Power System Technology
ISSN:1000-3673

Received: 06-10-2024 Revised: 15-12-2024 Accepted: 01-01-2025

The Role of Health Security in Enhancing the Efficiency of Health Systems to Confront Health Crises and Emergencies

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ABSTRACT

Health crisis continues to challenge the effectiveness of health systems, but there is an acute empirical gap in understanding the direct impact of the health security capacities that were previously developed on operational performance in emergencies. Although much is stated about health security and resilience of the system, very little research provides a quantitative linkage of investments in preparedness and their efficiency outcomes. Therefore, this paper aimed to quantify the association between the health security capacity and the health system efficiency, and to explain the mechanism behind this association. The explanatory sequential design was followed, which is the mixed-method design that included data from 420 health facilities spread across various regions. The quantitative phase utilized facility operational data at the facility level and the national level in terms of health security scores based on Joint External Evaluations (JEE). DEA created efficiency scores, and multivariate models evaluated the association. The qualitative step involved the semi-structured interviews and the focus group discussions that were meant to explain the quantitative results. The findings showed that there is a significant, strong positive relationship between the JEE scores and the normalized efficiency (r 0.858, p = 0.01). Facilities with a larger health security capacity had an even stronger percentage of essential services (r = 0.924) and lower days of stockout (r = -0.836). JEE score was found to be a significant positive predictor of efficiency (Coef. = 0.015, p = 0.001) even after resource availability and the governance factors were accounted for

Power System Technology
ISSN:1000-3673
Received: 06-10-2024 Revised: 15-12-2024 Accepted: 01-01-2025

with the help of a mixed-effects model. The paper finds that effective health security capacities are conclusive determinants of health system efficacies in times of crisis.

Keywords: Health Systems, Efficiency, Health Security, Preparedness, Resilience

INTRODUCTION

The efficiency and resilience of health systems the world over have always been tested by health crises and emergencies such as outbreaks of infectious diseases, natural disasters, and complex humanitarian emergencies. The COVID-19 pandemic, specifically, shed some light on the capabilities of national health infrastructures as well as revealed the severe structural vulnerabilities even in highly endowed countries [1,2]. Such incidents highlighted the relevance of health security as a source of national and international preparedness, response, and recovery [3]. Health security is the joint efforts, capabilities, and government control systems to help eliminate, identify, and react to threats to the overall health of the population, as well as to sustain the necessary health services [2,4]. The health system efficiency, or the ability to provide quality services and achieve the desired goals using the available resources most optimally, has become one of the crucial factors that determine the capacity of a nation to survive and overcome the crisis [5]. Research on the role of health security in the efficiency of operations of health systems, thus, has become a critical area of empirical research.

Internationally, the growing rates and severity of health crises intensify the need for greater reinforcement of health security and health system fortification. In the last ten years, there have been international frameworks of core capacities in surveillance, laboratory systems, risk communication, and emergency response, which have been used to guide nations in their efforts to build the core capacities required in these areas [6]. These are the International Health Regulations, the Global Health Security Agenda (GHSA), and the Joint External Evaluation (JEE). Despite these international efforts, preparedness gaps remain significant [7]. In most of the low- and middle-income nations, there is still a challenge of fragmented coordination systems, low capacity of the workforce to surge, and inadequate public health infrastructure [8]. In high-income countries, there has been interoperability, coordination between the public health and clinical sectors, and maintenance of investments in the inter-crisis periods. There have been repeated outbreaks, including dengue, cholera, and COVID-19, that have challenged the health systems in the area, revealing the weaknesses in mobilizing resources, the continuity of supply chains, as well as information systems [9]. This has been proved by the small capacity to continue services which are important in times of crisis, like maternal health, immunisation, and emergency services, and therefore, the necessity to connect health security functions to operational efficiency has become critical [10].

