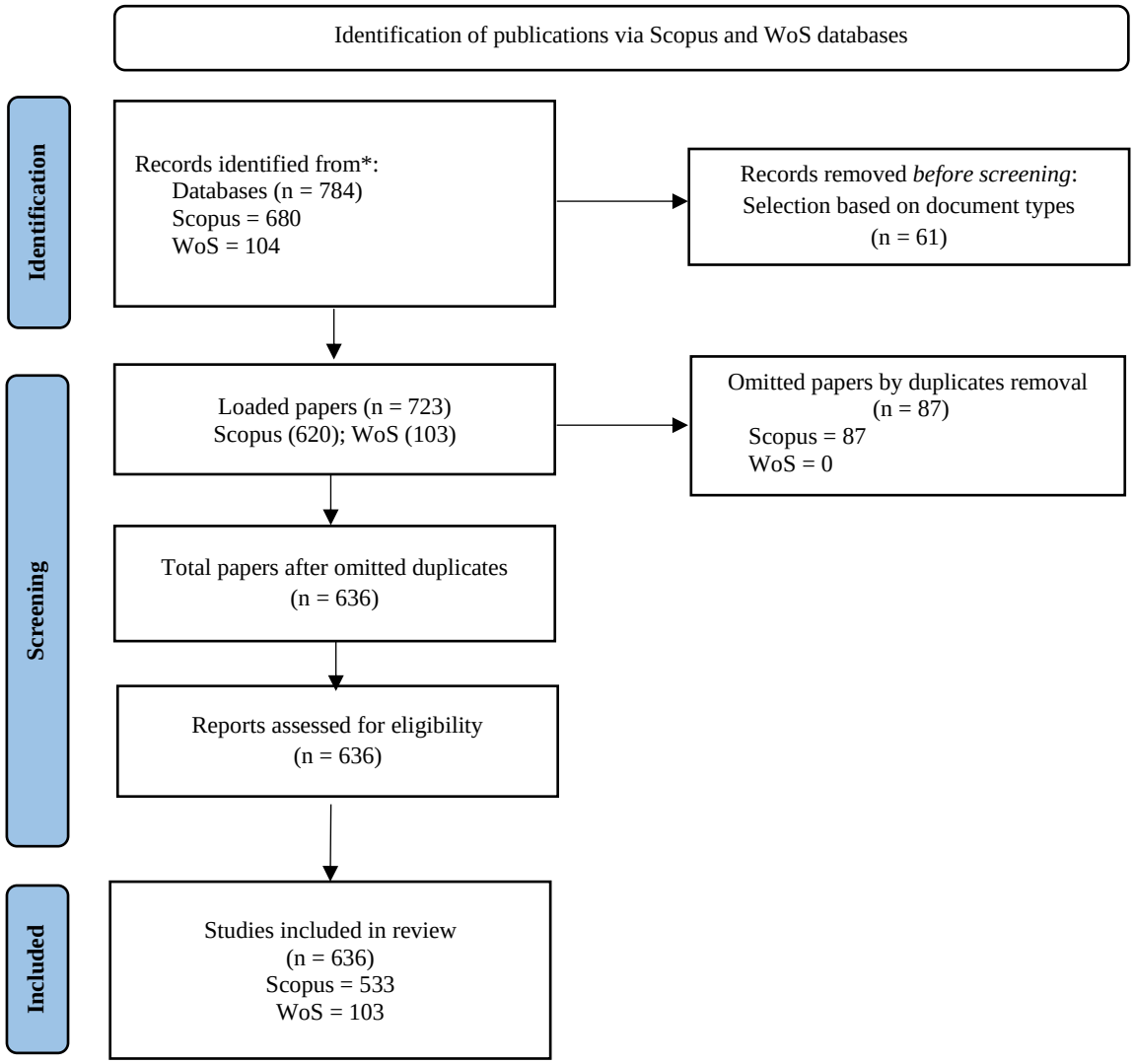
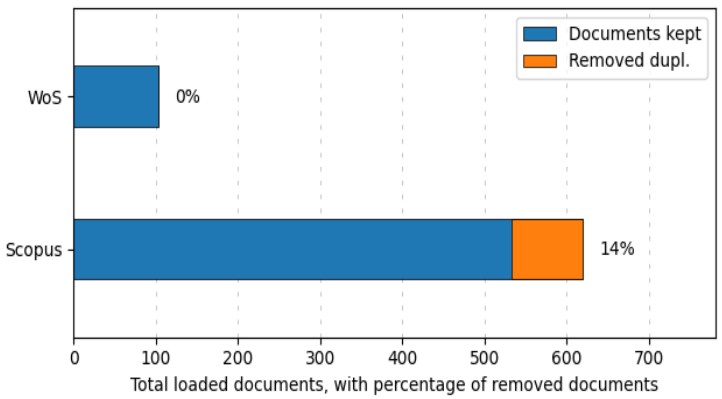


Figure 1:
Data Combination and Duplicates Removal



Data Charting

The publication growth graph depicts the development of publishing in the Scopus and WoS databases. This data holds significance in comprehending the general pattern of publications. To offer a more comprehensive understanding of the articles chosen in the preceding phase, we scrutinize the evolution graph of the top 10 authors' keywords and investigate the co-occurrence of these keywords.

