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An Integrated Risk Analysis Approach in Military Hospitals: Implications for Public Health Preparedness and Resilience

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ABSTRACT

Introduction: Military hospitals perform a dual function by providing healthcare services for soldiers and their families while also supporting public health needs during crises. This dual role generates complex hazards spanning biological, chemical, physical, and psychological dimensions, thereby requiring a comprehensive risk analysis framework. The objective of this study is to develop an integrated risk analysis approach comprising risk assessment, risk management, and risk communicationto strengthen occupational safety in military hospitals, with broader relevance for public health and global health security.

Methods: A mixed methods design was applied. Data were collected through direct observation and in-depth interviews with healthcare personnel, complemented by a structured survey using standardized questionnaires. Qualitative analysis was conducted using NVivo 12 and quantitative analysis using SEM PLS-4. The study involved 100 respondents comprising medical personnel, health workers, and staff at Rumah Sakit Pusat Pertahanan Negara (RSPPN) and Pusat Kesehatan TNI, selected through random sampling.

Results: Qualitative findings derived from NVivo 12 analysis revealed a multidimensional hazard spectrum characterized by weak cross sectoral coordination, limited personnel capacity, and insufficient integration among risk analysis components. Quantitative analysis using SEM PLS-4 further confirmed that Integrated Risk Analysis has a positive and statistically significant effect on Public Health Preparedness and Community Resilience (T-statistic = 11.046 > 1.96; p-value < 0.05); and F-square (0.18-efect moderat).

Conclusion: This study concludes that Integrated Risk Analysis exerts a significant influence on public health preparedness and community resilience in military hospitals. The findings underscore the necessity of strengthening management, integration, and cross sectoral communication. Nonetheless, the contextual limitations regarding research setting and sample size suggest the need for future studies with broader scope and institutional diversity to reinforce the generalizability of the findings.

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INTRODUCTION

Military hospitals possess a work environment that is considerably more complex than that of civilian hospitals due to their dual functions, namely providing healthcare services for military personnel and their families while simultaneously serving civilian populations under certain circumstances (1). This complexity includes biological hazards from infectious diseases, chemical risks from hazardous substances used in laboratories and pharmacies, physical risks such as radiation and medical equipment noise, and psychosocial risks arising from high work pressure during emergencies or conflict situations (2). These characteristics place military healthcare workers in a particularly vulnerable position, exposed to multiple, interacting occupational hazards. Without an integrated system of risk assessment, management, and communication, the potential for occupational accidents, health disorders, and a decline in hospital operational capacity becomes substantially heightened (3).

The Covid-19 pandemic clearly demonstrated that the capacity of military hospitals is not only relevant to defense interests but also contributes directly to public health and global health security (4). In Indonesia, military hospitals played a critical role in patient care, providing isolation facilities, supporting medical logistics distribution, and assisting in nationwide vaccination campaigns (5). This involvement illustrates that the military health system is an integral component of the national response to health crises (6). More broadly, in the global context, the ability of military hospitals to adapt and collaborate with civilian institutions has become an essential indicator of their contribution to international health security agendas, particularly within the framework of the International Health Regulations and the One Health approach (7). Strengthening occupational safety in military hospitals, therefore, is not only vital for the operational readiness of the armed forces but also for the resilience of broader society and the stability of global health (8).

Although numerous studies on occupational safety have been conducted in the health sector, there remain significant limitations in the integration of risk assessment, risk management, and risk communication within defense health systems (9). Military hospitals, with their complex environments involving biological, chemical, physical, and psychosocial hazards, require a more comprehensive and structured risk analysis framework. However, in practice, these three key components of risk analysis are often applied in isolation, without consistent and sustained synergy (10). This fragmented approach creates gaps in hazard control, reducing the effectiveness of mitigation measures. Consequently, the risks to healthcare workers, patients, and the sustainability of military hospital operations remain substantial, with implications for the broader readiness of national defense health systems.

Theoretical Framework; First, risk assessment involves a systematic process of identifying, evaluating, and prioritizing hazards including biological, chemical, physical, and psychosocial exposures faced by healthcare workers in both military and civilian hospitals. Second, risk management centers on the formulation of control strategies, allocation of resources, and implementation of mitigation policies in accordance with defense health standards, particularly in preparation for emergencies such as pandemics, biological threats, or conflict related disasters (ILO, 2018) (11). Third, risk communication serves as a critical mechanism to ensure that information on potential hazards, safety protocols, and mitigation measures is clearly conveyed to all stakeholders, including healthcare personnel, military personnel, and civilians involved (OSHA, 2016). Integrated Risk Management Theory, as articulated by the International Organization for Standardization (ISO 31000), asserts that risk management must be conducted in a holistic, integrated, systematic, and evidence based manner, encompassing the continuous processes of risk identification, analysis, evaluation, treatment, communication, and monitoring (12)(13). ISO 31000 emphasizes that risks cannot be managed in isolation by individual organizational units; rather, they must be embedded across all decision making processes, institutional governance mechanisms, resource allocation structures, and organizational culture to ensure coherence and effectiveness in managing complex and evolving threats (14). Resilience Theory, introduced by C.S. Holling (1973), posits that any system ecological, social, or institutional possesses an inherent capacity to absorb disturbances, adapt to changing conditions, and maintain its core functions even under stress or crisis. Resilience extends beyond merely returning to a previous state; it denotes the system's ability to transform, reorganize, and strengthen its capacities in anticipation of, during, and after disruptions (15). In this view, resilience embodies both adaptive persistence and transformative growth, enabling institutions to confront future threats with greater robustness and strategic preparedness (16).