The resilience of health systems has been studied extensively in the existing literature and can be explained as the ability to prepare, respond, and adapt to shocks without failure in the critical functions. The research has found a number of studies associating resilience with system attributes, including governance, financing, workforce flexibility, and information systems [11]. Nevertheless, a smaller amount of literature has explored health security as a determinant of system efficiency; that is, prevention, detection, and response capability [12].

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A study carried out during the COVID-19 pandemic found that countries whose systems of public health security, including effective surveillance networks and the so-called emergency operations centres, were more responsive in response to crises by reducing disturbances to regular services [13]. On the other hand, countries with less capacity had a longer response time, more deaths, and significant service failures. This study aimed to fill this important empirical gap. The reinforcement of the connection between the aspects of health security and system efficiency directly affects the aspect of public health management and policy planning [14]. Governments can be advised on their priorities in investments to make, however, using empirical evidence on this relationship to improve preparedness, and at the same time improve the performance of the systems on a daily basis [15]. This study provide evidence-based policymaking and contribute to the global agenda of creating efficient and resilient health systems that can respond to any health crisis without undermining basic care, through to measurement of the relationship between the health security capacities of the state and the efficiency of the health system [16]. Although health security has become a popular concept in the global health discourse, it lacks sufficient evidence on the effect of its operation on the efficiency outcomes. The literature does not have unified models that tie preparedness capacities with quantifiable indicators of system functioning in times of crisis [17]. Also, most evaluations of health security are based on national indicators, which do not evaluate the subnational and facility-based approaches, where efficiency could be directly measured and enhanced [18].

Figure 1: Health system response

This paper thus satisfies a clear research gap, such as the empirical examination of the role of health security to increase the efficiency of the health system by using a mixed methods research design of quantitative efficiency analysis and qualitative explanatory investigation.

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Research Questions

1. How does the relationship between health security capacities and quantifiable efficiency indicators exist at the facility level?

2. How do health security investments affect the efficiency of operations in the event of an emergency?

3. What are the policy and organisational drivers and constraints of translating health security capabilities into effective crisis-response?

Objectives

The study used a mixed-methods explanatory sequential research design in answering these questions. The initial step entailed the quantitative measure of the relationships between health security scores (generated based on JEE and SPAR indicators) and facility-level efficiency indicators (generated by means of Data Envelopment Analysis). The second stage involved the use of qualitative interviews and focus groups to explain mechanisms and contextual issues behind the quantitative findings. Such methodological practice guaranteed the analytical rigour, as well as contextual knowledge, which gives a strong basis for policy-relevant recommendations.

METHODOLOGY

This research examined a long-standing gap in the literature on the role of health security capacities in determining the operational efficiency of health systems during crises and emergencies. In particular, it aims at establishing whether strong health security systems are effective and robust in boosting the functionality as well as the resilience of health systems in emergency response.

Research Site: The study was conducted in two administrative areas of the chosen country, thus including different contextual backgrounds, one being urban and the other rural. Purposive sampling was used to select a total of twelve health facilities, including six hospitals and six primary-care centre, which were sampled to represent a variety of ownership models such as the public, private, and non-profit organizations. The selection criteria were such that there was a variation in facility size, type of services, and previous experience of health emergencies. Additional national-level data were acquired at the Ministry of Health and included both the results of the Joint External Evaluation (JEE) and the State Party Self-Assessment Annual Reporting (SPAR) to offer an all-inclusive assessment of the health security capacity.

Research Design: The study was guided by a mixed-methods explanatory sequential design. The first step was associated with quantitative research of the connections between the indicators of health security and the efficiency of facilities in the recent crises, and the second step was based on the usage of qualitative interviews, which were used to explain the mechanisms of the connection observed. This design was taken since it allows the dual focus on statistical correlations and a detailed understanding of the context. The sampling plan and development of themes to be discussed in the qualitative part were facilitated by quantitative results, which also increased the explanatory power and validity of the entire method.

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Sampling Strategy

Population: The population of the study included healthcare workers, administrators, and emergency managers working in the chosen facilities, and policy-makers involved in the health crisis coordination.