Reporting Results

In accordance with the objectives of the study, a succinct summary and report of the findings were prepared. ScientoPy was utilized for the analysis of publication growth, identification of active countries, and examination of keywords. VOSviewer was employed as a descriptive metric to ascertain the co-occurrence of authors' keywords. It is important to note that, to generate co-occurrence results for authors' keywords using VOSviewer, a minimum of two keywords is required. Additionally, the thesaurus files were carefully reviewed and modified, following the recommendation by Abdullah et al. (2022), as a precautionary measure against the duplication of authors' keywords.

The methodology employed in this study, known as a scoping review, aims to provide a comprehensive overview of existing research in a specific field. One of the primary purposes of conducting a scoping study is to identify any gaps or deficiencies in the current research body. In this study, our objective was to thoroughly examine and describe the current state of research on safety performance, as well as identify areas in which the literature is lacking. To carry out this analysis, articles sourced from Scopus and WoS were pre-processed using ScientoPy. The specific inclusion criteria for this scoping review can be found in Table 2.

1) Written in English.
2) Publications from 2013 and later.
3) Describe primary research.
4) Use the keyword safety performance in the authors keywords.

RESULTS

Scientometric Outcome

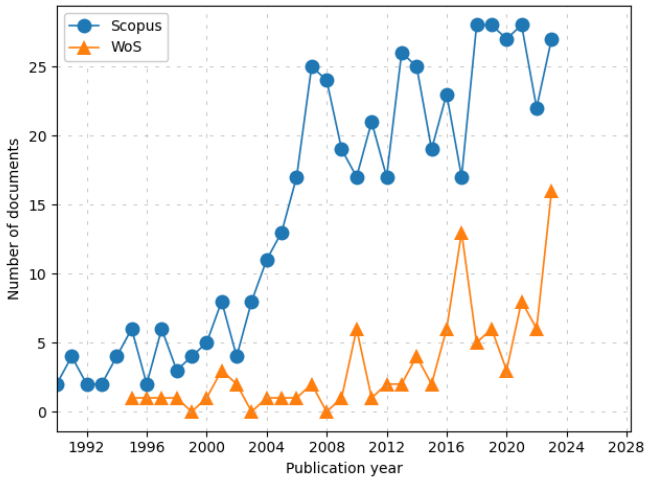
Publication Growth

Figure 2 illustrates the publication trend regarding safety performance in the military from 1992 to the projected data for 2023. The blue line represents the Scopus index, which demonstrates a steadily increasing trend and a significant level of interest in military safety performance research. Conversely, the orange line represents the WoS data, indicating a lower overall publication count and a less consistent publication rate. Both lines exhibit an initial gradual increase until the early 2000s, followed by a more pronounced rise, particularly in the Scopus data. This trend suggests that safety performance in military contexts has garnered greater attention and academic interest over the past two decades, possibly due to increased funding, regulatory changes, and advancements in military protocols and technology. The future projection indicates a stable or slightly increasing trend, thus implying continued relevance and ongoing research interest in this field.

The increasing publication volume on military safety performance over time demonstrates a growing academic interest and underscores the intricacies in understanding factors influencing safety performance such as safety leadership, risk perception, safety culture, and safety education. This pattern underscores the significance of continued dialogue among scholars, military subject matter experts (SMEs), and occupational safety and health (OSH) professionals. By fostering open communication and collaboration among these stakeholders, it is crucial for capitalizing on theoretical advancements, practical insights, and safety considerations in the field (McCullagh et al., 2022). These interactions play a crucial role in shaping comprehensive safety performance aspects in military contexts (Nestor, 2020). This active interdisciplinary engagement is vital for effectively addressing the evolving challenges in military safety performance.

