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Factors Influencing Hospitals' Disaster Preparedness in the Eastern Province of Saudi Arabia

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Abstract

Objective: The study aimed to identify the factors that influence the disaster preparedness of hospitals and validate an evaluation framework to assess hospital disaster preparedness (HDP) capability in the Eastern Province of Saudi Arabia.
Methods: A cross-sectional survey of all hospitals (n = 72) in the Eastern Region of Saudi Arabia was conducted. A factor analysis method was used to identify common factors and validate the evaluation framework to assess HDP capacity.
Results: Sixty-three (63) hospitals responded to the survey. A 3-factor structure was identified as key predicators of HDP capacity. The first factor was the most highly weighted factor, which included education and training (0.849), monitoring and assessing HDP (0.723), disaster planning (0.721), and command and control (0.713). The second factor included surge capacity (0.708), triage system (0.844), post-disaster recovery (0.809), and communication (0.678). The third factor represented safety and security (0.638) as well as logistics, equipment, and supplies (0.766).
Conclusion: The identified 3-factor structure provides an innovative approach to assist the operationalization of the concept of HDP capacity building and service improvement, as well as serve as a groundwork to further develop instrument for assessing HDP in future studies.

Disasters, a global issue in recent times,[1] arise from natural or manmade interventions and have substantial consequences that adversely affect lives and properties.[2,3] Globally, natural disasters have impacted > 3 million families and cost more than US $500 billion in the past 2 decades.[4]

Disasters, whenever they occur, have tested global preparedness and response competencies.[5] Hospitals, among the key establishments required to respond to emergency situations,[6] play an important role in providing health services to decrease disaster associated morbidity and mortality and, ultimately, minimizing impact on the community.[5–7] Hospitals are oftentimes overwhelmed by casualties during and after disasters,[8] a situation that is worsened if hospitals are directly impacted by the disaster.[9,10] It is thus important that hospitals sufficiently prepare for disasters to ensure that crisis situations are adequately managed to continuously deliver health services during disasters.[1,4]

Hospital disaster preparedness (HDP) is a key component of disaster management.[11,12] HDP comprises a multifaceted approach to knowledge development and capacity building to effectively deal with negative consequences associated with potential disasters.[13] From the opinion of experts, the scope of HDP in recent times has moved far beyond having robust structural or contemporary digital capacities to include suitable and optimal functioning in response during disasters.[14] This extension of scope of HDP has made difficult the identification of a very effective instrument for evaluating disaster preparedness among hospitals. While comprehensive, valid, and effective instruments are required to assess disaster's preparedness among hospitals, there is no consensus on a standardized, comprehensive instrument for this purpose. Various instruments have been developed for use worldwide, but these instruments are mostly situation-specific or one-dimensional,[14–16] and the commonest tool among them is the World Health Organization (WHO) Hospital Safety Index (HSI).[11,12] To date, most evaluation strategies employed in previous studies have used subjective approaches,[17–26] including analytic hierarchy and expert ratings.[27,28]

Tools or instruments with frameworks for assessing preparedness have measurement parameters or indicators that vary widely, and key factors or main drivers of HDP remain unclear. As equally important as all the numerous parameters in the various evaluation tools are to data interpretation, it is difficult to reduce such data without loss of critical information. With this study aiming to identify factors affecting HDP, a sophisticated multivariate statistical technique was required.[29] Among the many techniques that have been developed for this purpose, the principal component analysis (PCA) is among the most widely used approach for analysis

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of data with numerous parameters. The PCA is a multivariate statistical method that can drastically reduce dimensionality of a large data set in an interpretable way, such that most of the information in the data are preserved. The PCA identifies patterns and classifies the factors that influence a given phenomenon and is a technique widely used to identify data patterns in medical research.[29]

The aim of the present study was primarily to use a PCA approach to identify the factors that influence the HDP in the Eastern Province of the Kingdom of Saudi Arabia (KSA) for disasters using data gathered with a survey adapted from the WHO National Health Sector Emergency Preparedness and Response Tool and Hospital Emergency response checklist.[11,12] In addition, we aimed to validate an evaluation framework used to evaluate HDP in hospitals in the Eastern Province of KSA.