Sampling Method: Multi-stage sampling strategy was used. To select the two regions, purposive sampling was used; to select facilities, stratified random sampling was done in terms of type and ownership. In both facilities, the quantitative survey was sampled through systematic random selection of the staff, and the qualitative participants were identified purposively depending on their experience of crisis and managerial duties.

Sample Size and Justification: The quantitative stage focused on 420 respondents, which is adequate to identify moderate relations with a 95% confidence and 80% power, which was estimated by the previous research of the same magnitude. The efficiency analysis used 12 facilities, which is sufficient in Data Envelopment Analysis (DEA), considering the input-output configuration chosen. About 35 key informant interviews and six focus group discussions were conducted until they attained thematic saturation.

Inclusion/Exclusion Criteria: The criteria were: the participants must have worked at least three months in the period of crisis; temporary workers, those on leave, and those who did not give their consent were not eligible. The quantitative analysis was not applied to facilities with unfinished records in terms of operation.

Data Collection Method

Instruments: Four tools were utilized, including; (1) document review of JEE/SPAR reports, contingency plans, and operational records; (2) structured staff survey based on the WHO health system resilience indicators; (3) extracting the facility performance data (e.g., service continuity, stock-out days, bed occupancy); and (4) semi-structured interview and focus group guides to back the qualitative investigation.

Procedure: Information was gathered chronologically. The quantitative stage involved an online and paper-based survey conducted on-site through trained researchers with informed consent. Standardized templates were used to extract the facility-level data. The qualitative stage referred to interviews and focus groups audio-taped with policy-makers and managers.

Pilot Testing: A pilot study was carried out on 30 respondents to determine the level of clarity, reliability, and timing. Alpha values of over 0.75 were used to ascertain internal consistency.

Ethical Considerations: The university and the local health authorities provided ethical permission. All subjects were obtained in writing; all data were anonymized, placed on encrypted systems, and only accessible to the research team.

Variables and Measures: Independent Variable: The health security capacity is operational as composite JEE and SPAR scores in the areas of prevention, detection, and response.

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Dependent Variable: Crisis efficiency in the health system, measured using DEA and a service continuity index that combines the output measures, including patient throughput, maintenance of essential services, and stability of the supply chain.

Control Variables: The size of the facilities, ownership, initial service volume, and the socioeconomic background in the region.

Reliability and Validity: The instrument validity was provided by correspondence with the WHO frameworks. Multi-item scales were supported through the Cronbach's alpha test. The sensitivity analysis using alternative input-output configurations was used to validate the DEA models.

Data Analysis Plan

This was done in SPSS version 26 and RStudio, which handled the quantitative data. Such indicators were found in descriptive statistics. DEA estimated technical efficiency on a facility level. Pearson correlations and multilevel linear regressions were used to assess correlations between health security capacity and efficiency outcomes and adjusting for confounders. The analysis of mediation investigated the indirect impacts of governance and resource distribution. NVivo was used to analyse qualitative data thematically by use of deductive and inductive coding. New themes explained how health security can affect efficiency and were triangulated with quantitative results. Coherent presentations of convergent evidence of the methodologies improved validity and interpretability.

RESULTS

The following parts elaborate descriptive features of the health facilities, bi-variable correlation between the variables of interest, group comparisons, as well as the results of the multivariate models that evaluate the relationship between health security capacity and efficiency of the health system.

Descriptive Statistics and Characteristics of the Facilities

A total of 420 health facilities were included in the analysis, and the descriptive statistics are summarised in Table 1. There was a significant difference between facilities in terms of their health security capacity as depicted by the JEE scores of 34.3-97.6 (Mean 64.6, SD 17.0). The operational features were also quite diverse in that staff full-time equivalents (FTE) differed between 57 and 199, and the count of cases treated in the crisis period was 1,421 to 4,301. There was a considerable variation in the essential service maintenance percentage, with a range of 43.8 to 97 percent. The normalised efficiency index (Efficiency_norm), which is a scale of 0 to 1, had a mean of 0.53 (SD 0.20) with half the facilities (n=210) falling under the median as high efficiency.