Figure 2

The Evolution of Publication Growth (Source: Author, using ScientoPy 2.1.3)

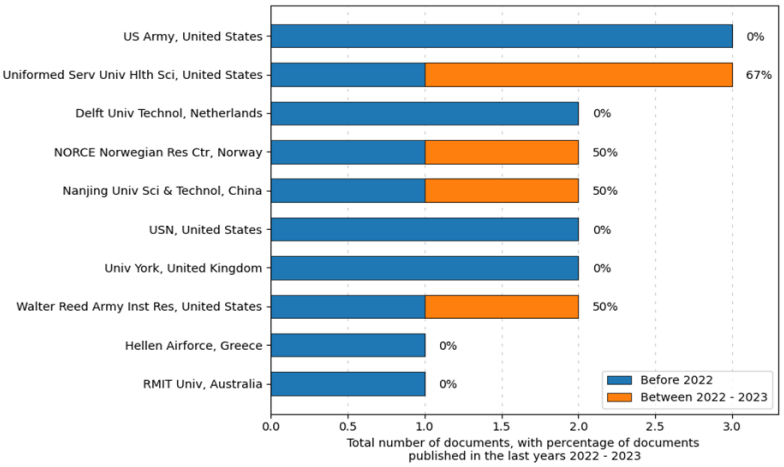


The Most Influential Academic Works

Figure 3 exhibits the global distribution and recent scholarly output on military safety performance by academic institutions. The figure presents a comparison of the total number of publications produced by each institution, categorised into those published prior to 2022 and those published between 2022 and 2023. It is important to highlight that the Uniformed Services University of the Health Sciences in the United States has witnessed a noteworthy surge in publications over the past two years, with 67% of its overall publications falling within this time frame, the highest among the listed institutions. Likewise, prominent institutions such as the NORCE Norwegian Research Centre in Norway and Nanjing University of Science & Technology in China also demonstrate that half of their total publications originated in the last two years. These observations indicate an emerging or revitalised emphasis on safety performance within military contexts. The findings suggest a substantial and potentially growing interest in this research area, particularly in recent years, as global institutions respond to evolving safety challenges confronted in military settings.

Figure 3

Institution Bar Trends Graph



Authors' Keywords

Figure 4 depicts the distribution and current publication patterns of authors' keywords relating to safety performance in the military. The keywords are categorized based on the total number of associated documents and the percentage of those documents published between 2022 and 2023. Among all the keywords, "Safety" is the most frequently utilized term and has consistently remained prominent, with 25% of its publications occurring in the past two years. Notably, "military" stands out as 43% of its total documents have been recently published, indicating a growing interest or emerging concerns in this particular area. Furthermore, "Safety performance" and "Safety culture" are also noteworthy subjects, with recent publications accounting for 23% and 25% of their respective overall counts. These keywords highlight specific domains of research that are presently active and evolving within military contexts, reflecting ongoing safety challenges or potential new developments.

Figure 4

The Bar-trend Graph of Research Themes and Topics Emerging (Source: Author, using ScientoPy 2.1.3)

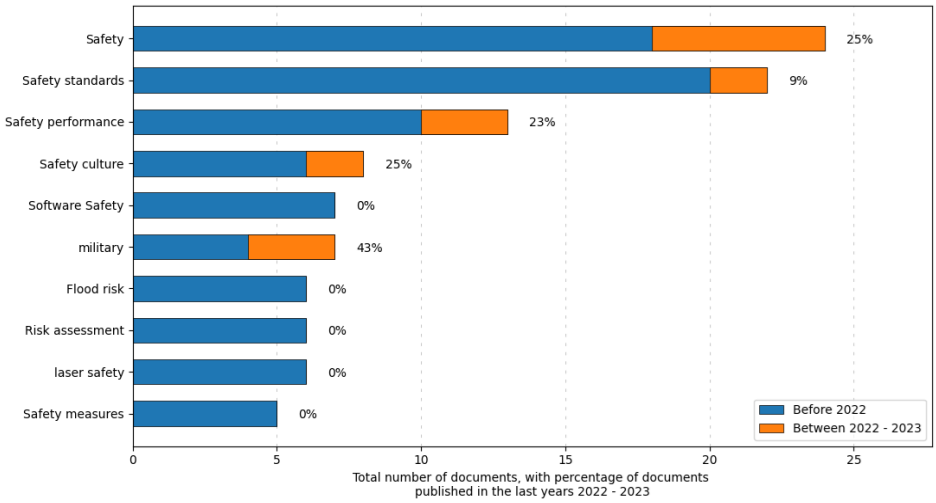
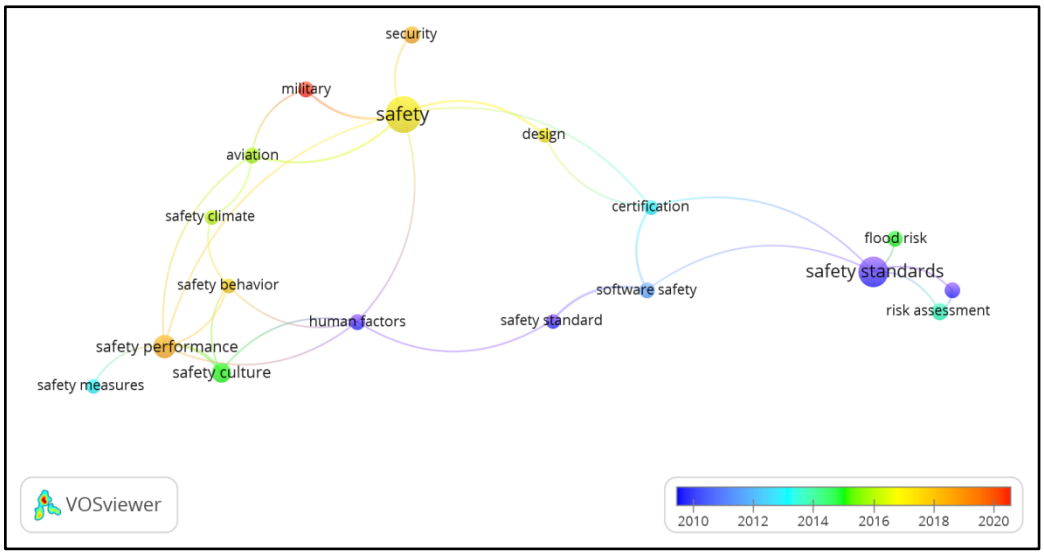