Integrating these three dimensions is essential not only for safeguarding occupational health within military environments but also for reinforcing public health systems and advancing the broader agenda of global health

security. Military hospitals fulfill a dual role that distinguishes them from civilian hospitals. On the one hand, they serve as primary healthcare facilities for soldiers, military families, and defense operations by providing medical services in both wartime and peacetime operations (17). On the other hand, they extend healthcare services to civilians, particularly during disasters, pandemics, or when public health facilities are overwhelmed. For instance, during the COVID-19 pandemic Indonesian military hospitals provided civilian patient care, established isolation facilities, and supported national vaccination program (18).

The study by Sofyana et al. (2024) emphasizes that community nursing based preparedness training is effective in enhancing the capacity of families and communities to cope with non-natural disasters. Meanwhile, Sari et al. (2023) highlight the importance of developing hospital resilience indicators that position health personnel at the core of governance for response, service continuity, and cross unit coordination during pandemic situations (15). Hung et al. (2021) argue that disaster education should be incorporated into nursing curricula in order to strengthen both clinical and community competencies in responding to pandemics and public health emergencies. Furthermore, Shiomitsu et al. (2022) demonstrate the relevance of experience based practices in post disaster shelters under conditions of limited resources, particularly in the context of displacement in Indonesia (14). Pires et al. (2025) emphasize the critical role of nurses in disaster mitigation and adaptation to climate change, with a particular focus on preventing community vulnerabilities (19). In line with this, Wootton (2023) underscores the evolution of the nursing role from being solely clinical care providers to functioning as systemic coordinators in addressing global emergencies. Koriyah (2023) also explains that health personnel play a vital role in flood management through education, infectious disease surveillance, and the administration of evacuation shelters, although weaknesses in logistics and field coordination remain evident (20).

Existing academic literature has largely concentrated on the integration of risk assessment, management, and communication in civilian contexts, such as general hospitals, manufacturing industries, and service sectors. In contrast, research on integrative approaches within military hospitals remains limited, particularly in relation to their contribution to global health security (21). Yet, military hospitals are not only defense supporting facilities but also critical actors in public health crisis response, including pandemics and cross border biological threats. This research gap highlights the urgent need for the development of an integrated risk analysis model tailored to military hospitals one that enhances occupational safety at the institutional level while simultaneously strengthening national health system capacity and advancing contributions to global health security through civil-military collaboration and cross sectoral approaches (22).

The primary objective of this study is to develop an integrated approach to risk analysis encompassing assessment, management, and communication, aimed at improving occupational safety in military hospitals. This approach is intended not only to enhance the protection of healthcare personnel and the operational effectiveness of military hospitals but also to provide broader relevance to public health and global health security. By adopting a comprehensive and adaptive framework, this study seeks to contribute theoretically to the literature on occupational safety in the defense health sector while also offering practical recommendations to support civil-military collaboration in addressing transnational health crises (23).

METHODS

Design

This study uses the mixed methods exploratory sequential approach, which is a research design that begins with a qualitative method to explore phenomena, identify the main issues, and formulate relevant indicators or variables. The results of the qualitative stage are then used as a basis for compiling quantitative research instruments that can test the initial findings more broadly and measurable. Thus, this design allows researchers to obtain a deep picture as well as a stronger empirical generalization, so that the results of the study not only explain the actual conditions, but also provide a basis for the formulation of a more comprehensive health policy model and strategy in dealing with anthropogenic disasters (24).

Data Source

Scientific articles from SINTA Indexed National Journal and International Journal Indexed Scopus is useful as a trusted reference source to strengthen theoretical foundations, compare findings, and provide empirical data

related to relevant research issues. Case Study regarding Indonesia's response to Pandemi Covid-19 as a real representation of anthropogenic disaster with systemic impacts. The results of research by survey method at the Pusat Pertahanan Negara (RSPPN) Hospital dr. Suyoto-Pusrehab-Ministry of Defense of the Republic of Indonesia at Jl. RC. Veteran Raya No.178, RT.9/RW.3, Bintaro, Kecamatan Pesanggrahan, South Jakarta-Indonesia and the results of in-depth interviews with 6 echelon II and echelon III officials at the Indonesian Military Health Center (Puskes TNI) at Jl. Cilangkap Jakarta Timur-Indonesia regarding the current condition of the Role of Health Defense Workers, the Gaps Health Defense System, and Health Workers Data (25).