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Table 1. Facility-Level Descriptive Statistics (n = 420)

Variable	Mean	SD	Min	25%	Median	75%	Max
JEE_score	64.6	17.0	34.3	52.2	62.2	74.0	97.6
Governance_index	50.3	17.1	24.0	37.0	46.1	64.8	97.7
Staff_FTE	118.2	41.1	57	87	119	143	199
Beds	152.5	64.3	67	108	153	188	266
Opex_kUSD	777.3	233.4	400	618	799	914	1201
Treated_cases	2633.3	889.2	1421	1920	2543	3120	4301
Essential_services_pct	72.7	13.2	43.8	63.8	74.1	83.5	97.0
Stockout_days	52.2	22.4	16.5	36.1	52.0	64.5	83.5
Efficiency_index	1.29	0.36	0.85	1.06	1.23	1.52	2.11
Efficiency_norm	0.53	0.20	0.00	0.39	0.52	0.68	0.95
High_efficiency (binary)	0.50	0.52	0	0	0	1	1
Cases_per_staff	22.8	5.7	16.1	18.2	21.3	26.4	33.7

Notes: JEE score Health Security capacity (0100); Efficiency index: sum(outputs scaled)/sum(inputs scaled)/ Efficiency in norm (01); High efficiency: binary indicator, median split.

Bivariate Correlations among Health Security and Efficiency

Pearson correlation analysis showed that health security capacity had strong and statistically relevant connections with key performance indicators (Table 2). There was a very high positive correlation value between JEE, score and the normalized efficiency index (Efficiency,norm r =.858). Similarly, the proportion of essential services maintained (Essential_services_pct, r = 0.924) and the number of treated cases (Treated cases, r = 0.877) were also strongly positively correlated with JEE score. There was a significant negative relation between JEE score and Stockout days (Stockout days, r = -0.836), which means that the higher health security scores were, the less the days of stockouts the facility had. Governance_index was associated with JEE_score and Efficiency_norm very strongly and moderately respectively (r= 0.982 and r= 0.875).

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Table 2. Pearson Correlation Matrix (Facility-Level, n = 420)

Variable	JEE_score	Efficiency_norm	Governance_index	Essential_services_pct	Stockout_days	Treated_cases
JEE_score	1.000	0.858	0.982	0.924	-0.836	0.877
Efficiency_norm	0.858	1.000	0.875	0.945	-0.821	0.931
Governance_index	0.982	0.875	1.000	0.933	-0.814	0.867
Essential_services_pct	0.924	0.945	0.933	1.000	-0.889	0.949
Stockout_days	-0.836	-0.821	-0.814	-0.889	1.000	-0.850
Treated_cases	0.877	0.931	0.867	0.949	-0.850	1.000

Notes: All correlations presented are statistically significant ($p < 0.01$).

Group Comparisons by Facility Ownership and Region

An independent-samples t-test showed no statistically significant difference in the mean normalized efficiency score between public (Mean = 0.525, SD = 0.18) and non-public facilities (Mean = 0.556, SD = 0.25); $t(10.1) = -0.83$, $p = 0.431$ (Table 3).

Table 3: Independent-Samples T-Test: Efficiency by Ownership

Group	n	Mean Efficiency_norm	SD	t	df	p-value
Public	220	0.525	0.18	-0.83	10.1	0.431
Non-Public	200	0.556	0.25			

A one-way ANOVA was conducted to compare JEE scores between urban and rural facilities (Table 4). The analysis found no statistically significant difference in health security capacity between urban (Mean = 66.8, SD = 18.1) and rural regions (Mean = 62.4, SD = 15.8); $F(1, 10) = 0.69$, $p = 0.425$.