Methods

Study Design and Population

This was a cross-sectional study of all hospitals (n = 72) in the Eastern Region of Saudi Arabia. The included hospitals were selected using convenience sampling.

Data Collection

Ethical approval to conduct the study was received from the Ministry of Health (MOH), KSA (IRB00010471) and the University of New England Human Research Ethics Committee (HE17-155). The questionnaire was delivered to all hospitals accompanied by a facilitating letter from the MOH as well as a cover letter stating the significance, aims, and objectives of the study as well as outlining ethical issues related to participation in the research. Each hospital designated a departmental head/director responsible for coordinating questionnaire completion. Returned questionnaires were reviewed for completeness and consistency, and data were transferred into a database for analysis. A total of 63 of 72 hospitals in the region responded to the survey, representing a response rate of 87.5%.

Study Questionnaire

The survey was adapted according to the WHO National Health Sector Emergency Preparedness and Response Tool and Hospital Emergency response checklist.[11,12] The questionnaire consists of 12 sections and 93 closed-ended questions. A pilot study tested the questionnaire. The data collected focused on the following 12 areas of interest: (1) hospital and physician demographic data; (2) command and control; (3) disaster plan; (4) hospital disaster communication; (5) education and training; (6) triage; (7) surge capacity; (8) hospital logistics, equipment, and supplies; (9) monitoring and assessing HDP; (10) safety and security; (11) post-disaster recovery; and (12) assessment of hospital's disaster preparedness indicators.

Data Analysis

Data were transferred from the returned self-reported questionnaires into an Excel spreadsheet. The data were checked for completeness, cleaned, and analyzed using SPSS. Several approaches to the data analysis were adopted. To determine the factors influencing hospital preparedness, factor analysis was used to analyze the data. Factor analysis permits testing of theories, including variables that are difficult to measure directly. It also helps create sets of questionnaire items (observed variables). The processes involved in the factor analysis included assessment of suitability for factor analysis, correlation matrices, factor extraction, choice of the number of factors to retain, rotation, component score coefficient matrix, and factor interpretation.[30] Kaiser–Meyer–Olkin (KMO) and Bartlett's Test of Sphericity were used to test whether factor analysis was suitable for the data as well as measure the level of correlation in the data. The items of the questionnaire were also analyzed using the principal component analysis. The scree plot was used to present the eigenvalue of each component. Factors were rotated using the Varimax rotation procedure. The rotated solution was used to determine the factors and their loadings. Reliability of the tool was calculated using Cronbach's alpha coefficient analysis and test-retest reliability. In addition, factor analysis was used to estimate the construct validity of the framework. The scores for each common factor were calculated and categorized according to level of care of participating hospitals. The scores of each factor by category of care level were compared using t-tests and 1-way analysis of variance. Analyses were conducted using SPSS, version 25, for Windows. An alpha level > 0.05 was considered for statistical significance.

Results

Inspection

The present study found the KMO Measure of Sampling Adequacy value to be 0.864, which is above the threshold of 0.7. This indicates that the sample size and data are adequate and appropriate for the factor analysis. The result of Bartlett's Test of Sphericity was significantly high ($P < 0.001$), indicating a high level of correlation in data. Thus, factor analysis is feasible for the current survey data and appropriate to be used for extraction of component factors in the present study.

Communalities

The proportion of variance accounted for in each variable in relation to the rest of the variables was estimated as initial communalities for correlation analyses. The extraction communalities are estimated of the variance in each accounted variable by the factor components in the factor solution. Table 1 shows the initial and extraction communalities of variables for factor analysis, from which extraction communalities were acceptable for the factor solution. Based on these estimates, all the variables fit well with factor solution, and none were excluded from the analysis.