Data Analysis Techniques.

Qualitative data were analyzed using thematic content analysis with the help of NVivo 12 software. The analysis included importing interview data into NVivo 12 conducting coding, categorization, data analysis using word clouds, data visualization, and interpreting the results into the research manuscript by identifying the main themes that describe gaps, challenges, and recommendations within the public health preparedness system.

Quantitative data were analyzed using SEM Partial Least Squares version 4, following the steps outlined below; Evaluation of the Outer Model (26). Validity testing uses the outer loading of indicators, which reflects how well the indicators measure the variable or the extent to which the indicators are valid in measuring the variable. The minimum acceptable outer loading value is 0.60. Reliability testing uses Cronbach's alpha and Composite Reliability, which describe the degree of internal consistency of a variable measured by multiple indicators. The minimum values for Cronbach's alpha and Composite Reliability are 0.70 (27). Convergent validity explains the extent to which the variance of the measurement items is captured by the construct, using the Average Variance Extracted, with a minimum of 0.50. Discriminant validity assesses whether a latent variable is theoretically distinct from other constructs and is empirically supported through statistical testing. Discriminant validity is measured using the Fornell-Larcker criterion (square root of AVE > inter construct correlations).

Evaluation of the Inner. Model relates to hypothesis testing, including: multicollinearity testing, where an inner VIF < 5 indicates no multicollinearity; and hypothesis testing, where a T -statistic > 1.96 and p-value < 0.05 means the hypothesis is accepted or there is a significant effect between the hypothesized variables. Evaluation of model goodness of fit. Then, the cross validated predictive ability test (CVPAT) in the correlation form validates the model's predictive strength by testing across the PLS algorithm, LM, and Average Indicator. If the average loss of PLS is lower than those of the other two algorithms, then the PLS model has high predictive power (28).

The population comprises healthcare personnel at the Pusat Pertahanan Negara (RSPPN) Hospital dr. Suyoto-Pusrehab-Ministry of Defense of the Republic of Indonesia at Jakarta Selatan and Indonesian Military Center (Puskes-TNI) at Jl. Cilangkap Jakarta Timur. The sample consists of 100 healthcare personnel from Indonesian Military and civil servants as respondents. The research instrument is a survey using a Likert scale (1-5) questionnaire distributed via Google Forms. This study was conducted in September 2025 in Jakarta, Indonesia.

Etikal Approval

This study was conducted under the Directive of the Rector of the Indonesian Defense University, Decree No. B/4732/IX/2025, dated 17 September 2025. All healthcare personnel and institutional representatives who participated were fully informed of the study objectives, procedures, and their rights, and provided consent prior to participation. The confidentiality and anonymity of all respondents were strictly safeguarded, and the research was carried out in full accordance with ethical principles of research and the prevailing regulations of the Indonesian Defense University.

RESULTS

Qualitative data analysis using NVivo 12

Figure 1. Word Cloud NVivo 12

Risk Assessment Results

The results of the risk assessment in military hospitals indicate that the spectrum of hazards encountered by healthcare personnel can be categorized into four principal dimensions: biological, chemical, physical, and psychological. Biological hazards include exposure to dangerous pathogens such as SARS-CoV-2, antibiotic resistant bacteria, and potential bioterrorism threats, all of which necessitate strict adherence to biosafety standards. Chemical hazards encompass the use of toxic substances in laboratories, cytotoxic drugs in pharmaceutical units, and large scale disinfectants that may cause acute or chronic poisoning. Physical hazards derive from diagnostic radiation, noise generated by medical equipment, non-ergonomic lighting, and fire risks associated with inadequate protection systems. Equally significant are psychological hazards, which include high occupational stress, dual responsibilities during emergencies, and the potential for burnout resulting from prolonged exposure to high risk environments. Such identification and categorization reveal that without comprehensive risk mapping, military hospitals will face difficulties in designing adaptive and layered mitigation strategies, thereby creating vulnerabilities not only for healthcare workers and military personnel but also for the strategic sustainability of military hospitals in supporting public health and national resilience(29).

Risk Management Practices

Risk management practices in military hospitals are principally implemented through strict adherence to Standard Operating Procedures (SOPs), systematic risk mitigation mechanisms, continuous training programs, the use of personal protective equipment (PPE), and the strengthening of fire protection systems. SOPs are designed to ensure consistency in hazard management, covering clinical procedures, medical waste management, and emergency response, thereby providing clear guidance for healthcare personnel in high-risk situations. Mitigation efforts are realized through technical measures such as specialized ventilation systems, isolation of hazardous areas, and work rotation to minimize cumulative exposure. Continuous training plays a vital role in updating professional competencies, enhancing preparedness, and reinforcing a culture of safety within the workplace. The disciplined use of PPE in accordance with international standards ranging from N-95 masks and gloves to radiation shields constitutes an indispensable layer of personal protection. At the same time, fire protection systems, including smoke detectors, automatic extinguishers, and standardized evacuation routes, serve as safeguards against secondary physical hazards.