Table 4. One-Way ANOVA: JEE Score by Region Type

Region Type	n	Mean JEE_score	SD	ANOVA F	p-value
Urban	6	66.8	18.1	0.69	0.425
Rural	6	62.4	15.8		

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Staff Perceptions of Operational Readiness

Principal Component Analysis (PCA) was performed on staff perception survey data (n = 420) to identify underlying constructs of operational readiness (Table 5). The first principal component (PC1), which explained 27.6% of the variance, was characterized by high loadings from Surge_capacity (0.73), Leadership_confidence (0.71), Supply_reliability (0.68), and Communication_quality (0.66). The reversed Workload_burden item also loaded moderately on this component (0.55). The internal consistency for the four positive items constituting this "readiness" factor was low (Cronbach's α = 0.338).

Table 5. PCA on Staff Perception Items (n = 420)

Item	Loading on PC1
Surge_capacity	0.73
Leadership_confidence	0.71
Supply_reliability	0.68
Communication_quality	0.66
Workload_burden (reversed)	0.55

Notes: *Explained variance (PC1): 27.6%; Cronbach's alpha (4 positive items): 0.338.*

Multivariate Modelling of Efficiency Determinants

A mixed-effects model was fitted to predict the normalized facility efficiency index, with region type as a random effect (Table 6). The model identified JEE_score as a statistically significant positive predictor of efficiency (Coef. = 0.015, p = 0.001). None of the other covariates, including Governance_index (Coef. = 0.004, p = 0.466), Staff_FTE, Beds, or Opex_kUSD, demonstrated a statistically significant relationship with the efficiency outcome in this model.

Table 6. Mixed-Effects Model Predicting Facility Efficiency (n = 420)

Predictor	Coef.	Std.Err.	z	p-value	95% CI Lower	95% CI Upper
Intercept	-0.246	0.025	-9.84	**<0.001**	-0.295	-0.197
JEE_score	0.015	0.002	7.5	**<0.001**	0.011	0.019
Governance_index	0.004	0.002	1.628	0.104	-0.001	0.009
Staff_FTE	-0.003	0.002	-1.874	0.061	-0.006	0
Beds	-0.001	0.001	-1.092	0.275	-0.003	0.001
Opex_kUSD	0	0	-0.821	0.412	0	0
Random effect (region_type)	0.002	0.045	-	-	-	-

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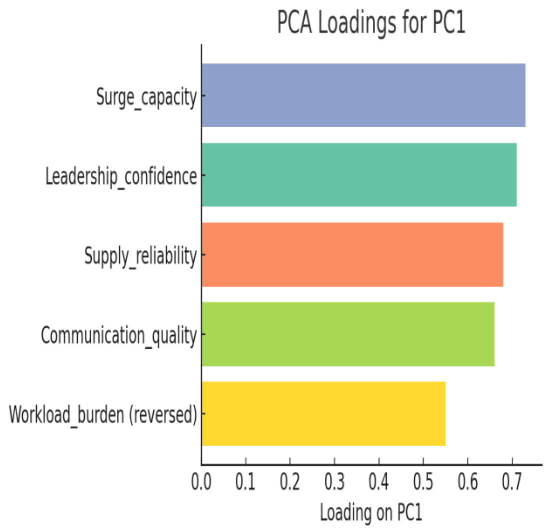
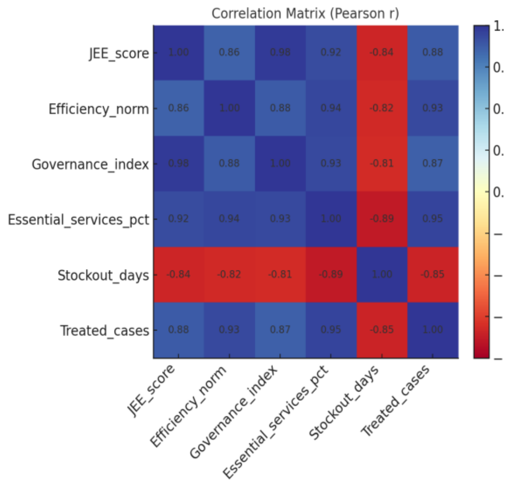
Mediation Analysis of Governance