Component Factors Extraction

A total of 10 components within the data set were identified. In the present study, the factor solution was first revealed by the number of factors that had eigenvalues > 1, along with theoretical considerations. Regarding the component extraction, the domain scores were treated as the independent variable. As shown in Table 2, the 3-factor solution accounted for 79.8% of the cumulative variance, and the domains had moderate loadings. The first factor explains 40.68% of variance in data, while the variance of 20.1% can be explained by factor 2. All the first 3 factors accounted for approximately 80% of the variance, an indication that the 3 factors could represent the most variance in data.

Rotation

The relationship between the extracted components and initial domains was not clear, so we used the rotation to further

Table 1. Communalities

Domains	Initial	Extraction
Command and control	1.0	0.77
Disaster plan	1.0	0.81
Communication	0.9	0.73
Education and training	1.0	0.86
Triage	1.0	0.75
Surge capacity	1.0	0.78
Logistics, equipment, and supplies	0.8	0.81
Monitoring and assessing hospital disaster preparedness	1.0	0.72
Safety and security	1.0	0.81
Post-disaster recovery	0.9	0.88

decentralize the extracted components and to render their relationship easily interpretable. As illustrated by the Rotated Component Matrix in Table 3, most of the information extracted by each of the 3 factors were drawn from different domains. The 3 factors remained after the rotation and the variables were ordered by the loading size. The values with magnitude > 0.6 identify variables contributing to the various component factors and aid their interpretation. The first factor holds information from 4 domains: education and training (0.849); monitoring and assessing HDP (0.723); disaster planning (0.721); and command and control (0.713). The second factor includes surge capacity (0.708), triage system (0.844), post-disaster recovery (0.809), and communication strategy (0.678). The third factor represents safety and security (0.638) as well as logistics, equipment, and supplies (0.766).

Reliability and Validity

This study examined the internal and external reliability of the questionnaire, using Cronbach's alpha test and test-retest method, respectively. The Cronbach's alpha for the parameters of our HDP framework ranged between 0.721 and 0.933. Given that, the rate of test-retest reliability ranged between 0.711 and 0.899. Table 4 shows Cronbach's alpha and test-retest reliability coefficient for the various parameters of the framework. The construct and structural validity of the framework was evaluated using factor analysis and was adjudged according to the factor loading and the cumulative contribution rate.

Establishing a Hospital Disaster Preparedness Capacity Evaluation Model

The 3 common factors showed the overall level of HDP form deferent perspectives. We calculated the capability score for HDP from weights calculated from the ratio of eigenvalue of each common factor to the sum of the 3 common factor eigenvalues. We developed the evaluation model as follows: $F = 0.518F1 + 0.115F2 + 0.062F3$, where F is the total overall hospital disaster preparedness capacity score and $F1$, $F2$, and $F3$ are common factor scores for each identified component factor. Tables 5–7 show comparisons of common factor scores between levels of care of hospitals.

Discussion

Disasters continue to threaten public health and negatively impact economic growth and impoverish developing nations. Achieving the effective assessment of hospitals' capability to handle disasters is important to stimulating discussions around a clear path to monitoring and improving a health emergency system. It is therefore imperative to identify factors that impact on hospitals' disaster preparedness and to establish an objective comprehensive framework for evaluation of hospitals in order to attain acceptable capacity to effectively handle disaster situations in this age of large data.[31,32]

The present study used principal component analysis to provide a 3-factor solution for measuring HDP using a survey instrument adopted from the WHO recommended all-hazard approach, and this presents a number of important findings. To the best of our knowledge, we are among the first to identify the key factors for assessing HDP. The factors identified open up important discussions about the concepts underlying the HDP set up. The current findings to some extent depart from the conclusions of previous research,[17–26] which center on only 1 or 2 aspects of HDP. The identified factors capture the primary and comprehensive components to show overall readiness and ability of hospitals to handle disasters. A multidimensional approach, which is more comprehensive and reliable for measuring HDP than the use of a limited number of dimensions, has been recently proposed.[18,21,33] In the present study, we identified the 3-factor structure, which assesses preparedness prior to disasters as well as shows the core elements of disaster functions and health outcomes before, during, and after disasters.