Figure 5 presents a VOSviewer visualization illustrating the evolving trends in authors' keywords pertaining to safety performance in the military from 2010 to 2020. The keywords are interconnected based on their co-occurrence in research publications, and the strength of their relationships is depicted by lines. The color gradient on the map signifies the significance of each keyword over time, with blue indicating earlier years and red indicating more recent years. The central theme of the network is "safety," which is linked to various subthemes such as "military," "aviation," "safety performance," and "safety culture." Over time, the focus has shifted from general safety aspects to more specific areas like "software safety" and "safety standards," which are displayed in warmer colors denoting recent attention. Keywords like "risk assessment" and "flood risk" are situated on the periphery of the map in cooler colors, suggesting either previous peaks in research focus or a less direct connection to the core theme of military safety. This visualization effectively demonstrates the dynamic and evolving nature of research in military safety, highlighting both enduring concerns and emerging focal areas.

Figure 5

Co-occurrence of Authors' Keywords

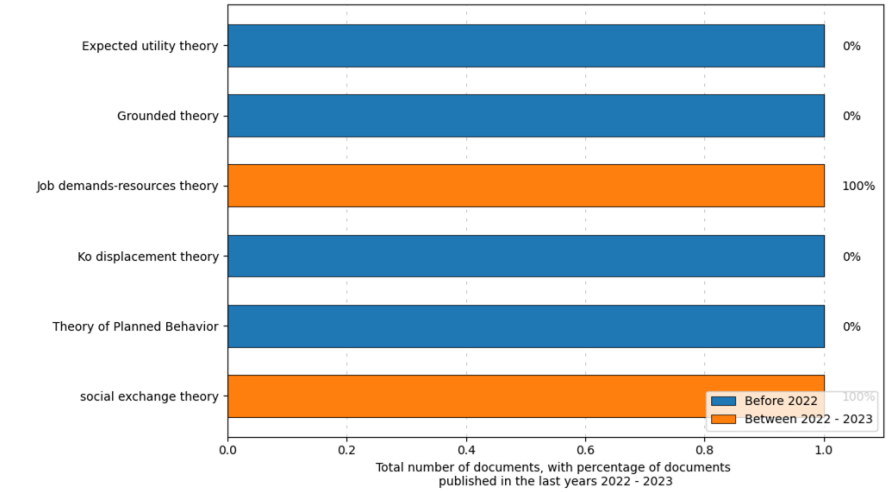


Foundational Theories

Figure 6 illustrates publication trends concerning the theoretical frameworks employed in studies related to military safety performance across two distinct time periods: prior to 2022 and during the period from 2022 to 2023. Notably, the Job Demands-Resources Theory and Social Exchange Theory exhibit significant growth with 100% of their publications emerging during the 2022-2023 interval. This trend suggests a recent increase in the relevance and application of these theories within the domain of military safety performance research. In contrast, Grounded Theory, Ko Displacement Theory, Expected Utility Theory, and the Theory of Planned Behavior have not yielded any publications during the 2022-2023 period, indicating that these frameworks have not been central to recent investigations in this area. The data reveal a discernible shift toward the adoption of contemporary frameworks such as Job Demands-Resources and Social Exchange Theories, which may reflect evolving perspectives on the complexities inherent in military safety and organizational dynamics in recent years.