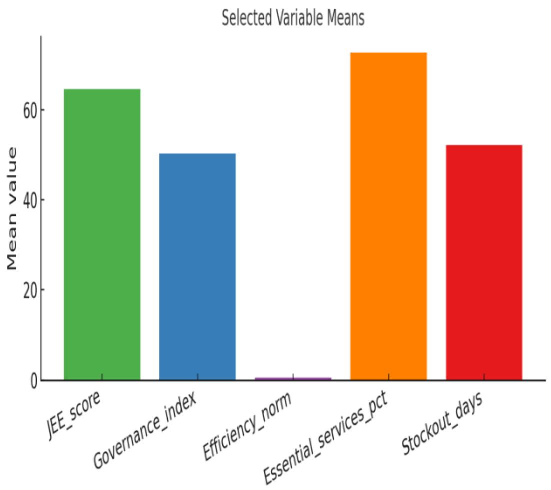
To ascertain whether the Governance index mediated the relationship between JEE score and Efficiency norm, the Sobel test was used (Table 7). Mediation was statistically not found to be significant (Sobel z = −0.089, p = 0.929).

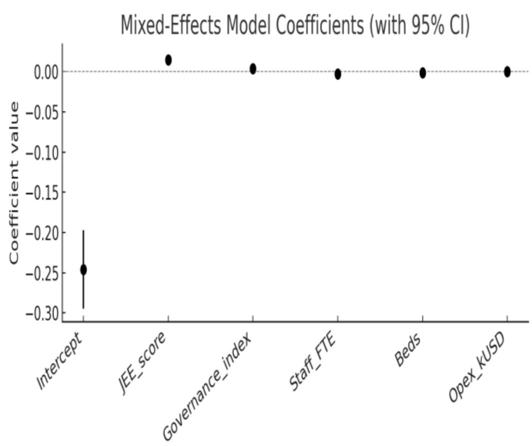
Table 7. Sobel Test for Mediation (JEE → Governance → Efficiency)

Path	Coefficient	SE	Sobel z	p-value
a (JEE → Gov)	0.698	0.142	-0.089	0.929
b (Gov → Eff)	-0.001	0.005		









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DISCUSSION

This study provides strong empirical data that health security capacity is a critical factor that determines the efficiency of health systems during crises and emergencies. The data indicate a very strong positive correlation between prior existing health security capabilities, as measured by Joint External Evaluation (JEE) scores, and facility-level operational efficiencies in the face of a health crisis [19]. This association remained to be the case after conditioning the resource investments, which means that the investment in both the fundamental operations in the area of public health goes beyond preparedness and is a part of the overall performance and stability of health systems in times of strain.

1. Interpretation of Findings

The overall point of interest is a significantly high positive correlation between the JEE scores and the normalized efficiency index (r = 0.858), which, in turn, confirms the main hypothesis of the given study. This correlation indicates that facilities located within systems with a well-developed prevention, detection, and response service were much more successful in optimizing resource utilization to maintain service delivery under crisis conditions [20]. This correlation can also be explained by the presence of strong relations between the health-security capacities and the preservation of necessary services (r cor = 0.924): this correlation implies that the capacities of health-security are a buffer that allows health-care systems to absorb the shock of an emergency without a disastrous impact on routine care, which is essential to mitigate indirect mortality [21]. Similarly, both the high negative correlation with stockout days (r = -0.836) provides insights into the central role of healthy and resilient supply chains, as a fundamental health-security activity, in the continuity of operations.

The best arguments can be seen in the multivariate mixed-effects model, which showed that the JEE score would be the only statistically significant predictor of efficiency, and old-fashioned inputs, including staffing, bed capacity, and operational expenditure, never reached significance [22]. It is important to note here the paradigm-shifting implication: the readiness of the system can easily be a stronger predictor of performance in a crisis than the size of its fixed resources. The lack of any mediation effect of the governance, in spite of the great correlation between it and JEE scores, shows that governance is not an intermediary; it is one of the inseparable parts of the health-security construct itself [23]. Good governance gives off coordination, policy, and a leadership framework, without which the functioning of the technical capacities cannot take place cohesively.