This integrated approach to risk management not only reduces the likelihood of workplace incidents but also strengthens the resilience of military hospitals as strategic institutions supporting the health of soldiers, civilian populations, and national defense readiness (30).

Risk Communication

Risk communication within military hospitals plays a strategic role in ensuring that information on potential hazards, safety protocols, and mitigation measures is clearly conveyed and consistently applied by all stakeholders. For medical staff, risk information is disseminated through formal mechanisms such as daily briefings, safety information boards, and written guidelines integrated into SOPs, thereby providing standardized references for addressing biological, chemical, and physical exposures. For civilian patients, risk communication is conducted through simple yet effective educational approaches, including leaflets, posters, and direct guidance from healthcare personnel, enabling patients to understand safety procedures without generating undue alarm. For external stakeholders such as local governments, civilian health agencies, and international organizations military hospitals deliver risk information through official reports, inter sectoral coordination, and joint communication forums that emphasize transparency and accountability. This multilayered communication model is essential for building trust, enhancing compliance, and reinforcing civil-military collaboration, thereby enabling military hospitals not only to safeguard their internal environment but also to contribute to public health stability and the broader agenda of global health security (31).

Integration Model

The integration model linking risk assessment, risk management, and risk communication within military hospitals requires planned, multilayered, and continuous synergy. Risk assessment constitutes the starting point through the systematic identification and categorization of hazards, thereby allowing potential threats to be clearly mapped and objectively prioritized. The outcomes of the assessment subsequently provide the foundation for risk management, which focuses on the formulation of SOPs, the implementation of technical and administrative mitigation measures, and the allocation of resources to minimize the likelihood of incidents. The effectiveness of such management measures, however, is contingent upon transparent and inclusive risk communication, ensuring that all information regarding risks and preventive actions is comprehensively understood by medical personnel, civilian patients, and external stakeholders alike. These three components cannot function in isolation; rather, strong integration produces a continuous cycle in which assessment informs management strategies, management is effectively communicated, and communication, in turn, generates feedback for further assessment. Such synergy enhances the institutional capacity of military hospitals not only to safeguard occupational safety internally but also to support the resilience of the national health system and the global health security agenda (32).

Weaknesses in Cross Sector Coordination

A fundamental obstacle to strengthening occupational safety in military hospitals lies in the weakness of cross sector coordination between the defense, health, and public sectors. At the policy level, the defense sector tends to prioritize threat based approaches, while the health sector emphasizes public service delivery, resulting in diverging priorities that impede the formulation of integrated protocols. In practice, communication mechanisms and command chains often operate in silos, leading to delays in the distribution of risk information, allocation of medical resources, and timely emergency responses. This shortcoming was evident during the early stages of the Covid19 pandemic, when epidemiological data, health logistics, and facility capacities between military and civilian hospitals were not fully synchronized. Such deficiencies in coordination not only heighten the vulnerability of military healthcare personnel but also diminish the effectiveness of the national health system in protecting civilian populations. Consequently, there is a pressing need for a more adaptive and structured framework of inter sectoral collaboration, enabling military hospitals to function optimally as strategic nodes in reinforcing national health resilience and advancing the global health security agenda (33).

Results of Quantitative Data Analysis

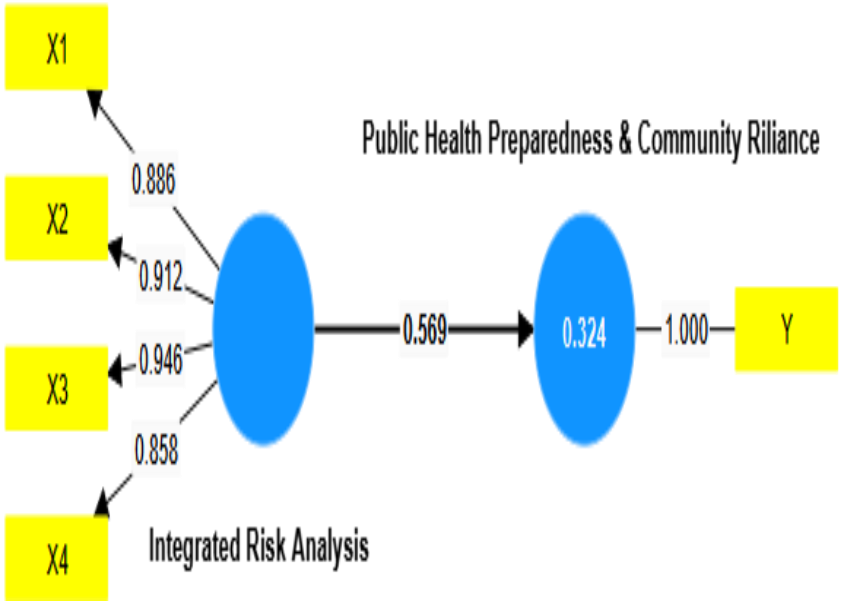

Figure 2. Outer Loading

The outer loading results demonstrate that the four indicators of Integrated Risk Analysis (X) namely X1 (biological, chemical, and physical hazards), X2 (psychological hazards), X3 (risk management practices), and X4 (risk communication) load very strongly on the construct, with values of 0.886, 0.912, 0.946, and 0.858 respectively. All values exceed the 0.70 threshold, thereby meeting the general criteria for convergent validity.