In addition, the results of the factor analysis conducted in this study are reassuring, as it identified factors largely consistent with the major concepts underlying HDP and the construction of its primary domains.[18,19,21,22,24] The first factor holds data primarily from 4 domains: education and training, monitoring and assessing HDP, hospital disaster planning, and command and control. The second factor describes domains that are closely related to important parameters: surge capacity, triage, post-disaster recovery, and communication. The third factor largely represents the domain of safety and security as well as logistics, equipment, and supplies, which focuses on hospital safety and disaster resources. It is also noteworthy that the 3-factor structure dovetails into the main recommendations of the WHO National Health Sector Emergency Preparedness and Response Tool and Hospital Emergency response checklist.[11,12] Additionally, this structure in part fits into the findings of several previous works, including Dobalian et al.'s research into developing valid measures of emergency management capabilities[34] and Der-Martirosian et al.'s works into assessment of disaster readiness within the US Department of Veterans Affairs Hospitals.[35]

The 3-factor structure proposes an approach to assessing overall level of hospital preparedness for disasters. The structure demonstrates a way to use self-assessment scales to categorize the level of HDP, and this involves the use of a questionnaire as a checklist for hospital's self-evaluation. It could estimate an overall score, in addition to calculating scores on particular aspects of hospital preparedness. This would enable hospitals to probe and identify any short falls and serve as the basis for quantifying improvements over a period. The different weights of each factor can be modeled to examine the differences in preparedness with regard to level of care, size, function, and regional location of hospitals. Therefore, institutions within countries, provinces, and regions can embark on targeted and coordinated capacity building with little effort.

Factor 1

Among the 3 factors, F1 was found to be the core component factor for evaluating HDP. F1 is characterized by variables from 4

Table 2. Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance%	Cumulative %	Total	Variance%	Cumulative %	Total	Variance%	Cumulative %
1	6.568	40.682	40.682	6.568	65.682	65.682	3.379	40.682	40.682
2	0.918	20.177	60.859	0.918	9.177	74.859	2.938	20.175	60.859
3	0.493	17.929	78.789	0.493	4.929	79.789	1.662	17.729	78.789
4	0.467	4.667	82.456						
5	0.426	4.257	86.713						
6	0.334	4.342	90.056						
7	0.309	4.087	95.143						
8	0.268	3.679	94.822						
9	0.135	2.346	99.168						
10	0.083	1.832	100.00						

Table 3. Rotated component matrix

Variables	Component factors		
	1	2	3
Education and training	**0.849**	0.264	0.170
Monitoring and assessing hospital disaster preparedness	**0.723**	0.040	0.450
Disaster plan	**0.721**	0.438	0.251
Command and control	**0.713**	0.399	0.397
Surge capacity	0.674	**0.708**	0.325
Triage	0.071	**0.844**	0.318
Post-disaster recovery	0.480	**0.809**	0.006
Communication	0.405	**0.678**	0.356
Safety and security	0.346	0.514	**0.638**
Logistics, equipment, and supplies	0.420	0.317	**0.766**

Table 4. Cronbach's alpha and test-retest reliability

Items	Cronbach's α	Test-retest reliability
Command and control	0.721	0.723
Disaster plan	0.933	0.744
Communication	0.808	0.812
Education and training	0.732	0.788
Triage	0.788	0.765
Surge capacity	0.811	0.849
Logistics, equipment, and supplies preparedness	0.723	0.739
Monitoring and assessing hospital disaster preparedness	0.744	0.799
Safety and security	0.912	0.899
Post-disaster recovery	0.822	0.729
Assessment of hospital's disaster preparedness indicators	0.814	0.711

Table 5. Comparison of three common factors between government and private hospitals (mean ± SD)

Factor	All hospital (n = 63)	Government hospitals (n = 37)	Private hospitals (n = 26)	*t*	*P-value*
Factor 1	3.02 ± 0.78	2.93 ± 0.82	3.14 ± 0.72	2.00	0.30
Factor 2	3.27 ± 0.78	3.10 ± 0.84	3.52 ± 0.63	1.99	0.04
Factor 3	2.67 ± 0.86	2.54 ± 1.00	2.85 ± 0.56	1.99	0.17