Figure 6

The Bar-trend Graph of Foundational Theories (Source: Author, using ScientoPy 2.1.3)



Scoping Outcomes

This section provides a thorough examination of how safety performance is addressed in military-related publications. This analysis is an essential first step in identifying areas of knowledge deficiency and guiding future research efforts. By doing so, it contributes to the existing body of knowledge and best practices. To conduct the scoping analysis, qualitative research questions were formulated, and the SPIDER tool was used as the search strategy in this study. Table 3 presents a compilation of publications based on extended author keywords obtained from ScientoPy. Initially, the information in Table 3 was condensed from a total of 104 documents. It is important to note that this study specifically focuses on the scoping analysis of research articles, excluding the other 94 records that were not classified as research papers at this stage.

Table 2

List of Inclusive Publications

Num	Sources	Sample	Phenomenon of Interest	Design	Evaluation	Research Type
1.	Wei & Kuo (2023)	Examined 725 military volunteers from Taiwan to explore the relationship between safety leadership, risk perception, safety culture, and safety performance	Explores how safety leadership affects risk perception, safety culture, and overall safety performance among military volunteer soldiers, highlighting the mediating role of risk perception and safety culture in this relationship	Questionnaire-based survey and convenience sampling to explore relationships among safety leadership, risk perception, safety culture, and safety performance among military volunteers, employing latent variable modeling and multiple hierarchical regression analysis to verify hypotheses	Understanding safety leadership enhances risk perception and safety performance among military volunteers, with risk perception and a strong safety culture amplifying this effect, though it relied on self-reported measures,	Quantitative

				after confirming construct reliability and validity.	which may affect objectivity.	
2.	Ibrahimkh & Hadidi (2023)	57 construction projects in Afghanistan, including 25 overseen by the US Army Corps of Engineers and 32 funded by the Afghan government, successfully gathering responses from contractors across various provinces	Focuses on comparing the safety levels of construction sites in Afghanistan managed under US Army Corps of Engineers (USACE) standards versus those following local government safety guidelines	Used a safety checklist with 104 items across 17 categories to assess construction site safety, analyzing data from 57 projects through quantitative methods like Spearman rank correlation and Mann-Whitney tests	Construction sites under USACE standards in Afghanistan are safer than those following local government guidelines, with USACE projects scoring 'very good' on safety performance compared to the 'poor' rating of government project	Quantitative
3.	Rowen et al., (2022)	Gathered 11,738 responses from officers and enlisted personnel on 146 U.S. Navy surface ships, which, after data cleaning, resulted in a final sample of 3,803 predominantly male (79%) respondents	Examines how work demands and resources, including operational tempo factors like stress, rest, and duty periods, impact safety culture, motivation, and perceived performance within the U.S. Navy	Used an exploratory Partial Least Squares (PLS) model to analyze survey data from U.S. Navy personnel, investigating how job demands, resources, safety culture, and safety motivation influence perceived safety performance	uses a PLS model to show how job demands and resources impact safety culture, motivation, and performance in the U.S. Navy, emphasizing the importance of rest and preparation, and suggests future research should use longitudinal data and a more diverse participant pool	Quantitative
4.	Armenis (2020)	Tested adapted LOSA and high-performance workshops on over 1,500 safety-critical operators from mining and power distribution, and references its use in over 20,000 airline flights, highlighting a diverse sample across high-reliability industries	Examines how work demands and resources affect safety culture, motivation, and perceived performance in the U.S. Navy, highlighting the balance between stress, work hours, rest, and preparation, and their influence on safety behavior and	Used a Partial Least Squares (PLS) model to analyze survey responses from U.S. Navy personnel, examining how job demands and resources like stress, rest, and preparation impact safety culture, motivation, and perceived safety performance	job demands like stress can motivate safety behaviors, but adequate rest is crucial for high safety performance, with perceived safety performance strongly linked to formal training rather than mission-specific training, and a	Quantitative