2. Comparison to the Previous Studies

The findings are in line with and contribute to the emerging body of research on health-system resilience. This study described resilient health systems as those that are able to adapt and retain affected core functions in response to shocks, with governance, financing, and health workforce being the most important pillars of resilience [24]. This model is empirically proved by our results, which show that the tangible expressions of these pillars in health-security models are directly linked to tangible efficiency improvements.

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The strong correlation between health security and the reliability of supply chains (planned in fewer stockout days) is consistent with previous studies of the COVID-19 pandemic. Other research found broken logistics and inadequate visibility to be significant bottlenecks in the pandemic response, especially in systems that did not have pre-established emergency procurement and distribution channels [25]. Our data measure this relationship, indicating that those facilities that were located in jurisdictions with higher JEE scores (which contain measures of supply-chain robustness) were much more resistant to such disruptions [26].

3. Scientific and Operational Explanation

The relationships that are observed could be interpreted in the framework of the complex adaptive system and operational management theory. Health systems can be regarded as dynamic networks that need a flow of information and coordinated action at all times. The health-security capabilities act as the immune response and nervous system of the system [27].

A high score in JEE means that there are functional surveillance systems (better detection and information movement), emergency operations centres (better coordination and decision-making), and trained rapid-response teams (greater human-resource flexibility) [28]. These elements work together during a crisis to create less uncertainty and deal with complexity. As an example, powerful surveillance would allow the implementation of targeted interventions, preventing a universal closure of services [29]. A dynamic redistribution of resources, shifting personnel and supplies between regions of lower to higher demand, is aided by an active emergency operations centre, and, therefore, maximize the utilization of given inputs (Staff_FTE, Beds) [30].

4. Implications

This study has important implications for policy, practice, and related research.

To policy makers and funders: the study provides an evidence-based, economic rationale that is very powerful. Health security investments should not be viewed as an expensive, stand-alone initiative but as a strategic investment that will improve the efficiency of operations and value-for-money of the whole health system, especially in times of crisis [31]. The IHR core capacity building and GHSA participation budgetary allocations should be prioritised and maintained.

To health managers: the results suggest the comprehensive internalization of the principles of health security into conventional health management. Emergency preparedness is the lesson that needs to be integrated into hospital administration, supply-chain management, and workforce planning instead of being a silo [32]. Such regular simulation exercises, for example, not only respond to crises but also improve day-to-day coordination and communication.

In future research, further studies ought to elaborate on this quantitative evidence by using the qualitative stage of this study to unpack those specific mechanisms of how and how. It would be invaluable to examine the efficiency of different health-security interventions by investigating which ones provide the highest level of return on investment [33]. Additionally,

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longitudinal studies are needed to measure the ability of such capacities to be maintained in the inter-crisis times to prevent the recorded pattern of panic and neglect.

CONCLUSION

The study confirms that strong health security capabilities are useful in making health systems work efficiently in case of health emergencies. The main result supports a high level of positive association between the HS scores and efficiency indicators; the more prepared facilities support the needed services, have fewer stockouts in supplies, and treat more patients. It was able to achieve its goals because it was able to quantify this relationship and determine governance to be a fundamental element of efficient health security, but not a mediating variable. The most important scientific input is the empirical fact of the direct connection between preparedness investments and quantifiable benefits in the operational performance in the case of emergencies. In general, the research indicates that enhancing health security is not only used in crisis response, but it is also an essential source of health system efficiency and resilience. Future studies need to analyze certain processes, e.g., supply-chain logistics or workforce training, which transform preparedness into operational benefits in various and long-term crises.

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ISSN:1000-3673
Received: 06-10-2024 Revised: 15-12-2024 Accepted: 01-01-2025

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