The implication is that the Average Variance Extracted (AVE) can be estimated at greater than 0.50 and the composite reliability at above 0.70. Among the indicators, X3 (≈0.946) provides the strongest contribution, followed by X2 (≈0.912), X1 (≈0.886), and X4 (≈0.858). Although X4 records the lowest value, it still falls within the high category and remains appropriate for retention. Accordingly, the measurement instrument is deemed valid and reliable, and the reflective measurement model is considered adequate (34).

Table 1. Construct Validity and Reability

Variable	Cronbach's alpha	Composite reliability (rhoa)	Average variance extracted (AVE)
Integrated Risk Analysis	0.924	0.964	0.812

Table 1 demonstrates that the variable Integrated Risk Analysis in the study Integrated Approach Risk Analysis in Military Hospitals for Public Health possesses excellent validity and reliability. The Cronbach's alpha of 0.924 indicates a high level of internal consistency among the indicators, while the Composite Reliability (rho-a) of 0.964 reflects very strong construct reliability. Furthermore, the Average Variance Extracted (AVE) of 0.812 exceeds the minimum threshold of 0.50, confirming that the indicators explain more than 81% of the variance of the measured construct. Therefore, these results affirm that the research instrument is both valid and reliable for analyzing an integrated approach to risk analysis in military hospitals (35).

Table 2. Fornell Lacker

Variable	Integrated Risk Analysis	Public Health Preparedness & Community Riliance
Integrated Risk Analysis	0.901	
Public Health Preparedness & Community Riliance	0.569	1.000

Table 2 presents the Fornell-Larcker criterion results, which confirm the discriminant validity between the constructs of Integrated Risk Analysis and Public Health Preparedness & Community Resilience. The square root of the AVE for Integrated Risk Analysis is 0.901, which is higher than its correlation with Public Health Preparedness and Community Resilience (0.569), indicating that the construct is more strongly related to its own indicators than to other constructs. Similarly, Public Health Preparedness and Community Resilience shows a strong internal validity value of 1.000. These results demonstrate that both constructs are distinct yet moderately correlated, ensuring that each measures a unique dimension within the integrated approach to risk analysis in military hospitals(36).

Evaluation of the Inner Model

Table 3. Hypotesis Test Direct Effect

Hypotesis	T statistics	P values
Integrated Risk Analysis to Public Health Preparedness & Community Riliance	11.046	0.000

The results of the hypothesis test (T-statistic = 11.046; $p < 0.001$) provide strong empirical validation of the postulate that Integrated Risk Analysis, as a higher-order construct formed from the mapping and control of biological, chemical, and physical hazards (X1), psychological hazards (X2), risk management practices (X3), and risk communication (X4), is positively correlated with the enhancement of Public Health Preparedness and Community Resilience. Substantively, these findings affirm the existence of a multidimensional hazard spectrum which, if managed in a fragmented manner, weakens the overall response. Conversely, the integrated model developed in this study demonstrates a coherent causal chain: risk assessment establishes an evidentiary basis for risk management (SOPs, PPE, ventilation, training, fire protection) that reduces exposure and safeguards the continuity of essential services, while inclusive, cross sectoral risk communication bridges inter agency coordination gaps, accelerates detection and isolation, increases surge capacity, strengthens interoperability with health authorities, and builds public trust and compliance.

Accordingly, the very high statistical significance is consistent with the proposed operational mechanisms, indicating that this integrated approach is not a nominal correlation but rather a systemic capability that reinforces occupational health and safety systems in military hospitals, enhances national preparedness for health crises, and broadens Indonesia's contribution to the architecture of global health security. The coefficient linking Integrated Risk Analysis to Public Health Preparedness and Community Resilience is highly significant. The T-statistic value of 11.046 indicates that the ratio of the coefficient to the standard error far exceeds the 1.96 threshold (the critical value for a two-tailed test at the 95% confidence level), thereby rejecting H_0: coefficient=0 and demonstrating that the 95% confidence interval excludes zero (indeed, even at the 99% level, the criterion is met, as the value surpasses 2.58). The p-value, approximately 0.000 (conventionally reported as $p < 0.001$ since p is never exactly zero), indicates that the probability of obtaining such an extreme statistic in the absence of a true effect is exceedingly small (< 0.1%). The conclusion, therefore, is that there is robust evidence that Integrated Risk Analysis significantly influences Public Health Preparedness and Community Resilience.