			performance		moderate model fit suggesting that job pressures and available resources significantly influence safety culture and behavior in the Navy	
5.	Pejovic et al., (2020)	Used EUROCONTROL DDR2 traffic demand data to analyze tactical flight trajectories, excluding military flights and those with 'ZZZZ' or 'AFIL' airports to focus on scheduled flights with complete information	Focuses on how the implementation of Free Route Airspace (FRA) affects traffic flow, safety, airspace complexity, and air traffic controller workload in the MUAC airspace	Combined traffic data analysis, safety performance evaluation, and workload assessment to examine the impact of Free Route Airspace (FRA) implementation in MUAC airspace, analyzing changes in traffic patterns, potential losses of separation, conflict risk, and controller workload before and after FRA implementation	Implementing Free Route Airspace (FRA) in MUAC airspace increased traffic complexity and workload, unexpectedly raising potential losses of separation and conflict risks, and increasing the density and size of conflict hotspots, suggesting that FRA's impact on safety and efficiency is complex and requires careful analysis	Quantitative
6.	Mei et al., (2019)	Used in this research consisted of 690 officers and soldiers from a troop with a good safety culture basis, out of which 687 valid questionnaires were collected for analysi	Focuses on understanding how building a strong safety culture within the armed forces impacts their overall safety performance, by analyzing factors like safety ideas, knowledge, facilities, codes, rewards, punishments, and technology	Used surveys and structural equation modeling (SEM) to examine the relationship between safety culture factors and safety performance in the armed forces, with questionnaires designed through discussions with management experts and military leaders using the Delphi method	A strong safety culture in the military, encompassing safety ideas, knowledge, facilities, codes, rewards, punishments, and technology, significantly improves safety performance, as shown by SEM	Quantitative
7.	Pejovic et al., (2019)	Analyzed 2017 summer and fall air traffic within FABEC airspace, using discrete simulation to assess the impact	Examines the relationship between air traffic demand, safety, and complexity in FABEC airspace	Used a case study approach with discrete simulation to analyze air traffic complexity and safety during two weeks in summer	Higher air traffic demand increases conflict risk and complexity in FABEC airspace, and	A case study

		of Free Route Airspace (FRA) implementation on traffic demand, safety, and complexity	across seasons, focusing on the impact of implementing Free Route Airspace (FRA)	and fall of 2017 within FABEC airspace, utilizing EUROCONTROL complexity metrics and a conflict risk assessment tool to explore the relationship between traffic demand, safety, and complexity	suggested that implementing Free Route Airspace (FRA) could improve operational and safety performance by potentially reducing these factors, though further analysis is needed	
8.	Sun et al., (2017)	Used safety performance indicators from China Civil Aviation standards and QAR monitoring items to evaluate airline fleet safety, identifying critical risks like loss of control and runway overrun through historical data and qualitative fault tree analysis to set operation quality indexes	Evaluates airline fleet safety performance to identify issues and improve safety management by examining the relationship between high consequence unsafe events and hidden low consequence events	Uses Reason's model to establish a multi-level safety performance index system for airline fleets, integrating indicators for unsafe behaviors, operation quality, risk management, safety assurance, and safety foundation, with a risk value model to calculate safety result indexes based on event frequency and severity	Evaluating airline safety performance helps understand safety levels, identify issues, and improve management by comparing fleet performances, using subjective and objective methods for a comprehensive view, and emphasizing continuous improvement in safety management	Evaluative research
9.	Jausan et al., (2017)	Distributed 400 questionnaires within a military aviation organization, collected 198 valid responses from a diverse sample including aircrew, maintenance, and support personnel, and used PLS-SEM for analysis, ensuring confidentiality and sufficient sample size	Examines how various individual, organizational, and environmental barriers impact the performance of safety reporting systems in military aviation, using PLS-SEM to evaluate their cumulative effect and improve overall safety performance	Surveyed military aviation personnel to identify barriers to safety reporting systems, using PLS-SEM to model their impact on system performance, and conducted a pilot survey to ensure question clarity and effectiveness	Organizational, environmental, and individual barriers significantly impact the effectiveness of safety reporting systems in military aviation, with PLS-SEM modeling showing that addressing these barriers can enhance safety performance by improving risk identification and management	Quantitative
10.	Martínez-Córcoles	Analyzed responses from	Examines how active	Used electronic surveys to assess	Active transactional	Quantitative

& Stephanou (2017)	161 male paratroopers in the Hellenic Armed Forces, collected from 300 distributed questionnaires, focusing on a diverse age range and educational backgrounds	transactional leadership behaviors influence safety performance among military paratroopers by affecting adherence to safety rules, participation in safety activities, and engagement in risky behaviors, with a positive safety climate being crucial in promoting safe practices and reducing risks	paratroopers' perceptions of leadership behaviors and safety performance, employing CFAs and SEMs to analyze the impact of active transactional leadership on safety performance, mediated by safety climate	leadership significantly improves safety performance among military paratroopers by fostering a positive safety climate, which enhances safety compliance and participation while reducing risky behaviors, with safety climate fully mediating the impact of contingent reward and partially mediating active management by exception on safety behaviors