Table 6. Comparison of three common factors between teaching and non-teaching hospitals (mean ± SD)

Factor	All hospital (n = 63)	Teaching hospitals (n = 2)	Non-teaching hospitals (n = 61)	*t*	*P-value*
Factor 1	3.02 ± 0.78	2.00 ± 0.35	3.05 ± 0.77	2.00	0.06
Factor 2	3.27 ± 0.78	2.00 ± 0.35	3.32 ± 0.76	2.00	0.018
Factor 3	2.67 ± 0.86	1.25 ± 0.35	2.71 ± 0.83	1.99	0.016

Table 7. Comparison of three common factors between three care levels of hospitals (mean ± SD)

Factor	Primary (n = 5)	Secondary (n = 48)	Tertiary (n = 10)	x^2	*P-value*
Factor 1	4.00 ± 0.40	3.12 ± 0.67	2.05 ± 0.40	23.73	< 0.001
Factor 2	4.10 ± 0.22	3.41 ± 0.65	2.23 ± 0.53	22.17	< 0.001
Factor 3	3.5 ± 0.35	2.81 ± 0.74	1.55 ± 0.50	22.29	< 0.001

One-way analysis of variance test.

domains—education and training of staff on disaster, monitoring and assessing HDP, hospital disaster plan, and command and control. The combination of the 4 domains is reasonable as the framework comprises essential ingredients for a hospital's preparedness for disasters. The 4 domains are greatly interrelated to the extent that 1 domain could possibly encapsulate the other 3 domains. Disaster education is an important component of disaster management and usually pursues 2 goals—prevention and mitigation. These include improved outcome for victims and enhanced safety for responders. Adequate disaster education contains, at least, guidelines and a basic training format with a component for evaluation of its effectiveness.[36] Also, well-trained and equipped personnel are vital elements of disaster response, and training presented in various types (classroom-based courses, e-learning, and drills) requires a standardized and evidence-based approach.[37]

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The command-and-control domain of F1 is a well-known organizational tool structured around several key principles: early implementation, modular makeup (which allows for expansion or contraction), and standardized terminology.[38] This domain uses a unified incident command system to ultimately develop, examine, and improve decision making and response capacity among hospitals. During emergencies, hospitals are required to identify and command various sectors and organize all available resources to respond effectively within a short period. This domain ensures several levels of command, including security and technical personal as well as medical team, all of whom must be available immediately when an incident arises. This level of command identifies the problem and initiates an appropriate emergency procedure. A second level serves as the next level when an incident is beyond the control of the first level. The second level contains at least 2 staff-level personnel: 1 medical hospital incident manager, who ensures the provision of appropriate incident medical care, and a hospital incident manager (non-medical), whose primary focus is on preserving hospital functionality and providing the medical hospital incident manager with necessary logistic and personnel support. The F1, which shows the rudimentary disaster management system, suggests the use of creative strategies to improve the operational functions of hospitals.

The findings of the current study are not a complete departure from previous studies, which used various tools to assess HDP.[17–26] In KSA, the TJC or Saudi Central Board for Accreditation of Healthcare Institutions requires all hospitals to have written disaster plans and conduct drills on regular basis to assess hospitals' readiness for disaster situations.[39,40] In the present study, the hospital disaster plan was identified as one of the most important domains in assessment of HDP. Shalhoub et al. made similar observations in a recent study conducted in Riyadh, which found that all 13 hospitals had disaster plans that mostly covered both internal and external disaster plans, as well as disaster preparedness committee.[41] While education and training remain a critical component of F1, an indication that it is an important predictor of HDP, previous studies measuring preparedness among hospitals have had mixed levels of readiness.[41,42]

Factor 2

F2 was a second highly weighted factor and relates with surge capacity, triage, post-disaster recovery, and communication. Triage remains an important component of daily emergency care and disaster management.[11,12,34,35,43] Given that F2 is a highly weighted factor, it is conventional that hospitals in previous studies have triage areas available. Hospitals have triage guidelines/protocols, dedicated forms for triage, and nearly all providers involved in triage had received training while a significant proportion of hospitals have a triage area designated for receiving mass casualties during disasters.[18,34,35,44] However, only up to one-third of providers involved in triaging had received training in another study.[45] The use of validated triage protocols and training ensures that effective care and appropriate resource utilization are delivered during disasters.