The hypothesis test T=11.046 and $p < 0.001$ thus confirms that Integrated Risk Analysis exerts a strong and statistically significant effect on Public Health Preparedness and Community Resilience, while aligning with substantive patterns of evidence indicating the presence of a multidimensional hazard spectrum (sources, situations, or actions with the potential to cause injury, illness, or damage), weaknesses in cross sectoral coordination, and the suboptimal integration of risk analysis elements in military hospitals. Mechanistically, the Integrated Risk Analysis construct, as formed by X1-X4, captures a reinforcing causal sequence: first, comprehensive risk assessment maps

biological, chemical, physical, and psychological hazards as systemic sources of risk; second, organizational bottlenecks explain why assessment outputs are not fully converted into effective risk management practices; third, inclusive risk communication functions as a lever that translates risk management into cross sectoral behaviors and collaboration, thereby accelerating detection and isolation, enhancing surge capacity, maintaining service continuity, and building public trust and compliance. Hence, the statistical significance extends beyond correlation, coherently reflecting the operational architecture of the integration model assessment, management, and communication (22).

When integration is strong, coordination frictions decrease, and performance on Public Health Preparedness and Community Resilience indicators improves. Conversely, when integration is weak, the hazard spectrum remains high and public preparedness declines. This signifies that when the three components of risk assessment, risk management, and risk communication are tightly interconnected and function synergistically, "friction" in inter agency coordination diminishes: information flows rapidly, decisions are made promptly, resources are effectively targeted, and safety messages are clearly understood by all stakeholders. As a result, public preparedness indicators improve cases are detected and isolated more quickly, surge capacity is readily deployable, essential services remain uninterrupted, and public trust and compliance increase. Conversely, if such interconnection is weak and each component operates in isolation, delays in information occur, SOPs become misaligned, and responsibilities are confused. The consequences are suboptimal hazard control, delayed responses, disrupted services, and ultimately diminished public preparedness (23).

Risk assessment thus functions as the foundation for management actions such as the establishment of SOPs, allocation of resources, and training programs, all of which are reinforced by communication mechanisms that ensure information is clear, timely, and accessible to all stakeholders. This causal chain leads to more effective hazard mapping and control, a reduction in workplace accidents, faster responses, sustained delivery of essential services, and heightened trust and compliance. The impact extends beyond strengthening occupational health and safety systems in military hospitals; it elevates national preparedness to confront health crises and, on a broader scale, contributes to global health security through harmonized cross sectoral and international coordination.

Table 4. R-square

Variable	R-square	R-square adjusted
Integrated Risk Analysis -> Public Health Preparedness & Community Riliance	0.51	0.48

An R-square value of 0.51 and an adjusted R-square of 0.48 indicate that Integrated Risk Analysis explains approximately half (51%) of the variance in Public Health Preparedness and Community Resilience, reflecting a moderate predictive strength of the model (37).

Table 5. (Q^2)

Variable	Q-square
Integrated Risk Analysis to Public Health Preparedness & Community Riliance	0.32

Q-square value of 0.32 indicates moderate predictive relevance, demonstrating that the model has a good level of accuracy in predicting Public Health Preparedness & Community Resilience(38).

Table 6. F-square

Variable	Integrated Risk Analysis	Public Health Preparedness & Community Riliance
Integrated Risk Analysis to Public Health Preparedness & Community Riliance		0.18

The F-square value of 0.18 indicates that Integrated Risk Analysis has a medium effect on Public Health Preparedness & Community Resilience. According to Cohen's criteria (0.02 = small, 0.15 = medium, 0.35 = large), this value falls within the medium category, meaning that the independent variable contributes meaningfully to the

model's predictive power. Thus, Integrated Risk Analysis exerts a significant influence in strengthening public health preparedness and community resilience, affirming that the integration of risk assessment, risk management, and risk communication plays an essential role in enhancing health resilience within military hospital contexts(39).

Evaluation of Model Fit

Table 7. VIF

Indicator	VIF
X1	1.707
X2	1.979
X3	2.323
X4	1.693
Y	1.498

All VIF values range from 1.498 to 2.323, indicating the absence of multicollinearity because all values are far below the critical threshold of 5. This confirms that each indicator provides a unique contribution, does not interfere statistically with other indicators, and that the structural model is stable and reliable for further analysis(40).

Table 8. Cross validated predictive ability test (CVPAT)

Variable	Pls loss	IA (Average Indicator) loss	Average loss difference
Public Health Preparedness & Community Riliance	0.178	0.260	5.104

Evaluation of Model Fit based on Table 8: Cross validated Predictive Ability Test (CVPAT) shows that the predictive power of the model for the construct Public Health Preparedness & Community Resilience is acceptable. The PLS loss value of 0.178 is lower than the IA (Average Indicator) loss value of 0.260**,** with an average loss difference of 5.104**,** indicating that the PLS path model provides better predictive accuracy compared to a naïve indicator benchmark. This result validates that the proposed integrated model of risk analysis not only demonstrates statistical significance but also possesses substantive predictive ability, thereby strengthening its relevance for assessing and enhancing preparedness and resilience in military hospital contexts(41).