10.	Martínez-Córcoles & Stephanou (2017)	Analyzed responses from 161 male paratroopers in the Hellenic Armed Forces, collected from 300 distributed questionnaires, focusing on a diverse age range and educational backgrounds	Examines how active transactional leadership behaviors influence safety performance among military paratroopers by affecting adherence to safety rules, participation in safety activities, and engagement in risky behaviors, with a positive safety climate being crucial in promoting safe practices and reducing risks	Used electronic surveys to assess paratroopers' perceptions of leadership behaviors and safety performance, employing CFAs and SEMs to analyze the impact of active transactional leadership on safety performance, mediated by safety climate	Active transactional leadership significantly improves safety performance among military paratroopers by fostering a positive safety climate, which enhances safety compliance and participation while reducing risky behaviors, with safety climate fully mediating the impact of contingent reward and partially mediating active management by exception on safety behaviors	Quantitative

DISCUSSION

Based on keyword analysis, safety appears to be most strongly associated with notational analysis, multivariate analysis, and kinetics. This finding emphasizes the crucial role of notational analysis in improving safety performance and the overall effectiveness of military missions. Notational analysis facilitates a proactive approach to safety and operational optimization, making it an indispensable tool. Furthermore, acknowledging the significance of dependability within notational analysis is key.

The topic of safety standards is of significant interest and warrants further investigation, particularly in the realm of safety performance within the military. Evaluating safety standards within military populations is a complex endeavour due to various risk factors, mission requirements, and operational environments (Ismail et al., 2024). As a result, establishing connections between hazards and health outcomes presents a substantial challenge. In military settings, safety standards play a critical role in assessing and mitigating risks to uphold operational effectiveness and ensure safety (Wei & Kuo, 2023). To design and evaluate safety standards effectively, it is recommended to employ methods based on sociotechnical systems theory, which emphasize the need for systematic rigor and common operating standards (de Vries & Bligård, 2019). Furthermore, a hierarchical probabilistic model is proposed for the continuous and quantitative assessment of safety risks (Allouch et al., 2019). This model, calibrated using Bayesian methods, offers a data-driven approach to accurately quantify the risks posed by different hazards in dynamic industrial settings. By enabling automated decision-making for resource

allocation towards risk mitigation in resource-constrained environments, it enhances operational safety and effectiveness.

To obtain a more advanced comprehension of how the military environment affects the safety performance of its members, it is imperative to consider multiple factors that contribute to this correlation. The military environment exerts a substantial influence on the safety performance of its members through various mechanisms. According to Bogaers (2023), high-stress conditions have the potential to engender heightened levels of perceived stress, which can impact decision-making and reaction times. As expounded upon by Wilkerson et al. (2023), training programs play a pivotal role in identifying subtle indications of altered brain processes subsequent to a concussion, which can have ramifications for safety performance. Exposure to hazardous situations, as elucidated by Kolaja et al. (2022) and Radzi et al. (2025), can elicit enduring effects on the physical and mental well-being of individuals, thereby influencing safety outcomes. Moreover, the culture of discipline and accountability, as underscored by Bogaers (2023) and Radzi et al. (2024b) can shape decisions related to the disclosure of mental health issues, consequently affecting overall well-being and subsequently, safety performance. Comprehending these factors is indispensable for enhancing safety measures and fostering the well-being of military personnel.

The Job Demands-Resources (JD-R) Theory and Social Exchange Theory (SET) are critical frameworks that significantly influence military safety performance within the context of Occupational Safety and Health (OSH) by affecting the mental and physical well-being of personnel. The JD-R Theory posits that job demands such as high workloads and stress, can lead to mental distress and exhaustion, which adversely impact safety performance. Conversely, job resources including support and job control, can mitigate these negative effects by reducing mental distress and promoting healthier behaviors, such as improved sleep and decreased substance use (Asare et al., 2021). In high-risk environments like the military, where psychological safety is paramount, cultivating an atmosphere in which personnel feel secure to express concerns without fear of interpersonal repercussions can enhance safety performance (Radzi, 2024). This notion aligns with the principles of SET, which posits that when organizations provide support and resources, employees are likely to reciprocate with enhanced performance and commitment (Hunt et al., 2021).