A critical indicator for measuring HDP is surge capacity, as the WHO recommends enhanced capacities of hospitals to respond adequately to disasters.[11,12] One of the domains driving F2 is surge capacity. Hospitals are recommended to develop adequate surge capacity by increasing the inpatient spaces, opening up unused areas, canceling elective surgeries, and using alternative areas for extra critical care space. While surge capacity is an important driver of HDP, previous studies have often fallen short of this recommendation with mostly less than half of participating hospitals meeting standards.[18,46,47] A possible explanation for very low surge capacity could be attributed to the use of different tools for assessment of this particular domain—thus, calling for a standardized comprehensive framework for measuring HDP.

Post-disaster recovery is another domain making up the F2. It is one of the key concepts recommended by the WHO[11,12] and remains an important path to full recovery to routine clinical care and readiness for future disasters. In this domain, hospitals should have organized meetings to lessons drawn from disaster responses. Recognition for service provision by staff of hospitals, volunteers, and other personnel is critical to motivating many after response to disasters. Little or no information has been found about previous studies using various frameworks that have looked at post-disaster recovery. Taken together, hospitals need to improve capacity in post-disaster recovery, as F2 is highly weighted in terms of HDP assessment.

Factor 3

The third factor represents the domain of safety and security as well as logistics, equipment, and supplies, which draws attention to hospital safety and disaster resources. Handling disasters without sufficient equipment, logistic services, and a regular supply of consumables could be detrimental to human lives as disasters are usually characterized by either physical or internal injuries. Recent studies have shown that most hospitals have adequate equipment and logistic services capacity, though some weaknesses have been reported.[18,35,45,48]

Safety and security for staff are also necessary to enable care for patients during disasters,[11,12] and it is not surprising that this domain is a key component of F3. Measurements of safety and security among responding hospitals in previous studies have been mixed.[35,44,45] It is therefore necessary that capacity is built in order to sufficiently respond to disasters whenever they occur. It is reassuring to note that tools for assessment were effective at identifying this domain in F3. Taken together, safety and security for staff have been identified as a key driver to hospitals' preparedness to disasters and so this area requires enhancement in order to handle disasters when they occur.

Limitations

This study has several limitations. First, the PCA to identify the factors influencing HDP was conducted on a fairly small sample ($n = 63$) of hospitals in a single region of KSA and may limit the findings from being generalizable to the entire Kingdom or other countries. The current work can be considered as exploratory and thus it is appropriate to validate the identified structure in another region or province, prior to rolling it out in a larger study. We propose that this structure be adopted by health care facilities in other areas or regions for further validation. Second, the present study is a cross-sectional one evaluating data requested from the hospital representatives. While attempts were made to review disaster plans during evaluation, our data are self-reported and are subject to reporting bias. There is also the possibility of an overestimation of positive responses, as respondents may have been concerned that investigators were conducting an official assessment for competency. Finally, the factors or indicators were adopted from the WHO checklist and selected based on a preliminary survey on the most important aspects of disaster preparedness in the study area. As such, mission-critical systems deemed important for continuity of operations were not selected, and thus indicators may not be applicable in all countries and thus limits its generalizability. Notwithstanding the limitations, the identified factors may serve as a checklist to assess the fundamental drivers of HDP and to further identify practices that could be prioritized to ensure that institutions are better prepared for future disasters.

Conclusion

The present study has identified a 3-factor structure for assessing HDP. The first factor includes education and training, monitoring and assessing HDP, planning for disaster, and command and control. The second factor includes surge capacity, triage system, post-disaster recovery, and communication. The third factor primarily includes safety and security as well as logistics, equipment, and supplies. This comprehensive structure offers an approach to theorize HDP and provides groundwork for developing a handy tool for measurement. While further work is still required, the current result provides a basic structure for future research.

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