Integration of Mixed Methods Findings

The integration of findings through a mixed methods approach provides robust and comprehensive validation of the strategic role of Integrated Risk Analysis in enhancing Public Health Preparedness and Community Resilience within military hospitals. The qualitative analysis conducted with NVivo 12 highlights the existence of a multidimensional hazard spectrum biological, chemical, physical, and psychological exacerbated by weak cross sectoral coordination, limited personnel capacity, and insufficient integration across risk analysis components. In parallel, the quantitative results derived from SEM PLS-4 demonstrate a statistically significant positive association between Integrated Risk Analysis and public health preparedness (T-statistic = 11.046 > 1.96; $p < 0.05$; and f-square 0.18), thereby underscoring that the reinforcement of management, integration, and cross-sectoral risk communication constitutes a critical determinant of resilience in both military and civilian health systems. The convergence of qualitative and quantitative evidence not only strengthens the internal validity of the study but also affirms its relevance to the broader agenda of global health security. Nevertheless, the contextual limitations particularly the restricted research setting and the relatively small number of respondentsconstrain the generalizability of these findings, thereby calling for further research with wider scope, cross-regional coverage, and institutional variation to test the replicability of this integrative model in diverse defense health contexts.

The integration of qualitative and quantitative findings in this study reveals a direct analytical convergence between the thematic patterns identified through NVivo 12 and the structural constructs tested in the SEM-PLS model. Qualitative themes such as weak cross sectoral coordination, limited personnel capacity, fragmented implementation of risk assessment, risk management, and risk communication, as well as the presence of multidimensional hazards provide substantive explanatory grounding for the statistically significant association demonstrated in the quantitative

analysis (T = 11.046; p < 0.05) between Integrated Risk Analysis and Public Health Preparedness and Community Resilience. For instance, the qualitative finding on inadequate risk communication aligns with the model R-square value (0.51), which empirically shows that integrated risk functions account for a substantial proportion of preparedness variance. Conversely, the quantitative confirmation of the model's predictive strength reinforces the interpretive insight that systemic fragmentation in risk governance materially undermines preparedness in military hospital settings. This narrative synthesis thus establishes epistemic coherence by demonstrating that the structural weaknesses captured qualitatively are mirrored in the quantitative model, thereby illustrating the methodological complementarity through which Integrated Risk Analysis emerges as a critical determinant of institutional resilience (42).

DISCUSSION

Interpretation of Key Findings

The integration of findings through a mixed methods approach provides compelling validation of the strategic role of Integrated Risk Analysis in strengthening Public Health Preparedness and Community Resilience within military hospitals. The qualitative analysis identified a multidimensional hazard spectrum biological, chemical, physical, and psychological exacerbated by weak cross-sectoral coordination, limited personnel capacity, and insufficient integration across risk analysis elements. In parallel, quantitative results confirmed a statistically significant positive association between Integrated Risk Analysis and preparedness indicators (T = 11.046; p < 0.05; and f-square = 0.18). Taken together, these findings underscore that the reinforcement of management, integration, and cross ectoral risk communication constitutes a critical determinant of resilience in both military and civilian health systems. Given their dual function, military hospitals must not only provide medical services for soldiers and their families but also sustain public health needs in times of crisis, thereby requiring a more comprehensive and integrated framework for risk governance (7).

Comparison with Previous Studies

In comparison with previous studies, these results converge with the work of Sofyana et al. (2024), who demonstrated that preparedness training enhances family and community resilience, and with Sari et al. (2023), who developed hospital resilience indicators emphasizing the centrality of health personnel in governance, service continuity, and coordination. The findings are also aligned with Hung et al. (2021), who argued for incorporating disaster education into nursing curricula to expand clinical and community competencies, as well as Shiomitsu et al. (2022), who underscored the relevance of experience-based practices in resource constrained post disaster shelters. Similarly, Pires et al. (2025) and Wootton (2023) highlight the expanding role of nurses in mitigation, adaptation, and systemic coordination during global emergencies. Koriyah (2023) further illustrates the critical contribution of health personnel in flood response through education, infectious disease surveillance, and shelter management, while simultaneously identifying persistent weaknesses in logistics and coordination issues that closely mirror the present study findings. The implications of these results highlight that risk assessment, risk management, and risk communication cannot operate in isolation. Their integration forms a coherent chain that reduces hazard exposure, safeguards service continuity, and enhances public trust. This strategic positioning of military hospitals makes them pivotal nodes in civil-military collaboration, particularly in responding to health crises. Such conclusions are consistent with the principles outlined by the ILO (2018) and OSHA (2016), both of which emphasize that integrated occupational safety is not only a fundamental right of healthcare workers but also a cornerstone of effective health protection systems (16).