The mining industry, which shares characteristics with military operations in terms of high-risk and demanding work conditions, demonstrates that prolonged working hours and a lack of routine can escalate injury risks, underscoring the necessity of effectively managing job demands and resources (Friedman et al., 2019). Moreover, the mental health of young workers, including those in military settings, can be adversely affected by poor employment conditions and psychosocial workplace exposures, such as low job control and high job demands, leading to diminished safety performance (Shields et al., 2021). The COVID-19 pandemic has further highlighted the imperative for robust support systems for essential workers, including military personnel, to safeguard their safety and well-being, thus emphasizing the significance of protective measures and adequate resources (Berry & Stuart, 2021). Consequently, integrating JD-R and SET into military OSH strategies can enhance safety performance by addressing both the demands and resources available to personnel, thereby fostering a supportive and secure working environment.

Based on a scoping analysis, ten studies have been published in journals indexed by Scopus and WoS since 2013. These studies examine safety performance within military contexts and present significant findings and themes. Wei and Kuo (2023) discovered that robust safety leadership enhances risk perception and safety performance among military volunteers. Ibrahimkh and Hadidi (2023)

demonstrated superior safety performance on USACE-managed construction sites in Afghanistan. Rowen et al. (2022) identified the impact of job demands and resources on safety culture and performance in the U.S. Navy, while Armenis (2020) emphasized the advantages of adapted LOSA and high-performance workshops. Pejovic et al. (2020) observed that the implementation of Free Route Airspace (FRA) in MUAC airspace increased traffic complexity and risks. Mei et al. (2019) stressed the importance of a strong safety culture within the armed forces. Other findings include the influence of air traffic demand on conflict risk (Pejovic et al., 2019), the necessity for comprehensive safety evaluations (Sun et al., 2017), the barriers to effective safety reporting (Jausan et al., 2017), and the role of transactional leadership in enhancing safety among paratroopers (Martínez-Córcoles & Stephanou, 2017). These studies highlight the interaction between leadership, culture, and operational factors in improving safety performance, advocating for continuous improvement in safety management within military settings.

The present studies primarily focus on a range of significant factors, including safety leadership, safety culture, job demands and resources, operational changes, safety reporting systems, training and safety compliance, risk assessment and management, comparative safety levels, and transactional leadership. These factors are of utmost importance in understanding the profound influence that various elements have on safety performance within military contexts. The central objective of these research findings is to identify effective strategies and practices capable of enhancing safety performance, reducing risks, and cultivating a positive safety culture within military establishments. By actively addressing these critical factors, military organizations can improve their safety management systems, leading to safer operational environments and better outcomes for personnel.

CONCLUSION

This study presents a comprehensive analysis of safety performance in military environments. By combining scientometric and scoping review methodologies, the study explores the complex nature of military safety performance, emphasizing the crucial role of safety leadership, culture, and technological advancements. The key findings highlight the importance of integrating safety performance indicators and utilizing technologies such as smart wearables to monitor the health of soldiers and enhance operational effectiveness.

The analysis reveals that safety performance in military settings is influenced by various factors, including job burnout, time pressure, operational stressors such as sleep deprivation, and psychological conditions like PTSD. Targeted interventions to address these factors can significantly improve safety behaviors and overall performance.

The scientometric analysis demonstrates a growing academic interest in military safety performance, with a noticeable increase in publications over the past two decades. The scoping review identifies gaps in current research and suggests that future studies should focus on areas such as the impact of technological changes on safety paradigms and the development of adaptive leadership strategies to manage evolving threats.

In summary, the study emphasizes the need for a comprehensive and adaptable approach to military safety performance, incorporating continuous training, technological advancements, and a strong safety culture. By addressing the identified challenges and promoting interdisciplinary collaboration, military organizations can enhance their safety management systems, resulting in safer operational environments and improved outcomes for personnel.

Limitation of the Current Study

One of the primary limitations of this study is the lack of a comprehensive publication list. The analysis of bibliometrics and scoping in this study relies solely on the Scopus and WoS databases. Nonetheless, future researchers had the opportunity to augment the present findings by incorporating additional databases such as Google Scholar, PubMed, and ERIC.

Contribution to the Body of Knowledge and Practices

This study makes a significant academic contribution to understanding and implementing military safety performance. It places particular emphasis on the essential roles played by safety leadership, culture, and technological advancements. The study emphasizes the importance of incorporating ongoing training, advanced technologies such as smart wearables, and adaptive leadership to effectively address psychological and operational stressors, including PTSD and job burnout. Through a thorough scientometric and scoping review, the study identifies emerging areas of research, consolidates existing literature, and highlights the importance of taking a holistic approach to safety. Policymakers and military leaders can derive great value from these insights to enhance safety protocols and operational effectiveness.

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