Transferability, Scalability, and Comparative Applicability

From a transferability perspective, the findings of this study demonstrate that the core components of the Integrated Risk Analysis framework namely risk assessment, risk management, and risk communication can be readily adapted for use in civilian hospitals that face similarly multidimensional hazards and cross sectoral coordination challenges. This applicability arises because both military and civilian hospitals operate within risk ecosystems that demand early detection, rapid response, and structured risk communication. Moreover, civilian hospitals are increasingly confronted with complex biological, chemical, physical, and psychosocial threats, making

the adoption of this model highly relevant for strengthening public health preparedness and community resilience. Thus, the transferability of this framework underscores its broad applicability and strategic value for enhancing health risk governance across diverse clinical settings (43,44).

In terms of scalability, the Integrated Risk Analysis framework exhibits strong operational flexibility, allowing it to expand from small functional units within military hospitals to institutional, regional, and even national health security systems. This scalability is enabled by the model's modular architecture comprising risk assessment, risk management, and risk communication which can be tailored to the operational needs of different organizational levels. Nevertheless, effective scale up requires parallel investments in human-resource capacity, supporting infrastructure, and cross sectoral integration, including collaboration among military actors, civilian institutions, local governments, and national health agencies (45).

Comparatively, civilian hospitals often operate under more decentralized governance structures, exhibit variable levels of operational discipline, and face fluctuating resource capacities, which can create gaps in risk coordination and emergency preparedness. In contrast, military hospitals offer a robust benchmark due to their clear command hierarchy, standardized crisis response procedures, and stronger culture of adherence to safety protocols. Accordingly, the Integrated Risk Analysis model not only provides an innovation for defense health systems but also establishes a transferable paradigm for strengthening resilience across the broader health care sector. This model demonstrates how disciplined risk governance and structured emergency response hallmarks of military health systems can be adapted to enhance the resilience of civilian hospitals in confronting multidimensional threats(46).

CONCLUSION

This study establishes that Integrated Risk Analysis encompassing risk assessment, risk management, and risk communication exerts a significant and positive influence on Public Health Preparedness and Community Resilience in military hospitals. The findings reveal that healthcare personnel within these institutions confront a multidimensional spectrum of hazards, including biological, chemical, physical, and psychological risks, compounded by weak cross-sectoral coordination, limited personnel capacity, and insufficient integration of risk management components. Quantitative evidence substantiates this relationship ($T = 11.046$; $p < 0.05$; and **F-square 0.18**), thereby validating the integrative model as an effective framework for reinforcing occupational safety and institutional resilience.

The implications of these results are twofold. At the institutional level, military hospitals must prioritize integrated risk governance by linking risk assessment outcomes to effective management practices and consolidating them through inclusive and transparent communication. At the national level, strengthening this integrative framework contributes not only to occupational safety but also to pandemic preparedness and civil-military collaboration, thereby positioning Indonesia as a more active participant in advancing the global health security agenda.

Accordingly, it is recommended that policymakers and defense health authorities develop regulations and policies that institutionalize Integrated Risk Analysis across military hospitals, with particular emphasis on cross sectoral coordination, capacity building for personnel, and the establishment of robust systemic communication mechanisms.

The novelty of this study lies in the contextual application of the Integrated Risk Analysis model specifically within Indonesian military hospitals an area previously unexplored thereby offering a strategic contribution and serving as a role model for strengthening health resilience in both defense and civilian hospital systems.

Nonetheless, this study has limitations. The restricted institutional setting and relatively small number of respondents constrain the generalizability of the results.

Future research should broaden its scope to encompass multiple military hospitals across diverse regions, incorporating varied institutional contexts and larger samples. Such efforts are essential for testing the replicability and external validity of the proposed integrative model. Overall, this study substantiates the argument that Integrated Risk Analysis is not merely a theoretical construct but rather a systemic capability essential for reinforcing occupational safety in military hospitals, elevating national preparedness for health crises, and advancing Indonesia's contribution to the global health security agenda.

AUTHOR'S CONTRIBUTION STATEMENT

Faonaso Harefa designed the research, Yahdiana Harahap and Dian Andriani Ratna Dewi analyzed the data, and R.M Tjahya Nurrobi, Sutanto, and Cecilia F. Harsono drafted the manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest that could influence the impartiality of this research. They affirm that there are no financial, institutional, or personal relationships with any organizations or entities that might have affected the interpretation or presentation of the findings. This declaration ensures the integrity, transparency, and objectivity of the study, reinforcing the credibility and trustworthiness of the published work.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors acknowledge that generative Artificial Intelligence (AI) tools, including ChatGPT and Grammarly, were utilized to assist in refining the language, improving readability, and ensuring structural coherence of the manuscript. All intellectual ideas, analytical interpretations, and conclusions presented in this article are entirely the authors' own work. The use of AI tools was limited to linguistic enhancement and did not influence the originality, scientific reasoning, or integrity of the research content.

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